

FINAL

**REMEDIAL INVESTIGATION/FEASIBILITY STUDY
FIELD SAMPLING AND ANALYSIS PLAN
FOR OPERABLE UNIT NO. 9
(SITES 65 AND 73)
MARINE CORPS BASE,
CAMP LEJEUNE, NORTH CAROLINA**

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LIST OF ACRONYMS AND ABBREVIATIONS

AST	aboveground storage tank
bgs	below ground surface
BOD	biological oxygen demand
CLEJ	Camp Lejeune
CLP	Contract Laboratory Program
COD	chemical oxygen demand
DO	dissolved oxygen
DON	Department of the Navy
DQO	Data Quality Objective
EMD	Environmental Management Division (Camp Lejeune)
ESD	Environmental Services Division
FSAP	Field Sampling and Analysis Plan
ID	inside diameter
IDW	investigation derived waste
LANTDIV	Naval Facilities Engineering Command, Atlantic Division
MCB	Marine Corps Base
MS/MSD	matrix spike/matrix spike duplicate
NAPL	non-aqueous phase liquid
NC DEHNR	North Carolina Department of Environment, Health, and Natural Resources
NCSPCS	North Carolina State Plans Coordinate System
OD	outside diameter
OU	operable unit
PPC	personal protective clothing
PPE	personal protective equipment
PVC	polyvinyl chloride
QAPP	Quality Assurance Project Plan
QA/QC	quality assurance/quality control
RCRA	Resource Conservation and Recovery Act
RI/FS	Remedial Investigation/Feasibility Study

SAP	Sampling and Analysis Plan
SOP	standard operating procedures
TAL	Target Analyte List
TCL	Target Compound List
TCLP	Toxicity Characteristics Leaching Procedure
TDS	total dissolved solids
TKN	total kjeldahl nitrogen
TOC	total organic carbon
TPH	total petroleum hydrocarbon
TSS	total suspended solids
$\mu\text{g/L}$	micrograms per liter
$\mu\text{g/kg}$	micrograms per kilogram
USEPA	United States Environmental Protection Agency
USCS	United Soil Classification System
UST	Underground Storage Tank
VOA	Volatile Organic Analyte
VOC	Volatile Organic Compound

1.0 SITE BACKGROUND

A description of the history and setting of Marine Corps Base (MCB), Camp Lejeune, and the two study sites (Sites 65 and 73) is contained in Section 2.0 of the Remedial Investigation/Feasibility Study (RI/FS) Work Plan.

2.0 SAMPLING OBJECTIVES

The sampling and data quality objectives (DQOs) for field investigations at Sites 65 and 73 are summarized in Section 3.0 of the RI/FS Work Plan.

3.0 SAMPLING LOCATIONS AND FREQUENCY

3.1 Site 65 - Engineer Dump Area

The following investigations and support activities will be conducted at Site 65.

- Surveying
- Soil Investigation (including trench excavations)
- Groundwater Investigation
- Ecological Investigation (including surface water, sediment, fish, and benthic sampling)

Each activity and investigation is described in the following subsections.

3.1.1 Surveying

This activity will involve the surveying of the current site features including roads, surface water bodies such as ponds and marshes and any significant features which were noted during the site visit. The locations of proposed soil borings, monitoring wells, surface water and sediment sample stations and test pit excavations will be established by the survey subcontractor prior to commencing the field program. Each location will be marked with a stake allowing the field teams to identify the location and the corresponding designation for each activity. Ground surface elevations and the horizontal control of each sampling location will be established.

Following the completion of the field program, all existing and newly installed monitoring wells, staff gauges, the trench excavations and any sample locations that were relocated during the field program will be surveyed. A reference point on the top of the PVC riser, and the ground elevation will be surveyed for each monitoring well. The vertical elevation and horizontal control for the staff gauges, and the horizontal control of the trench excavations will also be established.

Survey points will include a latitude coordinate, a longitude coordinate, and an elevation expressed in feet of mean sea level. The vertical accuracy of the survey will be within 0.01 feet and the horizontal accuracy will be within 0.1 feet. All survey points will be referenced to the North Carolina State Plane Coordinate System (NCSPCS).

3.1.2 Soil Investigation

A soil investigation will be conducted at Site 65 to provide surface and subsurface soil data to evaluate areas of concern identified by the preliminary investigation, determine the nature and extent of soil contamination at the site, support a baseline human health and ecological risk assessment and evaluate remedial action alternatives. The following subsections describe the tasks proposed for the field program.

3.1.2.1 Sampling Locations

The soil investigation involves the drilling of 13 soil borings and the excavation of seven test pits. Seven of the borings will be completed as shallow and deep groundwater monitoring wells (see Section 3.1.3).

The locations of the proposed soil borings are depicted on Figure 3-1. The proposed soil borings will be drilled to the top of the water table and continuously sampled. Three unsaturated soil samples will be obtained from each boring including one from the surface (0 to 12 inches), one from the interval just above the water table, and a third based on visual observations and field screening performed via photoionization detector.

No soil samples are needed from proposed intermediate groundwater monitoring well boring 65MW04B because this data will be obtained from the adjacent proposed shallow groundwater monitoring well boring 65MW04A.

In addition to the thirteen proposed soil borings, the soil investigation include seven proposed test pits. The approximate locations are depicted on Figure 3-1. Each proposed test pit will be excavated to approximately 10 feet long and 10 feet deep or to the top of the water table (whichever is encountered first). A single composite soil sample will be obtained from each test pit. If grossly contaminated soil is encountered in any of proposed test pits, an additional sample will be obtained to characterize and classify (i.e., hazardous/nonhazardous) the contamination.

Section 5.1 of this FSAP discusses the procedures for the collection and preparation of the soil samples collected during drilling and trenching activities.

3.1.2.2 Analytical Requirements

Samples collected from the soil borings (including borings completed as monitoring wells) will be analyzed for full Target Compound List (TCL) organics and Target Analyte List (TAL) metals. One composite sample from soil boring SB06 shall be analyzed for the following engineering parameters in addition to the previously stated analyses: total organic carbon (TOC), alkalinity, biological oxygen demand (BOD), redox potential, chemical oxygen demand (COD), microbial enumeration, total kjeldahl nitrogen (TKN), total phosphorus, Atterberg Limits, and particle-size distribution.

All soil samples obtained from the proposed test pits will be analyzed for full TCL organics and TAL metals in accordance with Contract Laboratory Program (CLP) methods. In addition, each soil sample will be analyzed for TPH via EPA Methods 8015 (California GC-FID) and 3550/5030 (sample preparation). If grossly contaminated soil is encountered within the test pits, a second sample shall be collected and analyzed for full TCL organics, TAL metals, TPH, full toxic characteristic leaching procedure (TCLP) and RCRA hazardous waste characterization (i.e., corrosivity, reactivity, ignitability, etc.). A summary of the soil sampling and analytical requirements is provided in Table 3-1.

3.1.3 **Groundwater Investigation**

A groundwater investigation will be conducted at Site 65 to characterize shallow and intermediate groundwater zones upgradient, directly beneath, and downgradient of the site. In addition, shallow groundwater will be characterized in the area located east of Site 65 and west of the nearby surface ponds. This area, for the most part, is used for training heavy equipment operators. The data will be used to determine the nature and extent of groundwater contamination, support a baseline human health and ecological risk assessment, and evaluate remedial alternatives.

3.1.3.1 Sampling Locations

For this investigation, four shallow (65MW04A, 65MW05A, 65MW06A, and 65MW07A) and three intermediate (65MW01B, 65MW02B, 65MW04B), monitoring wells are proposed. The proposed wells will be installed northeast (upgradient [65MW04A and 65MW04B]) of the site, adjacent to or within the site boundaries (65MW01B, 65MW02B, and 65MW05A) and on the outer edges of the heavy equipment training area (65MW06A and 65MW07A). The locations of the proposed wells are illustrated on Figure 3-1.

The shallow monitoring wells (Type II well construction) will be installed to depths ranging from approximately 20 to 30 below ground surface (bgs). The well screens for the shallow wells will be 15 feet in length and will intercept the water table (approximately 8 feet bgs). The intermediate wells (Type III well construction) will be installed beneath the first semi-confining (i.e., subsurface soil zone exhibiting considerably lower hydraulic conductivity than the zone in which the water table surface is contained) unit approximately 60 to 70 feet bgs. If a semi-confining unit is not encountered, then a Type II well will be installed in the upper portion of the Castle Hayne Aquifer (70 feet bgs). The screen length of the intermediate monitoring wells will be 10 to 20 feet and will intercept the zone in which the nearby water supply wells are screened. Well construction details for the proposed shallow Type II and Type III monitoring wells are illustrated on Figures 5-1 and 5-2 in Section 5.0 of the FSAP. Well installation procedures and well construction materials are discussed in Section 5.2 of the FSAP.

3.1.3.2 Analytical Requirements

One round of groundwater samples will be collected from the three existing (65MW01A, 65MW02A, and 65MW03) and seven newly installed monitoring wells (65MW01B, 65MW02B, 65MW04A, 65MW04B, 65MW05A, 65MW06A, and 65MW07A). Samples will be collected approximately one week following the development of the newly installed wells. All samples will be analyzed for full TCL organics, TAL metals (total), and TSS in accordance with CLP methods. In addition, a sample from monitoring well 65MW07A will be analyzed for total suspended solids (TSS), total dissolved solids (TDS), BOD, COD, TOC, TKN, total phosphorus, microbial enumeration, and alkalinity. Specific details on the procedures for the collection and preparation of groundwater samples are presented in Section 5.3 of the FSAP. A summary of the sampling and analytical requirements is provided in Table 3-1.

3.1.3.3 Water Level Measurements

A minimum of two rounds of groundwater and surface water level measurements will be obtained from all site monitoring wells and staff gauges. All measurements will be obtained within a four hour period. In addition, the water levels in one shallow and one intermediate well will be monitored continuously for a 24- to 48-hour period to evaluate the affects of tidal changes on groundwater at the site.

3.1.4 **Ecological Investigation**

An ecological investigation will be conducted as part of the RI/FS at Site 65 and will consist of collecting surface water, sediment, fish tissue and benthic macrovertebrate samples concurrently from each of the two surface ponds located east of the site, and from one sampling station along the intermittent stream channel that carries excess flow from the ponds/marsh. A total of four stations

(65SW/SD04 through 65SW/SD07) will be sampled. One surface water and two sediment samples (obtained from depths 0 to 6 inches and 6 to 12 inches) will be collected from each sampling station. Proposed sampling stations are depicted on Figure 3-1. Specific details on the procedures for collecting and preparing surface water and sediment samples are presented in Sections 5.4 and 5.5. of this FSAP, respectively. Sample procedures for fish and macroinvertebrate samples are provided in Section 5.6 of this FSAP.

All surface water and sediment samples will be analyzed for full TCL organics and TAL metals in accordance with CLP methods. Sediment samples will also be analyzed for TPH. Surface water samples will also be analyzed for hardness. The 0 to 6-inch sediment sample from sampling station SD-04 will be submitted for grain size analysis and both samples from each station (0 to 6 inches and 6 to 12 inches) will be analyzed for TOC. A summary of the sampling and analytical requirements is provided on Table 3-1.

Surface water elevations will be obtained from the ponds and the unnamed tributary during the field investigation. Staff gauges will be installed and used to measure surface water levels which will be correlated with groundwater level measurements from monitoring wells. A minimum of two rounds of staff gauge readings will be obtained.

Benthic macroinvertebrate samples will be collected at each of the surface water/sediment sample stations. These samples will be collected by the ecological sampling staff in accordance with the collection procedures identified in Section 5.6 and Appendix H.

Fish samples will also be collected from the three surface water/sediment/benthic sampling stations in accordance with the procedures identified in Section 5.6 and Appendix H. The ecological staff shall attempt to obtain at least 10 of the following types of fish: top carnivores (e.g., bass, blue gill, or sunfish), forage fish (e.g., minnows, chubs), and bottom feeders (e.g., catfish). The 10 fish representing the three types of fish will be submitted to the laboratory for compositing of whole body and fillets for a total of six samples. The samples will be analyzed for full TCL organics and TAL metals via CLP Methods. A summary of the sampling and analytical program is provided on Table 3-1.

3.2 Site 73 - Courthouse Bay Liquids Disposal Area

The following investigations and support activities will be conducted at Site 73.

- Surveying
- Soil Investigation
- Groundwater Investigation
- Ecological Investigation (including surface water, sediment, fish, crab, and benthic sampling)

Each activity and investigation is described in the following subsections.

3.2.1 Surveying

The site survey will involve the surveying of the current site features including roads, buildings, fence lines, vehicle wash racks, existing USTs and ASTs, tank paths, surface water bodies such as

creeks, marsh areas and the edge of Courthouse Bay, the location of the previously identified seep and any significant features which were noted during the site visit.

The locations of proposed soil borings, monitoring wells, and surface water and sediment sample stations will be established by the survey subcontractor prior to commencing the field program. Each location will be marked with a stake allowing the field teams to identify the location and the corresponding designation for each activity. Ground surface elevations and the horizontal control of each sampling location will be established.

Following the completion of the field program, vertical and horizontal control will be established for all of the existing and the newly installed monitoring wells, staff gauges and any sample locations that were relocated during the field program. A reference point on the top of the PVC riser, and the ground elevation will be surveyed for each monitoring well.

Survey points will include a latitude coordinate, a longitude coordinate, and an elevation expressed in feet of mean sea level. The vertical accuracy of the survey will be within 0.01 feet and the horizontal accuracy will be within 0.1 feet. All survey points will be referenced to the NCSPCS.

3.2.2 Soil Investigation

A soil investigation will be conducted at Site 73 to provide surface and subsurface soil data to evaluate areas of concern identified by the preliminary investigation, determine the nature and extent of soil contamination at the site, assess potential impacts to soil at existing and former UST locations, support a baseline human health and ecological risk assessment, and evaluate remedial action alternatives. The investigation will focus on the specific areas identified in the Work Plan. The following subsections describe the tasks proposed for the field program.

3.2.2.1 Sampling Locations

A projected 48 soil borings (including shallow and intermediate depth groundwater monitoring wells) will be drilled to characterize the shallow stratigraphy at the site and to collect samples for laboratory analysis. Thirty-four borings will be completed as groundwater monitoring wells (including 29 shallow and 5 intermediate monitoring wells). The shallow wells will be installed at an estimated depth of 20 feet and the intermediate wells at an estimated depth of 60 feet. The remaining 14 soil borings (i.e., non-monitoring well borings or "test borings") will be advanced to the water table (an estimated maximum depth of 8 feet). Additional soil borings may be required based on the analytical results of soil samples obtained from the proposed borings. The proposed drilling locations are identified on Figure 3-2.

Three unsaturated soil samples will be obtained from each soil boring if 6 feet or more of unsaturated soil is encountered. This includes one surface (0 to 12 inches) soil sample, one from the interval located just above the groundwater surface, and a third sample based on visual observations and field screening performed via a photoionization detector. If less than 6 feet of unsaturated soil is encountered, only two soil samples will be collected including a surface soil sample and another soil sample from the interval located just above the groundwater surface.

Two upgradient borings will be drilled northwest of the site in an area not believed to have been impacted by previous activities. One surface and one or two subsurface samples will be collected from one of the borings following the same protocol previously indicated and will be submitted for

analysis. Both of the borings will be converted to groundwater monitoring wells. One of the wells will be constructed such that the screened portion will intercept the water table (shallow zone) and the other will monitor the upper portion of the Castle Hayne Aquifer (intermediate zone). At other locations where both shallow and intermediate depth groundwater wells are constructed together to form a well cluster, soil samples will be obtained from only one of the borings.

Section 5.1 of the FSAP discusses the procedures for the collection and preparation of the soil samples collected during drilling and trenching activities.

3.2.2.2 Analytical Requirements

All soil samples collected from the soil borings will be analyzed for TCL volatiles, TCL semivolatiles, pesticides/PCBs, TAL metals, and TPH. Analytical methods for volatile analysis will be dependent on the boring location with respect to the UST being investigated or the area of concern. USTs which contain or have contained waste oil will require that soil samples be analyzed via Method 9071 (oil and grease) and 8021 (volatile organics), and 1311 (TCLP for organics and metals). One soil sample (MW-13) will be analyzed for the following in addition to the previously stated analyses: TOC, redox potential, BOD, COD, alkalinity, fluoride, chloride, microbial enumeration, TKN, total phosphorus, Atterberg limits, and particle size distribution.

A minimum of two composite samples of drill cuttings shall be obtained and analyzed in accordance with TCLP and for RCRA hazardous waste characteristics in order to assess disposal options.

Soil samples shall be analyzed in accordance with the parameters listed on Table 3-2. The parameters shown on Table 3-2 vary, depending on the area being investigated. The rationale for this sampling scheme is provided in Section 4.4.2 of the RI/FS Work Plan.

3.2.3 **Groundwater Investigation**

The purpose of the groundwater investigation is to determine the nature and extent of groundwater contamination in the shallow (water table) and intermediate (approximately 60 feet bgs) groundwater zones across the site, to provide data to support a baseline human health and ecological risk assessment, and evaluation of remedial action alternatives. The following subsections describe the tasks proposed for the field program.

It is anticipated that 29 soil borings will be completed as shallow groundwater monitoring wells (Type II well construction). The proposed locations are presented on Figure 3-2. The wells will be installed to depths ranging from approximately 15 to 30 feet bgs. The well screens for the shallow wells will be 15 feet in length and will intercept the water table (approximately 4 to 8 feet bgs).

In addition to the shallow groundwater monitoring wells, a minimum of five intermediate monitoring wells will be installed to delineate the extent of vertical contaminant migration (if any) at this site. The intermediate zone is defined as approximately 60 feet bgs corresponding to the depth of the upper screened portion of the water supply well (A5) located nearest the site. If a semi-confining unit (i.e., subsurface soil zone exhibiting considerably lower hydraulic conductivity than the zone in which the water table surface is contained) is encountered during advancement of the borehole, the well will be constructed as a Type III monitoring well. If a semi-confining unit is not encountered, then a Type II well will be installed at the specified depth. The screen length of the intermediate monitoring wells will be 10 to 20 feet. Well construction details for the proposed

shallow Type II and Type III monitoring wells are illustrated on Figures 5-1 and 5-2 in Section 5.0 of the FSAP. Well installation procedures and well construction materials are discussed in Section 5.2 in this FSAP.

Seventeen existing groundwater monitoring wells (A-5 [supply well], 73GW2, 73GW3, 73GW4, 73GW5, DW-2, MW-8, MW-9, MW-13, MW-16, MW-18, A47/3-8, A47/3-9, A47/3-11, A47/3-13, A47/3-16, and A47/322), installed during previous investigations, will be resampled as part of this investigation.

3.2.3.1 Sampling and Analysis

One round of groundwater samples will be collected from the 34 newly installed monitoring wells and from 17 existing wells. Samples will be collected approximately one week following the development of the newly installed wells. Depending on the focus of the reinvestigation, the following analytical methods will be used. Groundwater samples collected from monitoring wells proposed to investigate USTs which contain or have contained low boiling point fuels (i.e., gasoline or jet fuel) will be analyzed via Method 601/602, MTBE, EDB, and isopropyl ether. Groundwater samples collected from wells proposed to investigate USTs which contain or have contained high boiling point fuels (i.e., diesel) will be analyzed via Method 602 and 625 (plus 10 largest peaks). Groundwater samples collected from monitoring wells proposed to investigate USTs which contain or have contained used/waste oil will be analyzed via Method 5022 and 625 (with 10 highest peaks identified). All other monitoring wells will be analyzed for volatiles via Method 601/602 and TCL semivolatiles, pesticides, and PCBs via CLP protocols. In addition, all monitoring wells will be analyzed for TSS and TAL metals (total metals plus 5 percent of the samples for dissolved metals) via CLP protocols, and a sample from one monitoring well (MW-20) will be analyzed for BOD, COD, TOC, total kjeldahl nitrogen (TKN), TDS, total phosphorus, microbial enumeration, and alkalinity. Specific details on the procedures for the collection and preparation of groundwater samples are presented in Section 5.3 in this FSAP. Groundwater samples collected from the proposed monitoring wells shall be analyzed in accordance with the parameters listed on Table 3-2. The rationale for this sampling scheme is provided in Section 4.4.2 of the RI/FS Work Plan.

3.2.3.2 Water Level Measurements

A minimum of two rounds of groundwater and surface water level measurements will be obtained from all 34 newly installed monitoring wells, and the 17 existing wells sampled as part of this investigation. All measurements will be obtained within a four hour period. Additionally, two rounds of staff gauge readings will be collected during a 12-hour period at one hour increments to determine the tidal affect on the creeks and the portion of the Courthouse Bay adjacent to the site. The water levels in two shallow and two intermediate wells will be monitored continuously for a 24- to 48-hour period to evaluate the affects of tidal changes on groundwater at the site.

3.2.4 **Ecological Investigation**

An ecological investigation will be conducted at Site 73 and will consist of collecting surface water, sediment, fish, crab and benthic samples from various locations at AOCs 7, 8 and 9. A total of twelve stations (SW/SD01 through SW/SD12) will be sampled. One surface water and two sediment samples (0 to 6 inches and 6 to 12 inches) will be collected from each sampling station. Specific details on the procedures for collecting and preparing surface water and sediment samples are presented in Sections 5.4 and 5.5 of this FSAP, respectively. Proposed locations are presented in

Figure 3-2. An additional surface water sample will be obtained from the seeps observed in AOC #2.

Benthic macroinvertebrate samples will be collected at each of the surface water/sediment sample stations. These samples will be collected by the ecological sampling staff in accordance with the collection procedures identified in Appendix H.

Fish and crab/shellfish samples will also be collected from the three surface water/sediment/benthic sampling stations in accordance with the procedures identified in Section 5.6 and Appendix H. The ecological staff shall attempt to obtain at least 10 of the following types of fish: top carnivores (e.g., bass, blue gill, or sunfish), forage fish (e.g., minnows, chubs), and bottom feeders (e.g., catfish). The 10 fish representing the three types of fish will be submitted to the laboratory for compositing of whole body and fillets for a total of six samples. The samples will be analyzed for full TCL organics and TAL metals via CLP Methods. A summary of the sampling and analytical program is provided on Table 3-2.

All surface water, sediment, fish, crab, and benthic samples will be analyzed for full TCL organics and TAL metals in accordance with CLP methods. Sediment samples will also be analyzed for TPH and surface water samples will also be analyzed for hardness. The 0 to 6-inch sediment sample will be submitted for grain size analysis and both sediment samples from each sampling station (0 to 6 inches and 6 to 12 inches) will be analyzed for TOC. A summary of the sampling and analytical requirements is provided on Table 3-2.

Surface water elevations will be obtained from Courthouse Bay and the two unnamed creeks on each side of Site 73 leading to Courthouse Bay during the field investigation. Staff gauges will be installed and used to measure surface water levels which will be correlated with groundwater level measurements from monitoring wells. A minimum of two rounds of staff gauge readings will be obtained.

3.3 QA/QC Samples

QA/QC requirements for this investigation are presented in the Quality Assurance Project Plan (QAPP) which is provided as Section II of this FSAP. The following QA/QC samples will be collected at each of the four sites during field sampling activities:

- **Trip Blanks**

Trip blanks are defined as samples which originate from the analyte-free water taken from the laboratory to the sampling site and returned to the laboratory with the volatile organic analyte (VOA) samples. One trip blank should accompany each cooler containing samples for VOAs. The blanks should only be analyzed for volatile organics.

- **Equipment Rinsates**

Equipment rinsates are the final analyte-free/organic free water rinse from equipment decontamination procedures. Equipment rinsates will be collected daily during each sampling event. Initially, samples from every other day should be analyzed. If analytes pertinent to the project are found in the rinsates, the remaining

samples must be analyzed. The results from the rinsates will be used to evaluate the decontamination methods. This comparison is made during data validation and the rinsates are analyzed for the same parameters as the related samples.

One equipment rinsate will be collected per day of field sampling.

- **Field Blanks**

Three field blanks (ambient condition blanks) will be prepared at the commencement of each sampling event. One field blank will be prepared by pouring potable water (used for decontamination purposes) into one set of sample bottles. The second field blank will utilize analyte-free/organic-free water. Field blanks will be analyzed for the same parameters as the related samples.

- **Field Duplicates**

Field duplicates for soil samples are collected, homogenized, and split. All samples except VOAs are homogenized and split. Volatiles are not mixed, but select segments of soil are taken from the length of the core and placed in 4-ounce glass jars. The duplicates for water samples should be collected simultaneously. The water samples will not be composited.

Field duplicates will be collected at a frequency of 10 percent.

- **Matrix Spike/Matrix Spike Duplicates (MS/MSD)**

MS/MSD samples are collected to evaluate the matrix effect of the sample upon the analytical methodology. A matrix spike and matrix spike duplicate must be performed for each group of samples of a similar matrix

MS/MSD samples will be collected at a frequency of 5 percent.

3.4 Investigation Derived Waste

Investigation derived wastes (IDW) will be generated during the field program at OU No. 9. The IDW to be generated will include soil and mud cuttings, purge and development groundwater, spent decontamination fluid, and personal protective equipment (PPE) and clothing (PPC). Tables 3-3 and 3-4 summarize the estimated IDW quantities, the contaminants of concern for each IDW media, and the proposed management of each IDW per site. The following describes the procedures for IDW management for OU No. 9.

3.4.1 Soil IDW Management

Soil cuttings (and drilling mud) generated during soil boring and monitoring well installations, and spoil generated from trench excavations will be placed back into the boring or trench in the same order in which it was taken out, or spread out on the ground surface where wells will be constructed in the borehole. If the cuttings cannot be spread out (e.g., areas covered by concrete), the cuttings shall be containerized.

3.4.2 Groundwater IDW Management

Groundwater generated during well development and purging will be managed in one of two ways as described in Table 3-4. Groundwater collected from Site 65 will be discharged onto the ground surface unless the groundwater exhibits visual contamination (e.g., NAPL or oily sheen) or exhibits unusual odors (e.g., fuel or solvents). Groundwater from Site 73 will be temporarily containerized in tanks, sampled, and analyzed for TCL organics, TAL metals and RCRA hazardous waste characteristics. Contaminated groundwater will be transported and disposed off site and noncontaminated groundwater will be discharged on the ground surface at the site. Table 3-4 summarizes the groundwater IDW management options.

3.4.3 Decontamination IDW Management

Spent decontamination fluids will be containerized temporarily in drums at each site, sampled and analyzed for TCL organics, TAL metals and RCRA hazardous waste characteristics. Upon receipt of analytical data, the fluids will be transported off site for disposal (hazardous or nonhazardous depending on the analytical results).

3.4.4 PPE and PPC IDW Management

PPE (e.g., spent respirator cartridges) and PPC (e.g., tyvek) will be double bagged, labeled and disposed as solid waste in an on site refuse container. This container will be emptied at a sanitary landfill. If the PPE or PPC is exposed to potentially hazardous substances or excessively contaminated soil or groundwater, they will be placed in a drum and disposed in a solid waste landfill (Subtitle D).

SECTION 3

Tables

TABLE 3-1

**SITE 65 SAMPLING AND ANALYTICAL PROGRAM
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA**

Investigation	Sample Locations	Number of Samples	Analysis	Method	Turnaround Time
Soil Borings	SB06, SB07, SB08, SB09, SB10, SB11, MW01B, MW02B, MW04A, MW05, MW06A, and MW07A	2 to 3 samples per borehole, depending on the depth to the water table (24 to 36 soil samples)	TCL Organics	CLP/SOW	Routine
			TAL Metals	CLP/SOW	Routine
	SB06	1 composit sample	TOC	EPA 415.1	Routine
			Alkalinity	SM 403	Routine
			BOD	SM 507, EPA 405.1	Routine
			Redox Potential	ASTM 1498	NA
			COD	EPA 410.1	Routine
			Microbial Count	SM 907	Routine
			Nitrogen (TKN)	EPA 351.3	Routine
			Total Phosphorus	EPA 365.2	Routine
			Atterberg Limits	ASTM D4943-89	Routine
Particle Size	ASTM D422-63	Routine			
Test Pit	TP-01 through TP-07	1 composite sample from each test pit; 7 sample total	TCL Organics	CLP/SOW	Routine
			TAL Metals	CLP/SOW	Routine
			TPH	EPA 8015	Routine
	TP-01 through TP-07	1 sample of waste or discolored soil encountered during test pitting; number of samples to be determined based on field observations	TCL Organics	CLP/SOW	Routine
			TAL Metals	CLP/SOW	Routine
			Full TCLP	8240, 8270, 8080, 8150, and 6010	Routine
			Reactivity	SW 846 9012, 9030	Routine
			Corrosivity	SW 846 9010	Routine
			Ignitability	SW 846 1010	Routine
			TPH	EPA 8015	Routine

TABLE 3-1 (Continued)

**SITE 65 SAMPLING AND ANALYTICAL PROGRAM
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA**

Investigation	Sample Locations	Number of Samples	Analysis	Method	Turnaround Time
Groundwater	MW01A, MW01B, MW02A, MW02B, MW03, MW04A, MW04B, MW05, MW06A, and MW07A	1 round = 10 samples	TCL Organics	CLP/SOW	14 days
			TAL Metals	CLP/SOW	Routine
			TSS	EPA 160.2	Routine
	MW07A	1 round	TDS	EPA 160.1	Routine
			BOD	EPA 405.1	Routine
			COD	EPA 410.1	Routine
			TOC	EPA 415.1/9060	Routine
			TKN	EPA 351.3	Routine
			Total Phosphorus	EPA 365.2	Routine
			Microbial Count	SM 907	Routine
Surface Water	SW04, SW05, SW06, and SW07	1 round; 4 samples	Alkalinity	EPA 310.1	Routine
			TCL Organics	CLP/SOW	Routine
			TCL Metals	CLP/SOW	Routine
Sediment	SD04, SD05, SD06, and SD07	Two samples per location; 8 samples total	Hardness	EPA 130.2	Routine
			TCL Organics	CLP/SOW	Routine
			TAL Metals	CLP/SOW	Routine
			TPH	EPA 8015	Routine
	SD04	One surface sediment	TOC	EPA 415.1	Routine
Grain Size			ASTM D422-63	Routine	
Fish	SW04, SW05, and SW06	1 whole body carnivore 1 fillet carnivore 1 whole body forrage 1 fillet forrage 1 whole body bottom feeder 1 fillet bottom feeder	TCL Organics	CLP/SOW	Routine
			TAL Metals	CLP/SOW	Routine

TABLE 3-2

**SITE 73 SAMPLING AND ANALYTICAL PROGRAM
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA**

Investigation	Sample Locations	Number of Samples	Analysis	Method	Turnaround Time
Soil - UST A-47-1 Area and AOC No. 1	MW-13, DW-03, MW-14, MW-29, MW-12, SB-04, SB-05, SB-06, and MW-15.	2 to 3 samples per borehole; 18 to 27 samples total	Volatile Organics	8021 and 8240	Routine
			TCL Semi-volatiles	CLP/SOW	routine
			TCL Pesticides/PCBs	CLP/SOW	Routine
			Oil and Grease	9071	14 days
			TPH	8015 (5030 and 3550)	14 days
			TAL Metals	CLP-SOW	Routine
	MW-13	1 composite sample	TOC	EPA 403	Routine
			Alkalinity	SM 403	Routine
			BOD	SM507, EPA 405.1	Routine
			Redox Potential	ASTM 1498	NA
			COD	EPA 410.1	Routine
			Microbial count	SM 907	Routine
			Nitrogen (TKN)	EPA 351.3	Routine
			Total Phosphorus	EPA 365.2	Routine
Soil - UST A47/2, UST A-2, UST A-10/SA26, AOC 6 and AOC 3	SB-03, MW-28, MW-10, MW-04, MW-23, SB-07, SB-01, MW-02, MW-03, and A-5	2 to 3 samples per boring; 12 to 18 samples total	Oil and Grease	9071	14 days
			Volatile Organics	8021	Routine
			TPH	8015 (5030 and 3550)	14 days
Soil - UST A47/3, UST A47/4, UST A47/5, and UST A12-1	MW-17, MW-16, MW-26, MW-27, MW-11, SB-02, and MW-08	2 to 3 soil samples per boring; 14 to 21 samples total	TPH	8015 (5030 and 3550)	14 days

TABLE 3-2 (Continued)

SITE 73 SAMPLING AND ANALYTICAL PROGRAM
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

Investigation	Sample Locations	Number of Samples	Analysis	Method	Turnaround Time
Soil UST A12/2	MW-25 and MW-09	2 to 3 soil samples per boring, 4 to 6 samples total	TPH	8015 (5030 and 3550)	14 days
Soil - AOC 4 and 5	SB-13, SB-14, MW-18, MW-19, SB-08, SB-09, SB-10, SB-11, SB-12, MW-20, MW-21 MW-24	2 to 3 samples per boring; 24 to 36 samples total	TPH	8015 (5030 and 3550)	14 days
			Oil and Grease	9071	14 days
			TCL Organics	CLP/SOW	Routine
			TAL Metals	CLP/SOW	Routine
Soil - AOC 2	MW-05, MW-06, MW-07, and MW-22	2 to 3 samples per boring, 8 to 12 samples total	TCL Organics	CLP/SOW	Routine
			TAL Metals	CLP/SOW	Routine
			TPH	8015 (5030 and 3550)	14 days
	Soil IDW	1 composite sample per roll-off box; 2 samples total	TCLP Volatiles	1311/8240	Routine
			TCLP Semi-volatiles	1311/8270	Routine
			TCLP Metals	1311/6010	Routine
Groundwater - UST Area A47/1 and AOC No. 1	MW-13, MW-14, MW-11, MW-29, DW-03, MW-15, DW-04, MW-12, 73GW3, 73GW4, A47/3-8, and A47/3-9	1 round; 12 samples	Volatile Organics (including xylenes, MTBE, EDB and isopropyl ether)	601/602	14 days
			Semi-volatile organics	625	Routine
			TCL Pesticides/PCBs	CLP/SOW	Routine
			TAL Metals	CLP/SOW	Routine
			TSS	EPA 160.2	Routine
	MW-13	1 round	TDS	EPA 160.1	Routine
			BOD	EPA 405.1	Routine
			COD	EPA 410.1	Routine
			TOC	EPA 415.1/9060	Routine
			TKN	EPA 351.3	Routine
			Total Phosphorus	EPA 365.2	Routine
			Microbial Count	SM 907	Routine
			Alkalinity	EPA 310.1	Routine
			Acidity	EPA 305.2	Routine

TABLE 3-2 (Continued)

**SITE 73 SAMPLING AND ANALYTICAL PROGRAM
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA**

Investigation	Sample Locations	Number of Samples	Analysis	Method	Turnaround Time	
Groundwater - USTs A47/3, A47/4, A47/5, A12-1, A12-2 and AOC No. 6	MW-16, MW-26, MW-17, MW-27, MW-25, MW-08, MW-09, A47/3-13, A47/3-16, A47/3-22, A47/3-11, and DW-2	1 round; 12 samples	Volatile Organics, Xylenes, MTBE, EDB, and Isopropyl Ether	601/602	14 days	
			Semi-volatile Organics	625	Routine	
			TAL Metals	CLP/SOW	Routine	
			TSS	EPA 160.2	Routine	
	A47/3-13	1 round	TDS	EPA 160.1	Routine	
			BOD	EPA 405.1	Routine	
			COD	EPA 410.1	Routine	
			TOC	EPA 415.1/9060	Routine	
			TKN	EPA 351.3	Routine	
			Total Phosphorus	EPA 365.2	Routine	
			Microbial Count	SM 907	Routine	
	Groundwater - AOC Nos. 4 and 5	Existing: DW-12, MW-19, MW-13, MW-8, MW-18, MW-16 New: MW-18, MW-20, MW-21, MW-24, MW-19, DW-05	1 round; 12 samples	Volatile Organics, Xylenes, MTBE, EDB, and Isopropyl Ether	601/602	14 days
				Semi-volatile Organics	625	Routine
TAL Metals				CLP/SOW	Routine	
TSS				EPA 160.2	Routine	

TABLE 3-2 (Continued)

SITE 73 SAMPLING AND ANALYTICAL PROGRAM
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

Investigation	Sample Locations	Number of Samples	Analysis	Method	Turnaround Time
Groundwater - AOC Nos. 4 and 5	MW-20	1 round	TDS	EPA 160.1	Routine
			BOD	EPA 405.1	Routine
			COD	EPA 410.1	Routine
			TOC	EPA 415.1/9060	Routine
			TKN	EPA 351.3	Routine
			Total Phosphorus	EPA 365.2	Routine
			Microbial Count	SM 907	Routine
			Alkalinity	EPA 310.1	Routine
Groundwater - AOC No. 2	MW-05, MW-06, MW-07, MW-22, MW-23, MW-01, DW-01, and 73GW2	1 round; 8 samples	Volatile Organics	601/602	14 days
			Semi-volatile Organics	625	Routine
			TCL Pesticides/PCBs	CLP/SOW	Routine
			TAL Metals	CLP/SOW	Routine
			TSS	EPA 160.2	Routine
Groundwater - AOC 3, UST A10/SA-26, and UST A-2	MW-02, MW-03, MW-04, MW-23, MW-01, MW-01, DW-01, MW-28, and MW-10	1 round; 9 samples	Volatile Organics	502.2	14 days
			Semi-volatile Organics	625	Routine
			TAL Metals (Total)	CLP/SOW	Routine
			TSS	EPA 160.2	Routine
Surface Water	SW-01 through SW-12, and the seep (AOC 2)	1 round; 13 samples	TCL Organics	CLP/SOW	Routine
			TAL Metals	CLP/SOW	Routine
			Hardness	EPA 130.2	Routine

TABLE 3-2 (Continued)

**SITE 73 SAMPLING AND ANALYTICAL PROGRAM
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA**

Investigation	Sample Locations	Number of Samples	Analysis	Method	Turnaround Time
Sediment	SD-01 through SD-12	2 samples per station; 24 samples total	TCL Organics	CLP/SOW	Routine
			TAL Metals	CLP/SOW	Routine
			TPH	8015 (5030 and 3550)	Routine
			TOC	415.1	Routine
	SD-01 through SD-12	1 sample per station	Particle Size	ASTM D442-63	Routine
Fish/Crab	F/C-01, F/C-02, F/C-03	1 Whole Carnivore 1 Fillet Carnivore 1 Whole Forrage Fish 1 Fillet Forrage Fish 1 Whole Bottom Feeder 1 Fillet Bottom Feeder 1 Crab	TCL Organics	CLP/SOW	Routine
			TAL Metals	CLP/SOW	Routine

TABLE 3-3

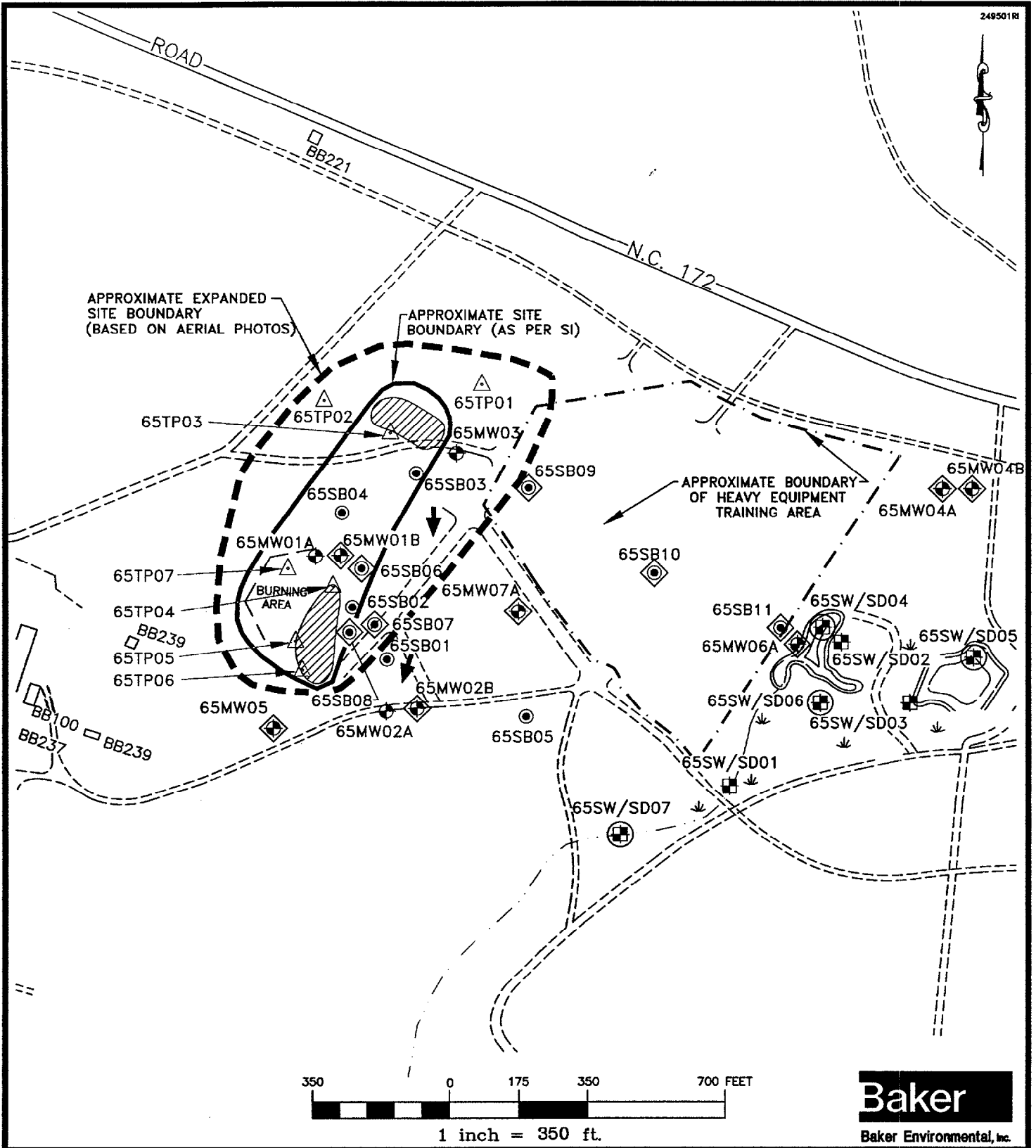
**ESTIMATED INVESTIGATION DERIVED WASTE QUANTITIES GENERATED
DURING VARIOUS SITE ACTIVITIES AT OPERABLE UNIT NO. 9
REMEDIAL INVESTIGATION/FEASIBILITY STUDY, CTO-0249
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA**

Site	Activity	Media	Estimated Quantity
65	Soil Boring/ Monitoring Well Installation	Soil/Mud Cuttings	14 yd ³
	Well Development	Groundwater	225 gallons
	Well Purging	Groundwater	225 gallons
	Decontamination	Liquids	200 gallons
73	Soil Boring/ Monitoring Well Installation	Soil/Mud Cuttings	68 yd ³
	Well Development	Groundwater	635 gallons
	Well Purging	Groundwater	635 gallons
	Decontamination	Liquids	200 gallons

TABLE 3-4

**INVESTIGATION DERIVED WASTE MANAGEMENT FOR OPERABLE UNIT NO. 9
REMEDIAL INVESTIGATION/FEASIBILITY STUDY, CTO-0249
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA**

Site	Media	Activity	Estimated Quantity	Contaminants of Concern	Management Option
65	Soil/Mud Cuttings	Soil borings/test pits	4.5 yd ³	Volatiles/ Semivolatiles/ Metals	Backfill cuttings/test pit spoil into borehole/test pit.
		Shallow well installation	1.5 yd ³	Volatiles/ Semivolatiles/ Metals	Spread cuttings onto ground near borehole.
		Intermediate well installation	8 yd ³	Volatiles/ Semivolatiles/ Metals	Spread cuttings onto ground near borehole.
	Groundwater	Background and upgradient - development and purging	50 gallons	Volatiles/ Semivolatiles/ Metals	Discharge onto ground surface; containerize groundwater if visually contaminated (NAPL) or solvent/fuel odor is noted.
		All remaining shallow/intermediate - development and purging	500 gallons	Volatiles/ Semivolatiles/ Metals	Discharge onto ground surface; containerize groundwater if visually contaminated (NAPL) or solvent/fuel odor is noted.
	Decontamination Fluids	Decontamination	200 gallons	Acetone	Containerize for offsite disposal at a TSDF.
73	Soil/Mud Cuttings	Soil borings	1 yd ³	Volatiles/ Semivolatiles	Backfill cuttings into borehole.
		Shallow well installation	7 yd ³	Volatiles/ Semivolatiles	Spread cuttings onto ground near borehole; if on concrete or asphalt, containerize cuttings in roll-off box.
		Intermediate well installation	10 yd ³	Volatiles/ Semivolatiles	Spread cuttings onto ground near borehole; if on concrete or asphalt, containerize cuttings in roll-off box.
	Groundwater	Background and upgradient monitoring wells - development and purging	120 gallons	Volatiles/ Semivolatiles	Contaminated groundwater is not expected, therefore, the groundwater will be discharged onto the surface near the well.
		All other wells	1,150 gallons	Volatiles/ Semivolatiles	Groundwater may be contaminated, therefore, groundwater will be temporarily contained pending analytical testing. A sample will be collected and if the groundwater is not contaminated, then it will be discharged at the site. Contaminated water will be transported off site for treatment.
	Decontamination Fluids	Decontamination	200 gallons	Acetone	Containerize fluids and drums for temporary storage; collect one composite sample and analyze for TCL organics, TAL metals, and RCRA hazardous waste characteristics. Decontamination fluids will be transported off site for treatment and disposal.



LEGEND

- | | |
|---|--|
| <ul style="list-style-type: none"> ☒ SI SURFACE WATER/SEDIMENT SAMPLE LOCATION ● SI SOIL BORING LOCATION ⊕ SI MONITORING WELL LOCATION ◊ PROPOSED SOIL BORING LOCATION ◊ PROPOSED MONITORING WELL LOCATION ▨ APPROXIMATE LOCATION OF VISIBLE DEBRIS PILES | <ul style="list-style-type: none"> ➔ APPROXIMATE GROUNDWATER FLOW DIRECTION --- APPROXIMATE INTERMITTENT STREAM LOCATION ⊕ PROPOSED SURFACE WATER/SEDIMENT/FISH AND BENTHIC SAMPLE LOCATION △ PROPOSED TEST PIT LOCATION |
|---|--|

FIGURE 3-1
PROPOSED AND EXISTING
SAMPLE LOCATION MAP
ENGINEER AREA DUMP
SITE 65
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



4.0 SAMPLE DESIGNATION

In order to identify and accurately track the various samples, all samples collected during this investigation, including QA/QC samples, will be designated with a unique number. The number will serve to identify the investigation, the site, the area within the site, the sample media, sampling location, the depth (soil) or round (groundwater) of sample, and QA/QC qualifiers.

The sample designation format is as follows:

Site # - Media/Station # - Depth/Round/QA/QC

An explanation of each of these identifiers is given below.

Site#	This investigation includes Sites 65 and 73.
Location	The location designation will refer to a surface feature or grid.
Media	SB = Soil Boring (soil sample from a boring) GW = Groundwater SW = Surface Water SD = Sediment W = Waste TP = Test Pit
Station#	Each soil test boring or monitoring well will be identified with a unique identification number.
QA/QC	(FB) = Field Blank (D) = Duplicate Sample (following depth/round) (TB) = Trip Blank (ER) = Equipment Rinsate
Depth/Round	Depth indicators will be used for soil samples. The number will refer to the depth of the top of the sampled interval. For example: 00 = ground surface to 1 foot below ground surface 01 = top of sample is 1 foot below ground surface 02 = top of sample is 3 feet below ground surface 03 = top of sample is 5 feet below ground surface Round indicator will be used for groundwater samples (round one and round two). For example:

Under this sample designation format the sample number 73-GW01DW-01D refers to:

73A2-GW01DW-01D Site 73, Area of Concern No. 2

73A2-GW01DW-01D Groundwater sample

73A2-GW01DW-01D Monitoring well #1

73A2-GW01DW-01D Deep well

73A2-GW01DW-01D Round 1

73A2-GW01DW-01D Duplicate (QA/QC) sample

The sample designation 65-SB11-00D refers to:

65-SB11-00D Site 65

65-SB11-00D Soil Boring

65-SB11-00D Test boring #11

65-SB11-00D Sample depth interval 0 to 12"

65-SB11-00D Duplicate (QA/QC) sample

This sample designation format will be followed throughout the project. Required deviations to this format in response to field conditions will be documented.

5.0 INVESTIGATIVE PROCEDURES

The investigative procedures to be used for Sites 65 and 73 will be discussed in the following subsections. These procedures include soil sample collection, monitoring well installation (both shallow and deep), aquatic sampling (fish/crabs/benthic), groundwater sample collection, surface water sample collection, sediment sample collection, decontamination procedures, surveying, handling of site investigation derived wastes, and water level measurements. Note that all of these procedures will follow the field methods described in the USEPA, Region IV, Environmental Services Division (ESD), Environmental Compliance Branch Standard Operating Procedures and Quality Assurance Manual (ECBSOPQAM), February 1, 1991. Additional guidance from other sources such as ASTM may be used, but if the ASTM and ESD methods are in conflict, the ESD procedure will be used.

5.1 Soil Sample Collection

Surface and subsurface soil samples will be collected at Sites 65 and 73. Soil samples will be collected from borings and during the installation of monitoring wells. Soil samples may also be collected from borings advanced by hand auger. Some soil samples will be collected from test pits (Site 65) excavated by a backhoe. All ground penetrations will receive utility clearance from the appropriate on-base personnel. Appendix A contains Baker's standard operating procedures (SOPs) for soil sample acquisition.

5.1.1 **Soil Borings Advanced by Hand Auger**

Hand augering is the most common manual method used to collect subsurface samples. Four-inch diameter augers with cutting heads are pushed and twisted into the ground and removed as the buckets are filled. The auger holes are advanced one bucket at a time. The practical depth of investigation using a hand auger is related to the material being sampled. Samples collected with a hand auger can be obtained from depths up to 10 feet. During this investigation, hand augers may be used to collect samples in areas inaccessible with a drill rig.

When a vertical sampling interval has been established, one auger bucket is used to advance the auger hole to the first desired sampling depth. Since discrete grab samples are to be collected to characterize each depth, a new bucket will be placed on the end of the auger extension immediately prior to collecting the next sample. The top several inches of soil should be removed from the bucket to minimize the chances of cross-contamination of the sample from fall-in of material from the upper portions of the hole. The bucket auger will be decontaminated between samples as outlined in Section 5.9.

5.1.2 **Soil Borings and Monitoring Well Boreholes**

Soil samples from soil borings advanced by a drilling rig will be collected using a split-spoon sampler. A split-spoon sampler is a steel tube, split in half lengthwise, with the halves held together by threaded collars at either end of the tube. This device can be driven into unconsolidated materials using a drive weight connected to the drilling rig. A split-spoon sampler (used for performing Standard Penetration Tests) is two inches outer diameter (OD) and 1-3/8-inches inner diameter (I.D.). This standard spoon is available in two common lengths providing either 20-inch or 26-inch internal longitudinal clearance for obtaining 18-inch or 24-inch long samples, respectively. Split-spoons capable of obtaining 24-inch long samples will be utilized during this investigation.

Split-spoon samples will be collected continuously to the ground water table in each boring once the surface sample is collected. Soil borings that will be converted into shallow monitoring wells (monitoring well boreholes) will be advanced approximately 13 feet below the water table. Soil borings converted into deep monitoring wells will be advanced to a depth of approximately 60 feet bgs, based on encountering the upper unit of the Castle Hayne Formation. The physical characteristics of the samples will be described by the site geologist. The soils will be classified referencing the Unified Soil Classification System (USCS). Soil sample descriptions will be recorded in the field geologist's notebook.

Selected split-spoon samples will be submitted to the laboratory for analysis. Typically, the surface sample and the sample collected just above the water table are submitted for analytical testing. Mid-depth samples may also be retained for analysis if indications of contamination are present (visual or by monitoring) or if the borings are greater than 10 feet. Soil samples will be collected at continuous 2-foot increments to the top of the water table. Below the water table, soil samples will be collected at 5 to 10-foot intervals (monitoring well installation). Surface soil samples will not be collected using a split-spoon sampler because a sufficient quantity of sample cannot be retained from 0 to 12 inches using this sampling device. Hence, surface samples will be collected using a stainless-steel hand auger. For borings only, split-spoon samples will be collected from approximately one foot to the top of the water table; for borings advanced for monitoring well installation, split spoon samples will be collected continuously from ground surface to the top of the water table.

The following procedures for collecting soil samples in split-spoons will be used:

1. The surface sample will be collected by driving the split-spoon with blows from a 140-pound hammer falling 30 inches in accordance with SOP Soil and Rock Sample Acquisition.
2. Advance the borehole to the desired depth using hollow stem auger drilling techniques. The split-spoon will be lowered into the borehole inside the hollow stem auger (this will ensure that undisturbed material will be sampled).
3. Drive the split-spoon using procedures outlined in 1 above.
4. Repeat this operation until the borehole has been advanced to the selected depth. Split-spoon samples will be collected continuously until groundwater is encountered.
5. Record in the field log book the number of blows required to effect each six inches of penetration or fraction thereof. The first six inches is considered to be a seating drive. The sum of the number of blows required for the second and third six inches of penetration is termed the penetration resistance, N. If the sampler is driven less than 18 inches, the penetration resistance is that for the last one foot of penetration. (If less than one foot is penetrated, the logs shall state the number of blows and the fraction of one foot penetrated.) In cases where samples are driven 24 inches, the sum of second and third 6-inch increments will be used to calculate the penetration resistance. (Refusal of the SPT will be noted as 50 blows over an interval equal to or less than 6 inches; the interval driven will be noted with the blow count.)

6. Bring the sampler to the surface and remove both ends and one half of the split-spoon such that the soil recovered rests in the remaining half of the barrel. Describe the recovery (length), composition, structure, consistency, color, condition, etc., of the recovered soil; then put into sample jars.
7. Split-spoon samplers shall be decontaminated after each use and prior to the initial use at a site according to procedures outlined in Section 5.9.

The following procedures are to be used for soil samples submitted to the laboratory:

1. After sample collection, remove the soil from the split-spoon sampler with a stainless steel spoon. Prior to filling laboratory containers, the soil sample should be mixed, in stainless steel bowls with stainless steel spoons, as thoroughly as possible to ensure that the sample is as representative as possible of the sample interval. Soil samples retained for VOC analysis should not be mixed. Discrete soil samples from different sections of the split-spoon, representative of the soil types encountered, will be placed in the sample jar with a minimum of disturbance. Further, sample containers for VOC analyses should be filled completely without head space remaining in the container to minimize volatilization.
2. Record all pertinent sampling information such as soil description, sample depth, sample number, sample location, and time of sample collection in the field log book. In addition, label, tag, and number the sample bottle(s) as outlined in Section 6.0.
3. Pack the samples for shipping. Attach seal to the shipping package. Chain-of-Custody Forms and Sample Request Forms will be properly filled out and enclosed or attached (Section 6.0).
4. Decontaminate the split-spoon sample as described in Section 5.6. Replace disposable latex gloves between sample stations to prevent cross-contamination of samples.

5.1.3 Test Pits (Site 65)

Test pits will be excavated using a backhoe. The following procedures apply to the excavation and backfilling of a typical test pit.

- The positions of the test pits shall be located in the field by the Field Team Leader or Site Manager. Utility clearance shall be obtained from Activity personnel for all test pit locations prior to excavation.
- Excavation equipment shall be thoroughly decontaminated prior to and after each test pit excavation.
- A safety zone shall be established around the test pit location prior to initiation of excavation.

- Excavation shall commence by removing lifts of no more than approximately 6 to 12 inches of soil.
- Test pit excavation will continue to a depth of 10 feet or to the water table (whichever is encountered first).
- Soil samples may be collected during the excavation. The collected sample shall consist of visually contaminated soil or soils exhibiting elevated levels of organics from monitoring instrument readings encountered during excavation. Samples will be collected from the backhoe bucket using a stainless steel trowel or spoon. Samples from the backhoe bucket will be collected from the center portion of the bucket to avoid contact. These samples will be logged, packaged, and submitted to the laboratory for analysis.
- The field inspector shall log the test pit soils and record observations and the test pit cross-section shall be sketched in the field log book with notable features identified.
- Test pit depths (and water levels) may be measured using an engineers rule (six foot) or a weighted measuring tape. Depths shall be measured from the ground surface.
- Upon completion, test pits shall be immediately backfilled.
- If debris is encountered, the debris that is removed from the test pit will be containerized and the excavation will be terminated (no additional debris will be removed).
- Test pit locations shall be marked with five wooden stakes; one at each corner and one in the center. The test pit number shall be recorded on the centrally located stake.

Backfilling of trenches and test pits is a normally accepted practice to reduce immediate site hazards and minimize the potential for rainwater accumulation and subsequent contaminant migration.

After inspection and completion of the appropriate test pit logs, backfill material should be returned to the pit under the direction of the field inspector. The test pit cover should be inspected and further regraded, if necessary. Where it is safe to do so, the backhoe bucket should be used to compact each one to 2-foot layer of clean backfill as it is placed, to reduce settling and compaction. Appendix B contains the SOPs for Test Pit Excavations.

5.2 Monitoring Well Installation

Shallow monitoring wells will be installed to monitor the shallow (water table) water-bearing zone. It is estimated that these wells will be installed from 15 to 30 feet. Procedures for the installation and construction of shallow monitoring wells are presented below (see Figure 5-1):

- Activity personnel will approve all monitoring well locations. These locations shall be free of underground or overhead utility lines.

- A borehole will be advanced by a drilling rig using 6-1/4-inch I.D. hollow stem augers. Initially, the boreholes may be advanced with 3-1/4-inch I.D. augers if flowing sand conditions are encountered. After the borehole has been advanced to its final depth with 3-1/4 inch augers, the borehole will be overdrilled with 6-1/4-inch I.D. augers.
- Soil (split spoon) samples will be collected continuously during borehole advancement once the surface sample is collected. Samples will be collected according to the procedures outlined in Section 5.1.2.
- Upon completion of the borehole to the desired depth, monitoring well construction materials will be installed (inside the hollow stem augers).
- PVC is the material selected for monitoring well construction. It was selected on the basis of its low cost, ease of use, and flexibility. USEPA Region IV requires justification of using PVC. Justification criteria for use of PVC as well as casing material are provided in Appendix C.
- Fifteen feet of 2-inch I.D., Schedule 40, #10 slot (0.010-inch) screen with a bottom cap will be installed. The screen will be connected to threaded, flush-joint, PVC riser. The riser will extend 2 to 3 feet above the surface. A PVC slip-cap vented to the atmosphere, will be placed at the top of the riser.
- The annular space around the screen will be backfilled with a well-graded medium-grained sand (No. 1 Silica Sand) as the hollow-stem augers are being withdrawn from the borehole. Sand shall be placed from the bottom of the boring (approximately 1 foot below the well) to approximately two feet above the top of the screened interval. A lesser distance above the top of the screened interval may be packed with sand if the well is very shallow to allow for placement of sealing materials.
- A sodium bentonite seal at least 24-inch thick, unless shallow groundwater conditions are encountered, will be placed above the sand pack. The bentonite shall be allowed to hydrate for at least 8 hours before further completion of the well.
- The annular space above the bentonite seal will be backfilled with a cement-bentonite grout consisting of either two parts sand per one part of cement and water, or three to four percent bentonite powder (by dry weight) and seven gallons of potable water per 94 pound bag of portland cement.
- The depth intervals of all backfill materials shall be measured with a weighted measuring tape to the nearest 0.1 foot and recorded in the field log book.
- The monitoring wells will be completed at the surface. The aboveground section of the PVC riser pipe will be protected by installation of a 4-inch diameter, 5-foot long steel casing (with locking cap and lock) into the cement grout. The bottom of the surface casing will be placed at a minimum of 2-1/2, but not more than 3-1/2 feet below the ground surface, as space permits. For very shallow wells, a steel

casing of less than 5 feet in length may be used. The protective steel casing shall not fully penetrate the bentonite seal.

- The top of each well will be protected with the installation of four, 3-inch diameter, 5-foot long steel pipes which will be installed around the outside of the concrete apron. The steel pipes shall be embedded to a minimum depth of 2.5 feet in 3,000 psi concrete. Each pipe shall also be filled with concrete. A concrete pad shall be placed at the same time the pipes are installed. The pad will be a minimum of 4 feet by 4 feet by 6 inches, extending two feet below the ground surface in the annular space and set two inches into the ground elsewhere. The protective casing and steel pipes will be painted with day-glo yellow paint, or equivalent.
- If necessary, in high-traffic areas, the monitoring well shall be completed at the surface using a "flush" man-hole type cover. If the well is installed through a paved or concrete surface, the annular space shall be grouted to a depth of at least 2.5 feet and the well shall be finished with a concrete collar. If the well has not been installed through a paved or concrete surface, the well shall be completed by construction of a concrete pad, a minimum of 4 feet by 4 feet by 6 inches, extending two feet below the ground surface in the annular space and set two inches into the ground elsewhere. If water table conditions prevent having a 24-inch bentonite seal and the concrete pad as specified, the concrete pad depth should be decreased. The concrete shall be crowned to meet the finished grade of the surrounding pavement, as required. If appropriate, the vault around the buried wellhead will have a water drain to the surrounding soil and a watertight cover.
- All wells will have a locking cap connected to the protective casing. Each well will be tagged which will contain general well construction information and marked as "Test Well - Not For Consumptive Use."

Figure 5-1 depicts a typical Type II shallow monitoring well construction diagram.

Procedures for the installation and construction of Type III deep wells are presented below:

- Activity personnel will approve all monitoring well locations. These locations will be installed free of underground or overhead utility lines.
- A borehole will be advanced initially using hollow stem augers to just below the water table (so that samples can be collected for laboratory analysis). The augers will be nominal 3/4-inch I.D. Continuous 2-foot split-spoon samples will be collected while the borehole is advanced. Samples will be collected according to the procedures outlined in Section 5.1.2.
- The borehole will be further advanced until completion using mud rotary drilling. The reason mud rotary drilling will be used is because of the unconsolidated formation and drilling depths anticipated. A tricon drill bit will be used for advancing the borehole.
- Split-spoon samples will be collected at approximate 5 to 10-foot intervals during borehole advancement (mud rotary drilling). If a clay layer is encountered which

may serve as a potential confining unit, continuous samples will be collected to determine the thickness of the layer. At that time, a decision will be made as to whether a Type-III well will be installed. Samples will be collected according to the procedures outlined in Section 5.1.2.

- Upon completion of the borehole to the desired depth, monitoring well construction materials will be installed.
- PVC is the material selected for monitoring well construction. It was selected on the basis of its low cost, ease of use and flexibility. USEPA Region IV requires justification of using PVC.
- Ten to twenty feet of 2-inch I.D., Schedule 40, # 10 slot (0.010-inch) screen with a bottom cap will be installed. The final determination for the length of the screen will be decided in the field based on the thickness of the upper portion of the Castle Hayne Formation.
- The annular space around the screen will be backfilled with a well-graded medium grain sand (No. 1 silica sand). Sand shall be placed from the bottom of the boring to approximately two feet above the top of the screened interval. A lesser distance above the top of the screened interval may be packed with sand if the well is very shallow to allow for placement of sealing materials.
- A sodium bentonite seal (typically bentonite pellets) at least 24-inches thick will be placed above the sand pack. The bentonite shall be allowed to hydrate for at least 8 hours before further completion of the well.
- The annular space above the bentonite seal will be backfilled with a cement-bentonite grout consisting of either two parts sand per one part of cement and water, or three to four percent bentonite powder (by dry weight) and seven gallons of potable water per 94 pound bag of portland cement. The cement-bentonite grout shall be installed using a tremie pipe, if applicable depths are anticipated (i.e., greater than 25 feet).
- The depth intervals of all backfill materials shall be measured with a weighted measuring tape to the nearest 0.1 foot and recorded in the field log book.
- The monitoring wells will be completed at the surface. The above-ground section of the PVC riser pipe will be protected by installation of a 4-inch diameter, 5-foot long steel casing (with locking cap and lock) into the cement grout. The bottom of the surface casing will be placed at a minimum of 2-1/2, but not more than 3-1/2 feet below the ground surface, as space permits.
- The top of each well will be protected with the installation of four, 3-inch diameter, 5-foot long steel pipes which will be installed around the concrete apron. The steel pipes shall be embedded to a minimum depth of 2.5 feet in 3,000 psi concrete. Each pipe shall also be filled with concrete. A concrete pad shall be placed at the same time the pipes are installed. The pad will be a minimum of 4 feet by 4 feet by 6 inches, extending two feet below the ground surface in the annular space and set

two inches into the ground elsewhere. The protective casing and steel pipes will be painted with day-glo yellow paint, or equivalent.

- If necessary, in high-traffic areas, the monitoring well shall be completed at the surface using a "flush" man-hole type cover. If the well is installed through a paved or concrete surface, the annular space shall be grouted to a depth of at least 2.5 feet and the well shall be finished with a concrete collar. If the well has not been installed through a paved or concrete surface, the well shall be completed by construction of a concrete pad, a minimum of 4 feet by 4 feet 6 inches, extending two feet below the ground surface in the annular space and set two inches into the ground elsewhere. If water table conditions prevent having a 24-inch bentonite seal and the concrete pad as specified, the concrete pad depth should be decreased. The concrete shall be crowned to meet the finished grade of the surrounding pavement, as required. If appropriate, the vault around the buried wellhead will have a water drain to the surrounding soil and a watertight cover.
- All wells will have a locking cap connected to the protective casing. Each well will be tagged which will contain general well construction information and marked as "Test Well - Not for Consumptive Use."

Figure 5-2 depicts a typical Type III deep monitoring well construction diagram.

All monitoring wells will be developed as specified in the USEPA Region IV ECBSOPQAM. The purposes of well development are to stabilize and increase the permeability of the filter pack around the well screen, to restore the permeability of the formation which may have been reduced by the drilling operations, and to remove fine-grained materials that may have entered the well or filter pack during installation. The selection of the well development method typically is based on drilling methods, well construction and installation details, and the characteristics of the formation.

Well development shall not be initiated until a minimum of 48 hours has elapsed subsequent to well completion. Shallow wells typically are developed via low-yield pumping in combination with surging using a surge block. Intermediate monitoring wells are developed using a submersible pump in combination with surging. Selection of a development device will be dependent on conditions encountered during monitoring well installation.

All wells shall be developed until well water appears relatively clear of fine-grained materials. Note that the water in some wells does not clear with continued development. Typical limits placed on well development may include any one of the following:

- Clarity of water based on visual determination
- A minimum well volume (typically three to five well volumes)
- Stability of pH, specific conductance, Eh, turbidity, and temperature measurements (typically less than 10 percent change between three successive measurements)
- Clarity based on turbidity measurements [typically less than 10 Net Turbidity Units (NTU)]

A record of the well development shall be completed to document the development process.

Usually, a minimum period of one week should elapse between the end of initial development and the first sampling event for a well. This equilibration period allows groundwater unaffected by the installation of the well to occupy the vicinity of the screened interval. Details on SOPs for monitoring well installation can be found in Appendix D.

5.3 Groundwater Sample Collection

Groundwater samples will be collected from existing and newly installed monitoring wells on site.

The collection of a groundwater sample includes the following steps:

1. First open the well cap and use volatile organic detection equipment (HNU or OVA) on the escaping gases at the well head to determine the need for respiratory protection. This task is usually performed by the Field Team Leader, Health and Safety Officer, or other designee.
2. When proper respiratory protection has been donned, sound the well for total depth and water level (decontaminated equipment) and record these data in the field logbook. Calculate the fluid volume in the well.
3. Lower the intake for the peristaltic pump (shallow wells under 25 feet in depth) or submersible pump [deep wells below 25 feet in depth (RediFlo-2® low yielding pumps)] into the well to a short distance below the water level (above screen, intake) and begin water removal. If the water level drops inside the well during purging, the flow rate shall be adjusted so that no net head loss occurs. A low flow (less than one gpm and less than the discharge rate sustained during well development) will be maintained during purging. Purged water will be temporarily stored in DOT-approved 55-gallon drums. Final treatment or disposal of purged water is addressed in Section 3.4.
4. Measure the rate of discharge using a bucket and stopwatch.
5. Purge a minimum of three to five well volumes before sampling. In low permeability strata (i.e., if the well is pumped to dryness), one volume will suffice. Allow the well to recharge as necessary, but preferably to 70 percent of the static water level, and then sample.
6. Record measurements of turbidity (most critical parameter; typically less than 10 turbidity units is considered "clear"), specific conductance, eH, temperature, and pH during purging (i.e., after each volume has been removed) to ensure the groundwater stabilizes. Less than 10 percent change between successive measurements shall be used to determine stability.
7. After it has been determined that the well has stabilized, samples will be collected directly from the peristaltic or submersible pump for all parameters except volatiles. Volatiles will be collected using a teflon bailer. When a teflon bailer is used, lower the bailer into the well, submerge into the groundwater, and retrieve. A teflon

coated line (only the portion in contact with the water table) will be used for lowering the bailer. Pour groundwater from the bailer into the laboratory-supplied sample bottles.

8. Samples for semivolatiles analysis will be collected first, followed by PCBs, pesticides, and metals. Volatiles will be sampled last since the pump will need to be withdrawn and a bailer inserted into the well for sample collection. Sample bottles will be filled in the same order for all monitoring wells.

Sample preservation handling procedures are outlined in Section 6.0.

Appendix E presents the SOP for groundwater sampling.

5.4 Surface Water Sample Collection

The following procedures will be used for the collection of surface water samples. At each station, samples will be collected at the approximate mid-vertical point or near the bank of the surface water body. Care will be taken to ensure that the sampler does not contact and/or stir up the sediments, while still being relatively close to the sediment-water interface.

The surface water samples will be collected by dipping the laboratory-supplied sample bottles directly into the water. Clean nitrile gloves will be worn by sampling personnel at each sampling station.

The water samples will be collected from near mid-stream at each station, where applicable. Water samples at the furthest downstream station will be collected first, with subsequent samples taken at the next upstream station(s). Sediment samples will be collected after the water samples to minimize sediment disturbance and suspension. Sampling personnel shall stand downstream at each station in order to minimize sediment disturbance.

All sample containers not containing preservative will be rinsed at least once with the sample water prior to final sample collection. In addition, the sampling container used to transfer the water into sample bottles containing preservatives will be rinsed once with sample water.

Care will be taken when collecting samples for analysis of VOCs to avoid excessive agitation that could result in loss of VOCs. VOC samples will be collected prior to the collection of the samples for analysis of the other parameters. Sample bottles will be filled in the same order at all sampling stations.

Temperature, pH, specific conductance, DO, and salinity measurements of the surface water will be measured in the field at each sampling location (at each sampling depth), immediately following sample collection.

The sampling location will be marked by placing a wooden stake and bright colored flagging at the nearest bank or shore. The sampling location will be marked with indelible ink on the stake. In addition, the distance from the shore and the approximate location will be estimated using triangulation methods, and recorded and sketched in the field log book. If permission is granted, photographs will be taken to document the physical and biological characteristics of the sampling location.

The following information will be recorded in the field log book:

- Project location, date and time
- Weather
- Sample location, number, and identification number
- Flow conditions (i.e., high, low, in flood, etc.)
- On site water quality measurements
- Visual description of water (i.e., clear, cloudy, muddy, etc.)
- Sketch of sampling location including boundaries of the water body, sample location (and depth), relative position with respect to the site, location of wood identifier stake
- Names of sampling personnel
- Sampling technique, procedure, and equipment used

Sample preservation and handling procedures are outlined in Section 6.0.

Details on surface water sample acquisition are presented in Appendix F.

5.5 Sediment Sample Collection

The following procedures will be used for the collection of sediment samples. At each station, surface and near surface sediment samples will be collected at a depth of 0 to 6 inches, and 6 to 12 inches. These intervals of sediment will be collected using a stainless steel hand-held coring instrument. A new or decontaminated stainless steel liner tube, fitted with an eggshell catcher to prevent sample loss, will be used at each station.

The coring device will be pushed into the sediments to a minimum depth of 15 inches, or until refusal, whichever is encountered first. The sediments in the 0 to 6-inch interval and 6 to 12-inch interval will be extruded with a decontaminated extruder into the appropriate sample containers. If less than 12 inches of sediments are obtained, the first 6 inches will be placed in the 0 to 6-inch container, and the remaining sediment will be placed into the 6 to 12-inch container.

The sampling procedures for using the hand-held coring instrument (i.e., stainless-steel core sampler) are outlined below:

1. Inspect and prepare the corer:
 - a. Inspect the core tube and, if one is being used, the core liner. Core tube and core liner must be firmly in place, free of obstruction throughout its length. Bottom edge of core tube, or of the nose piece, should be sharp and free of nicks or dents.
 - b. Check the flutter valve for ease of movement.
 - c. Check the flutter valve seat to make sure it is clear of any obstruction that could prevent a tight closure.
 - d. Attach a line securely to the core sampler. The line should be free of any frayed or worn sections, and sufficiently long to reach bottom.

2. Get in position for the sampling operation -- keeping in mind that disturbance of the bottom area to be sampled should be avoided.
3. Line up the sampler, aiming it vertically for the point where the sample is to be taken.
4. Push the core sampler, in a smooth and continuous movement, through the water and into the sediments -- increasing the thrust as necessary to obtain the penetration desired.
5. If the corer has not been completely submerged, close the flutter valve by hand and press it shut while the sample is retrieved. Warning: the flutter valve must be kept very wet if it is to seal properly.
6. Lift the core sampler clear of the water, keeping it as nearly vertical as possible, and handle the sample according to the type of core tube.
7. Secure and identify the new sample. Unscrew the nose cone. Pull the liner out. Push out any extra sediments (greater than 12 inches). Push out the sediments within the 6 to 12-inch interval, then push out the 0 to 6-inch sediment interval. Samples (with the exception of VOAs) will first be homogenized prior to being transferred to their containers.
8. Seal all sample jars tightly.
9. Label all samples.

Appendix F presents the SOP for sediment sampling.

5.6 Biological and Fish Sample Collection

Biological samples to be collected at Sites 65 and 73 are described in Section 3.0. Prior to initiating the sampling event, the following sampling area description information was recorded at each station:

- Project location, date and time
- Tide (low versus high)
- Weather
- Sample location, number, and identification number
- Flow conditions (i.e., high, low, in flood, etc.)
- On site water quality measurements
- Visual description of water (i.e., clear, cloudy, muddy, etc.)

- Description of sampling location including boundaries of the water body, sample location (and depth), relative position with respect to the site, location of wood identifier stake
- Names of sampling personnel
- Sampling technique, procedure, and equipment used
- Average width, depth and velocity of the water body
- Description of substrate
- Descriptions of other "abiotic" characteristics of the reach such as pools, riffles, runs, channel shape, degree of bank erosion, and shade/sun exposure
- Description of biotic community (i.e., flora, fauna, etc.)
- Description of other "biotic" characteristics of the reach including aquatic and riparian vegetation and wetlands

After the habitat review was complete, the field team leader will define and locate the stations for biological sampling. Every attempt will be made to define stations to exclude atypical habitats such as bridges and mouths of tributaries. In addition, upstream and downstream locations will be selected as ecologically similar as possible in their biotic and abiotic characteristics.

Field water quality measurements will be conducted at each station, prior to collection of the samples. These measurements include temperature, pH, DO, specific conductivity and salinity. All instruments will be calibrated in accordance with the manufacturers' instructions prior to conducting the measurements. All measurements, including the calibration procedures, will be recorded on field data sheets.

Appendix H presents the SOP for biological and fish sample collection.

5.6.1 Benthic Macroinvertebrate Sample Collection

Benthic macroinvertebrates will be collected at each station using a Standard Ponar Grab Sampler. At each station, three replicate samples will be completed, with one grab per replicate. The benthic macroinvertebrate samples will be collected in close proximity to where the sediment samples are collected.

After the sediments are collected, the contents of the sample will be placed into a small tub. The sediments in the tub are transferred to a No. 35 sieve (0.500 mm) and washed with water to remove small sediment particles. The remaining contents in the sieve are transferred into sample jars. Approximately half of the sample jar will be filled with the sample, and 10 to 15 percent (by weight) buffered formalin is added to fill the remainder of the jar. A 100 percent cotton paper label was placed inside the jar, identifying the station location and replicate number. The label is marked with a pencil. The outside of the jar is labeled using a black permanent marker with the station location and sample number. All the sample jars are stored in large plastic tubs until transfer to Baker Ecological Services Laboratory in Coraopolis, Pennsylvania.

5.6.1.1 Processing of Macroinvertebrate Samples

The samples will be returned to the Baker Ecological Services Laboratory for processing. The formalin in the jars will be replaced with 70% isopropyl alcohol. The samples will be sent to a laboratory for sorting of the benthic macroinvertebrates from the sample residue and subsequent taxonomic identification.

5.6.1.2 Analysis of Macroinvertebrates

Results of the benthic macroinvertebrate collection will be used to prepare the following descriptive statistics on a station-by-station basis: (1) a list of taxa collected; (2) a table of numbers of each taxa collected by replicate; and (3) relative pollution tolerance of the species.

The benthic macroinvertebrate communities will be examined using a mathematical expression of community structure (i.e., diversity index). Diversity data are useful because they condense a substantial amount of laboratory data into a single value. Separate values of the diversity index will be computed for sampling areas within the upstream, downstream and adjacent reaches. Analysis of the species diversity will be used to compare the community structure between the stations as well as evaluate the impact that the contaminants from the site may be having on the aquatic community.

The species collected during the aquatic surveys will be evaluated to determine their biological relevance, and pollution tolerance. Biological impairment of the benthic community may be indicated by the absence of generally pollution-sensitive macroinvertebrate species such as Ephemeroptera, Plecoptera, and Trichoptera; excess dominance by any one particular taxon; low overall taxa richness; or appreciable shifts in community composition relative to the reference condition. In addition, a Macroinvertebrate Biotic Index, based on North Carolina Biotic Index of benthic macroinvertebrates, will be used to assess stream quality, as appropriate.

5.6.2 Fish and Crab Collection

Fish will be collected at the designated stations using a combination of the following: gill nets, hoop nets, minnow traps, and catfish traps. In addition, crabs will be collected using crab pots. The following paragraphs discuss the procedures that are used for collecting the fish and crabs.

The gill nets used to collect the fish will be monofilament, 50 or 100 feet in length, 6 feet deep, and have a stretch mesh size ranging from 3 to 4 inches. The nets are deployed by securing both ends across the creek. At least two yellow buoys marked with Baker Environmental, the hotel phone number, and the scientific collection permit number will be attached to each net.

The gill nets will be deployed either in the morning or evening, and checked the following morning or evening. Fish that are dead for an extended period of time (i.e., bloating) will not be used for tissue analysis because of the potential for decomposition and leaching of contaminants from the organs into the edible portions of the fish.

Hoop nets will be used to collect fish. The hoop nets range in outer diameter from 2 to 3-1/2 feet and are 4-1/2 to 14 feet in length. The square mesh size is 1 to 1-1/2 inches. The nests are used with either 10-, 25- or 40-foot wings.

The hoop nets will be deployed by attaching each wing to a 6-1/2-foot fence post that is driven into the sediments, with the wings forming a 45 to 90 degree angle. The back of the hoop net is attached to a 6-1/2 fence post, and the net is stretched out to pull the wings taught. This post then was driven into the sediments to secure the nets in place. The nets are checked at least once daily, because these nets typically do not kill the captured fish.

Minnow traps will be deployed at each station along the bank facing downstream. The minnow traps will be baited and checked at the end of the sampling trip.

Catfish traps will be deployed at each station. The catfish traps are approximately 4 to 5 feet in length and 15 inches in diameter. They are deployed by weighing the traps and setting them in the channel. They are marked with a yellow buoy for easy retrieval.

Crab pots will be used to collect blue crabs at each of the stations. The crab pots will be either baited with chicken necks or dead fish obtained during the fish sampling. The crab pots are checked every few days.

The collected fish are separated into different species, and then measured and counted. The small fish (less than 20 mm) are weighed in groups of 10 or 20 because of their low individual weight; the larger fish are weighed individually. The proportion of individuals as hybrids and the proportion of individuals with disease, tumors, fin damage, and skeletal anomalies will be recorded at each station.

Most of the fish species are processed in the field and returned to the water body. Specimens that present taxonomic difficulties, or are too numerous for effective field processing, are preserved in 10 percent formalin and transported to the Baker Ecological Services Laboratory for taxonomic work. At a minimum, one representative fish from each species is preserved in 10 percent formalin as a voucher specimen.

Specimens submitted to the laboratory for chemical analysis will be wrapped in aluminum foil and placed into sealed plastic bags. A 100 percent cotton label is placed inside the bag, identifying the station number. A pencil will be used to mark the label. The outside of the bag is labeled with the station number using a black permanent marker and the bags are placed in a freezer.

5.6.2.1 Analysis of Fish and Crab Species

At each station, fish are collected for population statistics and fish and crabs are collected for tissue analysis. All fish will be weighed to the nearest gram and measured to the nearest tenth of a centimeter. The total length of the fish will be measured (i.e., the distance in a straight line from the anterior-most projecting part of the head to the farthest tip of the caudal fin when its rays are squeezed together).

Results of the fish collection effort will be used to prepare the following descriptive statistics on a station by station basis: 1) a list of fishes collected, 2) a table of numbers of each species collected by station (including hybrid and pathology statistics), 3) a table of fish population estimates in numbers per unit effort, and 4) a table of fish biomass estimates in weight per unit effort.

The fish and crab will be processed (e.g., filleted, homogenized) by the laboratory conducting the chemical analyses. If the time between sampling and preparation is longer than 48 hours, the fish and crab will be frozen.

5.7 Land Survey

Both Sites 65 and 73 will require survey information. Horizontal and vertical survey tolerances are addressed within the survey requirements under Section 3.0, for each of the sites. Appendix I provides a more detailed description of survey procedures and surveyor qualifications.

5.8 Monitoring and Data Collection Equipment

Field support activities and investigations will require the use of monitoring and data collection equipment. Specific conductance, turbidity, Eh, temperature, and pH readings will be recorded during groundwater and sample collection, and during well development. Appendix J, On-Site Water Quality Testing, provides specific procedures for collecting specific conductance, temperature, and pH readings.

Additional groundwater information will be obtained from the monitoring wells using water level meters, water-product level meters, and well depth meters. The operation and various uses of this data collection equipment is provided in Appendix K.

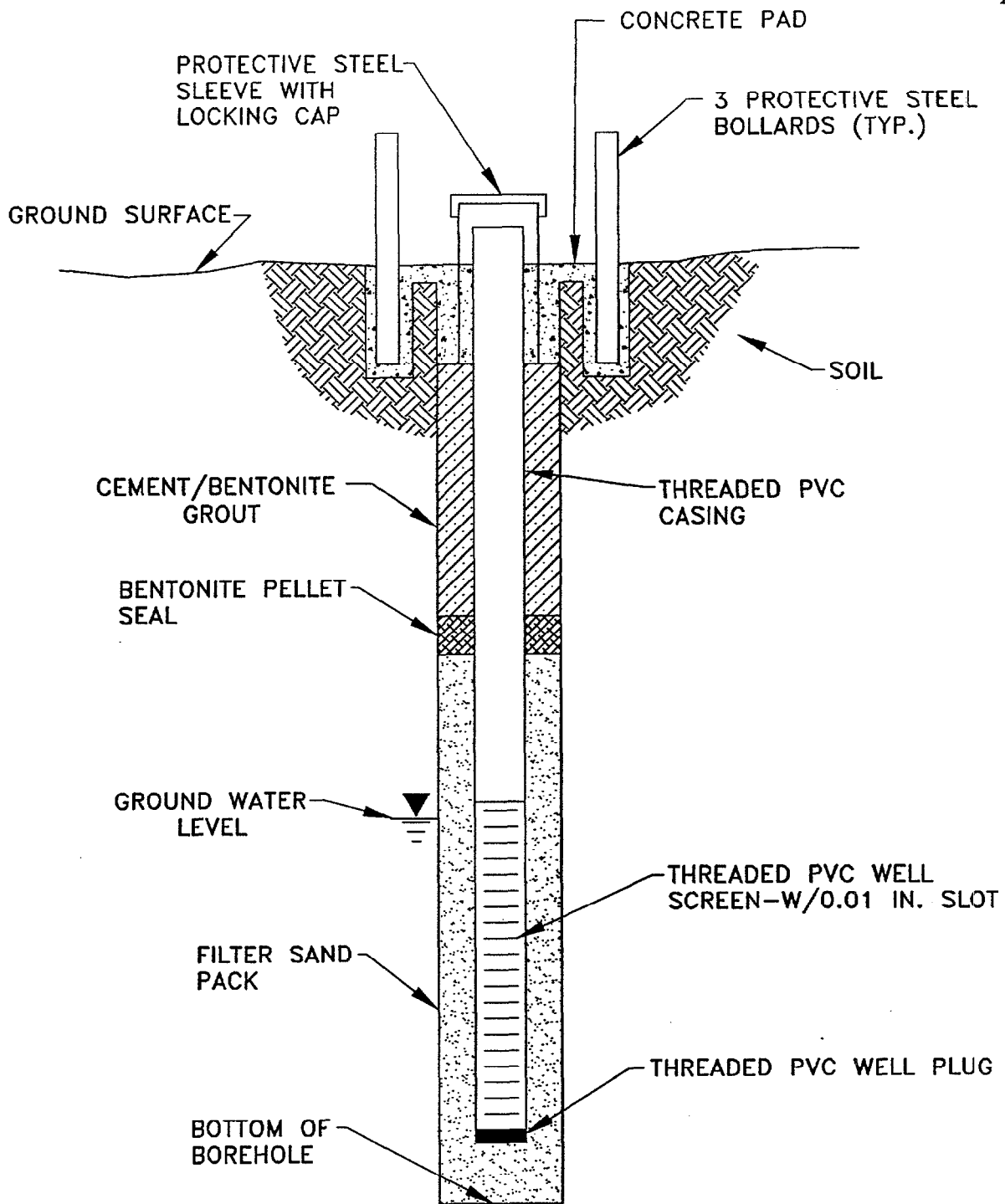
Health and safety monitoring and environmental media screening will be conducted using a photoionization detector (PID) and a combustible gas/oxygen meters (O₂/LEL). The operation and use of the PID is described in Appendix L. The Bacharach O₂/LEL meter will also be used during the sampling program, primarily to monitor health and safety conditions. Appendix M provides a description of the Bacharach O₂/LEL meter and operating procedures.

5.9 Decontamination

Equipment and materials that require decontamination fall into two broad categories:

1. Field measurement, sampling, and monitoring equipment (e.g. water level meters, bailers, split-spoon samplers, hand auger buckets, stainless steel spoons, etc.)
2. Machinery, equipment, and materials (e.g. drilling rigs, backhoes, drilling equipment, etc.)

Appendices N and O detail procedures for decontaminating the two categories of equipment, respectively.

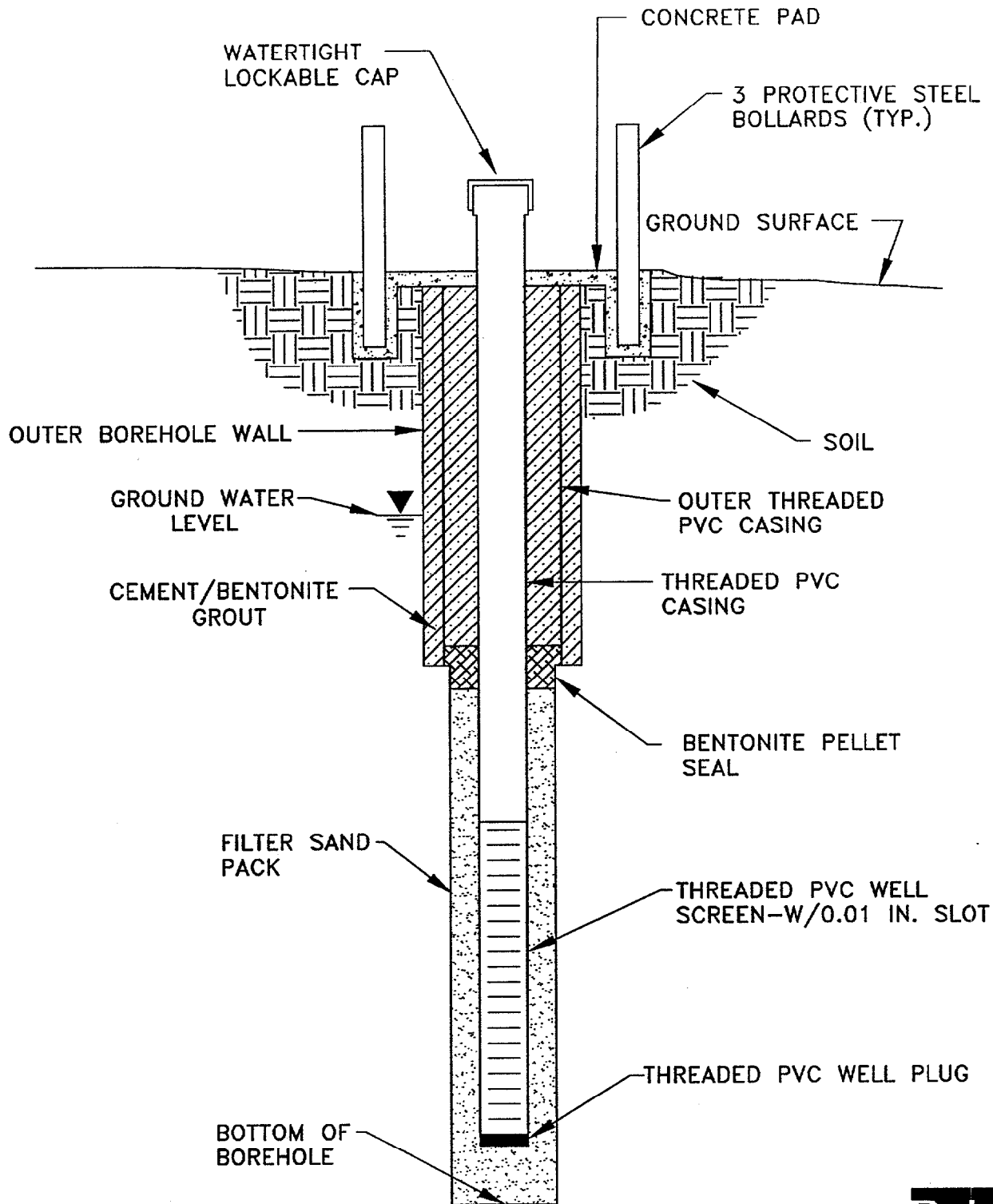


N.T.S.

Baker
Baker Environmental, Inc.

FIGURE 5-1
TYPICAL SHALLOW ABOVE GRADE TYPE II GROUNDWATER
MONITORING WELL CONSTRUCTION DIAGRAM

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



N.T.S.



FIGURE 5-2
TYPICAL INTERMEDIATE ABOVE GRADE TYPE III GROUNDWATER
MONITORING WELL CONSTRUCTION DIAGRAM

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

6.0 SAMPLE HANDLING AND ANALYSIS

Field activities will be conducted in accordance with the USEPA Region IV Environmental Compliance Branch Standard Operating Procedures and Quality Assurance Manual (February 1, 1991).

Bottle requirements, preservation requirements, and sample holding times are provided in Section 7.0 of the QAPP.

6.1 Sample Preservation and Handling

Sample preservation and handling procedures will be adhered to during the field program in order to maintain sample integrity. Preservation and handling procedures are provided in Appendix P of this FSAP.

6.2 Chain-of-Custody

Chain-of-custody procedures will be followed throughout the field program to ensure a documented, traceable link between measurement results and the sample or parameter they represent. These procedures are intended to provide a legally acceptable record of sample collection, identification, preparation, storage, shipping, and analysis. Chain-of-custody procedures to be followed during the field program are contained in Appendix Q.

6.3 Field Log Book

Field log books will be used to record sampling activities and information. Log books will be copied and submitted to the field site manager for filing upon completion of the field program. Entries will include general sampling information so that site activities may be reconstructed. In addition to the field log book, field forms (e.g. boring logs, well development records, etc) will be completed as support documentation for the field log book. Appendix R describes the general format of the field log book and applicable field forms.

7.0 SITE MANAGEMENT

This section outlines the responsibilities and reporting requirements of on-site personnel.

7.1 Field Team Responsibilities

The field portion of this project will consist of one field team. All field activities will be coordinated by a Site Manager. The Site Manager will ensure that all field activities are conducted in accordance with the project plans (the Work Plan, this Field Sampling and Analysis Plan, the Quality Assurance Project Plan, and the Health and Safety Plan). The Site Manager will report to the Baker Project Manager on a daily basis.

The Field Team will employ one or more drilling rigs for soil boring and monitoring well installation. Each rig(s) will be supervised by a Baker geologist. Two sampling technicians will be assigned to the field team. One of the sampling technicians will serve as the Site Health and Safety Officer.

7.2 Reporting Requirements

The Site Manager will report a summary of each day's field activities to the Project Manager or his/her designee. This may be done by telephone or telefax. The Site Manager will include, at a minimum, the following in his/her daily report:

- Baker personnel on site
- Other personnel on site
- Major activities of the day
- Subcontractor quantities (e.g., drilling footages)
- Samples collected
- Problems encountered
- Planned activities

The Site Manager will receive direction from the Project Manager regarding changes in scope of the investigation. All changes in scope will be discussed and agreed upon by LANTDIV, MCB, Camp Lejeune EMD, USEPA Region IV, and the NC DEHNR.

8.0 REFERENCES

U.S. Environmental Protection Agency (USEPA), 1992. Guidance for Performing Site Inspections Under CERCLA. Interim Final. Office of Emergency and Remedial Response, PB92-963375. EPA/540-R-92-021.

U.S. Department of the Navy (DON), 1992. Navy/Marine Corps Installation Restoration Manual. February 1992.

Environmental Science and Engineering, Inc. (ESE), 1990. Final Site Summary Report, Marine Corps Base Camp Lejeune, North Carolina. Prepared for Naval Facilities Engineering Command Atlantic Division. ESE Project No. 49-02036. September 1990.

U.S. Environmental Protection Agency (USEPA), 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. Interim Final. Office of Emergency and Remedial Response, OSWER Directive 9344.3-01. EPA/540/G-89-004.

Water and Air Research, Inc. (WAR), 1983. Initial Assessment Study of Marine Corps Base Camp Lejeune, North Carolina. Prepared for Naval Energy and Environmental Support Activity. April 1983.

APPENDIX A
Soil and Rock Sample Acquisition

SOP F102
Soil and Rock Sample Acquisition

**SOIL AND ROCK SAMPLE ACQUISITION
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SOIL AND ROCK SAMPLE ACQUISITION

1.0 PURPOSE

The purpose of this procedure is to describe the handling of rock cores and subsurface soil samples collected during drilling operations. Surface soil sampling also is described.

2.0 SCOPE

The methods described in this SOP are applicable for the recovery of subsurface soil and rock samples acquired by coring operations or soil sampling techniques such as split-barrel sampling and thin-walled tube sampling. Procedures for the collection of surface soil samples also are discussed. This SOP does not discuss drilling techniques or well installation procedures. ASTM procedures for "Penetration Test and Split-Barrel Sampling of Soils," "Thin-Walled Tube Sampling of Soils," and "Diamond Core Drilling for Site Investigation" have been included as Attachments A through C, respectively.

3.0 DEFINITIONS

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

Split-Barrel Sampler - A steel tube, split in half lengthwise, with the halves held together by threaded collars at either end of the tube. Also called a split-spoon sampler, this device can be driven into unconsolidated materials using a drive weight mounted on the drilling string. A standard split-spoon sampler (used for performing Standard Penetration Tests) is two inches O.D. and 1-3/8-inches inner diameter (I.D.). This standard spoon is available in two common lengths providing either 20-inch or 26-inch internal longitudinal clearance for obtaining 18-inch or 24-inch long samples, respectively.

Grab Sample - An individual sample collected from a single location at a specific time or period of time generally not exceeding 15 minutes. Grab samples are associated with surface water,

groundwater, wastewater, waste, contaminated surfaces, soil, and sediment sampling. Grab samples are typically used to characterize the media at a particular instant in time.

Composite Samples - A sample collected over time that typically consists of a series of discrete samples which are combined or "composited". Two types of composite samples are listed below:

- Areal Composite: A sample collected from individual grab samples collected on an areal or cross-sectional basis. Areal composites shall be made up of equal volumes of grab samples. Each grab sample shall be collected in an identical manner. Examples include sediment composites from quarter-point sampling of streams and soil samples from grid points.
- Vertical Composite: A sample collected from individual grab samples collected from a vertical cross section. Vertical composites shall be made up of equal volumes of grab samples. Each grab sample shall be collected in an identical manner. Examples include vertical profiles of soil/sediment columns, lakes and estuaries.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that, where applicable, project-specific plans are in accordance with these procedures, or that other approved procedures are developed. Furthermore, the Project Manager is responsible for development of documentation of procedures which deviate from those presented herein.

Field Team Leader - The Field Team Leader is responsible for selecting and detailing the specific sampling techniques and equipment to be used, and documenting these in the Sampling and Analysis Plan. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that personnel performing sampling activities have been briefed and trained to execute these procedures.

Drilling Inspector - It is the responsibility of the drilling inspector to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team Leader and/or the Project Manager. The Drilling Inspector is responsible for the proper acquisition of rock cores and subsurface soil samples.

Sampling Personnel - It is the responsibility of the field sampling personnel to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team Leader and/or the Project Manager. The sampling personnel are responsible for the proper acquisition of samples.

5.0 PROCEDURES

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

Surface soil samples serve to characterize the extent of surface contamination at various sites. These samples may be collected during initial site screening to determine gross contamination levels and levels of personal protection required as part of more intensive field sampling activities, to gather more detailed site data during design, or to determine the need for, or success of, cleanup actions.

Site construction activities may require that the engineering and physical properties of soil and rock be determined. Soil types, bearing strength, compressibility, permeability, plasticity, and moisture content are some of the geotechnical characteristics that may be determined by laboratory tests of soil samples. Rock quality, strength, stratigraphy, structure, etc. often are needed to design and construct deep foundations or remedial components.

5.1 Subsurface Soil Samples

This section discusses three methods for collecting subsurface soil samples: (1) split-spoon sampling; (2) shelly tube sampling; and, (3) bucket auger sampling. All three methods yield samples suitable for laboratory analysis. Copies of the ASTM procedures for split-spoon sampling and shelly-tube sampling are provided in Attachments A and B, respectively.

5.1.1 Split-Barrel (Split-Spoon) Sampling

The following procedures are to be used for split-spoon, geotechnical soil sampling:

1. Clean out the borehole to the desired sampling depth using equipment that will ensure that the material to be sampled is not disturbed by the operation.
2. Side-discharge bits are permissible. A bottom-discharge bit should not be used. The process of jetting through the sampler and then sampling when the desired depth is reached shall not be permitted. Where casing is used, it may not be driven below the sampling elevation.
3. The two-inch O.D. split-barrel (not for geotech) sampler should be driven with blows from a 140-pound hammer falling 30 inches in accordance with ASTM D1586-84, Standard Penetration Test.
4. Repeat this operation at intervals not longer than 5 feet in homogeneous strata, or as specified in the Sampling and Analysis Plan.
5. Record on the Field Test Boring Record or field logbook the number of blows required to effect each six inches of penetration or fraction thereof. The first six inches is considered to be a seating drive. The sum of the number of blows required for the second and third six inches of penetration is termed the penetration resistance, N . If the sampler is driven less than 18 inches, the penetration resistance is that for the last one foot of penetration. (If less than one foot is penetrated, the logs shall state the number of blows and the fraction of one foot penetrated.) In cases where samples are driven 24 inches, the sum of second and third six-inch increments will be used to calculate the penetration resistance. (Refusal of the SPT will be noted as 50 blows over an interval equal to or less than 6 inches; the interval driven will be noted with the blow count.)
6. Bring the sampler to the surface and remove both ends and one half of the split-spoon such that the soil recovered rests in the remaining half of the barrel. Describe carefully the recovery (length), composition, structure, consistency, color, condition, etc. of the recovered soil according to SOP F101; then put into jars without ramming. Jars with samples not taken for chemical analysis should be tightly closed, to prevent evaporation of the soil moisture. Affix labels to the jar and complete Chain-of-Custody and other required sample data forms (see SOP F302). Protect samples against extreme temperature changes and breakage by placing them in appropriate cartons stored in a protected area.

In addition to collecting soils for geotechnical purposes, split-spoon sampling can be employed to obtain samples for environmental analytical analysis. The following procedures are to be used for split-spoon, environmental soil sampling:

1. Follow sample collection procedures 1 through 6 as outlined in Section 5.2.1.

2. After sample collection, remove the soil from the split-spoon sampler. Prior to filling laboratory containers, the soil sample should be mixed thoroughly as possible to ensure that the sample is as representative as possible of the sample interval. Soil samples for volatile organic compounds should not be mixed. Further, sample containers for volatile organic compounds analyses should be filled completely without head space remaining in the container to minimize volatilization.
3. Record all pertinent sampling information such as soil description, sample depth, sample number, sample location, and time of sample collection in the Field Test Boring Record or field logbook. In addition, label, tag, and number the sample bottle(s).
4. Pack the samples for shipping (see SOP F300). Attach seal to the shipping package. Make sure that Chain-of-Custody Forms and Sample Request Forms are properly filled out and enclosed or attached (see SOP F301).
5. Decontaminate the split-spoon sample as described in SOP F501. Replace disposable latex gloves between sample stations to prevent cross-contaminating samples.

For obtaining composite soil samples (see Definitions), a slightly modified approach is employed. Each individual discrete soil sample from the desired sample interval will be placed into a stainless-steel, decontaminated bowl (or other appropriate container) prior to filling the laboratory sample containers. Special care should be taken to cover the bowl between samples with aluminum foil to minimize volatilization. Immediately after obtaining soils from the desired sampling interval, the sample to be analyzed for Volatile Organic Compounds (VOCs) should be collected. In the event that a composite sample is required, care should be taken to obtain a representative sampling of each sample interval. The remaining soils should be thoroughly mixed. Adequate mixing can be achieved by stirring in a circular fashion and occasionally turning the soils over. Once the remaining soils have been thoroughly combined, samples for analyses other than VOCs should be placed into the appropriate sampling containers.

5.1.2 Thin-Wall (Shelby Tube) Sampling

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

1. Clean out the hole to the sampling elevation, being careful to minimize the chance for disturbance or contamination of the material to be sampled.
2. The use of bottom discharge bits or jetting through an open-tube sampler to clean out the hole shall not be allowed. Any side discharge bits are permitted.

3. The sampler must be of a stationary piston-type, to limit sample disturbance and aid in retaining the sample. Either the hydraulically operated or control rod activated-type of stationary piston sampler may be used. Prior to inserting the tube sampler in the hole, check to ensure that the sampler head contains a check valve. The check valve is necessary to keep water in the rods from pushing the sample out of the tube sampler during sample withdrawal and to maintain a suction within the tube to help retain the sample.
4. With the sampling tube resting on the bottom of the hole and the water level in the boring at the natural 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 further than the length provided for the soil sample. Allow a free space in the tube for cuttings and sludge.
5. After pushing the tube, the sample should sit 5 to 15 minutes prior to removal. Immediately before removal, the sample must be sheared by rotating the rods with a pipe wrench a minimum of two revolutions.
6. Upon removal of the sampler tube from the hole, measure the length of sample in the tube and also the length penetrated. Remove disturbed material in the upper end of the tube and measure the length of sample again. After removing at least an inch of soil, from the lower end and after inserting an impervious disk, seal both ends of the tube with at least a 1/2-inch thickness of wax applied in a way that will prevent the wax from entering the sample. Newspaper or other types of filler must be placed in voids at either end of the sampler prior to sealing with wax. Place plastic caps on the ends of the sampler, tape them into place and then dip the ends in wax to seal them.
7. Affix labels to the tubes and record sample number, depth, penetration, and recovery length on the label. Mark the same information and "up" direction on the tube with indelible ink, and indicate the top of the sample. Complete chain-of-custody and other required forms (see SOP F302). 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.
8. From soil removed from the ends of the tube, make a careful description using the methods presented in SOP F101.
9. When thin-wall tube samplers are used to collect soil for certain chemical analyses, it may be necessary to avoid using wax, newspaper, or other fillers. The SAP for each site should address specific materials allowed dependent on analytes being tested.

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 Dension or Pitcher cores can be used in conjunction with the tube samplers to obtain undisturbed samples of stiff soils. Using these devices normally increases sampling costs and, therefore, their use should be weighed against the increased cost and the need for an

undisturbed sample. In any case, if a sample cannot be obtained with a tube sampler, an attempt should be made with a split-spoon sampler at the same depth so that at least one sample can be obtained for classification purposes.

5.1.3 Bucket (Hand) Auger Sampling

Hand augering is the most common manual method used to collect subsurface samples. Typically, 4-inch auger buckets with cutting heads are pushed and twisted into the ground and removed as the buckets are filled. The auger holes are advanced one bucket at a time. The practical depth of investigation using a hand auger is related to the material being sampled. In sands, augering is usually easily accomplished, but the depth of investigation is controlled by the depth at which sands begin to cave. At this point, auger holes usually begin to collapse and cannot practically be advanced to lower depths, and further samples, if required, must be collected using some type of pushed or driven device. Hand augering may also become difficult in tight clays or cemented sands. At depths approaching 20 feet, torquing of hand auger extensions becomes so severe that in resistant materials, powered methods must be used if deeper samples are required.

When a vertical sampling interval has been established, one auger bucket is used to advance the auger hole to the first desired sampling depth. If the sample at this location is to be a vertical composite of all intervals, the same bucket may be used to advance the hole, as well collect subsequent samples in the same hole. However, if discrete grab samples are to be collected to characterize each depth, a decontaminated bucket must be placed on the end of the auger extension immediately prior to collecting the next sample. The top several inches of soil should be removed from the bucket to minimize the chances of cross-contamination of the sample from fall-in of material from the upper portions of the hole. The bucket auger should be decontaminated between samples as outlined in SOP F502.

In addition to hand augering, powered augers can be used to advance a boring for subsurface soil collection. However, this type of equipment is technically a sampling aid and not a sampling device, and 20 to 25 feet is the typical lower depth range for this equipment. It is used to advance a hole to the required sample depth, at which point a hand auger is usually used to collect the sample.

5.2 Surface Soil Samples

Surface soils are generally classified as soils between the ground surface and 6 to 12 inches below ground surface. For loosely packed surface soils, stainless steel (organic analyses) or plastic (inorganic analyses) scoops or trowels, can be used to collect representative samples. For densely packed soils or deeper soil samples, a hand or power soil auger may be used.

The following methods are to be used:

1. Use a soil auger for deep samples (greater than 12 inches) or a scoop or trowel for surface samples. Remove debris, rocks, twigs, and vegetation before collecting the sample.
2. Immediately transfer the sample to the appropriate sample container. Attach a label and identification tag. Record all required information in the field logbook and on the sample log sheet, chain-of-custody record, and other required forms.
3. Classify and record a description of the sample, as discussed in SOP F101. Descriptions for surface soil samples should be recorded in the field logbook; descriptions for soil samples collected with power or hand augers shall be recorded on a Field Test Boring Record.
4. Store the sampling utensil in a plastic bag until decontamination or disposal. Use a new or freshly-decontaminated sampling utensil for each sample taken.
5. Pack and ship as described in SOP F304.
6. Mark the location with a numbered stake if possible and locate sample points on a sketch of the site or on a sketch in the field logbook.
7. When a representative composited sample is to be prepared (e.g., samples taken from a gridded area or from several different depths), it is best to composite individual samples in the laboratory where they can be more precisely composited on a weight or volume basis. If this is not possible, the individual samples (all of equal volume, i.e., the sample bottles should be full) should be placed in a stainless steel bucket (or other appropriate container), mixed thoroughly using a decontaminated stainless steel spatula or trowel, and a composite sample collected. In some cases, as delineated in project-specific sampling and analysis plans, laboratory compositing of the samples may be more appropriate than field compositing. Samples to be analyzed for parameters sensitive to volatilization should be composited and placed into the appropriate sample bottles immediately upon collection.

5.3 Rock Cores

Once rock coring has been completed and the core recovered, the rock core must 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) (see SOP F101). If split-barrels are used, the core may be measured and classified in the split barrel after opening and then transferred to a core box.

Each core shall be described and classified on a Field Test Boring Record using a uniform system as presented in SOP F101. If moisture content will be determined or if it is desirable to prevent drying (e.g., to prevent shrinkage of hydrated formations) or oxidation of the core, the core must be wrapped in plastic sleeves immediately after logging. Each plastic sleeve shall be labeled with indelible ink. The boring number, run number and the footage represented in each sleeve shall be included, as well as the top and bottom of the core run.

After sampling, rock cores must be placed in the sequence of recovery in wooden or plastic core boxes provided by the drilling contractor. Rock cores from different borings shall not be placed in the same core box. The core boxes should be constructed to accommodate 10 to 20 linear feet of core and should be constructed with hinged tops secured with screws, and a latch (usually a hook and eye) to keep the top securely fastened. 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 the run number shall be marked on the wooden partitions with indelible ink. The order of placing cores shall be the same in all core boxes. The top of each core obtained should 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, any 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 pertaining to the box's contents. At a minimum, the following information must be included:

- Project name
- Date
- CTO number
- Boring number

- Footage (depths)
- Run number(s)
- Recovery
- Rock Quality Designation (RQD)
- Box number (x of x)

It is also useful to draw a large diagram of the core in the box, on the inside of the box top. This provides more room for elevations, run numbers, recoveries, comments, etc., than could be entered on the upper edges of partitions or spaces in the core box.

For easy retrieval when core boxes are stacked, the sides and ends of the box should also be labeled and include CTO number, boring number, top and bottom depths of core and box number.

Due to the weight of the core, a filled core box should always be handled by two people. Core boxes stored on site should be protected from the weather. The core boxes should be removed from the site in a careful manner as soon as possible. Exposure to extreme heat or cold should be avoided whenever possible. Arrangements should be made to dispose of or return the core samples to the client for completion of the project.

6.0 QUALITY ASSURANCE RECORDS

Where applicable, Field Test Boring Records and Test Boring Records will serve as the quality assurance records for subsurface soil samples, rock cores and near surface soil samples collected with a hand or power auger. Observations shall be recorded in the Field Logbook as described in SOP F303. Chain-of-Custody records shall be completed for samples collected for laboratory analysis as described in SOP F101 and SOP F302.

7.0 REFERENCES

1. American Society for Testing and Materials, 1987. Standard Method for Penetration Test and Split-Barrel Sampling of Soils. ASTM Method D1586-84, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.
2. American Society for Testing and Materials, 1987. Standard Practice for Thin-Walled

Tube Sampling of Soils. Method D1587-83, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.

3. American Society for Testing and Materials, 1987. Standard Practice for Diamond Core Drilling for Site Investigation. Method D2113-83 (1987), Annual Book of Standards ASTM, Philadelphia, Pennsylvania.
4. U. S. EPA, 1991. Standard Operating Procedures and Quality Assurance Manual. Environmental Compliance Branch, U. S. EPA, Environmental Services Division, Athens, Georgia.

ATTACHMENT A

ASTM D1586-84

**STANDARD METHOD FOR PENETRATION TEST AND
SPLIT-BARREL SAMPLING OF SOILS**



Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils¹

This standard is issued under the fixed designation D 1586; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense. Consult the DOD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

^{ε1}NOTE—Editorial changes were made throughout October 1992.

1. Scope

1.1 This test method describes the procedure, generally known as the Standard Penetration Test (SPT), for driving a split-barrel sampler to obtain a representative soil sample and a measure of the resistance of the soil to penetration of the sampler.

1.2 This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. For a specific precautionary statement, see 5.4.1.

1.3 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 ASTM Standards:

- D 2487 Test Method for Classification of Soils for Engineering Purposes²
- D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)²
- D 4220 Practices for Preserving and Transporting Soil Samples²
- D 4633 Test Method for Stress Wave Energy Measurement for Dynamic Penetrometer Testing Systems²

3. Terminology

3.1 Descriptions of Terms Specific to This Standard

3.1.1 *anvil*—that portion of the drive-weight assembly which the hammer strikes and through which the hammer energy passes into the drill rods.

3.1.2 *cathead*—the rotating drum or windlass in the rope-cathead lift system around which the operator wraps a rope to lift and drop the hammer by successively tightening and loosening the rope turns around the drum.

3.1.3 *drill rods*—rods used to transmit downward force and torque to the drill bit while drilling a borehole.

3.1.4 *drive-weight assembly*—a device consisting of the

hammer, hammer fall guide, the anvil, and any hammer drop system.

3.1.5 *hammer*—that portion of the drive-weight assembly consisting of the 140 ± 2 lb (63.5 ± 1 kg) impact weight which is successively lifted and dropped to provide the energy that accomplishes the sampling and penetration.

3.1.6 *hammer drop system*—that portion of the drive-weight assembly by which the operator accomplishes the lifting and dropping of the hammer to produce the blow.

3.1.7 *hammer fall guide*—that part of the drive-weight assembly used to guide the fall of the hammer.

3.1.8 *N-value*—the blowcount representation of the penetration resistance of the soil. The *N-value*, reported in blows per foot, equals the sum of the number of blows required to drive the sampler over the depth interval of 6 to 18 in. (150 to 450 mm) (see 7.3).

3.1.9 ΔN —the number of blows obtained from each of the 6-in. (150-mm) intervals of sampler penetration (see 7.3).

3.1.10 *number of rope turns*—the total contact angle between the rope and the cathead at the beginning of the operator's rope slackening to drop the hammer, divided by 360° (see Fig. 1).

3.1.11 *sampling rods*—rods that connect the drive-weight assembly to the sampler. Drill rods are often used for this purpose.

3.1.12 *SPT*—abbreviation for Standard Penetration Test, a term by which engineers commonly refer to this method.

4. Significance and Use

4.1 This test method provides a soil sample for identification purposes and for laboratory tests appropriate for soil obtained from a sampler that may produce large shear strain disturbance in the sample.

4.2 This test method is used extensively in a great variety of geotechnical exploration projects. Many local correlations and widely published correlations which relate SPT blowcount, or *N-value*, and the engineering behavior of earthworks and foundations are available.

5. Apparatus

5.1 *Drilling Equipment*—Any drilling equipment that provides at the time of sampling a suitably clean open hole before insertion of the sampler and ensures that the penetration test is performed on undisturbed soil shall be acceptable. The following pieces of equipment have proven to be

¹ This method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Investigations.

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² Annual Book of ASTM Standards, Vol 04.08.

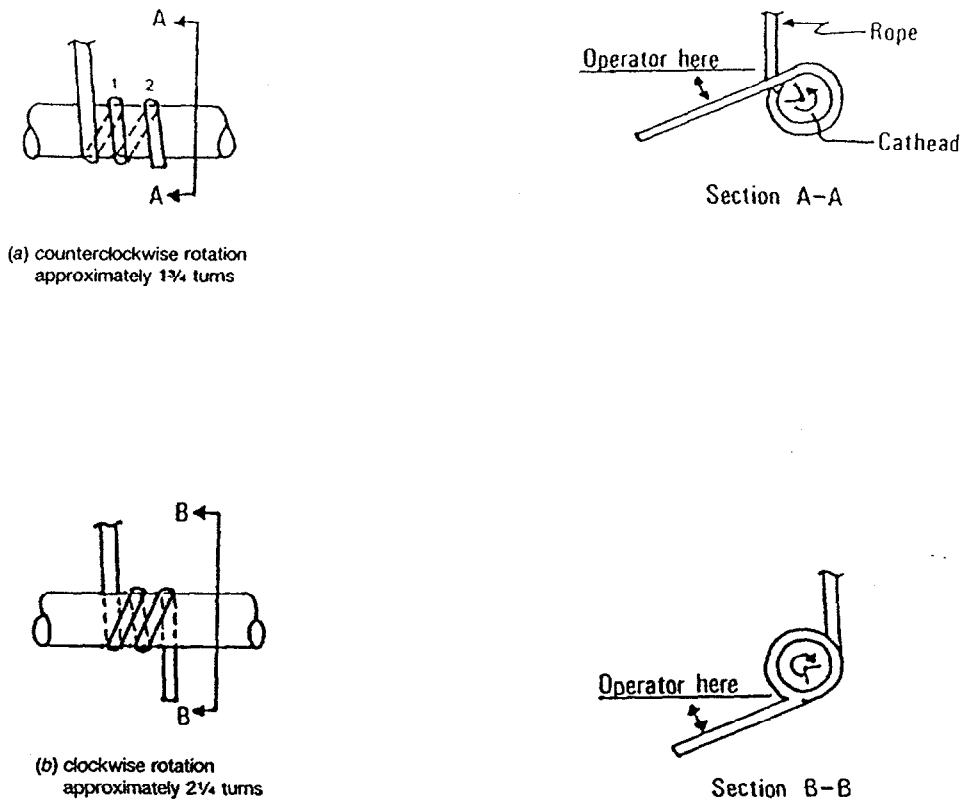


FIG. 1 Definitions of the Number of Rope Turns and the Angle for (a) Counterclockwise Rotation and (b) Clockwise Rotation of the Cathead

suitable for advancing a borehole in some subsurface conditions.

5.1.1 *Drag, Chopping, and Fishtail Bits*, less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used in conjunction with open-hole rotary drilling or casing-advancement drilling methods. To avoid disturbance of the underlying soil, bottom discharge bits are not permitted; only side discharge bits are permitted.

5.1.2 *Roller-Cone Bits*, less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used in conjunction with open-hole rotary drilling or casing-advancement drilling methods if the drilling fluid discharge is deflected.

5.1.3 *Hollow-Stem Continuous Flight Augers*, with or without a center bit assembly, may be used to drill the boring. The inside diameter of the hollow-stem augers shall be less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm).

5.1.4 *Solid, Continuous Flight, Bucket and Hand Augers*, less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used if the soil on the side of the boring does not cave onto the sampler or sampling rods during sampling.

5.2 *Sampling Rods*—Flush-joint steel drill rods shall be used to connect the split-barrel sampler to the drive-weight assembly. The sampling rod shall have a stiffness (moment of inertia) equal to or greater than that of parallel wall “A” rod (a steel rod which has an outside diameter of 1 3/8 in. (41.2 mm) and an inside diameter of 1 1/8 in. (28.5 mm).

NOTE 1—Recent research and comparative testing indicates the type rod used, with stiffness ranging from “A” size rod to “N” size rod, will usually have a negligible effect on the *N*-values to depths of at least 100 ft (30 m).

5.3 *Split-Barrel Sampler*—The sampler shall be constructed with the dimensions indicated in Fig. 2. The driving shoe shall be of hardened steel and shall be replaced or repaired when it becomes dented or distorted. The use of liners to produce a constant inside diameter of 1 3/8 in. (35 mm) is permitted, but shall be noted on the penetration record if used. The use of a sample retainer basket is permitted, and should also be noted on the penetration record if used.

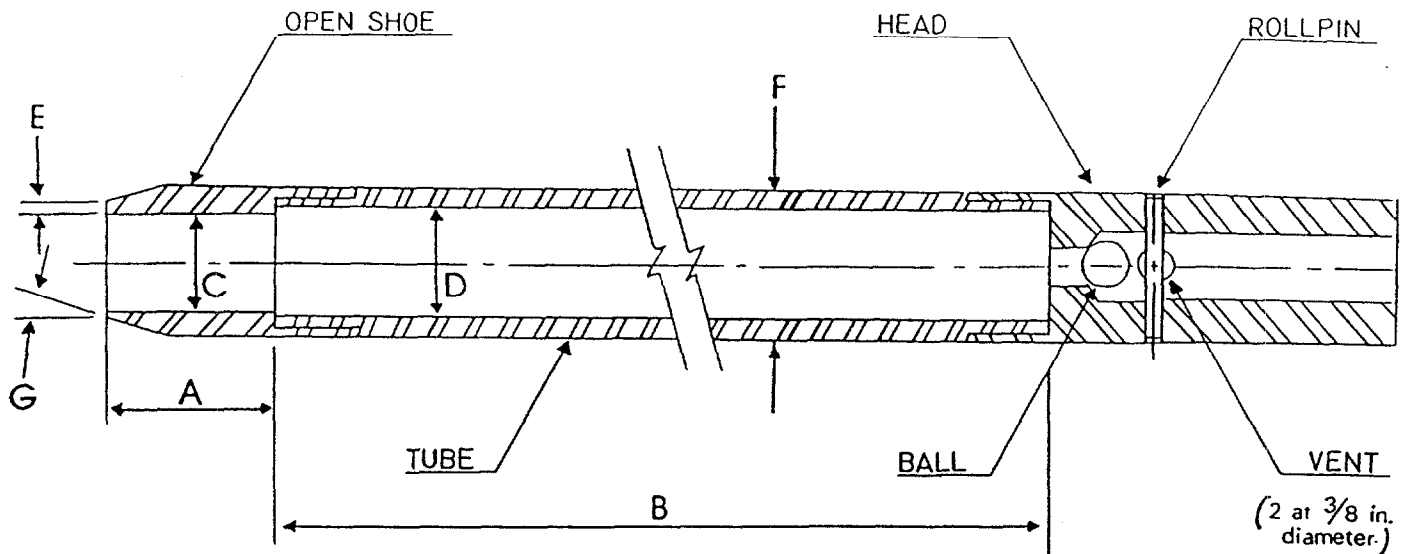
NOTE 2—Both theory and available test data suggest that *N*-values may increase between 10 to 30 % when liners are used.

5.4 Drive-Weight Assembly:

5.4.1 *Hammer and Anvil*—The hammer shall weigh 140 ± 2 lb (63.5 ± 1 kg) and shall be a solid rigid metallic mass. The hammer shall strike the anvil and make steel on steel contact when it is dropped. A hammer fall guide permitting a free fall shall be used. Hammers used with the cathead and rope method shall have an unimpeded overlift capacity of at least 4 in. (100 mm). For safety reasons, the use of a hammer assembly with an internal anvil is encouraged.

NOTE 3—It is suggested that the hammer fall guide be permanently marked to enable the operator or inspector to judge the hammer drop height.

5.4.2 *Hammer Drop System*—Rope-cathead, trip, semi-automatic, or automatic hammer drop systems may be used, providing the lifting apparatus will not cause penetration of



- 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 = 16.0° 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.

FIG. 2 Split-Barrel Sampler

the sampler while re-engaging and lifting the hammer.

5.5 *Accessory Equipment*—Accessories such as labels, sample containers, data sheets, and groundwater level measuring devices shall be provided in accordance with the requirements of the project and other ASTM standards.

6. Drilling Procedure

6.1 The boring shall be advanced incrementally to permit intermittent or continuous sampling. Test intervals and locations are normally stipulated by the project engineer or geologist. Typically, the intervals selected are 5 ft (1.5 m) or less in homogeneous strata with test and sampling locations at every change of strata.

6.2 Any drilling procedure that provides a suitably clean and stable hole before insertion of the sampler and assures that the penetration test is performed on essentially undisturbed soil shall be acceptable. Each of the following procedures have proven to be acceptable for some subsurface conditions. The subsurface conditions anticipated should be considered when selecting the drilling method to be used.

- 6.2.1 Open-hole rotary drilling method.
- 6.2.2 Continuous flight hollow-stem auger method.
- 6.2.3 Wash boring method.
- 6.2.4 Continuous flight solid auger method.

6.3 Several drilling methods produce unacceptable borings. The process of jetting through an open tube sampler and then sampling when the desired depth is reached shall not be permitted. The continuous flight solid auger method shall not be used for advancing the boring below a water table or below the upper confining bed of a confined non-cohesive stratum that is under artesian pressure. Casing

may not be advanced below the sampling elevation prior to sampling. Advancing a boring with bottom discharge bits is not permissible. It is not permissible to advance the boring for subsequent insertion of the sampler solely by means of previous sampling with the SPT sampler.

6.4 The drilling fluid level within the boring or hollow-stem augers shall be maintained at or above the in situ groundwater level at all times during drilling, removal of drill rods, and sampling.

7. Sampling and Testing Procedure

7.1 After the boring has been advanced to the desired sampling elevation and excessive cuttings have been removed, prepare for the test with the following sequence of operations.

7.1.1 Attach the split-barrel sampler to the sampling rods and lower into the borehole. Do not allow the sampler to drop onto the soil to be sampled.

7.1.2 Position the hammer above and attach the anvil to the top of the sampling rods. This may be done before the sampling rods and sampler are lowered into the borehole.

7.1.3 Rest the dead weight of the sampler, rods, anvil, and drive weight on the bottom of the boring and apply a seating blow. If excessive cuttings are encountered at the bottom of the boring, remove the sampler and sampling rods from the boring and remove the cuttings.

7.1.4 Mark the drill rods in three successive 6-in. (0.15-m) increments so that the advance of the sampler under the impact of the hammer can be easily observed for each 6-in. (0.15-m) increment.

7.2 Drive the sampler with blows from the 140-lb (63.5-

kg) hammer and count the number of blows applied in each 6-in. (0.15-m) increment until one of the following occurs:

7.2.1 A total of 50 blows have been applied during any one of the three 6-in. (0.15-m) increments described in 7.1.4.

7.2.2 A total of 100 blows have been applied.

7.2.3 There is no observed advance of the sampler during the application of 10 successive blows of the hammer.

7.2.4 The sampler is advanced the complete 18 in. (0.45 m) without the limiting blow counts occurring as described in 7.2.1, 7.2.2, or 7.2.3.

7.3 Record the number of blows required to effect each 6 in. (0.15 m) of penetration or fraction thereof. The first 6 in. is considered to be a seating drive. The sum of the number of blows required for the second and third 6 in. of penetration is termed the "standard penetration resistance," or the "*N*-value." If the sampler is driven less than 18 in. (0.45 m), as permitted in 7.2.1, 7.2.2, or 7.2.3, the number of blows per each complete 6-in. (0.15-m) increment and per each partial increment shall be recorded on the boring log. For partial increments, the depth of penetration shall be reported to the nearest 1 in. (25 mm), in addition to the number of blows. If the sampler advances below the bottom of the boring under the static weight of the drill rods or the weight of the drill rods plus the static weight of the hammer, this information should be noted on the boring log.

7.4 The raising and dropping of the 140-lb (63.5-kg) hammer shall be accomplished using either of the following two methods:

7.4.1 By using a trip, automatic, or semi-automatic hammer drop system which lifts the 140-lb (63.5-kg) hammer and allows it to drop 30 ± 1.0 in. (0.76 m \pm 25 mm) unimpeded.

7.4.2 By using a cathead to pull a rope attached to the hammer. When the cathead and rope method is used the system and operation shall conform to the following:

7.4.2.1 The cathead shall be essentially free of rust, oil, or grease and have a diameter in the range of 6 to 10 in. (150 to 250 mm).

7.4.2.2 The cathead should be operated at a minimum speed of rotation of 100 RPM, or the approximate speed of rotation shall be reported on the boring log.

7.4.2.3 No more than $2\frac{1}{4}$ rope turns on the cathead may be used during the performance of the penetration test, as shown in Fig. 1.

NOTE 4—The operator should generally use either $1\frac{3}{4}$ or $2\frac{1}{4}$ rope turns, depending upon whether or not the rope comes off the top ($1\frac{3}{4}$ turns) or the bottom ($2\frac{1}{4}$ turns) of the cathead. It is generally known and accepted that $2\frac{3}{4}$ or more rope turns considerably impedes the fall of the hammer and should not be used to perform the test. The cathead rope should be maintained in a relatively dry, clean, and unfrayed condition.

7.4.2.4 For each hammer blow, a 30-in. (0.76-m) lift and drop shall be employed by the operator. The operation of pulling and throwing the rope shall be performed rhythmically without holding the rope at the top of the stroke.

7.5 Bring the sampler to the surface and open. Record the percent recovery or the length of sample recovered. Describe the soil samples recovered as to composition, color, stratification, and condition, then place one or more representative portions of the sample into sealable moisture-proof containers (jars) without ramming or distorting any apparent

stratification. Seal each container to prevent evaporation of soil moisture. Affix labels to the containers bearing job designation, boring number, sample depth, and the blow count per 6-in. (0.15-m) increment. Protect the samples against extreme temperature changes. If there is a soil change within the sampler, make a jar for each stratum and note its location in the sampler barrel.

8. Report

8.1 Drilling information shall be recorded in the field and shall include the following:

- 8.1.1 Name and location of job,
- 8.1.2 Names of crew,
- 8.1.3 Type and make of drilling machine,
- 8.1.4 Weather conditions,
- 8.1.5 Date and time of start and finish of boring,
- 8.1.6 Boring number and location (station and coordinates, if available and applicable),
- 8.1.7 Surface elevation, if available,
- 8.1.8 Method of advancing and cleaning the boring,
- 8.1.9 Method of keeping boring open,
- 8.1.10 Depth of water surface and drilling depth at the time of a noted loss of drilling fluid, and time and date when reading or notation was made,
- 8.1.11 Location of strata changes,
- 8.1.12 Size of casing, depth of cased portion of boring,
- 8.1.13 Equipment and method of driving sampler,
- 8.1.14 Type sampler and length and inside diameter of barrel (note use of liners),
- 8.1.15 Size, type, and section length of the sampling rods, and
- 8.1.16 Remarks.

8.2 Data obtained for each sample shall be recorded in the field and shall include the following:

- 8.2.1 Sample depth and, if utilized, the sample number,
- 8.2.2 Description of soil,
- 8.2.3 Strata changes within sample,
- 8.2.4 Sampler penetration and recovery lengths, and
- 8.2.5 Number of blows per 6-in. (0.15-m) or partial increment.

9. Precision and Bias

9.1 *Precision*—A valid estimate of test precision has not been determined because it is too costly to conduct the necessary inter-laboratory (field) tests. Subcommittee D18.02 welcomes proposals to allow development of a valid precision statement.

9.2 *Bias*—Because there is no reference material for this test method, there can be no bias statement.

9.3 Variations in *N*-values of 100 % or more have been observed when using different standard penetration test apparatus and drillers for adjacent borings in the same soil formation. Current opinion, based on field experience, indicates that when using the same apparatus and driller, *N*-values in the same soil can be reproduced with a coefficient of variation of about 10 %.

9.4 The use of faulty equipment, such as an extremely massive or damaged anvil, a rusty cathead, a low speed cathead, an old, oily rope, or massive or poorly lubricated rope sheaves can significantly contribute to differences in *N*-values obtained between operator-drill rig systems.

9.5 The variability in N -values produced by different drill rigs and operators may be reduced by measuring that part of the hammer energy delivered into the drill rods from the sampler and adjusting N on the basis of comparative energies. A method for energy measurement and N -value

adjustment is given in Test Method D 4633.

10. Keywords

10.1 blow count; in-situ test; penetration resistance; split-barrel sampling; standard penetration test

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This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.

ATTACHMENT B

ASTM D1587-83

STANDARD PRACTICE FOR THIN-WALLED TUBE SAMPLING OF SOILS



Standard Practice for Thin-Walled Tube Sampling of Soils¹

This standard is issued under the fixed designation D 1587; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This practice has been approved for use by agencies of the Department of Defense and for listing in the DOD Index of Specifications and Standards.

1. Scope

1.1 This practice covers a procedure for using a thin-walled metal tube to recover relatively undisturbed soil samples suitable for laboratory tests of structural properties. Thin-walled tubes used in piston, plug, or rotary-type samplers, such as the Denison or Pitcher, must comply with the portions of this practice which describe the thin-walled tubes (5.3).

NOTE 1—This practice does not apply to liners used within the above samplers.

2. Referenced Documents

2.1 ASTM Standards:

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)²

D 3550 Practice for Ring-Lined Barrel Sampling of Soils²

D 4220 Practices for Preserving and Transporting Soil Samples²

3. Summary of Practice

3.1 A relatively undisturbed sample is obtained by pressing a thin-walled metal tube into the in-situ soil, removing the soil-filled tube, and sealing the ends to prevent the soil from being disturbed or losing moisture.

4. Significance and Use

4.1 This practice, or Practice D 3550, is used when it is necessary to obtain a relatively undisturbed specimen suitable for laboratory tests of structural properties or other tests that might be influenced by soil disturbance.

5. Apparatus

5.1 *Drilling Equipment*—Any drilling equipment may be used that provides a reasonably clean hole; that does not disturb the soil to be sampled; and that does not hinder the penetration of the thin-walled sampler. Open borehole diameter and the inside diameter of driven casing or hollow stem auger shall not exceed 3.5 times the outside diameter of the thin-walled tube.

5.2 *Sampler Insertion Equipment*, shall be adequate to provide a relatively rapid continuous penetration force. For

hard formations it may be necessary, although not recommended, to drive the thin-walled tube sampler.

5.3 *Thin-Walled Tubes*, should be manufactured as shown in Fig. 1. They should have an outside diameter of 2 to 5 in. and be made of metal having adequate strength for use in the soil and formation intended. Tubes shall be clean and free of all surface irregularities including projecting weld seams.

5.3.1 *Length of Tubes*—See Table 1 and 6.4.

5.3.2 *Tolerances*, shall be within the limits shown in Table 2.

5.3.3 *Inside Clearance Ratio*, should be 1 % or as specified by the engineer or geologist for the soil and formation to be sampled. Generally, the inside clearance ratio used should increase with the increase in plasticity of the soil being sampled. See Fig. 1 for definition of inside clearance ratio.

5.3.4 *Corrosion Protection*—Corrosion, whether from galvanic or chemical reaction, can damage or destroy both the thin-walled tube and the sample. Severity of damage is a function of time as well as interaction between the sample and the tube. Thin-walled tubes should have some form of protective coating. Tubes which will contain samples for more than 72 h shall be coated. The type of coating to be used may vary depending upon the material to be sampled. Coatings may include a light coat of lubricating oil, lacquer, epoxy, Teflon, and others. Type of coating must be specified by the engineer or geologist if storage will exceed 72 h. Plating of the tubes or alternate base metals may be specified by the engineer or geologist.

5.4 *Sampler Head*, serves to couple the thin-walled tube to the insertion equipment and, together with the thin-walled tube, comprises the thin-walled tube sampler. The sampler head shall contain a suitable check valve and a venting area to the outside equal to or greater than the area through the check valve. Attachment of the head to the tube shall be concentric and coaxial to assure uniform application of force to the tube by the sampler insertion equipment.

6. Procedure

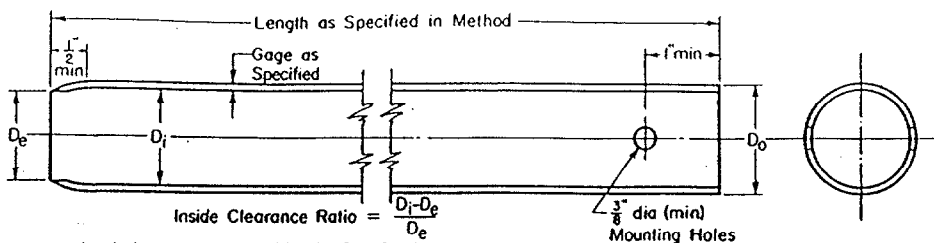
6.1 Clean out the borehole to sampling elevation using whatever method is preferred that will ensure the material to be sampled is not disturbed. If groundwater is encountered, maintain the liquid level in the borehole at or above ground water level during the sampling operation.

6.2 Bottom discharge bits are not permitted. Side discharge bits may be used, with caution. Jetting through an open-tube sampler to clean out the borehole to sampling elevation is not permitted. Remove loose material from the center of a casing or hollow stem auger as carefully as

¹ This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Investigations.

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² *Annual Book of ASTM Standards*, Vol 04.08.



NOTE 1—Minimum of two mounting holes on opposite sides for 2 to 3½ in. sampler.
 NOTE 2—Minimum of four mounting holes spaced at 90° for samplers 4 in. and larger.
 NOTE 3—Tube held with hardened screws.
 NOTE 4—Two-inch outside-diameter tubes are specified with an 18-gage wall thickness to comply with area ratio criteria accepted for “undisturbed samples.” Users are advised that such tubing is difficult to locate and can be extremely expensive in small quantities. Sixteen-gage tubes are generally readily available.

Metric Equivalents

	in.	mm
	¾	6.77
	½	12.7
	1	25.4
	2	50.8
	3½	88.9
	4	101.6

FIG. 1 Thin-Walled Tube for Sampling

TABLE 1 Suitable Thin-Walled Steel Sample Tubes^A

Outside diameter:	2	3	5
in.	2	3	5
mm	50.8	76.2	127
Wall thickness:			
Bwg	18	16	11
in.	0.049	0.065	0.120
mm	1.24	1.65	3.05
Tube length:			
in.	36	36	54
m	0.91	0.91	1.45
Clearance ratio, %	1	1	1

^A The three diameters recommended in Table 1 are indicated for purposes of standardization, and are not intended to indicate that sampling tubes of intermediate or larger diameters are not acceptable. Lengths of tubes shown are illustrative. Proper lengths to be determined as suited to field conditions.

TABLE 2 Dimensional Tolerances for Thin-Walled Tubes

Size Outside Diameter	Nominal Tube Diameters from Table 1 ^A Tolerances, in.		
	2	3	5
Outside diameter	+0.007	+0.010	+0.015
	-0.000	-0.000	-0.000
Inside diameter	+0.000	+0.000	+0.000
	-0.007	-0.010	-0.015
Wall thickness	±0.007	±0.010	±0.015
Ovality	0.015	0.020	0.030
Straightness	0.030/ft	0.030/ft	0.030/ft

^A Intermediate or larger diameters should be proportional. Tolerances shown are essentially standard commercial manufacturing tolerances for seamless steel mechanical tubing. Specify only two of the first three tolerances; that is, O.D. and I.D., or O.D. and Wall, or I.D. and Wall.

possible to avoid disturbance of the material to be sampled.

NOTE 2—Roller bits are available in downward-jetting and diffused-jet configurations. Downward-jetting configuration rock bits are not acceptable. Diffuse-jet configurations are generally acceptable.

6.3 Place the sample tube so that its bottom rests on the bottom of the hole. Advance the sampler without rotation by a continuous relatively rapid motion.

6.4 Determine the length of advance by the resistance and condition of the formation, but the length shall never exceed

5 to 10 diameters of the tube in sands and 10 to 15 diameters of the tube in clays.

NOTE 3—Weight of sample, laboratory handling capabilities, transportation problems, and commercial availability of tubes will generally limit maximum practical lengths to those shown in Table 1.

6.5 When the formation is too hard for push-type insertion, the tube may be driven or Practice D 3550 may be used. Other methods, as directed by the engineer or geologist, may be used. If driving methods are used, the data regarding weight and fall of the hammer and penetration achieved must be shown in the report. Additionally, that tube must be prominently labeled a “driven sample.”

6.6 In no case shall a length of advance be greater than the sample-tube length minus an allowance for the sampler head and a minimum of 3 in. for sludge-end cuttings.

NOTE 4—The tube may be rotated to shear bottom of the sample after pressing is complete.

6.7 Withdraw the sampler from the formation as carefully as possible in order to minimize disturbance of the sample.

7. Preparation for Shipment

7.1 Upon removal of the tube, measure the length of sample in the tube. Remove the disturbed material in the upper end of the tube and measure the length again. Seal the upper end of the tube. Remove at least 1 in. of material from the lower end of the tube. Use this material for soil description in accordance with Practice D 2488. Measure the overall sample length. Seal the lower end of the tube. Alternatively, after measurement, the tube may be sealed without removal of soil from the ends of the tube if so directed by the engineer or geologist.

NOTE 5—Field extrusion and packaging of extruded samples under the specific direction of a geotechnical engineer or geologist is permitted.

NOTE 6—Tubes sealed over the ends as opposed to those sealed with expanding packers should contain end padding in end voids in order to prevent drainage or movement of the sample within the tube.

7.2 Prepare and immediately affix labels or apply markings as necessary to identify the sample. Assure that the

markings or labels are adequate to survive transportation and storage.

8. Report

- 8.1 The appropriate information is required as follows:
 - 8.1.1 Name and location of the project,
 - 8.1.2 Boring number and precise location on project,
 - 8.1.3 Surface elevation or reference to a datum,
 - 8.1.4 Date and time of boring—start and finish,
 - 8.1.5 Depth to top of sample and number of sample,
 - 8.1.6 Description of sampler: size, type of metal, type of coating,
 - 8.1.7 Method of sampler insertion: push or drive,

8.1.8 Method of drilling, size of hole, casing, and drilling fluid used,

8.1.9 Depth to groundwater level: date and time measured,

8.1.10 Any possible current or tidal effect on water level,

8.1.11 Soil description in accordance with Practice D 2488,

8.1.12 Length of sampler advance, and

8.1.13 Recovery: length of sample obtained.

9. Precision and Bias

9.1 This practice does not produce numerical data; therefore, a precision and bias statement is not applicable.

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ATTACHMENT C

ASTM D2113-83 (1987)

**STANDARD PRACTICE FOR DIAMOND CORE DRILLING FOR
SITE INVESTIGATION**



Standard Practice for Diamond Core Drilling for Site Investigation¹

This standard is issued under the fixed designation D 2113; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice describes equipment and procedures for diamond core drilling to secure core samples of rock and some soils that are too hard to sample by soil-sampling methods. This method is described in the context of obtaining data for foundation design and geotechnical engineering purposes rather than for mineral and mining exploration.

2. Referenced Documents

2.1 ASTM Standards:

D 1586 Method for Penetration Test and Split-Barrel Sampling of Soils²

D 1587 Practice for Thin-Walled Tube Sampling of Soils²

D 3550 Practice for Ring-Lined Barrel Sampling of Soils²

3. Significance and Use

3.1 This practice is used to obtain core specimens of superior quality that reflect the in-situ conditions of the material and structure and which are suitable for standard physical-properties tests and structural-integrity determination.

4. Apparatus

4.1 *Drilling Machine*, capable of providing rotation, feed, and retraction by hydraulic or mechanical means to the drill rods.

4.2 *Fluid Pump or Air Compressor*, capable of delivering sufficient volume and pressure for the diameter and depth of hole to be drilled.

4.3 *Core barrels*, as required:

4.3.1 *Single Tube Type, WG Design*, consisting of a hollow steel tube, with a head at one end threaded for drill rod, and a threaded connection for a reaming shell and core bit at the other end. A core lifter, or retainer located within the core bit is normal, but may be omitted at the discretion of the geologist or engineer.

4.3.2 *Double Tube, Swivel-Type, WG Design*—An assembly of two concentric steel tubes joined and supported at the upper end by means of a ball or roller-bearing swivel arranged to permit rotation of the outer tube without causing rotation of the inner tube. The upper end of the outer tube, or removable head, is threaded for drill rod. A threaded connection is provided on the lower end of the outer tube for

a reaming shell and core bit. A core lifter located within the core bit is normal but may be omitted at the discretion of the geologist or engineer.

4.3.3 *Double-Tube, Swivel-Type, WT Design*, is essentially the same as the double tube, swivel-type, WG design, except that the WT design has thinner tube walls, a reduced annular area between the tubes, and takes a larger core from the same diameter bore hole. The core lifter is located within the core bit.

4.3.4 *Double Tube, Swivel Type, WM Design*, is similar to the double tube, swivel-type, WG design, except that the inner tube is threaded at its lower end to receive a core lifter case that effectively extends the inner tube well into the core bit, thus minimizing exposure of the core to the drilling fluid. A core lifter is contained within the core lifter case on the inner tube.

4.3.5 *Double Tube Swivel-Type, Large-Diameter Design*, is similar to the double tube, swivel-type, WM design, with the addition of a ball valve, to control fluid flow, in all three available sizes and the addition of a sludge barrel, to catch heavy cuttings, on the two larger sizes. The large-diameter design double tube, swivel-type, core barrels are available in three core per hole sizes as follows: 2 $\frac{3}{4}$ in. (69.85 mm) by 3 $\frac{3}{4}$ in. (98.43 mm), 4 in. (101.6 mm) by 5 $\frac{1}{2}$ in. (139.7 mm), and 6 in. (152.4 mm) by 7 $\frac{1}{4}$ in. (196.85 mm). Their use is generally reserved for very detailed investigative work or where other methods do not yield adequate recovery.

4.3.6 *Double Tube, Swivel-Type, Retrievable Inner-Tube Method*, in which the core-laden inner-tube assembly is retrieved to the surface and an empty inner-tube assembly returned to the face of the borehole through the matching large-bore drill rods without need for withdrawal and replacement of the drill rods in the borehole. The inner-tube assembly consists of an inner tube with removable core lifter case and core lifter at one end and a removable inner-tube head, swivel bearing, suspension adjustment, and latching device with release mechanism on the opposite end. The inner-tube latching device locks into a complementary recess in the wall of the outer tube such that the outer tube may be rotated without causing rotation of the inner tube and such that the latch may be actuated and the inner-tube assembly transported by appropriate surface control. The outer tube is threaded for the matching, large-bore drill rod and internally configured to receive the inner-tube latching device at one end and threaded for a reaming shell and bit, or bit only, at the other end.

4.4 *Longitudinally Split Inner Tubes*—As opposed to conventional cylindrical inner tubes, allow inspection of, and access to, the core by simply removing one of the two halves. They are not standardized but are available for most core barrels including many of the retrievable inner-tube types.

¹ This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Investigations.

Current edition approved June 24, 1983. Published August 1983. Originally published as D 2113-62 T. Last previous edition D 2113-70 (1976).

² Annual Book of ASTM Standards, Vol 04.08.

4.5 *Core Bits*—Core bits shall be surface set with diamonds, impregnated with small diamond particles, inserted with tungsten carbide slugs, or strips, hard-faced with various hard surfacing materials or furnished in saw-tooth form, all as appropriate to the formation being cored and with concurrence of the geologist or engineer. Bit matrix material, crown shape, water-way type, location and number of water ways, diamond size and carat weight, and bit facing materials shall be for general purpose use unless otherwise approved by the geologist or engineer. Nominal size of some bits is shown in Table 1.

NOTE 1—Size designation (letter symbols) used throughout the text and in Tables 1, 2, and 3 are those standardized by the Diamond Core Drill Manufacturers' Assoc. (DCDMA). Inch dimensions in the tables have been rounded to the nearest hundredth of an inch.

4.6 *Reaming Shells*, shall be surface set with diamonds, impregnated with small diamond particles, inserted with tungsten carbide strips or slugs, hard faced with various types of hard surfacing materials, or furnished blank, all as appropriate to the formation being cored.

4.7 *Core Lifters*—Core lifters of the split-ring type, either plain or hard-faced, shall be furnished and maintained, along with core-lifter cases or inner-tube extensions or inner-tube shoes, in good condition. Basket or finger-type lifters, together with any necessary adapters, shall be on the job and available for use with each core barrel if so directed by the geologist or engineer.

4.8 *Casings:*

4.8.1 *Drive Pipe or Drive Casing*, shall be standard weight (schedule 40), extra-heavy (schedule 80), double extra-heavy (schedule 160) pipe or W-design flush-joint casing as re-

quired by the nature of the overburden or the placement method. Drive pipe or W-design casing shall be of sufficient diameter to pass the largest core barrel to be used, and it shall be driven to bed rock or to firm seating at an elevation below water-sensitive formation. A hardened drive shoe is to be used as a cutting edge and thread protection device on the bottom of the drive pipe or casing. The drive shoe inside diameter shall be large enough to pass the tools intended for use, and the shoe and pipe or casing shall be free from burrs or obstructions.

4.8.2 *Casing*—When necessary to case through formations already penetrated by the borehole or when no drive casing has been set, auxiliary casing shall be provided to fit inside the borehole to allow use of the next smaller core barrel. Standard sizes of telescoping casing are shown in Table 2. Casing bits have an obstruction in their interior and will not pass the next smaller casing size. Use a casing shoe if additional telescoping is anticipated.

4.8.3 *Casing Liner*—Plastic pipe or sheet-metal pipe may be used to line an existing large-diameter casing. Liners, so used, should not be driven, and care should be taken to maintain true alignment throughout the length of the liner.

4.8.4 *Hollow Stem Auger*—Hollow stem auger may be used as casing for coring.

4.9 *Drill Rods:*

4.9.1 *Drill Rods of Tubular Steel Construction* are normally used to transmit feed, rotation, and retraction forces from the drilling machine to the core barrel. Drill-rod sizes that are presently standardized are shown in Table 3.

4.9.2 Large bore drill rods used with retrievable inner-tube core barrels are not standardized. Drill rods used with retrievable inner-tube core barrels should be those manufactured by the core-barrel manufacturer specifically for the core barrel.

4.9.3 *Composite Drill Rods* are specifically constructed from two or more materials intended to provide specific properties such as light weight or electrical nonconductivity.

4.9.4 *Nonmagnetic Drill Rods* are manufactured of nonferrous materials such as aluminum or brass and are used primarily for hole survey work. Some nonmagnetic rods have left-hand threads in order to further their value in survey work. No standard exists for nonmagnetic rods.

4.10 *Auxiliary Equipment*, shall be furnished as required by the work and shall include: roller rock bits, drag bits, chopping bits, boulder busters, fishtail bits, pipe wrenches, core barrel wrenches, lubrication equipment, core boxes, and marking devices. Other recommended equipment includes:

TABLE 1 Core Bit Sizes

Size Designation	Outside Diameter		Inside Diameter	
	in.	mm	in.	mm
RWT	1.16	29.5	0.375	18.7
EWT	1.47	37.3	0.905	22.9
EWG, EWM	1.47	37.3	0.845	21.4
AWT	1.88	47.6	1.281	32.5
AWG, AWM	1.88	47.6	1.185	30.0
BWT	2.35	59.5	1.750	44.5
BWG, BWM	2.35	59.5	1.655	42.0
NWT	2.97	75.3	2.313	58.7
NWG, NWM	2.97	75.3	2.155	54.7
2 1/4 x 3/4	3.84	97.5	2.69	68.3
HWT	3.89	98.8	3.187	80.9
HWG, ...	3.89	98.8	3.000	76.2
4 x 5/8	5.44	138.0	3.97	100.8
6 x 7/8	7.66	194.4	5.97	151.6

TABLE 2 Casing Sizes

Size Designation	Outside Diameter		Inside Diameter		Threads per in.	W/ Fit Hole Drilled with Core Bit Size
	in.	mm	in.	mm		
RW	1.144	36.5	1.19	30.1	5	EWT, EWG, EWM
EW	1.81	46.0	1.50	38.1	4	AWT, AWG, AWM
AW	2.25	57.1	1.91	48.4	4	BWT, BWG, BWM
BW	2.88	73.0	2.38	60.3	4	NWT, NWG, NWM
NW	3.50	88.9	3.00	76.2	4	HWT, HWG
HW	4.50	114.3	4.00	101.6	4	4 x 5/8
PW	5.50	139.7	5.00	127.0	3	6 x 7/8
SW	6.63	168.2	6.00	152.4	3	6 x 7/8
UW	7.63	193.6	7.00	177.6	2	...
ZW	6.63	219.0	6.00	203.2	2	...

TABLE 3 Drill Rods

Size Designation	Rod and Coupling Outside Diameter		Rod Inside Diameter		Coupling Bore, Threads		
	in.	mm	in.	mm	in.	mm	per in.
RW	1.09	27.7	0.72	18.2	0.41	10.3	4
EW	1.38	34.9	1.00	25.4	0.44	11.1	3
AW	1.72	43.6 ^a	1.34	34.1	0.63	15.8	3
BW	2.13	53.9	1.75	44.4	0.75	19.0	3
NW	2.63	66.6	2.25	57.1	1.38	34.9	3
HW	3.50	88.9	3.06	77.7	2.38	60.3	3

core splitter, rod wicking, pump-out tools or extruders, and hand sieve or strainer.

5. Transportation and Storage of Core Containers

5.1 Core Boxes, shall be constructed of wood or other durable material for the protection and storage of cores while enroute from the drill site to the laboratory or other processing point. All core boxes shall be provided with longitudinal separators and recovered cores shall be laid out as a book would read, from left to right and top to bottom, within the longitudinal separators. Spacer blocks or plugs shall be marked and inserted into the core column within the separators to indicate the beginning of each coring run. The beginning point of storage in each core box is the upper left-hand corner. The upper left-hand corner of a hinged core box is the left corner when the hinge is on the far side of the box and the box is right-side up. All hinged core boxes must be permanently marked on the outside to indicate the top and the bottom. All other core boxes must be permanently marked on the outside to indicate the top and the bottom and additionally, must be permanently marked internally to indicate the upper-left corner of the bottom with the letters UL or a splotch of red paint not less than 1 in.² Lid or cover fitting(s) for core boxes must be of such quality as to ensure against mix up of the core in the event of impact or upsetting of the core box during transportation.

5.2 Transportation of cores from the drill site to the laboratory or other processing point shall be in durable core boxes so padded or suspended as to be isolated from shock or impact transmitted to the transporter by rough terrain or careless operation.

5.3 Storage of cores, after initial testing or inspection at the laboratory or other processing point, may be in cardboard or similar less costly boxes provided all layout and marking requirements as specified in 5.1 are followed. Additional spacer blocks or plugs shall be added if necessary at time of storage to explain missing core. Cores shall be stored for a period of time specified by the engineer but should not normally be discarded prior to completion of the project for which they were taken.

6. Procedure

6.1 Use core-drilling procedures when formations are encountered that are too hard to be sampled by soil-sampling methods. A 1-in. (25.4-mm) or less penetration for 50 blows in accordance with Method D 1586 or other criteria established by the geologist or engineer, shall indicate that soil-sampling methods are not applicable.

6.1.1 Seat the casing on bedrock or in a firm formation to prevent raveling of the borehole and to prevent loss of

drilling fluid. Level the surface of the rock or hard formation at the bottom of the casing when necessary, using the appropriate bits. Casing may be omitted if the borehole will stand open without the casing.

6.1.2 Begin the core drilling using an N-size double-tube swivel-type core barrel or other size or type approved by the engineer. Continue core drilling until core blockage occurs or until the net length of the core barrel has been drilled in. Remove the core barrel from the hole and disassemble it as necessary to remove the core. Reassemble the core barrel and return it to the hole. Resume coring.

6.1.3 Place the recovered core in the core box with the upper (surface) end of the core at the upper-left corner of the core box as described in 5.1. Continue boxing core with appropriate markings, spacers, and blocks as described in 5.1. Wrap soft or friable cores or those which change materially upon drying in plastic film or seal in wax, or both, when such treatment is required by the engineer. Use spacer blocks or slugs properly marked to indicate any noticeable gap in recovered core which might indicate a change or void in the formation. Fit fracture, bedded, or jointed pieces of core together as they naturally occurred.

6.1.4 Stop the core drilling when soft materials are encountered that produce less than 50 % recovery. If necessary, secure samples of soft materials in accordance with the procedures described in Method D 1586, Practice D 1587, or Practice D 3550, or by any other method acceptable to the geologist or engineer. Resume diamond core drilling when refusal materials as described in 6.1 are again encountered.

6.2 Subsurface structure, including the dip of strata, 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 information about these features. If conditions prevent the continued advance of the core drilling, the hole should be cemented and redrilled, or reamed and cased, or cased and advanced with the next smaller-size core barrel, as required by the geologist or engineer.

6.3 Drilling mud or grouting techniques must be approved by the geologist or engineer prior to their use in the borehole.

6.4 Compatibility of Equipment:

6.4.1 Whenever possible, core barrels and drill rods should be selected from the same letter-size designation to ensure maximum efficiency. See Tables 1 and 3.

6.4.2 Never use a combination of pump, drill rod, and core barrel that yields a clear-water up-hole velocity of less than 120 ft/min.

6.4.3 Never use a combination of air compressor, drill rod, and core barrel that yields a clear-air up-hole velocity of less than 3000 ft/min.

7. Boring Log

- 7.1 The boring log shall include the following:
- 7.1.1 Project identification, boring number, location, date boring began, date boring completed, and driller's name.
 - 7.1.2 Elevation of the ground surface.
 - 7.1.3 Elevation of or depth to ground water and raising or lowering of level including the dates and the times measured.
 - 7.1.4 Elevations or depths at which drilling fluid return was lost.
 - 7.1.5 Size, type, and design of core barrel used. Size, type, and set of core bit and reaming shell used. Size, type, and length of all casing used. Description of any movements of the casing.
 - 7.1.6 Length of each core run and the length or percentage, or both, of the core recovered.
 - 7.1.7 Geologist's or engineer's description of the formation recovered in each run.
 - 7.1.8 Driller's description, if no engineer or geologist is present, of the formation recovered in each run.
 - 7.1.9 Subsurface structure description, including dip of strata and jointing, cavities, fissures, and any other observations made by the geologist or engineer that could yield information regarding the formation.

7.1.10 Depth, thickness, and apparent nature of the filling of each cavity or soft seam encountered, including opinions gained from the feel or appearance of the inside of the inner tube when core is lost. Record opinions as such.

7.1.11 Any change in the character of the drilling fluid or drilling fluid return.

7.1.12 Tidal and current information when the borehole is sufficiently close to a body of water to be affected.

7.1.13 Drilling time in minutes per foot and bit pressure in pound-force per square inch gage when applicable.

7.1.14 Notations of character of drilling, that is, soft, slow, easy, smooth, etc.

8. Precision and Bias

8.1 This practice does not produce numerical data; therefore, a precision and bias statement is not applicable.

NOTE 2—Inclusion of the following tables and use of letter symbols in the foregoing text is not intended to limit the practice to use of DCDMA tools. The table and text references are included as a convenience to the user since the vast majority of tools in use do meet DCDMA dimensional standards. Similar equipment of approximately equal size on the metric standard system is acceptable unless otherwise stipulated by the engineer or geologist.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.

APPENDIX B
Test Pit and Trench Excavation

SOP F106
Test Pit and Trench Excavation

**TEST PIT AND TRENCH EXCAVATION
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TEST PIT AND TRENCH EXCAVATION

1.0 PURPOSE

The purpose of this procedure is to provide general reference information and technical guidance on the excavation of exploratory test pits and trenches.

2.0 SCOPE

These procedures provide overall technical guidance and may be modified by site-specific requirements for field exploratory trenches and test pits. Conditions which would make trench excavation difficult (such as a shallow water table), dangerous (presence of explosive materials or underground utilities) or likely to cause environmental problems (such as potential rupture of buried containerized wastes), will require modifications to the procedures presented herein and may prevent implementation of the exploratory excavation program. Furthermore, the costs and difficulties in disposing of potentially hazardous materials removed from the test pits may constrain their use to areas where contamination potential is low. Consequently, the techniques described herein are most applicable in areas of low apparent contamination and where potentially explosive materials are not expected to be present.

3.0 DEFINITIONS

Trench - Trench means a narrow excavation (in relation to its length) made below the surface of the ground. In general, the depth is greater than the width, but the width of a trench (measured at the bottom) is not greater than 15 feet. If forms or other structures are installed or constructed in an excavation so as to reduce the dimension measured from the forms or structure to the side of the excavation to 15 feet or less (measured at the bottom of the excavation), the excavation is also considered to be a trench (definition from Federal Register, Vol. 54 No. 209, Tuesday, October 31, 1989, 29 CFR Part 1926 Occupational Safety and Health Standards - Excavations; Final Rule) (see Attachment A).

Test Pit - A test pit is a small excavation made below ground surface to characterize soil type and quality as well as determine the types of wastes buried. In general, a test pit is dug using a backhoe with dimensions measured as follows:

- Width - Typically two to three backhoe buckets wide
- Length - Typically five to 10 feet long
- Depth - Typically to top of water table or one to two feet below base of fill material

4.0 RESPONSIBILITIES

Project Manager - It is the responsibility of the Project Manager to ensure that field personnel responsible for trench and test pit excavation are familiar with these procedures. It also is the responsibility of the Project Manager to ensure that all appropriate documents (i.e., Test Pit Logs) have been completely and correctly filled out by the field inspector.

Field Team Leader - The Field Team Leader is responsible for the overall supervision of all test pit and trenching activities, and for ensuring that each test pit is properly and completely logged by the field inspector. It also is the responsibility of the Field Team Leader to ensure that all field inspectors have been briefed on these procedures.

Field Inspector - The Field Inspector is responsible for the direct supervision of test pit and trenching activities. It is the Field Inspector's responsibility to log each test pit, document subsurface conditions, complete appropriate forms, and to direct the test pit or trenching activities.

5.0 PROCEDURES

The procedures for test pit sizes, health and safety considerations, sampling, and backfilling are discussed in the following sections. Regulation for trench excavation, including trench sizes are given in the Tuesday October 31, 1989 edition of the Federal Register, 29 CFR Part 1926, "Occupation Safety and Health Standards - Excavations; Final Rule" (see Attachment A).

5.1 Test Pit Sizes

Test pits and trenches permit detailed exploration of the nature and contamination of in-situ materials, and the characteristics and stratification of near surface materials. The size of the excavation will depend on:

- Purpose and extent of the exploration.
- Space limitations imposed by site conditions (i.e., proximity to buildings, utilities, etc.).
- Contaminants present and the potential for release to the environment.
- Stability of the materials being excavated.
- Capabilities and limitations of the excavating equipment.

Test pits normally have a width ranging from two to ten feet or greater, depending on the objectives of the excavation and the equipment used. Test trenches are elongated test pits, usually three- to six-foot wide and extending for any desired length.

Standard equipment (i.e., backhoe) is readily available to excavate to depths of up to about 15 feet. However, larger and deeper excavations may be required. Standard equipment can be used to excavate deeper than their nominal limits by stepping or benching the excavation.

5.2 Health and Safety Considerations

Care must be taken by all on-site personnel during every phase of the test pit or trench excavation operation to avoid possible chemical and physical hazards. Chemical hazards may occur from direct exposure to excavated wastes or inhalation of volatilized materials. Physical hazards include the possible collapse of the trench or test pit, possible injury through violent contact with excavation equipment, or explosion or other forceful reaction upon contact with utilities exposed drums or other wastes.

All test pit and trench excavation activities must be carefully detailed in the site-specific Health and Safety Plan which will specify all precautions to be observed relative to possible chemical or physical hazards associated with these operations. Respiratory and personal protective equipment to be worn by all on-site personnel involved in excavation operations also will be specified in this document.

At locations where access is not restricted, a safety zone shall be established around the excavation. Additionally, personnel should, NOT under any circumstances, enter the excavation. Prior written approval and procedures documented in the Sampling and Analysis Plan and Health and Safety Plan, and approved by LANTDIV are required if entry into the excavation is to be considered. Additionally, a site Health and Safety Officer familiar with excavations shall be on site and shall direct the entry procedures.

5.3 Logging and Sampling

Test pits and/or trenches shall be logged and sampled by the Field Inspector. Soils shall be classified and described in accordance with the procedures given in SOP F101. Test Pit Records (see Figure 1) shall be legibly completed for all test pits. Samples shall only be collected from material in the equipment bucket, or from the pile of excavated materials. The excavation shall **NOT** be entered for the purpose of collecting samples.

5.4 Backfilling

Backfilling of trenches and test pits is a normally accepted practice to reduce immediate site hazards and minimize the potential for rainwater accumulation and subsequent contaminant migration.

After inspection and completion of the appropriate test pit logs, backfill material should be returned to the pit under the direction of the field inspector. Any hazardous and/or waste materials which are not returned to the excavation as backfill must be collected and properly disposed. If a low permeability layer is accidentally penetrated, or if a soil layer containing substantial quantities of contaminants is encountered, backfill material must consist of a soil-bentonite mix. The mix should be prepared in a proportion specified by the field inspector and should be covered by "clean" soil and graded to the original land contour. Where it is safe to do so, the backhoe bucket should be used to compact each one to two-foot layer of backfill as it is placed, to reduce settling and compaction. The test pit cover should be inspected and further regraded, if necessary after settling has occurred.



TEST PIT RECORD

PROJECT: _____
 CTO NO.: _____ TEST PIT NO.: _____
 COORDINATES: EAST _____ NORTH: _____
 SURFACE ELEVATION: _____ WATER LEVEL: _____
 WEATHER: _____ DATE: _____

REMARKS: _____

DEFINITIONS								
HNU = Photo Ionization Detector Reading OVA = Organic Vapor Analyzer Reading				Lab Class. = USCS (ASTM D-2487) or AASHTO (ASTM D-3282) Lab Moist. = Moisture Content (ASTM D-2216) Dry Weight Basis				
Depth (Ft.)	Sample Type and No.	HNU or (OVA) ppm		Lab. Class.	Lab. Moist %	Soil Strat	Visual Description (Principal Constituents, Gradation, Color, Moisture Content, Organic Content, Plasticity, and Other Observations)	Elevation (MSL)
		Field	Head Space					
1								
2								
3								
4								
5								
6								
7								
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5.5 Test Pit Excavation Procedures

The following procedures apply to the excavation and backfilling of a typical test pit. Note that if a subcontractor is procured to perform the test pit operations, the subcontractor must provide both an equipment operator and a supervisor:

- The positions of the test pits shall be located in the field by the field team leader.
- Utility clearance shall be obtained for all test pit locations prior to excavation. Contact appropriate Base personnel as well as MISS Utility (VA, MD, DC) or ULOCO (NC).

MISS Utility (1-800-552-7001)
ULOCO (1-800-632-4949)

- Excavation equipment shall be thoroughly decontaminated prior to and after each test pit excavation.
- A safety zone shall be established around the test pit location prior to initiation of excavation activities.
- Excavation shall commence by removing lifts of no more than approximately 6 to 12 inches of soil.
- The field inspector shall log the test pit soils and record observations on a Test Pit Record (Figure 1). Additionally, the test pit cross-section shall be sketched in the Field Logbook with notable features identified.
- If applicable, soil or waste samples shall be collected either from the backhoe bucket or from the pile of excavated materials following all appropriate SOPs (i.e., F102).
- Test pit depths (and water levels) may be measured using an engineers rule (six foot) or a weighted measuring tape. Depths shall be measured from the ground surface.
- Upon completion, test pits shall be immediately backfilled as described in Section 5.4.
- Test pit locations shall be marked with five wooden stakes; one at each corner and one in the center. The test pit number shall be recorded on the centrally located stake.
- If applicable, the test pit will be surveyed by a registered land surveyor or measured and referenced to nearby permanent site structures (i.e., buildings, curbs, fences, etc.).

6.0 **QUALITY ASSURANCE RECORDS**

The Quality Assurance Records that should be prepared include Test Pit Records and the Field Logbook.

7.0 REFERENCES

OSHA , 1989. Occupational Safety and Health Standards - Excavations; Final Rule. 29 CFR Part 1926.

ATTACHMENT A

OSHA - EXCAVATIONS, FINAL RULE

29 CFR PART 1926

**Final
Rules
for
Federal
Standards**

Tuesday
October 31, 1989

Part II

Department of Labor

Occupational Safety and Health
Administration

29 CFR Part 1926
Occupational Safety and Health
Standards—Excavations; Final Rule

PART 1926—[AMENDED]

Subpart M—[Amended]

1. By revising the authority citation for subpart M of part 1926 to read as follows:

Authority: Sec. 107, Contract Work Hours and Safety Standards Act (Construction Safety Act) (40 U.S.C. 333); Secs. 4, 6, 8, Occupational Safety and Health Act of 1970 (29 U.S.C. 653, 655, 657); Secretary of Labor's Order No. 12-71 (36 FR 8754), 8-76 (41 FR 25059), or 9-83 (48 FR 35738), as applicable, and 29 CFR part 1911.

2. By revising subpart P of part 1926 to read as follows:

Subpart P—Excavations

Sec.

1926.650 Scope, application, and definitions applicable to this subpart.

1926.651 General requirements.

1926.652 Requirements for protective systems.

Appendix A to Subpart P—Soil Classification

Appendix B to Subpart P—Sloping and Benching

Appendix C to Subpart P—Timber Shoring for Trenches

Appendix D to Subpart P—Aluminum Hydraulic Shoring for Trenches

Appendix E to Subpart P—Alternatives to Timber Shoring

Appendix F to Subpart P—Selection of Protective Systems

Subpart P—Excavations

Authority: Sec. 107, Contract Worker Hours and Safety Standards Act (Construction Safety Act) (40 U.S.C. 333); Secs. 4, 6, 8, Occupational Safety and Health Act of 1970 (29 U.S.C. 653, 655, 657); Secretary of Labor's Order No. 12-71 (36 FR 8754), 8-76 (41 FR 25059), or 9-83 (48 FR 35738), as applicable, and 29 CFR part 1911.

§ 1926.650 Scope, application, and definitions applicable to this subpart.

(a) *Scope and application.* This subpart applies to all open excavations made in the earth's surface. Excavations are defined to include trenches.

(b) *Definitions applicable to this subpart.*

Accepted engineering practices means those requirements which are compatible with standards of practice required by a registered professional engineer.

Aluminum Hydraulic Shoring means a pre-engineered shoring system comprised of aluminum hydraulic cylinders (crossbraces) used in conjunction with vertical rails (uprights) or horizontal rails (walers). Such system is designed, specifically to support the

sidewalls of an excavation and prevent cave-ins.

Bell-bottom pier hole means a type of shaft or footing excavation, the bottom of which is made larger than the cross section above to form a belled shape.

Benching (Benching system) means a method of protecting employees from cave-ins by excavating the sides of an excavation to form one or a series of horizontal levels or steps, usually with vertical or near-vertical surfaces between levels.

Cave-in means the separation of a mass of soil or rock material from the side of an excavation, or the loss of soil from under a trench shield or support system, and its sudden movement into the excavation, either by falling or sliding, in sufficient quantity so that it could entrap, bury, or otherwise injure and immobilize a person.

Competent person 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.

Cross braces mean the horizontal members of a shoring system installed perpendicular to the sides of the excavation, the ends of which bear against either uprights or wales.

Excavation means any man-made cut, cavity, trench, or depression in an earth surface, formed by earth removal.

Faces or *sides* means the vertical or inclined earth surfaces formed as a result of excavation work.

Failure means the breakage, displacement, or permanent deformation of a structural member or connection so as to reduce its structural integrity and its supportive capabilities.

Hazardous atmosphere means an atmosphere which by reason of being explosive, flammable, poisonous, corrosive, oxidizing, irritating, oxygen deficient, toxic, or otherwise harmful, may cause death, illness, or injury.

Kickout means the accidental release or failure of a cross brace.

Protective system means a method of protecting employees from cave-ins, from material that could fall or roll from an excavation face or into an excavation, or from the collapse of adjacent structures. Protective systems include support systems, sloping and benching systems, shield systems, and other systems that provide the necessary protection.

Ramp means an inclined walking or working surface that is used to gain access to one point from another, and is constructed from earth or from

structural materials such as steel or wood.

Registered Professional Engineer means a person who is registered as a professional engineer in the state where the work is to be performed. However, a professional engineer, registered in any state is deemed to be a "registered professional engineer" within the meaning of this standard when approving designs for "manufactured protective systems" or "tabulated data" to be used in interstate commerce.

Sheeting means the members of a shoring system that retain the earth in position and in turn are supported by other members of the shoring system.

Shield (Shield system) means a structure that is able to withstand the forces imposed on it by a cave-in and thereby protect employees within the structure. Shields can be permanent structures or can be designed to be portable and moved along as work progresses. Additionally, shields can be either premanufactured or job-built in accordance with § 1926.652 (c)(3) or (c)(4). Shields used in trenches are usually referred to as "trench boxes" or "trench shields."

Shoring (Shoring system) means a structure such as a metal hydraulic, mechanical or timber shoring system that supports the sides of an excavation and which is designed to prevent cave-ins.

Sides. See "Faces."

Sloping (Sloping system) means a method of protecting employees from cave-ins by excavating to form sides of an excavation that are inclined away from the excavation so as to prevent cave-ins. The angle of incline required to prevent a cave-in varies with differences in such factors as the soil type, environmental conditions of exposure, and application of surcharge loads.

Stable rock means natural solid mineral material that can be excavated with vertical sides and will remain intact while exposed. Unstable rock is considered to be stable when the rock material on the side or sides of the excavation is secured against caving-in or movement by rock bolts or by another protective system that has been designed by a registered professional engineer.

Structural ramp means a ramp built of steel or wood, usually used for vehicle access. Ramps made of soil or rock are not considered structural ramps.

Support system means a structure such as underpinning, bracing, or shoring, which provides support to an adjacent structure, underground

installation, or the sides of an excavation.

Tabulated data means tables and charts approved by a registered professional engineer and used to design and construct a protective system.

Trench (Trench excavation) means a narrow excavation (in relation to its length) made below the surface of the ground. In general, the depth is greater than the width, but the width of a trench (measured at the bottom) is not greater than 15 feet (4.6 m). If forms or other structures are installed or constructed in an excavation so as to reduce the dimension measured from the forms or structure to the side of the excavation to 15 feet (4.6 m) or less (measured at the bottom of the excavation), the excavation is also considered to be a trench.

Trench box. See "Shield."

Trench shield. See "Shield."

Uprights means the vertical members of a trench shoring system placed in contact with the earth and usually positioned so that individual members do not contact each other. Uprights placed so that individual members are closely spaced, in contact with or interconnected to each other, are often called "sheeting."

Wales means horizontal members of a shoring system placed parallel to the excavation face whose sides bear against the vertical members of the shoring system or earth.

§ 1926.651 General requirements.

(a) *Surface encumbrances.* All surface encumbrances that are located so as to create a hazard to employees shall be removed or supported, as necessary, to safeguard employees.

(b) *Underground installations.* (1) The estimated location of utility installations, such as sewer, telephone, fuel, electric, water lines, or any other underground installations that reasonably may be expected to be encountered during excavation work, shall be determined prior to opening an excavation.

(2) Utility companies or owners shall be contacted within established or customary local response times, advised of the proposed work, and asked to establish the location of the utility underground installations prior to the start of actual excavation. When utility companies or owners cannot respond to a request to locate underground utility installations within 24 hours (unless a longer period is required by state or local law), 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.

(3) When excavation operations approach the estimated location of underground installations, the exact location of the installations shall be determined by safe and acceptable means.

(4) While the excavation is open, underground installations shall be protected, supported or removed as necessary to safeguard employees.

(c) *Access and egress*—(1) *Structural ramps.* (i) Structural ramps that are used solely by employees as a means of access or egress from excavations shall be designed by a competent person. Structural ramps used for access or egress of equipment shall be designed by a competent person qualified in structural design, and shall be constructed in accordance with the design.

(ii) Ramps and runways constructed of two or more structural members shall have the structural members connected together to prevent displacement.

(iii) Structural members used for ramps and runways shall be of uniform thickness.

(iv) Cleats or other appropriate means used to connect runway structural members shall be attached to the bottom of the runway or shall be attached in a manner to prevent tripping.

(v) Structural ramps used in lieu of steps shall be provided with cleats or other surface treatments on the top surface to prevent slipping.

(2) *Means of egress from trench excavations.* A stairway, ladder, ramp or other safe means of egress shall be located in trench excavations that are 4 feet (1.22 m) or more in depth so as to require no more than 25 feet (7.62 m) of lateral travel for employees.

(d) *Exposure to vehicular traffic.* Employees exposed to public vehicular traffic shall be provided with, and shall wear, warning vests or other suitable garments marked with or made of reflectorized or high-visibility material.

(e) *Exposure to falling loads.* No employee shall be permitted underneath loads handled by lifting or digging equipment. Employees shall be required to stand away from any vehicle being loaded or unloaded to avoid being struck by any spillage or falling materials. Operators may remain in the cabs of vehicles being loaded or unloaded when the vehicles are equipped, in accordance with § 1926.601(b)(6), to provide adequate protection for the operator during loading and unloading operations.

(f) *Warning system for mobile equipment.* When mobile equipment is operated adjacent to an excavation, or

when such equipment is required to approach the edge of an excavation, and the operator does not have a clear and direct view of the edge of the excavation, a warning system shall be utilized such as barricades, hand or mechanical signals, or stop logs. If possible, the grade should be away from the excavation.

(g) *Hazardous atmospheres*—(1) *Testing and controls.* In addition to the requirements set forth in subparts D and E of this part (29 CFR 1926.50–1926.107) to prevent exposure to harmful levels of atmospheric contaminants and to assure acceptable atmospheric conditions, the following requirements shall apply:

(i) Where oxygen deficiency (atmospheres containing less than 19.5 percent oxygen) or a hazardous atmosphere exists or could reasonably be expected to exist, such as in excavations in landfill areas or excavations in areas where hazardous substances are stored nearby, the atmospheres in the excavation shall be tested before employees enter excavations greater than 4 feet (1.22 m) in depth.

(ii) Adequate precautions shall be taken to prevent employee exposure to atmospheres containing less than 19.5 percent oxygen and other hazardous atmospheres. These precautions include providing proper respiratory protection or ventilation in accordance with subparts D and E of this part respectively.

(iii) Adequate precaution shall be taken such as providing ventilation, to prevent employee exposure to an atmosphere containing a concentration of a flammable gas in excess of 20 percent of the lower flammable limit of the gas.

(iv) When controls are used that are intended to reduce the level of atmospheric contaminants to acceptable levels, testing shall be conducted as often as necessary to ensure that the atmosphere remains safe.

(2) *Emergency rescue equipment.* (i) Emergency rescue equipment, such as breathing apparatus, a safety harness and line, or a basket stretcher, shall be readily available where hazardous atmospheric conditions exist or may reasonably be expected to develop during work in an excavation. This equipment shall be attended when in use.

(ii) Employees entering bell-bottom pier holes, or other similar deep and confined footing excavations, shall wear a harness with a life-line securely attached to it. The lifeline shall be separate from any line used to handle materials, and shall be individually

attended at all times while the employee wearing the lifeline is in the excavation.

(h) *Protection from hazards associated with water accumulation.* (1) Employees shall not work in excavations in which there is accumulated water, or in excavations in which water is accumulating, unless adequate precautions have been taken to protect employees against the hazards posed by water accumulation. The precautions necessary to protect employees adequately vary with each situation, but could include special support or shield systems to protect from cave-ins, water removal to control the level of accumulating water, or use of a safety harness and lifeline.

(2) If water is controlled or prevented from accumulating by the use of water removal equipment, the water removal equipment and operations shall be monitored by a competent person to ensure proper operation.

(3) If excavation work interrupts the natural drainage of surface water (such as streams), diversion ditches, dikes, or other suitable means shall be used to prevent surface water from entering the excavation and to provide adequate drainage of the area adjacent to the excavation. Excavations subject to runoff from heavy rains will require an inspection by a competent person and compliance with paragraphs (h)(1) and (h)(2) of this section.

(i) *Stability of adjacent structures.* (1) Where the stability of adjoining buildings, walls, or other structures is endangered by excavation operations, support systems such as shoring, bracing, or underpinning shall be provided to ensure the stability of such structures for the protection of employees.

(2) Excavation below the level of the base or footing of any foundation or retaining wall that could be reasonably expected to pose a hazard to employees shall not be permitted except when:

(i) A support system, such as underpinning, is provided to ensure the safety of employees and the stability of the structure; or

(ii) The excavation is in stable rock; or

(iii) A registered professional engineer has approved the determination that the structure is sufficiently removed from the excavation so as to be unaffected by the excavation activity; or

(iv) A registered professional engineer has approved the determination that such excavation work will not pose a hazard to employees.

(3) Sidewalks, pavements, and appurtenant structure shall not be undermined unless a support system or another method of protection is

provided to protect employees from the possible collapse of such structures.

(j) *Protection of employees from loose rock or soil.* (1) Adequate protection shall be provided to protect employees from loose rock or soil that could pose a hazard by falling or rolling from an excavation face. Such protection shall consist of scaling to remove loose material; installation of protective barricades at intervals as necessary on the face to stop and contain falling material; or other means that provide equivalent protection.

(2) Employees shall be protected from excavated or other materials or equipment that could pose a hazard by falling or rolling into excavations. Protection shall be provided by placing and keeping such materials or equipment at least 2 feet (.61 m) from the edge of excavations, or by the use of retaining devices that are sufficient to prevent materials or equipment from falling or rolling into excavations, or by a combination of both if necessary.

(k) *Inspections.* (1) Daily inspections of excavations, the adjacent areas, and protective systems shall be made by a competent person for evidence of a situation that could result in possible cave-ins, indications of failure of protective systems, hazardous atmospheres, or other hazardous conditions. An inspection shall be conducted by the competent person prior to the start of work and as needed throughout the shift. Inspections shall also be made after every rainstorm or other hazard increasing occurrence. These inspections are only required when employee exposure can be reasonably anticipated.

(2) Where the competent person finds evidence of a situation that could result in a possible cave-in, indications of failure of protective systems, hazardous atmospheres, or other hazardous conditions, exposed employees shall be removed from the hazardous area until the necessary precautions have been taken to ensure their safety.

(l) *Fall protection.* (1) Where employees or equipment are required or permitted to cross over excavations, walkways or bridges with standard guardrails shall be provided.

(2) Adequate barrier physical protection shall be provided at all remotely located excavations. All wells, pits, shafts, etc., shall be barricaded or covered. Upon completion of exploration and similar operations, temporary wells, pits, shafts, etc., shall be backfilled.

§ 1926.652 Requirements for protective systems.

(a) *Protection of employees in excavations.* (1) Each employee in an excavation shall be protected from cave-ins by an adequate protective system designed in accordance with paragraph (b) or (c) of this section except when:

(i) Excavations are made entirely in stable rock; or

(ii) Excavations are less than 5 feet (1.52m) in depth and examination of the ground by a competent person provides no indication of a potential cave-in.

(2) Protective systems shall have the capacity to resist without failure all loads that are intended or could reasonably be expected to be applied or transmitted to the system.

(b) *Design of sloping and benching systems.* The slopes and configurations of sloping and benching systems shall be selected and constructed by the employer or his designee and shall be in accordance with the requirements of paragraph (b)(1); or, in the alternative, paragraph (b)(2); or, in the alternative, paragraph (b)(3), or, in the alternative, paragraph (b)(4), as follows:

(1) *Option (1)—Allowable configurations and slopes.* (i) Excavations shall be sloped at an angle not steeper than one and one-half horizontal to one vertical (34 degrees measured from the horizontal), unless the employer uses one of the other options listed below.

(ii) Slopes specified in paragraph (b)(1)(i) of this section, shall be excavated to form configurations that are in accordance with the slopes shown for Type C soil in Appendix B to this subpart.

(2) *Option (2)—Determination of slopes and configurations using Appendices A and B.* Maximum allowable slopes, and allowable configurations for sloping and benching systems, shall be determined in accordance with the conditions and requirements set forth in appendices A and B to this subpart.

(3) *Option (3)—Designs using other tabulated data.* (i) Designs of sloping or benching systems shall be selected from and be in accordance with tabulated data, such as tables and charts.

(ii) The tabulated data shall be in written form and shall include all of the following:

(A) Identification of the parameters that affect the selection of a sloping or benching system drawn from such data;

(B) Identification of the limits of use of the data, to include the magnitude and configuration of slopes determined to be safe;

(C) Explanatory information as may be necessary to aid the user in making a correct selection of a protective system from the data.

(iii) At least one copy of the tabulated data which identifies the registered professional engineer who approved the data, shall be maintained at the jobsite during construction of the protective system. After that time the data may be stored off the jobsite, but a copy of the data shall be made available to the Secretary upon request.

(4) *Option (4)—Design by a registered professional engineer.* (i) Sloping and benching systems not utilizing Option (1) or Option (2) or Option (3) under paragraph (b) of this section shall be approved by a registered professional engineer.

(ii) Designs shall be in written form and shall include at least the following:

(A) The magnitude of the slopes that were determined to be safe for the particular project;

(B) The configurations that were determined to be safe for the particular project; and

(C) The identity of the registered professional engineer approving the design.

(iii) At least one copy of the design shall be maintained at the jobsite while the slope is being constructed. After that time the design need not be at the jobsite, but a copy shall be made available to the Secretary upon request.

(c) *Design of support systems, shield systems, and other protective systems.* Designs of support systems, shield systems, and other protective systems shall be selected and constructed by the employer or his designee and shall be in accordance with the requirements of paragraph (c)(1); or, in the alternative, paragraph (c)(2); or, in the alternative, paragraph (c)(3); or, in the alternative, paragraph (c)(4) as follows:

(1) *Option (1)—Designs using appendices A, C and D.* Designs for timber shoring in trenches shall be determined in accordance with the conditions and requirements set forth in appendices A and C to this subpart. Designs for aluminum hydraulic shoring shall be in accordance with paragraph (c)(2) of this section, but if manufacturer's tabulated data cannot be utilized, designs shall be in accordance with appendix D.

(2) *Option (2)—Designs Using Manufacturer's Tabulated Data.* (i) Design of support systems, shield systems, or other protective systems that are drawn from manufacturer's tabulated data shall be in accordance with all specifications, recommendations, and limitations issued or made by the manufacturer.

(ii) Deviation from the specifications, recommendations, and limitations issued or made by the manufacturer shall only be allowed after the manufacturer issues specific written approval.

(iii) Manufacturer's specifications, recommendations, and limitations, and manufacturer's approval to deviate from the specifications, recommendations, and limitations shall be in written form at the jobsite during construction of the protective system. After that time this data may be stored off the jobsite, but a copy shall be made available to the Secretary upon request.

(3) *Option (3)—Designs using other tabulated data.* (i) Designs of support systems, shield systems, or other protective systems shall be selected from and be in accordance with tabulated data, such as tables and charts.

(ii) The tabulated data shall be in written form and include all of the following:

(A) Identification of the parameters that affect the selection of a protective system drawn from such data;

(B) Identification of the limits of use of the data;

(C) Explanatory information as may be necessary to aid the user in making a correct selection of a protective system from the data.

(iii) At least one copy of the tabulated data, which identifies the registered professional engineer who approved the data, shall be maintained at the jobsite during construction of the protective system. After that time the data may be stored off the jobsite, but a copy of the data shall be made available to the Secretary upon request.

(4) *Option (4)—Design by a registered professional engineer.* (i) Support systems, shield systems, and other protective systems not utilizing Option 1, Option 2 or Option 3, above, shall be approved by a registered professional engineer.

(ii) Designs shall be in written form and shall include the following:

(A) A plan indicating the sizes, types, and configurations of the materials to be used in the protective system; and

(B) The identity of the registered professional engineer approving the design.

(iii) At least one copy of the design shall be maintained at the jobsite during construction of the protective system. After that time, the design may be stored off the jobsite, but a copy of the design shall be made available to the Secretary upon request.

(d) *Materials and equipment.* (1) Materials and equipment used for protective systems shall be free from

damage or defects that might impair their proper function.

(2) Manufactured materials and equipment used for protective systems shall be used and maintained in a manner that is consistent with the recommendations of the manufacturer, and in a manner that will prevent employee exposure to hazards.

(3) When material or equipment that is used for protective systems is damaged, a competent person shall examine the material or equipment and evaluate its suitability for continued use. If the competent person cannot assure the material or equipment is able to support the intended loads or is otherwise suitable for safe use, then such material or equipment shall be removed from service, and shall be evaluated and approved by a registered professional engineer before being returned to service.

(e) *Installation and removal of support—(1) General.* (i) Members of support systems shall be securely connected together to prevent sliding, falling, kickouts, or other predictable failure.

(ii) Support systems shall be installed and removed in a manner that protects employees from cave-ins, structural collapses, or from being struck by members of the support system.

(iii) Individual members of support systems shall not be subjected to loads exceeding those which those members were designed to withstand.

(iv) Before temporary removal of individual members begins, additional precautions shall be taken to ensure the safety of employees, such as installing other structural members to carry the loads imposed on the support system.

(v) Removal shall begin at, and progress from, the bottom of the excavation. Members shall be released slowly so as to note any indication of possible failure of the remaining members of the structure or possible cave-in of the sides of the excavation.

(vi) Backfilling shall progress together with the removal of support systems from excavations.

(2) *Additional requirements for support systems for trench excavations.*

(i) Excavation of material to a level no greater than 2 feet (.61 m) below the bottom of the members of a support system shall be permitted, but only if the system is designed to resist the forces calculated for the full depth of the trench, and there are no indications while the trench is open of a possible loss of soil from behind or below the bottom of the support system.

(ii) Installation of a support system shall be closely coordinated with the excavation of trenches.

(f) *Sloping and benching systems.* Employees shall not be permitted to work on the faces of sloped or benched excavations at levels above other employees except when employees at the lower levels are adequately protected from the hazard of falling, rolling, or sliding material or equipment.

(g) *Shield systems*—(1) *General.* (i) Shield systems shall not be subjected to loads exceeding those which the system was designed to withstand.

(ii) Shields shall be installed in a manner to restrict lateral or other hazardous movement of the shield in the event of the application of sudden lateral loads.

(iii) Employees shall be protected from the hazard of cave-ins when entering or exiting the areas protected by shields.

(iv) Employees shall not be allowed in shields when shields are being installed, removed, or moved vertically.

(2) *Additional requirement for shield systems used in trench excavations.* Excavations of earth material to a level not greater than 2 feet (.61 m) below the bottom of a shield shall be permitted, but only if the shield is designed to resist the forces calculated for the full depth of the trench, and there are no indications while the trench is open of a possible loss of soil from behind or below the bottom of the shield.

Appendix A to Subpart P

Soil Classification

(a) *Scope and application*—(1) *Scope.* This appendix describes a method of classifying soil and rock deposits based on site and environmental conditions, and on the structure and composition of the earth deposits. The appendix contains definitions, sets forth requirements, and describes acceptable visual and manual tests for use in classifying soils.

(2) *Application.* This appendix applies when a sloping or benching system is designed in accordance with the requirements set forth in § 1926.652(b)(2) as a method of protection for employees from cave-ins. This appendix also applies when timber shoring for excavations is designed as a method of protection from cave-ins in accordance with appendix C to subpart P of part 1926, and when aluminum hydraulic shoring is designed in accordance with appendix D. This Appendix also applies if other protective systems are designed and selected for use from data prepared in accordance with the requirements set forth in § 1926.652(c), and the use of the data is predicated on the use of the soil classification system set forth in this appendix.

(b) *Definitions.* The definitions and examples given below are based on, in whole or in part, the following: American Society for

Testing Materials (ASTM) Standards D653-85 and D2488; The Unified Soils Classification System, The U.S. Department of Agriculture (USDA) Textural Classification Scheme; and The National Bureau of Standards Report BSS-121.

Cemented soil means a soil in which the particles are held together by a chemical agent, such as calcium carbonate, such that a hand-size sample cannot be crushed into powder or individual soil particles by finger pressure.

Cohesive soil means clay (fine grained soil), or soil with a high clay content, which has cohesive strength. Cohesive soil does not crumble, can be excavated with vertical sideslopes, and is plastic when moist. Cohesive soil is hard to break up when dry, and exhibits significant cohesion when submerged. Cohesive soils include clayey silt, sandy clay, silty clay, clay and organic clay.

Dry soil means soil that does not exhibit visible signs of moisture content.

Fissured means a soil material that has a tendency to break along definite planes of fracture with little resistance, or a material that exhibits open cracks, such as tension cracks, in an exposed surface.

Granular soil means gravel, sand, or silt, (coarse grained soil) with little or no clay content. Granular soil has no cohesive strength. Some moist granular soils exhibit apparent cohesion. Granular soil cannot be molded when moist and crumbles easily when dry.

Layered system means two or more distinctly different soil or rock types arranged in layers. Micaceous seams or weakened planes in rock or shale are considered layered.

Moist soil means a condition in which a soil looks and feels damp. Moist cohesive soil can easily be shaped into a ball and rolled into small diameter threads before crumbling. Moist granular soil that contains some cohesive material will exhibit signs of cohesion between particles.

Plastic means a property of a soil which allows the soil to be deformed or molded without cracking, or appreciable volume change.

Saturated soil means a soil in which the voids are filled with water. Saturation does not require flow. Saturation, or near saturation, is necessary for the proper use of instruments such as a pocket penetrometer or shear vane.

Soil classification system means, for the purpose of this subpart, a method of categorizing soil and rock deposits in a hierarchy of Stable Rock, Type A, Type B, and Type C, in decreasing order of stability. The categories are determined based on an analysis of the properties and performance characteristics of the deposits and the environmental conditions of exposure.

Stable rock means natural solid mineral matter that can be excavated with vertical sides and remain intact while exposed.

Submerged soil means soil which is underwater or is free seeping.

Type A means cohesive soils with an unconfined compressive strength of 1.5 ton per square foot (tsf) (144 kPa) or greater. Examples of cohesive soils are: clay, silty clay, sandy clay, clay loam and, in some

cases, silty clay loam and sandy clay loam. Cemented soils such as caliche and hardpan are also considered Type A. However, no soil is Type A if:

- (i) The soil is fissured; or
- (ii) The soil is subject to vibration from heavy traffic, pile driving, or similar effects; or
- (iii) The soil has been previously disturbed; or
- (iv) The soil is part of a sloped, layered system where the layers dip into the excavation on a slope of four horizontal to one vertical (4H:1V) or greater; or
- (v) The material is subject to other factors that would require it to be classified as a less stable material.

Type B means:

- (i) Cohesive soil with an unconfined compressive strength greater than 0.5 tsf (48 kPa) but less than 1.5 tsf (144 kPa); or
- (ii) Granular cohesionless soils including: angular gravel (similar to crushed rock), silt, silt loam, sandy loam and, in some cases, silty clay loam and sandy clay loam.

(iii) Previously disturbed soils except those which would otherwise be classed as Type C soil.

(iv) Soil that meets the unconfined compressive strength or cementation requirements for Type A, but is fissured or subject to vibration; or

(v) Dry rock that is not stable; or

(vi) Material that is part of a sloped, layered system where the layers dip into the excavation on a slope less steep than four horizontal to one vertical (4H:1V), but only if the material would otherwise be classified as Type B.

Type C means:

- (i) Cohesive soil with an unconfined compressive strength of 0.5 tsf (48 kPa) or less; or
- (ii) Granular soils including gravel, sand, and loamy sand; or
- (iii) Submerged soil or soil from which water is freely seeping; or
- (iv) Submerged rock that is not stable; or
- (v) Material in a sloped, layered system where the layers dip into the excavation on a slope of four horizontal to one vertical (4H:1V) or steeper.

Unconfined compressive strength means the load per unit area at which a soil will fail in compression. It can be determined by laboratory testing, or estimated in the field using a pocket penetrometer, by thumb penetration tests, and other methods.

Wet soil means soil that contains significantly more moisture than moist soil, but in such a range of values that cohesive material will slump or begin to flow when vibrated. Granular material that would exhibit cohesive properties when moist will lose those cohesive properties when wet.

(c) *Requirements*—(1) *Classification of soil and rock deposits.* Each soil and rock deposit shall be classified by a competent person as Stable Rock, Type A, Type B, or Type C in accordance with the definitions set forth in paragraph (b) of this appendix.

(2) *Basis of classification.* The classification of the deposits shall be made based on the results of at least one visual and at least one manual analysis. Such analyses

shall be conducted by a competent person using tests described in paragraph (d) below, or in other recognized methods of soil classification and testing such as those adopted by the American Society for Testing Materials, or the U.S. Department of Agriculture textural classification system.

(3) *Visual and manual analysis.* The visual and manual analyses, such as those methods being acceptable in paragraph (d) of this appendix, shall be designed and conducted to provide sufficient quantitative and qualitative information as may be necessary to identify properly the properties, factors, and conditions affecting the classification of the deposits.

(4) *Layered systems.* In a layered system, the system shall be classified in accordance with its weakest layer. However, each layer may be classified individually where a more stable layer lies under a less stable layer.

(5) *Reclassification.* If, after classifying a deposit, the properties, factors, or conditions affecting its classification change in any way, the changes shall be evaluated by a competent person. The deposit shall be reclassified as necessary to reflect the changed circumstances.

(d) *Acceptable visual and manual tests.*—

(1) *Visual tests.* Visual analysis is conducted to determine qualitative information regarding the excavation site in general, the soil adjacent to the excavation, the soil forming the sides of the open excavation, and the soil taken as samples from excavated material.

(i) Observe samples of soil that are excavated and soil in the sides of the excavation. Estimate the range of particle sizes and the relative amounts of the particle sizes. Soil that is primarily composed of fine-grained material is cohesive material. Soil composed primarily of coarse-grained sand or gravel is granular material.

(ii) Observe soil as it is excavated. Soil that remains in clumps when excavated is cohesive. Soil that breaks up easily and does not stay in clumps is granular.

(iii) Observe the side of the opened excavation and the surface area adjacent to the excavation. Crack-like openings such as tension cracks could indicate fissured material. If chunks of soil spill off a vertical side, the soil could be fissured. Small spalls are evidence of moving ground and are indications of potentially hazardous situations.

(iv) Observe the area adjacent to the excavation and the excavation itself for evidence of existing utility and other underground structures, and to identify previously disturbed soil.

(v) Observe the opened side of the excavation to identify layered systems. Examine layered systems to identify if the layers slope toward the excavation. Estimate the degree of slope of the layers.

(vi) Observe the area adjacent to the excavation and the sides of the opened excavation for evidence of surface water, water seeping from the sides of the excavation, or the location of the level of the water table.

(vii) Observe the area adjacent to the excavation and the area within the excavation for sources of vibration that may affect the stability of the excavation face.

(2) *Manual tests.* Manual analysis of soil samples is conducted to determine quantitative as well as qualitative properties of soil and to provide more information in order to classify soil properly.

(i) *Plasticity.* Mold a moist or wet sample of soil into a ball and attempt to roll it into threads as thin as 1/4-inch in diameter. Cohesive material can be successfully rolled into threads without crumbling. For example, if at least a two inch (50 mm) length of 1/4-inch thread can be held on one end without tearing, the soil is cohesive.

(ii) *Dry strength.* If the soil is dry and crumbles on its own or with moderate pressure into individual grains or fine powder, it is granular (any combination of gravel, sand, or silt). If the soil is dry and falls into clumps which break up into smaller clumps, but the smaller clumps can only be broken up with difficulty, it may be clay in any combination with gravel, sand or silt. If the dry soil breaks into clumps which do not break up into small clumps and which can only be broken with difficulty, and there is no visual indication the soil is fissured, the soil may be considered unfissured.

(iii) *Thumb penetration.* The thumb penetration test can be used to estimate the unconfined compressive strength of cohesive soils. (This test is based on the thumb penetration test described in American Society for Testing and Materials (ASTM) Standard designation D2488—"Standard Recommended Practice for Description of Soils (Visual—Manual Procedure).") Type A soils with an unconfined compressive strength of 1.5 tsf can be readily indented by the thumb; however, they can be penetrated by the thumb only with very great effort. Type C soils with an unconfined compressive strength of 0.5 tsf can be easily penetrated several inches by the thumb, and can be molded by light finger pressure. This test should be conducted on an undisturbed soil sample, such as a large clump of spoil, as soon as practicable after excavation to keep to a minimum the effects of exposure to drying influences. If the excavation is later exposed to wetting influences (rain, flooding), the classification of the soil must be changed accordingly.

(iv) *Other strength tests.* Estimates of unconfined compressive strength of soils can also be obtained by use of a pocket penetrometer or by using a hand-operated shearvane.

(v) *Drying test.* The basic purpose of the drying test is to differentiate between cohesive material with fissures, unfissured cohesive material, and granular material. The procedure for the drying test involves drying a sample of soil that is approximately one inch thick (2.54 cm) and six inches (15.24 cm) in diameter until it is thoroughly dry:

(A) If the sample develops cracks as it dries, significant fissures are indicated.

(B) Samples that dry without cracking are to be broken by hand. If considerable force is necessary to break a sample, the soil has significant cohesive material content. The soil can be classified as a unfissured cohesive material and the unconfined compressive strength should be determined.

(C) If a sample breaks easily by hand, it is either a fissured cohesive material or a

granular material. To distinguish between the two, pulverize the dried clumps of the sample by hand or by stepping on them. If the clumps do not pulverize easily, the material is cohesive with fissures. If they pulverize easily into very small fragments, the material is granular.

Appendix B to Subpart P

Sloping and Benching

(a) *Scope and application.* This appendix contains specifications for sloping and benching when used as methods of protecting employees working in excavations from cave-ins. The requirements of this appendix apply when the design of sloping and benching protective systems is to be performed in accordance with the requirements set forth in § 1926.852(b)(2).

(b) Definitions.

Actual slope means the slope to which an excavation face is excavated.

Distress means that the soil is in a condition where a cave-in is imminent or is likely to occur. Distress is evidenced by such phenomena as the development of fissures in the face of or adjacent to an open excavation; the subsidence of the edge of an excavation; the slumping of material from the face or the bulging or heaving of material from the bottom of an excavation; the spalling of material from the face of an excavation; and raveling, i.e., small amounts of material such as pebbles or little clumps of material suddenly separating from the face of an excavation and trickling or rolling down into the excavation.

Maximum allowable slope means the steepest incline of an excavation face that is acceptable for the most favorable site conditions as protection against cave-ins, and is expressed as the ratio of horizontal distance to vertical rise (H:V).

Short term exposure means a period of time less than or equal to 24 hours that an excavation is open.

(c) *Requirements.*—(1) *Soil classification.* Soil and rock deposits shall be classified in accordance with appendix A to subpart P of part 1926.

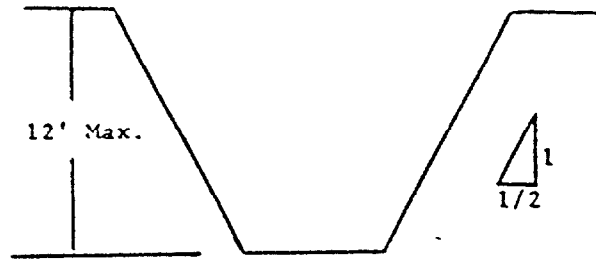
(2) *Maximum allowable slope.* The maximum allowable slope for a soil or rock deposit shall be determined from Table B-1 of this appendix.

(3) *Actual slope.* (i) The actual slope shall not be steeper than the maximum allowable slope.

(ii) The actual slope shall be less steep than the maximum allowable slope, when there are signs of distress. If that situation occurs, the slope shall be cut back to an actual slope which is at least 1/4 horizontal to one vertical (1/4H:1V) less steep than the maximum allowable slope.

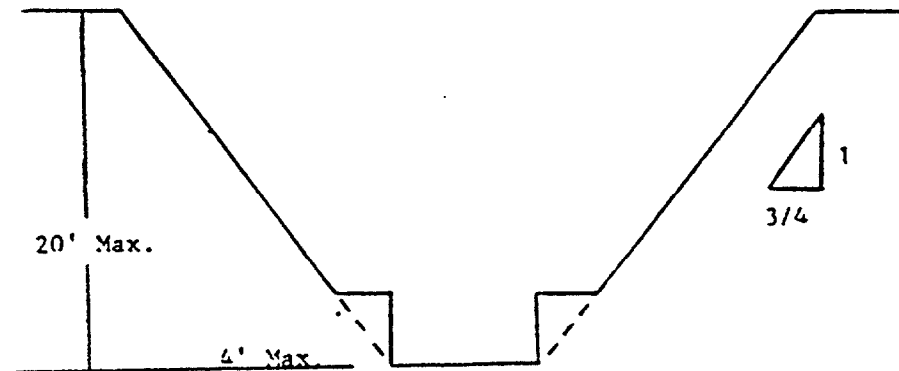
(iii) When surcharge loads from stored material or equipment, operating equipment, or traffic are present, a competent person shall determine the degree to which the actual slope must be reduced below the maximum allowable slope, and shall assure that such reduction is achieved. Surcharge loads from adjacent structures shall be evaluated in accordance with § 1926.851(i).

(4) *Configurations.* Configurations of sloping and benching systems shall be in accordance with Figure B-1.

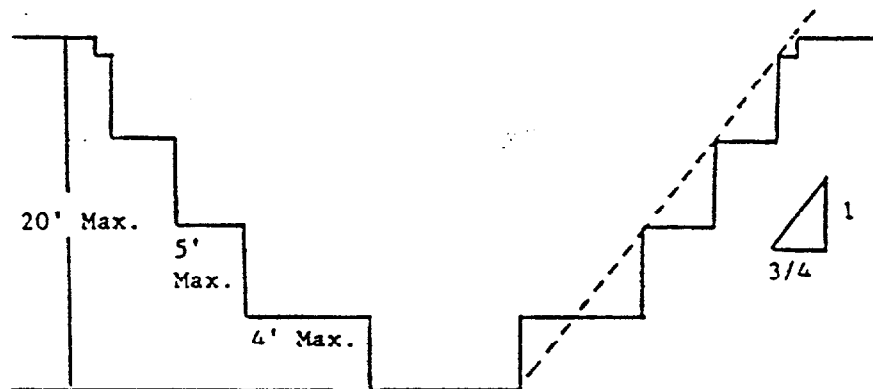


Simple Slope—Short Term

2. All benched excavations 20 feet or less in depth shall have a maximum allowable slope of $\frac{3}{4}$ to 1 and maximum bench dimensions as follows:

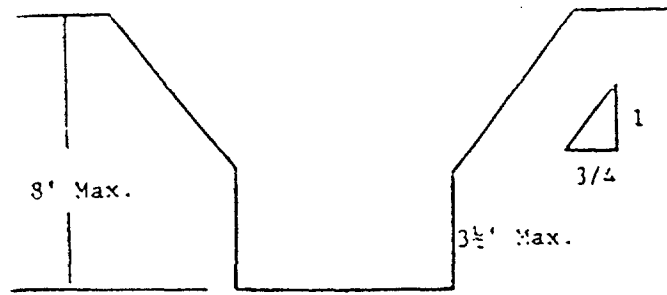


Simple Bench



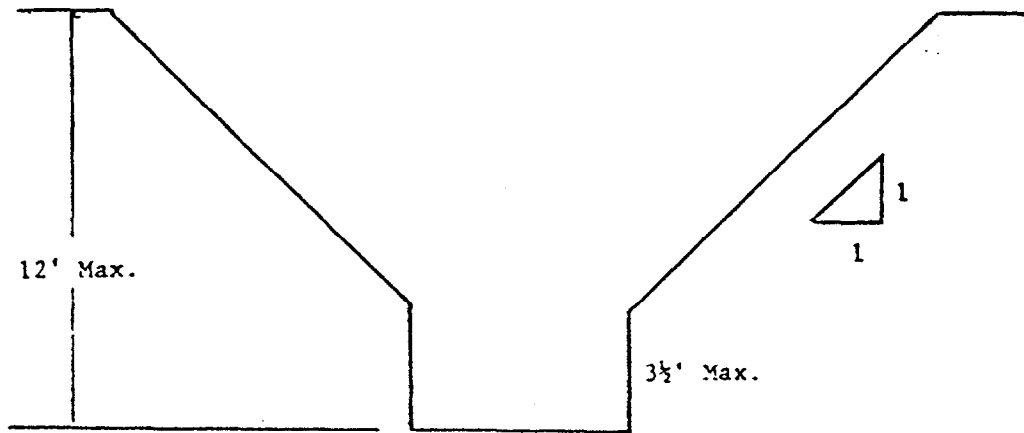
Multiple Bench

3. All excavations 8 feet or less in depth which have unsupported vertically sided lower portions shall have a maximum vertical side of $3\frac{1}{4}$ feet.



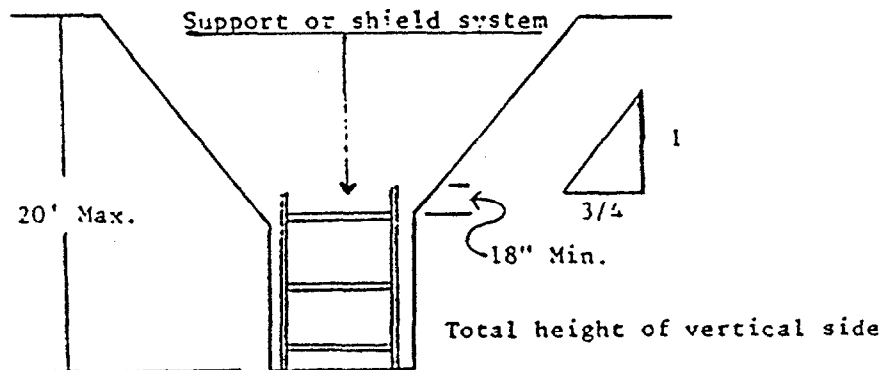
Unsupported Vertically Sided Lower Portion—Maximum 8 Feet in Depth

All excavations more than 8 feet but not more than 12 feet in depth which unsupported vertically sided lower portions shall have a maximum allowable slope of 1:1 and a maximum vertical side of 3 1/4 feet.



Unsupported Vertically Sided Lower Portion—Maximum 12 Feet in Depth

All excavations 20 feet or less in depth which have vertically sided lower portions that are supported or shielded shall have a maximum allowable slope of 3/4:1. The support or shield system must extend at least 18 inches above the top of the vertical side.

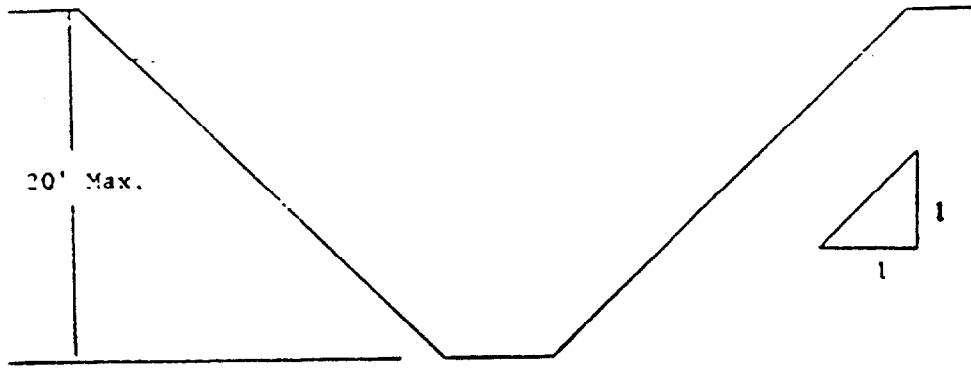


Supported or Shielded Vertically Sided Lower Portion

4. All other simple slope, compound slope, and vertically sided lower portion excavations shall be in accordance with the other options permitted under § 1926.652(b).

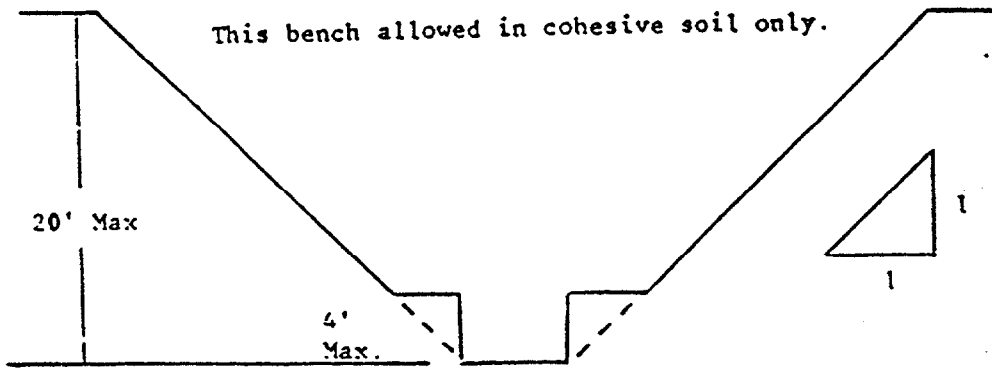
B-1.2 Excavations Made in Type B Soil

1. All simple slope excavations 20 feet or less in depth shall have a maximum allowable slope of 1:1.

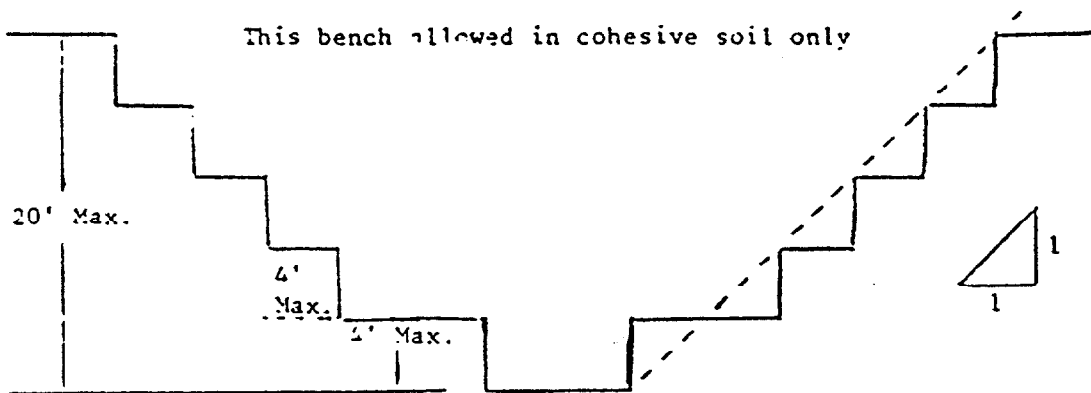


Simple Slope

2. All benched excavations 20 feet or less in depth shall have a maximum allowable slope of 1:1 and maximum bench dimensions as follows:

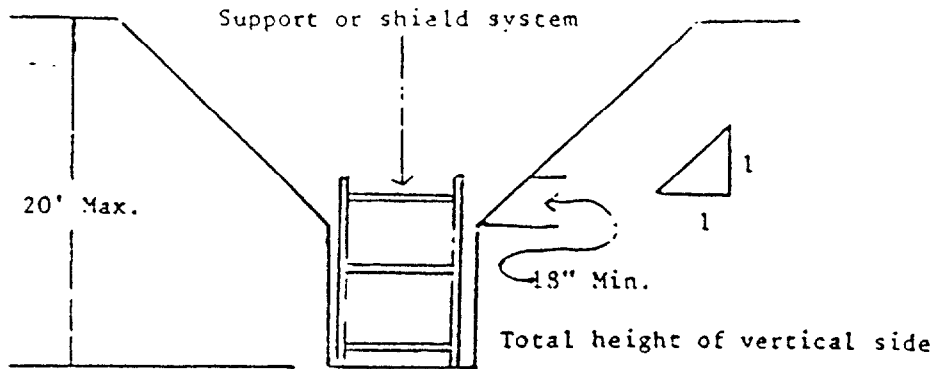


Single Bench



Multiple Bench

3. All excavations 20 feet or less in depth which have vertically sided lower portions shall be shielded or supported to a height at least 18 inches above the top of the vertical side. All such excavations shall have a maximum allowable slope of 1:1.

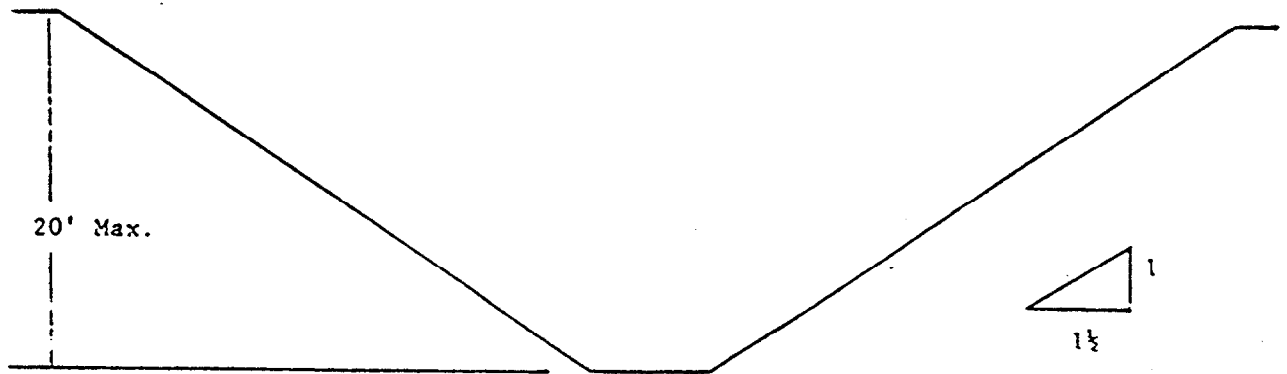


Vertically Sided Lower Portion

4. All other sloped excavations shall be in accordance with the other options permitted in § 1926.652(b).

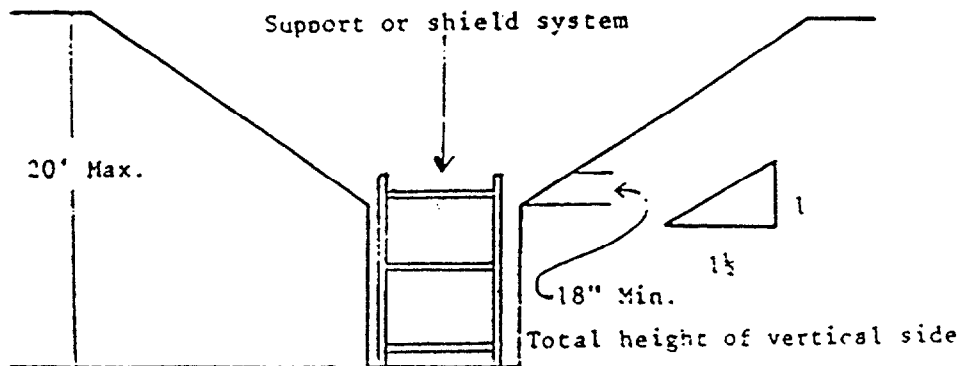
B-1.3 Excavations Made in Type C Soil

1. All simple slope excavations 20 feet or less in depth shall have a maximum allowable slope of 1½:1.



Simple Slope

2. All excavations 20 feet or less in depth which have vertically sided lower portions shall be shielded or supported to a height at least 18 inches above the top of the vertical side. All such excavations shall have a maximum allowable slope of 1½:1.

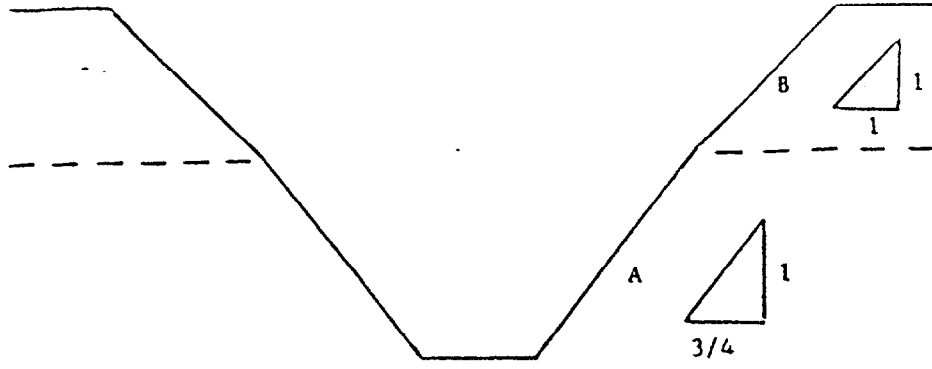


Vertical Sided Lower Portion

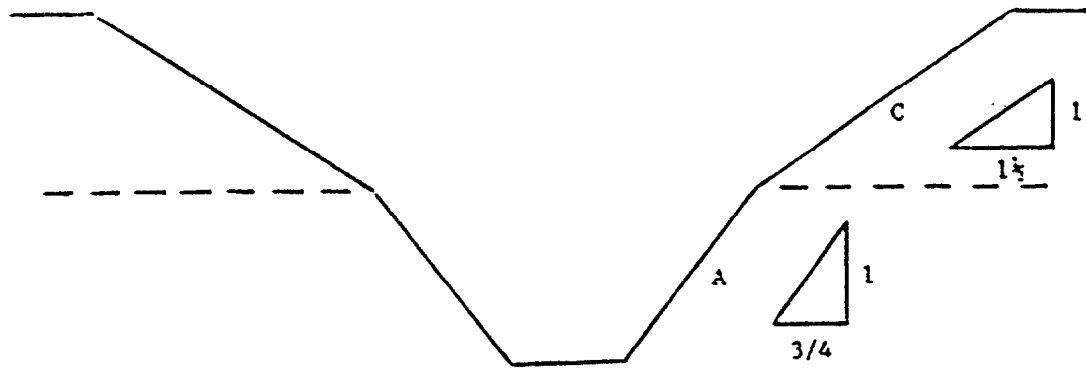
3. All other sloped excavations shall be in accordance with the other options permitted in § 1926.652(b).

B-1.4 Excavations Made in Layered Soils

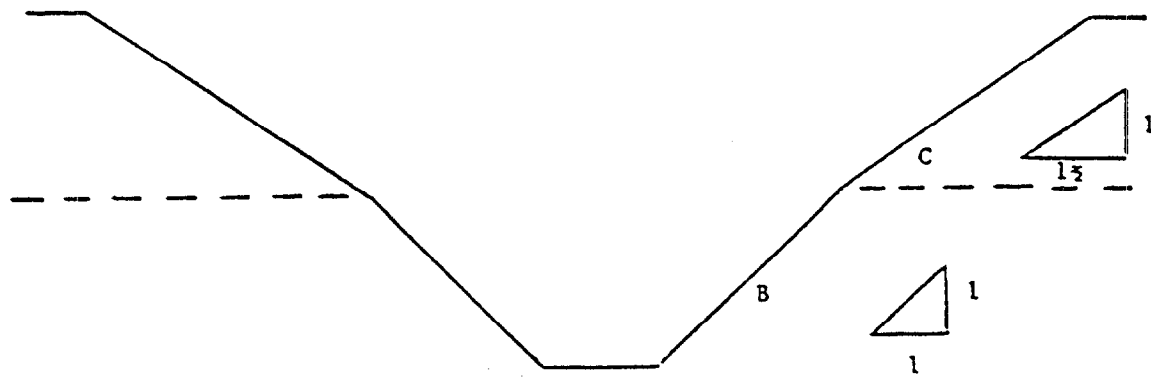
1. All excavations 20 feet or less in depth made in layered soils shall have a maximum allowable slope for each layer as set forth below.



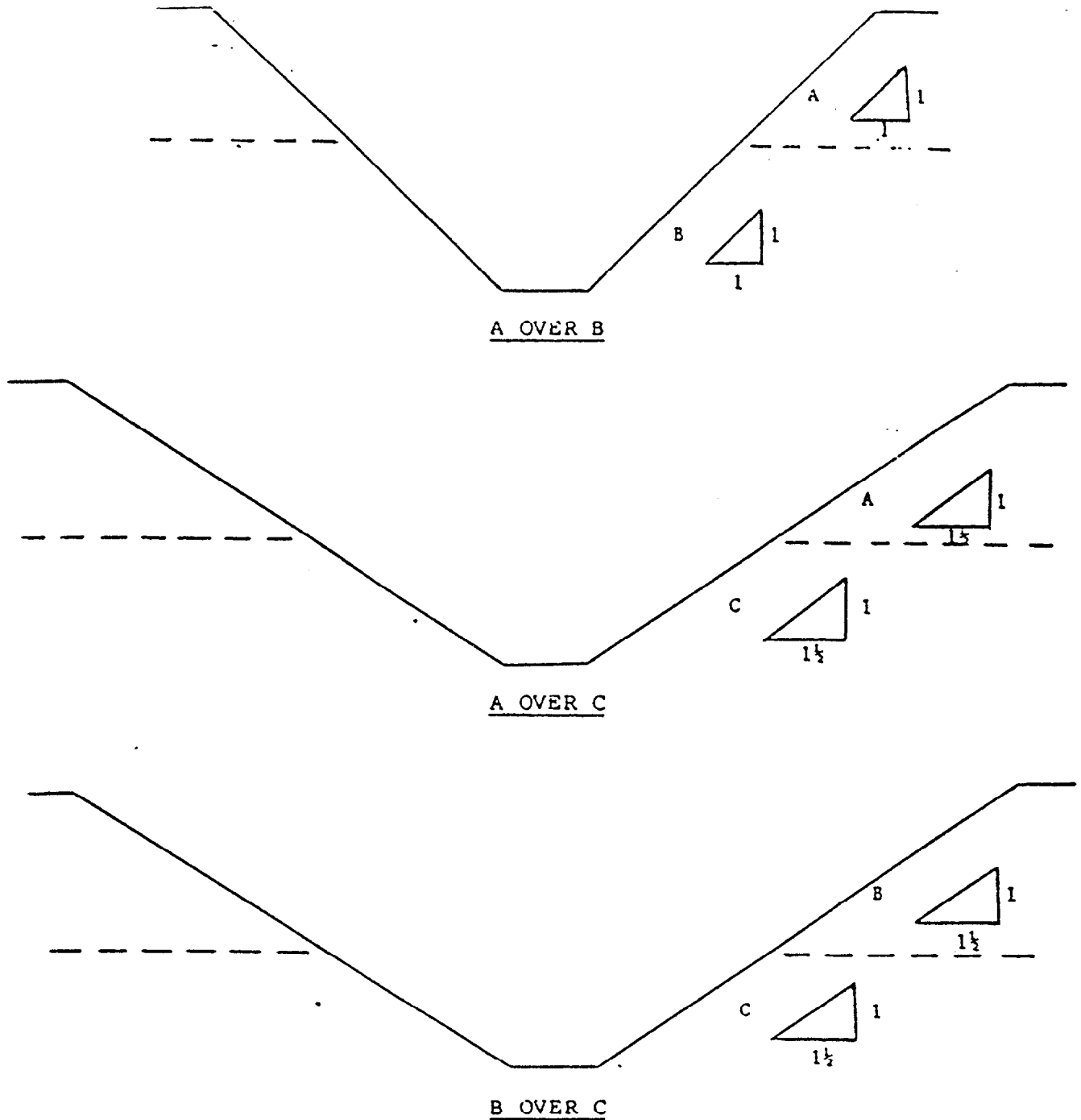
B OVER A



C OVER A



C OVER B



2. All other sloped excavations shall be in accordance with the other options permitted in § 1926.652(b).

Appendix C to Subpart P
Timber Shoring for Trenches

(a) *Scope.* This appendix contains information that can be used timber shoring is provided as a method of protection from cave-ins in trenches that do not exceed 20

feet (6.1 m) in depth. This appendix must be used when design of timber shoring protective systems is to be performed in accordance with § 1926.652(c)(1). Other timber shoring configurations; other systems of support such as hydraulic and pneumatic systems; and other protective systems such as sloping, benching, shielding, and freezing

systems must be designed in accordance with the requirements set forth in § 1926.652(b) and § 1926.852(c).

(b) *Soil Classification.* In order to use the data presented in this appendix, the soil type or types in which the excavation is made must first be determined using the soil

classification method set forth in appendix A of subpart P of this part.

(c) *Presentation of Information.* Information is presented in several forms as follows:

(1) Information is presented in tabular form in Tables C-1.1, C-1.2, and C-1.3, and Tables C-2.1, C-2.2 and C-2.3 following paragraph (g) of the appendix. Each table presents the minimum sizes of timber members to use in a shoring system, and each table contains data only for the particular soil type in which the excavation or portion of the excavation is made. The data are arranged to allow the user the flexibility to select from among several acceptable configurations of members based on varying the horizontal spacing of the crossbraces. Stable rock is exempt from shoring requirements and therefore, no data are presented for this condition.

(2) Information concerning the basis of the tabular data and the limitations of the data is presented in paragraph (d) of this appendix, and on the tables themselves.

(3) Information explaining the use of the tabular data is presented in paragraph (e) of this appendix.

(4) Information illustrating the use of the tabular data is presented in paragraph (f) of this appendix.

(5) Miscellaneous notations regarding Tables C-1.1 through C-1.3 and Tables C-2.1 through C-2.3 are presented in paragraph (g) of this Appendix.

(d) *Basis and limitations of the data.*—(1) *Dimensions of timber members.* (i) The sizes of the timber members listed in Tables C-1.1 through C-1.3 are taken from the National Bureau of Standards (NBS) report, "Recommended Technical Provisions for Construction Practice in Shoring and Sloping of Trenches and Excavations." In addition, where NBS did not recommend specific sizes of members, member sizes are based on an analysis of the sizes required for use by existing codes and on empirical practice. (ii) The required dimensions of the members listed in Tables C-1.1 through C-1.3 refer to actual dimensions and not nominal dimensions of the timber. Employers wanting to use nominal size shoring are directed to Tables C-2.1 through C-2.3, or have this choice under § 1926.652(c)(3), and are referred to The Corps of Engineers, The Bureau of Reclamation or data from other acceptable sources.

(2) *Limitation of application.* (i) It is not intended that the timber shoring specification apply to every situation that may be experienced in the field. These data were developed to apply to the situations that are most commonly experienced in current trenching practice. Shoring systems for use in situations that are not covered by the data in this appendix must be designed as specified in § 1926.652(c).

(ii) When any of the following conditions are present, the members specified in the tables are not considered adequate. Either an alternate timber shoring system must be designed or another type of protective system designed in accordance with § 1926.652.

(A) When loads imposed by structures or by stored material adjacent to the trench weigh in excess of the load imposed by a two-foot soil surcharge. The term "adjacent"

as used here means the area within a horizontal distance from the edge of the trench equal to the depth of the trench.

(B) When vertical loads imposed on cross braces exceed a 240-pound gravity load distributed on a one-foot section of the center of the crossbrace.

(C) When surcharge loads are present from equipment weighing in excess of 20,000 pounds.

(D) When only the lower portion of a trench is shored and the remaining portion of the trench is sloped or benched unless: The sloped portion is sloped at an angle less steep than three horizontal to one vertical; or the members are selected from the tables for use at a depth which is determined from the top of the overall trench, and not from the toe of the sloped portion.

(e) *Use of Tables.* The members of the shoring system that are to be selected using this information are the cross braces, the uprights, and the wales, where wales are required. Minimum sizes of members are specified for use in different types of soil. There are six tables of information, two for each soil type. The soil type must first be determined in accordance with the soil classification system described in appendix A to subpart P of part 1926. Using the appropriate table, the selection of the size and spacing of the members is then made. The selection is based on the depth and width of the trench where the members are to be installed and, in most instances, the selection is also based on the horizontal spacing of the crossbraces. Instances where a choice of horizontal spacing of crossbracing is available, the horizontal spacing of the crossbraces must be chosen by the user before the size of any member can be determined. When the soil type, the width and depth of the trench, and the horizontal spacing of the crossbraces are known, the size and vertical spacing of the crossbraces, the size and vertical spacing of the wales, and the size and horizontal spacing of the uprights can be read from the appropriate table.

(f) *Examples to Illustrate the Use of Tables C-1.1 through C-1.3.*

(1) *Example 1.*

A trench dug in Type A soil is 13 feet deep and five feet wide.

From Table C-1.1, for acceptable arrangements of timber can be used.

Arrangement #1

Space 4×4 crossbraces at six feet horizontally and four feet vertically.

Wales are not required.

Space 3×8 uprights at six feet horizontally. This arrangement is commonly called "skip shoring."

Arrangement #2

Space 4×8 crossbraces at eight feet horizontally and four feet vertically.

Space 8×8 wales at four feet vertically.

Space 2×6 uprights at four feet horizontally.

Arrangement #3

Space 6×6 crossbraces at 10 feet horizontally and four feet vertically.

Space 8×10 wales at four feet vertically.

Space 2×6 uprights at five feet horizontally.

Arrangement #4

Space 6×6 crossbraces at 12 feet horizontally and four feet vertically.

Space 10×10 wales at four feet vertically.

Spaces 3×8 uprights at six feet horizontally.

(2) *Example 2.*

A trench dug in Type B soil in 13 feet deep and five feet wide. From Table C-1.2 three acceptable arrangements of members are listed.

Arrangement #1.

Space 6×6 crossbraces at six feet horizontally and five feet vertically.

Space 8×8 wales at five feet vertically.

Space 2×6 uprights at two feet horizontally.

Arrangement #2

Space 6×8 crossbraces at eight feet horizontally and five feet vertically.

Space 10×10 wales at five feet vertically.

Space 2×6 uprights at two feet horizontally.

Arrangement #3

Space 8×8 crossbraces at 10 feet horizontally and five feet vertically.

Space 10×12 wales at five feet vertically.

Space 2×6 uprights at two feet vertically.

(3) *Example 3.*

A trench dug in Type C soil is 13 feet deep and five feet wide.

From Table C-1.3 two acceptable arrangements of members can be used.

Arrangement #1

Space 8×8 crossbraces at six feet horizontally and five feet vertically.

Space 10×12 wales at five feet vertically.

Position 2×6 uprights as closely together as possible.

If water must be retained use special tongue and groove uprights to form tight sheeting.

Arrangement #2

Space 8×10 crossbraces at eight feet horizontally and five feet vertically.

Space 12×12 wales at five feet vertically.

Position 2×6 uprights in a close sheeting configuration unless water pressure must be resisted. Tight sheeting must be used where water must be retained.

(4) *Example 4.*

A trench dug in Type C soil is 20 feet deep and 11 feet wide. The size and spacing of members for the section of trench that is over 15 feet in depth is determined using Table C-1.3. Only one arrangement of members is provided.

Space 8×10 crossbraces at six feet horizontally and five feet vertically.

Space 12×12 wales at five feet vertically.

Use 3×6 tight sheeting.

Use of Tables C-2.1 through C-2.3 would follow the same procedures.

(g) *Notes for all Tables.*

1. Member sizes at spacings other than indicated are to be determined as specified in § 1926.652(c), "Design of Protective Systems."

2. When conditions are saturated or submerged use Tight Sheeting. Tight Sheeting refers to the use of specially-edged timber planks (e.g., tongue and groove) at least three inches thick, steel sheet piling, or similar construction that when driven or placed in position provide a tight wall to resist the lateral pressure of water and to prevent the loss of backfill material. Close Sheeting refers to the placement of planks side-by-side allowing as little space as possible between them.

3. All spacing indicated is measured center to center.

4. Wales to be installed with greater dimension horizontal.

5. If the vertical distance from the center of the lowest crossbrace to the bottom of the trench exceeds two and one-half feet, uprights shall be firmly embedded or a mudsill shall be used. Where uprights are embedded, the vertical distance from the center of the lowest crossbrace to the bottom of the trench shall not exceed 36 inches.

When mudsills are used, the vertical distance

shall not exceed 42 inches. Mudsills are wales that are installed at the toe of the trench side.

6. Trench jacks may be used in lieu of or in combination with timber crossbraces.

7. Placement of crossbraces. When the vertical spacing of crossbraces is four feet, place the top crossbrace no more than two feet below the top of the trench. When the vertical spacing of crossbraces is five feet, place the top crossbrace no more than 2.5 feet below the top of the trench.

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TABLE C-1.1

TIMBER TRENCH SHORING -- MINIMUM TIMBER REQUIREMENTS *

SOIL TYPE A $P_a = 25 \times H + 72$ psf (2 ft Surcharge)

DEPTH OF TRENCH (FEET)	SIZE (ACTUAL) AND SPACING OF MEMBERS **													
	HORIZ. SPACING (FEET)	CROSS BRACES					VERT. SPACING (FEET)	WALES		UPRIGHTS				
		WIDTH OF TRENCH (FEET)						SIZE (IN)	VERT. SPACING (FEET)	MAXIMUM ALLOWABLE HORIZONTAL SPACING (FEET)				
		UP TO 4	UP TO 6	UP TO 9	UP TO 12	UP TO 15				CLOSE	4	5	6	8
5 TO 10	UP TO 6	4X4	4X4	4X6	6X6	6X6	4	Not Req'd	---				2X6	
	UP TO 8	4X4	4X4	4X6	6X6	6X6	4	Not Req'd	---					2X8
	UP TO 10	4X6	4X6	4X6	6X6	6X6	4	8X8	4			2X6		
	UP TO 12	4X6	4X6	6X6	6X6	6X6	4	8X8	4				2X6	
10 TO 15	UP TO 6	4X4	4X4	4X6	6X6	6X6	4	Not Req'd	---				3X8	
	UP TO 8	4X6	4X6	6X6	6X6	6X6	4	8X8	4		2X6			
	UP TO 10	6X6	6X6	6X6	6X8	6X8	4	8X10	4			2X6		
	UP TO 12	6X6	6X6	6X6	6X8	6X8	4	10X10	4				3X8	
15 TO 20	UP TO 6	6X6	6X6	6X6	6X8	6X8	4	6X8	4	3X6				
	UP TO 8	6X6	6X6	6X6	6X8	6X8	4	8X8	4	3X6				
	UP TO 10	8X8	8X8	8X8	8X8	8X10	4	8X10	4	3X6				
	UP TO 12	8X8	8X8	8X8	8X8	8X10	4	10X10	4	3X6				
OVER 20	SEE NOTE 1													

* Mixed oak or equivalent with a bending strength not less than 850 psi.

** Manufactured members of equivalent strength may be substituted for wood.

TABLE C-1.2

TIMBER TRENCH SHORING -- MINIMUM TIMBER REQUIREMENTS *

SOIL TYPE B $P_a = 45 \times H + 72$ psf (2 ft. Surcharge)

DEPTH OF TRENCH (FEET)	SIZE (ACTUAL) AND SPACING OF MEMBERS**													
	HORIZ. SPACING (FEET)	CROSS BRACES					VERT. SPACING (FEET)	WALES		UPRIGHTS				
		WIDTH OF TRENCH (FEET)						SIZE (IN)	VERT. SPACING (FEET)	MAXIMUM ALLOWABLE HORIZONTAL SPACING (FEET)				
		UP TO 4	UP TO 6	UP TO 9	UP TO 12	UP TO 15				CLOSE	2	3		
5 TO 10	UP TO 6	4X6	4X6	6X6	6X6	6X6	5	6X8	5			2X6		
	UP TO 8	6X6	6X6	6X6	6X8	6X8	5	8X10	5			2X6		
	UP TO 10	6X6	6X6	6X6	6X8	6X8	5	10X10	5			2X6		
	See Note 1													
10 TO 15	UP TO 6	6X6	6X6	6X6	6X8	6X8	5	8X8	5		2X6			
	UP TO 8	6X8	6X8	6X8	8X8	8X8	5	10X10	5		2X6			
	UP TO 10	8X8	8X8	8X8	8X8	8X10	5	10X12	5		2X6			
	See Note 1													
15 TO 20	UP TO 6	6X8	6X8	6X8	8X8	8X8	5	8X10	5	3X6				
	UP TO 8	8X8	8X8	8X8	8X8	8X10	5	10X12	5	3X6				
	UP TO 10	8X10	8X10	8X10	8X10	10X10	5	12X12	5	3X6				
	See Note 1													
OVER 20	SEE NOTE 1													

* Mixed oak or equivalent with a bending strength not less than 850 psi.

** Manufactured members of equivalent strength may be substituted for wood.

* Douglas fir or equivalent with a bending strength not less than 1500 psi.
 ** Manufactured members of equivalent strength may be substituted for wood.

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TABLE C-1.3

TIMBER TRENCH SHORING -- MINIMUM TIMBER REQUIREMENTS *
 SOIL TYPE C $P_a = 80 \text{ X H} + 72 \text{ psf (2 ft. Surcharge)}$

DEPTH OF TRENCH (FEET)	SIZE (ACTUAL) AND SPACING OF MEMBERS**												
	HORIZ. SPACING (FEET)	CROSS BRACES					VERT. SPACING (FEET)	SIZE (IN.)	VERT. SPACING (FEET)	UPRIGHTS			
		WIDTH OF TRENCH (FEET)								MAXIMUM ALLOWABLE HORIZONTAL SPACING (FEET) (See Note 2)			
		UP TO 4	UP TO 6	UP TO 9	UP TO 12	UP TO 15				CLOSE			
5 TO 10	UP TO 6	6X8	6X8	6X8	8X8	8X8	5	8X10	5	2X6			
	UP TO 8	8X8	8X8	8X8	8X8	8X10	5	10X12	5	2X6			
	UP TO 10	8X10	8X10	8X10	8X10	10X10	5	12X12	5	2X6			
	See Note 1												
10 TO 15	UP TO 6	8X8	8X8	8X8	8X8	8X10	5	10X12	5	2X6			
	UP TO 8	8X10	8X10	8X10	8X10	10X10	5	12X12	5	2X6			
	See Note 1												
	See Note 1												
15 TO 20	UP TO 6	8X10	8X10	8X10	8X10	10X10	5	12X12	5	3X6			
	See Note 1												
	See Note 1												
	See Note 1												

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TABLE C-2.1

TIMBER TRENCH SHORING -- MINIMUM TIMBER REQUIREMENTS *

SOIL TYPE A $P_a = 25 X H + 72$ psf (2 ft. Surcharge)

DEPTH OF TRENCH (FEET)	SIZE (S4S) AND SPACING OF MEMBERS **													
	HORIZ. SPACING (FEET)	CROSS BRACES					VERT. SPACING (FEET) †	HALES		UPRIGHTS				
		WIDTH OF TRENCH (FEET)						SIZE (IN)	VERT. SPACING (FEET)	MAXIMUM ALLOWABLE HORIZONTAL SPACING (FEET)				
		UP TO 4	UP TO 6	UP TO 9	UP TO 12	UP TO 15				CLOSE	4	5	6	8
5 TO 10	UP 6 TO	4X4	4X4	4X4	4X4	4X6	4	Not Req'd	Not Req'd				4X6	
	UP 8 TO	4X4	4X4	4X4	4X6	4X6	4	Not Req'd	Not Req'd					4X8
	UP 10 TO	4X6	4X6	4X6	6X6	6X6	4	8X8	4			4X6		
	UP 12 TO	4X6	4X6	4X6	6X6	6X6	4	8X8	4				4X6	
10 TO 15	UP 6 TO	4X4	4X4	4X4	6X6	6X6	4	Not Req'd	Not Req'd				4X10	
	UP 8 TO	4X6	4X6	4X6	6X6	6X6	4	6X8	4		4X6			
	UP 10 TO	6X6	6X6	6X6	6X6	6X6	4	8X8	4			4X8		
	UP 12 TO	6X6	6X6	6X6	6X6	6X6	4	8X10	4		4X6		4X10	
15 TO 20	UP 6 TO	6X6	6X6	6X6	6X6	6X6	4	6X8	4	3X6				
	UP 8 TO	6X6	6X6	6X6	6X6	6X6	4	8X8	4	3X6	4X12			
	UP 10 TO	6X6	6X6	6X6	6X6	6X8	4	8X10	4	3X6				
	UP 12 TO	6X6	6X6	6X6	6X8	6X8	4	8X12	4	3X6	4X12			
OVER 20	SEE NOTE 1													

* Douglas fir or equivalent with a bending strength not less than 1500 psi.

** Manufactured members of equivalent strength may be substituted for wood.

TABLE C-2.2

TIMBER TRENCH SHORING -- MINIMUM TIMBER REQUIREMENTS *
 SOIL TYPE B P_a = 45 X H + 72 psf (2 ft. Surcharge)

DEPTH OF TRENCH (FEET)	SIZE (S4S) AND SPACING OF MEMBERS **													
	HORIZ. SPACING (FEET)	CROSS BRACES					VERT. SPACING (FEET)	WALES		UPRIGHTS				
		WIDTH OF TRENCH (FEET)						SIZE (IN)	VERT. SPACING (FEET)	MAXIMUM ALLOWABLE HORIZONTAL SPACING (FEET)				
		UP TO 4	UP TO 6	UP TO 9	UP TO 12	UP TO 15				CLOSE	2	3	4	6
5 TO 10	UP TO 6	4X6	4X6	4X6	6X6	6X6	5	6X8	5			3X12 4X8		4X12
	UP TO 8	4X6	4X6	6X6	6X6	6X6	5	8X8	5		3X8		4X8	
	UP TO 10	4X6	4X6	6X6	6X6	6X8	5	8X10	5			4X8		
	See Note 1													
10 TO 15	UP TO 6	6X6	6X6	6X6	6X8	6X8	5	8X8	5	3X6	4X10			
	UP TO 8	6X8	6X8	6X8	8X8	8X8	5	10X10	5	3X6	4X10			
	UP TO 10	6X8	6X8	8X8	8X8	8X8	5	10X12	5	3X6	4X10			
	See Note 1													
15 TO 20	UP TO 6	6X8	6X8	6X8	6X8	8X8	5	8X10	5	4X6				
	UP TO 8	6X8	6X8	6X8	8X8	8X8	5	10X12	5	4X6				
	UP TO 10	8X8	8X8	8X8	8X8	8X8	5	12X12	5	4X6				
	See Note 1													
OVER .20	SEE NOTE 1													

* Douglas fir or equivalent with a bending strength not less than 1500 psi.
 ** Manufactured members of equivalent strength may be substituted for wood.

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TABLE C-2.3

TIMBER TRENCH SHORING -- MINIMUM TIMBER REQUIREMENTS *

SOIL TYPE C $P_a = 80 \times H + 72$ psf (2 ft. Surcharge)

DEPTH OF TRENCH (FEET)	SIZE (S4S) AND SPACING OF MEMBERS **													
	HORIZ. SPACING (FEET)	CROSS BRACES					VERT. SPACING (FEET)	WALES		UPRIGHTS				
		WIDTH OF TRENCH (FEET)						SIZE (IN)	VERT. SPACING (FEET)	MAXIMUM ALLOWABLE HORIZONTAL SPACING (FEET)				
		UP TO 4	UP TO 6	UP TO 9	UP TO 12	UP TO 15				CLOSE				
5 TO 10	UP TO 6	6X6	6X6	6X6	6X6	8X8	5	8X8	5	3X6				
	UP TO 8	6X6	6X6	6X6	8X8	8X8	5	10X10	5	3X6				
	UP TO 10	6X6	6X6	8X8	8X8	8X8	5	10X12	5	3X6				
	See Note 1													
10 TO 15	UP TO 6	6X8	6X8	6X8	8X8	8X8	5	10X10	5	4X6				
	UP TO 8	8X8	8X8	8X8	8X8	8X8	5	12X12	5	4X6				
	See Note 1													
	See Note 1													
15 TO 20	UP TO 6	8X8	8X8	8X8	8X10	8X10	5	10X12	5	4X6				
	See Note 1													
	See Note 1													
	See Note 1													
OVER 20	SEE NOTE 1													

* Douglas fir or equivalent with a bending strength not less than 1500 psi.

** Manufactured members of equivalent strength may be substituted for wood.

Appendix D to Subpart P

Aluminum Hydraulic Shoring for Trenches

(a) *Scope.* This appendix contains information that can be used when aluminum hydraulic shoring is provided as a method of protection against cave-ins in trenches that do not exceed 20 feet (6.1m) in depth. This appendix must be used when design of the aluminum hydraulic protective system cannot be performed in accordance with § 1926.652(c)(2).

(b) *Soil Classification.* In order to use data presented in this appendix, the soil type or types in which the excavation is made must first be determined using the soil classification method set forth in appendix A of subpart P of part 1926.

(c) *Presentation of Information.* Information is presented in several forms as follows:

(1) Information is presented in tabular form in Tables D-1.1, D-1.2, D-1.3 and E-1.4. Each table presents the maximum vertical and horizontal spacings that may be used with various aluminum member sizes and various hydraulic cylinder sizes. Each table contains data only for the particular soil type in which the excavation or portion of the excavation is made. Tables D-1.1 and D-1.2 are for vertical shores in Types A and B soil. Tables D-1.3 and D-1.4 are for horizontal waler systems in Types B and C soil.

(2) Information concerning the basis of the tabular data and the limitations of the data is presented in paragraph (d) of this appendix.

(3) Information explaining the use of the tabular data is presented in paragraph (e) of this appendix.

(4) Information illustrating the use of the tabular data is presented in paragraph (f) of this appendix.

(5) Miscellaneous notations (footnotes) regarding Table D-1.1 through D-1.4 are presented in paragraph (g) of this appendix.

(6) Figures, illustrating typical installations of hydraulic shoring, are included just prior to the Tables. The illustrations page is entitled "Aluminum Hydraulic Shoring: Typical Installations."

(d) *Basis and limitations of the data.*

(1) Vertical shore rails and horizontal wales are those that meet the Section Modulus requirements in the D-1 Tables. Aluminum material is 6061-T6 or material of equivalent strength and properties.

(2) Hydraulic cylinders specifications. (i) 2-inch cylinders shall be a minimum 2-inch inside diameter with a minimum safe working capacity of no less than 18,000 pounds axial compressive load at maximum extension. Maximum extension is to include full range of cylinder extensions as recommended by product manufacturer.

(ii) 3-inch cylinders shall be a minimum 3-inch inside diameter with a safe working capacity of not less than 30,000 pounds axial compressive load at extensions as recommended by product manufacturer.

(3) *Limitation of application.*

(i) It is not intended that the aluminum hydraulic specification apply to every situation that may be experienced in the field. These data were developed to apply to the situations that are most commonly

experienced in current trenching practice. Shoring systems for use in situations that are not covered by the data in this appendix must be otherwise designed as specified in § 1926.652(c).

(ii) When any of the following conditions are present, the members specified in the Tables are not considered adequate. In this case, an alternative aluminum hydraulic shoring system or other type of protective system must be designed in accordance with § 1926.652.

(A) When vertical loads imposed on cross braces exceed a 100 Pound gravity load distributed on a one foot section of the center of the hydraulic cylinder.

(B) When surcharge loads are present from equipment weighing in excess of 20,000 pounds.

(C) When only the lower portion or a trench is shored and the remaining portion of the trench is sloped or benched unless: The sloped portion is sloped at an angle less steep than three horizontal to one vertical; or the members are selected from the tables for use at a depth which is determined from the top of the overall trench, and not from the toe of the sloped portion.

(e) *Use of Tables D-1.1, D-1.2, D-1.3 and D-1.4.* The members of the shoring system that are to be selected using this information are the hydraulic cylinders, and either the vertical shores or the horizontal wales. When a waler system is used the vertical timber sheeting to be used is also selected from these tables. The Tables D-1.1 and D-1.2 for vertical shores are used in Type A and B soils that do not require sheeting. Type B soils that may require sheeting, and Type C soils that always require sheeting are found in the horizontal wale Tables D-1.3 and D-1.4. The soil type must first be determined in accordance with the soil classification system described in appendix A to subpart P of part 1926. Using the appropriate table, the selection of the size and spacing of the members is made. The selection is based on the depth and width of the trench where the members are to be installed. In these tables the vertical spacing is held constant at four feet on center. The tables show the maximum horizontal spacing of cylinders allowed for each size of wale in the waler system tables, and in the vertical shore tables, the hydraulic cylinder horizontal spacing is the same as the vertical shore spacing.

(f) *Example to Illustrate the Use of the Tables:*(1) *Example 1:*

A trench dug in Type A soil is 6 feet deep and 3 feet wide. From Table D-1.1: Find vertical shores and 2 inch diameter cylinders spaced 8 feet on center (o.c.) horizontally and 4 feet on center (o.c.) vertically. (See Figures 1 & 3 for typical installations.)

(2) *Example 2:*

A trench is dug in Type B soil that does not require sheeting, 13 feet deep and 5 feet wide. From Table D-1.2: Find vertical shores and 2 inch diameter cylinders spaced 6.5 feet o.c. horizontally and 4 feet o.c. vertically. (See Figures 1 & 3 for typical installations.)

(3) A trench is dug in Type B soil that does not require sheeting, but does experience some minor raveling of the trench face. The trench is 16 feet deep and 9 feet wide. From

Table D-1.2: Find vertical shores and 2 inch diameter cylinder (with special oversleeves as designated by footnote #2) spaced 5.5 feet o.c. horizontally and 4 feet o.c. vertically, plywood (per footnote (g)(7) to the D-1 Table) should be used behind the shores. (See Figures 2 & 3 for typical installations.)

(4) *Example 4:* A trench is dug in previously disturbed Type B soil, with characteristics of a Type C soil, and will require sheeting. The trench is 16 feet deep and 12 feet wide. 8 foot horizontal spacing between cylinders is desired for working space. From Table D-1.3: Find horizontal wale with a section modulus of 14.0 spaced at 4 feet o.c. vertically and 3 inch diameter cylinder spaced at 9 feet maximum o.c. horizontally. 3x12 timber sheeting is required at close spacing vertically. (See Figure 4 for typical installation.)

(5) *Example 5:* A trench is dug in Type C soil, 9 feet deep and 4 feet wide. Horizontal cylinder spacing in excess of 6 feet is desired for working space. From Table D-1.4: Find horizontal wale with a section modulus of 7.0 and 2 inch diameter cylinders spaced at 6.5 feet o.c. horizontally. Or, find horizontal wale with a 14.0 section modulus and 3 inch diameter cylinder spaced at 10 feet o.c. horizontally. Both wales are spaced 4 feet o.c. vertically. 3x12 timber sheeting is required at close spacing vertically. (See Figure 4 for typical installation.)

(g) *Footnotes, and general notes, for Tables D-1.1, D-1.2, D-1.3, and D-1.4.*

(1) For applications other than those listed in the tables, refer to § 1926.652(c)(2) for use of manufacturer's tabulated data. For trench depths in excess of 20 feet, refer to § 1926.652(c)(2) and § 1926.652(c)(3).

(2) 2 inch diameter cylinders, at this width, shall have structural steel tube (3.5x3.5x0.1875) oversleeves, or structural oversleeves of manufacturer's specification, extending the full, collapsed length.

(3) Hydraulic cylinders capacities. (i) 2 inch cylinders shall be a minimum 2-inch inside diameter with a safe working capacity of not less than 18,000 pounds axial compressive load at maximum extension. Maximum extension is to include full range of cylinder extensions as recommended by product manufacturer.

(ii) 3-inch cylinders shall be a minimum 3-inch inside diameter with a safe work capacity of not less than 30,000 pounds axial compressive load at maximum extension. Maximum extension is to include full range of cylinder extensions as recommended by product manufacturer.

(4) All spacing indicated is measured center to center.

(5) Vertical shoring rails shall have a minimum section modulus of 0.40 inch.

(6) When vertical shores are used, there must be a minimum of three shores spaced equally, horizontally, in a group.

(7) Plywood shall be 1.125 in. thick softwood or 0.75 inch, thick, 14 ply, arctic white birch (Finland form). Please note that plywood is not intended as a structural member, but only for prevention of local raveling (sloughing of the trench face) between shores.

(8) See appendix C for timber specifications.

(9) Wales are calculated for simple span conditions.

(10) See appendix D, item (d), for basis and limitations of the data.

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ALUMINUM HYDRAULIC SHORING TYPICAL INSTALLATIONS

FIGURE NO. 1

VERTICAL ALUMINUM
HYDRAULIC SHORING
(SPOT BRACING)

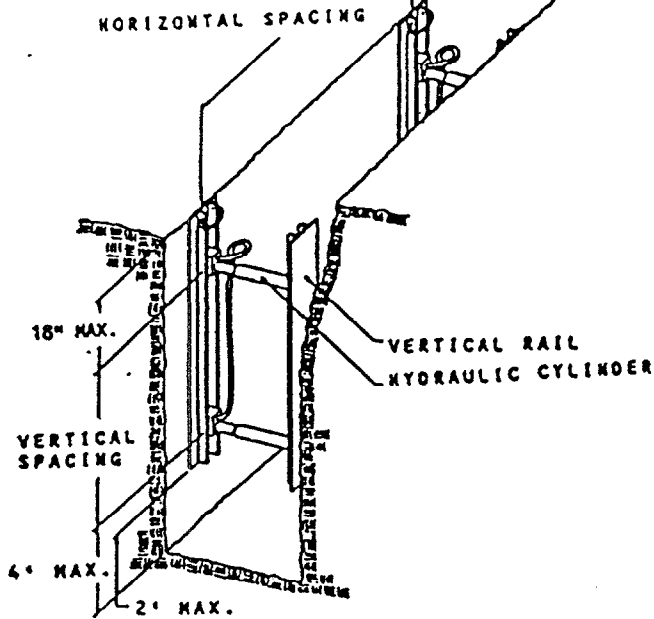


FIGURE NO. 2

VERTICAL ALUMINUM
HYDRAULIC SHORING
(WITH PLYWOOD)

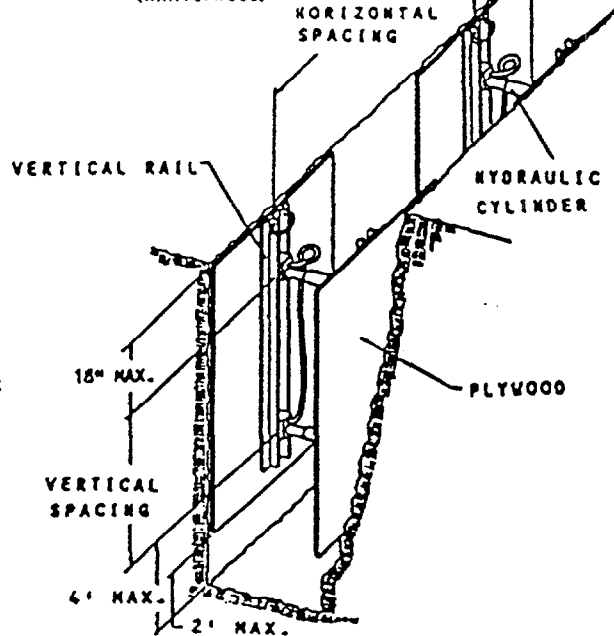


FIGURE NO. 3

VERTICAL ALUMINUM
HYDRAULIC SHORING
(STACKED)

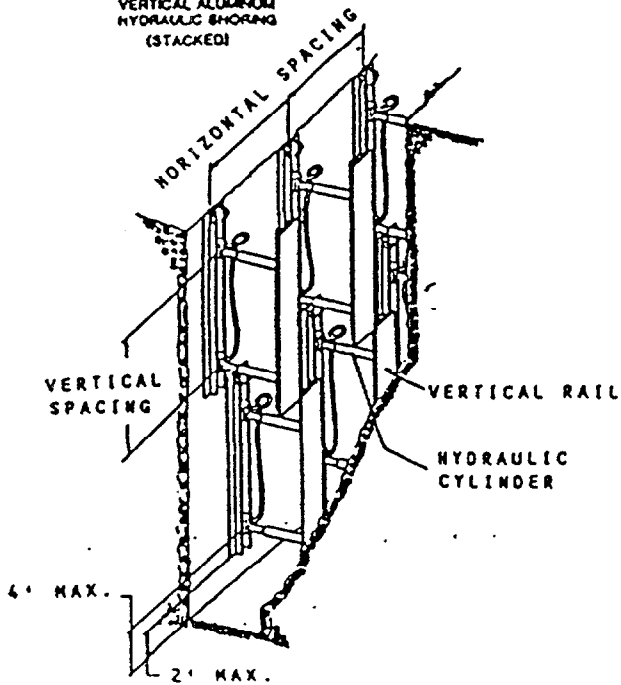
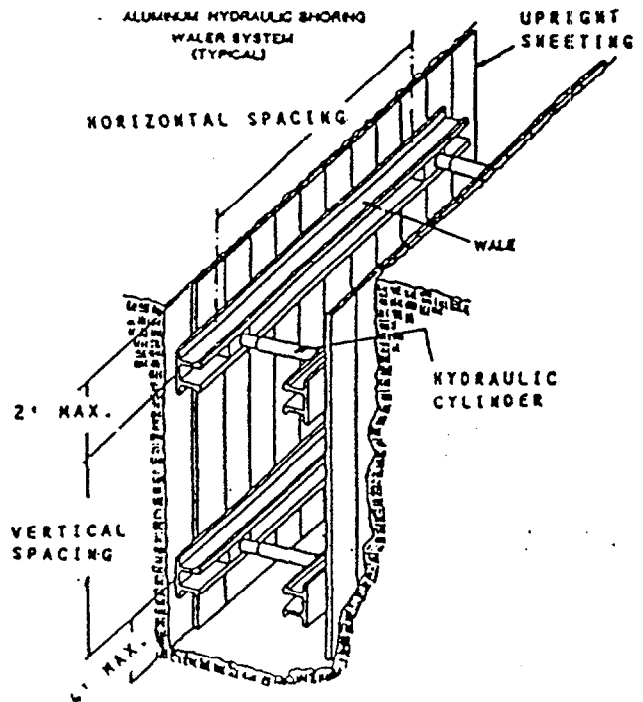


FIGURE NO. 4

ALUMINUM HYDRAULIC SHORING
WALE SYSTEM
(TYPICAL)



**TABLE D - 1.1
ALUMINUM HYDRAULIC SHORING
VERTICAL SHORES
FOR SOIL TYPE A**

DEPTH OF TRENCH (FEET)	HYDRAULIC CYLINDERS				
	MAXIMUM HORIZONTAL SPACING (FEET)	MAXIMUM VERTICAL SPACING (FEET)	WIDTH OF TRENCH (FEET)		
			UP TO 8	OVER 8 UP TO 12	OVER 12 UP TO 15
OVER 5 UP TO 10	8	4	2 INCH DIAMETER	2 INCH DIAMETER NOTE (2)	3 INCH DIAMETER
OVER 10 UP TO 15	8				
OVER 15 UP TO 20	7				
OVER 20	NOTE (1)				

Footnotes to tables, and general notes on hydraulic shoring, are found in Appendix D, Item (g)

Note (1): See Appendix D, Item (g) (1)

Note (2): See Appendix D, Item (g) (2)

**TABLE D - 1.2
ALUMINUM HYDRAULIC SHORING
VERTICAL SHORES
FOR SOIL TYPE B**

DEPTH OF TRENCH (FEET)	HYDRAULIC CYLINDERS				
	MAXIMUM HORIZONTAL SPACING (FEET)	MAXIMUM VERTICAL SPACING (FEET)	WIDTH OF TRENCH (FEET)		
			UP TO 8	OVER 8 UP TO 12	OVER 12 UP TO 15
OVER 5 UP TO 10	8	4	2 INCH DIAMETER	2 INCH DIAMETER NOTE (2)	3 INCH DIAMETER
OVER 10 UP TO 15	6.5				
OVER 15 UP TO 20	5.5				
OVER 20	NOTE (1)				

Footnotes to tables, and general notes on hydraulic shoring, are found in Appendix D, Item (g)

Note (1): See Appendix D, Item (g) (1)

Note (2): See Appendix D, Item (g) (2)

TABLE D - 1.3
ALUMINUM HYDRAULIC SHORING
WALER SYSTEMS
FOR SOIL TYPE B

DEPTH OF TRENCH (FEET)	WALES		HYDRAULIC CYLINDERS						TIMBER UPRIGHTS		
	VERTICAL SPACING (FEET)	SECTION MODULUS (IN ³)	WIDTH OF TRENCH (FEET)						MAX. HORIZ. SPACING (ON CENTER)		
			UP TO 8		OVER 8 UP TO 12		OVER 12 UP TO 15		SOLID SHEET	2 FT.	3 FT.
			HORIZ. SPACING	CYLINDER DIAMETER	HORIZ. SPACING	CYLINDER DIAMETER	HORIZ. SPACING	CYLINDER DIAMETER			
OVER 5 UP TO 10	4	3.5	8.0	2 IN	8.0	2 IN NOTE(2)	8.0	3 IN	---	---	3x12
		7.0	9.0	2 IN	9.0	2 IN NOTE(2)	9.0	3 IN			
		14.0	12.0	3 IN	12.0	3 IN	12.0	3 IN			
OVER 10 UP TO 15	4	3.5	6.0	2 IN	6.0	2 IN NOTE(2)	6.0	3 IN	---	3x12	---
		7.0	8.0	3 IN	8.0	3 IN	8.0	3 IN			
		14.0	10.0	3 IN	10.0	3 IN	10.0	3 IN			
OVER 15 UP TO 20	4	3.5	5.5	2 IN	5.5	2 IN NOTE(2)	5.5	3 IN	3x12	---	---
		7.0	6.0	3 IN	6.0	3 IN	6.0	3 IN			
		14.0	9.0	3 IN	9.0	3 IN	9.0	3 IN			
OVER 20	NOTE (1)										

Footnotes to tables, and general notes on hydraulic shoring, are found in Appendix D, Item (g)

Notes (1): See Appendix D, item (g) (1)

Notes (2): See Appendix D, Item (g) (2)

* Consult product manufacturer and/or qualified engineer for Section Modulus of available wales.

**TABLE D - 1.4
ALUMINUM HYDRAULIC SHORING
WALER SYSTEMS
FOR SOIL TYPE C.**

DEPTH OF TRENCH (FEET)	WALES		HYDRAULIC CYLINDERS						TIMBER UPRIGHTS		
	VERTICAL SPACING (FEET)	SECTION MODULUS (IN ³)	WIDTH OF TRENCH (FEET)						MAX. HORIZ SPACING (ON CENTER)		
			UP TO 8		OVER 8 UP TO 12		OVER 12 UP TO 15		SOLID SHEET	2 FT.	3 FT.
			HORIZ. SPACING	CYLINDER DIAMETER	HORIZ. SPACING	CYLINDER DIAMETER	HORIZ. SPACING	CYLINDER DIAMETER			
OVER 5 UP TO 10	4	3.5	6.0	2 IN	6.0	2 IN NOTE(2)	6.0	3 IN	3x12	—	—
		7.0	6.5	2 IN	6.5	2 IN NOTE(2)	6.5	3 IN			
		14.0	10.0	3 IN	10.0	3 IN	10.0	3 IN			
OVER 10 UP TO 15	4	3.5	4.0	2 IN	4.0	2 IN NOTE(2)	4.0	3 IN	3x12	—	—
		7.0	5.5	3 IN	5.5	3 IN	5.5	3 IN			
		14.0	8.0	3 IN	8.0	3 IN	8.0	3 IN			
OVER 15 UP TO 20	4	3.5	3.5	2 IN	3.5	2 IN NOTE(2)	3.5	3 IN	3x12	—	—
		7.0	5.0	3 IN	5.0	3 IN	5.0	3 IN			
		14.0	6.0	3 IN	6.0	3 IN	6.0	3 IN			
OVER 20	NOTE (1)										

Footnotes to tables, and general notes on hydraulic shoring, are found in Appendix D, Item (g)

Notes (1): See Appendix D, item (g) (1)

Notes (2): See Appendix D, Item (g) (2)

* Consult product manufacturer and/or qualified engineer for Section Modulus of available wales.

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Appendix E to Subpart P—Alternatives to Timber Shoring

Figure 1. Aluminum Hydraulic Shoring

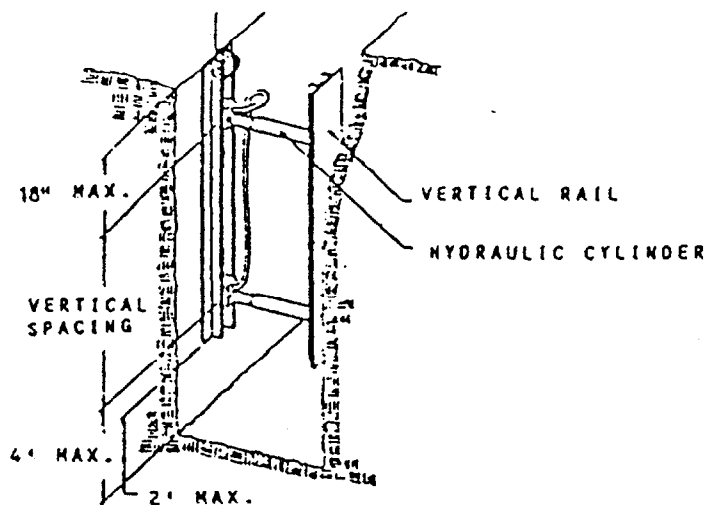
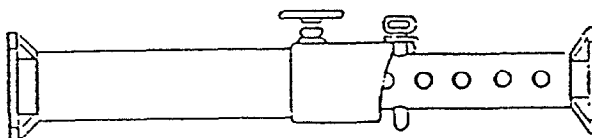
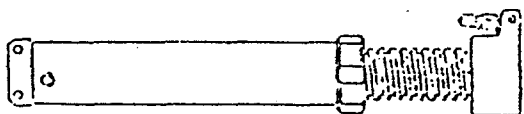


Figure 2. Pneumatic/hydraulic Shoring



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Figure 3. Trench Jacks (Screw Jacks)

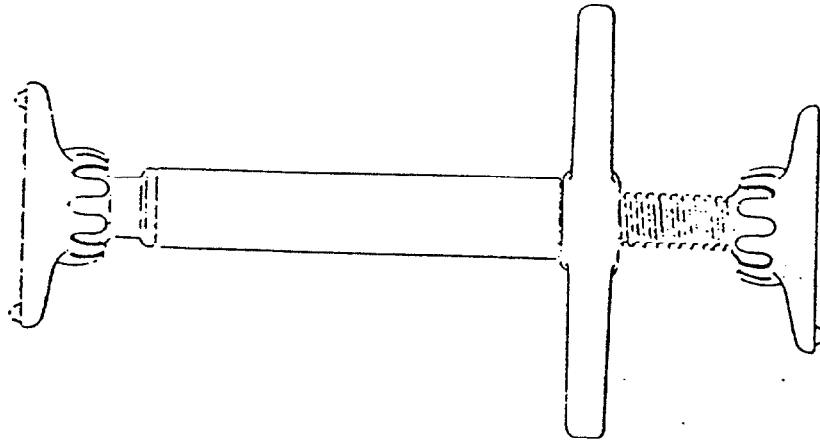
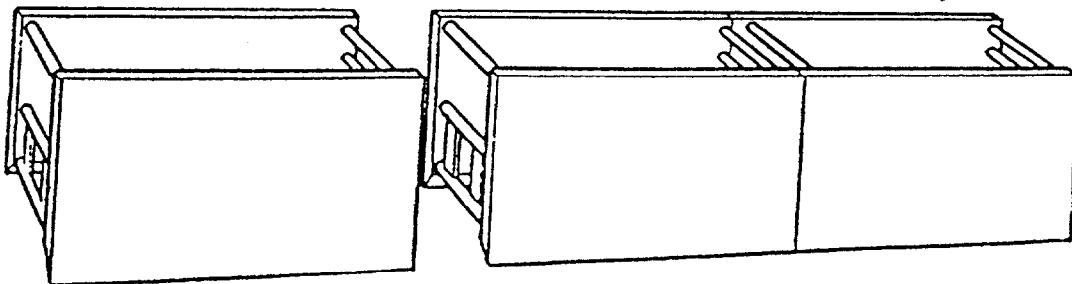
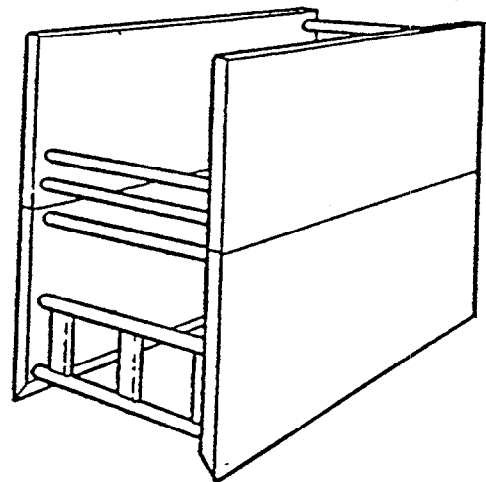
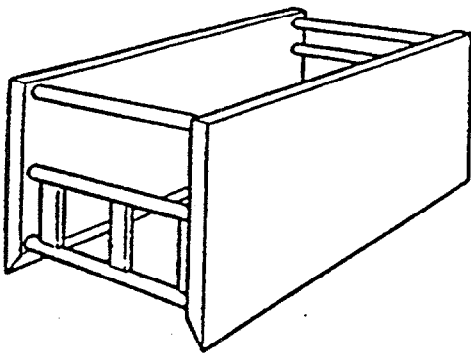


Figure 4. Trench Shields



Appendix F to Subpart P—Selection of Protective Systems

The following figures are a graphic summary of the requirements contained in subpart P for excavations 20 feet or less in depth. Protective systems for use in excavations more than 20 feet in depth must be designed by a registered professional engineer in accordance with § 1926.852 (b) and (c).

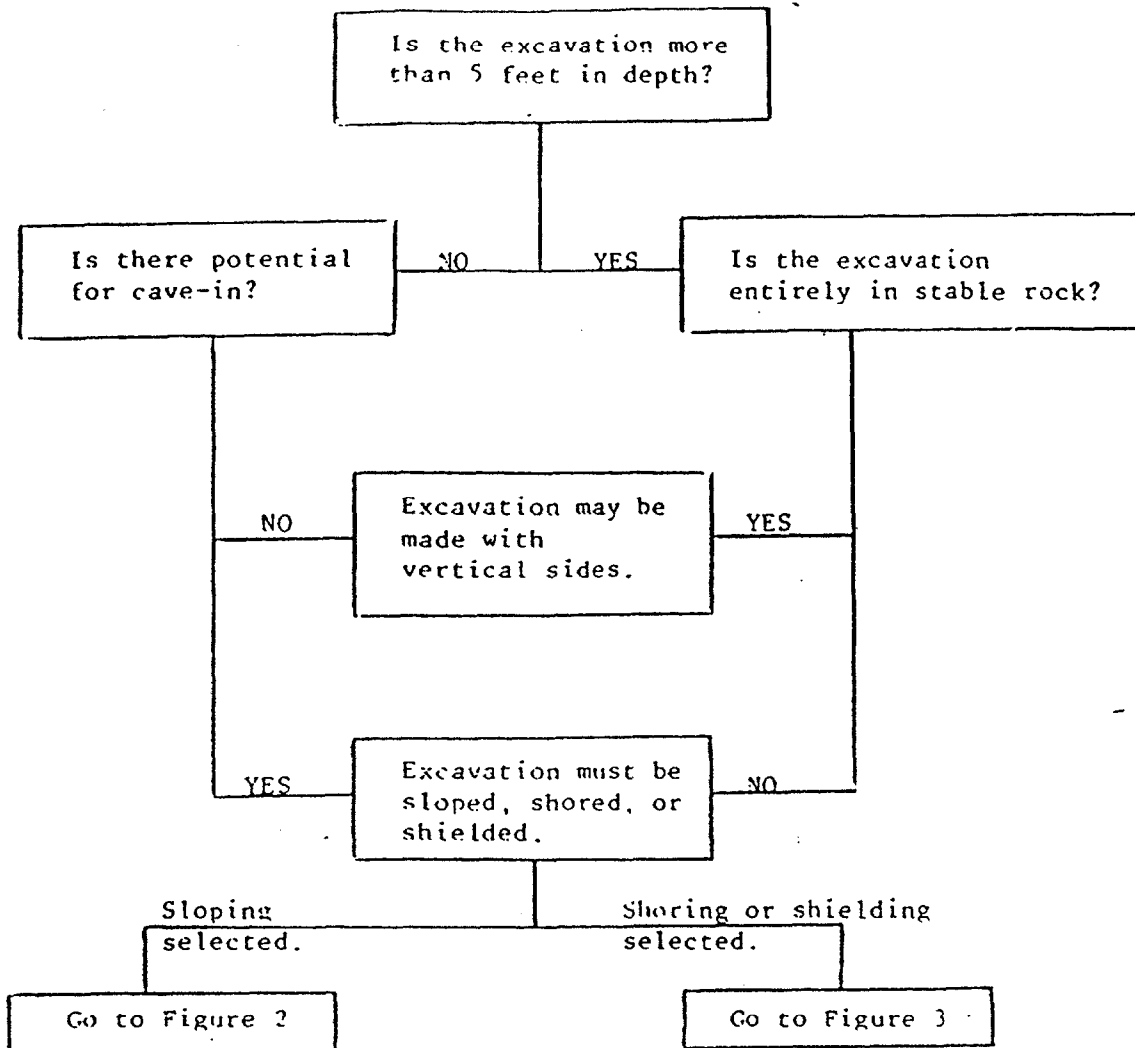


FIGURE 1 - PRELIMINARY DECISIONS

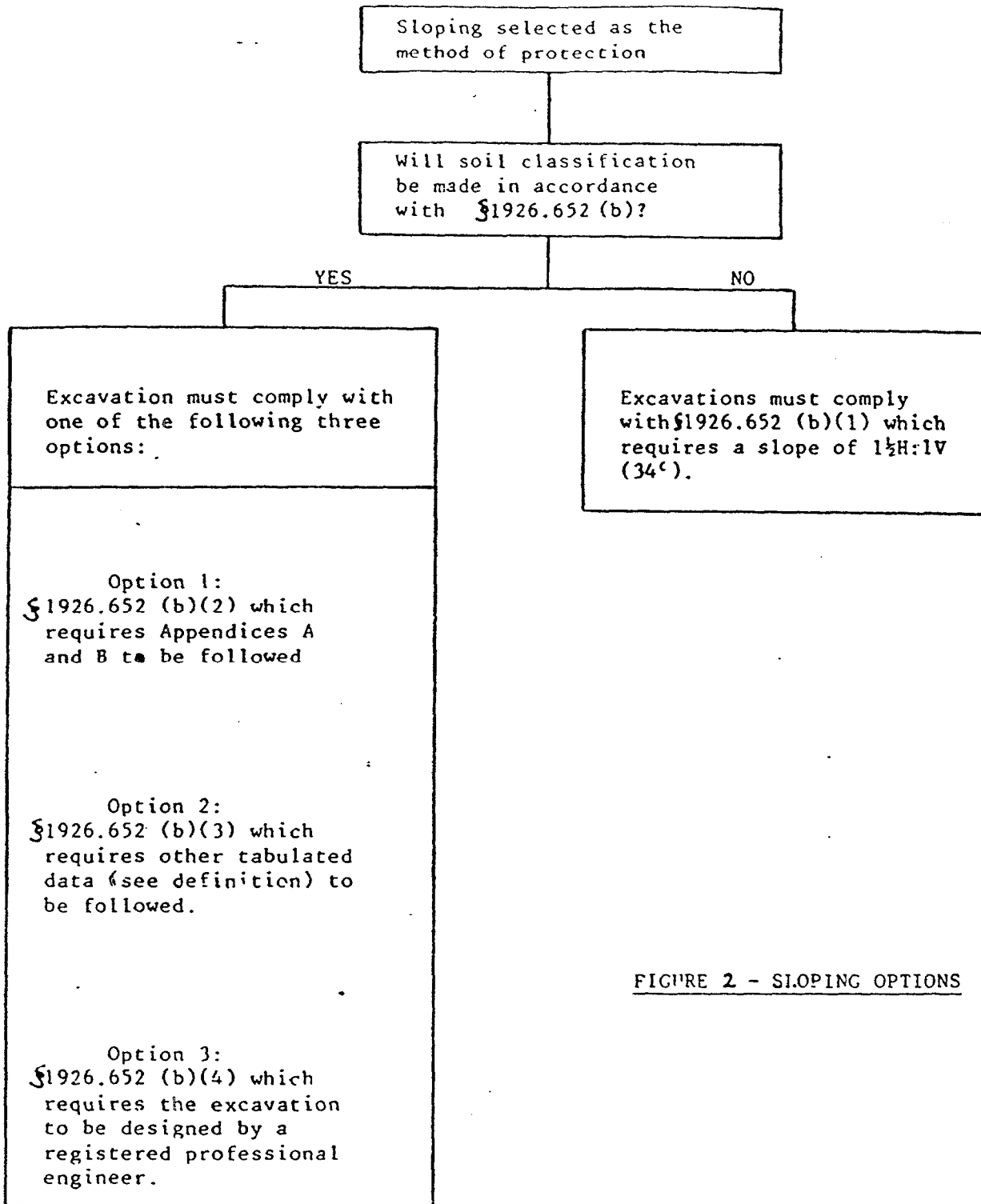


FIGURE 2 - SLOPING OPTIONS

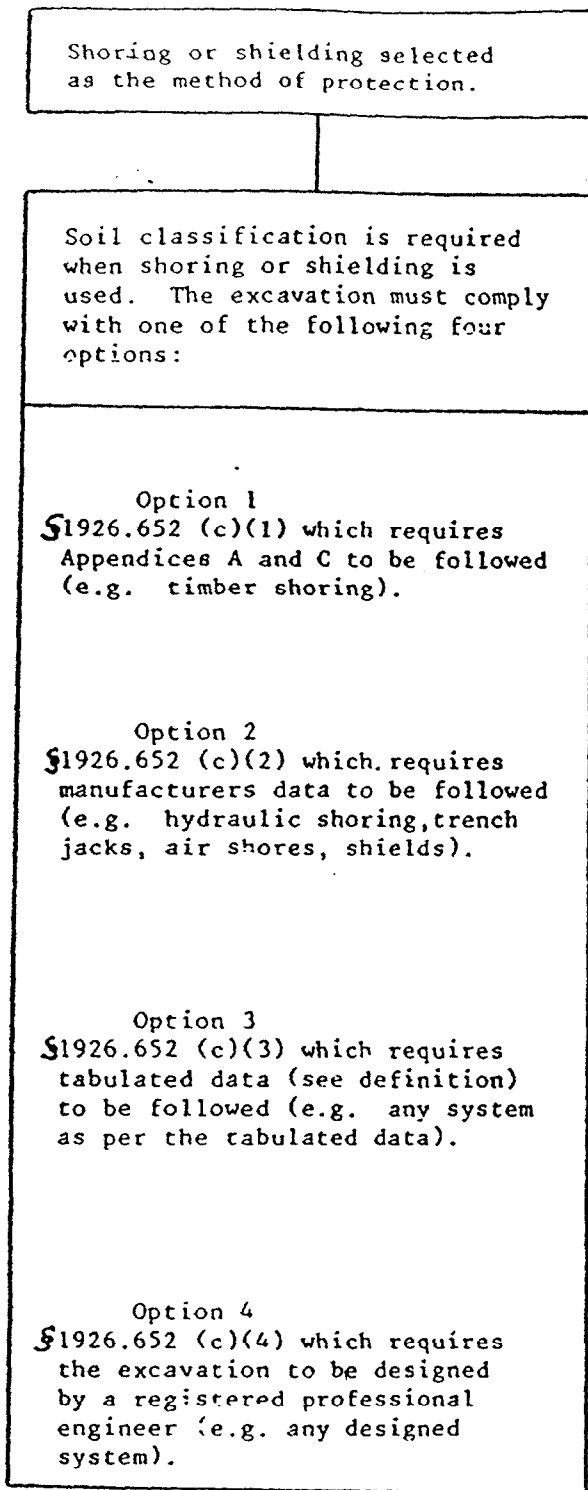


FIGURE 3 - SHORING AND SHIELDING OPTIONS

[FR Doc. 89-25217 Filed 10-30-89; 8:45 am]

BILLING CODE 4510-26-C

APPENDIX C
Justification Criteria for Use of PVC as
Well Casing Material

The following is USEPA Region IV minimum seven point information requirements to justify the use of PVC as an alternate casing material for groundwater monitoring wells. If requested, justification of the use of PVC should be developed by addressing each of the following items:

1. The DQOs for the groundwater samples to be collected.

Level IV DQOs will be used for analyses of groundwater samples collected during this project. Analytical parameters have been selected to characterize the presence or absence of contamination and to assess any associated risks to human health or the environment.

2. The anticipated (organic) compounds.

	Maximum Groundwater Organic Concentrations ($\mu\text{g/L}$)
Site 65	
4,4'-DDD	0.63
Arsenic	308
Beryllium	4.9
Copper	127
Chromium	364
Lead	132
Manganese	474
Site 73	
Benzene	38
Bromodichloromethane	20
Chloroform	38
Dibromochloromethane	10
1,1-Dichloroethylene	2.3
Trans-1,2-dichloroethene	360
Methylene Chloride	12
Toluene	4
Vinyl Chloride	74
Phenols	15
Cadmium	10
Chromium	95
Lead	109
Oil and Grease	2,000
Ethylbenzene	3.3
Xylenes	10
Pyrene	1.4
Fluoranthene	13
Indeno(1,2,3-cd)pyrene	9.6
Anthracene	2.9
Acenaphthene	2.2
Acenaphthylene	0.8
Naphthalene	3.5
Phenanthrene	0.6

The concentrations listed above represent maximums at each site. These compounds are not necessarily present in all wells at a site.

There are two primary concerns regarding sample bias associated with use of PVC well casing under these conditions. One is that organic contaminants will leach from the PVC well casing. The other is that organic contaminants that may be present in the groundwater would adsorb onto the PVC. Either of these could result in biased analytical results.

It is important to note that all stagnant water from inside the well casing is purged immediately before sample collection. The time required to do this is expected to be much less than that required for groundwater sampling bias phenomena (adsorbing/leaching) to develop.

3. The anticipated residence time of the sample in the well and the aquifer's productivity.

Samples collected immediately after purging (i.e., "fresh" from the aquifer).

Aquifer productivity: Subsurface soil samples are mostly fine sand. Hydraulic conductivity is estimated at 0.0001 to 0.01 cm/sec. The wells should recharge (enough to sample) before any sorbing/leaching of organics can occur. Aquifer tests conducted by O'Brien and Gere (1988) provided information of the following aquifer characteristics:

transmissivity:	500 gpd/ft.
well yield:	3 gpm
saturated thickness:	19-22 ft.
radius of influence:	300-400 ft.

4. The reasons for not using other casing materials.

Costs associated with use of stainless steel and teflon casing materials are prohibitive. PVC strength will be sufficient for this investigation. Existing groundwater quality data indicate that leaching/sorbing of organic materials from/onto the PVC will not be extensive enough to bias future groundwater analysis. PVC is lighter and more flexible than stainless steel.

5. Literature on the adsorption characteristics of the compounds and elements of interest.

The following was originally presented in National Water Well Association (NWWA, 1989):

Miller (1982) conducted a study to determine if PVC exhibited any tendency to sorb potential contaminants from solution. Trichloroethene and 1,1,2-trichloroethane did not sorb to PVC. Reynolds and Gillham (1985) found that 1,1,2,2-tetrachloroethane could sorb to PVC. The sorption was slow enough that groundwater sampling bias would not be significant if well development (purging the well of stagnant water) and sampling were to take place in the same day.

6. **Whether the wall thickness of the PVC casing would require a larger annular space when compared to other well construction materials.**

It will not. Hollow stem augers used during drilling operations will be of sufficient diameter for installation of the PVC casing.

7. **The type of PVC to be used and, if available, the manufacturers specifications, and an assurance that the PVC to be used does not leach, mask, react or otherwise interfere with the contaminants being monitored within the limits of the DQOs.**

Baker will request the appropriate manufacturers specifications and assurances regarding this requirement. This material will be supplied to Baker by the drilling subcontractor.

References for Attachment A:

National Water Well Association, 1989, Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells, Dublin, Ohio, 398 pp.

Miller, G.D., 1982, Uptake of lead, chromium and trace level volatile organics exposed to synthetic well casings, Proceedings of the Second National Symposium on Aquifer Restoration and Ground-Water Monitoring, National Water Well Association, Dublin, Ohio, pp. 236-245.

Reynolds, G.W. and Robert W. Gillham, 1985, Absorption of halogenated organic compounds by polymer materials commonly used in ground-water monitors, Proceedings of the Second Canadian/American Conference on Hydrogeology, National Water Well Association, Dublin, Ohio, pp. 125-132.

APPENDIX D
Monitoring Well Installation

SOP F103
Monitoring Well Installation

**MONITORING WELL INSTALLATION
TABLE OF CONTENTS**

- 1.0 PURPOSE**
- 2.0 SCOPE**
- 3.0 DEFINITIONS**
- 4.0 RESPONSIBILITIES**
- 5.0 PROCEDURES**
 - 5.1 Well Installation**
 - 5.2 Drive Points**
 - 5.3 Surface Completion**
 - 5.4 Well Development**
 - 5.5 Contaminated Materials Handling**
 - 5.6 Well Construction Logs**
- 6.0 QUALITY ASSURANCE RECORDS**
- 7.0 REFERENCES**

MONITORING WELL INSTALLATION

1.0 PURPOSE

The purpose of this procedure is to provide general guidance and reference material regarding the installation of monitoring wells at various sites.

2.0 SCOPE

This SOP describes the methods of installing a groundwater monitoring well, and creating a Monitoring Well Installation Record. This SOP does not discuss drilling, soil sampling, borehole logging or related activities. These other activities are discussed in SOPs F102 and F101 entitled Soil and Rock Sample Acquisition, and Borehole and Sample Logging, respectively.

3.0 DEFINITIONS

Monitoring Well - A monitoring well is a well which is properly screened, cased, and sealed to intercept a discrete zone of the subsurface, and is capable of providing a groundwater level and sample representative of the zone being monitored.

Piezometer - A piezometer is a pipe or tube inserted into an aquifer or other water-bearing zone, open to water flow at the bottom, open to the atmosphere at the top, and used to measure water level elevations. Piezometers are not used for the collection of groundwater quality samples or aquifer characteristic data other than water level elevations.

Drive Point - A monitoring well which includes a screen casing and hardened point fabricated from stainless steel that is driven into the soil to complete the well. The drive point can also be installed by hand augering to try to formulate a sand pack around the screen.

4.0 RESPONSIBILITIES

Project Manager - It is the responsibility of the Project Manager to ensure that field personnel installing monitoring wells are familiar with these procedures. The Project Manager also is

responsible for ensuring that all appropriate documents (e.g., test boring logs, monitoring well construction logs, etc.) have been correctly and completely filled out by the drilling inspector.

Field Team Leader - The Field Team Leader is responsible for the overall supervision of all drilling, boring and well installation activities, and for ensuring that the well is completely and correctly installed and logged. The Field Team Leader also is responsible for ensuring that all drilling inspectors have been briefed on these procedures. The Field Team Leader is responsible to provide copies of the well construction logs and field log books to the Project File via the Project Manager on a weekly basis, unless otherwise specified by the Project Manager.

Drilling Inspector (Site Geologist) - The Drilling Inspector or Site Geologist is responsible for the direct supervision of drilling and well installation activities. It is the Drilling Inspector's responsibility to record details of the well installation, document subsurface conditions, complete the appropriate forms, supervise the drilling crew (or drilling supervisor), and record quantities of the drillers billable labor and materials.

5.0 PROCEDURES

The objectives for the use of each monitoring well and of the entire array of wells must be clearly defined before the monitoring system is designed. Within the monitoring system, different monitoring wells may serve different purposes and, therefore, may require different types of construction. During all phases of the well design (both office and field), 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 monitoring wells may include:

- Determining groundwater flow directions and velocities.
- Sampling or monitoring for groundwater contamination.
- Determining aquifer characteristics (e.g., hydraulic conductivity).
- Facilitating site remediation via injection or recovery.

In cases where only the groundwater flow direction or velocity needs to be determined, cluster piezometers or wells (i.e., wells completed to different depths in different boreholes at one data collection station) may be used. For groundwater quality monitoring or aquifer characteristic

determination, monitoring wells or cluster wells should be used. In areas that are inaccessible to drill rigs (i.e., unstable surface soils), driven wells (drive points) may be used.

Siting of monitoring wells shall be performed after a preliminary estimation of groundwater flow direction. Typically, site visits, topographic mapping, regional/local hydrogeologic information, previously installed piezometers or monitoring wells, or information supplied by local drilling companies will provide information for siting wells. Flexibility should be maintained, so that well locations may be modified during the field investigation to account for site conditions (e.g., underground utilities). The elevation and horizontal location of all monitoring wells shall be determined through a site survey upon completion of well installation.

Guidelines for Navy underground storage tank (UST) monitoring well construction are given in Attachment A.

5.1 Well Installation

The methods discussed in this section are applicable to shallow, small diameter monitoring wells. Project-specific modifications to these methods shall be documented in the Sampling and Analysis Plan. These modifications may include larger diameter shallow wells, extraction wells, deep monitoring wells requiring surface casing and other specially constructed well types. Typical shallow monitoring well construction details are shown in Figures A-1 and A-2 in Attachment A for wells with flush-mounted and stick-up wells, respectively.

Note that these procedures discuss well installation using a PVC screen and riser pipe. Other materials such as stainless steel or Teflon also are available. However, PVC generally is much less expensive and easier to work with than either stainless steel or Teflon. A disadvantage to using PVC is the potential for degradation of the materials, or release (leaching) of constituents into the groundwater. Because of these concerns, justification for using PVC must be developed on a project-specific basis. The checklist shown in Attachment B provides a format for developing this justification.

Upon completion of each boring (refer to SOP F101 and F102 for Borehole and Sample Logging, and Soil and Rock Sample Acquisition, respectively), monitoring wells will usually

be constructed using either two-inch or four-inch inside diameter (I.D.) screen and riser. Schedule 40 PVC, threaded, flush-joint casings with a continuous #10 slot (0.010-inch), threaded, flush-joint PVC screen. A larger or smaller diameter screen may be used to accommodate site-specific geologic conditions. If wells are to be constructed over 100 feet in length, or in high traffic areas, or under other unusual conditions, Schedule 80 PVC may be used because of its greater strength.

An appropriate length of well screen shall be installed in each boring. The length of screen typically varies from 1 to 20 feet depending on site-specific conditions. For UST and/or light non-aqueous phase liquid (LNAPL) applications, the screen should be installed such that at least two-feet of screen is above the water table and the remainder of the screen extends below the water surface so that free product can enter the well. Should very shallow water table conditions be encountered, the screened interval in both the saturated and unsaturated zones may be reduced to ensure an adequate well seal above the screened interval. If this situation is expected, it should be addressed in the project plans, as necessary. A six-inch section of PVC casing may be placed at the bottom of each screen to act as a settling cup for fines which may pass through the filter pack and screen.

Other applications may call for different screen placement depending on the zone to be monitored and the expected contaminants. For example, monitoring for dense non-aqueous phase liquids (DNAPLS) may require placing the screened interval in a "sump" at the base of the aquifer. Depending on the purpose of the monitoring well, the riser pipe may extend from the top of the screened interval to either six inches below the ground surface (for flush-mounted wells) to between approximately one and two feet above the ground surface for wells completed with stick-up.

The annular space around the screen is to be successfully backfilled with a well graded quartz-sand, sodium bentonite and cement/bentonite grout as the hollow-stem augers are being withdrawn from the borehole. The sand size used in well construction will be appropriate for the formation monitored by the well. Sand shall carefully be placed, preferably via tremie pipe, from the bottom of the boring to a minimum of two feet (or 20 percent of the total screen length) above the top of the screened interval. A lesser distance above the top of the screened interval may be packed with sand if the well is very shallow to allow for placement of sealing materials.

A sodium bentonite seal at least two- to three-foot thick shall be placed above the sand pack. The bentonite shall be allowed to hydrate for at least ~~20 minutes~~ **8 hours** before further completion of the well. Deionized water will be added to the well to hydrate the bentonite, if necessary. For deep wells, a bentonite slurry may be more appropriate than pellets due to problems with bridging in the annular space.

The annular space above the bentonite seal will be backfilled with a cement-bentonite grout consisting of three to four percent bentonite powder (by dry weight) and seven gallons of potable water per 94 pound bag of portland cement. The grout mixture shall be specified in the project plans. The grout will be tremied into the annular space, preferably with a side-discharge tremie pipe, into annular spaces greater than ten feet high. If the annular space is less than ten feet high, the grout may be poured directly into the annular space.

The depth intervals of all backfill materials shall be measured with a weighted measuring tape to the nearest 0.1 foot and recorded on the Field Monitoring Well Construction Record or in a field logbook.

5.2 Drive Points

Drive points may be constructed in one of two ways. If the drive point is hammered into place, no other well construction will take place. (Note that the well assembly is fabricated from 2-inch diameter stainless steel and includes a screen casing, and hardened point). If a hand augered borehole is used, the following procedure will be utilized: a 4-inch diameter hand auger will be advanced to the desired depth below the water table. If the borehole collapses, a 5-inch diameter PVC pipe could be hammered into the collapsing borehole and reaugered to clean out the soils until final depth is achieved. A 2-inch diameter drive point will be placed in the open borehole. A sand pack will be placed around the drive point to a depth that is approximately 1 foot above the screened interval (if conditions permit). A bentonite seal will be placed above the sand pack to the top of the borehole. Grout will not be used in drive points. Because of the anticipated marsh conditions, concrete surface completion will not be required. The drive points will be sampled according to SOP F104, "Groundwater Sample Acquisition." After installation, the drive points will be developed. To assist with the development, the well screens will be cleaned with a wire brush and distilled water, and then developed according to Section 5.3 of SOP F103 "Monitoring Well Installation."

5.3 Surface Completion

There are several methods for surface completion of monitoring wells. Two such methods are discussed below.

The first method considers wells completed with stick-up. The aboveground section of the PVC riser pipe will be protected by installation of a four or six-inch diameter, five-foot long steel casing with locking cap and lock into the cement grout. The bottom of the surface casing will be placed at a minimum of 2-1/2, but not more than 3-1/2 feet below the ground surface. For very shallow wells, a steel casing of less than five-feet in length may be used, as space permits. The protective steel casing shall not fully penetrate the bentonite seal.

The top of each well will be protected with the installation of three, three-inch diameter, five-foot long steel pipes for UST projects (four for IR projects) and have a concrete apron. The steel pipes shall be embedded to a minimum depth of 2.5-feet in 3,000 psi concrete. Each pipe shall also be filled with concrete. A concrete apron approximately five-feet by five-feet by 0.5-foot thick shall be placed at the same time the pipes are installed. The steel pipes shall be painted with day-glo yellow paint, or equivalent.

The second method considers flush-mounted wells, typically installed in traffic areas. The monitoring well shall be completed at the surface using a "flush" mount type cover. If the well is installed through a paved or concrete surface, the annular space shall be grouted to a depth of at least 2.5-feet and the well shall be finished with a concrete collar. If the well has not been installed through a paved or concrete surface, the well shall be completed by construction of a five-foot by five-foot by 0.5-foot thick apron made of 3,000 psi concrete. The concrete shall be crowned to meet the finished grade of the surrounding pavement, as required. If appropriate, the vault around the buried wellhead will have a water drain to the surrounding soil and a watertight cover.

Project specific tasks may require that all monitoring wells shall be labeled by metal stamping on the exterior of the protective steel casing locking cap, and also by labeling on the exterior of the steel casing or manhole cover in accordance with applicable state and local requirements. For underground storage tank applications, the labeling shall consist of the letters UGW (UST Groundwater), and a number specific to each well. A sign reading "Not For Potable Use or Disposal" also shall be firmly attached to each well. Alternately, well identification

information may be stamped on a metal plate and attached to the well protective steel casing or embedded in the concrete apron, if appropriate.

5.4 Well Development

There are two stages of well development, initial and sampling. Sampling development is described in SOP F104, Groundwater Sample Acquisition. Initial development takes place after the completion materials have stabilized, as the last part of well construction.

The purposes of the initial development are to stabilize and increase the permeability of the filter pack around the well screen, to restore the permeability of the formation which may have been reduced by the drilling operations, and to remove fine-grained materials that may have entered the well or filter pack during installation. The selection of the well development method typically is based on drilling methods, well construction and installation details, and the characteristics of the formation. Any equipment that is introduced into the well during development shall be decontaminated in accordance with the SOP F501, entitled "Decontamination of Drilling Rigs and Monitoring Well Materials." A detailed discussion of well development is provided in Driscoll, 1986.

Well development shall not be initiated until a minimum of 24 hours has elapsed subsequent to well completion. This time period will allow the cement grout to set. Wells typically are developed using bailers, low-yield pumping, or surging with a surge block or air. The appropriate method shall be specified in the project plans.

In general, all wells shall be developed until well water runs relatively clear of fine-grained materials. Note that the water in some wells does not clear with continued development. Typical limits placed on well development may include any one of the following:

- Clarity of water based on visual determination.
- A minimum pumping time period (typically one hour for shallow wells 10 to 30 feet deep).
- A minimum borehole volume (typically five borehole volumes) or until well goes dry.
- Stability of specific conductance and temperature measurements (typically less than 10 percent change between three successive measurements).

In addition, a volume equal to any water added during drilling will be removed above and beyond the requirement specified above.

Well development limits shall be specified in project-specific plans. A record of the well development (Figure A-3 in Attachment A) also shall be completed to document the development process.

Usually, a minimum period of two weeks should elapse between the end of initial development and the first sampling event for a well. This equilibration period allows groundwater unaffected by the installation of the well to occupy the vicinity of the screened interval. However, this stabilization period may be adjusted based upon project-specific requirements.

5.5 Contaminated Materials Handling

SOP F504, entitled "Handling of Site Investigation Derived Waste," discusses the procedures to be used for the handling of auger cuttings, decontamination water, steam pad water, and development and purge water. Specific handling procedures should be delineated in the project plans. In general, all site investigation generated wastes shall be containerized unless otherwise specified by LANTRDIV. The disposition of these wastes shall be determined after receipt of the appropriate analytical results.

5.6 Well Construction Logs

Field Well Construction Logs shall be completed by the Drilling Inspector for each monitoring well installed. These logs preferably shall be completed as the well is being constructed. However, due to space limitations on this form it may be more practical to record well installation information in the field logbook and later transfer it to the Well Construction Log. If well construction information is recorded in the field logbook, it must be transferred to the appropriate form within five days, and prior to demobilization from the field.

Field Well Construction Logs (in Attachment C), shall include not only well construction information, but also information pertaining to the amount of materials used for construction. Some of the following items shall be recorded on the Field Well Construction Log, or in the field logbook, as appropriate:

- Project name and location.
- CTO number.
- Date and weather.
- Well identification designation.
- Drilling company and driller.
- Top of casing elevation (information collected after the site survey).
- Pay items including amount of screen and riser pipe used, amounts of cement, bentonite and sand used, and other well construction items.
- Well casing and borehole diameters.
- Elevations of (or depth to) top of steel casing, bottom of well, top of filter pack, top of bentonite seal, top of screen.

The information on the Field Well Construction Log will be used to generate a final Well Construction Log which combines the Field Boring and Well Construction Logs into one package. An example of all three documents is presented in Attachment C.

6.0 QUALITY ASSURANCE RECORDS

The Field Well Construction Record is the principle quality assurance record generated from well installation activities. Additionally, a Field Well Development Record shall also be completed, as well as pertinent comments in the field logbook.

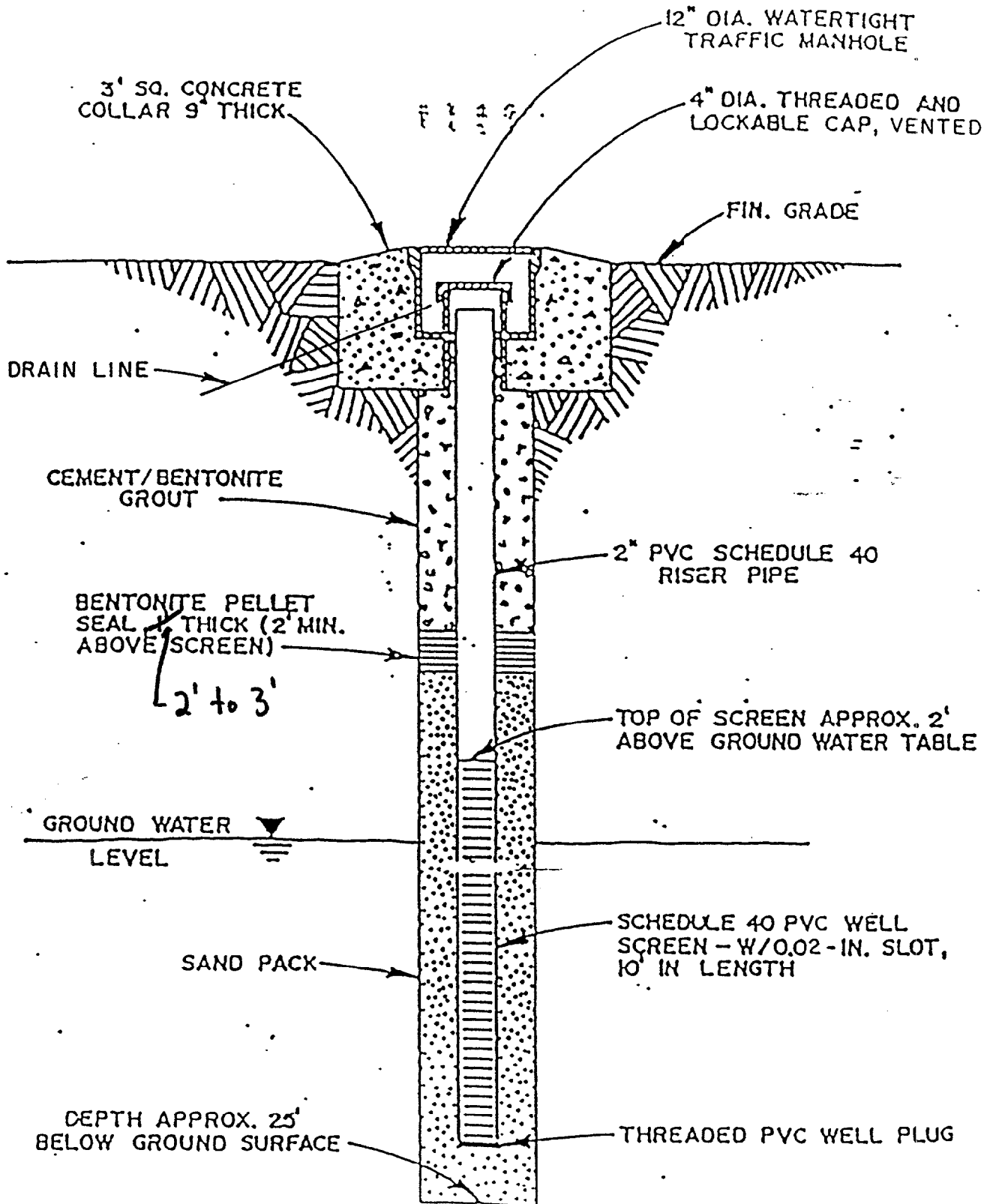
7.0 REFERENCES

1. Driscoll, Fletcher, G. Groundwater and Wells, Johnson division. St. Paul, Minnesota. 2nd ed. 1986.
2. Roscoe Moss Company. Handbook of Ground Water Development. John Wiley & Sons. New York. 1990.
3. USEPA. RCRA Ground-Water Monitoring Technical Enforcement Guidance Document. September, 1986.
4. Aller, L. et al. Handbook of Suggested Practices for the Design and Installation of Ground Water Monitoring Wells. National Water Well Association. Dublin, Ohio. June, 1989.

ATTACHMENT A

MONITORING WELL CONSTRUCTION

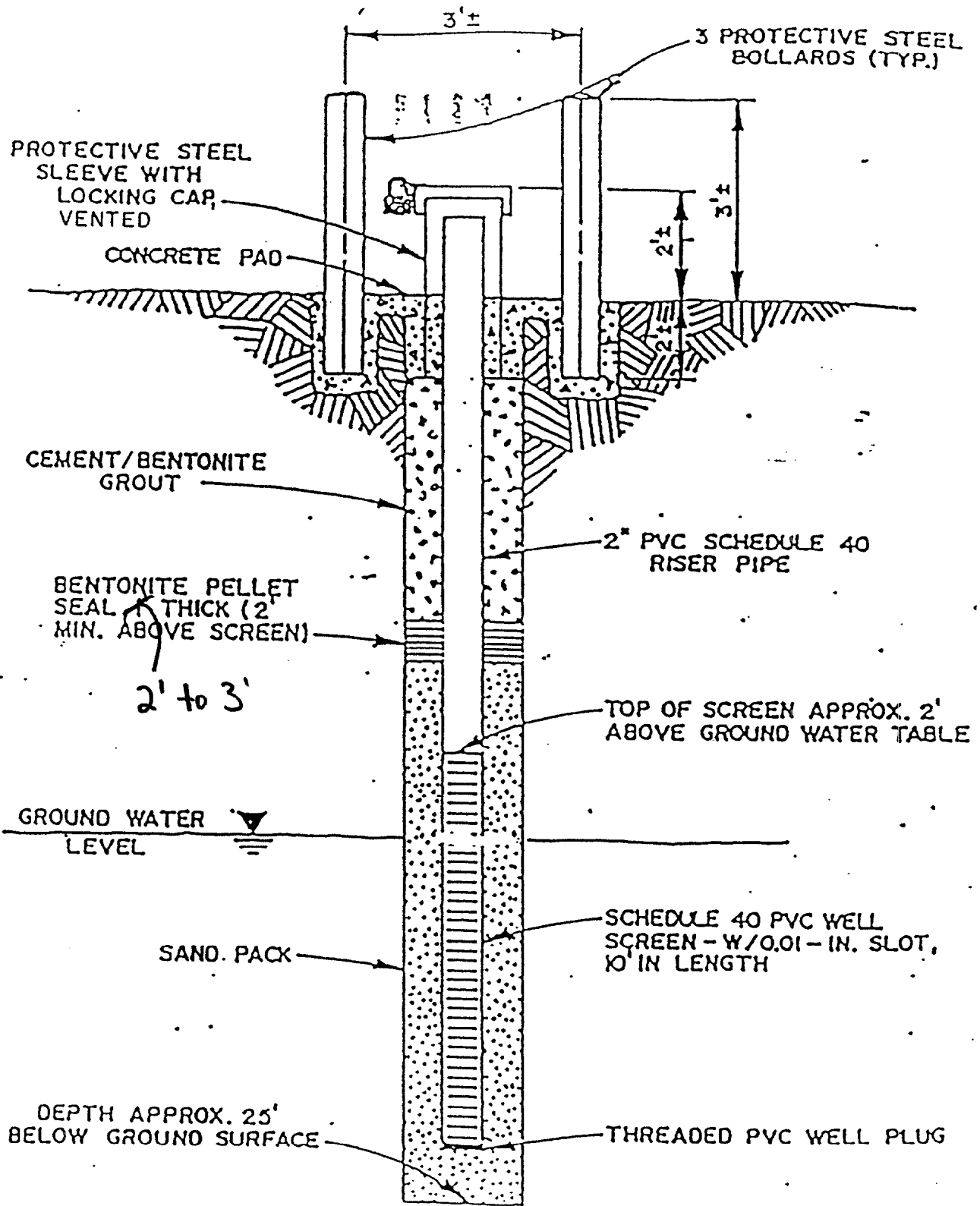
Figure A-1



MONITORING WELL CONSTRUCTION DETAIL
(TRAFFIC AREA)

NOT TO SCALE

Figure A-2



MONITORING WELL CONSTRUCTION DETAIL
(NON TRAFFIC AREA)

NOT TO SCALE

FIGURE A.3

FIELD WELL DEVELOPMENT RECORD



PROJECT: _____

CTO NO.: _____ WELL NO.: _____

DATE: _____

GEOLOGIST/ENGINEER: _____

TIME START	DEVELOPMENT DATA						
	TIME	CUMULATIVE VOLUME (gallons)	pH	TEMP (°C)	SPEC. COND. (µmhos/cm)	TEMP (°C)	COLOR AND TURBIDITY
TIME FINISH							
INITIAL WATER LEVEL (FT)							
TOTAL WELL DEPTH (TD)							
WELL DIAMETER (INCHES)							
CALCULATED WELL VOLUME							
BOREHOLE DIAMETER (INCHES)							
BOREHOLE VOLUME							
AMOUNT OF WATER ADDED DURING DRILLING							
DEVELOPMENT METHOD							
PUMP TYPE							
TOTAL TIME (A)							
AVERAGE FLOW (GPM)(B)							
TOTAL ESTIMATED WITHDRAWAL AxB =	OBSERVATIONS/NOTES						
HNU/OVA READING							

ATTACHMENT B

ALTERNATE WELL CASING MATERIAL JUSTIFICATION

ATTACHMENT B

ALTERNATE WELL CASING MATERIAL JUSTIFICATION

The following is EPA's minimum seven point information requirements to justify the use of PVC as an alternate casing material for groundwater monitoring wells. If requested by EPA (USEPA Region IV), justification of the use of PVC should be developed by addressing each of the following items.

1. The Data Quality Objectives (DQOs) for the samples to be collected from wells with PVC casing as per EPA/540/G-87/003, "Data Quality Objectives for Remedial Response Activities."
2. The anticipated compounds and their concentration ranges.
3. The anticipated residence time of the sample in the well and the aquifer's productivity.
4. The reasons for not using other casing materials.
5. Literature on the adsorption characteristics of the compounds and elements of interest for the type of PVC to be used.
6. Whether the wall thickness of the PVC casing would require a larger annular space when compared to other well construction materials.
7. The type of PVC to be used and, if available, the manufacturers specifications, and an assurance that the PVC to be used does not leach, mask, react or otherwise interfere with the contaminants being monitored within the limits of the DQOs.

ATTACHMENT C

**FIELD TEST BORING RECORD AND
FIELD WELL CONSTRUCTION RECORD FORMS**

Baker

Baker Environmental, Inc.

TEST BORING AND WELL CONSTRUCTION RECORD

PROJECT: _____
S.O. NO.: _____ BORING NO.: _____
COORDINATES: EAST: _____ NORTH: _____
ELEVATION: SURFACE: _____ TOP OF PVC CASING: _____

RIG:					DATE	PROGRESS (FT)	WEATHER	WATER DEPTH (FT)	TIME
SPLIT SPOON	CASING	AUGERS	CORE BARREL						
SIZE (DIAM.)									
LENGTH									
TYPE									
HAMMER WT.									
FALL									
STICK UP									

REMARKS:

SAMPLE TYPE		WELL INFORMATION	DIAM	TYPE	TOP DEPTH (FT)	BOTTOM DEPTH (FT)
S = Split Spoon	A = Auger					
T = Shelby Tube	W = Wash					
R = Air Rotary	C = Core					
D = Denison	P = Piston					
N = No Sample						

Depth (Ft.)	Sample Type and No.	Samp. Rec. Ft. & %	SPT or RQD	Lab. Class. or Pen. Rate	PID (ppm)	Visual Description	Well Installation Detail			Elevation Ft. MSL
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

Match to Sheet 2

DRILLING CO.: _____ BAKER REP.: _____
DRILLER: _____ BORING NO.: _____ SHEET 1 OF _____



Baker Environmental, Inc

TEST BORING AND WELL CONSTRUCTION RECORD

PROJECT: _____ BORING NO.: _____
S.O. NO.: _____

SAMPLE TYPE						DEFINITIONS							
S = Split Spoon	A = Auger					SPT = Standard Penetration Test (ASTM D-1586) (Blows/0.5')							
T = Shelby Tube	W = Wash					RQD = Rock Quality Designation (%)							
R = Air Rotary	C = Core					Lab. Class. = USCS (ASTM D-2487) or AASHTO (ASTM D-3282)							
D = Denison	P = Piston					Lab. Moist. = Moisture Content (ASTM D-2216) Dry Weight Basis							
N = No Sample													
Depth (Ft.)	Sample Type and No.	Samp. Rec. (Ft. & %)	SPT or RQD	Lab. Class. or Pen. Rate	PID (ppm)	Visual Description			Well Installation Detail			Elevation Ft. MSL	
11													
12													
13													
14													
15													
16													
17													
18													
19													
20													
21													
22													
23													
24													
25													
26													
27													
28													
29													
30													

DRILLING CO.: _____
DRILLER: _____

BAKER REP.: _____
BORING NO.: _____

APPENDIX E
Groundwater Sample Acquisition

SOP F104
Groundwater Sample Acquisition

**GROUNDWATER SAMPLE ACQUISITION
TABLE OF CONTENTS**

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- 2.0 SCOPE**
- 3.0 DEFINITIONS**
- 4.0 RESPONSIBILITIES**
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 - 5.2 Calculations of Well Volume**
 - 5.3 Evacuation of Static Water (Purging)**
 - 5.3.1 Evacuation Devices**
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 - 5.4.1 Sampling Methods**
 - 5.4.2 Sample Containers**
 - 5.4.3 Preservation of Samples and Sample Volume Requirements**
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- 7.0 REFERENCES**

GROUNDWATER SAMPLE ACQUISITION

1.0 PURPOSE

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

2.0 SCOPE

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

3.0 DEFINITIONS

None.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for development of documentation of procedures which deviate from those presented herein.

Field Team Leader - The Field Team Leader is responsible for selecting and detailing the specific groundwater sampling techniques and equipment to be used, and documenting these in the Sampling and Analysis Plan. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and that personnel performing sampling activities have been briefed and trained to execute these procedures.

Sampling Personnel - It is the responsibility of the field sampling personnel to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team

Leader and the Project Manager. The sampling personnel are responsible for the proper acquisition of groundwater samples.

5.0 PROCEDURES

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

The groundwater sampling program should be developed with reference to ASTM D4448-85A, Standard Guide for Sampling Groundwater Monitoring Wells (Attachment A). This reference is not intended as a monitoring plan or procedure for a specific application, but rather is a review of methods. Specific methods shall be stated in the Sampling and Analysis Plan (SAP).

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 largely isolated and become stagnant. To safeguard against collecting non-representative stagnant water in a sample, the following approach should be followed during sample withdrawal:

1. All monitoring wells shall be pumped or bailed prior to withdrawing a sample. Evacuation of three to five volumes is recommended for a representative sample.
2. Wells that can be pumped or bailed to dryness with the sampling equipment being used, shall be evacuated and allowed to recover prior to sample withdrawal. If the recovery rate is fairly rapid and time allows, evacuation of at least three well volumes of water is preferred; otherwise, a sample will be taken when enough water is available to fill the sample containers.

Stratification of contaminants may exist in the aquifer formation. This is from concentration gradients due to dispersion and diffusion processes in a homogeneous layer, and from

separation of flow streams by physical division (for example, around clay leases) or by contrasts in permeability (for example, between a layer of silty, fine sand and a layer of medium sand).

Pumping rates and volumes for non-production wells during sampling development should be moderate; pumping rates for production wells should be maintained at the rate normal for that well. Excessive pumping can dilute or increase the contaminant concentrations in the recovered sample compared to what is representative of the integrated water column at that point, thus result in the collection of a non-representative sample. Water produced during purging shall be collected, stored or treated and discharged as allowed. Disposition of purge water is usually site specific and must be addressed in the Sampling and Analysis Plan.

5.1 Sampling, Monitoring, and Evacuation Equipment

Sample containers shall conform with EPA regulations for the appropriate contaminants and to the specific Quality Assurance Project Plan.

The following list is an example of the type of equipment that generally must be on hand when sampling groundwater wells:

1. Sample packaging and shipping equipment - Coolers for sample shipping and cooling, chemical preservatives, and appropriate packing cartons and filler, labels and chain-of-custody documents.
2. Field tools and instrumentation - Thermometer; pH meter; specific conductivity meter; appropriate keys (for locked wells) or bolt-cutter; tape measure; water-level indicator; and, where applicable, flow meter.
3. Pumps
 - a. Shallow-well pumps - Centrifugal, pitcher, suction, or peristaltic pumps with droplines, air-lift apparatus (compressor and tubing), as applicable.
 - b. Deep-well pumps - Submersible pump and electrical power generating unit, bladder pump with compressed air source, or air-lift apparatus, as applicable.
4. Tubing - Sample tubing such as teflon, polyethylene, polypropylene, or PVC. Tubing type shall be selected based on specific site requirements and must be chemically inert to the groundwater being sampled.
5. Other Sampling Equipment - Bailers, teflon-coated wire, stainless steel single strand wire, and polypropylene monofilament line (not acceptable in EPA Region I) with

tripod-pulley assembly (if necessary). Bailers shall be used to obtain samples for volatile organics from shallow and deep groundwater wells.

6. Pails - Plastic, graduated.
7. Decontamination solutions - Decontamination materials are discussed in SOP F501 and F502.

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

5.2 Calculations of Well Volume

Calculation of gallons/linear feet from a well

$$V = \pi r^2 h$$

Where: V = volume of standing water in well
r = well radius
h = feet of standing water in well

Table 5-1 lists gallons and cubic feet of water per standing foot of water for a variety of well diameter.

**TABLE 5-1
WELL VOLUMES**

Diameter of Casing or Hole (in.)	Gallons per Foot of Depth	Cubic Feet per Foot of Depth
1	0.041	0.0055
2	0.163	0.0218
4	0.653	0.0873
6	1.469	0.1963
8	2.611	0.3491
10	4.080	0.5454

Notes:

1. Gallons per foot of depth will be multiplied by amount of standing water to obtain well volume quantity.
2. 1 gallon = 3.785 liters
1 meter = 3.281 feet
1 gallon water weighs 8.33 pounds = 3.785 kilograms
1 liter water weighs 1 kilogram = 2.205 pounds
1 gallon per foot of depth = 12.419 liters per foot of depth
1 gallon per meter of depth = 12.419 x 10⁻³ cubic meters per meter of depth

To insure that the proper volume of water has been removed from the well prior to sampling, it is first necessary to determine the volume of standing water in the well pipe or casing. The volume can be easily calculated by the following method. Calculations shall be entered in the field logbook:

1. Obtain all available information on well construction (location, casing, screens, etc.).
2. Determine well or casing diameter.
3. Measure and record static water level (depth below ground level or top of casing reference point), using one of the methods described in Section 5.1 of SOP F202.
4. Determine the depth of the well (if not known from past records) to the nearest 0.01-foot by sounding using a clean, decontaminated weighted tape measure.
5. Calculate number of linear feet of static water (total depth or length of well pipe or casing minus the depth to static water level).
6. Calculate the volume of water in the casing:

$$VW = \pi D^2 (TD - DW)$$

$$V_{gal} = VW \times 7.48 \text{ gallons/ft}^3$$

$$V_{purge} = V_{gal} (\# \text{ Well Vol})$$

Where:

- V_W = Volume of water in well in cubic feet (i.e., one well volume)
 π = pi, 3.14
 D = Well diameter in feet (use $(D/12)$ if D is in inches)
 TD = Total depth of well in feet (below ground surface or top of casing)
 DW = Depth to water in feet (below ground surface or top of casing)
 V_{gal} = Volume of water in well in gallons
 V_{purge} = Volume of water to be purged from well in gallons
 $\# \text{ Well Vol.}$ = Number of well volumes of water to be purged from the well (typically three to five)

7. Determine the minimum number of gallons to be evacuated before sampling. (Note: V_{purge} should be rounded to the next highest whole gallon. For example, 7.2 gallons should be rounded to 8 gallons.)

5.3 Evacuation of Static Water (Purging)

The amount of flushing a well should 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.

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

An alternative method of purging a well, and one accepted in EPA Regions I and IV, is to purge a well continuously (usually using a low volume, low flow pump) while monitoring specific conductance, pH, and water temperature until the values stabilize. The well is considered properly purged when the values have stabilized.

The Project Manager shall define the objectives of the groundwater sampling program in the Sampling and Analysis Plan, and provide appropriate criteria and guidance to the sampling personnel on the proper methods and volumes of well purging.

5.3.1 Evacuation Devices

The following discussion is limited to those devices which are commonly used at hazardous waste sites. 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 (e.g., Teflon-coated) 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.
- Inexpensive.
- Minimal outgassing of volatile organics while the sample is in the bailer.
- Relatively easy to decontaminate.

Limitations on the use of bailers include the following:

- Potentially excessively 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, peristaltic, and pitcher pumps. Centrifugal and diaphragm pumps can be used for well evacuation at a fast pumping rate and for sampling at a low pumping rate. The peristaltic pump is a low volume pump (generally not suitable for well purging) that uses rollers to squeeze a flexible tubing, thereby creating suction. This tubing can be dedicated to a well to prevent cross contamination. The pitcher pump is a common farm hand-pump.

These pumps are all portable, inexpensive and readily available. However, because they are based on suction, their use is restricted to areas with water levels within 10 to 25 feet of the ground surface. A significant limitation is that the vacuum created by these pumps will cause significant loss of dissolved gases, including volatile organics. In addition, the complex internal components of these pumps may be difficult to decontaminate.

Gas-Lift Samplers - This group of samplers uses gas pressure either in the annulus of the well or in a venturi to force the water up a sampling tube. These pumps are also relatively inexpensive. Gas lift pumps 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. An inert gas such as nitrogen is generally used as a gas source.

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 air 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 two-inch diameter wells and larger. These pumps can lift water from considerable depths (several hundred feet).

Limitations of this class of pumps include:

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

5.4 Sampling

The sampling approach consisting of the following, should be developed as part of the Sampling and Analysis Plan prior to the field work:

1. Background and objectives of sampling.
2. Brief description of area and waste characterization.
3. Identification of sampling locations, with map or sketch, and applicable well construction data (well size, depth, screened interval, reference elevation).
4. Sampling equipment to be used.
5. 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 should be sampled last to reduce the risk of cross-contamination between wells as a result of the sampling procedures.
6. Sample preservation requirements.
7. Schedule.
8. List of team members.
9. Other information, such as the necessity for a warrant or permission of entry, requirement for split samples, access problems, location of keys, etc.

5.4.1 Sampling Methods

The collection of a groundwater sample includes the following steps:

1. First open the well cap and use volatile organic detection equipment (HNu or OVA) on the escaping gases at the well head to determine the need for respiratory protection. This task is usually performed by the Field Team Leader, Health and Safety Officer, or other designee.
2. When proper respiratory protection has been donned, sound the well for total depth and water level (decontaminated equipment) and record these data in the field logbook. Calculate the fluid volume in the well according to Section 5.2 of this SOP.
3. Lower purging equipment or intake into the well to a short distance below the water level and begin water removal. Collect the purged water and dispose of it in an acceptable manner (e.g., DOT-approved 55-gallon drum).
4. Measure the rate of discharge frequently. A bucket and stopwatch are most commonly used; other techniques include using pipe trajectory methods, weir boxes or flow meters.
5. Observe peristaltic pump intake for degassing "bubbles" and all pump discharge lines. If bubbles are abundant and the intake is fully submerged, this pump is not suitable for collecting samples for volatile organics. The preferred method for collecting volatile organic samples and the accepted method by EPA Regions I through IV is with a bailer.
6. Purge a minimum of three to five well volumes before sampling. In low permeability strata (i.e., if the well is pumped to dryness), one volume will suffice. Allow the well to recharge as necessary, but preferably to 70 percent of the static water level, and then sample.
7. Record measurements of specific conductance, temperature, and pH during purging to ensure the groundwater stabilizes. Generally, these measurements are made after three, four, and five well volumes.
8. 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 the sampling level before filling (this requires use of other than a "bucket-type" bailer). Purged water should be collected in a designated container and disposed of in an acceptable manner.
9. (For pump and packer assembly only). Lower assembly into well so that packer is positioned just above the screen or open section and inflate. Purge a volume equal to at least twice the screened interval or unscreened open section volume below the packer before sampling. Packers should always be tested in a casing section above ground to determine proper inflation pressures for good sealing.
10. In the event that recovery time of the well is very slow (e.g., 24 hours), sample collection can be delayed until the following day. If the well has been bailed early in

the morning, sufficient water may be standing in the well by the day's end to permit sample collection. If the well is incapable of producing a sufficient volume of sample at any time, take the largest quantity available and record in the logbook.

11. Add preservative if required (see SOP F301). Label, tag, and number the sample bottle(s).
12. Purgeable organics vials (40 ml) should be completely filled to prevent volatilization and extreme caution should be exercised when filling a vial to avoid turbulence which could also produce volatilization. The sample should be carefully poured down the side of the vial to minimize turbulence. As a rule, it is best to gently pour the last few drops into the vial so that surface tension holds the water in a "convex meniscus." The cap is then applied and some overflow is lost, but air space in the bottle is eliminated. After capping, turn the bottle over and tap it to check for bubbles; if any are present, repeat the procedure.
13. Replace the well cap. Make sure the well is readily identifiable as the source of the samples.
14. Pack the samples for shipping (see SOP F301). Attach custody seals to the shipping container. Make sure that Chain-of-Custody forms and Sample Analysis Request forms are properly filled out and enclosed or attached (see SOP F302).
15. Decontaminate all equipment.

5.4.2 Sample Containers

For most samples and analytical parameters, either glass or plastic containers are satisfactory. SOP F301 describes the required sampling containers for various analytes at various concentrations. Container requirements shall follow those given in NEESA 20.2-047B.

5.4.3 Preservation of Samples and Sample Volume Requirements

Sample preservation techniques and volume requirements depend on the type and concentration of the contaminant and on the type of analysis to be performed. SOP F301 describes the sample preservation and volume requirements for most of the chemicals that will be encountered during hazardous waste site investigations. Sample volume and preservation requirements shall follow those given in NEESA 20.2-047B.

5.4.4 Field Filtration

In general, preparation and preservation of water samples involve some form of filtration. All filtration must occur in the field immediately upon collection. The recommended method is through the use of a disposable in-line filtration module (0.45 micron filter) utilizing the pressure provided by the upstream pumping device for its operation.

In Region I, all inorganics are to be collected and preserved in the filtered form, including metals. In Region II, metals samples are to be collected and preserved unfiltered. In Regions III and IV, samples collected for metals analysis are also to be unfiltered. However, if metals analysis of monitoring wells is required, then both an unfiltered and filtered sample are to be collected, regardless of regulatory requirements. Filtration and preservation are to occur immediately in the field with the sample aliquot passing through a 0.45 micron filter. Samples for organic analyses shall never be filtered. Filters must be prerinsed with organic-free, deionized water.

5.4.5 Handling and Transporting Samples

After collection, samples should be handled as little as possible. It is preferable to use self-contained "chemical" ice (e.g., "blue ice") to reduce the risk of contamination. If water ice is used, it should be double-bagged and steps taken to ensure that the melted ice does not cause sample containers to be submerged, and thus possibly become cross-contaminated. All sample containers should be enclosed in plastic bags or cans to prevent cross-contamination. Samples should be secured in the ice chest to prevent movement of sample containers and possible breakage. Sample packing and transportation requirements are described in SOP F301.

5.4.6 Sample Holding Times

Holding times (i.e., allowed time between sample collection and analysis) for routine samples are given in NEESA 20.2-047B.

6.0 QUALITY ASSURANCE RECORDS

Quality assurance records will be maintained for each sample that is collected. The following information will be recorded in the Field Logbook:

- Sample identification (site name, location, project no.; sample name/number and location; sample type and matrix; time and date; sampler's identity).
- Sample source and source description.
- Field observations and measurements (appearance; volatile screening; field chemistry; sampling method; volume of water purged prior to sampling; number of well volumes purged).
- Sample disposition (preservatives added; lab sent to; date and time).
- Additional remarks, as appropriate.

Proper chain-of-custody procedures play a crucial role in data gathering. SOP F302 describes the requirements for correctly completing a chain-of-custody form. Chain-of-custody forms (and sample analysis request forms) are considered quality assurance records.

7.0 REFERENCES

American Society of Testing and Materials. 1987. Standard Guide for Sampling Groundwater Monitoring Wells. Method D4448-85A, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.

U. S. EPA, 1991. Standard Operating Procedures and Quality Assurance Manual. Environmental Compliance Branch, U. S. EPA, Environmental Services Division, Athens, Georgia.

ATTACHMENT A

ASTM D4448-85A

STANDARD GUIDE FOR SAMPLING GROUNDWATER MONITORING WELLS



Standard Guide for Sampling Groundwater Monitoring Wells¹

This standard is issued under the fixed designation D 4448; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide covers procedures for obtaining valid, representative samples from groundwater monitoring wells. The scope is limited to sampling and "in the field" preservation and does not include well location, depth, well development, design and construction, screening, or analytical procedures.

1.2 This guide is only intended to provide a review of many of the most commonly used methods for sampling groundwater quality monitoring wells and is not intended to serve as a groundwater monitoring plan for any specific application. Because of the large and ever increasing number of options available, no single guide can be viewed as comprehensive. The practitioner must make every effort to ensure that the methods used, whether or not they are addressed in this guide, are adequate to satisfy the monitoring objectives at each site.

1.3 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Summary of Guide

2.1 The equipment and procedures used for sampling a monitoring well depend on many factors. These include, but are not limited to, the design and construction of the well, rate of groundwater flow, and the chemical species of interest. Sampling procedures will be different if analyzing for trace organics, volatiles, oxidizable species, or trace metals is needed. This guide considers all of these factors by discussing equipment and procedure options at each stage of the sampling sequence. For ease of organization, the sampling process can be divided into three steps: well flushing, sample withdrawal, and field preparation of samples.

2.2 Monitoring wells must be flushed prior to sampling so that the groundwater is sampled, not the stagnant water in the well casing. If the well casing can be emptied, this may be done although it may be necessary to avoid oxygen contact with the groundwater. If the well cannot be emptied, procedures must be established to demonstrate that the sample represents groundwater. Monitoring an indicative parameter such as pH during flushing is desirable if such a parameter can be identified.

2.3 The types of species that are to be monitored as well as the concentration levels are prime factors for selecting sampling devices (1, 2).² The sampling device and all materials and devices the water contacts must be constructed of materials that will not introduce contaminants or alter the analyte chemically in any way.

2.4 The method of sample withdrawal can vary with the parameters of interest. The ideal sampling scheme would employ a completely inert material, would not subject the sample to negative pressure and only moderate positive pressure, would not expose the sample to the atmosphere, or preferably, any other gaseous atmosphere before conveying it to the sample container or flow cell for on-site analysis.

2.5 The degree and type of effort and care that goes into a sampling program is always dependent on the chemical species of interest and the concentration levels of interest. As the concentration level of the chemical species of analytical interest decreases, the work and precautions necessary for sampling are increased. Therefore, the sampling objective must clearly be defined ahead of time. For example, to prepare equipment for sampling for mg/L (ppm) levels of Total Organic Carbon (TOC) in water is about an order of magnitude easier than preparing to sample for $\mu\text{g/L}$ (ppb) levels of a trace organic like benzene. The specific precautions to be taken in preparing to sample for trace organics are different from those to be taken in sampling for trace metals. No final Environmental Protection Agency (EPA) protocol is available for sampling of trace organics. A short guidance manual, (3) and an EPA document (4) concerning monitoring well sampling, including considerations for trace organics are available.

2.6 Care must be taken not to cross contaminate samples or monitoring wells with sampling or pumping devices or materials. All samples, sampling devices, and containers must be protected from the environment when not in use. Water level measurements should be made before the well is flushed. Oxidation-reduction potential, pH, dissolved oxygen, and temperature measurements and filtration should all be performed on the sample in the field, if possible. All but temperature measurement must be done prior to any significant atmospheric exposure, if possible.

2.7 The sampling procedures must be well planned and all sample containers must be prepared and labeled prior to going to the field.

3. Significance and Use

3.1 The quality of groundwater has become an issue of national concern. Groundwater monitoring wells are one of

¹ This guide is under the jurisdiction of ASTM Committee D-34 on Waste Disposal and is the direct responsibility of Subcommittee D34.01 on Sampling and Monitoring.

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² The boldface numbers in parentheses refer to a list of references at the end of this guide.

TABLE 1 Typical Container and Preservation Requirements for a Ground-Water Monitoring Program

Sample and Measurement	Volume Required (mL)	Container P—Polyethylene G—Glass	Preservative	Maximum Holding Time
Metals As/Ba/Cd/Cr/Fe Pb/Se/ Ag/Mn/Na	1000-2000	P/G (special acid cleaning)	high purity nitric acid to pH <2	6 months
Mercury	200-300	P/G (special acid cleaning)	high purity nitric acid to pH <2 +0.05 % K ₂ Cr ₂ O ₇	28 days
Radioactivity alpha/beta/radium	4000	P/G (special acid cleaning)	high purity nitric acid to pH <2	6 months
Phenolics	500-1000	G	cool, 4°C H ₂ SO ₄ to pH <2	28 days
Miscellaneous	1000-2000	P	cool, 4°C	28 days
Fluoride	300-500	P		28 days
Chloride	50-200	P/G		28 days
Sulfate	100-500	P/G		48 hours
Nitrate	100-250	P/G		6 h
Coliform	100	P/G		on site/24 h
Conductivity	100	P/G		on site/6 h
pH	100	P/G		48 h
Turbidity	100	P/G		
Total organic carbon (TOC)	25-100	P/G	cool, 4°C or cool, 4°C HCl or H ₂ SO ₄ to pH <2	24 h 28 days
Pesticides, herbicides and total organic halogen (TOX)	1000-4000	G/TFE-fluoro- carbon lined cap solvent rinsed	cool, 4°C	7 days/extraction +30 days/analysis
Extractable organics	1000-2000	G/TFE-fluoro- carbon-lined cap solvent rinsed	cool, 4°C	7 days/extraction +30 days/analysis
Organic purgeables acrolein/acrylonitrile	25-120	G/vial TFE-fluorocar- bon-lined sep- tum	cool, 4°C	14 days 3 days

the more important tools for evaluating the quality of groundwater, delineating contamination plumes, and establishing the integrity of hazardous material management facilities.

3.2 The goal in sampling groundwater monitoring wells is to obtain samples that are truly representative of the aquifer or groundwater in question. This guide discusses the advantages and disadvantages of various well flushing, sample withdrawal, and sample preservation techniques. It reviews the parameters that need to be considered in developing a valid sampling plan.

4. Well Flushing (Purging)

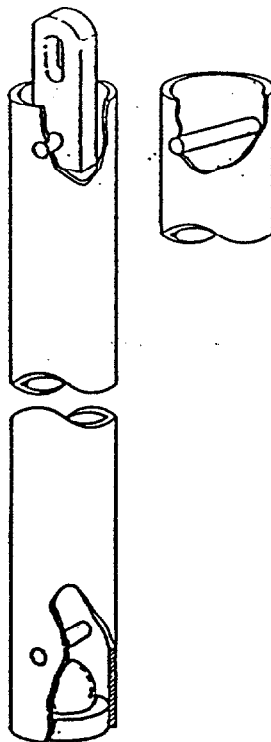
4.1 Water that stands within a monitoring well for a long period of time may become unrepresentative of formation water because chemical or biochemical change may cause water quality alterations and even if it is unchanged from the time it entered the well, the stored water may not be representative of formation water at the time of sampling, or both. Because the representativeness of stored water is questionable, it should be excluded from samples collected from a monitoring well.

4.2 The surest way of accomplishing this objective is to remove all stored water from the casing prior to sampling. Research with a tracer in a full scale model 2 in. PVC well (5) indicates that pumping 5 to 10 times the volume of the well via an inlet near the free water surface is sufficient to remove all the stored water in the casing. The volume of the well may

be calculated to include the well screen and any gravel pack if natural flow through these is deemed insufficient to keep them flushed out.

4.3 In deep or large diameter wells having a volume of water so large as to make removal of all the water impractical, it may be feasible to lower a pump or pump inlet to some point well below the water surface, purge only the volume below that point then withdraw the sample from a deeper level. Research indicates this approach should avoid most contamination associated with stored water (5, 6, 7). Sealing the casing above the purge point with a packer may make this approach more dependable by preventing migration of stored water from above. But the packer must be above the top of the screened zone, or stagnant water from above the packer will flow into the purged zone through the well's gravel/sand pack.

4.4 In low yielding wells, the only practical way to remove all standing water may be to empty the casing. Since it is not always possible to remove all water, it may be advisable to let the well recover (refill) and empty it again at least once. If introduction of oxygen into the aquifer may be of concern, it would be best not to uncover the screen when performing the above procedures. The main disadvantage of methods designed to remove all the stored water is that large volumes may need to be pumped in certain instances. The main advantage is that the potential for contamination of samples with stored water is minimized.



NOTE—Taken from Ref (15).

FIG. 1 Single Check Valve Baller

4.5 Another approach to well flushing is to monitor one or more indicator parameters such as pH, temperature, or conductivity and consider the well to be flushed when the indicator(s) no longer change. The advantage of this method is that pumping can be done from any location within the casing and the volume of stored water present has no direct bearing on the volume of water that must be pumped. Obviously, in a low yielding well, the well may be emptied before the parameters stabilize. A disadvantage of this approach is that there is no assurance in all situations that the stabilized parameters represent formation water. If significant drawdown has occurred, water from some distance away may be pulled into the screen causing a steady parameter reading but not a representative reading. Also, a suitable indicator parameter and means of continuously measuring it in the field must be available.

4.6 Gibb (4, 8) has described a time-drawdown approach using a knowledge of the well hydraulics to predict the percentage of stored water entering a pump inlet near the top of the screen at any time after flushing begins. Samples are taken when the percentage is acceptably low. As before, the advantage is that well volume has no direct effect in the duration of pumping. A current knowledge of the well's hydraulic characteristics is necessary to employ this approach. Downward migration of stored water due to effects other than drawdown (for example density differences) is not accounted for in this approach.

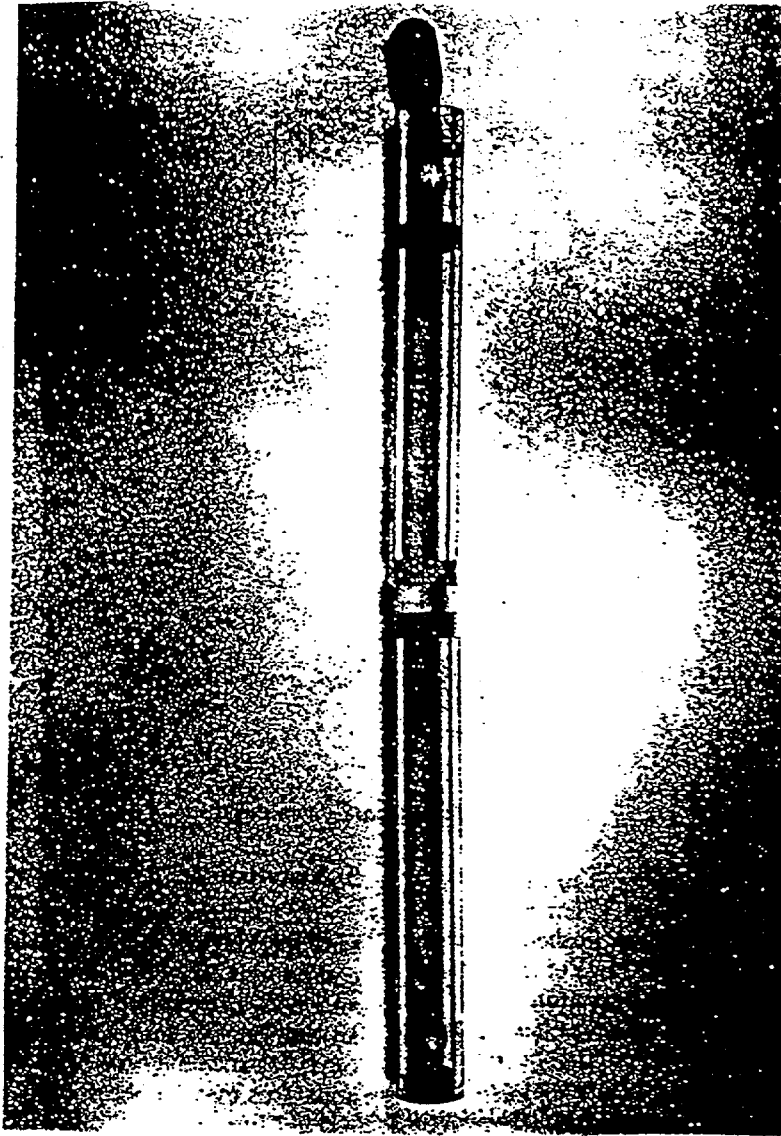
4.7 In any flushing approach, a withdrawal rate that minimizes drawdown while satisfying time constraints should be used. Excessive drawdown distorts the natural flow patterns around a well and can cause contaminants that were not present originally to be drawn into the well.

5. Materials and Manufacture

5.1 The choice of materials used in the construction of sampling devices should be based upon a knowledge of what compounds may be present in the sampling environment and how the sample materials may interact via leaching, adsorption, or catalysis. In some situations, PVC or some other plastic may be sufficient. In others, an all glass apparatus may be necessary.

5.2 Most analytical protocols suggest that the devices used in sampling and storing samples for trace organics analysis ($\mu\text{g/L}$ levels) must be constructed of glass or TFE-fluorocarbon resin, or both. One suggestion advanced by the EPA is that the monitoring well be constructed so that only TFE-fluorocarbon tubing be used in that portion of the sampling well that extends from a few feet above the water table to the bottom of the borehole. (3, 5) Although this type of well casing is now commercially available, PVC well casings are currently the most popular. If adhesives are avoided, PVC well casings are acceptable in many cases although their use may still lead to some problems if trace organics are of concern. At present, the type of background presented by PVC and interactions occurring between PVC and groundwater are not well understood. Tin, in the form of an organotin stabilizer added to PVC, may enter samples taken from PVC casing. (9)

5.3 Since the most significant problem encountered in trace organics sampling, results from the use of PVC adhesives in monitoring well construction, threaded joints might avoid the problem (3, 5). Milligram per litre (parts per million) levels of compounds such as tetrahydrofuran, methyl-ethyl-ketone, and toluene are found to leach into



NOTE—Taken from Ref (17).

FIG. 2 Acrylic Point Source Bailer

groundwater samples from monitoring well casings sealed with PVC solvent cement. Pollutant phthalate esters (8, 10) are often found in water samples at ppb levels; the EPA has found them on occasion at ppm levels in their samples. The ubiquitous presence of these phthalate esters is unexplained, except to say that they may be leached from plastic pipes, sampling devices, and containers.

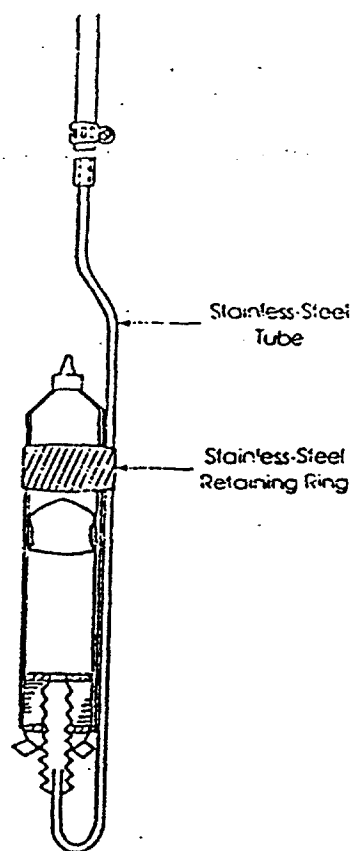
5.4 TFE-fluorocarbon resins are highly inert and have sufficient mechanical strength to permit fabrication of sampling devices and well casings. Molded parts are exposed to high temperature during fabrication which destroys any organic contaminants. The evolution of fluorinated compounds can occur during fabrication, will cease rapidly, and does not occur afterwards unless the resin is heated to its melting point.

5.5 Extruded tubing of TFE-fluorocarbon for sampling may contain surface traces of an organic solvent extrusion aid. This can be removed easily by the fabricator and, once

removed by flushing, should not affect the sample. TFE-fluorocarbon FEP and TFE-fluorocarbon PFA resins do not require this extrusion aid and may be suitable for sample tubing as well. Unsintered thread-sealant tape of TFE-fluorocarbon is available in an "oxygen service" grade and contains no extrusion aid and lubricant.

5.6 Louneman, et al. (11) alludes to problems caused by a lubricating oil used during TFE-fluorocarbon tubing extrusion. This reference also presents evidence that a fluorinated ethylene-propylene copolymer adsorbed acetone to a degree that later caused contamination of a gas sample.

5.7 Glass and stainless steel are two other materials generally considered inert in aqueous environments. Glass is probably among the best choices though it is not inconceivable it could adsorb some constituents as well as release other contaminants (for example, Na, silicate, and Fe). Of course, glass sampling equipment must be handled carefully in the field. Stainless steel is strongly and easily machined to



NOTE—Taken from Ref (21).

FIG. 3 Schematic of the Inverted Syringe Sampler

fabricate equipment. Unfortunately, it is not totally immune to corrosion that could release metallic contaminants. Stainless steel contains various alloying metals, some of these (for example Ni) are commonly used as catalysts for various reactions. The alloyed constituents of some stainless steels can be solubilized by the pitting action of nonoxidizing anions such as chloride, fluoride, and in some instances sulfate, over a range of pH conditions. Aluminum, titanium, polyethylene, and other corrosion resistant materials have been proposed by some as acceptable materials, depending on groundwater quality and the constituents of interest.

5.8 Where temporarily installed sampling equipment is used, the sampling device that is chosen should be non-plastic (unless TFE-fluorocarbon), cleanable of trace organics, and must be cleaned between each monitoring well use in order to avoid cross-contamination of wells and samples. The only way to ensure that the device is indeed "clean" and acceptable is to analyze laboratory water blanks and field water blanks that have been soaked in and passed through the sampling device to check for the background levels that may result from the sampling materials or from field conditions. Thus, all samplings for trace materials should be accompanied by samples which represent the field background (if possible), the sampling equipment background, and the laboratory background.

5.9 Additional samples are often taken in the field and spiked (spiked-field samples) in order to verify that the sample handling procedures are valid. The American Chem-

ical Society's committee on environmental improvement has published guidelines for data acquisition and data evaluation which should be useful in such environmental evaluation (10, 12).

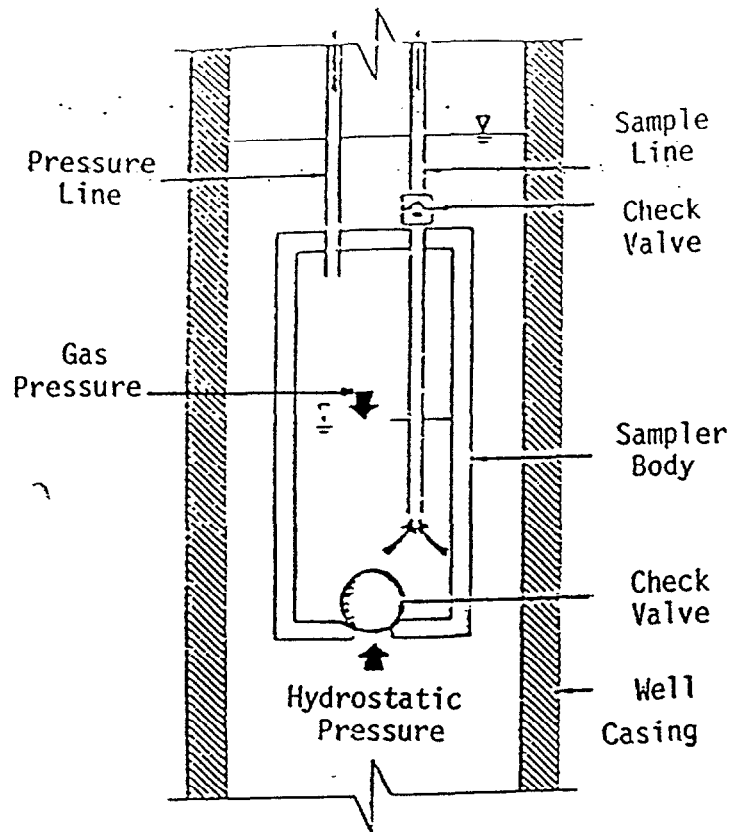
6. Sampling Equipment

6.1 There is a fairly large choice of equipment presently available for groundwater sampling from single screen wells and well clusters. The sampling devices can be categorized into the following eight basic types.

6.1.1 Down-Hole Collection Devices:

6.1.1.1 Bailers, messenger bailers, or thief samplers (10, 14) are examples of down-hole devices that probably provide valid samples once the well has been flushed. They are not practical for removal of large volumes of water. The devices can be constructed in various shapes and sizes from a variety of materials. They do not subject the sample pressure extremes.

6.1.1.2 Bailers do expose part of the sample to the atmosphere during withdrawal. Bailers used for sampling volatile organic compounds should have a sample cock or draft valve in or near the bottom of the sampler allowing withdrawal of a sample from the well below the exposure surface of the water or the first few inches of the sample should be discarded. Suspension lines for bailers and other samplers should be kept off the ground and free of other contaminating materials that could be carried into the well. Down-hole devices are not very practical for use in de-



NOTE—Taken from Ref (5).

FIG. 4 The Principal of Gas Displacement Pumping

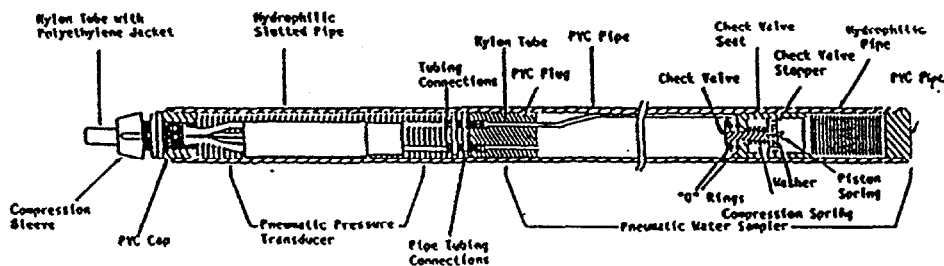
wells. However, potential sample oxidation during transfer of the sample into a collection vessel and time constraints for lowering and retrieval for deep sampling are the primary disadvantages.

6.1.1.3 Three down-hole devices are the single and double check valve bailers and thief samplers. A schematic of a single check valve unit is illustrated in Fig. 1. The bailer may be threaded in the middle so that additional lengths of blank casing may be added to increase the sampling volume. TFE-fluorocarbon or PVC are the most common materials used for construction (15).

6.1.1.4 In operation, the single check valve bailer is lowered into the well, water enters the chamber through the bottom, and the weight of the water column closes the check

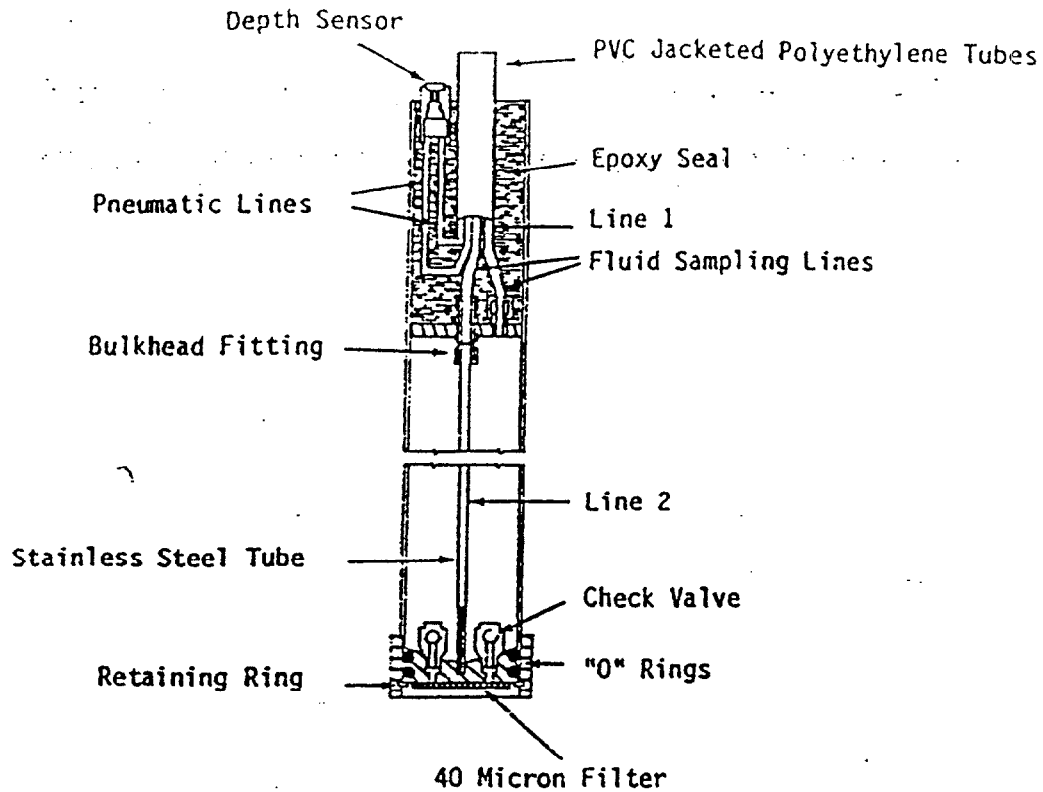
valve upon bailer retrieval. The specific gravity of the ball should be about 1.4 to 2.0 so that the ball almost sits on the check valve seat during chamber filling. Upon bailer withdrawal, the ball will immediately seat without any samples loss through the check valve. A similar technique involves lowering a sealed sample container within a weighted bottle into the well. The stopper is then pulled from the bottle via a line and the entire assembly is retrieved upon filling of the container (14, 16).

6.1.1.5 A double check valve bailer allows point source sampling at a specific depth (15, 17). An example is shown in Fig. 2. In this double check valve design, water flows through the sample chamber as the unit is lowered. A venturi tapered inlet and outlet ensures that water passes freely through the



NOTE—Taken from Ref (41).

FIG. 5 Pneumatic Water Sampler With Internal Transducer



NOTE—Taken from Ref (42).

FIG. 6 Pneumatic Sampler With Externally Mounted Transducer

unit. When a depth where the sample is to be collected is reached, the unit is retrieved. Because the difference between each ball and check valve seat is maintained by a pin that blocks vertical movement of the check ball, both check valves close simultaneously upon retrieval. A drainage pin is placed into the bottom of the bailer to drain the sample directly into a collection vessel to reduce the possibility of air oxidation. The acrylic model in Fig. 2 is threaded at the midsection allowing the addition of threaded casing to increase the sampling volume.

6.1.1.6 Another approach for obtaining point source samples employs a weighted messenger or pneumatic change to "trip" plugs at either end of an open tube (for example, tube water sampler or thief sampler) to close the chamber (18). Foerst, Kemmerer, and Bacon samplers are of this variety (14, 17, 19). A simple and inexpensive pneumatic sampler was recently described by Gillham (20). The device (Fig. 3) consists of a disposable 50 mL plastic syringe modified by sawing off the plunger and the finger grips. The syringe is then attached to a gas-line by means of a rubber stopper assembly. The gas-line extends to the surface, and is used to drive the stem-less plunger, and to raise and lower the syringe into the hole. When the gas-line is pressurized, the rubber plunger is held at the tip of the syringe. The sampler is then lowered into the installation, and when the desired depth is reached, the pressure in the gas-line is reduced to atmospheric (or slightly less) and water enters the syringe. The sampler is then retrieved from the installation and the syringe detached from the gas-line. After the tip is sealed, the syringe is used as a short-term storage container. A number

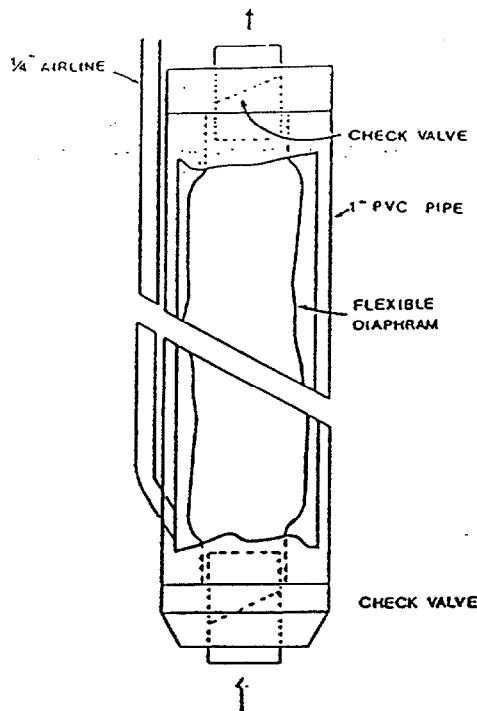
of thief or messenger devices are available in various materials and shapes.

6.1.2 Suction Lift Pumps:

6.1.2.1 Three types of suction lift pumps are the direct line, centrifugal, and peristaltic. A major disadvantage of any suction pump is that it is limited in its ability to raise water by the head available from atmospheric pressure. Thus, if the surface of the water is more than about 25 ft below the pump, water may not be withdrawn. The theoretical suction limit is about 34 ft, but most suction pumps are capable of maintaining a water lift of only 25 ft or less.

6.1.2.2 Many suction pumps draw the water through some sort of volute in which impellers, pistons, or other devices operate to induce a vacuum. Such pumps are probably unacceptable for most sampling purposes because they are usually constructed of common materials such as brass or mild steel and may expose samples to lubricants. They often induce very low pressures around rotating vanes or other such parts such that degassing or even cavitation may occur. They can mix air with the sample via small leaks in the casing, and they are difficult to adequately clean between uses. Such pumps are acceptable for purging of wells, but should not generally be used for sampling.

6.1.2.3 One exception to the above statements is a peristaltic pump. A peristaltic pump is a self-priming, low volume suction pump which consists of a rotor with ball bearing rollers (21). Flexible tubing is inserted around the pump rotor and squeezed by heads as they revolve in a circular pattern around the rotor. One end of the tubing is placed into the well while the other end can be connected



NOTE—Taken from Ref (4).

FIG. 7 Bladder Pump

directly to a receiving vessel. As the rotor moves, a reduced pressure is created in the well tubing and an increased pressure (<40 psi) on the tube leaving the rotor head. A drive shaft connected to the rotor head can be extended so that multiple rotor heads can be attached to a single drive shaft.

6.1.2.4 The peristaltic pump moves the liquid totally within the sample tube. No part of the pump contacts the liquid. The sample may still be degassed (cavitation is unlikely) but the problems due to contact with the pump mechanism are eliminated. Peristaltic pumps do require a fairly flexible section of tubing within the pumphead itself. A section of silicone tubing is commonly used within the peristaltic pumphead, but other types of tubing can be used particularly for the sections extending into the well or from the pump to the receiving container. The National Council of the Paper Industry for Air and Stream Improvement (22) recommends using medical grade silicone tubing for organic sampling purposes as the standard grade uses an organic vulcanizing agent which has been shown to leach into samples. Medical grade silicone tube is, however, limited to use over a restricted range of ambient temperatures. Various manufacturers offer tubing lined with TFE-fluorocarbon or Viton³ for use with their pumps. Gibb (1, 8) found little difference between samples withdrawn by a peristaltic pump and those taken by a bailer.

6.1.2.5 A direct method of collecting a sample by suction consists of lowering one end of a length of plastic tubing into the well or piezometer. The opposite end of the tubing is connected to a two way stopper bottle and a hand held or

mechanical vacuum pump is attached to a second tubing leaving the bottle. A check valve is attached between the two lines to maintain a constant vacuum control. A sample can then be drawn directly into the collection vessel without contacting the pump mechanism (5, 23, 24).

6.1.2.6 A centrifugal pump can be attached to a length of plastic tubing that is lowered into the well. A foot valve is usually attached to the end of the well tubing to assist in priming the tube. The maximum lift is about 4.6 m (15 ft) for such an arrangement (23, 25, 26).

6.1.2.7 Suction pump approaches offer a simple sample retrieval method for shallow monitoring. The direct line method is extremely portable though considerable oxidation and mixing may occur during collection. A centrifugal pump will agitate the sample to an even greater degree although pumping rates of 19 to 151 Lpm (5 to 40 gpm) can be attained. A peristaltic pump provides a lower sampling rate with less agitation than the other two pumps. The withdrawal rate of peristaltic pumps can be carefully regulated by adjustment of the rotor head revolution.

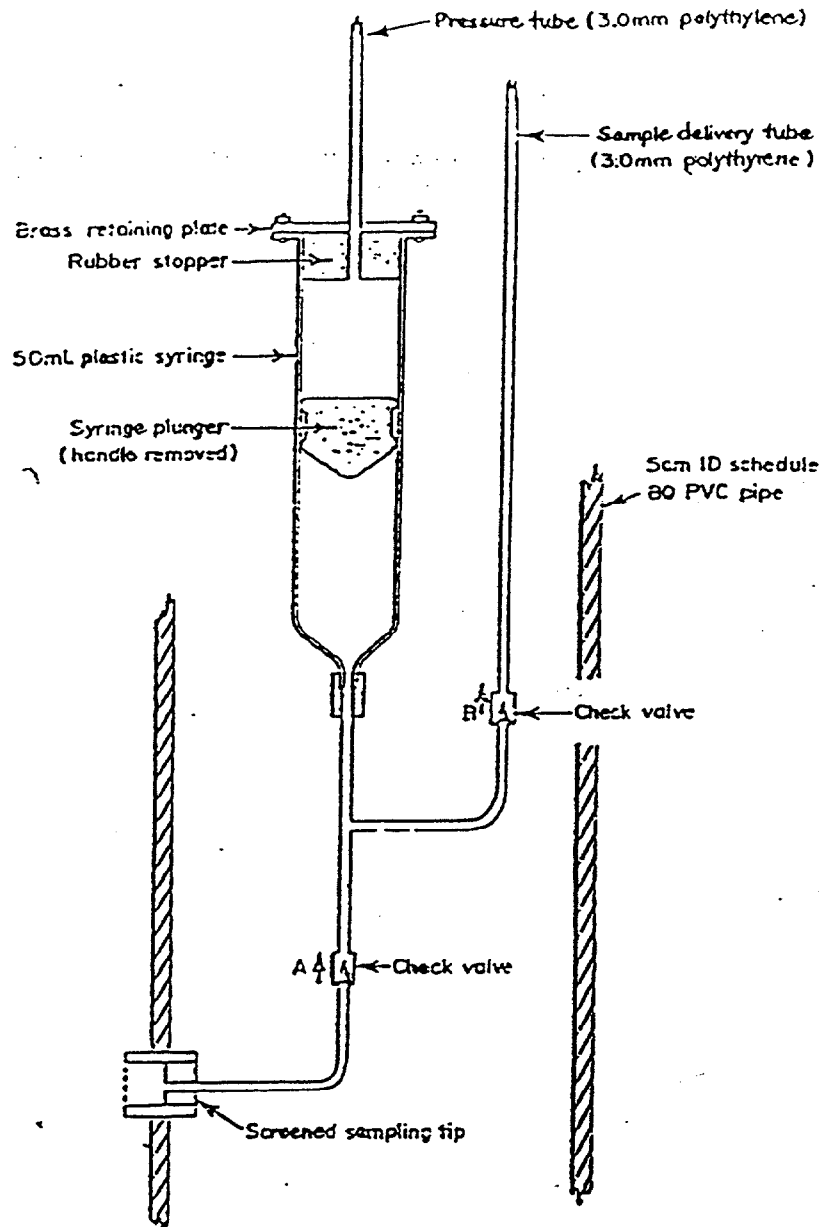
6.1.2.8 All three systems can be specially designed so that the water sample contacts only the TFE fluorocarbon or silicone tubing prior to sample bottle entry. Separate tubing is recommended for each well or piezometer sampled.

6.1.3 Electric Submersible Pumps:

6.1.3.1 A submersible pump consists of a sealed electric motor that powers a piston or helical single thread worm at a high rpm. Water is brought to the surface through an access tube. Such pumps have been used in the water well industry for years and many designs exist (5, 26).

6.1.3.2 Submersible pumps provide relatively high discharge rates for water withdrawal at depths beyond suction

³ Viton is a trademark of E. I. du Pont de Nemours & Co., Wilmington, DE 19898 and has been found suitable for this purpose.



NOTE—Taken from Ref (48).

FIG. 8 Positive Displacement Syringe Pump

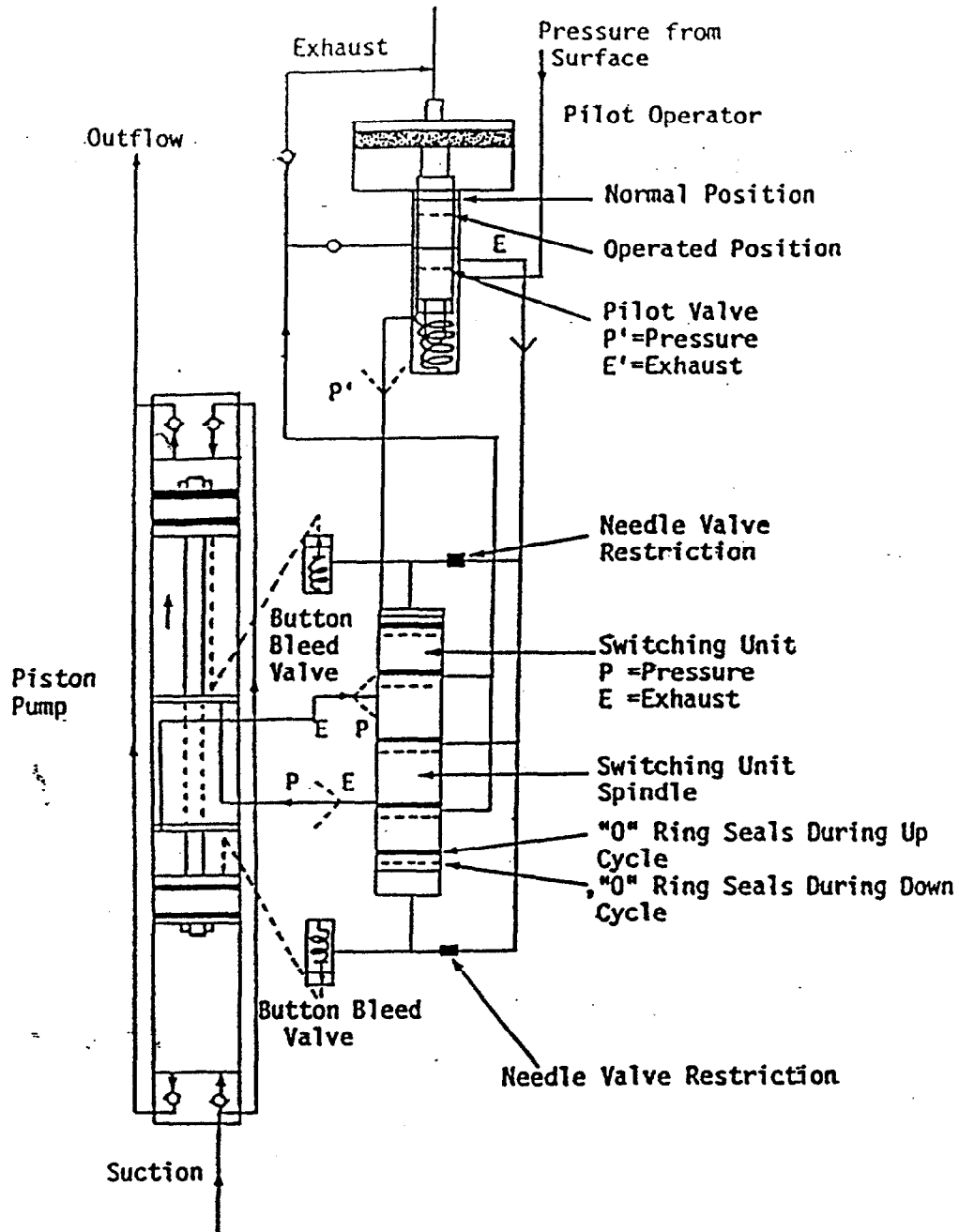
lift capabilities. A battery operated unit 3.6 cm (1.4 in.) in diameter and with a 4.5 Lpm (1.2 gpm) flow rate at 33.5 m (110 ft) has been developed (27). Another submersible pump has an outer diameter of 11.4 cm (4.5 in.) and can pump water from 91 m (300 ft). Pumping rates vary up to 53.0 Lpm (14 gpm) depending upon the depth of the pump (28).

6.1.3.3 A submersible pump provides higher extraction rates than many other methods. Considerable sample agitation results, however, in the well and in the collection tube during transport. The possibility of introducing trace metals into the sample from pump materials also exists. Steam cleaning of the unit followed by rinsing with unchlorinated, deionized water is suggested between sampling when analysis for organics in the parts per million (ppm) or parts per billion (ppb) range is required (29).

6.1.4 Gas-Lift Pumps:

6.1.4.1 Gas-lift pumps use compressed air to bring a water sample to the surface. Water is forced up an eductor pipe that may be the outer casing or a smaller diameter pipe inserted into the well annulus below the water level (30, 31).

6.1.4.2 A similar principle is used for a unit that consists of a small diameter plastic tube perforated in the lower end. This tube is placed within another tube of slightly larger diameter. Compressed air is injected into the inner tube; the air bubbles through the perforations, thereby lifting the water sample via the annulus between the outer and inner tubing (32). In practice, the eductor line should be submerged to a depth equal to 60 % of the total submerged eductor length during pumping (26). A 60 % ratio is considered optimal although a 30 % submergence ratio is adequate.



Note—Taken from Ref (49).

FIG. 9 Gas Driven Piston Pump

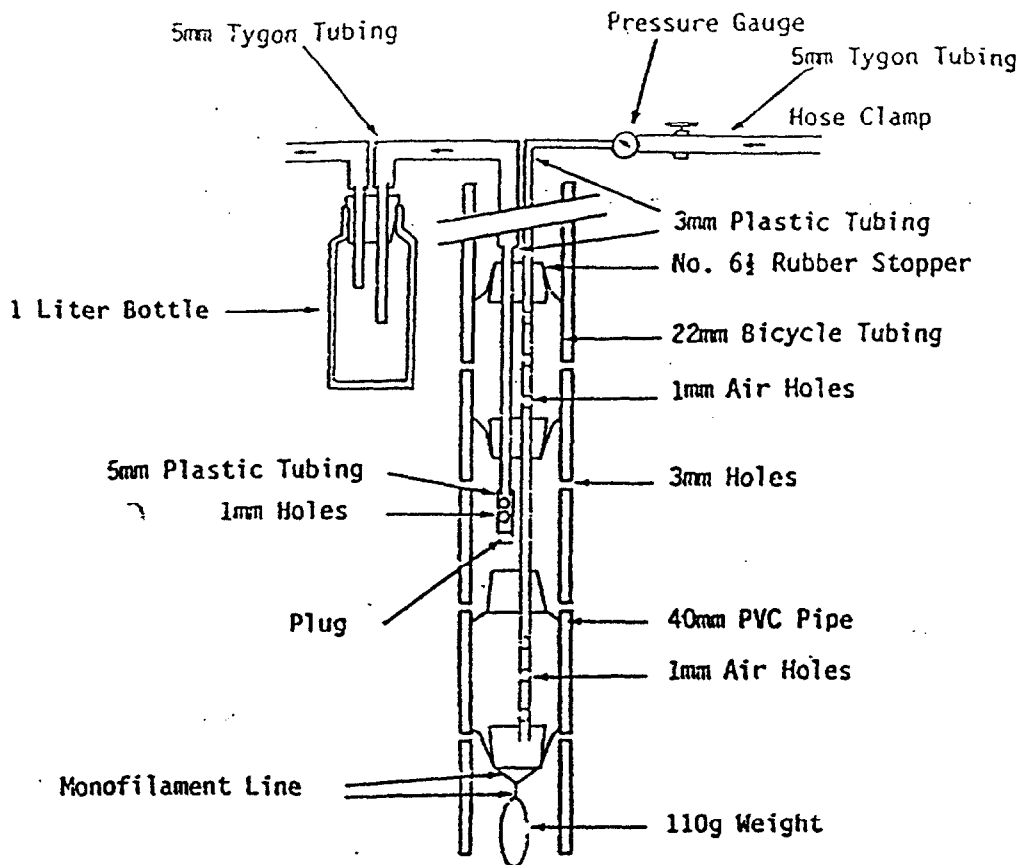
6.1.4.3 The source of compressed gas may be a hand pump for depths generally less than 7.6 m (25 ft). For greater depths, air compressors, pressurized air bottles, and air compressed from an automobile engine have been used.

6.1.4.4 As already mentioned, gas-lift methods result in considerable sample agitation and mixing within the well, and cannot be used for samples which will be tested for volatile organics. The eductor pipe or weighted plastic tubing is a potential source of sample contamination. In addition, Gibb (8) uncovered difficulties in sampling for inorganics. These difficulties were attributed to changes in redox, pH,

and species transformation due to solubility constant changes resulting from stripping, oxidation, and pressure changes.

6.1.5 Gas Displacement Pumps:

6.1.5.1 Gas displacement or gas drive pumps are distinguished from gas-lift pumps by the method of sample transport. Gas displacement pumps force a discrete column of water to the surface via mechanical lift without extensive mixing of the pressurized gas and water as occurs with air-lift equipment. The principle is shown schematically in Fig. 4. Water fills the chamber. A positive pressure is applied to the



NOTE—Taken from Ref (53).

FIG. 10 Packer Pump Arrangement

gas line closing the sampler check valve and forcing water up the sample line. By removing the pressure the cycle can be repeated. Vacuum can also be used in conjunction with the gas (30). The device can be permanently installed in the well (33, 34, 35) or lowered into the well (36, 37).

6.1.5.2 A more complicated two stage design constructed of glass with check valves made of TFE-fluorocarbon has been constructed (38, 39). The unit was designed specifically for sample testing for trace level organics. Continuous flow rates up to 2.3 Lpm (0.6 gpm) are possible with a 5.1 cm (2 in.) diameter unit.

6.1.5.3 Gas displacement pumps have also been developed with multiple functions. The water sampler in Fig. 5 provides piezometric data measurements with an internally mounted transducer (40). A sampler with its transducer exposed externally for piezometric measurements is illustrated in Fig. 6 (41). The sensor can activate the gas source at the surface to cause sample chamber pressurization at the predetermined depth. Another design can be used as a water sampler or as a tool for injecting brine or other tracers into a well (42).

6.1.5.4 Gas displacement pumps offer reasonable potential for preserving sample integrity because little of the driving gas comes in contact with the sample as the sample is conveyed to the surface by a positive pressure. There is, however, a potential loss of dissolved gasses or contamination from the driving gas and the housing materials.

6.1.6 Bladder Pumps:

6.1.6.1 Bladder pumps, also referred to as gas-operated squeeze pumps, consist of a flexible membrane enclosed by a rigid housing. Water enters the membrane through a check valve in the vessel bottom; compressed gas injected into the cavity between the housing and bladder forces the sample through a check valve at the top of the membrane and into a discharge line (Fig. 7). Water is prevented from re-entering the bladder by the top check valve. The process is repeated to cycle the water to the surface. Samples taken from depths of 30.5 m (100 ft) have been reported.

6.1.6.2 A variety of design modifications and materials are available (43, 44). Bladder materials include neoprene, rubber, ethylene propylene terpolymer (E.P.T.), nitrile, and the fluorocarbon Viton.³ A bladder made of TFE-fluorocarbon is also under development (45). Automated sampling systems have been developed to control the time between pressurization cycles (46).

6.1.6.3 Bladder pumps provide an adaptable sampling tool due primarily to the number of bladder shapes that are feasible. These devices have a distinct advantage over gas displacement pumps in that there is no contact with the driving gas. Disadvantages include the large gas volumes required, low pumping rates, and potential contamination from many of the bladder materials, the rigid housing, or both.

6.1.7 Gas Driven Piston Pumps:

6.1.7.1 A simple and inexpensive example of a gas driven piston pump is a syringe pump (47). The pump (Fig. 8) is constructed from a 50 mL plastic syringe with plunger stem removed. The device is connected to a gas line to the surface and the sample passes through a check valve arrangement to a sampling container at the surface. By successively applying positive and negative pressure to the gas-line, the plunger is activated driving water to the surface.

6.1.7.2 A double piston pump powered by compressed air is illustrated in Fig. 9. Pressurized gas enters the chamber between the pistons; the alternating chamber pressurization activates the piston which allows water entry during the suction stroke of the piston and forces the sample to the surface during the pressure stroke (48). Pumping rates between 9.5 and 30.3 L/hr (2.5 to 8 gal/hr) have been reported from 30.5 m (100 ft). Depths in excess of 457 m (1500 ft) are possible.

6.1.7.3 The gas piston pump provides continuous sample withdrawal at depths greater than is possible with most other approaches. Nevertheless, contribution of trace elements from the stainless steel and brass is a potential problem and the quantity of gas used is significant.

6.1.8 Packer Pump Arrangement:

6.1.8.1 A packer pump arrangement provides a means by which two expandable "packers" isolate a sampling unit between two packers within a well. Since the hydraulic or pneumatic activated packers are wedged against the casing wall or screen, the sampling unit will obtain water samples only from the isolated well portion. The packers are deflated for vertical movement within the well and inflated when the desired depth is attained. Submersible, gas lift, and suction pumps can be used for sampling. The packers are usually constructed from some type of rubber or rubber compound (48, 49, 50, 51). A packer pump unit consisting of a vacuum sampler positioned between two packers is illustrated in Fig. 10 (52).

6.1.8.2 A packer assembly allows the isolation of discrete sampling points within a well. A number of different samplers can be situated between the packers depending upon the analytical specifications for sample testing. Vertical movement of water outside the well casing during sampling is possible with packer pumps but depends upon the pumping rate and subsequent disturbance. Deterioration of the expandable materials will occur with time with the increased possibility of undesirable organic contaminants contributing to the water sample.

7. Sample Containers and Preservation

7.1 Complete and unequivocal preservation of samples, whether domestic wastewater, industrial wastes, or natural waters, is practically impossible. At best, preservation techniques only retard the chemical and biological changes that inevitably continue after the sample is removed from the source. Therefore, insuring the timely analysis of a sample should be one of the foremost considerations in the sampling plan schedule. Methods of preservation are somewhat limited and are intended to retard biological action, retard hydrolysis of chemical compounds and complexes, and reduce the volatility of constituents. Preservation methods are generally limited to pH control, chemical addition, refrigeration and freezing. For water samples, immediate

refrigeration just above freezing (4°C in wet ice) is often the best preservation technique available, but it is not the only measure nor is it applicable in all cases. There may be special cases where it might be prudent to include a recording thermometer in the sample shipment to verify the maximum and minimum temperature to which the samples were exposed. Inexpensive devices for this purpose are available.

7.2 All bottles and containers must be specially pre-cleaned, pre-labelled, and organized in ice-chests (isolating samples and sampling equipment from the environment) before one goes into the field. Otherwise, in any comprehensive program utter chaos usually develops in the field or laboratory. The time in the field is very valuable and should be spent on taking field notes, measurements, and in documenting samples, not on labelling and organizing samples. Therefore, the sampling plan should include clear instructions to the sampling personnel concerning the information required in the field data record logbook (notebook), the information needed on container labels for identification, the chain-of-custody protocols, and the methods for preparing field blanks and spiked samples. Example of detailed plans and documentation procedures have been published (14, 53).

7.3 The exact requirements for the volumes of sample needed and the number of containers to use may vary from laboratory to laboratory. This will depend on the specific analyses to be performed, the concentration levels of interest, and the individual laboratory protocols. The manager of the sampling program should make no assumptions about the laboratory analyses. He should discuss the analytical requirements of the sampling program in detail with the laboratory coordinator beforehand. This is especially the case since some analyses and preservation measures must be performed at the laboratory as soon as possible after the samples arrive. Thus, appropriate arrangements must be made.

7.4 There are a number of excellent references available which list the containers and preservation techniques appropriate for water and soils (13, 14, 50, 54, 55, 56). The "Handbook for Sampling and Sample Preservation of Water and Wastewater" is an excellent reference and perhaps the most comprehensive one (14). Some of this information is summarized in Table 1.

7.5 Sample containers for trace organic samples require special cleaning and handling considerations (57). The sample container for purgeable organics consist of a screw-cap vial (25 to 125 mL) fitted with a TFE-fluorocarbon faced silicone septum. The vial is sealed in the laboratory immediately after cleaning and is only opened in the field just prior to pouring sample into it. The water sample then must be sealed into the vial headspace free (no air bubbles) and immediately cooled (4°C) for shipment. Multiple samples (usually about four taken from one large sample container) are taken because leakage of containers may cause losses, may allow air to enter the containers, and may cause erroneous analysis of some constituents. Also, some analyses are best conducted on independent protected samples.

7.6 The purgeable samples must be analyzed by the laboratory within 14 days after collection, unless they are to be analyzed for acrolein or acrylonitrile (in which case they are to be analyzed within 3 days). For samples for solvent extractions (extractable organics-base neutrals, acids and

pesticides), the sample bottles are narrow mouth, screw cap quart bottles or half-gallon bottles that have been pre-cleaned, rinsed with the extracting organic solvent and oven dried at 105°C for at least 1 h. These bottles must be sealed with TFE-fluorocarbon lined caps (Note). Samples for organic extraction must be extracted within 7 days and analyzed within 30 days after extraction. Special pre-cleaned, solvent rinsed and oven-dried stainless steel beakers (one for each monitoring well) may be used for transferring samples from the sampling device to the sample containers.

NOTE—When collecting samples, the bottles should not be overfilled or prerinsed with sample before filling because oil and other materials may remain in the bottle. This can cause erroneously high results.

7.7 For a number of groundwater parameters, the most meaningful measurements are those made in the field at the time of sample collection or at least at an on-site laboratory. These include the water level in the well and parameters that sometimes can change rapidly with storage. A discussion of the various techniques for measuring the water level in the well is contained in a NCASI publication (5) and detailed procedures are outlined in a U.S. Geological Survey publication (58). Although a discussion of these techniques is beyond the scope of this guide, it is important to point out that accurate measurements must be made before a well is flushed or only after it has had sufficient time to recover. Parameters that can change rapidly with storage include specific conductance, pH, turbidity, redox potential, dissolved oxygen, and temperature. For some of the other

parameters, the emphasis in groundwater monitoring is on the concentration of each specific dissolved component, not the total concentration of each. Samples for these types of measurements should be filtered through 0.45 µm membrane filters ideally in the field or possibly at an on-site laboratory as soon as possible. Analyses often requiring filtered samples include all metals, radioactivity parameters, total organic carbon, dissolved orthophosphate (if needed), and total dissolved phosphorous (if needed) (13, 14). If metals are to be analyzed, filter the sample prior to acid preservation. For TOC organics, the filter material should be tested to assure that it does not contribute to the TOC. The type or size of the filter to be used is not well understood. However, if results of metal, TOC or other parameters that could be effected by solids are to be compared, the same filtering procedure must be used in each case. Repeated analytical results should state whether the samples were filtered and how they were filtered.

7.8 Shipment and receipt of samples must be coordinated with the laboratory to minimize time in transit. All samples for organic analysis (and many other parameters), should arrive at the laboratory within one day after it is shipped and be maintained at about 4°C with wet ice. The best way to get them to the laboratory in good condition is to send them in sturdy insulated ice chests (coolers) equipped with bottle dividers. 24-h courier service is recommended, if personal delivery service is not practical.

REFERENCES

- (1) Gibb, J. P., Schuller, R. M., Griffin, R. A., *Monitoring Well Sampling and Preservation Techniques*, EPA-600/9-80-101, 1980.
- (2) Pettyjohn, W. A., Dunlap, W. J., Cosby, R. L., Keeley, J. W., "Sampling Ground Water for Organic Contaminants," *Ground Water*, Vol 19, (2), March/April 1981, pp. 180-189.
- (3) Dunlap, W. J., McNabb, J. F., Scaff, M. R., Cosby, R. L., *Sampling for Organic Chemicals and Microorganisms in the Subsurface*, EPA-600/2-77-176, NTIS PB 276 679, August 1977, 35 pp.
- (4) Scaff, M. R., McNabb, J. F., Dunlap, W. J., and Cosby, R. L., *Manual of Ground Water Quality Sampling Procedures*, National Water Well Association, NTIS PB-82 103 045, 1981.
- (5) "A Guide to Groundwater Sampling," *NCASI Technical Bulletin*, No. 362, January 1982.
- (6) Humenick, M. J., Turk, L. J., Coldrin, M., "Methodology for Monitoring Ground Water at Uranium Solution Mines," *Ground Water*, Vol 18 (3), May-June 1980, p. 262.
- (7) Marsh, J. M., and Lloyd, J. W., "Details of Hydrochemical Variations in Flowing Wells," *Ground Water*, Volume 18 (4), July-August 1980, p. 366.
- (8) Gibb, J. P., Schuller, R. M., Griffin, R. A., "Collection of Representative Water Quality Data from Monitoring Wells," *Proceeding of the Municipal Solid Waste Resource Recovery Symposium*, EPA-600/9-81-002A, March 1981.
- (9) Boettner, E. A., Gwendolyn, L. B., Zand, H., Aquino, R., *Organic and Organotin Compounds Leached from PVC and CPVC Pipe*, NTIS P8 82-108 333, 1982.
- (10) Junk, G. A., Svec, H. J., Vick, R. D., Avery, M. J., "Contamination of Water by Synthetic Polymer Tubes," *Environmental Science and Technology*, Vol 8 (13) 1100, December 1974.
- (11) Louneman, W. A., Bufalini, J. J., Kuntz, R. L., and Meeks, S. A., "Contamination from Fluorocarbon Films," *Environmental Science and Technology*, Vol 15 (1), January 1981.
- (12) ASC Committee on Environmental Improvement. "Guidelines for Data Acquisition and Data Quality Evaluation in Environmental Chemistry." *Analytical Chemistry*, Vol 52, 1980, pp. 2242-2249.
- (13) *Procedures Manual for Ground Water Monitoring at Solid Waste Disposal Facilities*, EPA/530/SW-611, August 1977.
- (14) *Handbook for Sampling and Sample Preservation of Water and Wastewater*, U.S. Dept. of Commerce NTIS PB-259 946, September 1976.
- (15) Timco Manufacturing Co., Inc., "Variable Capacity Bailer," *Timco Geotechnical Catalogue*, Prairie du Sac, WI, 1982.
- (16) deVera, E., Simmons, B., Stephens, R., Storm, D., *Samplers and Sampling Procedures for Hazardous Waste Streams*, Environmental Protection Agency, EPA-600/2-80-018, 1980, p. 51.
- (17) Morrison, R., *Ground Water Monitoring Technology*, Timco Manufacturing Co., 1982, p. 276.
- (18) Eijelkamp, "Equipment for Soil Research," *General Catalogue*, Geisbeck, The Netherlands, 1979, pp. 82-83.
- (19) Wood, W., "Guidelines for Collection and Field Analysis of Ground-Water Samples for Selected Unstable Constituents," *Techniques of Water-Resources Investigations of the United States Geological Survey*, Chapter D2, 1976, p. 24.
- (20) Gilham, R. W., "Syringe Devices for Groundwater Monitoring," *Ground Water Monitoring Review*, Vol 2 (2), Spring 1982, p. 36.
- (21) Masterflex, *Masterflex Pump Catalogue*, Barnant Corp., Barrington, IL, 1981.
- (22) "Guidelines for Contracting Sampling and Analyses for Priority Pollutants in Pulp and Paper Industry Effluents," *NCASI Stream Improvement Technical Bulletin*, No. 335, August 1980.
- (23) Allison, L., "A Simple Device for Sampling Ground Water in Auger Holes," *Soil Science Society of America Proceedings* 35: 844-45, 1971.
- (24) Willardson, L., Meek, B., Huber, M., "A Flow Path Ground Water

- Sampler," *Soil Science Society of America Proceedings* 36: 965-66, 1972.
- (25) Wilson, L., *Monitoring in the Vadose Zone: A Review of Technical Elements and Methods*, U.S. Environmental Protection Agency, EPA-600/17-80-134, 1980, p. 180.
 - (26) *Ground Water and Wells*, Johnson, E. E., Inc., St. Paul, MN, 1980, p. 440.
 - (27) Keck, W. G. and Associates, *New "Keck" Submersible Water Sampling Pump for Groundwater Monitoring*, Keck, W. G. and Associates, East Lansing, MI, 1981.
 - (28) McMillion, L., and Keeley, J. W., "Sampling Equipment for Ground-Water Investigation," *Ground Water*, Vol 6, 1968, pp. 9-11.
 - (29) Industrial and Environmental Analysts, Inc., *Procedures and Equipment for Groundwater Monitoring*, Industrial and Environmental Analysts, Inc., Essex Junction, VT, 1981.
 - (30) Trescott, P., and Pinder, G., "Air Pump for Small-Diameter Piezometers," *Ground Water*, Vol 8, 1970, pp. 10-15.
 - (31) Sommerfeldt, T., and Campbell, D., "A Pneumatic System to Pump Water From Piezometers," *Ground Water*, Vol 13, p. 293.
 - (32) Smith, A., "Water Sampling Made Easier with New Device," *The Johnson Drillers Journal*, July-August 1976, pp. 1-2.
 - (33) Morrison, R., and Ross, D., "Monitoring for Groundwater Contamination at Hazardous Waste Disposal Sites," *Proceedings of 1978 National Conference on Control of Hazardous Material Spills*, April 13, Miami Beach, FL, 1968, pp. 281-286.
 - (34) Morrison, R., and Brewer, P. "Air-Lift Samplers for Zone-of-Saturation Monitoring," *Ground Water Monitoring Review*, Spring 1981, pp. 52-54.
 - (35) Morrison, R., and Timmons, R., "Groundwater Monitoring II," *Groundwater Digest*, Vol 4, 1981, pp. 21-24.
 - (36) Bianchi, W. C., Johnson, C., Haskell, E., "A Positive Action Pump for Sampling Small Bore Holes," *Soil Science Society of America Proceedings*, Vol 26, 1961, pp. 86-87.
 - (37) Timmons, R., Discussion of "An All-Teflon Bailer and An Air-Driven Pump for Evacuating Small-Diameter Ground-Water Wells" by D. Buss and K. Bandt, *Ground Water*, Vol 19, 1981, pp. 666-667.
 - (38) Timco Manufacturing Co., Inc., "Gas Lift Teflon Pump," *Timco Geotechnical Catalogue*, Prairie du Sac, WI, 1982.
 - (39) Tomson, M., King, K., Ward, C., "A Nitrogen Powered Continuous Delivery, All Glass Teflon Pumping System for Groundwater Sampling from Below 10 Meters," *Ground Water*, Vol 18, 1980, pp. 444-446.
 - (40) *Pneumatic Water Sampler*, Slope Indicator Co., Seattle, WA, 1982.
 - (41) Petur Instrument Co., Inc., *Petur Liquid Sampler*, Petur Instrument Co., Inc., Seattle, WA, 1982.
 - (42) Idler, G., "Modification of an Electronic Downhole Water Sampler," *Ground Water*, Vol 18, 1980, pp. 532-535.
 - (43) *Remote Sampler Model 200*, Markland Specialty Engineering, Ltd., Etobicoke, Ontario, Bulletin 200/78, 1978.
 - (44) Middleburg, R., "Methods for Sampling Small Diameter Wells for Chemical Quality Analysis," *Presented at the National Conference on Quality Assurance of Environmental Measurements*, Nov. 27-29, Denver, CO, 1978.
 - (45) *Air Squeeze Pump*, Leonard Mold and Die Works, Denver, CO, 1982.
 - (46) *Automatic Sampler Controller: Markland Model 105 and 2105*, Markland Specialty Engineering, Ltd., Etobicoke, Ontario, Bulletin 105/78, 1981.
 - (47) Gillham, R. W., and Johnson, P. E., "A Positive Displacement Ground-Water Sampling Device," *Ground Water Monitoring Review*, Vol 1 (2), Summer 1981, p. 33.
 - (48) Signor, D., "Gas-Driven Pump for Ground-Water Samples," *U.S. Geological Survey, Water Resources Investigation 78-72*, Open File Report, 1978.
 - (49) *Tigre Tierra HX Pneumatic Packer*, Tigre Tierra, Inc., Puyallup, WA, 1981.
 - (50) Cherry, R., "A Portable Sampler for Collecting Water Samples from Specific Zones in Uncased or Screened Wells," *U.S. Geological Survey*, Prof. Paper 25-C, 1965, pp. 214-216.
 - (51) Grisak, G., Merritt, W., Williams, D., "Fluoride Borehole Dilution Apparatus for Groundwater Velocity Measurements," *Canadian Geotechnical Journal*, Vol 14, 1977, pp. 554-561.
 - (52) Galgowski, C., Wright, W., "A Variable-Depth Ground-Water Sampler," *Soil Science Society of America Proceedings*, Vol 44, 1980, pp. 1120-1121.
 - (53) *Samplers and Sampling Procedures for Hazardous Waste Streams*, USEPA MERL Laboratory, Cincinnati, OH, EPA-600/2-80-018, January 1980.
 - (54) *Methods for Chemical Analysis of Water and Wastes*, EPA-600/4-79-020, USEPA EMSL Laboratory, Cincinnati, OH, March 1979.
 - (55) *Federal Register*, Vol 44, No. 244, Dec. 18, 1979, pp. 75050-75052.
 - (56) *Standard Methods for the Examination of Water and Wastewater*, APAA, 14th ed., Washington, DC, 1976, pp. 38-45.
 - (57) *Handbook for Analytical Quality Control in Water and Wastewater Laboratories*, EPA-600/4-79-019, USEPA EMSL Laboratory, Cincinnati, OH, March 1979.
 - (58) U.S. Department of Interior, "Groundwater," Chapter II, *National Handbook of Recommended Methods for Water Data Acquisition*, 1980.

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APPENDIX F
Surface Water and Sediment Sample Acquisition

SOP F105
Surface Water and Sediment Sample Acquisition

**SURFACE WATER AND SEDIMENT SAMPLE ACQUISITION
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SURFACE WATER AND SEDIMENT SAMPLE ACQUISITION

1.0 PURPOSE

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

2.0 SCOPE

The information presented in this SOP is generally applicable to all environmental sampling of surface waters (Section 5.2) and aquatic sediments (Section 5.3), except where the analyte(s) may interact with the sampling equipment.

Specific sampling problems may require the adaptation of existing equipment or design of new equipment. Such innovations shall be documented and presented in the Sampling and Analysis Plan.

3.0 DEFINITIONS

Grab Sample - An individual sample collected from a single location at a specific time or period of time generally not exceeding 15 minutes.

Composite Sample - A sample collected over time that typically consists of a series of discrete samples which are combined or composited.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for development of documentation for procedures which deviate from those presented herein.

Field Team Leader - The Field Team Leader is responsible for selecting and detailing the specific surface water and/or sediment sampling techniques and equipment to be used, and

documenting these in the Sampling and Analysis Plan. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and that personnel performing sampling activities have been briefed and trained to execute these procedures.

Sampling Personnel - It is the responsibility of the field sampling personnel to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team Leader and/or the Project Manager. The sampling personnel are responsible for the proper acquisition of surface water and sediment samples.

5.0 PROCEDURES

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

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

5.1 Defining the Sampling Program

Many factors must be considered in developing a sampling program for surface water or sediments including study objectives; accessibility; site topography; flow, mixing and other physical characteristics of the water body; point and diffuse sources of contamination; and personnel and equipment available to conduct the study. For waterborne constituents, dispersion depends on the vertical and lateral mixing within the body of water. For sediments, dispersion depends on bottom current or flow characteristics, sediment characteristics (density, size) and geochemical properties (which effect adsorption/desorption). The sampling

plan must therefore reflect not only the mixing characteristics of streams and lakes, but also the role of fluvial-sediment transport, deposition, and chemical sorption.

5.1.1 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: (a) overland runoff; (b) leachate influx to the waterbody; (c) direct waste disposal (solid or liquid) into the water body; and (d) groundwater flow influx to the water body. 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 (when 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 nondetectable concentrations. Such dispersion does not, however, always readily occur throughout the entire body of water; the mixing may be limited to specific flow streams within the water body. For example, obtaining a representative sample of contamination from the center of a channel 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 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 on particulate matter. Nitrogen, phosphorus, and the heavy metals also may be transported by particulates. Samples will be collected with a representative amount of suspended material; transfer from the sampling device shall include transferring a proportionate amount of the suspended material.

The first step in selecting sampling locations, therefore, is to review site history, define hydrologic boundaries and features of the site, and identify the sources, pathways and potential distribution of contamination based on these considerations. The numbers, types and general locations of required samples upgradient, on site and downgradient can then be identified.

5.1.2 Location of Sampling Stations

Accessibility is the primary factor affecting sampling costs. The desirability and utility of a sample for analysis and description of site conditions must be balanced against the costs of collection as controlled by accessibility. Wading or sampling from a stream bank often is sufficient for springs, seeps, and small streams. Bridges or piers are the first choice for locating a sampling station on a larger stream or small river; they provide ready access and also permit the sampling technician to sample any point across the stream or river. 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.

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. Use of boats or wading to collect samples requires the use of U. S. Coast Guard approved personal flotation devices (PFDs).

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

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

5.1.3 Frequency of Sampling

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

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

5.2 Surface Water Sample Collection

This section presents methods for collection of samples from various surface water bodies, as well as a description of types of surface water sampling equipment. The guidance in this section should be used to develop specific sampling procedures based on site conditions and investigation goals. A summary of sampling techniques and procedures is given in Section 5.2.5.

5.2.1 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) method.

Samples from different depths or cross-sectional locations, collected 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 collected depend on the river's width, depth, discharge, and amount of suspended sediment. With a greater number of individual points sampled, it is 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 location 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 greater than three feet in depth, two samples at each station shall be taken from just below the surface, and just above the bottom.

5.2.2 Lakes, Ponds and Reservoirs

Lakes, ponds, and reservoirs have a much greater tendency to stratify according to physical or chemical differences than rivers and streams. The relative lack of mixing requires that more samples be obtained.

The number of water sampling locations 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 conducted on each aliquot of the vertical composite. In naturally-formed ponds, the deepest point may have to be determined empirically; in impoundments, the deepest point is usually near the dam.

In lakes and larger reservoirs, several vertical grab samples shall be composited to form a single sample. These vertical samples often are collected 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 sample consists of several vertical samples collected at various depths.

As it is likely that poor mixing may occur in lakes with irregular shape (with bays and coves that are protected from the wind), separate composite samples may be needed to adequately represent water quality. Similarly, additional samples are recommended where discharges, tributaries, land use characteristics, and other such factors are suspected of influencing water quality.

Many lake measurements now are 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.

5.2.3 Estuaries

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

- Mixed estuary - characterized by the absence of a vertical halocline (gradual or no marked increase in salinity in the water column) and a gradual increase in salinity seaward. Typically this type of estuary is shallow and is found in major freshwater sheetflow areas. Being well mixed, the sampling locations are not critical in this type of estuary.

- Salt wedge estuary - characterized by a sharp vertical increase in salinity and stratified freshwater flow along the surface. In these estuaries the vertical mixing forces cannot override the density differential between fresh and saline waters. In effect, a salt wedge tapering inland moves horizontally, back and forth, with the tidal phase. If contamination is being introduced into the estuary from upstream, water sampling from the salt wedge may miss it entirely.
- Oceanic estuary - characterized by salinities approaching full strength oceanic waters. Seasonally, freshwater inflow is small with the preponderance of the fresh-saline water mixing occurring near, or at, the shore line.

Sampling in estuarine areas normally is 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 coupled with vertical dissolved oxygen and temperature profiles.

5.2.4 Surface Water Sampling Equipment

The selection of sampling equipment depends on the site conditions and sample type required.

The most frequently used samplers are:

- Dip sampler
- Weighted bottle
- Kemmerer
- Depth-Integrating Sampler

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

The criteria for selecting a sampler include:

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

Each sample (grab or each aliquot collected for compositing) shall be measured for: specific conductance; temperature; pH; and dissolved oxygen (optional) as soon as it is recovered. These analyses will provide information on water mixing/stratification and potential contamination.

5.2.4.1 Dip Sampling

Water often is 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. Dip sampling often is the most appropriate sampling method for springs, seeps, ditches, and small streams.

5.2.4.2 Weighted Bottle Sampling

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

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

- Gently lower the sampler to the desired depth so as not to remove the stopper prematurely (watch for bubbles).
- Pull out the stopper with a sharp jerk of the sampler line.
- Allow the bottle to fill completely, as evidenced by the absence of air bubbles.
- Raise the sampler and cap the bottle.
- Decontaminate the outside of the bottle. The bottle can be used as the sample container (as long as original bottle is an approved container).

5.2.4.3 Kemmerer

If samples are desired at a specific depth, and the parameters to be measured do not require a Teflon coated sampler, a standard Kemmerer sampler may be used. The Kemmerer sampler is a brass, stainless steel or acrylic cylinder with rubber stoppers that leave the ends open while being lowered in a vertical position to allow free passage of water through the cylinder. 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.

5.2.5 Surface Water Sampling Techniques

Most samples taken during site investigations are grab samples. Typically, surface water sampling involves immersing the sample container directly in the body of water. The following suggestions are applicable to sampling springs, seeps, ditches, culverts, small streams and other relatively small bodies of water, and are presented to help ensure that the samples obtained are representative of site conditions:

- The most representative samples will likely be collected from near mid-stream, the center of flow in a culvert, etc.
- Downstream samples shall be collected first, with subsequent samples taken while moving upstream. Care shall be taken to minimize sediment disturbance while collecting surface water samples. If necessary, sediment samples shall be collected after the corresponding surface water sample.
- Samples may be collected either by immersing the approved sample container or a glass or nalgene beaker into the water. Sample bottles (or beakers) which do not contain preservatives shall be rinsed at least once with the water to be sampled prior to sample collection.
- Care shall be taken to avoid excessive agitation of the water which may result in the loss of volatile constituents. Additionally, samples for volatile organic analyses shall be collected first, followed by the samples for other constituents.
- Measurements for temperature, pH, specific conductance, or other field parameters, as appropriate, shall be collected immediately following sample collection for laboratory analyses.
- All samples shall be handled as described in SOP F301.
- The sampling location shall be marked via wooden stake placed at the nearest bank or shore. The sampling location number shall be marked with indelible ink on the stake.

- The following information shall be recorded in the field logbook:
 - ▶ Project location, date and time.
 - ▶ Weather.
 - ▶ Sample location number and sample identification number.
 - ▶ Flow conditions (i.e., high, low, in flood, etc.) and estimate of flow rate.
 - ▶ Visual description of water (i.e., clear, cloudy, muddy, etc.).
 - ▶ On-site water quality measurements.
 - ▶ Sketch of sampling location including boundaries of water body, sample location (and depth), relative position with respect to the site, location of wood identifier stake.
 - ▶ Names of sampling personnel.
 - ▶ Sampling technique, procedure, and equipment used.

General guidelines for collection of samples from larger streams, ponds or other water bodies are as follows:

- The most representative samples are obtained from mid-channel at mid-stream depth in a well-mixed stream.
- For sampling running water, it is suggested that the farthest downstream sample be obtained first and that subsequent samples be taken as one works upstream. Work may also proceed from zones suspected of low contamination to zones of high contamination.
- It is suggested that sample containers which do not contain preservative be rinsed at least once with the water to be sampled before the sample is taken.
- To sample a pond or other standing body of water, the surface area may be divided into grids. A series of samples taken from each grid is combined into one composite sample, or several grids are selected at random.
- Care should be taken to avoid excessive agitation of the water that would result in the loss of volatile constituents.
- When obtaining samples in 40 ml septum vials for volatile organics analysis, it is important to exclude any air space in the top of the bottle and to be sure that the Teflon liner faces inward. The bottle can be turned upside down to check for air bubbles after the bottle is filled and capped.
- 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.
- Measurements for temperature, pH, specific conductance, or other field parameters, as appropriate shall be collected immediately following sample collection for laboratory analysis.

- All samples shall be handled as described in SOP F301.
- Items to be recorded in the field logbook are the same as those described above for small streams.

5.3 Sediment Sampling

Sediment samples usually are collected at the same locations as surface water samples. If only one sediment sample is to be collected, the sample location shall be approximately at the center of the water body. If, however, multiple samples are required, sediment samples should be collected along a cross-section to characterize the bed material. A common procedure for obtaining multiple samples is to sample at quarter points along the cross-section of flow. As with surface water samples, sediment samples should be collected from downstream to upstream.

5.3.1 Sampling Equipment and Techniques

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

When boats are used for sampling, U. S. Coast Guard approved personal flotation devices must be provided and two individuals must undertake the sampling. An additional person shall remain on-shore in visual contact at all times.

The following samplers may be used to collect bottom materials:

- Scoop sampler
- Dredge samplers
- Bucket/hand auger
- Stainless steel spoon or trowel

5.3.1.1 Scoop Sampler

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

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

5.3.1.2 Dredges

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

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

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

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

5.3.1.3 Bucket (Hand) Auger

Bucket (hand) augering is a viable method for collecting sediment samples in narrow, intermittent streams or tidal flats. Typically, a 4-inch auger bucket with a cutting head is pushed and twisted into the ground and removed as the bucket is filled. The auger hole is advanced one bucket at a time, to a depth specified in the project plans.

When a specific vertical sampling interval is required, one auger bucket is used to advance the auger hole to the first desired sampling depth. If the sample at this location is to be a vertical composite of all intervals, the same bucket may be used to advance the hole, as well collect subsequent samples in the same hole. However, if discrete grab samples are to be collected to characterize each depth, a new bucket must be placed on the end of the auger extension immediately prior to collecting the next sample. The top several inches of sediment should be removed from the bucket to minimize the changes of cross-contamination of the sample from fall-in of material from the upper portions of the hole. The bucket auger should be decontaminated between samples as outlined in SOP F502.

5.3.1.4 Stainless Steel Spoon or Trowel

For loosely packed sediments, a stainless steel scoop or trowel can be used to collect a representative sample, in narrow intermittent streams or tidal flats.

Use the scoop or trowel to collect the sample from a desired depth. Remove heavy debris, rocks, and twigs before collecting the sample. Immediately transfer the sample to the appropriate sample container. Attach a label and identification tag. Record all required information in the field logbook and on the sample log sheet, chain-of-custody record, and other required forms.

5.3.2 **Sediment Sampling Procedure**

The following general procedure should be used, where applicable, for sampling sediment from springs, seeps, small streams, ditches, or other similar small bodies of water. Procedures sampling larger bodies of water (i.e., rivers, lakes, estuaries, etc.) should be developed on a project-specific basis, as needed.

With the exception of samples collected for VOC analysis, the sediment sample shall be homogenized in a stainless steel mixing bowl.

- Sediment samples shall be collected only after the corresponding surface water sample has been collected, if one is to be collected.
- Sediment samples shall be collected from downstream locations to upstream locations.
- Samples shall be collected by excavating a sufficient amount of bottom material using a scoop, beaker, spoon, trowel, or auger. Samples should be collected with the sampling device facing upstream and the sample collected from downstream to upstream. Care should be taken to minimize the loss of fine-grained materials from the sample. *Sampling personnel shall stand downstream of the sample location when collecting samples directly from the stream.*
- The sample shall be transferred to the appropriate sample containers. Sampling personnel shall use judgment in removing large plant fragments to limit bias caused by bio-organic accumulation.
- All samples shall be handled as described in SOP F301.
- The sampling location shall be marked via a wooden stake placed at the nearest bank or shore. The sample location number shall be marked on the stake with indelible ink.
- The following information shall be recorded in the field logbook:
 - ▶ Project location, date and time.
 - ▶ Weather.
 - ▶ Sample location number and sample identification number.
 - ▶ Flow conditions.
 - ▶ Sketch of sampling location including boundaries of water body, sample location, water depth, sample collection depth, relative position with respect to the site, location of wooden identifier stake.
 - ▶ Chemical analyses to be performed.
 - ▶ Description of sediment (refer to SOP F001).

6.0 QUALITY ASSURANCE RECORDS

The description of the sampling event in the field logbook shall serve as a quality assurance record. Other records include chain-of-custody and sample analysis request forms as discussed in SOP F302.

7.0 REFERENCES

1. Feltz, H. R., 1980. Significance of Bottom Material Data in Evaluating Water Quality in Contaminants and Sediments. Ann Arbor, Michigan, Ann Arbor Science Publishers, Inc., V. 1, p. 271-287.

2. Kittrell, F. W., 1969. A Practical Guide to Water Quality Studies of Streams. U.S. Federal Water Pollution Control Administration, Washington, D.C., 135p.
3. U.S. EPA, 1991. Standard Operating Procedures and Quality Assurance Manual. Environmental Compliance Branch, USEPA Environmental Services Division, Athens, Georgia.
4. U.S. Geological Survey, 1977. National Handbook of Recommended Methods for Water-Data Acquisition. Office of Water Data Coordination, USGS, Reston, Virginia.

APPENDIX G
Borehole and Sample Logging

SOP F101
Borehole and Sample Logging

**BOREHOLE AND SAMPLE LOGGING
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BOREHOLE AND SAMPLE LOGGING

1.0 PURPOSE

This SOP provides general reference information and technical guidance on borehole and sample logging. Borehole logs provide information that is used in the determination of geological conditions, assessment of contaminant distribution, and the evaluation of remedial actions.

2.0 SCOPE

This SOP provides descriptions of the standard techniques for borehole and sample logging. These techniques shall be used to provide consistent descriptions of subsurface lithology for each boring that is logged. While experience is the only method to develop confidence and accuracy in the description of soil and rock, the field geologist/engineer may develop adequate classifications through careful, thorough observation and consistent application of the classification procedure.

3.0 DEFINITIONS

Soil classifications and terms are given in Sections 5.2 and 5.3. Rock classification and terms are presented in Section 5.4.

4.0 RESPONSIBILITIES

Project Manager - It is the responsibility of the Project Manager to ensure that field personnel responsible for borehole logging are familiar with these procedures. It also is the responsibility of the Project Manager to ensure that the appropriate documents (e.g., test boring logs, field logbooks, etc.) have been correctly and completely filled out by the drilling inspector.

Field Team Leader - The Field Team Leader is responsible for the overall supervision of the drilling and boring activities, and for ensuring that each borehole is completely logged by the responsible drilling inspector. The Field Team Leader also is responsible for ensuring that all drilling inspectors have been briefed on these procedures.

Drilling Inspector - The drilling inspector (site geologist) is responsible for the direct supervision of boring and sampling activities. It is the Drilling Inspector's responsibility to log each boring, document subsurface conditions, complete the appropriate forms, and direct the drilling crew (or drilling supervisor).

5.0 PROCEDURES

The classification of soil and rock is one of the most important jobs of a drilling inspector or site geologist. It is imperative that the drilling inspector understand and accurately use the field classification system described in this SOP to maintain a consistent flow of information. This identification is based on both visual examination and manual tests. The results of the boring activities, including soil and rock classifications, shall be recorded on a Field Test Boring Record (see Figure 1) or the field notebook.

5.1 Test Boring Record

Each boring shall be fully described in a Field Test Boring Record (Figure 1). The drilling inspector shall log the boring, as it is being drilled, by recording relevant data on the Boring Record. It may be more appropriate to record the boring information in a bound field log book in cases where the information will not easily fit on the boring record. Field Test Boring Records may then be transcribed from the field log book, but must be completed at a minimum, on a weekly basis. The Field Test Boring Records must be completely filled out and signed prior to demobilization from the field activity. Field Test Boring Records must also be legible. Completed Field Test Boring Records shall be converted to report format using a Test Boring Record. An example of a completed Test Boring Record is provided in Attachment A.

The data which is to be included on the Boring Records, when applicable is listed below.

1. Project name, location, and Contract Task Order Number.
2. Date(s).
3. Identifying number and location of each boring.
4. If required, soil classifications and associated depths in accordance with the Unified Soil Classification System (see Section 5.2 and Attachment B). These classifications will be noted in the field by the drilling inspector and revised, if necessary, based on



TEST BORING RECORD

PROJECT: _____
S.O. NO.: _____ BORING NO.: _____
COORDINATES: EAST: _____ NORTH: _____
ELEVATION: SURFACE: _____ TOP OF PVC CASING: _____

RIG:					DATE	PROGRESS (FT)	WEATHER	WATER DEPTH (FT)	TIME
SPLIT SPOON	CASING	AUGERS	CORE BARREL						
SIZE (DIAM.)									
LENGTH									
TYPE									
HAMMER WT.									
FALL									
STICK UP									

REMARKS:

<p align="center">SAMPLE TYPE</p> <p>S = Split Spoon A = Auger T = Shelby Tube W = Wash R = Air Rotary C = Core D = Denison P = Piston N = No Sample</p>	<p align="center">DEFINITIONS</p> <p>SPT = Standard Penetration Test (ASTM D-1586) (Blows/0.5') RQD = Rock Quality Designation (%) Lab Class. = USCS (ASTM D-2487) or AASHTO (ASTM D-3282) Lab Moist. = Moisture Content (ASTM D-2216) Dry Weight Basis</p>
---	---

Depth (Ft.)	Sample Type and No.	Samp. Rec. Ft. & %	SPT or RQD	Lab. Class. or Pen. Rate	PID (ppm)	Visual Description	Elevation
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

Match to Sheet 2

Baker

TEST BORING RECORD

Baker Environmental, Inc.

PROJECT: _____
 S.O. NO.: _____ BORING NO.: _____

SAMPLE TYPE						DEFINITIONS	
S = Split Spoon A = Auger T = Shelby Tube W = Wash R = Air Rotary C = Core D = Denison P = Piston N = No Sample						SPT = Standard Penetration Test (ASTM D-1586) (Blows/0.5') RQD = Rock Quality Designation (%) Lab Class. = USCS (ASTM D-2487) or AASHTO (ASTM D-3282) Lab Moist. = Moisture Content (ASTM D-2216) Dry Weight Basis	
Depth (Ft.)	Sample Type and No.	Samp. Rec. (Ft. & %)	SPT or RQD	Lab. Class. or Pen. Rate	PID (ppm)	Visual Description	Elevation
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
28							
29							
30							

DRILLING CO.: _____
 DRILLER: _____

BAKER REP.: _____
 BORING NO.: _____ SHEET 2 OF 2

laboratory analysis and review. Both field determined USCS soil classification and a soil description shall be included on the log.

5. Depth limits, and the type and number of samples taken.
6. The number of blows required for each six-inch penetration of a split-spoon sampler and for each 12-inch penetration of casing. The percentage of sample recovered, hammer weight, fall length, and hydraulic pressures to push thin-walled tubes.
7. Depth to water as first encountered during drilling operations, along with the method of determination. Any distinct water bearing zones shall also be delineated.
8. Loss of drilling fluid and the interval over which loss occurred.
9. Identification of equipment used, including type of drilling rig, auger types and sizes, etc.
10. Start date and completion dates for the boring.
11. Name of the drilling company and the driller.
12. Size and length of the casing used in each hole.
13. Observations of visual contamination.
14. Field instrument readings (i.e., photoionization detector, organic vapor analyzer).

As the boring is advanced, the inspector shall evaluate the samples and the cuttings to determine the location of each stratigraphic unit. The descriptions should contain color, grain-size, consistency moisture, etc., in addition to the USCS classification category (Section 5.3.7).

Each sample collected for chemical or geotechnical analysis shall be handled as described in SOP #F102.

5.2 Soil Classification

The data shall be recorded on a Field Test Boring Record, or in a field logbook. The method of deriving the classification should be described, or reference made to this SOP or other applicable manuals. Both the soil classification and the soil descriptions must be entered on the Field Test Boring Record. If required, the soil classification shall consist of the two-letter USCS classification; the soil description shall be much more detailed.

Where required, soils will be classified according to the Unified Soil Classification System (USCS). This method of classification is detailed in Attachment B and identifies soil types on the basis of grain-size and liquid limits, and categorizes them through the use of two letters. Although some laboratory testing is required for full USCS classification, preliminary classifications may be made in the field.

Fine-grained soils 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; peat is designated by "Pt." Coarse-grained soils are divided into sand (S) or gravel (G). The careful study of the USCS will aid in developing the competence and consistency necessary for the classification of soils.

The second letter of the two-letter USCS symbol provides information about the grain size distribution of granular soil, or the plasticity characteristics of fine-grained soils. These second letter modifiers are (P) poorly graded/well sorted, (W) well graded/poorly sorted, (C) clayey, (M) silty, (L) low plasticity, or (H) high plasticity.

5.3 Soil Descriptions

The Test Boring Records shall contain complete soil descriptions in addition to the two-letter USCS classification, if required. Soil descriptions include the following components: grain size identification with descriptive terms indicating the relative percentage of each grain size, color, consistency or relative density, moisture content, organic content, plasticity, and other pertinent observations such as visual contamination, HNu measurements, etc. A summary of the soil description components is given in Attachment C.

5.3.1 Grain Size Identification

In nature, soils are comprised of varying size, shape, and combinations of the various grain types. The following terms are used to indicate soil grain size:

<u>Size</u>	<u>Size Limits</u>
Cobbles	3-inches to 12-inches
Coarse gravel	3/4-inches to 3-inches
Fine gravel	4.76 mm (# 4 sieve size) to 3/4-inches
Coarse sand	2 mm (# 10 sieve size) to 4.76 mm
Medium sand	0.42 mm (# 40 sieve size) to 2 mm
Fine sand	0.074 mm (# 200 sieve size) to 0.42 mm
Silt	0.002 mm to 0.074 mm
Clay	less than 0.002 mm

The proportion of each grain size (by weight percent) is indicated using the descriptive terms:

Trace	0 to 10 percent
Little	10 to 20 percent
Some	20 to 35 percent
And (or an adjective form of the grain size, i.e., sandy, silty, clayey)	35 to 50 percent

Some examples of soil grain size descriptions are:

- Silty fine sand: 50 to 65 percent fine sand and 35 to 50 percent silt.
- Medium to coarse sand, some silt: 65 to 90 percent medium to coarse sand, 20 to 35 percent silt.
- Fine sandy silt, trace clay: 50 to 65 percent silt, 35 to 50 percent fine sand, and 0 to 10 percent clay.

The soil type may be classified as noncohesive, granular soils or as cohesive, fine-grained soils as discussed in Section 5.3.3. The grain shape of a soil usually does not need to be determined unless unusual or unique features are readily apparent.

5.3.2 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 between borings.

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

The term "mottled" shall be used to indicate soil irregularly marked with spots of different colors. Soil color charts shall not be used unless specified by the Project Manager.

5.3.3 Relative Density and Consistency

To classify the relative density and/or consistency of a soil, the drilling inspector first shall identify the soil type. Granular soils contain predominantly sands and gravels. These types of soil are noncohesive (particles do not adhere well when compressed). Conversely, fine-grained soils which contain predominantly silts and clays are cohesive (particles will adhere when compressed).

The density of noncohesive, granular soils or the consistency of cohesive soils is classified according to standard penetration resistances obtained from split barrel sampling performed according to ASTM D-1586. Standard penetration resistance is the number of blows required to drive a split-barrel sampler with a two-inch outside diameter 12-inches into the material using a 140-pound hammer falling freely through 30-inches. In cases where geotechnical information is required, the standard penetration test is performed by driving the sampler through an 18-inch sample interval, the number of blows will then be recorded for each six-inch increment. The density designation of granular soils is obtained by adding the number of blows required to penetrate the last 12 inches of the sample interval. It is important to note that if gravel and 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 must be noted on the Field Test Boring Record and referenced to the sample number. In cases where soil sampling for environmental analytical analysis is required, 24-inch spoon barrels can be used in order to obtain a sufficient quantity of sample for required analysis. Accordingly, the second and third six-inch increments will be used to calculate the relative density.

The relative density designations for noncohesive soils are:

<u>Designation</u>	<u>Standard Penetration Resistance (Blows per Foot)</u>
Very loose	Less than 4
Loose	4 to 10
Medium dense	10 to 30
Dense	30 to 50
Very dense	Greater than 50

The consistency of cohesive soils is also determined by blow counts as shown:

<u>Designation</u>	<u>Standard Penetration Resistance (Blows per Foot)</u>
Very Soft	Less than 2
Soft	2 to 4
Medium Stiff	4 to 8
Stiff	8 to 15
Very Stiff	15 to 30
Hard	Over 30

5.3.4 Moisture Content

Moisture content is estimated in the field according to four categories: dry, damp, moist, and wet:

<u>Designation</u>	<u>Moisture Content</u>	<u>Descriptive</u>
Dry	0 to 10 percent	Little/no perceptible moisture
Damp	10 to 20 percent	Some perceptible moisture - not compactable
Moist	20 to 35 percent	Compactable
Wet	35 to 50 percent	Above compactable range

Little or no water should appear in dry soil. Wet soils appear to contain all the water they can possibly hold (i.e., saturated). Damp and moist are subjective. Laboratory tests for water content shall be performed if the natural water content is important.

5.3.5 Stratification

Stratification can only be determined after the split-barrel sampler is opened. Typically, bedding thicknesses are described as follows:

<u>Designation</u>	<u>Bedding Spacing</u>
Indistinct	No bedding apparent
Laminated	Less than 1/2-inch
Very thin	1/2-inch to 1-inch
Thin	1-inch to 4-inches
Medium	4-inches to 1-foot
Thick	1-foot to 3-feet
Massive	Greater than three feet

5.3.6 Texture/Fabric/Bedding

The texture/fabric/bedding of a soil shall be described, where appropriate. Texture is described as the relative angularity of the soil particles: rounded, subrounded, subangular, angular. Fabric shall be noted as to whether the particles are flat or bulky and whether there is a particular relation or orientation. The bedding structure also shall be noted (e.g., stratified, lensatic, nonstratified, heterogeneous varved, etc.).

5.3.7 Summary of Soil Descriptions

In summary, soils shall be classified in a similar manner by each drilling inspector. The soil description shall include:

- Soil grain size with appropriate descriptors
- Color
- Relative density and/or consistency
- Moisture content
- Stratification
- Texture/fabric/bedding
- Other distinguishing features

These descriptors are evaluated and the soil classified according the USCS system. All information, measurements and observations shall be legibly recorded on a Field Test Boring Record.

5.4 Sedimentary Rock Classifications

Rocks are grouped into three main divisions: sedimentary, igneous, and metamorphic. Sedimentary rocks are the most predominant type exposed at the earth's surface. As such, this section will consider only classification of sedimentary rocks. Standard geologic references should be used for the complete classification of sedimentary, igneous and metamorphic rocks.

For the purpose of completing the Field Test Boring Record in the field, sedimentary rocks should be classified using the following hierarchy:

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

5.4.1 Rock Type

There are numerous names for sedimentary rocks such as sandstone, shale, siltstone, claystone, conglomerate, limestone, dolomite, coal, etc. The drilling inspector should select the most appropriate rock type based on experience. Some of the references listed in Section 7.0 provide a more complete discussion of sedimentary rock types.

In addition to selecting a rock type, the drilling inspector should record the grain size (and composition of grains and cement, if apparent) on the Field Test Boring Record. The following designation should be used to describe grain size in sedimentary rocks:

<u>Designation</u>	<u>Grain Size Diameter</u>
Cobbles	Greater than 64 mm (2.5-inches)
Pebbles	4 mm (0.16-inches) to 64 mm
Granules	2 mm (0.08-inches) to 4mm
Very Coarse Sand	1 mm to 2 mm
Coarse Sand	0.5 mm to 1 mm
Medium Sand	0.25 mm to 0.5 mm
Fine Sand	0.125 mm to 0.25 mm
Very Fine Sand	0.0625 mm to 0.125 mm
Silt	0.0039 mm to 0.0625 mm
Clay	Smaller than 0.0039 mm

For individual boundaries of grain size, a scale can be used for coarse-grained rocks. However, the division between silt and clay likely will not be measurable in the field. This boundary shall be determined by use of a hand lens. If the grains cannot be seen with the unaided eye, but are distinguishable with a hand lens (5x magnification) the grain size is silt. If the grains are not distinguishable with a hand lens, the grain size is clay.

5.4.2 Color

The color of rock can be determined in a manner similar to that for soil samples. Rock cores or fragments shall be classified while wet, when possible. Rock color charts shall not be used unless specified by the Project Manager.

5.4.3 Bedding Thickness

The bedding thickness designation for soils (Section 5.3.5) shall also be used for rock descriptions.

5.4.4 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 follows:

- **Very Soft** - Very soft indicates that the rock is easily gouged by a knife, easily scratched by a fingernail, and/or easily broken by hand
- **Soft** - Soft indicates that the rock may be gouged by a knife, scratched by a fingernail, difficult to break by hand, and/or powders when hit by a hammer.
- **Medium Hard** - Medium hard indicates that the rock is easily scratched by a knife and/or is easily broken when hit by a hammer.
- **Hard** - Hard indicates that the rock is difficult to scratch with a knife but may be broken with a hammer.
- **Very Hard** - Very hard indicates that the rock is difficult to break with a hammer.

Note the difference in usage between the words "scratch" and "gouge". A scratch shall be considered a slight depression in the rock while a gouge is much deeper.

5.4.5 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 measured and is described by the following terms:

- Very Broken - Less than a two-inch spacing between fractures
- Broken - A two-inch to one-foot spacing between fractures
- Blocky - A one-foot to three-foot spacing between fractures
- Massive - A three-foot to ten-foot spacing between fractures

5.4.6 Rock Quality Designation

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 four inches and dividing by the total length of core run:

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

Where:

r = Total length of all pieces of the lithologic unit being measured, which are greater than four inches, 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 core run.

The results of the RQD calculations shall be recorded on the Field Test Boring Record.

5.4.7 Weathering

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

- Decomposed - Soft to very soft, bedding and fractures indistinct, no cementation.
- Highly weathered - very soft to soft, with medium hard relic rock fragments, little to moderate cementation. Vugs and openings in bedding and fracture planes, some of which may be filled.

- Weathered - Soft to medium hard. Good cementation, bedding and fractures are pronounced. Uniformly stained.
- Slightly weathered - Medium hard. Fractures pronounced, nonuniform staining, bedding distinct.
- Fresh - Medium hard to hard. No staining. Fractures may be present, bedding may or may not be distinct.

5.4.8 Other Characteristics

The following items should be included in rock description, where applicable:

- Description of contacts between rock units (sharp or gradational)
- Stratification
- Description of any filled cavities
- Cementation (calcareous, siliceous, hematitic, etc.)
- Description of joints and open fractures (with strike and dip, if possible)
- Observation of the presence of fossils

5.4.9 Additional Terms

The following terms also are used to further identify rocks:

- Seam - thin (12-inches or less), probably continuous layer.
- Some - Indicates significant (15 to 40 percent) amounts of an accessory material.
- Few - Indicates insignificant (0 to 15 percent) amounts of an accessory material.
- Interbedded - Indicates thin or very thin alternating seams of material occurring in approximately equal amounts.
- Interlayered - Indicates thick alternating seams of material occurring in approximately equal amounts.

6.0 QUALITY ASSURANCE RECORDS

Quality Assurance Records shall consist of completed Field Test Boring Records and Test Boring Records.

7.0 REFERENCES

1. American Society for Testing and Materials, 1990. Standard Methods for Classification of Soils for Engineering Purposes. ASTM Method D2487-90, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.
2. American Society for Testing and Materials, 1990. Standard Practice for Description and Identification of Soils (Visual - Manual Procedure). ASTM Method D2488-90, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.

ATTACHMENT A

EXAMPLE TEST BORING RECORD

Baker

Baker Environmental, Inc.

TEST BORING RECORD

PROJECT: Building P-64

S.O. NO.: 19010-51-SRN

BORING NO.: B-1

COORDINATES: EAST: _____

NORTH: _____

ELEVATION: SURFACE: _____

TOP OF PVC CASING: _____

RIG: Mobile B-57									
	SPLIT SPOON	CASING	AUGERS	CORE BARREL	DATE	PROGRESS (FT)	WEATHER	WATER DEPTH (FT)	TIME
SIZE (DIAM.)	1-3/8" ID		6-1/4" ID		5/31/91	14.0	Sunny, 80°-90°F	---	---
LENGTH	2.0'		5.0'						
TYPE	STD.		HSA						
HAMMER WT.	140#								
FALL	30"								
STICK UP									

REMARKS: Advanced boring to 14 ft. taking continuous 2-foot split-spoon samples; no monitoring well installed - borehole grouted to surface.

SAMPLE TYPE S = Split Spoon A = Auger T = Shelby Tube W = Wash R = Air Rotary C = Core D = Denison P = Piston N = No Sample			DEFINITIONS SPT = Standard Penetration Test (ASTM D-1586) (Blows/0.5") RQD = Rock Quality Designation (%) Lab Class. = USCS (ASTM D-2487) or AASHTO (ASTM D-3282) Lab Moist. = Moisture Content (ASTM D-2216) Dry Weight Basis		
---	--	--	---	--	--

Depth (Ft.)	Sample Type and No.	Samp. Rec. Ft. & %	SPT or RQD	Lab. Class. or Pen. Rate	PID (ppm)	Visual Description	Elevation
1			3			TOPSOIL, grass roots; tan, gray; medium dense; dry	1.0'
2	S-1	1.3 2.0 65%	7 9 5			SAND, fine-grained, trace gravel, trace silt; tan, brown; loose; moist to damp	
3			4				
4	S-2	1.3 2.0 65%	3 4 4			SAND, fine-grained, trace silt, trace grass roots; tan, brown; loose; moist to damp	4.0'
5			11				
6	S-3	2.0 2.0 100%	12 10 8			SAND, fine to medium-grained, trace silt; tan, brown, orange; medium dense; moist to wet; water table at 6.0'	
7			3				7.0'
8	S-4	1.8 2.0 90%	4 3 4			SAND, medium to coarse-grained, trace silt; tan, gray, orange; loose; wet	
9			1				9.0'
10	S-5	2.0 2.0 100%	0 1 1			SAND, medium-grained, trace silt; gray, orange; very loose; wet	

Match to Sheet 2

DRILLING CO.: ATEC Associates

BAKER REP.: R. Bonelli

DRILLER: M. Miller

BORING NO.: B-1

SHEET 1 OF 2

TEST BORING RECORD

PROJECT: Building P-64

S.O. NO.: 19010-51-SRN

BORING NO.: B-1

SAMPLE TYPE						DEFINITIONS	
S = Split Spoon	A = Auger					SPT = Standard Penetration Test (ASTM D-1586) (Blows/0.5')	
T = Shelby Tube	W = Wash					RQD = Rock Quality Designation (%)	
R = Air Rotary	C = Core					Lab Class. = USCS (ASTM D-2487) or AASHTO (ASTM D-3282)	
D = Denison	P = Piston					Lab Moist. = Moisture Content (ASTM D-2216) Dry Weight Basis	
N = No Sample							
Depth (Ft.)	Sample Type and No.	Samp. Rec. (Ft. & %)	SPT or RQD	Lab. Class. or Pen. Rate	PID (ppm)	Visual Description	Elevation
11	S-6	2.0 2.0 100%	1		0	SAND, medium-grained, trace silt; gray; very loose; wet	
12			1				
13			0				
14	S-7	2.0 2.0 100%	0		0	SAND, medium-grained, trace silt; gray; very loose; wet	14.0'
14			1				
15						End of Boring at 14.0'	
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
28							
29							
30							

ATTACHMENT B

UNIFIED SOIL CLASSIFICATION SYSTEM

ATTACHMENT C

SOIL AND ROCK DESCRIPTION SUMMARY

<u>SOIL DESCRIPTION</u>			<u>ROCK DESCRIPTIONS</u>		
<u>GRAIN SIZE IDENTIFICATION</u>			<u>HARDNESS</u>		
<u>NAME</u>	<u>SIZE LIMITS</u>		Very Soft -	Easily gouged by knife, easily scratched by fingernail, easily broken by hand	
Boulder	12" OR MORE		Soft -	Gouged by knife, scratched by fingernail, difficult to break by hand, powders with hammer	
Cobbles	3" - 12"		Medium Hard -	Easily scratched by knife, easily broken with hammer	
Coarse Gravel	3/4" - 3"		Hard -	Difficult to scratch, breaks with hammer	
Fine Gravel	4.76 mm (#4) - 3/4"		Very Hard -	Difficult to break, rings when struck	
Coarse Sand	2 mm (#10) - 4.76 mm (#4)		<u>WEATHERING</u>		
Medium Sand	0.42 mm (#40) - 2 mm (#10)		Decomposed	Soft to Very soft, bedding and fractures indistinct, no cementation.	
Fine Sand	0.074 mm (#200)-0.42 mm (#40)		Highly Weathered	Very soft to soft, with medium hard relict rock fragments: little to moderate cementation. Vugs, openings in bedding and fractures (may be filled).	
Silt	0.002 mm-0.074 mm (#200)		Weathered	Soft to medium hard. Good cementation. bedding and fractures are pronounced. Uniformly stained.	
Clay	Less than 0.002 mm		Slightly Weathered	Medium hard. Fractures pronounced, non-uniform staining, bedding distinct.	
<u>RELATIVE DENSITY</u>			Fresh	Medium hard to hard. No staining. Fractures may be present. Bedding may or may not be indistinct.	
<u>NONCOHESIVE SOIL</u>			<u>BEDDING AND FRACTURES:</u>		
<u>TERM</u>	<u>SPT (Blows/ft)</u>		<u>SPACING</u>	<u>BEDDING</u>	<u>FRACTURES</u>
Very Loose	Below 4		LESS THAN 1/2" (1 cm)	Indistinct	Fissile
Loose	4-10		1/2" to 1" (1cm-3cm)	Laminated	Very Close
Medium Dense	10-30		1" TO 4" (3cm-10cm)	Very Thin	Close
Dense	30-50		4" TO 1' (10cm-30cm)	Thin	Moderate
Very Dense	OVER 50		1' TO 3' (30 cm-1m)	Moderate	Wide
<u>COHESIVE SOILS</u>			3' TO 10' (1m-3m)	Thick	Very Wide
<u>TERM</u>	<u>SPT (Blows/ft)</u>				
Very Soft	BELOW 2				
Soft	2-4				
Medium Stiff	4-8				
Stiff	8-15				
Very Stiff	15-30				
Hard	OVER 30				
<u>MOISTURE</u>					
	<u>DESCRIPTIVE TERMS</u>				
Dry	Trace	0-10%			
Damp	Little	10-20%			
Moist	Some	20-35%			
Wet	And	35-50%			
<u>CONTACTS:</u>			<u>SAMPLE TYPE</u>		
_____ = DEFINITE			S = Split Spoon		
_____ = INDEFINITE			T = Shelby Tube		
..... = GRADATIONAL			R = Air Rotary		
			D = Denison		
			A = Auger		
			W = Wash (Roller Bit)		
			C = Core		
			P = Piston		
			N = No Sample Taken		
			<u>ABBREVIATIONS</u>		
			HS = Hollow Stem		
			NP = Non Plastic		
			-PL = Below the Plastic Limit		
			PL = At the Plastic Limit		
			+PL = Above the Plastic Limit		
			+LL = Above the Liquid Limit		
			SPT = Standard Penetration Test		
			RQD = Rock Quality Designation		

ROCK SYMBOLS

HARDNESS

	CONGLOMERATE		LIMESTONE
	BRECCIA		DOLOMITE
	SANDSTONE		COAL
	SILTSTONE		VOID
	SHALE		UNDIFFERENTIATED
	CLAYSTONE		

V. SOFT - CORE RECOVERY < 50%, EASILY GOUGED BY KNIFE OR SCREWDRIVER, EASILY SCRATCHED BY FINGERNAIL, EASILY BROKEN BY HAND

SOFT - CORE RECOVERY 50 - 75%, GOUGED BY KNIFE OR SCREWDRIVER, SCRATCHED BY FINGERNAIL, DIFFICULT TO BREAK BY HAND, POWDERS w/HAMMER

MED. HD. - CORE RECOVERY > 75%, EASILY SCRATCHED BY KNIFE OR SCREWDRIVER, EASILY BROKEN BY HAMMER

HD. - DIFFICULT TO SCRATCH, BREAKS w/HAMMER

V. HD. - DIFFICULT TO BREAK, RINGS WHEN STRUCK

SPACING

- LESS THAN 1/8" (1cm)
- 1/4" To 1" (1cm-3cm)
- 1" To 4" (3cm-10cm)
- 4" To 1' (10cm-30cm)
- 1' To 3' (30cm-1m)
- 3' To 10' (1m-3m)

BEDDING

- INDISTINCT
- LAMINATED
- VERY THIN
- THIN
- MODERATE
- THICK
- MASSIVE

FRACTURES

- FISSILE
- VERY CLOSE
- CLOSE
- MODERATE
- WIDE
- VERY WIDE

WEATHERING

DECOMPOSED - SOFT - V. SOFT, BEDDING AND FRACTURES INDISTINCT, NO CEMENTATION

HL. WTHR. - V. SOFT - SOFT, w/MED. HD. RELICT ROCK FRAGMENTS; LITTLE TO MOD. CEMENTATION, VUGS, OPENINGS IN BEDDING AND FRACTURES (MAY BE CLAY OR CALC. FILLED)

WTHR. - SOFT TO MED. HD., GOOD CEMENTATION, BEDDING AND FRACTURES ARE PRONOUNCED, UNIFORMLY STAINED

SL. WTHR. - MED. HD., FRACTURES PRONOUNCED, NON-UNIFORM STAINING, BEDDING DISTINCT

FRESH - MED. HD. TO HD., NO STAINING, FRACTURES MAY BE PRESENT, BEDDING MAY OR MAY NOT BE DISTINCT

COMMON LOCAL SEDIMENTARY ROCK CLASSIFICATIONS

MM APP. SIEVE SIZE	NO FIZZ			SLIGHT FIZZ		RAPID FIZZ		
	% CARBONATE →							
2.0 #10-20	CONGLOMERATE - If particles rounded BRECCIA - If particles angular; classify both particles and matrix as below							
VERY COARSE GRAINED	SANDSTONE	CALCAREOUS SANDSTONE	ARENACEOUS LIMESTONE	LIMESTONE	EASILY VISIBLE - ROUGH			
COARSE GRAINED								
MEDIUM GRAINED								
FINE GRAINED								
VERY FINE GRAINED								
.005	SILTSTONE SHALE (IF LAM OR FIS.)	CALC. SILTSTONE CALC. SHALE (MARL)	SILTY LIMESTONE (ARG)	CRYSTALLINE	SLIGHTLY VISIBLE GRITTY			
	CLAYSTONE	CALC. CLAYSTONE	CLAYEY LIMESTONE		NOT VISIBLE SMOOTH			

$RQD = \frac{L}{R}$ - NTYPE CORE ONLY

L - TOTAL LENGTH IN A RUN OF CORE PIECES LONGER THAN 4"

R = LENGTH OF THE RUN

← % SILICATE

ROCK DESCRIPTIONS



Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)¹

This standard is issued under the fixed designation D 2488; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This practice covers procedures for the description of soils for engineering purposes.

1.2 This practice also describes a procedure for identifying soils, at the option of the user, based on the classification system described in Test Method D 2487. The identification is based on visual examination and manual tests. It must be clearly stated in reporting an identification that it is based on visual-manual procedures.

1.2.1 When precise classification of soils for engineering purposes is required, the procedures prescribed in Test Method D 2487 shall be used.

1.2.2 In this practice, the identification portion assigning a group symbol and name is limited to soil particles smaller than 3 in. (75 mm).

1.2.3 The identification portion of this practice is limited to naturally occurring soils (disturbed and undisturbed).

NOTE 1—This practice may be used as a descriptive system applied to such materials as shale, claystone, shells, crushed rock, etc. (See Appendix X2).

1.3 The descriptive information in this practice may be used with other soil classification systems or for materials other than naturally occurring soils.

1.4 *This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific precautionary statements see Section 8.

1.5 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 ASTM Standards:

D 653 Terminology Relating to Soil, Rock, and Contained Fluids²

D 1452 Practice for Soil Investigation and Sampling by Auger Borings²

D 1586 Method for Penetration Test and Split-Barrel Sampling of Soils²

D 1587 Practice for Thin-Walled Tube Sampling of Soils²

D 2113 Practice for Diamond Core Drilling for Site Investigation²

D 2487 Test Method for Classification of Soils for Engineering Purposes²

D 4083 Practice for Description of Frozen Soils (Visual-Manual Procedure)²

3. Terminology

3.1 Definitions:

3.1.1 Except as listed below, all definitions are in accordance with Terminology D 653.

NOTE 2—For particles retained on a 3-in. (75-mm) US standard sieve, the following definitions are suggested:

Cobbles—particles of rock that will pass a 12-in. (300-mm) square opening and be retained on a 3-in. (75-mm) sieve, and

Boulders—particles of rock that will not pass a 12-in. (300-mm) square opening.

3.1.1.2 *clay*—soil passing a No. 200 (75- μ m) sieve that can be made to exhibit plasticity (putty-like properties) within a range of water contents, and that exhibits considerable strength when air-dry. For classification, a clay is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index equal to or greater than 4, and the plot of plasticity index versus liquid limit falls on or above the "A" line (see Fig. 3 of Test Method D 2487).

3.1.1.3 *gravel*—particles of rock that will pass a 3-in. (75-mm) sieve and be retained on a No. 4 (4.75-mm) sieve with the following subdivisions:

coarse—passes a 3-in. (75-mm) sieve and is retained on a 3/4-in. (19-mm) sieve.

fine—passes a 3/4-in. (19-mm) sieve and is retained on a No. 4 (4.75-mm) sieve.

3.1.1.4 *organic clay*—a clay with sufficient organic content to influence the soil properties. For classification, an organic clay is a soil that would be classified as a clay, except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.1.5 *organic silt*—a silt with sufficient organic content to influence the soil properties. For classification, an organic silt is a soil that would be classified as a silt except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.1.6 *peat*—a soil composed primarily of vegetable tissue in various stages of decomposition usually with an organic odor, a dark brown to black color, a spongy consistency, and a texture ranging from fibrous to amorphous.

3.1.1.7 *sand*—particles of rock that will pass a No. 4

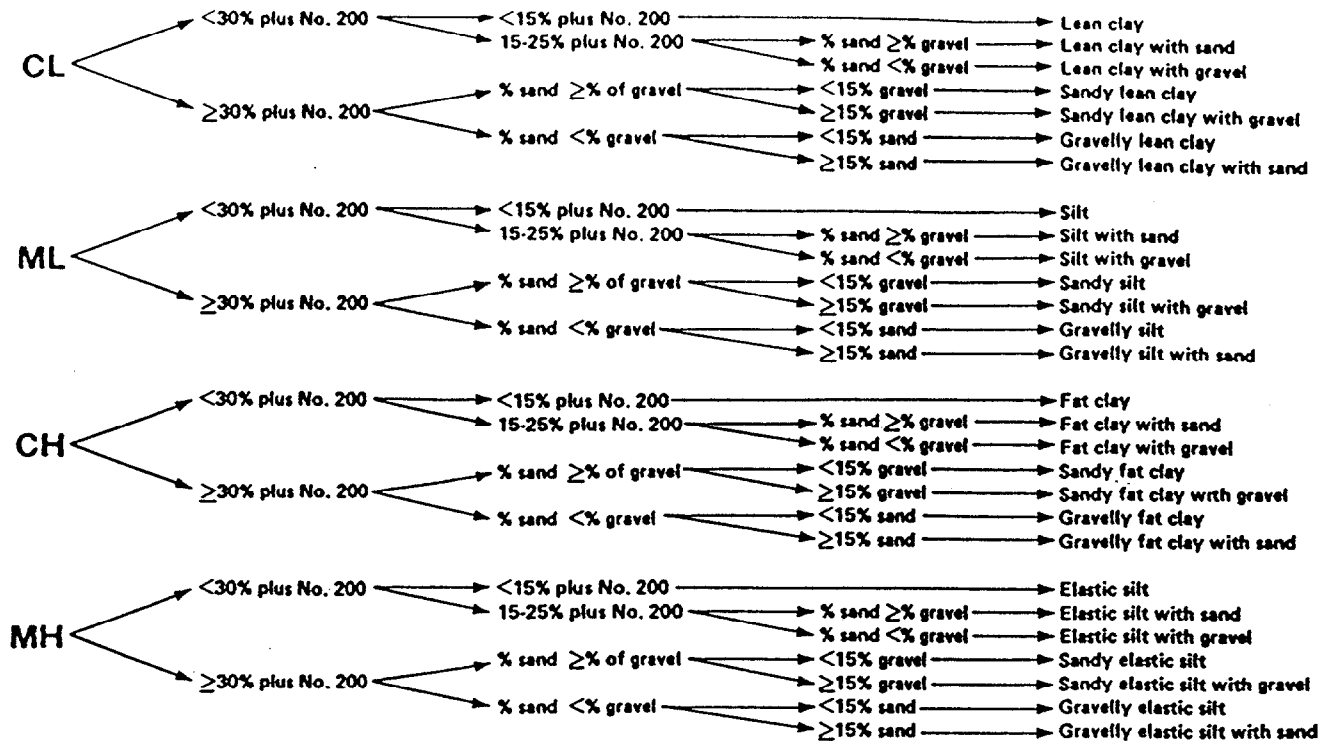
¹ This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.07 on Identification and Classification of Soils.

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² Annual Book of ASTM Standards, Vol 04.08.

GROUP SYMBOL

GROUP NAME



Note—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

FIG. 1a Flow Chart for Identifying Inorganic Fine-Grained Soil (50 % or more fines)

(4.75-mm) sieve and be retained on a No. 200 (75-μm) sieve with the following subdivisions:

coarse—passes a No. 4 (4.75-mm) sieve and is retained on a No. 10 (2.00-mm) sieve.

medium—passes a No. 10 (2.00-mm) sieve and is retained on a No. 40 (425-μm) sieve.

fine—passes a No. 40 (425-μm) sieve and is retained on a No. 200 (75-μm) sieve.

3.1.1.8 *silt*—soil passing a No. 200 (75-μm) sieve that is nonplastic or very slightly plastic and that exhibits little or no strength when air dry. For classification, a silt is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index less than 4, or the plot of plasticity index versus liquid limit falls below the “A” line (see Fig. 3 of Test Method D 2487).

4. Summary of Practice

4.1 Using visual examination and simple manual tests, this practice gives standardized criteria and procedures for describing and identifying soils.

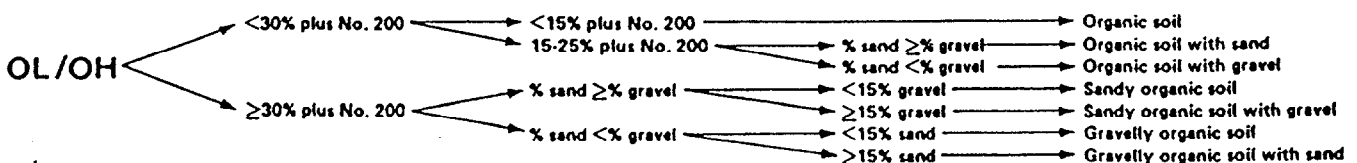
4.2 The soil can be given an identification by assigning a group symbol(s) and name. The flow charts, Figs. 1a and 1b for fine-grained soils, and Fig. 2, for coarse-grained soils, can be used to assign the appropriate group symbol(s) and name. If the soil has properties which do not distinctly place it into a specific group, borderline symbols may be used, see Appendix X3.

NOTE 3—It is suggested that a distinction be made between *dual symbols* and *borderline symbols*.

Dual Symbol—A dual symbol is two symbols separated by a hyphen, for example, GP-GM, SW-SC, CL-ML used to indicate that the soil has been identified as having the properties of a classification in accordance with Test Method D 2487 where two symbols are required. Two symbols are required when the soil has between 5 and 12 % fines or

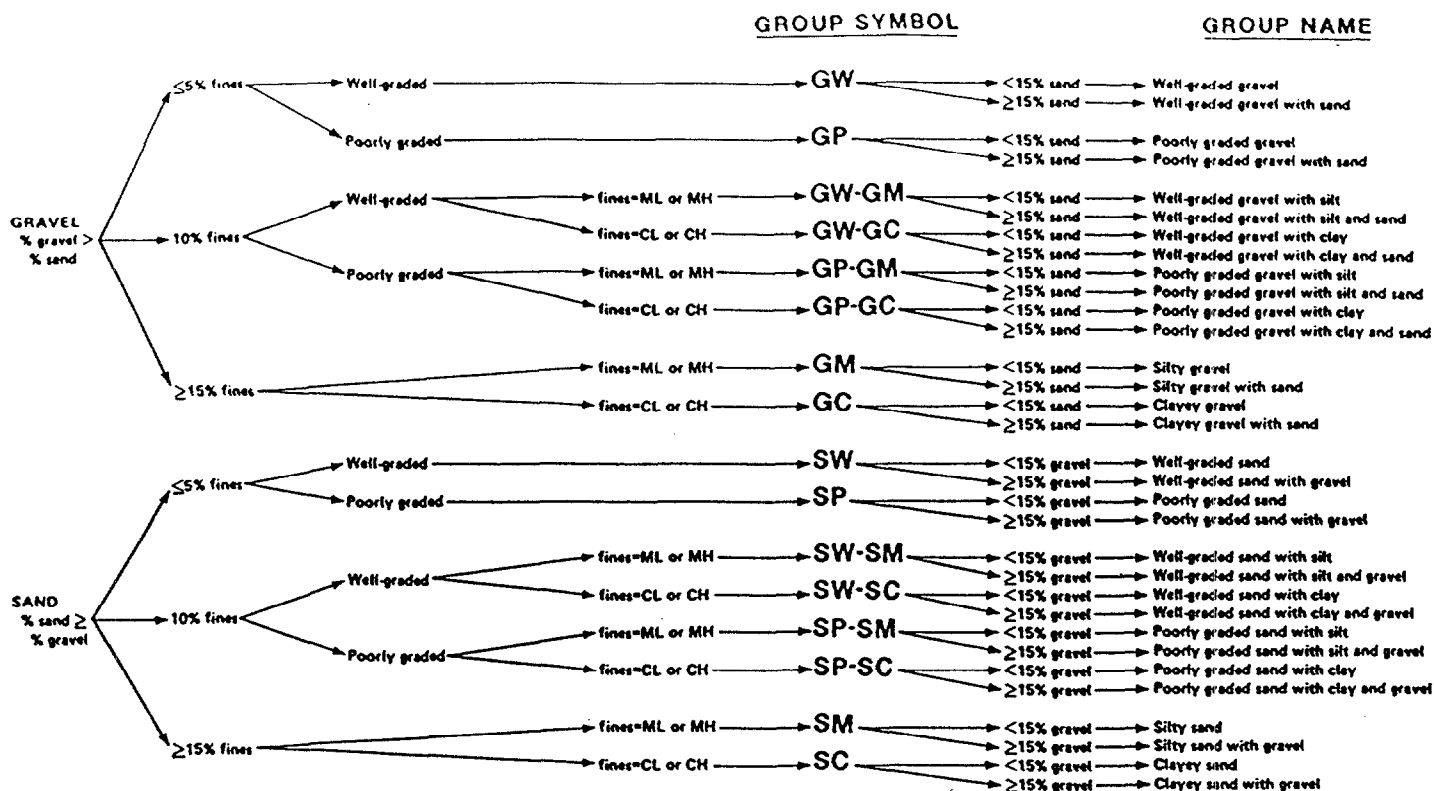
GROUP SYMBOL

GROUP NAME



Note—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

FIG. 1b Flow Chart for Identifying Organic Fine-Grained Soil (50 % or more fines)



NOTE—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

FIG. 2 Flow Chart for Identifying Coarse-Grained Soils (less than 50 % fines)

when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart.

Borderline Symbol—A borderline symbol is two symbols separated by a slash, for example, CL/CH, GM/SM, CL/ML. A borderline symbol should be used to indicate that the soil has been identified as having properties that do not distinctly place the soil into a specific group (see Appendix X3).

5. Significance and Use

5.1 The descriptive information required in this practice can be used to describe a soil to aid in the evaluation of its significant properties for engineering use.

5.2 The descriptive information required in this practice should be used to supplement the classification of a soil as determined by Test Method D 2487.

5.3 This practice may be used in identifying soils using the classification group symbols and names as prescribed in Test Method D 2487. Since the names and symbols used in this practice to identify the soils are the same as those used in Test Method D 2487, it shall be clearly stated in reports and all other appropriate documents, that the classification symbol and name are based on visual-manual procedures.

5.4 This practice is to be used not only for identification of soils in the field, but also in the office, laboratory, or wherever soil samples are inspected and described.

5.5 This practice has particular value in grouping similar soil samples so that only a minimum number of laboratory tests need be run for positive soil classification.

NOTE 4—The ability to describe and identify soils correctly is learned more readily under the guidance of experienced personnel, but it may also be acquired systematically by comparing numerical laboratory test

results for typical soils of each type with their visual and manual characteristics.

5.6 When describing and identifying soil samples from a given boring, test pit, or group of borings or pits, it is not necessary to follow all of the procedures in this practice for every sample. Soils which appear to be similar can be grouped together; one sample completely described and identified with the others referred to as similar based on performing only a few of the descriptive and identification procedures described in this practice.

5.7 This practice may be used in combination with Practice D 4083 when working with frozen soils.

6. Apparatus

6.1 *Required Apparatus:*

6.1.1 *Pocket Knife or Small Spatula.*

6.2 *Useful Auxiliary Apparatus:*

6.2.1 *Small Test Tube and Stopper (or jar with a lid).*

6.2.2 *Small Hand Lens.*

7. Reagents

7.1 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean water from a city water supply or natural source, including non-potable water.

7.2 *Hydrochloric Acid*—A small bottle of dilute hydrochloric acid, HCl, one part HCl (10 N) to three parts water (This reagent is optional for use with this practice). See Section 8.

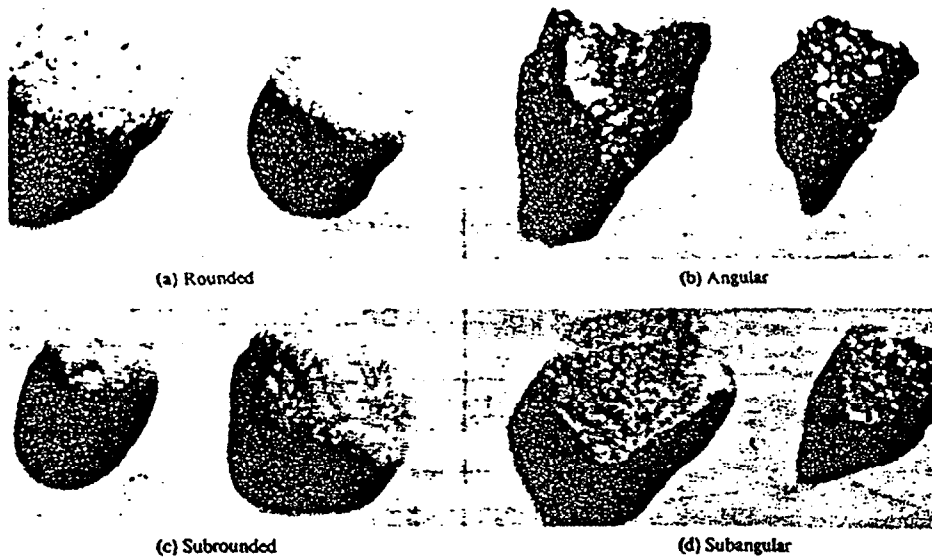


FIG. 3 Typical Angularity of Bulky Grains

8. Safety Precautions

8.1 When preparing the dilute HCl solution of one part concentrated hydrochloric acid (10 N) to three parts of distilled water, slowly add acid into water following necessary safety precautions. Handle with caution and store safely. If contact comes into contact with the skin, rinse thoroughly with water.

8.2 Caution—Do not add water to acid.

9. Sampling

9.1 The sample shall be considered to be representative of the stratum from which it was obtained by an appropriate, accepted, or standard procedure.

NOTE 5—Preferably, the sampling procedure should be identified as having been conducted in accordance with Practices D 1452, D 1587, or D 2113, or Method D 1586.

9.2 The sample shall be carefully identified as to origin.

NOTE 6—Remarks as to the origin may take the form of a boring number and sample number in conjunction with a job number, a geologic stratum, a pedologic horizon or a location description with respect to a permanent monument, a grid system or a station number and offset with respect to a stated centerline and a depth or elevation.

9.3 For accurate description and identification, the minimum amount of the specimen to be examined shall be in

TABLE 1 Criteria for Describing Angularity of Coarse-Grained Particles (see Fig. 3)

Description	Criteria
Angular	Particles have sharp edges and relatively plane sides with unpolished surfaces
Subangular	Particles are similar to angular description but have rounded edges
Subrounded	Particles have nearly plane sides but have well-rounded corners and edges
Rounded	Particles have smoothly curved sides and no edges

accordance with the following schedule:

Maximum Particle Size, Sieve Opening	Minimum Specimen Size, Dry Weight
4.75 mm (No. 4)	100 g (0.5 lb)
9.5 mm (3/8 in.)	200 g (0.5 lb)
19.0 mm (3/4 in.)	1.0 kg (2.2 lb)
38.1 mm (1 1/2 in.)	8.0 kg (18 lb)
75.0 mm (3 in.)	60.0 kg (132 lb)

NOTE 7—If random isolated particles are encountered that are significantly larger than the particles in the soil matrix, the soil matrix can be accurately described and identified in accordance with the preceding schedule.

9.4 If the field sample or specimen being examined is smaller than the minimum recommended amount, the report shall include an appropriate remark.

10. Descriptive Information for Soils

10.1 Angularity—Describe the angularity of the sand (coarse sizes only), gravel, cobbles, and boulders, as angular, subangular, subrounded, or rounded in accordance with the criteria in Table 1 and Fig. 3. A range of angularity may be stated, such as: subrounded to rounded.

10.2 Shape—Describe the shape of the gravel, cobbles, and boulders as flat, elongated, or flat and elongated if they meet the criteria in Table 2 and Fig. 4. Otherwise, do not mention the shape. Indicate the fraction of the particles that have the shape, such as: one-third of the gravel particles are flat.

10.3 Color—Describe the color. Color is an important property in identifying organic soils, and within a given

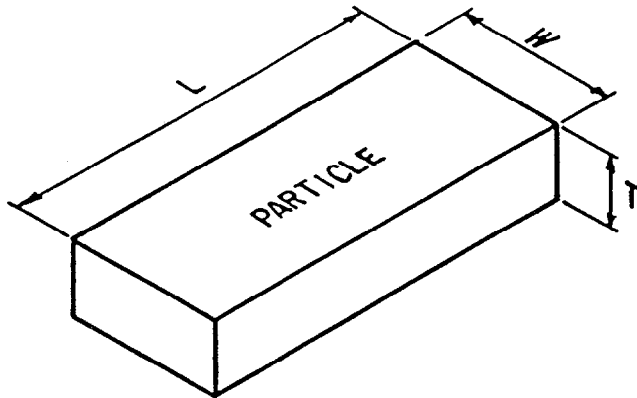
TABLE 2 Criteria for Describing Particle Shape (see Fig. 4)

The particle shape shall be described as follows where length, width, and thickness refer to the greatest, intermediate, and least dimensions of a particle, respectively.

Flat	Particles with width/thickness > 3
Elongated	Particles with length/width > 3
Flat and elongated	Particles meet criteria for both flat and elongated

PARTICLE SHAPE

W = WIDTH
T = THICKNESS
L = LENGTH



FLAT: $W/T > 3$
ELONGATED: $L/W > 3$
FLAT AND ELONGATED:
- meets both criteria

FIG. 4 Criteria for Particle Shape

TABLE 3 Criteria for Describing Moisture Condition

Description	Criteria
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, usually soil is below water table

locality it may also be useful in identifying materials of similar geologic origin. If the sample contains layers or patches of varying colors, this shall be noted and all representative colors shall be described. The color shall be described for moist samples. If the color represents a dry condition, this shall be stated in the report.

10.4 *Odor*—Describe the odor if organic or unusual. Soils containing a significant amount of organic material usually have a distinctive odor of decaying vegetation. This is especially apparent in fresh samples, but if the samples are dried, the odor may often be revived by heating a moistened sample. If the odor is unusual (petroleum product, chemical, and the like), it shall be described.

10.5 *Moisture Condition*—Describe the moisture condition as dry, moist, or wet, in accordance with the criteria in Table 3.

10.6 *HCl Reaction*—Describe the reaction with HCl as none, weak, or strong, in accordance with the criteria in Table 4. Since calcium carbonate is a common cementing agent, a report of its presence on the basis of the reaction with dilute hydrochloric acid is important.

TABLE 4 Criteria for Describing the Reaction With HCl

Description	Criteria
None	No visible reaction
Weak	Some reaction, with bubbles forming slowly
Strong	Violent reaction, with bubbles forming immediately

TABLE 5 Criteria for Describing Consistency

Description	Criteria
Very soft	Thumb will penetrate soil more than 1 in. (25 mm)
Soft	Thumb will penetrate soil about 1 in. (25 mm)
Firm	Thumb will indent soil about 1/4 in. (6 mm)
Hard	Thumb will not indent soil but readily indented with thumbnail
Very hard	Thumbnail will not indent soil

10.7 *Consistency*—For intact fine-grained soil, describe the consistency as very soft, soft, firm, hard, or very hard, in accordance with the criteria in Table 5. This observation is inappropriate for soils with significant amounts of gravel.

10.8 *Cementation*—Describe the cementation of intact coarse-grained soils as weak, moderate, or strong, in accordance with the criteria in Table 6.

10.9 *Structure*—Describe the structure of intact soils in accordance with the criteria in Table 7.

10.10 *Range of Particle Sizes*—For gravel and sand components, describe the range of particle sizes within each component as defined in 3.1.2 and 3.1.6. For example, about 20 % fine to coarse gravel, about 40 % fine to coarse sand.

10.11 *Maximum Particle Size*—Describe the maximum particle size found in the sample in accordance with the following information:

10.11.1 *Sand Size*—If the maximum particle size is a sand size, describe as fine, medium, or coarse as defined in 3.1.6. For example: maximum particle size, medium sand.

10.11.2 *Gravel Size*—If the maximum particle size is a gravel size, describe the maximum particle size as the smallest sieve opening that the particle will pass. For example, maximum particle size, 1 1/2 in. (will pass a 1 1/2-in. square opening but not a 3/4-in. square opening).

10.11.3 *Cobble or Boulder Size*—If the maximum particle size is a cobble or boulder size, describe the maximum dimension of the largest particle. For example: maximum dimension, 18 in. (450 mm).

10.12 *Hardness*—Describe the hardness of coarse sand and larger particles as hard, or state what happens when the particles are hit by a hammer, for example, gravel-size particles fracture with considerable hammer blow, some gravel-size particles crumble with hammer blow. "Hard" means particles do not crack, fracture, or crumble under a hammer blow.

10.13 Additional comments shall be noted, such as the presence of roots or root holes, difficulty in drilling or augering hole, caving of trench or hole, or the presence of mica.

10.14 A local or commercial name or a geologic interpre-

TABLE 6 Criteria for Describing Cementation

Description	Criteria
Weak	Crumbles or breaks with handling or little finger pressure
Moderate	Crumbles or breaks with considerable finger pressure
Strong	Will not crumble or break with finger pressure

TABLE 7 Criteria for Describing Structure

Description	Criteria
Stratified	Alternating layers of varying material or color with layers at least 6 mm thick; note thickness
Laminated	Alternating layers of varying material or color with the layers less than 6 mm thick; note thickness
Fissured	Breaks along definite planes of fracture with little resistance to fracturing
Slickensided	Fracture planes appear polished or glossy, sometimes striated
Blocky	Cohesive soil that can be broken down into small angular lumps which resist further breakdown
Lensed	Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay; note thickness
Homogeneous	Same color and appearance throughout

tation of the soil, or both, may be added if identified as such.
 10.15 A classification or identification of the soil in accordance with other classification systems may be added if identified as such.

11. Identification of Peat

11.1 A sample composed primarily of vegetable tissue in various stages of decomposition that has a fibrous to amorphous texture, usually a dark brown to black color, and an organic odor, shall be designated as a highly organic soil and shall be identified as peat, PT, and not subjected to the identification procedures described hereafter.

12. Preparation for Identification

2.1 The soil identification portion of this practice is used on the portion of the soil sample that will pass a 3-in. (75-mm) sieve. The larger than 3-in. (75-mm) particles must be removed, manually, for a loose sample, or mentally, for an intact sample before classifying the soil.

12.2 Estimate and note the percentage of cobbles and the percentage of boulders. Performed visually, these estimates will be on the basis of volume percentage.

NOTE 8—Since the percentages of the particle-size distribution in Test Method D 2487 are by dry weight, and the estimates of percentages for gravel, sand, and fines in this practice are by dry weight, it is recommended that the report state that the percentages of cobbles and boulders are by volume.

12.3 Of the fraction of the soil smaller than 3 in. (75 mm), estimate and note the percentage, by dry weight, of the gravel, sand, and fines (see Appendix X4 for suggested procedures).

NOTE 9—Since the particle-size components appear visually on the basis of volume, considerable experience is required to estimate the percentages on the basis of dry weight. Frequent comparisons with laboratory particle-size analyses should be made.

12.3.1 The percentages shall be estimated to the closest 5 %. The percentages of gravel, sand, and fines must add up to 100 %.

12.3.2 If one of the components is present but not in sufficient quantity to be considered 5 % of the smaller than 3-in. (75-mm) portion, indicate its presence by the term *trace*, for example, trace of fines. A trace is not to be considered in the total of 100 % for the components.

13. Preliminary Identification

13.1 The soil is *fine grained* if it contains 50 % or more

fines. Follow the procedures for identifying fine-grained soils of Section 14.

13.2 The soil is *coarse grained* if it contains less than 50 % fines. Follow the procedures for identifying coarse-grained soils of Section 15.

14. Procedure for Identifying Fine-Grained Soils

14.1 Select a representative sample of the material for examination. Remove particles larger than the No. 40 sieve (medium sand and larger) until a specimen equivalent to about a handful of material is available. Use this specimen for performing the dry strength, dilatancy, and toughness tests.

14.2 Dry Strength:

14.2.1 From the specimen, select enough material to mold into a ball about 1 in. (25 mm) in diameter. Mold the material until it has the consistency of putty, adding water if necessary.

14.2.2 From the molded material, make at least three test specimens. A test specimen shall be a ball of material about ½ in. (12 mm) in diameter. Allow the test specimens to dry in air, or sun, or by artificial means, as long as the temperature does not exceed 60°C.

14.2.3 If the test specimen contains natural dry lumps, those that are about ½ in. (12 mm) in diameter may be used in place of the molded balls.

NOTE 10—The process of molding and drying usually produces higher strengths than are found in natural dry lumps of soil.

14.2.4 Test the strength of the dry balls or lumps by crushing between the fingers. Note the strength as none, low, medium, high, or very high in accordance with the criteria in Table 8. If natural dry lumps are used, do not use the results of any of the lumps that are found to contain particles of coarse sand.

14.2.5 The presence of high-strength water-soluble cementing materials, such as calcium carbonate, may cause exceptionally high dry strengths. The presence of calcium carbonate can usually be detected from the intensity of the reaction with dilute hydrochloric acid (see 10.6).

14.3 Dilatancy:

14.3.1 From the specimen, select enough material to mold into a ball about ½ in. (12 mm) in diameter. Mold the material, adding water if necessary, until it has a soft, but not sticky, consistency.

14.3.2 Smooth the soil ball in the palm of one hand with the blade of a knife or small spatula. Shake horizontally, striking the side of the hand vigorously against the other hand several times. Note the reaction of water appearing on

TABLE 8 Criteria for Describing Dry Strength

Description	Criteria
None	The dry specimen crumbles into powder with mere pressure of handling
Low	The dry specimen crumbles into powder with some finger pressure
Medium	The dry specimen breaks into pieces or crumbles with considerable finger pressure
High	The dry specimen cannot be broken with finger pressure. Specimen will break into pieces between thumb and a hard surface
Very high	The dry specimen cannot be broken between the thumb and a hard surface

TABLE 9 Criteria for Describing Dilatancy

Description	Criteria
None	No visible change in the specimen
Slow	Water appears slowly on the surface of the specimen during shaking and does not disappear or disappears slowly upon squeezing
Rapid	Water appears quickly on the surface of the specimen during shaking and disappears quickly upon squeezing

TABLE 10 Criteria for Describing Toughness

Description	Criteria
Low	Only slight pressure is required to roll the thread near the plastic limit. The thread and the lump are weak and soft
Medium	Medium pressure is required to roll the thread to near the plastic limit. The thread and the lump have medium stiffness
High	Considerable pressure is required to roll the thread to near the plastic limit. The thread and the lump have very high stiffness

the surface of the soil. Squeeze the sample by closing the hand or pinching the soil between the fingers, and note the reaction as none, slow, or rapid in accordance with the criteria in Table 9. The reaction is the speed with which water appears while shaking, and disappears while squeezing.

14.4 Toughness:

14.4.1 Following the completion of the dilatancy test, the test specimen is shaped into an elongated pat and rolled by hand on a smooth surface or between the palms into a thread about 1/8 in. (3 mm) in diameter. (If the sample is too wet to roll easily, it should be spread into a thin layer and allowed to lose some water by evaporation.) Fold the sample threads and reroll repeatedly until the thread crumbles at a diameter of about 1/8 in. The thread will crumble at a diameter of 1/8 in. when the soil is near the plastic limit. Note the pressure required to roll the thread near the plastic limit. Also, note the strength of the thread. After the thread crumbles, the pieces should be lumped together and kneaded until the lump crumbles. Note the toughness of the material during kneading.

14.4.2 Describe the toughness of the thread and lump as low, medium, or high in accordance with the criteria in Table 10.

14.5 Plasticity—On the basis of observations made during the toughness test, describe the plasticity of the material in accordance with the criteria given in Table 11.

14.6 Decide whether the soil is an *inorganic* or an *organic* fine-grained soil (see 14.8). If inorganic, follow the steps given in 14.7.

14.7 Identification of Inorganic Fine-Grained Soils:

TABLE 11 Criteria for Describing Plasticity

Description	Criteria
Nonplastic	A 1/8-in. (3-mm) thread cannot be rolled at any water content
Low	The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit
Medium	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rerolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit

14.7.1 Identify the soil as a *lean clay*, CL, if the soil has medium to high dry strength, no or slow dilatancy, and medium toughness and plasticity (see Table 12).

14.7.2 Identify the soil as a *fat clay*, CH, if the soil has high to very high dry strength, no dilatancy, and high toughness and plasticity (see Table 12).

14.7.3 Identify the soil as a *silt*, ML, if the soil has no to low dry strength, slow to rapid dilatancy, and low toughness and plasticity, or is nonplastic (see Table 12).

14.7.4 Identify the soil as an *elastic silt*, MH, if the soil has low to medium dry strength, no to slow dilatancy, and low to medium toughness and plasticity (see Table 12).

NOTE 11—These properties are similar to those for a lean clay. However, the silt will dry quickly on the hand and have a smooth, silky feel when dry. Some soils that would classify as MH in accordance with the criteria in Test Method D 2487 are visually difficult to distinguish from lean clays, CL. It may be necessary to perform laboratory testing for proper identification.

14.8 Identification of Organic Fine-Grained Soils:

14.8.1 Identify the soil as an *organic soil*, OL/OH, if the soil contains enough organic particles to influence the soil properties. Organic soils usually have a dark brown to black color and may have an organic odor. Often, organic soils will change color, for example, black to brown, when exposed to the air. Some organic soils will lighten in color significantly when air dried. Organic soils normally will not have a high toughness or plasticity. The thread for the toughness test will be spongy.

NOTE 12—In some cases, through practice and experience, it may be possible to further identify the organic soils as organic silts or organic clays, OL or OH. Correlations between the dilatancy, dry strength, toughness tests, and laboratory tests can be made to identify organic soils in certain deposits of similar materials of known geologic origin.

14.9 If the soil is estimated to have 15 to 25 % sand or gravel, or both, the words “with sand” or “with gravel” (whichever is more predominant) shall be added to the group name. For example: “lean clay with sand, CL” or “silt with gravel, ML” (see Figs. 1a and 1b). If the percentage of sand is equal to the percentage of gravel, use “with sand.”

14.10 If the soil is estimated to have 30 % or more sand or gravel, or both, the words “sandy” or “gravelly” shall be added to the group name. Add the word “sandy” if there appears to be more sand than gravel. Add the word “gravelly” if there appears to be more gravel than sand. For example: “sandy lean clay, CL”, “gravelly fat clay, CH”, or “sandy silt, ML” (see Figs. 1a and 1b). If the percentage of sand is equal to the percent of gravel, use “sandy.”

15. Procedure for Identifying Coarse-Grained Soils (Contains less than 50 % fines)

15.1 The soil is a *gravel* if the percentage of gravel is estimated to be more than the percentage of sand.

TABLE 12 Identification of Inorganic Fine-Grained Soils from Manual Tests

Soil Symbol	Dry Strength	Dilatancy	Toughness
ML	None to low	Slow to rapid	Low or thread cannot be formed
CL	Medium to high	None to slow	Medium
MH	Low to medium	None to slow	Low to medium
CH	High to very high	None	High

TABLE 13 Checklist for Description of Soils

1. Group name
2. Group symbol
3. Percent of cobbles or boulders, or both (by volume)
4. Percent of gravel, sand, or fines, or all three (by dry weight)
5. Particle-size range:
Gravel—fine, coarse
Sand—fine, medium, coarse
6. Particle angularity: angular, subangular, subrounded, rounded
7. Particle shape: (if appropriate) flat, elongated, flat and elongated
8. Maximum particle size or dimension
9. Hardness of coarse sand and larger particles
10. Plasticity of fines: nonplastic, low, medium, high
11. Dry strength: none, low, medium, high, very high
12. Dilatancy: none, slow, rapid
13. Toughness: low, medium, high
14. Color (in moist condition)
15. Odor (mention only if organic or unusual)
16. Moisture: dry, moist, wet
17. Reaction with HCl: none, weak, strong
For intact samples:
18. Consistency (fine-grained soils only): very soft, soft, firm, hard, very hard
19. Structure: stratified, laminated, fissured, slickensided, lensed, homogeneous
20. Cementation: weak, moderate, strong
21. Local name
22. Geologic interpretation
23. Additional comments: presence of roots or root holes, presence of mica, gypsum, etc., surface coatings on coarse-grained particles, caving or sloughing of auger hole or trench sides, difficulty in augering or excavating, etc.

reaction with HCl; original field sample had about 5 % (by volume) subrounded cobbles, maximum dimension, 150 mm.

In-Place Conditions—Firm, homogeneous, dry, brown

Geologic Interpretation—Alluvial fan

NOTE 14—Other examples of soil descriptions and identification are given in Appendixes X1 and X2.

NOTE 15—If desired, the percentages of gravel, sand, and fines may be stated in terms indicating a range of percentages, as follows:

Trace—Particles are present but estimated to be less than 5 %

Few—5 to 10 %

Little—15 to 25 %

Some—30 to 45 %

Mostly—50 to 100 %

16.2 If, in the soil description, the soil is identified using a classification group symbol and name as described in Test Method D 2487, it must be distinctly and clearly stated in log forms, summary tables, reports, and the like, that the symbol and name are based on visual-manual procedures.

17. Precision and Bias

17.1 This practice provides qualitative information only, therefore, a precision and bias statement is not applicable.

18. Keywords

18.1 classification; clay; gravel; organic soils; sand; silt; soil classification; soil description; visual classification

15.2 The soil is a *sand* if the percentage of gravel is estimated to be equal to or less than the percentage of sand.

15.3 The soil is a *clean gravel* or *clean sand* if the percentage of fines is estimated to be 5 % or less.

15.3.1 Identify the soil as a *well-graded gravel*, GW, or as a *well-graded sand*, SW, if it has a wide range of particle sizes and substantial amounts of the intermediate particle sizes.

15.3.2 Identify the soil as a *poorly graded gravel*, GP, or as a *poorly graded sand*, SP, if it consists predominantly of one size (uniformly graded), or it has a wide range of sizes with some intermediate sizes obviously missing (gap or skip graded).

15.4 The soil is either a *gravel with fines* or a *sand with fines* if the percentage of fines is estimated to be 15 % or more.

15.4.1 Identify the soil as a *clayey gravel*, GC, or a *clayey sand*, SC, if the fines are clayey as determined by the procedures in Section 14.

15.4.2 Identify the soil as a *silty gravel*, GM, or a *silty sand*, SM, if the fines are silty as determined by the procedures in Section 14.

15.5 If the soil is estimated to contain 10 % fines, give the soil a dual identification using two group symbols.

15.5.1 The first group symbol shall correspond to a clean gravel or sand (GW, GP, SW, SP) and the second symbol shall correspond to a gravel or sand with fines (GC, GM, SC, SM).

15.5.2 The group name shall correspond to the first group symbol plus the words "with clay" or "with silt" to indicate plasticity characteristics of the fines. For example: "well-graded gravel with clay, GW-GC" or "poorly graded sand with silt, SP-SM" (see Fig. 2).

15.6 If the specimen is predominantly sand or gravel but contains an estimated 15 % or more of the other coarse-grained constituent, the words "with gravel" or "with sand" shall be added to the group name. For example: "poorly graded gravel with sand, GP" or "clayey sand with gravel, SC" (see Fig. 2).

15.7 If the field sample contains any cobbles or boulders, or both, the words "with cobbles" or "with cobbles and boulders" shall be added to the group name. For example: "silty gravel with cobbles, GM."

16. Report

16.1 The report shall include the information as to origin, and the items indicated in Table 13.

NOTE 13—Example: *Clayey Gravel with Sand and Cobbles, GC*—About 50 % fine to coarse, subrounded to subangular gravel; about 30 % fine to coarse, subrounded sand; about 20 % fines with medium plasticity, high dry strength, no dilatancy, medium toughness; weak

APPENDIXES

(Nonmandatory Information)

XI. EXAMPLES OF VISUAL SOIL DESCRIPTIONS

X1.1 The following examples show how the information required in 16.1 can be reported. The information that is included in descriptions should be based on individual circumstances and need.

X1.1.1 *Well-Graded Gravel with Sand (GW)*—About 75 % fine to coarse, hard, subangular gravel; about 25 % fine to coarse, hard, subangular sand; trace of fines; maximum size, 75 mm, brown, dry; no reaction with HCl.

X1.1.2 *Silty Sand with Gravel (SM)*—About 60 % predominantly fine sand; about 25 % silty fines with low plasticity, low dry strength, rapid dilatancy, and low toughness; about 15 % fine, hard, subrounded gravel, a few gravel-size particles fractured with hammer blow; maximum size, 25 mm; no reaction with HCl (Note—Field sample size smaller than recommended).

In-Place Conditions—Firm, stratified and contains lenses of silt 1 to 2 in. (25 to 50 mm) thick, moist, brown to gray;

in-place density 106 lb/ft³; in-place moisture 9 %.

X1.1.3 *Organic Soil (OL/OH)*—About 100 % fines with low plasticity, slow dilatancy, low dry strength, and low toughness; wet, dark brown, organic odor; weak reaction with HCl.

X1.1.4 *Silty Sand with Organic Fines (SM)*—About 75 % fine to coarse, hard, subangular reddish sand; about 25 % organic and silty dark brown nonplastic fines with no dry strength and slow dilatancy; wet; maximum size, coarse sand; weak reaction with HCl.

X1.1.5 *Poorly Graded Gravel with Silt, Sand, Cobbles and Boulders (GP-GM)*—About 75 % fine to coarse, hard, subrounded to subangular gravel; about 15 % fine, hard, subrounded to subangular sand; about 10 % silty nonplastic fines; moist, brown; no reaction with HCl; original field sample had about 5 % (by volume) hard, subrounded cobbles and a trace of hard, subrounded boulders, with a maximum dimension of 18 in. (450 mm).

X2. USING THE IDENTIFICATION PROCEDURE AS A DESCRIPTIVE SYSTEM FOR SHALE, CLAYSTONE, SHELLS, SLAG, CRUSHED ROCK, AND THE LIKE

X2.1 The identification procedure may be used as a descriptive system applied to materials that exist in-situ as shale, claystone, sandstone, siltstone, mudstone, etc., but convert to soils after field or laboratory processing (crushing, slaking, and the like).

X2.2 Materials such as shells, crushed rock, slag, and the like, should be identified as such. However, the procedures used in this practice for describing the particle size and plasticity characteristics may be used in the description of the material. If desired, an identification using a group name and symbol according to this practice may be assigned to aid in describing the material.

X2.3 The group symbol(s) and group names should be placed in quotation marks or noted with some type of distinguishing symbol. See examples.

X2.4 Examples of how group names and symbols can be incorporated into a descriptive system for materials that are not naturally occurring soils are as follows:

X2.4.1 *Shale Chunks*—Retrieved as 2 to 4-in. (50 to

100-mm) pieces of shale from power auger hole, dry, brown, no reaction with HCl. After slaking in water for 24 h, material identified as "Sandy Lean Clay (CL)"; about 60 % fines with medium plasticity, high dry strength, no dilatancy, and medium toughness; about 35 % fine to medium, hard sand; about 5 % gravel-size pieces of shale.

X2.4.2 *Crushed Sandstone*—Product of commercial crushing operation; "Poorly Graded Sand with Silt (SP-SM)"; about 90 % fine to medium sand; about 10 % nonplastic fines; dry, reddish-brown, strong reaction with HCl.

X2.4.3 *Broken Shells*—About 60 % gravel-size broken shells; about 30 % sand and sand-size shell pieces; about 10 % fines; "Poorly Graded Gravel with Sand (GP)."

X2.4.4 *Crushed Rock*—Processed from gravel and cobbles in Pit No. 7; "Poorly Graded Gravel (GP)"; about 90 % fine, hard, angular gravel-size particles; about 10 % coarse, hard, angular sand-size particles; dry, tan; no reaction with HCl.

X3. SUGGESTED PROCEDURE FOR USING A BORDERLINE SYMBOL FOR SOILS WITH TWO POSSIBLE IDENTIFICATIONS.

X3.1 Since this practice is based on estimates of particle size distribution and plasticity characteristics, it may be difficult to clearly identify the soil as belonging to one category. To indicate that the soil may fall into one of two

possible basic groups, a borderline symbol may be used with the two symbols separated by a slash. For example: SC/CL or CL/CH.

X3.1.1 A borderline symbol may be used when the

percentage of fines is estimated to be between 45 and 55 %. One symbol should be for a coarse-grained soil with fines and the other for a fine-grained soil. For example: GM/ML or CL/SC.

X3.1.2 A borderline symbol may be used when the percentage of sand and the percentage of gravel are estimated to be about the same. For example: GP/SP, SC/GC, GM/SM. It is practically impossible to have a soil that would have a borderline symbol of GW/SW.

X3.1.3 A borderline symbol may be used when the soil could be either well graded or poorly graded. For example: GW/GP, SW/SP.

X3.1.4 A borderline symbol may be used when the soil could either be a silt or a clay. For example: CL/ML, CH/MH, SC/SM.

X3.1.5 A borderline symbol may be used when a fine-

grained soil has properties that indicate that it is at the boundary between a soil of low compressibility and a soil of high compressibility. For example: CL/CH, MH/ML.

X3.2 The order of the borderline symbols should reflect similarity to surrounding or adjacent soils. For example: soils in a borrow area have been identified as CH. One sample is considered to have a borderline symbol of CL and CH. To show similarity, the borderline symbol should be CH/CL.

X3.3 The group name for a soil with a borderline symbol should be the group name for the first symbol, except for:

CL/CH lean to fat clay
ML/CL clayey silt
CL/ML silty clay

X3.4 The use of a borderline symbol should not be used indiscriminately. Every effort shall be made to first place the soil into a single group.

X4. SUGGESTED PROCEDURES FOR ESTIMATING THE PERCENTAGES OF GRAVEL, SAND, AND FINES IN A SOIL SAMPLE

X4.1 *Jar Method*—The relative percentage of coarse- and fine-grained material may be estimated by thoroughly shaking a mixture of soil and water in a test tube or jar, and then allowing the mixture to settle. The coarse particles will fall to the bottom and successively finer particles will be deposited with increasing time; the sand sizes will fall out of suspension in 20 to 30 s. The relative proportions can be estimated from the relative volume of each size separate. This method should be correlated to particle-size laboratory terminations.

X4.2 *Visual Method*—Mentally visualize the gravel size particles placed in a sack (or other container) or sacks. Then, do the same with the sand size particles and the fines. Then, mentally compare the number of sacks to estimate the percentage of plus No. 4 sieve size and minus No. 4 sieve size

present. The percentages of sand and fines in the minus sieve size No. 4 material can then be estimated from the wash test (X4.3).

X4.3 *Wash Test (for relative percentages of sand and fines)*—Select and moisten enough minus No. 4 sieve size material to form a 1-in (25-mm) cube of soil. Cut the cube in half, set one-half to the side, and place the other half in a small dish. Wash and decant the fines out of the material in the dish until the wash water is clear and then compare the two samples and estimate the percentage of sand and fines. Remember that the percentage is based on weight, not volume. However, the volume comparison will provide a reasonable indication of grain size percentages.

X4.3.1 While washing, it may be necessary to break down lumps of fines with the finger to get the correct percentages.

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Standard Test Method for Classification of Soils for Engineering Purposes¹

This standard is issued under the fixed designation D 2487; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This test method has been approved for use by agencies of the Department of Defense. Consult the DOD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This test method describes a system for classifying mineral and organo-mineral soils for engineering purposes based on laboratory determination of particle-size characteristics, liquid limit, and plasticity index and shall be used when precise classification is required.

NOTE 1—Use of this standard will result in a single classification group symbol and group name except when a soil contains 5 to 12 % fines or when the plot of the liquid limit and plasticity index values falls into the crosshatched area of the plasticity chart. In these two cases, a dual symbol is used, for example, GP-GM, CL-ML. When the laboratory test results indicate that the soil is close to another soil classification group, the borderline condition can be indicated with two symbols separated by a slash. The first symbol should be the one based on this standard, for example, CL/CH, GM/SM, SC/CL. Borderline symbols are particularly useful when the liquid limit value of clayey soils is close to 50. These soils can have expansive characteristics and the use of a borderline symbol (CL/CH, CH/CL) will alert the user of the assigned classifications of expansive potential.

1.2 The group symbol portion of this system is based on laboratory tests performed on the portion of a soil sample passing the 3-in. (75-mm) sieve (see Specification E 11).

1.3 As a classification system, this test method is limited to naturally occurring soils.

NOTE 2—The group names and symbols used in this test method may be used as a descriptive system applied to such materials as shale, claystone, shells, crushed rock, etc. See Appendix X2.

1.4 This test method is for qualitative application only.

NOTE 3—When quantitative information is required for detailed designs of important structures, this test method must be supplemented by laboratory tests or other quantitative data to determine performance characteristics under expected field conditions.

1.5 The system is based on the widely recognized Unified Soil Classification System which was adopted by several U.S. Government agencies in 1952 as an outgrowth of the Airfield Classification System developed by A. Casagrande.²

1.6 *This standard does not purport to address the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

¹ This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.07 on Identification and Classification of Soils.

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² Casagrande, A., "Classification and Identification of Soils," *Transactions*, ASCE, 1948, p. 901.

2. Referenced Documents

2.1 ASTM Standards:

- C 117 Test Method for Materials Finer Than 75- μ m (No. 200) Sieve in Mineral Aggregates by Washing³
- C 136 Method for Sieve Analysis of Fine and Coarse Aggregates³
- C 702 Practice for Reducing Field Samples of Aggregate to Testing Size³
- D 420 Practice for Investigating and Sampling Soil and Rock for Engineering Purposes⁴
- D 421 Practice for Dry Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants⁴
- D 422 Method for Particle-Size Analysis of Soils⁴
- D 653 Terminology Relating to Soil, Rock, and Contained Fluids⁴
- D 1140 Test Method for Amount of Material in Soils Finer than the No. 200 (75- μ m) Sieve⁴
- D 2216 Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures⁴
- D 2217 Practice for Wet Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants⁴
- D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)⁴
- D 4083 Practice for Description of Frozen Soils (Visual-Manual Procedure)⁴
- D 4318 Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils⁴
- D 4427 Classification of Peat Samples by Laboratory Testing⁴
- E 11 Specification for Wire-Cloth Sieves for Testing Purposes³

3. Terminology

3.1 *Definitions*—Except as listed below, all definitions are in accordance with Terms and Symbols D 653.

NOTE 4—For particles retained on a 3-in. (75-mm) U.S. standard sieve, the following definitions are suggested:

Cobbles—particles of rock that will pass a 12-in. (300-mm) square opening and be retained on a 3-in. (75-mm) U.S. standard sieve, and
Boulders—particles of rock that will not pass a 12-in. (300-mm) square opening

3.1.1 *gravel*—particles of rock that will pass a 3-in.

³ *Annual Book of ASTM Standards*, Vol 04.02.

⁴ *Annual Book of ASTM Standards*, Vol 04.08.

(75-mm) sieve and be retained on a No. 4 (4.75-mm) U.S. standard sieve with the following subdivisions:

Coarse—passes 3-in. (75-mm) sieve and retained on ¾-in. (19-mm) sieve, and

Fine—passes ¾-in. (19-mm) sieve and retained on No. 4 (4.75-mm) sieve.

3.1.2 *sand*—particles of rock that will pass a No. 4 (4.75-mm) sieve and be retained on a No. 200 (75-µm) U.S. standard sieve with the following subdivisions:

Coarse—passes No. 4 (4.75-mm) sieve and retained on No. 10 (2.00-mm) sieve,

Medium—passes No. 10 (2.00-mm) sieve and retained on No. 40 (425-µm) sieve, and

Fine—passes No. 40 (425-µm) sieve and retained on No. 200 (75-µm) sieve.

3.1.3 *clay*—soil passing a No. 200 (75-µm) U.S. standard sieve that can be made to exhibit plasticity (putty-like properties) within a range of water contents and that exhibits considerable strength when air dry. For classification, a clay is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index equal to or greater than 4, and the plot of plasticity index versus liquid limit falls on or above the “A” line.

3.1.4 *silt*—soil passing a No. 200 (75-µm) U.S. standard sieve that is nonplastic or very slightly plastic and that exhibits little or no strength when air dry. For classification, a silt is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index less than 4 or if the plot of plasticity index versus liquid limit falls below the “A” line.

3.1.5 *organic clay*—a clay with sufficient organic content influence the soil properties. For classification, an organic clay is a soil that would be classified as a clay except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.6 *organic silt*—a silt with sufficient organic content to influence the soil properties. For classification, an organic silt is a soil that would be classified as a silt except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.7 *peat*—a soil composed of vegetable tissue in various stages of decomposition usually with an organic odor, a dark-brown to black color, a spongy consistency, and a texture ranging from fibrous to amorphous.

3.2 Descriptions of Terms Specific to This Standard:

3.2.1 *coefficient of curvature, C_c*—the ratio $(D_{30})^2 / (D_{10} \times D_{60})$, where D_{60} , D_{30} , and D_{10} are the particle diameters corresponding to 60, 30, and 10 % finer on the cumulative particle-size distribution curve, respectively.

3.2.2 *coefficient of uniformity, C_u*—the ratio D_{60} / D_{10} , where D_{60} and D_{10} are the particle diameters corresponding to 60 and 10 % finer on the cumulative particle-size distribution curve, respectively.

4. Summary of Test Method

4.1 As illustrated in Table 1, this classification system identifies three major soil divisions: coarse-grained soils, fine-grained soils, and highly organic soils. These three divisions further subdivided into a total of 15 basic soil groups.

4.2 Based on the results of visual observations and prescribed laboratory tests, a soil is catalogued according to the basic soil groups, assigned a group symbol(s) and name, and

thereby classified. The flow charts, Fig. 1 for fine-grained soils, and Fig. 2 for coarse-grained soils, can be used to assign the appropriate group symbol(s) and name.

5. Significance and Use

5.1 This test method classifies soils from any geographic location into categories representing the results of prescribed laboratory tests to determine the particle-size characteristics, the liquid limit, and the plasticity index.

5.2 The assigning of a group name and symbol(s) along with the descriptive information required in Practice D 2488 can be used to describe a soil to aid in the evaluation of its significant properties for engineering use.

5.3 The various groupings of this classification system have been devised to correlate in a general way with the engineering behavior of soils. This test method provides a useful first step in any field or laboratory investigation for geotechnical engineering purposes.

5.4 This test method may also be used as an aid in training personnel in the use of Practice D 2488.

5.5 This test method may be used in combination with Practice D 4083 when working with frozen soils.

6. Apparatus

6.1 In addition to the apparatus that may be required for obtaining and preparing the samples and conducting the prescribed laboratory tests, a plasticity chart, similar to Fig. 3, and a cumulative particle-size distribution curve, similar to Fig. 4, are required.

NOTE 5—The “U” line shown on Fig. 3 has been empirically determined to be the approximate “upper limit” for natural soils. It is a good check against erroneous data, and any test results that plot above or to the left of it should be verified.

7. Sampling

7.1 Samples shall be obtained and identified in accordance with a method or methods, recommended in Recommended Practice D 420 or by other accepted procedures.

7.2 For accurate identification, the minimum amount of test sample required for this test method will depend on which of the laboratory tests need to be performed. Where only the particle-size analysis of the sample is required, specimens having the following minimum dry weights are required:

Maximum Particle Size, Sieve Opening	Minimum Specimen Size, Dry Weight
4.75 mm (No. 4)	100 g (0.25 lb)
9.5 mm (¾ in.)	200 g (0.5 lb)
19.0 mm (¾ in.)	1.0 kg (2.2 lb)
38.1 mm (1½ in.)	8.0 kg (18 lb)
75.0 mm (3 in.)	60.0 kg (132 lb)

Whenever possible, the field samples should have weights two to four times larger than shown.

7.3 When the liquid and plastic limit tests must also be performed, additional material will be required sufficient to provide 150 g to 200 g of soil finer than the No. 40 (425-µm) sieve.

7.4 If the field sample or test specimen is smaller than the minimum recommended amount, the report shall include an appropriate remark.

TABLE 1 Soil Classification Chart

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests ^A				Soil Classification	
				Group Symbol	Group Name ^B
Coarse-Grained Soils More than 50 % retained on No. 200 sieve	Gravels More than 50 % of coarse fraction retained on No. 4 sieve	Clean Gravels Less than 5 % fines ^C	$Cu \geq 4$ and $1 \leq Cc \leq 3^E$	GW	Well-graded gravel ^F
		Gravels with Fines More than 12 % fines ^C	$Cu < 4$ and/or $1 > Cc > 3^E$	GP	Poorly graded gravel ^F
			Fines classify as ML or MH	GM	Silty gravel ^{F,G,H}
	Sands 50 % or more of coarse fraction passes No. 4 sieve	Clean Sands Less than 5 % fines ^D	$Cu \geq 6$ and $1 \leq Cc \leq 3^E$	SW	Well-graded sand
		Sands with Fines More than 12 % fines ^D	$Cu < 6$ and/or $1 > Cc > 3^E$	SP	Poorly graded sand ^F
			Fines classify as ML or MH	SM	Silty sand ^{G,H,I}
Fine-Grained Soils 50 % or more passes the No. 200 sieve	Silt and Clays Liquid limit less than 50	inorganic	$PI > 7$ and plots on or above "A" line ^J	CL	Lean clay ^{K,L,M}
		organic	$PI < 4$ or plots below "A" line ^J	ML	Silt ^{K,L,M}
	Silt and Clays Liquid limit 50 or more	inorganic	Liquid limit - oven dried / Liquid limit - not dried < 0.75	OL	Organic clay ^{K,L,M,N} Organic silt ^{K,L,M,O}
			PI plots on or above "A" line	CH	Fat clay ^{K,L,M}
		organic	PI plots below "A" line	MH	Elastic silt ^{K,L,M}
			Liquid limit - oven dried / Liquid limit - not dried < 0.75	OH	Organic clay ^{K,L,M,P} Organic silt ^{K,L,M,O}
Highly organic soils	Primarily organic matter, dark in color, and organic odor		PT	Peat	

^A Based on the material passing the 3-in. (75-mm) sieve.

^B If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

^C Gravels with 5 to 12 % fines require dual symbols:

- GW-GM well-graded gravel with silt
- GW-GC well-graded gravel with clay
- GP-GM poorly graded gravel with silt
- GP-GC poorly graded gravel with clay

^D Sands with 5 to 12 % fines require dual symbols:

- SW-SM well-graded sand with silt
- SW-SC well-graded sand with clay
- SP-SM poorly graded sand with silt
- SP-SC poorly graded sand with clay

$$^E Cu = D_{60}/D_{10} \quad Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$$

^F If soil contains ≥ 15 % sand, add "with sand" to group name.

^G If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

^H If fines are organic, add "with organic fines" to group name.

^I If soil contains ≥ 15 % gravel, add "with gravel" to group name.

^J If Atterberg limits plot in hatched area, soil is a CL-ML, silty clay.

^K If soil contains 15 to 29 % plus No. 200, add "with sand" or "with gravel," whichever is predominant.

^L If soil contains ≥ 30 % plus No. 200, predominantly sand, add "sandy" to group name.

^M If soil contains ≥ 30 % plus No. 200, predominantly gravel, add "gravelly" to group name.

^N $PI \geq 4$ and plots on or above "A" line.

^O $PI < 4$ or plots below "A" line.

^P PI plots on or above "A" line.

^Q PI plots below "A" line.

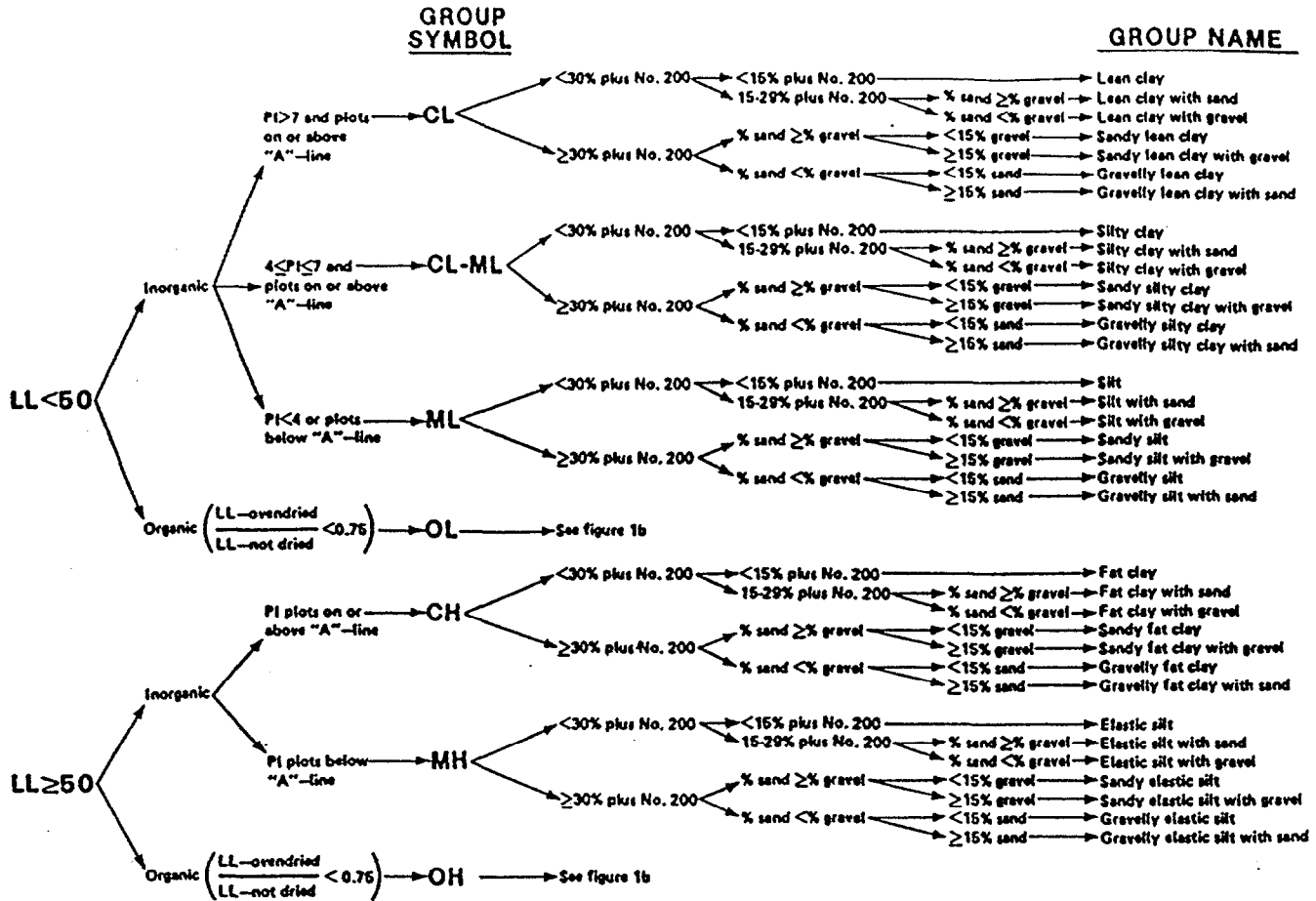


FIG. 1a Flow Chart for Classifying Fine-Grained Soil (50 % or More Passes No. 200 Sieve)

8. Classification of Peat

8.1 A sample composed primarily of vegetable tissue in various stages of decomposition and has a fibrous to amorphous texture, a dark-brown to black color, and an organic odor should be designated as a highly organic soil and shall be classified as peat, PT, and not subjected to the classification procedures described hereafter.

8.2 If desired, classification of type of peat can be performed in accordance with Classification D 4427.

9. Preparation for Classification

9.1 Before a soil can be classified according to this test method, generally the particle-size distribution of the minus 3-in. (75-mm) material and the plasticity characteristics of the minus No. 40 (425-μm) sieve material must be determined. See 9.8 for the specific required tests.

9.2 The preparation of the soil specimen(s) and the testing for particle-size distribution and liquid limit and plasticity index shall be in accordance with accepted standard procedures. Two procedures for preparation of the soil specimens for testing for soil classification purposes are given in appendixes X3 and X4. Appendix X3 describes the wet preparation method and is the preferred method for cohesive soils that have never dried out and for organic soils.

9.3 When reporting soil classifications determined by this test method, the preparation and test procedures used shall be reported or referenced.

9.4 Although the test procedure used in determining the particle-size distribution or other considerations may require a hydrometer analysis of the material, a hydrometer analysis is not necessary for soil classification.

9.5 The percentage (by dry weight) of any plus 3-in. (75-mm) material must be determined and reported as auxiliary information.

9.6 The maximum particle size shall be determined (measured or estimated) and reported as auxiliary information.

9.7 When the cumulative particle-size distribution is required, a set of sieves shall be used which include the following sizes (with the largest size commensurate with the maximum particle size) with other sieve sizes as needed or required to define the particle-size distribution:

- 3-in. (75-mm)
- ¾-in. (19.0-mm)
- No. 4 (4.75-mm)
- No. 10 (2.00-mm)
- No. 40 (425-μm)
- No. 200 (75-μm)

9.8 The tests required to be performed in preparation for classification are as follows:

9.8.1 For soils estimated to contain less than 5 % fines, a plot of the cumulative particle-size distribution curve of the fraction coarser than the No. 200 (75-μm) sieve is required. The cumulative particle-size distribution curve may be plotted on a graph similar to that shown in Fig. 4.

GROUP SYMBOL

GROUP NAME

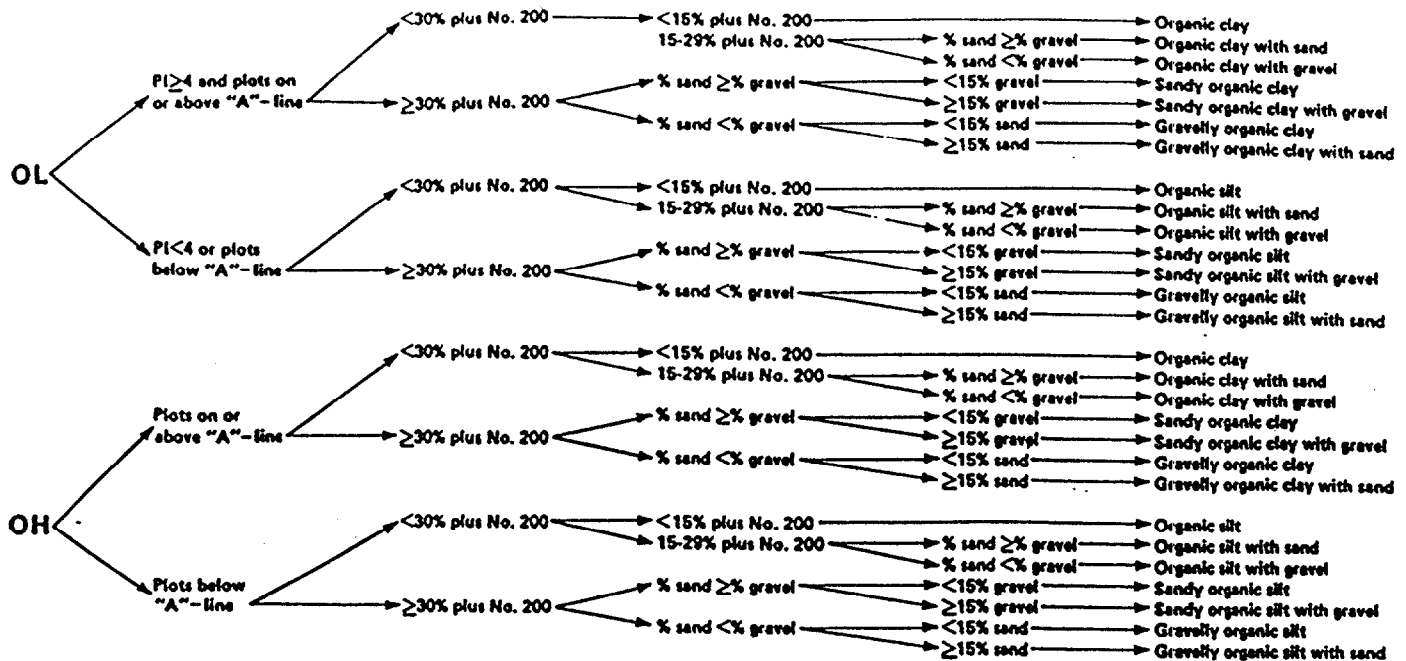


FIG. 1b Flow Chart for Classifying Organic Fine-Grained Soil (50 % or More Passes No. 200 Sieve)

GROUP SYMBOL

GROUP NAME

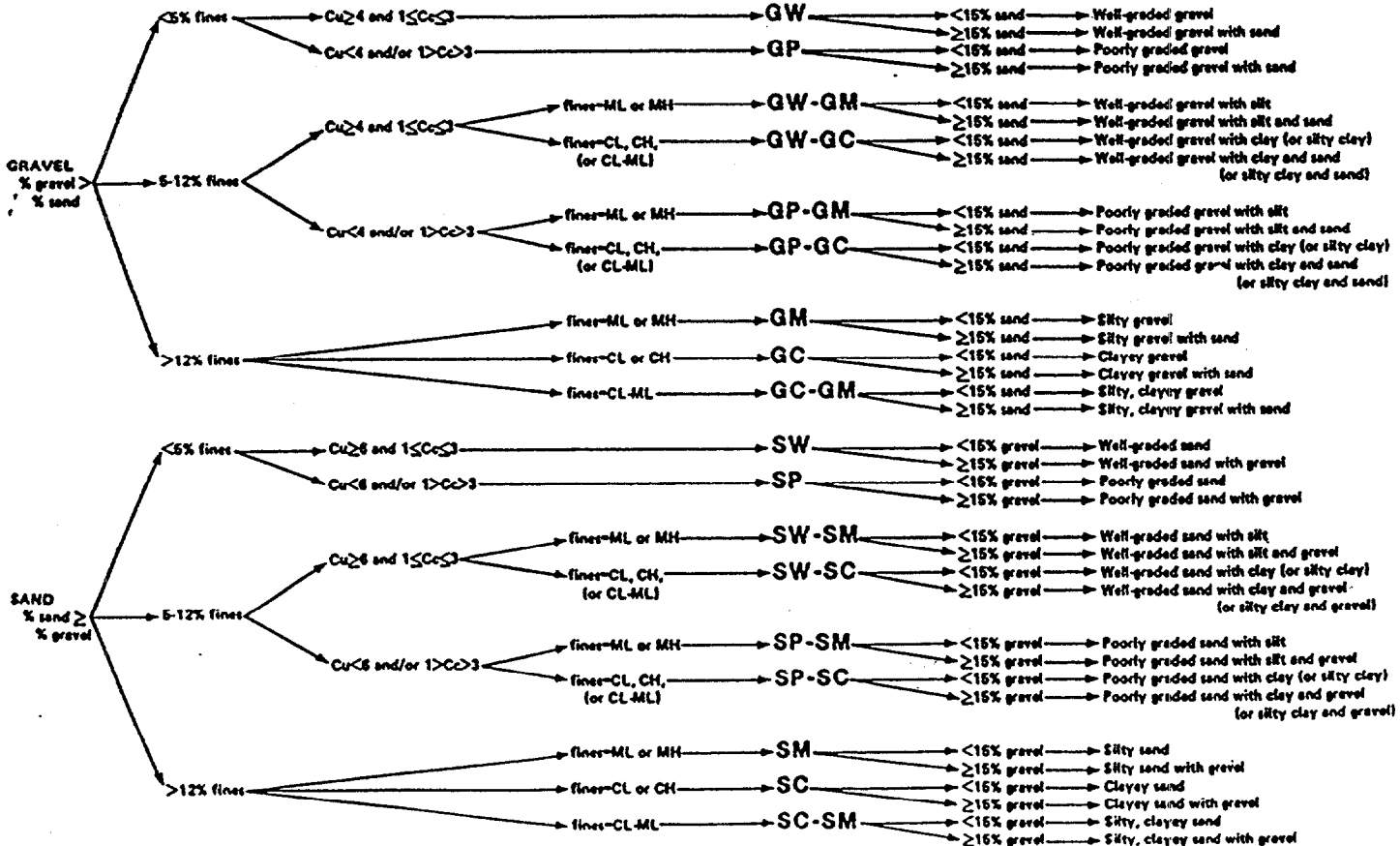


FIG. 2 Flow Chart for Classifying Coarse-Grained Soils (More Than 50 % Retained on No. 200 Sieve)

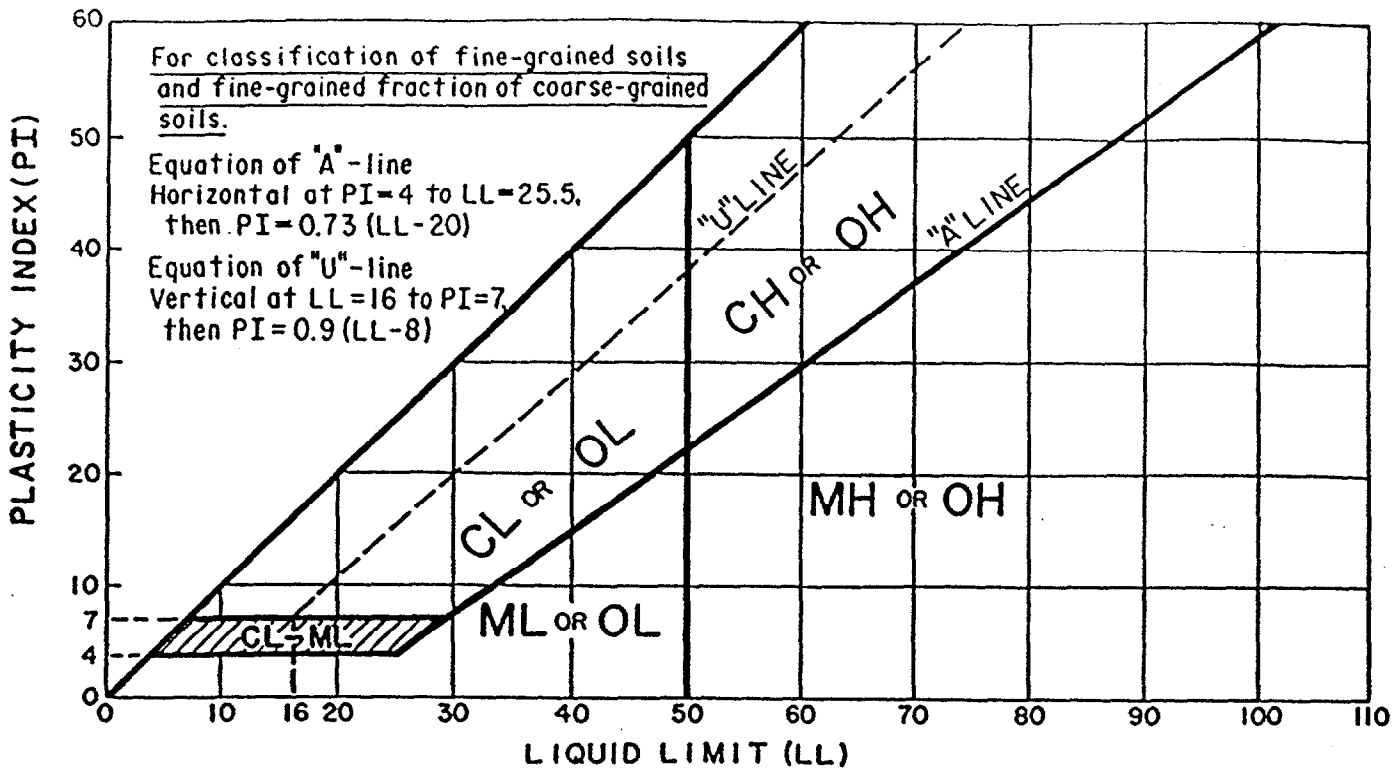


FIG. 3 Plasticity Chart

9.8.2 For soils estimated to contain 5 to 15 % fines, a relative particle-size distribution curve, as described in 9.8.1, is required, and the liquid limit and plasticity index are required.

9.8.2.1 If sufficient material is not available to determine the liquid limit and plasticity index, the fines should be estimated to be either silty or clayey using the procedures described in Practice D 2488 and so noted in the report.

9.8.3 For soils estimated to contain 15 % or more fines, a determination of the percent fines, percent sand, and percent gravel is required, and the liquid limit and plasticity index are required. For soils estimated to contain 90 % fines or more, the percent fines, percent sand, and percent gravel may be estimated using the procedures described in Practice D 2488 and so noted in the report.

10. Preliminary Classification Procedure

10.1 Class the soil as fine-grained if 50 % or more by dry weight of the test specimen passes the No. 200 (75- μ m) sieve and follow Section 11.

10.2 Class the soil as coarse-grained if more than 50 % by dry weight of the test specimen is retained on the No. 200 (75- μ m) sieve and follow Section 12.

11. Procedure for Classification of Fine-Grained Soils (50 % or more by dry weight passing the No. 200 (75- μ m) sieve)

The soil is an inorganic clay if the position of the plasticity index versus liquid limit plot, Fig. 3, falls on or above the "A" line, the plasticity index is greater than 4, and the presence of organic matter does not influence the liquid limit as determined in 11.3.2.

NOTE 6—The plasticity index and liquid limit are determined on the minus No. 40 (425 μ m) sieve material.

11.1.1 Classify the soil as a *lean clay*, CL, if the liquid limit is less than 50. See area identified as CL on Fig. 3.

11.1.2 Classify the soil as a *fat clay*, CH, if the liquid limit is 50 or greater. See area identified as CH on Fig. 3.

NOTE 7—In cases where the liquid limit exceeds 110 or the plasticity index exceeds 60, the plasticity chart may be expanded by maintaining the same scale on both axes and extending the "A" line at the indicated slope.

11.1.3 Classify the soil as a *silty clay*, CL-ML, if the position of the plasticity index versus liquid limit plot falls on or above the "A" line and the plasticity index is in the range of 4 to 7. See area identified as CL-ML on Fig. 3.

11.2 The soil is an inorganic silt if the position of the plasticity index versus liquid limit plot, Fig. 3, falls below the "A" line or the plasticity index is less than 4, and presence of organic matter does not influence the liquid limit as determined in 11.3.2.

11.2.1 Classify the soil as a *silt*, ML, if the liquid limit is less than 50. See area identified as ML on Fig. 3.

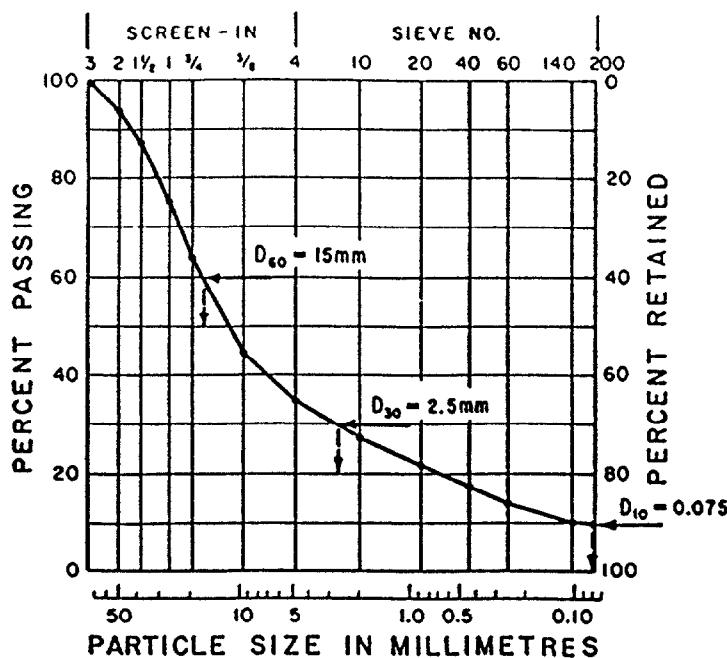
11.2.2 Classify the soil as an *elastic silt*, MH, if the liquid limit is 50 or greater. See area identified as MH on Fig. 3.

11.3 The soil is an organic silt or clay if organic matter is present in sufficient amounts to influence the liquid limit as determined in 11.3.2.

11.3.1 If the soil has a dark color and an organic odor when moist and warm, a second liquid limit test shall be performed on a test specimen which has been oven dried at $110 \pm 5^\circ\text{C}$ to a constant weight, typically over night.

11.3.2 The soil is an organic silt or organic clay if the liquid limit after oven drying is less than 75 % of the liquid

SIEVE ANALYSIS



$$C_u = \frac{D_{60}}{D_{10}} = \frac{15}{0.075} = 200 \quad C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}} = \frac{(2.5)^2}{0.075 \times 15} = 5.6$$

FIG. 4 Cumulative Particle-Size Plot

limit of the original specimen determined before oven drying (see Procedure B of Practice D 2217).

11.3.3 Classify the soil as an *organic silt* or *organic clay*, OL, if the liquid limit (not oven dried) is less than 50 %. Classify the soil as an *organic silt*, OL, if the plasticity index is less than 4, or the position of the plasticity index versus liquid limit plot falls below the "A" line. Classify the soil as an *organic clay*, OL, if the plasticity index is 4 or greater and the position of the plasticity index versus liquid limit plot falls on or above the "A" line. See area identified as OL (or CL-ML) on Fig. 3.

11.3.4 Classify the soil as an *organic clay* or *organic silt*, OH, if the liquid limit (not oven dried) is 50 or greater. Classify the soil as an *organic silt*, OH, if the position of the plasticity index versus liquid limit plot falls below the "A" line. Classify the soil as an *organic clay*, OH, if the position of the plasticity index versus liquid-limit plot falls on or above the "A" line. See area identified as OH on Fig. 3.

11.4 If less than 30 % but 15 % or more of the test specimen is retained on the No. 200 (75- μ m) sieve, the words "with sand" or "with gravel" (whichever is predominant) shall be added to the group name. For example, lean clay with sand, CL; silt with gravel, ML. If the percent of sand is equal to the percent of gravel, use "with sand."

11.5 If 30 % or more of the test specimen is retained on the No. 200 (75- μ m) sieve, the words "sandy" or "gravelly" shall be added to the group name. Add the word "sandy" if 30 % or more of the test specimen is retained on the No. 200 (75- μ m) sieve and the coarse-grained portion is predominantly sand. Add the word "gravelly" if 30 % or more of the test specimen is retained on the No. 200 (75- μ m) sieve and the coarse-grained portion is predominantly gravel. For

example, sandy lean clay, CL; gravelly fat clay, CH; sandy silt, ML. If the percent of sand is equal to the percent of gravel, use "sandy."

12. Procedure for Classification of Coarse-Grained Soils (more than 50 % retained on the No. 200 (75- μ m) sieve)

12.1 Class the soil as gravel if more than 50 % of the coarse fraction [plus No. 200 (75- μ m) sieve] is retained on the No. 4 (4.75-mm) sieve.

12.2 Class the soil as sand if 50 % or more of the coarse fraction [plus No. 200 (75- μ m) sieve] passes the No. 4 (4.75-mm) sieve.

12.3 If 12 % or less of the test specimen passes the No. 200 (75- μ m) sieve, plot the cumulative particle-size distribution, Fig. 4, and compute the coefficient of uniformity, C_u , and coefficient of curvature, C_c , as given in Eqs 1 and 2.

$$C_u = D_{60}/D_{10} \quad (1)$$

$$C_c = (D_{30})^2/(D_{10} \times D_{60}) \quad (2)$$

where:
 D_{10} , D_{30} , and D_{60} = the particle-size diameters corresponding to 10, 30, and 60 %, respectively, passing on the cumulative particle-size distribution curve, Fig. 4.

NOTE 8—It may be necessary to extrapolate the curve to obtain the D_{10} diameter.

12.3.1 If less than 5 % of the test specimen passes the No. 200 (75- μ m) sieve, classify the soil as a *well-graded gravel*, GW, or *well-graded sand*, SW, if C_u is greater than 4.0 for gravel or greater than 6.0 for sand, and C_c is at least 1.0 but not more than 3.0.

12.3.2 If less than 5 % of the test specimen passes the No. 200 (75- μ m) sieve, classify the soil as *poorly graded gravel*,

GP, or *poorly graded sand*, SP, if either the Cu or the Cc criteria for well-graded soils are not satisfied.

12.4 If more than 12 % of the test specimen passes the No. 200 (75- μ m) sieve, the soil shall be considered a coarse-grained soil with fines. The fines are determined to be either clayey or silty based on the plasticity index versus liquid limit plot on Fig. 3. (See 9.8.2.1 if insufficient material available for testing). (See NOTE 6)

12.4.1 Classify the soil as a *clayey gravel*, GC, or *clayey sand*, SC, if the fines are clayey, that is, the position of the plasticity index versus liquid limit plot, Fig. 3, falls on or above the "A" line and the plasticity index is greater than 7.

12.4.2 Classify the soil as a *silty gravel*, GM, or *silty sand*, SM, if the fines are silty, that is, the position of the plasticity index versus liquid limit plot, Fig. 3, falls below the "A" line or the plasticity index is less than 4.

12.4.3 If the fines plot as a silty clay, CL-ML, classify the soil as a *silty, clayey gravel*, GC-GM, if it is a gravel or a *silty, clayey sand*, SC-SM, if it is a sand.

12.5 If 5 to 12 % of the test specimen passes the No. 200 (75- μ m) sieve, give the soil a dual classification using two group symbols.

12.5.1 The first group symbol shall correspond to that for a gravel or sand having less than 5 % fines (GW, GP, SW, SP), and the second symbol shall correspond to a gravel or sand having more than 12 % fines (GC, GM, SC, SM).

12.5.2 The group name shall correspond to the first group symbol plus "with clay" or "with silt" to indicate the plasticity characteristics of the fines. For example, well-graded gravel with clay, GW-GC; poorly graded sand with silt, SP-SM (See 9.8.2.1 if insufficient material available for testing).

NOTE 9—If the fines plot as a *silty clay*, CL-ML, the second group symbol should be either GC or SC. For example, a poorly graded sand with 10 % fines, a liquid limit of 20, and a plasticity index of 6 would be classified as a poorly graded sand with silty clay, SP-SC.

12.6 If the specimen is predominantly sand or gravel but

contains 15 % or more of the other coarse-grained constituent, the words "with gravel" or "with sand" shall be added to the group name. For example, poorly graded gravel with sand, clayey sand with gravel.

12.7 If the field sample contained any cobbles or boulders or both, the words "with cobbles," or "with cobbles and boulders" shall be added to the group name. For example, silty gravel with cobbles, GM.

13. Report

13.1 The report should include the group name, group symbol, and the results of the laboratory tests. The particle-size distribution shall be given in terms of percent of gravel, sand, and fines. The plot of the cumulative particle-size distribution curve shall be reported if used in classifying the soil. Report appropriate descriptive information according to the procedures in Practice D 2488. A local or commercial name or geologic interpretation for the material may be added at the end of the descriptive information if identified as such. The test procedures used shall be referenced.

NOTE 10—*Example: Clayey Gravel with Sand and Cobbles (GC)*—46 % fine to coarse, hard, subrounded gravel; 30 % fine to coarse, hard, subrounded sand; 24 % clayey fines, LL = 38, PI = 19; weak reaction with HCl; original field sample had 4 % hard, subrounded cobbles; maximum dimension 150 mm.

In-Place Conditions—firm, homogeneous, dry, brown,
Geologic Interpretation—alluvial fan.

NOTE 11—Other examples of soil descriptions are given in Appendix XI.

14. Precision and Bias

14.1 This test method provides qualitative data only; therefore, a precision and bias statement is nonapplicable.

15. Keywords

15.1 Atterberg limits; classification; clay; gradation; gravel; laboratory classification; organic soils; sand; silt; soil classification; soil tests

APPENDIXES

(Nonmandatory Information)

XI. EXAMPLES OF DESCRIPTIONS USING SOIL CLASSIFICATION

XI.1 The following examples show how the information required in 13.1 can be reported. The appropriate descriptive information from Practice D 2488 is included for illustrative purposes. The additional descriptive terms that would accompany the soil classification should be based on the intended use of the classification and the individual circumstances.

XI.1.1 *Well-Graded Gravel with Sand (GW)*—73 % fine to coarse, hard, subangular gravel; 23 % fine to coarse, hard, subangular sand; 4 % fines; Cc = 2.7, Cu = 12.4.

XI.1.2 *Silty Sand with Gravel (SM)*—61 % predominantly fine sand; 23 % silty fines, LL = 33, PI = 6; 16 % fine, hard, subrounded gravel; no reaction with HCl; (field sample

smaller than recommended). *In-Place Conditions*—Firm, stratified and contains lenses of silt 1 to 2 in. thick, moist, brown to gray; in-place density = 106 lb/ft³ and in-place moisture = 9 %.

XI.1.3 *Organic Clay (OL)*—100 % fines, LL (not dried) = 32, LL (oven dried) = 21, PI (not dried) = 10; wet, dark brown, organic odor, weak reaction with HCl.

XI.1.4 *Silty Sand with Organic Fines (SM)*—74 % fine to coarse, hard, subangular reddish sand; 26 % organic and silty dark-brown fines, LL (not dried) = 37, LL (oven dried) = 26, PI (not dried) = 6, wet, weak reaction with HCl.

XI.1.5 *Poorly Graded Gravel with Silt, Sand, Cobbles and Boulders (GP-GM)*—78 % fine to coarse, hard, subrounded to subangular gravel; 16 % fine to coarse, hard, subrounded

to subangular sand; 6 % silty (estimated) fines; moist, brown; no reaction with HCl; original field sample had 7 % hard,

subrounded cobbles and 2 % hard, subrounded boulders with a maximum dimension of 18 in.

X2. USING SOIL CLASSIFICATION AS A DESCRIPTIVE SYSTEM FOR SHALE, CLAYSTONE, SHELLS, SLAG, CRUSHED ROCK, ETC.

X2.1 The group names and symbols used in this test method may be used as a descriptive system applied to materials that exist in situ as shale, claystone, sandstone, siltstone, mudstone, etc., but convert to soils after field or laboratory processing (crushing, slaking, etc.).

X2.2 Materials such as shells, crushed rock, slag, etc., should be identified as such. However, the procedures used in this method for describing the particle size and plasticity characteristics may be used in the description of the material. If desired, a classification in accordance with this test method may be assigned to aid in describing the material.

X2.3 If a classification is used, the group symbol(s) and group names should be placed in quotation marks or noted with some type of distinguishing symbol. See examples.

X2.4 Examples of how soil classifications could be incorporated into a description system for materials that are not naturally occurring soils are as follows:

X2.4.1 *Shale Chunks*—Retrieved as 2 to 4-in. pieces of shale from power auger hole, dry, brown, no reaction with HCl. After laboratory processing by slaking in water for 24 h, material classified as “Sandy Lean Clay (CL)”—61 % clayey fines, LL = 37, PI = 16; 33 % fine to medium sand; 6 % gravel-size pieces of shale.

X2.4.2 *Crushed Sandstone*—Product of commercial crushing operation; “Poorly Graded Sand with Silt (SP-SM)”—91 % fine to medium sand; 9 % silty (estimated) fines; dry, reddish-brown, strong reaction with HCl.

X2.4.3 *Broken Shells*—62 % gravel-size broken shells; 31 % sand and sand-size shell pieces; 7 % fines; would be classified as “Poorly Graded Gravel with Sand (GP)”.

X2.4.4 *Crushed Rock*—Processed gravel and cobbles from Pit No. 7; “Poorly Graded Gravel (GP)”—89 % fine, hard, angular gravel-size particles; 11 % coarse, hard, angular sand-size particles, dry, tan; no reaction with HCl; Cc = 2.4, Cu = 0.9.

X3. PREPARATION AND TESTING FOR CLASSIFICATION PURPOSES BY THE WET METHOD

X3.1 This appendix describes the steps in preparing a soil sample for testing for purposes of soil classification using a wet-preparation procedure.

X3.2 Samples prepared in accordance with this procedure should contain as much of their natural water content as possible and every effort should be made during obtaining, preparing, and transporting the samples to maintain the natural moisture.

X3.3 The procedures to be followed in this test method assume that the field sample contains fines, sand, gravel, and plus 3-in. (75-mm) particles and the cumulative particle-size distribution plus the liquid limit and plasticity index values are required (see 9.8). Some of the following steps may be omitted when they are not applicable to the soil being tested.

X3.4 If the soil contains plus No. 200 (75- μ m) particles that would degrade during dry sieving, use a test procedure for determining the particle-size characteristics that prevents this degradation.

X3.5 Since this classification system is limited to the portion of a sample passing the 3-in. (75-mm) sieve, the plus 3-in. (75-mm) material shall be removed prior to the determination of the particle-size characteristics and the liquid limit and plasticity index.

X3.6 The portion of the field sample finer than the 3-in. (75-mm) sieve shall be obtained as follows:

X3.6.1 Separate the field sample into two fractions on a 3-in. (75-mm) sieve, being careful to maintain the natural water content in the minus 3-in. (75-mm) fraction. Any particles adhering to the plus 3-in. (75-mm) particles shall be brushed or wiped off and placed in the fraction passing the 3-in. (75-mm) sieve.

X3.6.2 Determine the air-dry or oven-dry weight of the

fraction retained on the 3-in. (75-mm) sieve. Determine the total (wet) weight of the fraction passing the 3-in. (75-mm) sieve.

X3.6.3 Thoroughly mix the fraction passing the 3-in. (75-mm) sieve. Determine the water content, in accordance with Method D 2216, of a representative specimen with a minimum dry weight as required in 7.2. Save the water-content specimen for determination of the particle-size analysis in accordance with X3.8.

X3.6.4 Compute the dry weight of the fraction passing the 3-in. (75-mm) sieve based on the water content and total (wet) weight. Compute the total dry weight of the sample and calculate the percentage of material retained on the 3-in. (75-mm) sieve.

X3.7 Determine the liquid limit and plasticity index as follows:

X3.7.1 If the soil disaggregates readily, mix on a clean, hard surface and select a representative sample by quartering in accordance with Methods C 702.

X3.7.1.1 If the soil contains coarse-grained particles coated with and bound together by tough clayey material, take extreme care in obtaining a representative portion of the No. 40 (425- μ m) fraction. Typically, a larger portion than normal has to be selected, such as the minimum weights required in 7.2.

X3.7.1.2 To obtain a representative specimen of a basically cohesive soil, it may be advantageous to pass the soil through a $\frac{3}{4}$ -in. (19-mm) sieve or other convenient size so the material can be more easily mixed and then quartered or split to obtain the representative specimen.

X3.7.2 Process the representative specimen in accordance with Procedure B of Practice D 2217.

X3.7.3 Perform the liquid-limit test in accordance with Test Method D 4318, except the soil shall not be air dried prior to the test.

X3.7.4 Perform the plastic-limit test in accordance with Test Method D 4318, except the soil shall not be air dried prior to the test, and calculate the plasticity index.

X3.8 Determine the particle-size distribution as follows:

X3.8.1 If the water content of the fraction passing the 3-in. (75-mm) sieve was required (X3.6.3), use the water-content specimen for determining the particle-size distribution. Otherwise, select a representative specimen in accordance with Practice C 702 with a minimum dry weight as required in 7.2.

X3.8.2 If the cumulative particle-size distribution including a hydrometer analysis is required, determine the particle-size distribution in accordance with Method D 422. See 9.7 for the set of required sieves.

X3.8.3 If the cumulative particle-size distribution without a hydrometer analysis is required, determine the particle-size distribution in accordance with Method C 136. See 9.7 for the set of required sieves. The specimen should be soaked until all clayey aggregations have softened and then washed in accordance with Test Method C 117 prior to performing the particle-size distribution.

X3.8.4 If the cumulative particle-size distribution is not required, determine the percent fines, percent sand, and percent gravel in the specimen in accordance with Test Method C 117, being sure to soak the specimen long enough to soften all clayey aggregations, followed by Method C 136 using a nest of sieves which shall include a No. 4 (4.75-mm) sieve and a No. 200 (75- μ m) sieve.

X3.8.5 Calculate the percent fines, percent sand, and percent gravel in the minus 3-in. (75-mm) fraction for classification purposes.

X4. AIR-DRIED METHOD OF PREPARATION OF SOILS FOR TESTING FOR CLASSIFICATION PURPOSES

X4.1 This appendix describes the steps in preparing a soil sample for testing for purposes of soil classification when air-drying the soil before testing is specified or desired or when the natural moisture content is near that of an air-dried state.

X4.2 If the soil contains organic matter or mineral colloids that are irreversibly affected by air drying, the wet-preparation method as described in Appendix X3 should be used.

X4.3 Since this classification system is limited to the portion of a sample passing the 3-in. (75-mm) sieve, the plus 3-in. (75-mm) material shall be removed prior to the determination of the particle-size characteristics and the liquid limit and plasticity index.

X4.4 The portion of the field sample finer than the 3-in. (75-mm) sieve shall be obtained as follows:

X4.4.1 Air dry and weigh the field sample.

X4.4.2 Separate the field sample into two fractions on a 3-in. (75-mm) sieve.

X4.4.3 Weigh the two fractions and compute the percentage of the plus 3-in. (75-mm) material in the field sample.

X4.5 Determine the particle-size distribution and liquid limit and plasticity index as follows (see 9.8 for when these tests are required):

X4.5.1 Thoroughly mix the fraction passing the 3-in. (75-mm) sieve.

X4.5.2 If the cumulative particle-size distribution including a hydrometer analysis is required, determine the particle-size distribution in accordance with Method D 422. See 9.7 for the set of sieves that is required.

X4.5.3 If the cumulative particle-size distribution without a hydrometer analysis is required, determine the particle-size distribution in accordance with Test Method D 1140 followed by Method C 136. See 9.7 for the set of sieves that is required.

X4.5.4 If the cumulative particle-size distribution is not required, determine the percent fines, percent sand, and percent gravel in the specimen in accordance with Test Method D 1140 followed by Method C 136 using a nest of sieves which shall include a No. 4 (4.75-mm) sieve and a No. 200 (75- μ m) sieve.

X4.5.5 If required, determine the liquid limit and the plasticity index of the test specimen in accordance with Test Method D 4318.

X5. RATIONALE

X5.1 Significant revisions were made to the standard which appeared as D 2487 - 83 from the previous version of D 2487 - 69 (1975). The changes are documented in the literature.

X5.2 Changes in this version from the last include the

addition of 8.2 on classification of peat, the addition of 4.5 on classification of frozen soils, the addition of NOTE 6 for clarification of materials used to determine the plasticity index and liquid limit, and the addition of Appendix X5 on Rationale.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.

APPENDIX H
Biological and Fish Sample Collection

SOP F802
Fish Population Sampling Using
Electrofishing Procedures

FISH POPULATION SAMPLING USING ELECTROFISHING PROCEDURES
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FISH POPULATION SAMPLING USING ELECTROFISHING PROCEDURES

1.0 PURPOSE

The purpose of this SOP is to provide general reference information and technical guidance on sampling and characterizing fish communities using electrofishing procedures. The collected samples provide information used in the determination of population statistics of the fish community and can be used to collect fish samples for chemical analysis of tissues. This information will be used in the assessment of risks to human health and the environment.

2.0 SCOPE

This guideline provides information on proper sampling equipment and techniques for the collection of fish in shallow streams, ponds, and near shore areas of lakes and impoundments. Review of the information contained herein will facilitate planning of the field sampling effort by describing standard sampling techniques. The techniques described should be followed whenever applicable, noting that site-specific conditions or project-specific plans may require adjustments in methods.

3.0 DEFINITIONS

Abiotic - Non-biological components of the environment, including water body structure and natural or manmade disturbances.

Biotic - Biological components of the environment, including organisms and vegetation.

Bow - The front of a boat.

Reach - The designated portion of a stream or river.

Riffles - A stretch of water flowing over, rocks, debris, or shallow sediments causing a disturbance of the water.

Riparian - Along the bank of a river or lake.

Runs - A stretch of water flowing without any disturbances.

Stern - The back of a boat.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for development of documentation of procedures that deviate from those presented herein.

Field Team Leader - The Field Team Leader is responsible for selecting and detailing the specific sampling techniques and equipment to be used, and documenting these in the Sampling and Analysis Plan. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that personnel performing sampling activities have been briefed and trained to execute these procedures.

Sampling Personnel - It is the responsibility of the field sampling personnel to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team Leader and/or the Project Manager.

5.0 PROCEDURES

The methods for collecting fish via electrofishing include identifying appropriate sample areas and utilizing the proper electrofishing techniques. The primary considerations in selecting appropriate sampling areas include the following:

- Identify areas with suitable salinity for electroshocking
- Identify sampling locations that are representative of the fish population of the area
- Identify areas that are navigable by boat or barge

Proper electrofishing procedures are described in the sections to follow.

5.1 Equipment

The following list is an example of the type of equipment that generally must be on hand when collecting fish samples with electroshocking equipment:

- Sampling Boat
- Electroshocking equipment, including generator, control panel, all necessary cables, shocking ring, and rubber gloves.
- Live Well (large tub) with overflow pipe to outside of boat
- 12-volt marine battery and charger
- 12-volt water pump
- Fish Measuring Board
- 0-16 oz scale, 1-4 lb scale, 1-15 lb scale
- Large and small fish nets
- Appropriate sampling keys for species to be sampled, and any required instruments to aid in the identification
- Field sampling data sheets
- Glass jars for storage of fish
- Formalin[®]
- Permanent Marker
- Camera
- Required Personal Protective Equipment
- Portable Air Pumps

5.2 Preliminary Activities

Apply for and receive applicable scientific collection permits as required by the state. Contact the local fish or game officials and inform them of the proposed sampling activities.

Collect and determine all information pertinent to the fish sampling project, including water depth, station locations, nearby boat access locations, known sediment contamination, any waterway obstructions or inconsistencies (e.g. shallow or grassy areas, low structures, pipe crossings), any other biological studies previously conducted on or near the site, species used locally for human consumption and the degree of such consumption, species most likely

present, and the most appropriate sampling method for the species of interest that is permitted by law.

Before sampling occurs, conduct a site reconnaissance using a site map. The objective of this exercise is to categorize habitats, and map dividing lines and descriptors identifying the various types of habitats available. Make notations on the map depicting the "abiotic" characteristics of the reach including features such as pools, riffles, runs, substrate, water depth, channel shape, degree of bank erosion, shade/sun exposure, and relative current velocity and direction. Also make notations on the site map to show "biotic" characteristics of the reach including fish species observed, evidence of fisherman use, and aquatic and riparian vegetation including wetlands. In addition, identify station locations at this point, along with the total area to be sampled. Choose the station locations, where possible, to represent ecologically similar aquatic environments.

Set up a continuous flow through water system using the live wells and the pumps. Place the overflow pipes about five inches from the top of the well. Attach a mesh/screen over the inlet of the overflow pipe to prevent loss of small fish species.

5.3 Operating Procedure

Sampling from a Boat

Prior to launching, check the boat's gasoline tank to ensure that there is a sufficient amount of gasoline (oil mixture 50:1) for the daily activities. Load and launch the boat at access ramp as described in SOP F904. Set up the boat for the most comfortable and efficient working conditions.

Attach the anode from the generator to the bolt at the bottom of the boat. Hook up the generator to the junction box and connect the cathode ring to the junction box. Ensure the electroshocker is working properly before leaving shore. When the boat's engine and the electroshocker are operating properly, proceed to the first station location.

Conduct sampling in areas that will ensure adequate qualitative and/or quantitative representation of the fish community, whichever is necessary. These areas should include riffles/runs, shorelines, snags, natural fish holding areas, vegetation beds and other habitats.

After arriving at the station, drop and secure the anchor. Try to position the boat parallel with direction of water flow, if applicable. Fill the live wells about half-full with site water, and start the flow-through water system (if applicable); otherwise fill the live wells with water and place the portable air diffusers in the water.

Position the field personnel that will be shocking and collecting the fish at the bow of the boat, behind the shocking rail. These personnel should wear rubber gloves, rubber boots, and life preservers.

If the sampling occurs on a water body that has significant flow, begin shocking at the furthest downstream location, and continue in the upstream direction.

Start the generator. The person shocking the fish should hold the cathode ring in front of the boat, and then apply power. Pulse the power to prevent fish in the collection path from being repelled.

The field personnel collecting the fish should keep the net between the shocking ring and the boat, trying to collect all the stunned fish. Periodically empty the fish from the net into the live wells to prevent them from swimming out of the net.

At the end of a sampling reach, identify, measure, weigh and release the specimens. Record the proportion of individuals as hybrids and the proportion of individuals with disease, tumors, fin damage, and skeletal anomalies. Also record all other pertinent information, including shocking time, on a field data sheet.

To the extent possible, process all species in the field and return them to the stream alive. If specimens present taxonomic difficulties, or are too numerous for effective field processing, preserve them in 10% Formalin®, and transport them to the Baker Ecological Services Laboratory for taxonomic work and measurements.

At a minimum, preserve one representative fish from each species in 10% formalin as a voucher specimen. Record the station location, date sampled, and species name on the label.

Sampling from the Barge

If the water is too shallow for the boat, use the small barge to carry the electroshocking equipment and live wells. Put on chest waders, and ensure that they do not leak. Set up barge for most comfortable and efficient working conditions.

Attach the anode from the generator to the bolt at the bottom of the barge. Hook up the generator to the junction box and connect the cathode ring to the junction box. Ensure the electroshocker is working properly before leaving shore, and wade to first station location.

Conduct sampling in areas that will ensure adequate qualitative and/or quantitative representation of the fish community, whichever is necessary. These areas should include riffles/runs, shorelines, snags, natural fish holding areas, vegetation beds and other habitats.

Fill live wells about half-full with site water, and start the flow-through water system, if applicable. Otherwise fill the live wells with water and place the portable air diffusers in the water.

Position the field personnel that will be shocking and collecting the fish to the either side of the barge. These personnel should wear rubber gloves and life preservers.

If the sampling occurs on a water body that has significant flow, shocking should be started at furthest downstream location, and continued in the upstream direction.

Hold the shocking ring in front of the barge. and then apply power to the shocker. The power should be pulsed as not to repel all the fish in the collection path. Start the generator. The person shocking the fish should hold the cathode ring in front of the boat, and then apply power. Pulse the power to prevent fish in the collection path from being repelled.

The field personnel collecting the fish should keep the net between the shocking ring and the barge. Try to collect all stunned fish. Periodically empty the fish from the net into the live wells to prevent them from swimming out of the net. Seines may be used downstream of shocking activities in some small water bodies to collect fish that may have been missed by the nets.

At the end of a sampling reach, identify, measure, weigh and release the specimens. Record the proportion of individuals as hybrids and the proportion of individuals with disease, tumors, fin damage, and skeletal anomalies. Also record all other pertinent information, including shocking time, on a field data sheet (see Attachment 1 for an example of a data sheet).

To the extent possible, process all species in the field and return them to the stream alive. If specimens present taxonomic difficulties, or are too numerous for effective field processing, preserve them in 10% Formalin[®], and transport them to the Baker Ecological Services Laboratory for taxonomic work and measurements.

At a minimum, preserve one representative fish from each species in 10% Formalin[®] as a voucher specimen. Record the station location, date sampled, and species name on the label.

6.0 QUALITY ASSURANCE RECORDS

Quality assurance records will be maintained for each sample that is collected. The following information will be recorded in the Field Logbook:

- Sample identification (site name, location, project no.; sample name/number and location; sample type and matrix; time and date; sampler's identity).
- Field observations and measurements (field chemistry, photograph description, environmental setting, and the length of the electroshock).
- Additional remarks, as appropriate

Record all observations in the Field Logbook as described in SOP F202. Complete field sheets for the collected samples.

7.0 REFERENCES

Smith-Root, Inc. Gas Powered Pulsator Instruction Manual.

U.S. EPA, 1987. U.S. Environmental Protection Agency, Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference. Office of Emergency and Remedial Response, Office of Waste Programs Enforcement. December 1987.

U.S. EPA, 1987. U.S. Environmental Protection Agency. A Compendium of Superfund Field Operations Methods. Office of Emergency and Remedial Response, Office of Waste Programs Enforcement. December 1987.

ATTACHMENT 1

**FIELD DATA SHEET
FISH COLLECTION**

FISH COLLECTION FIELD DATA SHEET

Project: _____ Date: _____

Station: _____ Run Length: _____

Generator: Run _____ Stop _____

SPECIES			SPECIES			SPECIES		
Length	Weight	Anomalies*	Length	Weight	Anomalies*	Length	Weight	Anomalies*

* Discolorization, deformities, eroded fins, excessive mucus, excessive external parasite fungus, poor condition, reddening, tumors and ulcers.

SOP F803
Preparation of Fish and Shellfish Samples for
Chemical Analysis

**PREPARATION OF FISH AND SHELLFISH SAMPLES FOR
CHEMICAL ANALYSIS OF TISSUE**

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 - 5.7 Tissue Preparation for Shipment to Laboratory**
- 6.0 QUALITY ASSURANCE RECORDS**
- 7.0 REFERENCES**

PREPARATION OF FISH AND SHELLFISH SAMPLES FOR CHEMICAL ANALYSIS OF TISSUE

1.0 PURPOSE

The purpose of this SOP is to provide general reference information and technical guidance on the preparation of fish and shellfish samples for chemical analysis of their body tissue. The chemical analysis of body tissue provides information used in the determination of the potential bioaccumulation of contaminants for the assessment of risks to human health and the environment.

2.0 SCOPE

This guideline provides information on proper methods for the preparation of fish and shellfish samples for chemical analysis of their tissue. Review of the information contained herein will facilitate planning of the field sampling effort by describing standard sampling and preparation techniques. The techniques described should be followed whenever applicable, noting that site-specific conditions or project-specific plans may require adjustments to the methods.

3.0 DEFINITIONS

Top carnivore species - freshwater predator species feeding on other fish.

Commercial and recreational species - fish species that are harvested and consumed by humans.

Forage species - omnivorous species that are prey for top carnivores and game fish.

Bottom species - species feeding on or near the bottom (sediments) of the surface water body.

Shellfish species - bivalve mollusks and crustacean species that are harvested and consumed by humans.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for development of documentation of procedures that deviate from those presented herein.

Field Team Leader - The Field Team Leader is responsible for selecting and detailing the specific sampling techniques and equipment to be used, and documenting these in the Sampling and Analysis Plan. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that personnel performing sampling activities have been briefed and trained to execute these procedures.

Sampling Personnel - It is the responsibility of the field sampling personnel to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team Leader and/or the Project Manager.

5.0 PROCEDURES

The procedures for preparing the fish and shellfish samples for chemical analysis of tissues include collecting, weighing, measuring, and processing the fish and shellfish samples for shipment. The primary concerns in preparing the fish and shellfish for analysis is to ensure the sample size is adequate and the sample is not contaminated by improper handling.

5.1 Equipment

The following list is an example of the type of equipment that generally must be on hand when preparing fish samples for tissue analysis:

- Fish Measuring Board or Ruler
- 0-16 oz scale, 1-4 lb scale, 1-15 lb scale
- Appropriate sampling keys for species to be sampled, and any required instruments to aid in the identification
- Field sampling data sheets
- Decontamination Supplies:

- Hexane
- Acetone
- Non-phosphate Detergent
- Distilled Water
- Permanent Marker
- Camera
- Latex Gloves
- Wash Bottles
- Funnels
- Labels
- Field Log Books
- Scrub Brush
- Plain White Paper Towels
- Garbage Bags
- Zip-lock Freezer Bags
- Freezer
- Dry Ice

5.2 Preliminary Activities

Contact a chemical analysis laboratory that has the required capability for tissue analysis and set up a subcontract agreement with them. Review the sample preparation requirements with the laboratory. Have the laboratory send an adequate number of coolers for shipping the tissue samples. Determine from the laboratory what the minimum amount of tissue sample required for analysis of all the specified parameters. In addition, determine the holding time for a processed sample, and any other special instructions the laboratory may have.

Ensure adequate volume of decontamination chemicals for entire trip. Determine where dry ice may be purchased within close proximity to the site or hotel, and where the closest federal express (FEDEX) drop-off is, or if FEDEX picks up from the hotel. Make arrangements for a freezer at the sampling area/hotel or ship the fish tissue samples out daily on wet ice.

5.3 Selection of Target Species

When choosing a target species for collection, consideration will be given to the commonly consumed fish species in the area, the fish species ability to bioaccumulate contaminants, and the geographic distribution of the species. Table 2 from USEPA (1993) that present recommended target species for freshwater studies, recommended species for estuarine/marine studies are presented in Attachment 1.

Freshwater collection - at a minimum, target species for freshwater studies should include one bottom fish and one top carnivore and/or commercial and recreational fish species for determining human health and environment risks. In addition, one forage species and one shellfish species should be included for determining environmental risks.

Estuarine/Marine collection - target species for saltwater studies should include one shellfish and one top carnivore and/or commercial and recreational fish species for determining human health and environment risks. In addition, one forage species should be included for determining environmental risks.

5.4 Sample Processing Procedure

Gather fish specimens using the appropriate fish collecting SOP as determined by the site reconnaissance.

The following steps will be taken with each fish and shellfish collected: identify the sample specimen, sort and inspect the samples, rinse the samples and group by target species, prepare the sample for shipment to the laboratory.

Weigh the collected fish/shellfish to the nearest gram and measure to the nearest tenth of a centimeter. The total length of the fish will be measured by the distance in a straight line from the anterior-most projecting part of the head to the farthest tip of the caudal fin when its rays are squeezed together. The total length of the shellfish will be measured for bivalve mollusks by the distance (height) from the umbo to the anterior shell margin. The total length of the crustaceans will be measured for 1) crabs by the distance of the lateral width of the carapace, 2) shrimp and crayfish by the distance from the rostrum to the tip of the telson, and 3) lobsters, either the length of the carapace for spiny and clawed lobsters or the length of the

tail for spiny lobsters. Also record the presence of morphological abnormalities (e.g., hybrids, diseased, tumors, fin damage, lesions, skeletal anomalies). Ensure that enough fish will be collected to provide an adequate sample volume for laboratory analysis. Record all information on a field data sheet.

The fish will be processed (e.g., filleted, homogenized) by the contracted analytical laboratory. If the time between field sampling and laboratory preparation will be longer than 48 hours, the fish will be frozen until shipped to the laboratory.

5.5 Composite Samples

The recommended weight of composite samples of fish and shellfish tissue is 500 grams of tissue for analysis. The total composite weight should range from a minimum of 250 grams to a maximum of 1,000 grams. This sample size will provide sufficient sample material to analyze for typical contaminants of concern and meet minimum QA/QC requirements. However, because sample size requirements may vary among laboratories and the analytical methods used, determine the minimum amount of tissue required by the analytical laboratory for analysis of all the specified parameters for the specific project.

For finfish, three to ten individuals will be collected per target species per composite sample. For shellfish, three to fifty individuals will be collected for a composite sample. A few of the shellfish collected may be resected (edible portions removed) to determine the wet weight of the edible portion to assist in estimating the number of individuals needed to obtain a 500 gram sample.

The same number of individuals will be collected for each composite sample per sampling location and per target species.

5.6 Preservation of Sample Integrity

Sample integrity is preserved by prevention of a loss of contaminants already existing in the tissue and prevention of extraneous tissue contamination. Sample integrity will be preserved by ensuring the fish skin is not lacerated by the sampling gear and ensuring the shellfish are not cracked. In addition, consideration will be taken in preventing the tissue samples and

sample gear from coming directly in contact with grease, engine fluid, engine exhaust, dust, cooler, or ice.

5.7 Tissue Preparation for Shipment to Laboratory

After the initial processing to determine species, size, and morphological abnormalities, each fish will be wrapped individually in aluminum foil and placed in a labeled waterproof freezer bag. The shellfish specimen will be individually wrapped in multiple layers of aluminum foil. If necessary, clean cork stoppers will be placed over the protruding spines or pincers of the shellfish before wrapping in foil. A 100% cotton paper label will be placed inside the bag, identifying the project, station location, date, and replicate number. A pencil will be used to mark the label. The outside of the bag also will be labeled with the project, station location, date, and replicate number using a black permanent marker. The bags will be stored on wet ice in coolers if shipment to the laboratories is within 48 hours. If longer, the bags will be stored in a freezer.

Carefully pack the samples in the coolers for shipment to the laboratory. Fill the top and bottom of the coolers with a sufficient amount of wet ice, if shipment to the laboratories is within 48 hours, or with a sufficient amount of dry ice. Enclose the chain-of-custody inside the cooler. Place a chain-of-custody seal on the cooler and tape the cooler closed. Attach a completed FEDEX label to the cooler and drop off at a FEDEX office. If dry ice is being used, note on FEDEX label.

6.0 QUALITY ASSURANCE RECORDS

Quality assurance records will be maintained for each sample that is collected. The following information will be recorded in the Field Logbook:

- Sample identification (site name, location, project no.; sample name/number and location; sample type and matrix; time and date; sampler's identity).
- Field observations and measurements (sample setting, appearance of substrate, sampling method, and photograph descriptions).
- Additional remarks, as appropriate.

Proper chain-of-custody procedures play a crucial role in data gathering. SOP F201 describes requirements for completing a chain-of-custody form. Chain-of-custody forms are considered quality assurance records.

7.0 REFERENCES

U.S. EPA, 1993. U.S. Environmental Protection Agency, Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories Volume 1 Fish and Sampling Analyses. Office of Water. August 1993. EPA 823-R-93-002

ATTACHMENT 1

**RECOMMENDED TARGET SPECIES TABLES
FROM USEPA, 1993**

**GUIDANCE FOR ASSESSING CHEMICAL CONTAMINANT DATA FOR USE IN
FISH ADVISORIES. VOLUME 1 FISH SAMPLING AND ANALYSIS**

Table 3-1. Recommended Target Species for Inland Fresh Waters

Family name	Common name	Scientific name
<i>Percichthyidae</i>	White bass	<i>Morone chrysops</i>
<i>Centrarchidae</i>	Largemouth bass	<i>Micropterus salmoides</i>
	Smallmouth bass	<i>Micropterus dolomieu</i>
	Black crappie	<i>Pomoxis nigromaculatus</i>
	White crappie	<i>Pomoxis annularis</i>
<i>Percidae</i>	Walleye	<i>Stizostedion vitreum</i>
	Yellow perch	<i>Perca flavescens</i>
<i>Cyprinidae</i>	Common carp	<i>Cyprinus carpio</i>
<i>Catostomidae</i>	White sucker	<i>Catostomus commersoni</i>
<i>Ictaluridae</i>	Channel catfish	<i>Ictalurus punctatus</i>
	Flathead catfish	<i>Pylodictis olivaris</i>
<i>Esocidae</i>	Northern pike	<i>Esox lucius</i>
<i>Salmonidae</i>	Lake trout	<i>Salvelinus namaycush</i>
	Brown trout	<i>Salmo trutta</i>
	Rainbow trout	<i>Oncorhynchus mykiss</i> ^a

^aFormerly *Salmo gairdneri*.

Table 3-2. Recommended Target Species for Great Lakes Waters

Family name	Common name	Scientific name
<i>Percichthyidae</i>	White bass	<i>Morone chrysops</i>
<i>Centrarchidae</i>	Smallmouth bass	<i>Micropterus dolomieu</i>
<i>Percidae</i>	Walleye	<i>Stizostedion vitreum</i>
<i>Cyprinidae</i>	Common carp	<i>Cyprinus carpio</i>
<i>Catostomidae</i>	White sucker	<i>Catostomus commersoni</i>
<i>Ictaluridae</i>	Channel catfish	<i>Ictalurus punctatus</i>
<i>Esocidae</i>	Muskellunge	<i>Esox masquinongy</i>
<i>Salmonidae</i>	Chinook salmon	<i>Oncorhynchus tshawytscha</i>
	Lake trout	<i>Salvelinus namaycush</i>
	Brown trout	<i>Salmo trutta</i>
	Rainbow trout	<i>Oncorhynchus mykiss</i> ^a

^aFormerly *Salmo gairdneri*.

Table 3-7. Recommended Target Species for Northeast Atlantic Estuaries and Marine Waters (Maine through Connecticut)

Family name	Common name	Scientific name
Finfish Species		
<i>Anguillidae</i>	American eel	<i>Anguilla rostrata</i>
<i>Percichthyidae</i>	Striped bass	<i>Morone saxatilis</i>
<i>Pomatomidae</i>	Bluefish	<i>Pomatomus saltatrix</i>
<i>Sparidae</i>	Scup	<i>Stenotomus chrysops</i>
<i>Sciaenidae</i>	Weakfish	<i>Cynoscion regalis</i>
<i>Bothidae</i>	Summer flounder	<i>Paralichthys dentatus</i>
	Four-spotted flounder	<i>Paralichthys oblongus</i>
<i>Pleuronectidae</i>	Winter flounder	<i>Pseudopleuronectes americanus</i>
	Yellowtail flounder	<i>Limanda ferruginea</i>
	American dab	<i>Hippoglossoides platessoides</i>
Shellfish Species		
<i>Bivalves</i>	Soft-shell clam	<i>Mya arenaria</i>
	Hard clam	<i>Mercenaria mercenaria</i>
	Ocean quahog	<i>Arctica islandica</i>
	Surf clam	<i>Spisula solidissima</i>
	Blue mussel	<i>Mytilus edulis</i>
<i>Crustaceans</i>	American lobster	<i>Homarus americanus</i>
	Eastern rock crab	<i>Cancer irroratus</i>

Table 3-8. Recommended Target Species for Mid-Atlantic Estuaries and Marine Waters (New York through Virginia)

Family name	Common name	Scientific name
Finfish Species		
<i>Anguillidae</i>	American eel	<i>Anguilla rostrata</i>
<i>Ictaluridae</i>	Channel catfish	<i>Ictalurus punctatus</i>
	White catfish	<i>Ictalurus catus</i>
<i>Percichthyidae</i>	White perch	<i>Morone americana</i>
	Striped bass	<i>Morone saxatilis</i>
<i>Pomatomidae</i>	Bluefish	<i>Pomatomus saltatrix</i>
<i>Sparidae</i>	Scup	<i>Stenotomus chrysops</i>
<i>Sciaenidae</i>	Weakfish	<i>Cynoscion regalis</i>
	Spot	<i>Leiostomus xanthurus</i>
	Atlantic croaker	<i>Micropogonias undulatus</i>
	Red drum	<i>Sciaenops ocellatus</i>
<i>Bothidae</i>	Summer flounder	<i>Paralichthys dentatus</i>
<i>Pleuronectidae</i>	Winter flounder	<i>Pseudopleuronectes americanus</i>
Shellfish Species		
<i>Bivalves</i>	Hard clam	<i>Mercenaria mercenaria</i>
	Soft-shell clam	<i>Mya arenaria</i>
	Ocean quahog	<i>Arctica islandica</i>
	Surf clam	<i>Spisula solidissima</i>
	Blue mussel	<i>Mytilus edulis</i>
	American oyster	<i>Crassostrea virginica</i>
<i>Crustaceans</i>	Blue crab	<i>Callinectes sapidus</i>
	American lobster	<i>Homarus americanus</i>
	Eastern rock crab	<i>Cancer irroratus</i>

Table 3-9. Recommended Target Species for Southeast Atlantic Estuaries and Marine Waters (North Carolina through Florida)

Family name	Common name	Scientific name
Finfish Species		
<i>Anguillidae</i>	American eel	<i>Anguilla rostrata</i>
<i>Ictaluridae</i>	Channel catfish White catfish	<i>Ictalurus punctatus</i> <i>Ictalurus catus</i>
<i>Percichthyidae</i>	White perch Striped bass	<i>Morone americana</i> <i>Morone saxatilis</i>
<i>Sciaenidae</i>	Spot Atlantic croaker Red drum	<i>Leiostomus xanthurus</i> <i>Micropogonias undulatus</i> <i>Sciaenops ocellatus</i>
<i>Bothidae</i>	Southern flounder Summer flounder	<i>Paralichthys lethostigma</i> <i>Paralichthys dentatus</i>
Shellfish Species		
<i>Bivalves</i>	Hard clam American oyster	<i>Mercenaria mercenaria</i> <i>Crassostrea virginica</i>
<i>Crustaceans</i>	West Indies spiny lobster Blue crab	<i>Panulirus argus</i> <i>Callinectes sapidus</i>

Table 3-10. Recommended Target Species for Gulf of Mexico Estuaries and Marine Waters (West Coast of Florida through Texas)

Family name	Common name	Scientific name
Finfish Species		
<i>Ictaluridae</i>	Blue catfish	<i>Ictalurus furcatus</i>
	Channel catfish	<i>Ictalurus punctatus</i>
<i>Ariidae</i>	Hardhead catfish	<i>Arius felis</i>
<i>Sciaenidae</i>	Spotted seatrout	<i>Cynoscion nebulosus</i>
	Spot	<i>Leiostomus xanthurus</i>
	Atlantic croaker	<i>Micropogonias undulatus</i>
	Red drum	<i>Sciaenops ocellatus</i>
<i>Bothidae</i>	Gulf flounder	<i>Paralichthys albigutta</i>
	Southern flounder	<i>Paralichthys lethostigma</i>
Shellfish Species		
<i>Bivalves</i>	American oyster	<i>Crassostrea virginica</i>
	Hard clam	<i>Mercenaria mercenaria</i>
<i>Crustaceans</i>	White shrimp	<i>Penaeus setiferus</i>
	Blue crab	<i>Callinectes sapidus</i>
	Gulf stone crab	<i>Menippe adina</i>
	West Indies spiny lobster	<i>Panulirus argus</i>

Table 3-11. Recommended Target Species for Pacific Northwest Estuaries and Marine Waters (Alaska through Oregon)

Family name	Common name	Scientific name
Finfish Species		
<i>Embiotocidae</i>	Redtail Surfperch	<i>Amphistichus rhodoterus</i>
<i>Scorpaenidae</i>	Copper rockfish	<i>Sebastes caurinus</i>
	Black rockfish	<i>Sebastes melanops</i>
<i>Bothidae</i>	Speckled sanddab	<i>Citharichthys stigmaeus</i>
	Pacific sanddab	<i>Citharichthys sordidus</i>
<i>Pleuronectidae</i>	Starry flounder	<i>Platichthys stellatus</i>
	English sole	<i>Parophrys vetulus</i>
<i>Salmonidae</i>	Coho salmon	<i>Onchorhynchus kisutch</i>
	Chinook salmon	<i>Onchorhynchus tshawytscha</i>
Shellfish Species		
<i>Bivalves</i>	Blue mussel	<i>Mytilus edulis</i>
	California mussel	<i>Mytilus californianus</i>
	Pacific oyster	<i>Crassostrea gigas</i>
	Horseneck clam	<i>Tresus capax</i>
	Pacific littleneck clam	<i>Protothaca staminea</i>
	Soft-shell clam	<i>Mya arenaria</i>
	Manila clam	<i>Venerupis japonica</i>
<i>Crustaceans</i>	Dungeness crab	<i>Cancer magister</i>
	Red crab	<i>Cancer productus</i>

Table 3-12. Recommended Target Species for Northern California Estuaries and Marine Waters (Klamath River through Morro Bay)

Family name	Common name	Scientific name
Finfish Species		
<i>Triakidae</i>	Leopard shark	<i>Triakis semifasciata</i>
<i>Sciaenidae</i>	White croaker	<i>Genyonemus lineatus</i>
<i>Embiotocidae</i>	Redtailed surfperch Striped seaperch	<i>Amphistichus rhodoterus</i> <i>Embiotoca lateralis</i>
<i>Scorpaenidae</i>	Black rockfish Yellowtail rockfish Bocaccio	<i>Sebastes melanops</i> <i>Sebastes flavidus</i> <i>Sebastes paucispinis</i>
<i>Bothidae</i>	Pacific sanddab Speckled sanddab	<i>Citharichthys sordidus</i> <i>Citharichthys stigmaeus</i>
<i>Pleuronectidae</i>	Starry flounder English sole	<i>Platichthys stellatus</i> <i>Parophrys vetulus</i>
<i>Salmonidae</i>	Coho salmon Chinook salmon	<i>Onchorhynchus kisutch</i> <i>Onchorhynchus tshawytscha</i>
Shellfish Species		
<i>Bivalves</i>	Blue mussel California mussel Pacific littleneck clam Soft-shell clam	<i>Mytilus edulis</i> <i>Mytilus californianus</i> <i>Protothaca staminea</i> <i>Mya arenaria</i>
<i>Crustaceans</i>	Dungeness crab Red crab Pacific rock crab	<i>Cancer magister</i> <i>Cancer productus</i> <i>Cancer antennarius</i>

Table 3-13. Recommended Target Species for Southern California Estuaries and Marine Waters (Santa Monica Bay to Tijuana Estuary)

Family name	Common name	Scientific name
Finfish Species		
<i>Serranidae</i>	Kelp bass	<i>Paralabrax clathratus</i>
	Barred sand bass	<i>Paralabrax nebulifer</i>
<i>Sciaenidae</i>	White croaker	<i>Genyonemus lineatus</i>
	Corbina	<i>Menticirrhus undulatus</i>
<i>Embiotocidae</i>	Black perch	<i>Embiotoca jacksoni</i>
	Walleye surf perch	<i>Hyperprosopon argenteum</i>
	Barred surfperch	<i>Amphistichus argenteus</i>
<i>Scorpaenidae</i>	California scorpionfish	<i>Scorpaena guttata</i>
	Widow rockfish	<i>Sebastes entomelas</i>
	Blue rockfish	<i>Sebastes mystinus</i>
	Bocaccio	<i>Sebastes paucispinis</i>
<i>Pleuronectidae</i>	Diamond turbot	<i>Hypsopetta guttulata</i>
	Dover sole	<i>Microstomus pacificus</i>
Shellfish Species		
<i>Bivalves</i>	Blue mussel	<i>Mytilus edulis</i>
	California mussel	<i>Mytilus californianus</i>
	Pacific littleneck clam	<i>Protothaca staminea</i>
<i>Crustaceans</i>	Pacific rock crab	<i>Cancer antennarius</i>
	Red crab	<i>Cancer productus</i>
	California rock lobster	<i>Panulirus interruptus</i>

SOP F804
Fish Population Sampling Using
Gill Net Procedures

FISH POPULATION SAMPLING USING GILL NET PROCEDURES

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FISH POPULATION SAMPLING USING GILL NET PROCEDURES

1.0 PURPOSE

The purpose of this SOP is to provide general reference information and technical guidance on the procedure to sample and characterize fish communities using gill net procedures. The collected samples provide information used in the determination of population statistics of the fish community and can be used to collect fish samples for chemical analysis of tissues. This information will be used in the assessment of risks to human health and the environment.

2.0 SCOPE

This guideline provides information on proper sampling equipment and techniques for the collection of fish in streams, ponds, and nearshore areas of lakes, impoundments, bays, and estuaries, and the ocean shoreline. This technique is most effective in slow moving streams and rivers, and open areas in lakes and impoundments. Swift moving water bodies tend to tangle the nets.

Review of the information contained herein will facilitate planning of the field sampling effort by describing standard sampling techniques. The technique described should be followed whenever applicable, noting that site-specific conditions or project-specific plans may require adjustments in methods.

3.0 DEFINITIONS

Abiotic - Non-biological components of the environment, including water body structure and natural or manmade disturbances.

Bow - The front of a boat.

Biotic - Biological components of the environment, including organisms and vegetation.

Reach - The designated portion of a stream or river.

Riffles - A stretch of water flowing over, rocks, debris, or shallow sediments causing a disturbance of the water.

Riparian - Along the bank of a river or lake.

Stern - The back of a boat.

Runs - A stretch of water flowing without any disturbances.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for development of documentation of procedures that deviate from those presented herein.

Field Team Leader - The Field Team Leader is responsible for selecting and detailing the specific sampling techniques and equipment to be used, and documenting these in the Sampling and Analysis Plan. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that personnel performing sampling activities have been briefed and trained to execute these procedures.

Sampling Personnel - It is the responsibility of the field sampling personnel to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team Leader and/or the Project Manager.

5.0 PROCEDURES

The primary consideration for collecting fish using gill nets is identifying sampling locations where there is a steady traffic of fish. Accurate and timely deployment and retrieval of the gill nets is a key variable in the success of the fish collection effort. Detailed procedures for conducting fish populations utilizing gill nets are described in the sections to follow.

5.1 Equipment

The following list is an example of the type of equipment that generally must be on hand when collecting fish samples with gill net:

- Sampling boat
- Gill nets (the size mesh is dependent on the size fish desired for collection)
- Flotation and weights to properly set the nets
- Fish Measuring Board
- 0-16 oz scale, 1-4 lb scale, 1-15 lb scale
- Live Well (large tub) with overflow pipe to outside of boat
- Appropriate sampling keys for species to be sampled, and any required instruments to aid in the identification
- Field sampling data sheets
- Glass jars for storage of fish
- Formalin®
- Black Permanent Marker
- Camera
- Required Personal Protective Equipment
- Portable Air Pumps

5.2 Preliminary Activities

Apply for and receive applicable scientific collection permits as required by the state. Contact local fish or game officials and inform them of your activities.

Collect and determine all information pertinent to the fish sampling project, including water depth, station locations, nearby boat access locations, known sediment contamination, tidal variation, any waterway obstructions or inconsistencies (e.g. shallow or grassy areas, low structures, pipe crossings), any other biological studies previously conducted on or near the site, species used locally for human consumption and the degree of such consumption, species most likely present, and the most appropriate sampling method for the species of interest that is permitted by law.

Before sampling occurs, conduct a site reconnaissance using a site map. The objective of this exercise is to categorize habitats, and map dividing lines and descriptors identifying the various types of habitats available. Make notations on the map depicting the "abiotic" characteristics of the reach including features such as pools, riffles, runs, substrate, water depth, channel shape, degree of bank erosion, shade/sun exposure, and relative current velocity and direction. Also make notations on the site map to show "biotic" characteristics of the reach including fish species observed, evidence of fisherman use, and aquatic and riparian vegetation including wetlands. In addition, identify station locations at this point, along with the total area to be sampled. Choose the station locations, where possible, to represent ecologically similar aquatic environments.

Ensure adequate number of sample collection jars and volume of Formalin® for entire trip.

Set up a continuous flow through water system using the live wells and the pumps. Place the overflow pipes about five inches from the top of the well. Attach a mesh/screen over the inlet of the overflow pipe to prevent loss of small fish species.

5.3 Operating Procedure

Determine the area to be sampled, and mark it with flagging, if possible. Field personnel that are setting the net should be standing on the platform on the bow of the boat. Place one end of the gill net with a weight attached to the bottom and a buoy attached to the top into the water, stretch the gill net across the area to be sampled by pulling it along with the boat. If there is a discernible flow, the net will be set in the upstream direction.

The net should remain in the sample location for 8 to 12 hours before retrieving. Field personnel that are collecting the fish should be standing on the platform on the bow of the boat. The net should be pulled slowly from the water and the collected fish removed as the net is being removed from the water. Place the collected fish into the live wells.

Conduct sampling in areas that will ensure adequate qualitative and/or quantitative representation of the fish community, whichever is necessary. These areas should include riffles/runs, shorelines, snags, natural fish holding areas, vegetation beds and other habitats.

Upon retrieval of a gill net, identify, measure, weigh and release the specimens. Record the proportion of individuals as hybrids and the proportion of individuals with disease, tumors, fin damage, skeletal anomalies, and any other pertinent information on a field data sheet.

To the extent possible, process all species in the field and return them to the stream alive. If specimens present taxonomic difficulties, or are too numerous for effective field processing, preserve them in 10% Formalin®, and transport them to the Baker Ecological Services Laboratory for taxonomic work and measurements.

At a minimum, preserve one representative fish from each species in 10% Formalin® as a voucher specimen. Record the station location, date sampled, and species name on the label.

6.0 QUALITY ASSURANCE RECORDS

Quality Assurance records will be maintained for each sample that is collected. The following information will be recorded in the Field Logbook:

- Sample identification (site name, location, project no.; sample name/number and location; sample type and matrix; time and date; sampler's identity).
- Field observations and measurements (sample setting, appearance of substrate, sampling method, and photograph descriptions).
- Additional remarks, as appropriate.

Record all observations in the Field Logbook as described in SOP F202. Complete field sheets for the collected samples.

7.0 REFERENCES

Brower, 1977. James E. Brower and H. Jerrold Zar. Field and Laboratory Methods for General Ecology. Wm. C. Brown Company Publishers. 1977.

Ricker, 1971. Ricker, W.E. Methods for Assessment of Fish Production in Fresh Waters. International Biological Programme Handbook No. 3. 1971.

U.S. EPA, 1987. U.S. Environmental Protection Agency. A Compendium of Superfund Field Operations Methods. Office of Emergency and Remedial Response, Office of Waste Programs Enforcement. December 1987.

U.S. EPA, 1989. Warren-Hicks, William, Parkhurst, Benjamin R., Baker, Samuel S. Jr. Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference. U.S. EPA, Environmental Research Laboratory, Corvallis, OR 97333. March 1989.

SOP F805
Fish Population Sampling Using
Seining Procedures

**FISH POPULATION SAMPLING USING SEINING PROCEDURES
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FISH POPULATION SAMPLING USING SEINING PROCEDURES

1.0 PURPOSE

The purpose of this SOP is to provide general reference information and technical guidance on the procedure to sample and characterize fish communities using seining procedures. The collected samples provide information used in the determination of population statistics of the fish community and can be used to collect fish samples for chemical analysis of tissues. This information will be used in the assessment of risks to human health and the environment.

2.0 SCOPE

This guideline provides information on proper sampling equipment and techniques for the collection of fish in shallow streams, ponds, and nearshore areas of lakes, impoundments, bays, estuaries, and ocean shoreline. This technique is more suited for use in smooth-bottomed, low-sloped areas.

This procedure is not very effective when the seine is pulled over weeds and other obstructions as they may tend to roll up, and allow the fish to pass under the seine.

Review of the information contained herein will facilitate planning of the field sampling effort by describing standard sampling techniques. The technique described should be followed whenever applicable, noting that site-specific conditions or project-specific plans may require adjustments in methods.

3.0 DEFINITIONS

Abiotic - Non-biological components of the environment, including water body structure and natural or manmade disturbances.

Biotic - Biological components of the environment, including organisms and vegetation.

Bow - The front of the boat.

Reach - The designated portion of a stream or river.

Riffles - A stretch of water flowing over, rocks, debris, or shallow sediments causing a disturbance of the water.

Riparian - Along the bank of a river or lake.

Runs - A stretch of water flowing without any disturbances.

Stern - The back of the boat.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for development of documentation of procedures that deviate from those presented herein.

Field Team Leader - The Field Team Leader is responsible for selecting and detailing the specific sampling techniques and equipment to be used, and documenting these in the Sampling and Analysis Plan. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that personnel performing sampling activities have been briefed and trained to execute these procedures.

Sampling Personnel - It is the responsibility of the field sampling personnel to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team Leader and/or the Project Manager.

5.0 PROCEDURES

The primary considerations for collecting fish for population studies include identifying sampling locations, proper sampling techniques for the haul seine and proper documentation of samples. Detailed procedures for conducting fish populations utilizing the haul seine are described in the sections to follow.

5.1 Equipment

The following list is an example of the type of equipment that generally must be on hand when collecting fish samples with a haul seine:

- Seine
- Fish Measuring Board
- 0-16 oz scale, 1-4 lb scale, 1-15 lb scale
- Appropriate sampling keys for species to be sampled, and any required instruments to aid in the identification
- Live Well (large tub) with overflow pipe to outside of boat
- Field sampling data sheets
- Glass jars for storage of fish
- Formalin®
- Black Permanent Marker
- Camera
- Required Personal Protective Equipment
- Portable Air Pumps

5.2 Preliminary Activities

Apply for and receive applicable scientific collection permits as required by the state. Contact local fish or game officials and inform them of your activities.

Collect and determine all information pertinent to the fish sampling project, including water depth, station locations, nearby boat access locations, known sediment contamination, any waterway obstructions or inconsistencies (e.g. shallow or grassy areas, low structures, pipe crossings), any other biological studies previously conducted on or near the site, species used locally for human consumption and the degree of such consumption, species most likely present, and the most appropriate sampling method for the species of interest that is permitted by law.

Before sampling occurs, conduct a site reconnaissance using a site map. The objective of this exercise is to categorize habitats, and map dividing lines and descriptors identifying the various types of habitats available. Make notations on the map depicting the "abiotic"

characteristics of the reach including features such as pools, riffles, runs, substrate, water depth, channel shape, degree of bank erosion, tidal variations shade/sun exposure, and relative current velocity and direction. Also make notations on the site map to show "biotic" characteristics of the reach including fish species observed, evidence of fisherman use, and aquatic and riparian vegetation including wetlands. In addition, identify station locations at this point, along with the total area to be sampled. Choose the station locations, where possible, to represent ecologically similar aquatic environments.

Ensure adequate number of sample collection jars and volume of Formalin® for entire trip.

Set up a continuous flow through water system using the live wells and the pumps. Place the overflow pipes about five inches from the top of the well. Attach a mesh/screen over the inlet of the overflow pipe to prevent loss of small fish species.

5.3 Operating Procedure

Determine the area to be sampled, and mark it with flagging, if possible. Stretch the seine across the area to be sampled, with a minimum of one field personnel on either side of the seine. Ensure that the weighted side of the seine is at the bottom. Best results are achieved when the water level is no deeper than two thirds the height of the slack net.

Rapidly walk through the water at the same speed, while keeping a constant distance apart. If sampling in a stream, walk upstream against the current. As the end of the sampling area approaches, pull the seine rapidly toward the shore, and lift the weighted end out of the water. Place the collected fish into the live wells.

If other field personnel are present, have them walk towards the seine to chase the fish in that direction. In addition, have them help to lift the seine when the sampling effort is complete.

Conduct sampling in areas that will ensure adequate qualitative and/or quantitative representation of the fish community, whichever is necessary. These areas should include riffles/runs, shorelines, snags, natural fish holding areas, vegetation beds and other habitats.

At the end of a sampling reach, identify, measure, weigh and release the specimens. Record the proportion of individuals as hybrids and the proportion of individuals with disease,

tumors, fin damage, skeletal anomalies, and any other pertinent information on a field data sheet.

At a minimum, preserve one representative fish from each species in 10% Formalin[®] as a voucher specimen. Record the station location, date sampled, and species name on the label.

6.0 QUALITY ASSURANCE RECORDS

Quality Assurance records will be maintained for each sample that is collected. The following information will be recorded in the Field Logbook:

- Sample identification (site name, location, project no.; sample name/number and location; sample type and matrix; time and date; sampler's identity).
- Field observations and measurements (sample setting, appearance of substrate, sampling method, and photograph descriptions).
- Additional remarks, as appropriate.

Record all observations in the Field Logbook as described in SOP F202. Complete field sheets for the collected samples.

7.0 REFERENCES

Brower, 1977. James E. Brower and H. Jerrold Zar. Field and Laboratory Methods for General Ecology. Wm. C. Brown Company Publishers. 1977.

Ricker, 1971. Ricker, W.E. Methods for Assessment of Fish Production in Fresh Waters. International Biological Programme Handbook No. 3. 1971.

U.S. EPA, 1987. U.S. Environmental Protection Agency. A Compendium of Superfund Field Operations Methods. Office of Emergency and Remedial Response, Office of Waste Programs Enforcement. December 1987.

U.S. EPA, 1989. Warren-Hicks, William, Parkhurst, Benjamin R., Baker, Samuel S. Jr.
Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference. U.S.
EPA, Environmental Research Laboratory, Corvallis, OR 97333. March 1989.

SOP F806
Benthic Macroinvertebrate Ponar Sampling

**BENTHIC MACROINVERTEBRATE PONAR SAMPLING PROCEDURES
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BENTHIC MACROINVERTEBRATE PONAR SAMPLING PROCEDURES

1.0 PURPOSE

The purpose of this SOP is to provide general reference information and technical guidance on the procedure to sample and characterize benthic macroinvertebrate populations using a Ponar grab. The collected samples provide information used in the determination of population statistics of the benthic macroinvertebrate community. This information will be used in the assessment of risks to the environment.

2.0 SCOPE

This guideline provide information on proper sampling techniques for the collection of benthic macroinvertebrates living in various types of sludges and sediments from silts to granular. This technique may not be appropriate if the sediment is hard and/or rocky.

Review of the information contained herein will facilitate the planning of the field sampling effort by describing standard sampling techniques. The techniques described should be followed whenever applicable, noting that site-specific conditions or project-specific plans may require adjustments in the methods.

3.0 DEFINITIONS

Abiotic - Non-biological components of the environment, including water body structure and natural or manmade disturbances.

Benthic Macroinvertebrate - Organisms living on the bottom of water bodies.

Biotic - Biological components of the environment, including organisms and vegetation.

Bow - The front of the boat.

Reach - The designated portion of a stream or river.

Riffles - A stretch of water flowing over, rocks, debris, or shallow sediments causing a disturbance of the water.

Riparian - Along the bank of a river or lake.

Runs - A stretch of water flowing without any disturbances.

Stern - The back of the boat.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for development of documentation of procedures that deviate from those presented herein.

Field Team Leader - The Field Team Leader is responsible for selecting and detailing the specific sampling techniques and equipment to be used, and documenting these in the Sampling and Analysis Plan. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that personnel performing sampling activities have been briefed and trained to execute these procedures.

Sampling Personnel - It is the responsibility of the field sampling personnel to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team Leader and/or the Project Manager.

5.0 PROCEDURES

The primary considerations in collecting benthic macroinvertebrate samples include proper operation of the ponar sampler and proper techniques for sample preparation. Proper benthic macroinvertebrate sampling procedures using the ponar are described in the sections to follow.

5.1 Sampling Equipment

The following list is an example of the type of equipment that generally must be on hand when collecting benthic macroinvertebrate samples with the ponar:

- Sampling Boat
- Ponar
- 1/2" Nylon Rope or Crane with Winch and Aircraft Cable
- Plastic Tub (approximate size 2'x2'x6")
- Wash Tub
- 12" sieve (0.500mm)
- 16 oz Straight Side Widemouth Polypropylene Jars
- 70% Isopropyl Alcohol
- Buffered Formalin®
- Teflon Spatula
- Wash Bottles
- 100% Rag Paper Labels
- Black Permanent Marker
- Camera
- Required Personal Protective Equipment

5.2 Preliminary Activities

Apply for and receive applicable scientific collection permits as required by the state. Contact local fish or game officials and inform them of the proposed sampling activities.

Collect and determine all information pertinent to the benthic sampling project, including water depth, station locations, nearby boat access locations, sediment composition, known sediment contamination, any waterway obstructions or inconsistencies (e.g. shallow or grassy areas, low structures, pipe crossings), and any other biological studies previously conducted on or near the site.

Before sampling occurs, conduct a site reconnaissance using a site map. The objective of this exercise is to categorize habitats, and map dividing lines and descriptors identifying the various types of habitats available. Make notations on the map depicting the "abiotic"

characteristics of the reach including features such as pools, riffles, runs, substrate, water depth, channel shape, degree of bank erosion, shade/sun exposure, and relative current velocity and direction. Also make notations on the site map to show "biotic" characteristics of the reach including fish species observed, evidence of fisherman use, and aquatic and riparian vegetation including wetlands. In addition, identify station locations at this point, along with the total area to be sampled. Choose the station locations, where possible, to represent ecologically similar aquatic environments.

Ensure adequate number of sample collection jars and volume of Formalin® and alcohol for entire trip. If regional area dictates, additional alcohol may be purchased at site.

5.3 Operating Procedure

Prior to launching, check to the boat's gasoline tank to ensure that there is a sufficient amount of gasoline (oil mixture 50:1) for the daily activities. Load and launch the boat at access ramp. Set up the boat for most comfortable and efficient working conditions. When the boat's engine is operating properly, drive to the first station location.

After arriving at the station, drop and secure the anchor. Try to position the boat parallel with direction of water flow, if applicable. Fill the wash tub about half-full with site water.

Attach a 1/2" nylon rope to the ponar, placing the rope through the pulley located on the shocking rail at the bow of the boat. If the crane and winch is used, attach the aircraft cable from the winch to the ponar. Secure the ponar open, maintaining tension on the line, and lower it slowly until the ponar reaches the sediments. Do not allow the ponar to free-fall, because the ponar may twist during descent and land improperly. In addition, a free-falling ponar may cause a pressure wave and blowout the sediment surface layer when the grab reaches the bottom.

When the ponar contacts the sediment, release the tension in the line to close the ponar. After the ponar closes, lift it at a slow but steady rate to prevent sample loss or washout. Place the ponar into the small tub, and open it to release the contents. Discard sample and repeat the procedure if debris prevented complete closure of the ponar and/or little or no sediment was collected.

Transfer the contents in the tub to the sieve, keeping the sieve over the wash tub. Shake the sieve in the wash tub to remove small particles (less than 0.500 mm) and transfer the remaining contents into sample jars. Use a teflon spatula to transfer the bulk of the sample to the jars, and wash down the remaining portion of the sample into the jars using a wash bottle. Decant off the overlying water in jar through the sieve. Wash down any remaining sample in the sieve into the jars using a minimal amount of water.

Fill approximately half of the sample jar with sample, and add 70% isopropyl alcohol for freshwater samples or 10% buffered Formalin® for saltwater samples to fill the remainder of the jar. Place a 100% cotton paper label inside the jar, identifying the project, station location, date, and replicate number, and close the lid tightly. Use a pencil to mark the label. Label the outside of jar with the project, station location, date, and replicate number using a black permanent marker, and store in jars in containers.

Collect a minimum of three replicate samples at each sampling location unless otherwise specified in the project proposal.

6.0 QUALITY ASSURANCE RECORDS

Quality assurance records will be maintained for each sample that is collected. The following information will be recorded in the Field Logbook:

- Sample identification (site name, location, project no.; sample name/number and location; sample type and matrix; time and date; sampler's identity).
- Field observations and measurements (sample setting, appearance of substrate, sampling method, and photograph descriptions).
- Additional remarks, as appropriate.

Proper chain-of-custody procedures play a crucial role in data gathering. SOP F201 describes requirements for completing a chain-of-custody form. Chain of custody forms are considered quality assurance records.

7.0 REFERENCES

ASTM, 1990. American Society for Testing and Materials. Annual Book of ASTM Standards: Water and Environmental Technology, Vol. 11.04. American Society for Testing and Materials, Philadelphia, PA. 1993

N.J. DEP, 1988. New Jersey Department of Environmental Protection. Field Sampling Procedures Manual. Division of Hazardous Site Mitigation, Bureau of Environmental Measurements and Quality Assurance. February 1988.

U.S. EPA, 1987. U.S. Environmental Protection Agency. A Compendium of Superfund Field Operations Methods. Office of Emergency and Remedial Response, Office of Waste Programs Enforcement. December 1987.

U.S. EPA, 1987. U.S. Environmental Protection Agency, Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference. Office of Emergency and Remedial Response, Office of Waste Programs Enforcement. December 1987.

SOP F807
Dredge Sampling

**DREDGE SAMPLING PROCEDURES
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DREDGE SAMPLING PROCEDURES

1.0 PURPOSE

The purpose of this guideline is to provide general reference information on the sampling of benthic populations using a dredge. The collected samples provides information used in the determination of population statistics of the benthic community and can be used to collect fish and shellfish samples for chemical analysis of tissues. This information will be used in the assessment of risks to human health and the environment.

2.0 SCOPE

The purpose of this SOP is to provide general reference information and technical guidance on proper sampling equipment and techniques for the collection of benthic populations in sludges and sediments from silts to granular. Review of the information contained herein will facilitate planning of the field sampling effort by describing standard sampling techniques. The techniques described should be followed whenever applicable, noting that site-specific conditions or project specific plans may require adjustments in methods.

3.0 DEFINITIONS

Abiotic - Non-biological components of the environment, including water body structure and natural or manmade disturbances.

Benthic Populations - Organisms living on the bottom of water bodies including fish, shellfish, and benthic macroinvertebrates.

Biotic - Biological components of the environment, including organisms and vegetation.

Bow - The front of the boat.

Reach - The designated portion of a stream or river.

Riparian - Along the bank of a river or lake.

Stern - The back of the boat.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for development of documentation of procedures that deviate from those presented herein.

Field Team Leader - The Field Team Leader is responsible for selecting and detailing the specific sampling techniques and equipment to be used, and documenting these in the Sampling and Analysis Plan. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that personnel performing sampling activities have been briefed and trained to execute these procedures.

Sampling Personnel - It is the responsibility of the field sampling personnel to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team Leader and/or the Project Manager.

5.0 PROCEDURES

The primary considerations in collecting benthic populations samples include proper operation of the dredge sampler and proper techniques for sample preparation. Proper benthic population sampling procedures using the dredge are described in the sections to follow.

5.1 Equipment

The following list is an example of the type of equipment that generally must be on hand when collecting benthic population samples with the dredge:

- Sampling Boat
- Dredge
- 1/2" Nylon Rope or Crane with Winch and Aircraft Cable
- Plastic Tub (approximate size 2'x2'x6")
- 12" sieve (0.500mm)

- Gallon Ziploc Bags
- Teflon Spatula
- Wash Bottles
- Permanent Marker
- Field Data Sheets
- Field Log Books
- Camera
- Required Personal Protective Equipment

5.2 Preliminary Activities

Apply for and receive applicable scientific collection permits as required by the state. Contact the local fish or game officials and inform them of the proposed sampling activities.

Collect and determine all information pertinent to the sampling project, including water depth, station locations, nearby boat access locations, known sediment contamination, tidal variations, any waterway obstructions or inconsistencies (e.g. shallow or grassy areas, low structures, pipe crossings), any other biological studies previously conducted on or near the site, species used locally for human consumption and the degree of such consumption, species most likely present, and the most appropriate sampling method for the species of interest that is permitted by law.

Before sampling occurs, conduct a site reconnaissance using a site map. The objective of this exercise is to categorize habitats, and map dividing lines and descriptors identifying the various types of habitats available. Make notations on the map depicting the "abiotic" characteristics of the reach including features such as pools, riffles, runs, substrate, water depth, channel shape, degree of bank erosion, shade/sun exposure, tidal variations, and relative current velocity and direction. Also make notations on the site map to show "biotic" characteristics of the reach including fish species observed, evidence of fisherman use, and aquatic and riparian vegetation including wetlands. In addition, identify station locations at this point, along with the total area to be sampled. Choose the station locations, where possible, to represent ecologically similar aquatic environments.

5.3 Operating Procedure

Prior to launching, check to the boat's gasoline tank to ensure that there is a sufficient amount of gasoline (oil mixture 50:1) for the daily activities. Load and launch the boat at access ramp as described in SOP F904. Set up the boat for most comfortable and efficient working conditions.

When the boat's engine is operating properly, drive to the first station location and drop and secure the anchor. Try to position the boat parallel with direction of water flow, if applicable.

Secure 1/2" nylon rope to the dredge, and run the line through the handles at the stern of the boat. Lower the dredge to the bottom of the water body. Pull up the anchor and start the boat engine. Drag the dredge slowly over the sediment, (maintaining approximately a 10:1 ratio of rope length to depth of water) until the desired distance is sampled. Slowly raise the dredge out of the water and empty its contents into the tub.

Collect benthic species desired. Fish and shellfish samples can be stored in holding tanks for processing for population statistics or coolers with ice for processing for tissue analysis. Benthic macroinvertebrates should be separated from abiotic debris and placed in sample jars or ziploc bags, and preserved with proper preservative (saltwater - buffered Formalin® or freshwater - alcohol). Place a 100% cotton paper label inside the sample container, identifying the project, station location, date, and replicate number. Use a pencil to mark the label. Label the outside of sample container using a black permanent marker, with the project, station location, date, and replicate number.

Collect a minimum of three replicate samples at each sampling location unless otherwise specified in the project proposal.

6.0 QUALITY ASSURANCE RECORDS

Quality assurance records will be maintained for each sample that is collected. The following information will be recorded in the Field Logbook:

- Sample identification (site name, location, project no.; sample name/number and location; sample type and matrix; time and date; sampler's identity).

- Field observations and measurements (sample setting, appearance of substrate, sampling method, and photograph descriptions).
- Additional remarks, as appropriate.

Proper chain-of-custody procedures play a crucial role in data gathering. SOP F201 describes requirements for currently completing a chain-of-custody form. Chain of custody forms are considered quality assurance records.

7.0 REFERENCES

Brower, 1977. James E. Brower and H. Jerrold Zar. Field and Laboratory Methods for General Ecology. Wm. C. Brown Company Publishers. 1977.

U.S. EPA, 1987. U.S. Environmental Protection Agency, Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference. Office of Emergency and Remedial Response, Office of Waste Programs Enforcement. December 1987.

U.S. EPA, 1987. U.S. Environmental Protection Agency. A Compendium of Superfund Field Operations Methods. Office of Emergency and Remedial Response, Office of Waste Programs Enforcement. December 1987.

APPENDIX I
Land Survey

SOP F801
Land Survey

**LAND SURVEYING
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- 6.0 HEALTH AND SAFETY**
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LAND SURVEYING

1.0 PURPOSE

This procedure describes methods and equipment commonly used by a Registered Land Surveyor when compiling by survey the vertical and horizontal locations of on-site monitoring wells and other site structures, and topographic features associated with study areas at various Naval Activity locations.

2.0 SCOPE

The information presented in this SOP is generally applicable to all the various Naval Activity locations, except where state-specific requirements differ concerning certifications, licenses and registrations.

Specific surveying problems encountered by the survey crew may require the adaptation of existing equipment or design of new equipment. Such innovations shall be documented in the survey crew's Field Logbook.

3.0 DEFINITIONS

North American Datum (NAD) - Datum used during the absence of established horizontal and vertical control.

Mean Sea Level (MSL) - Adopted as a datum plane for the measurement of elevations and depths.

Horizontal Control - Horizontal location of an object from surveyed corners or other features on permanent land monuments in the immediate site area. Will be based on North American Datum (NAD).

Vertical Control - Vertical location of an object compared to the adjacent ground surface.

Bench Mark - Precisely determined elevation above or below sea level. May also have horizontal control (northing, easting) determined for location.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with acceptable surveying practices as required by the state in which the work is performed.

Field Team Leader - The Field Team Leader is responsible for ensuring that procedures are implemented in the field and that personnel performing surveying activities have been briefed and trained to execute these procedures.

5.0 PROCEDURES

Baker requires the services of a Registered Land Surveyor to determine by survey the elevations and horizontal locations of monitoring wells and other site structures, and topographic features associated with study areas at various Navy Activity locations. The surveyor will mobilize to the site within seven days upon receiving the notice-to-proceed. All site surveys must be completed in the time frame agreed upon. The site map shall be completed within ten days of completion of the site survey.

5.1

Specifically, Baker requires the following:

Delineate the elevations of groundwater monitoring wells to an accuracy of 0.01 feet, referenced to United States Geological Survey Mean Sea Level (MSL) from the nearest datum bench mark. Each Naval Activity has identified existing bench marks that may be used for control; however, these bench marks may not be directly adjacent to the survey sites.

5.1.1

The elevation point for each well casing and a permanent mark designating the elevation point shall be established on each well. In addition, the ground surface elevation for each well

shall be established. Some of the wells will be flush-mounted level with the pavement; thus the land surface elevation will be above the "top of casing" elevation for those wells.

5.1.2

Determine the elevation of the directly adjacent ground surface to an accuracy of 0.1 feet.

5.2

Delineate the horizontal location of each well from surveyed corners or other features on permanent land monuments in the immediate site area to an accuracy of 0.1 foot, referenced to North American Datum (NAD). Baker will supply an existing Navy property plot plan or CADD file for each site to the subcontractor that will serve as the base map for locating surveyed points. All permanent points established during control traverses shall be shown.

5.3

Locate various drainage trenches/structures and significant topographic features at Baker's request via the survey. A Baker representative may be present during survey activities to identify points and features to be located. If no Baker representative will be present, the subcontractor will be notified in advance as to what features or types of features are to be included in the survey.

5.4

In the absence of Activity-established horizontal and vertical control, all survey points will be based on North American Datum (NAD) for horizontal control and MSL for vertical control.

5.5

The subcontractor shall provide Baker with a letter report containing all relevant survey information along with one legible copy of the field survey notes recorded when determining the surveyed elevations, location of wells, and requested topographic information. The subcontractor shall also provide one reproducible, legible copy of the property map showing the well designation, "top-of-casing" elevation and location at each well, and a table listing the

well designation, "top-of-casing" ground surface elevations, coordinates for each well, and plotted horizontal features. Baker cannot verify the accuracy of Navy-supplied site maps, it is recognized that the subcontractor's responsibility in plotting features is to provide most accurate locations possible on mapping available. Tabulated data provided by the subcontractor, however, must be accurate on an MSL datum specified above. All deliverables must be in ACAD R12.

5.6

The subcontractor shall perform these services in accordance with standard, acceptable surveying practices as required by the state in which the work is performed and all work shall be conducted under the supervision of a Registered Land Surveyor, duly licensed to work in the state.

6.0 HEALTH AND SAFETY

The subcontractor is to provide for and assume responsibility for adequate health and safety protection for on-site personnel. Baker requires contracted land surveyors to provide evidence of having received OSHA-specified training to conduct work on potentially hazardous sites. The specific content of the training requirements are outlined in 29 CFR 1910.120(e). These requirements include:

- Minimum of 24 hours of hazardous waste training
- Eight hours of additional training for supervisors
- Eight hours of hazardous waste refresher training for every year after the initial 24-hour training
- Medical surveillance as specified in the specific OSHA regulations

At least one of the on-site surveying personnel must have the 32 hour supervisor hazardous waste training. The subcontractor is to provide to Baker personnel on-site or in Baker's offices copies of current training and medical certifications, and to assure that this documentation accompanies their personnel onto the job site.

7.0 QUALITY ASSURANCE RECORDS

The Field Logbook shall serve as the quality assurance record for on-site surveying activities.

APPENDIX J
On-Site Water Quality Testing

SOP F201
On-Site Water Quality Testing

**ON-SITE WATER QUALITY TESTING
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ON-SITE WATER QUALITY TESTING (FIELD PARAMETERS)

1.0 PURPOSE

This SOP describes the procedures and equipment required to measure the following parameters of an aqueous sample in the field:

- pH
- Specific Conductance (Sc)/Salinity
- Temperature (T)
- Dissolved Oxygen Concentration (DO)
- Turbidity (Secchi Disc)

The first three are the usual field parameters; dissolved oxygen may be used in particular applications according to project requirements.

2.0 SCOPE

These procedures are applicable for use in an on-site water quality monitoring program to be conducted during a Remedial Investigation or Site Investigation at a hazardous or nonhazardous site. The procedures and equipment described are applicable to nearly all aqueous samples, including potable well water, monitoring well water, surface water, leachate and drummed water, etc.

This procedure provides generic information for measuring the parameters listed above with instruments and techniques in common use. Since instruments from different manufacturers may vary, review of the manufacturer's literature pertaining to the use of a specific instrument is required before use.

3.0 DEFINITIONS

Conductance - A measurement of water's capacity for conveying electrical current and is directly related to the concentrations of ionized substances in the water. The units of measurement for conductance (mhos) are the inverse of ohms, the unit commonly used to express resistance. Conductivity and specific conductance are used synonymously.

Electrolytic Cell - An electrochemical cell in which electrical energy is supplied from an external source. This cell functions in much the same way as a galvanic cell, only in the opposite direction due to the external source of applied voltage.

Galvanic Cell - An electrochemical cell in which chemical energy is spontaneously converted to electrical energy. The electrical energy produced is supplied to an external circuit.

Oxidation - The process in which an atom or group of atoms loses electrons to achieve an increasing positive charge.

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. The range of pH is 0 to 14 standard units.

Resistance - A measure of the solution's ability to oppose the passage of electrical current. For metals and solutions, resistance is defined by Ohm's Law, $E = IR$, where E is the potential difference (in units of volts), I is the current (in units of Amperes), and R is the resistance (in units of ohms).

Secchi disc - A metal disc having four quadrants, two opposing ones painted black and the other two either white or unpainted. The Secchi disc is used to measure turbidity based on the depth of light penetration.

Turbidity - An optical property of water that causes light to be scattered or absorbed in the water, resulting in decrease in water transparency. It is a function of at least three variables: 1) dissolved chemicals, such as tannins, acids, or salts; 2) suspended particles, such as silt, clay, and organic matter; and, 3) density of microbial and planktonic life.

Salinity refers to the total amount of soluble salts in water, either naturally or added to the environment as pollutants.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for determining which on-site water quality measurements shall be made, the data quality objectives (DQOs) for these measurements, and for ensuring that these measurements are made in accordance with project-specific plans.

Field Team Leader - The Field Team Leader is responsible for determining that these water quality measurement procedures are implemented in the field in accordance with this SOP, or in accordance with project-specific plans, and to ensure that personnel performing sampling activities have been briefed and trained to execute these procedures.

Sampling Personnel - It is the responsibility of the field sampling personnel to follow these procedures for collecting on-site water quality measurements including instrument calibration, quality control and recording of results, as well as care and maintenance of the instruments in the field.

5.0 PROCEDURES

The following sections provide general procedures for collecting pH, specific conductance/salinity, temperature, dissolved oxygen concentration and turbidity measurements.

5.1 Measurement of pH

Measurement of pH is one of the most important and frequently used tests in water chemistry. Practically every phase of water supply and wastewater treatment, such as acid-base neutralization, water softening, and corrosion control, is pH dependent. Likewise, the pH of leachate can be correlated with other chemical analyses to determine the probable source of contamination. It is therefore important that reasonably accurate pH measurements be taken.

Measurements of pH also can be used to check the quality and corrosivity of soil and solid waste samples. However, these samples must be immersed in water prior to analysis; specific measurement techniques for solids are not described here.

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; the pH meter is used 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 most cases, use of a pH meter will be required.

5.1.1 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 with the indicator compound on the paper. Depending on the indicator and the pH range of interest, a variety of different colors can be used. Typical indicators are weak acids or bases, or both. Process chemistry and molecular transformations leading to the color change are variable and complex.

Use of a pH meter relies on the same principle as other ion-specific electrodes. Measurement relies on the establishment of a potential difference across a glass or other type of membrane. The membrane is conductive to ionic species and, in combination with a standard or reference electrode, a potential difference proportional to hydrogen ion concentration can be generated and measured.

5.1.2 Equipment

The following equipment and reagents are needed for taking pH measurements:

- Portable pH meter, or pH indicator paper, such as Mydrion or Alkacid, to cover the pH range 2 through 12.

- Laboratory-prepared buffer solutions of pH 4, 7 and 10, or other buffers which bracket the expected pH range.

5.1.3 Measurement Techniques for Field Determination of pH

A. pH Meter

Standardization, calibration, and operation and maintenance shall be performed according to the manufacturers instructions. The following procedure is used for measuring pH with a pH meter:

1. The batteries and instrument shall be checked and calibrated prior to initiation of the field effort.
2. The accuracy of the buffer solutions used for field and laboratory calibration shall be checked. Buffer solutions need to be changed often due to degradation upon exposure to the atmosphere.
3. Immerse the tip of the electrodes in water overnight. If this is not possible due to field conditions, immerse the electrode tip in water for at least an hour before use. The electrode tip may be immersed in a rubber or plastic sack containing buffer solution for field transport or storage. This is not applicable for all electrodes as some must be stored dry.
4. 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).
5. Immerse the electrode(s) in a pH-7 buffer solution.
6. Adjust the temperature compensator to the proper temperature (on models with automatic temperature adjustment, immerse the temperature probe into the buffer solution). It is best to maintain the buffer solution at or near expected sample temperature before calibration, if possible.
7. Adjust the pH meter to read 7.0.

8. Remove the electrode(s) from the buffer and rinse well with distilled-deionized water. Immerse the electrode(s) in pH-4 or 10 buffer solution (depending on the expected pH of the sample) and adjust the slope control to read the appropriate pH. For best results, the standardization and slope adjustments shall be repeated at least once.
9. Immerse the electrode(s) in the unknown solution, slowly stirring the probe until the pH stabilizes. Stabilization may take several seconds to minutes. If the pH continues to drift, the sample temperature may not be stable, a chemical reaction (e.g., degassing) may be taking place in the sample, or the meter or electrode may be malfunctioning. This must be clearly noted in the logbook.
10. After adjusting the temperature compensator to the sample temperature, read and record the pH of the solution. The pH value shall be recorded to the nearest 0.1 pH unit. Also record the sample temperature. All measurements shall be recorded in the Field Logbook.
11. Upon completion of measurement and removal of the electrode from the sample, the electrode shall be thoroughly rinsed with deionized water.
12. The electrode(s) shall remain immersed in deionized water when not in use.

The sample used for pH measurement shall never be saved for subsequent conductivity or chemical analysis. All pH electrodes leak small quantities of electrolytes (e.g., sodium or potassium chloride) into the solution. Precipitation of saturated electrolyte solution within the electrode, especially at colder temperatures, or in cold water, may result in slow electrode response. Any visual observation of conditions which may interfere with pH measurement, such as oily materials, or turbidity, shall be noted in the Field Logbook.

B. 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, or 8 to 14) and narrow-range (many available, with ranges as narrow as 1.5 pH units). The appropriate range of pH paper shall be selected. If the pH is unknown the investigation shall start with wide-range paper.

5.2 Measurement of Specific Conductance/Salinity

Conductance provides a measure of dissolved ionic species in water and can be used to suggest the direction and extent of migration of contaminants in groundwater or surface water. Salinity refers to the total amount of soluble salts in water, either naturally or added to the environment as pollutants. One basic measure of salinity is the ability of water to conduct electric current, and, therefore, a measurement of specific conductance provides a measurement of salinity and the same instrument can be used. Salinity measurements are important in ecological field investigations because flora and fauna can be limited in their distribution based on the salinity of the sampled waters.

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 and salinity measurement soon after taking a sample, since temperature changes, precipitation reactions, and absorption of carbon dioxide from the air all affect the specific conductance.

5.2.1 Principles of Equipment Operation

An aqueous system containing ions will conduct an electric current. In a direct-current field, the positive ions (cations) migrate toward the negative electrode (cathode), while the negatively charged ions (anions) migrate toward the positive electrode (anode). Most

inorganic acids, bases and salts (such as hydrochloric acid, sodium carbonate, or sodium chloride, respectively) are relatively good conductors. Conversely, organic compounds such as sucrose or benzene, which do not disassociate in aqueous solution, conduct a current very poorly, if at all.

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 also may be used as a measure of conductance. The core element of the apparatus is the conductivity cell containing the solution of interest. Depending on ionic strength of the aqueous solution to be tested, a potential difference is developed across the cell which can be converted directly or indirectly (depending on instrument type) to a measurement of specific conductance.

5.2.2 Equipment

A portable conductivity meter, probe and thermometer are needed for taking specific conductance and salinity measurements. A variety of conductivity meters are available which also may be used to monitor salinity and temperatures. Probe types and cable lengths vary, so equipment may be obtained to meet the specific requirements of the sampling program.

5.2.3 Measurement Techniques for Specific Conductance/Salinity

Standardization, calibration, and operation and maintenance shall be performed according to manufacturers instructions. The steps involved in taking specific conductance and salinity measurements are listed below.

1. Check batteries and calibrate instrument before going into the field.
2. Calibrate the instrument daily when used. Potassium chloride solutions with a specific conductance closest to the values expected in the field shall be used. Calibration information shall be recorded in the field logbook.
3. Rinse the cell with one or more portions of the sample to be tested or with deionized water.

4. Immerse the electrode in the sample and measure the conductivity and salinity. If specified, adjust the temperature setting to the sample temperature.
5. Read and record the results on the Calibration Form (in the absence of the Calibration Form, the Field Logbook will be used).
6. If the meter does not compensate for temperature variations, the corrections given in Attachment A shall be applied.
7. On some meters, specific conductivity and salinity measurements may need to be reported with the associated temperature measurement. If the conductivity and salinity has been corrected, the measurements shall be reported as "corrected to 25°C." (See Attachment A)
 - a. Do not take readings if the sample temperature is less than 10° C, because the calibration curve no longer follows a straight line below this temperature. If necessary, heat the sample in your vehicle to at least 10° C.
 - b. Measure the sample temperature to the nearest 0.1° C to comply with SW-846.
 - c. Only report results to the nearest two significant digits for the most circumstances, because of the inherent inaccuracy in the test and conversion procedure.

examples:

- a calculated reading of 2353 umhos/cm @ 25° C should be reported as 2400 umhos/cm @ 25° C
- a calculated reading of 2325 should be reported as 2300
- a calculated reading of 337 should be reported as 340
- etc.

5.3 Measurement of Temperature

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 prior to sample collection. Collected water samples may rapidly equilibrate with the temperature of their surroundings.

5.3.1 Equipment

Temperature measurements may be taken with Thermistor, alcohol-toluene, mercury or bimetal thermometers. In addition, various meters such as specific conductance or dissolved oxygen meters, which have temperature measurement capabilities, may also be used. Using such instrumentation along with suitable probes and cables, in-situ measurements of temperature can be performed.

5.3.2 Measurement Techniques for Water Temperature

If a thermometer is used on a collected water sample:

- Immerse the thermometer in the sample until temperature equilibrium is obtained (1-3 minutes). To avoid the possibility of contamination, the thermometer shall not be inserted into samples which will undergo subsequent chemical analysis.
- Record values in a Field Logbook to the nearest 0.5 or 0.1°C, depending on the measurement device used.

If a temperature meter or probe is to be used, the instrument shall be calibrated according to the manufacturer's recommendations with an approved thermometer.

5.4 Measurement of Dissolved Oxygen Concentration

Dissolved oxygen (DO) levels in natural water and wastewater depend on the physical, chemical and biochemical activities in the water body. Conversely, the growth of many aquatic organisms, as well as the rate of corrosivity, are dependent on the dissolved oxygen concentration. Thus, analysis for dissolved oxygen is a key test in water pollution and waste treatment process control. If at all possible, DO measurements shall be taken in-situ, since concentration may show a large change in a short time, if the sample is not adequately preserved.

The method discussed here 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. DO meters also are free from interference caused by color, turbidity, colloidal material or suspended matter.

5.4.1 Principles of Equipment Operation

Dissolved oxygen probes normally are electrochemical cells that have two solid metal electrodes of different potential immersed in an electrolyte. The electrolyte is retained by an oxygen-permeable membrane. The metal of higher 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 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, but to leave the surface of the solution undisturbed.

Dissolved oxygen probes are relatively free of interferences. Interferences that can occur are reactions with oxidizing gases (such as chlorine) or with gases such as hydrogen sulfide which are not easily depolarized from the indicating electrode. If gaseous interference is suspected, it shall be noted in the Field Logbook and checked if possible. Temperature variations also can cause interference because probes exhibit temperature sensitivity. Automatic temperature compensation normally is provided by the manufacturer. Attachment B presents variations of DO in water as a function of temperature and salinity.

5.4.2 Equipment

The following, similar or equivalent, equipment is needed to measure dissolved oxygen concentration:

- YSI Model 56 dissolved oxygen monitor (or equivalent).
- Dissolved oxygen/temperature probe.
- Sufficient cable to allow the probe to contact the sample.

5.4.3 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.

1. Calibrate equipment and check batteries in the laboratory before going to the field.
2. The probe shall be conditioned in a water sample for as long 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.
3. The instrument shall be calibrated in the field before each measurement or group of closely spaced measurements by placing the probe in a water sample of known dissolved oxygen concentration (i.e., determined by Winkler method) or in a freshly air-saturated water sample of known temperature. Dissolved oxygen values for air-saturated water can be determined by consulting a table listing oxygen solubilities as a function of temperature and salinity (see Attachment B).
4. Immerse the probe in the sample. Be sure to provide for sufficient flow past the membrane, either by stirring the sample, or placing the probe in a flowing stream. Probes without stirrers which are placed in wells should be moved up and down.
5. Record the dissolved oxygen content and temperature of the sample in a Field Logbook.

6. Recalibrate the probe when the membrane is replaced, or following similar maintenance, 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. Be sure to record whether the liquid was analyzed in-situ, or whether a sample was taken.

Special care shall be taken during sample collection to avoid turbulence which can lead to increased oxygen dissolution and positive test interferences.

5.5 Measurement of Turbidity Using a Secchi Disc

In combination with other parameters, turbidity can be a useful indicator of the likelihood of biological action in a water body. It can be used to determine the depth of light penetration of surface water and the distribution and intensity of photosynthesis in the body of water. Turbidity measurements shall be taken in-situ with a Secchi disc.

5.5.1 Equipment

Turbidity measurements may be taken with a Secchi disc. In addition, turbidity may be measured using a colimeter or a spectrophotometer. These are ex-situ measurements conducted in a laboratory environment.

5.5.2 Measurement Techniques for Turbidity

Observations must be made through a shaded area of water surface.

- Standard conditions for the use of the Secchi disc are: 1) clear sky; (2) sun directly overhead; 3) shaded, protected side of boat or under a sun shade; 4) minimal waves or ripples; and, 5) any departure from these conditions should be specifically stated on field sheets.
- Rope accurately graduated in meters with 0.1 meter graduations for the first meter and 0.5 meters thereafter.

- Observer's eye should be 1 meter above the surface of the water.
- Observations should be made during the middle of the day.
- Lower the disc into the water, noting the depth at which it disappears, then lift the disc and note the depth at which it reappears. The average of the two readings is considered to be the limit of visibility and is recorded in a Field Logbook to the nearest 0.1 meter (first meter) or 0.5 meter, depending on the depth of visibility.

6.0 QUALITY ASSURANCE RECORDS

Quality assurance records for on-site water quality management consists principally of observations and measurements recorded in the Field Logbook. Records of instrument calibration, malfunction, repair, etc., shall be maintained in an Equipment Logbook as described in the Navy CLEAN Contractor Quality Control Plan.

7.0 REFERENCES

American Public Health Association, 1980. Standard Methods for the Examination of Water and Wastewater, 15th Edition, APHA, Washington, D.C.

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

U.S. Geological Survey, 1984. National Handbook of Recommended Methods for Water Data Acquisition, Chapter 5: Chemical and Physical Quality of Water and Sediment. U.S. Department of the Interior, Reston, Virginia.

ATTACHMENT A

SPECIFIC CONDUCTANCE CONVERSION TABLE

**ATTACHMENT A
SPECIFIC CONDUCTANCE CONVERSION TABLE**

Temperature Degrees C	Calculated Multiplier	Temperature Degrees C	Calculated Multiplier	Temperature Degrees C	Calculated Multiplier	Temperature Degrees C	Calculated Multiplier	Temperature Degrees C	Calculated Multiplier
10	1.402	12	1.330	14	1.266	16	1.208	20	1.106
10.1	1.398	12.1	1.327	14.1	1.263	16.1	1.205	20.1	1.103
10.2	1.394	12.2	1.324	14.2	1.260	16.2	1.202	20.2	1.101
10.3	1.390	12.3	1.320	14.3	1.257	16.3	1.199	20.3	1.099
10.4	1.387	12.4	1.317	14.4	1.254	16.4	1.197	20.4	1.096
10.5	1.383	12.5	1.314	14.5	1.251	16.5	1.194	20.5	1.094
10.6	1.379	12.6	1.310	14.6	1.248	16.6	1.191	20.6	1.092
10.7	1.376	12.7	1.307	14.7	1.245	16.7	1.188	20.7	1.089
10.8	1.372	12.8	1.304	14.8	1.242	16.8	1.186	20.8	1.087
10.9	1.369	12.9	1.301	14.9	1.239	16.9	1.183	20.9	1.085
11	1.365	13	1.297	15	1.236	17	1.180	21	1.083
11.1	1.361	13.1	1.294	15.1	1.233	17.1	1.178	21.1	1.080
11.2	1.358	13.2	1.291	15.2	1.230	17.2	1.175	21.2	1.078
11.3	1.354	13.3	1.288	15.3	1.227	17.3	1.172	21.3	1.076
11.4	1.351	13.4	1.285	15.4	1.225	17.4	1.170	21.4	1.074
11.5	1.347	13.5	1.281	15.5	1.222	17.5	1.167	21.5	1.072
11.6	1.344	13.6	1.278	15.6	1.219	17.6	1.165	21.6	1.069
11.7	1.341	13.7	1.275	15.7	1.216	17.7	1.162	21.7	1.067
11.8	1.337	13.8	1.272	15.8	1.213	17.8	1.159	21.8	1.065
11.9	1.334	13.9	1.269	15.9	1.210	17.9	1.157	21.9	1.063

Notes:

- Do not make specific conductance measurements at temperatures below 10° C.
- Measure temperature to the nearest 0.1° C.
- Report all conductivities at 25° C, to two significant digits.
- This conversion table is based on a temperature coefficient of 0.0191 (as per SW-846) and a cell constant of 1, where the ratio of conductivity at 25 C to the conductivity at temperature t° C equals $1/(1 + 0.0191[t-25])$.
- The temperature coefficient and cell constants are only approximate, actual values may differ.
- The more the temperature deviates from 25° C, the greater the uncertainty in applying the temperature correction.

ATTACHMENT A (Continued)
SPECIFIC CONDUCTANCE CONVERSION TABLE

Temperature Degrees C	Calculated Multiplier	Temperature Degrees C	Calculated Multiplier	Temperature Degrees C	Calculated Multiplier	Temperature Degrees C	Calculated Multiplier	Temperature Degrees C	Calculated Multiplier
22	1.061	24	1.019	26	0.981	28	0.946	30	0.913
22.1	1.059	24.1	1.017	26.1	0.979	28.1	0.944	30.1	0.911
22.2	1.057	24.2	1.016	26.2	0.978	28.2	0.942	30.2	0.910
22.3	1.054	24.3	1.014	26.3	0.976	28.3	0.941	30.3	0.908
22.4	1.052	24.4	1.012	26.4	0.974	28.4	0.939	30.4	0.907
22.5	1.050	24.5	1.010	26.5	0.972	28.5	0.937	30.5	0.905
22.6	1.048	24.6	1.008	26.6	0.970	28.6	0.936	30.6	0.903
22.7	1.046	24.7	1.006	26.7	0.969	28.7	0.934	30.7	0.902
22.8	1.044	24.8	1.004	26.8	0.967	28.8	0.932	30.8	0.900
22.9	1.042	24.9	1.002	26.9	0.965	28.9	0.931	30.9	0.899
23	1.040	25	1.000	27	0.963	29	0.929	31	0.897
23.1	1.038	25.1	0.998	27.1	0.961	29.1	0.927	31.1	0.896
23.2	1.036	25.2	0.996	27.2	0.960	29.2	0.926	31.2	0.894
23.3	1.034	25.3	0.994	27.3	0.958	29.3	0.924	31.3	0.893
23.4	1.032	25.4	0.992	27.4	0.956	29.4	0.922	31.4	0.891
23.5	1.029	25.5	0.991	27.5	0.954	29.5	0.921	31.5	0.890
23.6	1.027	25.6	0.989	27.6	0.953	29.6	0.919	31.6	0.888
23.7	1.025	25.7	0.987	27.7	0.951	29.7	0.918	31.7	0.887
23.8	1.023	25.8	0.985	27.8	0.949	29.8	0.916	31.8	0.885
23.9	1.021	25.9	0.983	27.9	0.948	29.9	0.914	31.9	0.884

Notes:

- Do not make specific conductance measurements at temperatures below 10° C.
- Measure temperature to the nearest 0.1° C.
- Report all conductivities at 25° C, to two significant digits.
- This conversion table is based on a temperature coefficient of 0.0191 (as per SW-846) and a cell constant of 1, where the ratio of conductivity at 25 C to the conductivity at temperature t° C equals $1/(1 + 0.0191[t-25])$.
- The temperature coefficient and cell constants are only approximate, actual values may differ.
- The more the temperature deviates from 25° C, the greater the uncertainty in applying the temperature correction.

ATTACHMENT B

**VARIATION OF DISSOLVED OXYGEN CONCENTRATION
IN WATER AS A FUNCTION OF TEMPERATURE AND SALINITY**

ATTACHMENT B

**VARIATION OF DISSOLVED OXYGEN CONCENTRATION
IN WATER AS A FUNCTION OF TEMPERATURE AND SALINITY**

Temperature °C	Dissolved Oxygen mg/l					
	Chloride Concentration in Water					Difference/ 100 mg chloride
	0	5,000	10,000	15,000	20,000	
0	14.6	13.8	13.0	12.1	11.3	0.017
1	14.2	13.4	12.6	11.8	11.0	0.106
2	13.8	13.1	12.3	11.5	10.8	0.015
3	13.5	12.7	12.0	11.2	10.5	0.015
4	13.1	12.4	11.7	11.0	10.3	0.014
5	12.8	12.1	11.4	10.7	10.0	0.014
6	12.5	11.8	11.1	10.5	9.8	0.014
7	12.2	11.5	10.9	10.2	9.6	0.013
8	11.9	11.2	10.6	10.0	9.4	0.013
9	11.6	11.0	10.4	9.8	9.2	0.012
10	11.3	10.7	10.1	9.6	9.0	0.012
11	11.1	10.5	9.9	9.4	8.8	0.011
12	10.8	10.3	9.7	9.2	8.6	0.011
13	10.6	10.1	9.5	9.0	8.5	0.011
14	10.4	9.9	9.3	8.8	8.3	0.010
15	10.2	9.7	9.1	8.6	8.1	0.010
16	10.0	9.5	9.0	8.5	8.0	0.010
17	9.7	9.3	8.8	8.3	7.8	0.010
18	9.5	9.1	8.6	8.2	7.7	0.009
19	9.4	8.9	8.5	8.0	7.6	0.009
20	9.2	8.7	8.3	7.9	7.4	0.009
21	9.0	8.6	8.1	7.7	7.3	0.009
22	8.8	8.4	8.0	7.6	7.1	0.008
23	8.7	8.3	7.9	7.4	7.0	0.008
24	8.5	8.1	7.7	7.3	6.9	0.008
25	8.4	8.0	7.6	7.2	6.7	0.008

ATTACHMENT B
(Continued)
VARIATION OF DISSOLVED OXYGEN CONCENTRATION
IN WATER AS A FUNCTION OF TEMPERATURE AND SALINITY

Temperature °C	Dissolved Oxygen mg/l					
	Chloride Concentration in Water					Difference/ 100 mg chloride
	0	5,000	10,000	15,000	20,000	
26	8.2	7.8	7.4	7.0	6.6	0.008
27	8.1	7.7	7.3	6.9	6.5	0.008
28	7.9	7.5	7.1	6.8	6.4	0.008
29	7.8	7.4	7.0	6.6	6.3	0.008
30	7.6	7.3	6.9	6.5	6.1	0.008

Note: In a chloride solution, conductivity can be roughly related to chloride concentration (and therefore used to correct measured D.O. concentration) using Attachment A.

Appendix K
Water Level, Water-Product Level Measurements,
and Well Depth Measurements

SOP F202

**Water Level, Water-Product Level Measurements,
and Well Depth Measurements**

**WATER LEVEL, WATER-PRODUCT LEVEL MEASUREMENTS, AND
WELL DEPTH MEASUREMENTS
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- 5.0 PROCEDURES**
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 - 5.3 Well Depth Measurements
 - 5.4 Decontamination of Measuring Devices
- 6.0 QUALITY ASSURANCE RECORDS**
- 7.0 REFERENCES**

WATER LEVEL, WATER-PRODUCT LEVEL MEASUREMENTS, AND WELL DEPTH MEASUREMENTS

1.0 PURPOSE

The purpose of this procedure is to describe the method of determining various down-hole measurements: groundwater levels and product (or non-aqueous phase liquid, NAPL) levels, if present, and total depth of groundwater monitoring wells and piezometers.

2.0 SCOPE

The methods described in this SOP generally are applicable to the measurement of groundwater levels, product or NAPL levels, and well depths in monitoring wells and piezometers.

3.0 DEFINITIONS

None.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other approved procedures are developed.

Field Team Leader - The Field Team Leader is responsible for ensuring that these procedures are implemented in the field, and for ensuring that personnel performing these activities have been briefed and trained to execute these procedures.

Sampling Personnel - It is the responsibility of the sampling personnel to follow these procedures or to follow documented, project-specific procedures as directed by the Field Team Leader and/or the Project Manager. The sampling personnel are responsible for the proper acquisition of down-hole measurements.

5.0 PROCEDURES

Calculations of groundwater elevations and product or NAPL interface level measurements collected from a monitoring well give an indication of:

- The horizontal hydraulic gradient and the direction of groundwater flow.
- The vertical hydraulic gradient, if well nests are used (i.e., the direction of groundwater flow in the vertical plane).
- Floating or sinking product thicknesses which are also known as Light Non-Aqueous Phase Liquids (LNAPLS) and Dense Non-Aqueous Phase Liquids (DNAPLS), respectively.

This information, when combined with other site specific information such as hydraulic conductivity or transmissivity, extent of contamination, and product density, may be used to estimate the rate of contaminant movement or source areas, etc.

Well depth is one of the factors used to determine the zone that a well monitors. Well depth also is used in the calculation of purge volumes as discussed in SOP F104, Groundwater Sample Acquisition.

The following sections briefly discuss the procedures for measuring groundwater levels, product or NAPL levels, and well depth. For all of the procedures discussed, it is assumed that the measurement will be taken from the top of the PVC or stainless steel casing (though other measuring points can be used), and that horizontal and vertical control is available for each well through a site survey, such that measurements may be converted to elevations above Mean Sea Level (MSL) or some other consistent datum.

The manufacturer's instructions for all equipment referenced herein should be read by the equipment operator(s) and accompany the equipment to the field.

5.1 Water Level Measurement

Water levels in groundwater monitoring wells shall be measured from the top of the protective steel casing, unless otherwise specified in the project plans, using an electronic water level measuring device (water level indicator). Water levels are measured by lowering the probe

into the well until the device indicates that water has been encountered, usually with either a constant buzz, or a light, or both. The water level is recorded to the nearest foot (0.01) using the graduated markings on the water level indicator cord. This measurement, when subtracted from the measuring point elevation, yields the groundwater elevation.

Groundwater levels shall always be measured to the nearest 0.01 foot. However, reporting of water level elevations depends on the accuracy of the vertical control (typically either 0.1 or 0.01 foot).

5.2 Product or NAPL Level Measurements

The procedure for product or NAPL level measurement is nearly identical to that for groundwater elevation measurements. The only differences are the use of an interface probe that detects both NAPLs and water, and the indication signal given by the measurement device. Typically, encountering NAPLs in a monitoring well is indicated by a constant sound. When water is encountered, the signal becomes an alternating on/off beeping sound. This allows for the collection of measurements for both the top of the NAPL layer in a well and the water/NAPL interface.

The apparent water table elevation below the product level will be determined by subtracting the "depth to water" from the measuring point elevation. The corrected water table elevation will then be calculated using the following equation:

$$WTE_c = WTE_a + (\text{Free Product Thickness} \times 0.80)$$

Where:

- WTE_c = Corrected water table elevation
- WTE_a = Apparent water table elevation
- 0.80 = Average value for the density of petroleum hydrocarbons. Site-specific data will be used where available.

5.3 Well Depth Measurements

Well depths typically are measured using a weighted measuring tape. A water level meter may also be used. The tape is lowered down the well until resistance is no longer felt, indicating that the weight has touched the bottom of the well. The weight should be moved in

an up and down motion a few times so that obstructions, if present, may be bypassed. The slack in the tape then is collected until the tape is taut. The well depth measurement is read directly off of the measuring tape, at the top of the PVC or stainless steel casing, to the nearest 0.01-foot and recorded in the Field Logbook. If a water level indicator is used, add the distance from the bottom of the probe to the point where water levels are measured.

5.4 Decontamination of Measuring Devices

Water level indicators, interface probes and weighted measuring tapes that come in contact with groundwater must be decontaminated using the following steps after use in each well:

- Rinse with potable water
- Rinse with deionized water
- Rinse with:
 - ▶ Methanol or acetone (EPA Region I)
 - ▶ Methanol or acetone (EPA Region II)
 - ▶ Methanol (EPA Region III)
 - ▶ Isopropanol (EPA Region IV)
- Rinse with deionized water

Portions of the water level indicators or other similar equipment that do not come into contact with groundwater, but may encounter incidental contact during use, need only undergo potable water and deionized water rinses.

6.0 QUALITY ASSURANCE RECORDS

The Field Logbook shall serve as the quality assurance record for water, product level or well depth measurements.

7.0 REFERENCE

U. S. EPA, 1991. Standard Operating Procedures and Quality Assurance Manual. Environmental Compliance Branch, U. S. EPA, Environmental Services Division, Athens, Georgia.

APPENDIX L
Photoionization Detector (PID)

SOP F203
Photoionization Detector (PID)
HNu Models PI 101 and DL 101

**PHOTOIONIZATION DETECTOR (PID)
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- 1.0 PURPOSE**
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- 5.0 PROCEDURES**
 - 5.1 Calibration
 - 5.2 Operation
 - 5.3 Interferences and Potential Problems
 - 5.4 Maintenance
- 6.0 QUALITY ASSURANCE RECORDS**
- 7.0 REFERENCES**

**PHOTOIONIZATION DETECTOR (PID)
HNu MODELS PI 101 and DL 101**

1.0 PURPOSE

The purpose of this SOP is to provide general reference information for using the HNu Model PI 101 or DL 101 photoionization detector (PID), or an equivalent or similar instrument, in the field. Calibration and operation, along with field maintenance will be included in this SOP.

2.0 SCOPE

This procedure provides information on the field operation and general maintenance of the HNu (PID). Application of the information contained herein will ensure that this type of field monitoring equipment will be used properly. Review of the manufacturer's instruction manual is necessary for more complete information.

These procedures refer only to monitoring for health and safety. The methods are not directly applicable to surveillance of air quality for analytical purposes.

3.0 DEFINITIONS

Ionization Potential - In this case, a numeric equivalent that expresses the amount of energy needed to replace an electron with a photon. This energy is further defined in terms of electron volts (eV).

PID - Photoionization Detector

ppm - parts per million: parts of vapor or gas per million parts of air (directly proportional to calibration gas).

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other approved procedures

are developed. The Project Manager is responsible for selecting qualified individuals for the monitoring activities.

Project Health and Safety Officer (PHSO) - The Project Health and Safety Officer is responsible for developing a site-specific Health and Safety Plan (HASP) which specifies air monitoring requirements.

Field Team Leader - It is the responsibility of the Field Team Leader to implement these procedures in the field, and to ensure that the Field Investigation Personnel performing air monitoring activities, have been briefed and trained to execute these procedures before the start of site operations.

Site Health and Safety Officer (SHSO) - The SHSO is responsible for ensuring that the specified air monitoring equipment is on site, calibrated, and used correctly by the Field Personnel. The SHSO will coordinate these activities with the Field Team Leader.

Field Investigation Personnel - It is the responsibility of the Field Investigation Personnel to follow these procedures or to follow documented project-specific procedures as directed by the Field Team Leader/Site Health and Safety Officer. The Field Investigation Personnel are responsible for documenting all air monitoring results in both the Field Logbook and the daily Realtime Air Monitoring Log during each field investigation.

5.0 PROCEDURES

The HNu utilizes the principle of photoionization whereby contaminant molecules enter the ion chamber and electrons are displaced by ultraviolet photons producing positive ions. These displaced positive ions are in turn collected on a special electrode. As the positive ions collect on the electrode, they create an electrical current which is amplified and displayed on the meter as a concentration in parts per million (ppm).

The HNu is only effective for contaminants that have ionization potentials (IP) of less than or equal to the electron volt (eV) capacity of the lamp (i.e., methane, having an IP of 12.98 eV, will not be detected at a lamp potential of 11.7 eV). The standard lamp is 10.2 eV with optional lamps of 9.5 eV and 11.7 eV, respectively. For the PI 101 the span settings should be as

follows: 1.0 for 9.5 eV lamps; 9.8 for 10.2 eV lamps; and 5.0 for 11.7 eV lamps. During calibration, these span settings will be adjusted as necessary, using the span control knob.

The following subsections will discuss HNu calibration, operation, and maintenance. These sections, however, should not be used as a substitute for the manufacturer's instruction manual.

5.1 Calibration

For calibration purposes, the following items will be needed:

- *Gas cylinder containing 95 to 100 parts per million (ppm) of isobutylene, balance in air.
- A 0.30 liters per minute regulator.
- Connector tubing.
- Screwdriver set.
- Calibration Gas Humidifier (for high humidity environments).
- Photoionization Detector (PID) Calibration Form.

*Note: Do not rely on accuracy of rated cylinder concentration when content drops to <200 psi.

Prior to each use, make sure that the battery is fully charged, the ultraviolet lamp is working, and that the fan is operating and drawing air into the probe (fan operates at approximately 100-200 cc/minute for the PI 101 and 225 cc/minute for the DL 101). Procedures for completing these preliminary activities are given in the manufacturer's instruction manual.

PI 101

To calibrate the HNu PI 101, the steps provided below should be followed. For an itemized description of the calibration process, refer to Section 3-5 in the manufacturer's instruction manual. The HNu PI 101 should be calibrated on a daily basis.

- Turn the function control switch to the standby position and zero the instrument by turning the zero adjustment knob to align the indicator needle with zero on the readout meter.
- Set the range on the HNu and allow the instrument to warm up a few minutes before calibrating. Choices for range are 0-20, 0-200, and 0-2,000 ppm, respectively. Range choice must take into account the concentration of the calibration gas. For example, if you are using a concentration of 100 ppm isobutylene as the calibration gas, your

range should be set on the 0-200 scale. If you have to zero the instrument in the desired range, record background if present.

- Attach tubing to the regulator (use the Calibration Gas Humidifier in high humidity environments).
- Attach the free end of the tubing to the probe and turn on the calibration gas.
- Calibrate the PID to benzene equivalents. Using the 10.2 eV (lamp) probe and 100 ppm isobutylene, the meter should read 56 units. Using the 11.7 eV (lamp) probe and 100 ppm isobutylene, the meter should read 65 units. If the reading on the meter is not ± 5 percent of the concentration of the calibration gas, adjust the span setting knob until the meter reads accordingly. If after adjusting the span setting knob the readout meter is still not responding, refer to the manufacturer's instruction manual. Also, when the HNu is calibrated it should respond to a minimum of 90 percent of the concentration of the calibration gas within three seconds after introduction of that gas. If proper calibration cannot be obtained, internal calibration may be required. Note, only qualified personnel should perform internal calibrations.
- Record the calibration on the "Photoionization Detector (PID) Calibration Form".

DL 101

To calibrate the HNu DL 101, the steps provided below should be followed. For an itemized description of the calibration process, refer to Section 4.4 in the manufacturer's instruction manual.

- Press and release the POWER button on the keypad and wait for the screen to stabilize then press the CALIBRATE key until "Calibrate?" appears. At this point press the ENTER key until "Elec_Zero? Yes" appears on the screen in which case you will press the ENTER key, again, to confirm the electronic zero.
- The display will now read "CE/ENT/EXIT Conc = ____ ppm" which requires the concentration of the calibration gas (noted on the side of the calibration gas bottle) to be entered on the keypad. The display will prompt you to "Attach gas to probe and /ENTER/" so attach tubing to probe (use the calibration gas humidifier in high humidity environments), open valve, and press ENTER key. Press ENTER again when "Press ENTER when Ready: xxx ppm" appears on screen. This will cause "Calibrating...Please Wait" to appear on screen.

Note: This calibration is effective when the instrument is in the Survey Mode, which is the default mode. For calibrations other the one described, or if proper calibration cannot be obtained, refer to the manufacturer's instruction manual.

- For calibrations using an alternate gas or span values, refer to Section 4.5 of the manufacturer's instruction manual.
- Record the calibration on the "Photoionization Detector (PID) Calibration Form" which accompanies each HNu.

5.2 Operation

PI 101

Note: IMPORTANT - The HNu should be "zeroed" in a fresh air environment if at all possible. If there is a background concentration, it must be documented and then zeroed out.

- Prior to each use of the HNu, check that the battery is fully charged by turning the dial to BATT and making sure that it is within range. Also make sure that the ultraviolet lamp and the fan are working properly.
- Select your desired range. HNu ranges consists of a 0-20, 0-200, and 0-2,000 ppm, respectively. Consult with the Field Team Leader for more information when choosing the appropriate range, however, in most instances the range will be set initially at 0-20.
- When HNu is used intermittently, turn knob to STANDBY to help in extending the life of the UV lamp when operating in a low humidity environment. Otherwise, leave the knob set to the range desired so that the UV lamp will "burn off" any accumulated moisture.

Note: When using the PI 101 HNu, make sure that the probe does not contact water or soil during sampling. This will cause erroneous readings and will possibly damage the instrument.

DL 101

The DL 101 is designed to default to the survey mode when initially powered up, therefore once the calibration has been completed, the instrument is ready to go. Within the survey mode several options are available, briefly these options include:

1. The Site Function

The Site function assigns a number to a site that is being analyzed. Press the Site Key on the keypad to enter a specific site number, or press the gray button on the rear of the probe to increment a site number.

2. Logging Data

The Log function stores data in memory. To log data, press the Log key on the keypad or the Log button on the back of the probe. "Log" will appear in the upper right corner of the display when activated and disappears when not activated. To turn logging off, press either the Log key on the keypad or the red Log button on the rear of the probe.

- The DL 101 allows for the interchanging of different voltage lamps, however, refer to the manufacturer's instructions before attempting to change the lamp.
- The DL 101 also offers three other modes of operation, the Hazardous Waste Mode, the Industrial Hygiene Mode, and the Leak Detection Mode. Each of these modes increases the range of capabilities for this instrument which is covered in detail in the manufacturer's instruction manual.

Note: When using the DL 101 HNu, make sure that the probe does not contact water or soil during sampling. This will cause erroneous readings and will possibly damage the instrument.

5.3 Interferences and Potential Problems

A number of factors can affect the response of the PI 101 HNu and DL 101 HNu.

- High humidity can cause lamp fogging and decreased sensitivity. This can be significant when soil moisture levels are high, or when monitoring a soil gas well that is accessible to groundwater.
- High concentrations of methane can cause a downscale deflection of the meter.
- High and low temperature, electrical fields, FM radio transmission, and naturally occurring compounds, such as terpenes in wooded areas, will also affect instrument response.

5.4 Maintenance

The best way to keep an HNu operating properly is to keep it as clean as possible. HNu's should be decontaminated and wiped down after each use.

Corrective Maintenance

- The ultraviolet lamp should be periodically cleaned using a special compound supplied by HNu Systems, Inc. for the 10.2 eV lamp, and a chlorinated solvent such as 1,1,1-trichloroethane for the 11.7eV lamp. Consult the manufacturer's instruction manual for specific cleaning instructions.
- The ionization chamber can be periodically cleaned with methyl alcohol and a swab.

Note: UV lamp and ion chamber cleaning is accomplished by following the procedures outlined in Section 5.2, however, this should only be performed by trained personnel.

- Documenting the HNu's observed symptoms and then referring to the manufacturer's instruction manual section on troubleshooting (Section 6.0) also can be employed. If this does not work, the Field Team Leader should be consulted for an appropriate course of action.

Repair and Warranty Repair - HNu's have different warranties for different parts, so documenting the problem and sending it into the manufacturer assists in expediting repair time and obtaining appropriate warranty service.

5.5 SHIPPING AND HANDLING

Following is information regarding the transport of the HNu meter and calibration gas.

- If HNu is to be carried on in aircraft, the calibration gas must be removed from the carrying case as cylinders of compressed gas are not permitted on passenger aircraft. The calibration gas should either be shipped to the site of its intended use, or purchased locally.
- Shipping of the calibration gas requires the completion of a form (specified by the shipping company) that identifies the package as a compressed gas. Compressed gas stickers must be affixed to the package.

6.0 QUALITY ASSURANCE RECORDS

Quality assurance records will be maintained for each air monitoring event. The following information shall be recorded in the Field Logbook.

- Identification - Site name, location, CTO number, activity monitored, (surface water sampling, soil sampling, etc.) serial number, time, resulting concentration, comments and identity of air monitoring personnel.
- Field observations - Appearance of sampled media (if definable).
- Additional remarks (e.g., the HNu meter had wide range fluctuations during air monitoring activities).

APPENDIX M
Bacharach Combustible Gas/Oxygen Meter and
Personal Gas Monitor Carbon Monoxide Meter

**BACHARACH COMBUSTIBLE GAS/
OXYGEN METER PERSONAL GAS MONITOR
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BACHARACH COMBUSTIBLE GAS/ OXYGEN METER AND PERSONAL GAS MONITOR

1.0 PURPOSE

The purpose of this SOP is to provide general reference information for using the Bacharach Sentinel 4 and Bacharach Sniffer® 503-A meters in the field. Calibration and operation, along with field maintenance, will be included in this SOP.

2.0 SCOPE

This procedure provides information into the field operation and general maintenance of the Sentinel 4 Sniffer and 503-A. Review of the information contained herein will ensure that this type of field monitoring equipment will be properly utilized. Review of the owner's instruction manuals is a necessity for more detailed descriptions.

3.0 DEFINITIONS

Carbon Monoxide Sensor - Expresses the Carbon Monoxide concentration in parts per million (ppm).

Combustible Gas - Combustible gas is expressed as a percent of the lower explosive limit (LEL).

Hydrogen Sulfide Sensor - Expresses the Hydrogen Sulfide concentration in parts per million (ppm).

Oxygen Sensor - Expresses the Oxygen concentration as a percentage.

ppm - parts per million: parts of vapor or gas per million parts of air by volume.

Sentinel 4 - Combustible Gas/Oxygen/Hydrogen Sulfide/Carbon Monoxide meter.

Sniffer 503-A - portable Combustible Gas and Oxygen Alarm instrument.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project -specific plans are in accordance with these procedures, where applicable, or that other approved procedures are developed. The Project Manager is responsible for selecting qualified individuals for the monitoring activities.

Project Health and Safety Officer (PHSO) - The Project Health and Safety Officer is responsible for developing a site-specific Health and Safety Plan (HASP) which specifies air monitoring requirements.

Field Team Leader - It is the responsibility of the Field Team Leader to implement these procedures in the field, and to ensure that the Field Investigation Personnel performing air monitoring activities, have been briefed and trained to execute these procedures before the start of site operations.

Site Health and Safety Officer (SHSO) - The SHSO is responsible for ensuring that the specified air monitoring equipment is on site, calibrated, and used correctly by the Field Personnel. The SHSO will coordinate these activities with the Field Team Leader.

Field Investigation Personnel - It is the responsibility of the Field Investigation Personnel to follow these procedures or to follow documented project-specific procedures as directed by the Field Team Leader/Site Health and Safety Officer. The Field Investigation Personnel are responsible for documenting all air monitoring results in the Field Logbook during each field investigation.

5.0 PROCEDURES

The Sentinel 4 Personal Gas Monitor and Sniffer 503-A utilize the principle of detecting sensors. The following four paragraphs discuss theory of operation as it applies to each functional sensor.

The combustible gas sensor uses two elements that are wound with a platinum wire. One of the elements is impregnated with a catalyst to oxidize combustible gases. The other element

is impregnated with material that will also oxidize combustible gases, but will respond to temperature and humidity conditions. When the meter is turned on, an electrical current is passed through the elements and wires. As a combustible gas enters the chamber the elements will oxidize the combustible gas, thus increasing the heat and resistance of the element. This change in resistance causes a system imbalance, which produces a measurable signal proportional to the combustible gas concentration.

The percent oxygen is measured utilizing an electrochemical sensor. As atmospheric oxygen enters the meter it diffuses into the sensor which converts the amount of oxygen in the sensor to a voltage signal. This voltage is directly proportional to percent oxygen in the atmosphere.

The concentration of hydrogen sulfide is measured utilizing an electrochemical sensor. As atmospheric hydrogen sulfide enters the meter it diffuses into the sensor which converts the amount of hydrogen sulfide in the sensor to a voltage signal. This voltage is directly proportional to the atmospheric hydrogen sulfide concentration.

The concentration of carbon monoxide as measured utilizing an electrochemical sensor. As atmospheric carbon monoxide enters the meter it diffuses into the sensor which converts the amount of carbon monoxide in the sensor to a voltage signal. This voltage is directly proportional to the atmospheric carbon monoxide concentration.

The Sentinel 4 Personal Gas Monitor and Sniffer 503-A are intrinsically safe for use in Class I, Division 1, Groups A, B, C and D hazard areas. One fact that needs to be expressed is that this type of monitoring equipment utilizes internal oxidation of combustibles, if the meter is placed in an oxygen deficient atmosphere, the combustible reading may be affected. Review of each of the instruction manuals will aid in determining the percentage of oxygen that affects the combustible gas readings.

The following subsections will discuss Sentinel 4 and Sniffer 503-A calibration, operation, and maintenance. These sections, however, do not take the place of the instruction manual.

5.1 Calibration

Sentinel 4

Due to the numerous steps involved in calibration, it is recommended that you follow the calibration procedures (on a daily basis) as outlined in the instruction manual from pages 5-12 to 5-20.

NOTE: A calibration kit will be provided for each Sentinel 4. This kit contains a cylinder for the combustible gas sensor, one cylinder for the hydrogen sulfide sensor, and one cylinder for the carbon monoxide sensor. The oxygen sensor can be calibrated with (uncontaminated/fresh air environment) atmospheric air and does not need cylinder gas.

Note: When a single sensor doesn't zero, none of the sensors are zeroed.

Sniffer® 503-A

Oxygen Detector

1. Check battery charge by turning function switch to "BATTERY TEST," if battery is in recharge zone instrument will need to be charged.
2. To zero the oxygen detector, turn function switch to "BATTERY TEST" position and press "TEST" switch and observe the O₂ meter indication. If indicator is zero, no further adjustment is necessary. If not, follow procedures in Section 5.4.1 of the Operations Manual.
3. To calibrate the oxygen detector, turn function switch to "BATTERY TEST" position. Unlock the "OXYGEN CALIB" knob and adjust it for an O₂ meter indication of 21 or at the CAL mark. Relock "OXYGEN CALIB" knob. If using zero calibration gas, follow procedures in Section 5.4.2 of the Operator's Manual.
4. Record on Calibration Sheet.

% LEL Detector

1. Check battery charge by turning function switch to "BATTERY TEST," if batter is in recharge zone, instrument will need to be charged. Allow 5 minutes for the instrument to warm up.
2. Turn function switch to the % LEL position.

Note: To eliminate the annoyance of the audible alarm, cover the alarm with a hand or duct tape during calibration. The tape must be removed, prior to operation!!

3. Connect calibration gas (typically 30% of the LEL) and allow gas to flow for 1 minute.

Note: If calibration gas has a concentration value, not a % LEL value, the % LEL can be calculated as follows:

$$\% \text{ calibration gas (i.e., methane)} \times 20\% \text{ LEL (meter alarm setting)} = \% \text{ LEL calibration setting}$$

If meter indication is within $\pm 5\%$ of LEL calibration gas, no further adjustment is required. If not, follow procedures in Section 5.5.4 of Operator's Manual.

Sniffer® 503-A

1. Connect sample probe and tubing to the instrument's sample inlet (refer to Sections 8.4 and 8.5 for the Operator's Manual for available hoses and probes.
2. Check that battery is in Operational Range.
3. Turn instrument to % LEL range and allow to warm up for 1 minute.
4. Check in a fresh air environment that % LEL reads 0% and that O₂ indicator reads 21% (calibration mark).

5. Sample air/gas from area to be tested, allow 30 seconds for readings to stabilize. When finished, allow at least 10 seconds (longer if extension line is used) to purge sample line.
6. If instrument is operating erratically, refer to "TROUBLESHOOTING" Section (Table 5-2) in Operator's Manual.

5.2 Operation

Sentinel 4

Due to the Sentinel 4 having many functions in terms of operation, it is recommended that you follow the operational procedures as outlined in the instruction manual from pages 6-1 to 6-34. NOTE: Since the Sentinel 4 is capable of measuring four different parameters, an understanding of the alarm, error, and fault messages must be obtained. This can be done by reviewing the troubleshooting table found on pages 9-2 to 9-9.

5.3 Site Maintenance

After each use, the meters should be recharged and the outside of the instruments should be wiped clean with a soft cloth.

5.4 Scheduled Maintenance

<u>Function</u>	<u>Frequency</u>
Check alarm and settings	Monthly/before each use
Clean screens and gaskets around sensors	Monthly
Replace sensors	Biannually or when calibration is unsuccessful

6.0 QUALITY ASSURANCE RECORDS

Quality assurance records will be maintained for each air monitoring event. The following information shall be recorded in the Field Logbook.

- Identification - Site name, date, location, CTO number, activity monitored, (surface water sampling, soil sampling, etc), serial number, time, resulting concentration, comments and identity of air monitoring personnel.
- Field observations - Appearance of sampled media (if definable).
- Additional remarks (e.g., the Sentinel 4 or Sniffer 503-A had wide range fluctuations during air monitoring activities.)

NOTE: The "Toxic Gas Meter Calibration Form" will be completed daily, prior to performing any air monitoring.

7.0 REFERENCES

Bacharach Installation, Operation, Maintenance Manual, Sentinel 4 Personal Gas Monitor, 1990.

Bacharach Installation, Operation, Maintenance Manual, Sniffer® 503-A, Rev. 3 - October 1990.

APPENDIX N
Decontamination of Sampling and
Monitoring Equipment

1.0 PROCEDURES

Sampling and monitoring equipment decontamination procedures are described below.

1.1 Sampling Equipment Decontamination Procedures

Equipment and materials utilized during this investigation that will require decontamination includes:

- Field measurement and sampling equipment: water level meters, bailers, compositing bottles, hand corers, hydropunch tool, etc.

The following decontamination procedures are taken from USEPA IV Standard Operating Procedures (1991).

1.1.1 **Cleaning Procedures for Teflon® or Glass Field Sampling Equipment used for the Collection of Samples for Trace Organic Compounds and/or Metals Analyses**

1. Equipment will be washed thoroughly with laboratory detergent and hot water using a brush to remove any particulate matter or surface film.
2. The equipment will be rinsed thoroughly with hot tap water.
3. Rinse equipment with isopropyl alcohol.
4. Rinse equipment thoroughly with deionized water.
6. Rinse equipment twice with solvent and allow to air dry for at least 24 hours.
7. Wrap equipment in one layer of aluminum foil. Roll edges of foil into a "tab" to allow for easy removal. Seal the foil wrapped equipment in plastic and date.
8. Rinse the Teflon® or glass sampling equipment thoroughly with tap water in the field as soon as possible after use.

When this sampling equipment is used to collect samples that contain oil, grease, or other hard to remove materials, it may be necessary to rinse the equipment several times with pesticide-grade acetone or hexane to remove the materials before proceeding with Step 1. In extreme cases, it may be necessary to steam clean the field equipment before proceeding with Step 1. If the field equipment cannot be cleaned utilizing these procedures, it should be discarded.

Small and awkward equipment such as vacuum bottle inserts and well bailers may be soaked in the nitric acid solution instead of being rinsed with it. Fresh nitric acid solution should be prepared for each cleaning session.

1.1.2 Cleaning Procedures for Stainless Steel or Metal Sampling Equipment used for the Collection of Samples for Trace Organic Compounds and/or Metals Analyses

1. Wash equipment thoroughly with laboratory detergent and hot water using a brush to remove any particulate matter or surface film.
2. Rinse equipment thoroughly with hot tap water.
3. Rinse equipment thoroughly with deionized water.
4. Rinse equipment twice with solvent and allow to air dry for at least 24 hours.
5. Wrap equipment in one layer of aluminum foil. Roll edges of foil into a "tab" to allow for easy removal. Seal the foil wrapped equipment in plastic and date.
6. Rinse the stainless steel or metal sampling equipment thoroughly with tap water in the field as soon as possible after use.

When this sampling equipment is used to collect samples that contain oil, grease, or other hard to remove materials, it may be necessary to rinse the equipment several times with pesticide-grade acetone or hexane to remove the materials before proceeding with Step 1. In extreme cases, when equipment is painted, badly rusted, or coated with materials that are difficult to remove, it may be necessary to steam clean, wire brush, or sandblast equipment before proceeding with Step 1. Any metal sampling equipment that cannot be cleaned using these procedures should be discarded.

1.1.3 Reusable Glass Composite Sample Containers

1. Wash containers thoroughly with hot tap water and laboratory detergent, using a bottle brush to remove particulate matter and surface film.
2. Rinse containers thoroughly with hot tap water.
3. Rinse containers with at least 10 percent nitric acid.
4. Rinse containers thoroughly with tap water.
5. Rinse containers thoroughly with deionized water.
6. Rinse twice with solvent and allow to air dry for at least 24 hours.
7. Cap with aluminum foil or Teflon® film.
8. After using, rinse with tap water in the field, seal with aluminum foil to keep the interior of the container wet, and return to the laboratory.

When these containers are used to collect samples that contain oil, grease, or other hard to remove materials, it may be necessary to rinse the container several times with pesticide-grade acetone before proceeding with Step 1. If these materials cannot be removed with acetone, the container should be discarded. Glass reusable composite containers used to collect samples at pesticide, herbicide, or other chemical manufacturing facilities that produce toxic or noxious compounds shall be properly disposed of (preferably at the facility) at the conclusion of sampling activities and shall not be returned for cleaning. Also, glass composite

containers used to collect in-process wastewater samples at industrial facilities shall be discarded after sampling. Any bottles that have a visible film, scale, or discoloration remaining after this cleaning procedure shall also be discarded.

1.1.4 Plastic Reusable Composite Sample Containers

1. Proceed with the cleaning procedures as outlined in Section 1.1.3 but omit the solvent rinse.

Plastic reusable sample containers used to collect samples from facilities that produce toxic or noxious compounds or are used to collect in-process waste stream samples at industrial facilities will be properly disposed (preferably at the facility) of at the conclusion of the sampling activities and will not be returned for cleaning. Any plastic composite sample containers that have a visible film, scale, or other discoloration remaining after this cleaning procedure will be discarded.

1.1.5 Well Sounders or Tapes Used to Measure Ground Water Levels

1. Wash with laboratory detergent and tap water.
2. Rinse with tap water.
3. Rinse with deionized water.
4. Allow to air dry overnight.
5. Wrap equipment in aluminum foil (with tab for easy removal), seal in plastic, and date.

1.1.6 Submersible Pumps and Hoses Used to Purge Ground Water Wells

1. Using a brush, scrub the exterior of the contaminated hose and pump with soapy water.
2. Rinse the soap from the outside of pump and hose with tap water.
3. Rinse the tap water residue from the outside of pump and hose with deionized water.
4. Equipment should be placed in a polyethylene bag or wrapped with polyethylene film to prevent contamination during storage or transit.

APPENDIX O
Decontamination of Drilling Rigs and
Monitoring Well Materials

1.0 PROCEDURE

The various drilling equipment and materials involved with test boring, test pit excavation, subsurface soil sampling, and monitoring well construction must be properly decontaminated to ensure that chemical analysis results reflect actual concentrations present at sampling locations. These procedures will minimize the potential for cross contamination between sampling locations and the transfer of contamination off site, and were taken from U.S.EPA IV Standard Operating Procedures (1991).

1.1 Large Machinery and Equipment

All drilling rigs, drilling and sampling equipment, backhoes, and all other associated equipment involved in the drilling and sampling activities shall be cleaned and decontaminated before entering the designated drill site. All equipment should be inspected before entering the site to ensure that there are no fluids leaking and that all gaskets and seals are intact. All drilling and associated equipment entering a site shall be clean of any contaminants that may have been transported from another hazardous waste site, thereby minimizing the potential for cross-contamination. Before site drilling activities are initiated, all drilling equipment shall be thoroughly cleaned and decontaminated at the designated cleaning/decontamination area. The following requirements and procedures are to be strictly adhered to on all drilling activities.

Any portion of the drill rig, backhoe, etc., that is over the borehole (kelly bar or mast, backhoe buckets, drilling platform, hoist or chain pulldowns, spindles, cathead, etc.) shall be steam cleaned before being brought on the site to remove all rust, soil and other material which may have come from other hazardous waste sites. The drill rig and/or other equipment associated with the drilling and sampling activities shall be inspected to insure that all oil, grease, hydraulic fluid, etc., have been removed, and all seals and gaskets are intact and there are no fluid leaks. No oils or grease shall be used to lubricate drill stem threads or any other drilling equipment being used over the borehole or in the borehole without EPA approval. If drill stems have a tendency to tighten during drilling, Teflon® string can be used on the drill stem threads. The drill rig(s) shall be steam cleaned prior to drilling each borehole. In addition, all downhole sampling equipment that will come into contact with the downhole equipment and sample medium shall be cleaned and decontaminated by the following procedures.

1. Clean with tap water and laboratory grade, phosphate-free detergent, using a brush, if necessary, to remove particulate matter and surface films. Steam cleaning and/or high pressure hot water washing may be necessary to remove matter that is difficult to remove with the brush. Hollow-stem augers, drill rods, shelby tubes, etc., that are hollow or have holes that transmit water or drilling fluids, shall be cleaned on the inside and outside. The steam cleaner and/or high pressure hot water washer shall be capable of generating a pressure of at least 2500 PSI and producing hot water and/or steam (200°F plus).
2. Rinse thoroughly with tap water (potable).

NOTE: Tap water (potable) may be applied with a pump sprayer. All other decontamination liquids (D.I. water, organic-free water, and solvents), however, must be applied with non-interfering containers. These containers shall be made of glass, Teflon®, or stainless steel. This aspect of the decontamination procedures used by the driller will be inspected by the site geologist and/or other responsible person prior to beginning of operations.

3. Rinse thoroughly with deionized water.
4. Rinse twice with solvent (pesticide grade isopropanol).
5. Rinse thoroughly with organic-free water and allow to air dry. Do not rinse with deionized or distilled water.

Organic-free water can be processed on site by purchasing or leasing a mobile deionization-organic filtration system.

In some cases when no organic-free water is available, it is permissible (with approval) to leave off the organic-free water rinse and allow the equipment air dry before use.

6. Wrap with aluminum foil, if appropriate, to prevent contamination if equipment is going to be stored or transported. Clean plastic can be used to wrap augers, drill stems, casings, etc., if they have been air dried.
7. All downhole augering, drilling and sampling equipment shall be sandblasted before Step #1 if painted, and/or if there is a buildup of rust, hard or caked matter, etc., that cannot be removed by steam and/or high pressure cleaning. All sandblasting shall be performed prior to arrival on site.
8. All well casing, tremie tubing, etc., that arrive on site with printing and/or writing on them shall be removed before Step #1. Emery cloth or sand paper can be used to remove the printing and/or writing. Most well material suppliers can supply materials without the printing and/or writing if specified when materials are ordered.
9. Well casing, tremie tubing, etc., that are made of plastic (PVC) shall not be solvent rinsed during the cleaning and decontamination process. Used plastic materials that cannot be cleaned are not acceptable and shall be discarded.

Cleaning and decontamination of all equipment shall occur at a designated area on the site, downgradient, and downwind from the clean equipment drying and storage area. All cleaning of drill rods, auger flights, well screen and casing, etc., will be conducted above the plastic sheeting using saw horses or other appropriate means. At the completion of the drilling activities, the pit shall be backfilled with the appropriate material designated by the Site Manager, but only after the pit has been sampled, and the waste/rinse water has been pumped into 55-gallon drums. No solvent rinsates will be placed in the pit unless prior approval is granted. All solvent rinsates shall be collected in separate containers for proper disposal.

APPENDIX P
Sample Preservation and Handling

SOP F301
Sample Preservation and Handling

**SAMPLE PRESERVATION AND HANDLING
TABLE OF CONTENTS**

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SAMPLE PRESERVATION AND HANDLING

1.0 PURPOSE

This SOP describes the appropriate containers for samples of particular matrices, and the steps necessary to preserve those samples when shipped off site for chemical analysis. It also identifies the qualifications for individuals responsible for the transportation of hazardous materials and samples and the regulations set forth by the Department of Transportation regarding the same.

2.0 SCOPE

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

Many water and soil samples are unstable and may change in chemical character during shipment. Therefore, preservation of the sample may be necessary when the time interval between field collection and laboratory analysis is long enough to produce changes in either the concentration or the physical condition of the constituent(s). While complete and irreversible preservation of samples is not possible, preservation does retard the chemical and biological changes that may occur after the sample is collected.

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

Typical sample container and preservation requirements for the CLEAN Program are referenced in NEESA 20.2-047B and are provided in Attachment A of this SOP. Note that sample container requirements (i.e., volumes) may vary by laboratory.

The Department of Transportation, Code of Federal Regulations (CFR) Title 49 establishes regulations for all materials offered for transportation. The transportation of environmental

samples for analysis is regulated by Code of Federal Regulations Title 40 (Protection of the Environment), along with 49 CFR Part 172 Subpart H. The transportation of chemicals used as preservatives and samples identified as hazardous (as defined by 49 CFR Part 171.8) are regulated by 49 CFR Part 172.

3.0 DEFINITIONS

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

Normality (N) - Concentration of a solution expressed as equivalents per liter, where an equivalent is the amount of a substance containing one mole of replaceable hydrogen or its equivalent. Thus, a one molar solution of HCl, containing one mole of H, is "one-normal," while a one molar solution of H₂SO₄ containing two moles of H, is "two-normal."

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for development of documentation of procedures which deviate from those presented herein. The Project Manager is also responsible for proper certification of individuals responsible for transportation of samples of hazardous substances.

Field Team Leader - It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that personnel performing sampling activities have been briefed and trained to execute these procedures. The Field Team Leader is responsible to ensure all samples and/or hazardous substances are properly identified, labeled, and packaged prior to transportation.

Sampling Personnel - It is the responsibility of the field sampling personnel to initiate sample preservation and handling. It is also the responsibility of the field sampling personnel to understand and adhere to the requirements for proper transportation of samples and/or hazardous substances.

5.0 PROCEDURES

The following procedures discuss sample containerization and preservation techniques that are to be followed when collecting environmental samples for laboratory analysis.

5.1 Sample Containers

For most samples and analytical parameters either glass or plastic containers are satisfactory. In general, if the analyte(s) to be measured is organic in nature, the container shall be made of glass. If the analyte(s) is inorganic, then glass or plastic containers may be used. Containers shall be kept out of direct sunlight (to minimize biological or photo-oxidation/photolysis of constituents) until they reach the analytical laboratory. The sample container shall have approximately five to ten percent air space ("ullage") to allow for expansion/vaporization if the sample is heated during transport (one liter of water at 4°C expands by 15 milliliters if heated to 130°F/55°C); however, head space for volatile organic analyses shall be omitted.

The analytical laboratory shall provide sample containers that have been certified clean according to USEPA procedures. Shipping containers for samples, consisting of sturdy ice chests, are to be provided by the laboratory.

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

General sample container, preservative, and holding time requirements are listed in Attachment A.

5.2 Preservation Techniques

The preservation techniques to be used for various analytes are listed in Attachment A. Reagents required for sample preservation will either be added to the sample containers by

laboratory prior to their shipment to the field or added in the field using laboratory supplied preservatives. Some of the more commonly used sample preservation techniques include storage of sample at a temperature of 4°C, acidification of water samples, and storage of samples in dark (i.e. amber) containers to prevent the samples from being exposed to light.

All samples shall be stored at a temperature of 4°C. Additional preservation techniques shall be applied to water samples as follows:

- Water samples to be analyzed for volatile organics shall be acidified.
- Water samples to be analyzed for semivolatile organics shall be stored in dark containers.
- Water samples to be analyzed for pesticides/PCBs shall be stored in dark containers.
- Water samples to be analyzed for inorganic compounds shall be acidified.

These preservation techniques generally apply to samples of low-level contamination. The preservation techniques utilized for samples may vary. However, unless documented otherwise in the project plans, all samples shall be considered low concentration. All samples preserved with chemicals shall be clearly identified by indicating on the sample label that the sample is preserved.

5.3 Sample Holding Times

The elapsed time between sample collection and initiation of laboratory analyses is considered the holding time and must be within a prescribed time frame for each individual analysis to be performed. Sample holding times for routine sample collection are provided in Attachment A.

6.0 **SAMPLE HANDLING AND TRANSPORTATION**

After collection, the outside of all sample containers will be wiped clean with a damp paper towel; however sample handling should be minimized. Personnel should use extreme care to ensure that samples are not contaminated. If samples are placed in an ice chest, personnel should ensure that melted ice cannot cause sample containers to become submerged, as this may result in sample cross-contamination and loss of sample labels. Sealable plastic bags, (zipper-type bags), should be used when glass sample containers are placed in ice chests to prevent cross-contamination, if breakage should occur.

Samples may be hand delivered to the laboratory or they may be shipped by common carrier. Relevant regulations for the storage and shipping of samples are contained in 40 CFR 261.4(d). Parallel state regulations may also be relevant. Shipment of dangerous goods by air cargo is also regulated by the United Nations/International Civil Aviation Organization (UN/ICAO). The Dangerous Goods Regulations promulgated by the International Air Transport Association (IATA) meet or exceed DOT and UN/ICAO requirements and should be used for shipment of dangerous goods via air cargo. Standard procedure for shipping environmental samples are given in Attachment B.

7.0 REFERENCES

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

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

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

USEPA, Region IV, 1991. Environmental Compliance Branch Standard Operating Procedures and Quality Assurance Manual. Athens, Georgia.

Protection of the Environment, Code of Federal Regulation, Title 40, Parts 260 to 299.

Transportation, Code of Federal Regulation, Title 49, Parts 100 to 177.

ATTACHMENT A

**REQUIRED CONTAINER, PRESERVATION TECHNIQUES
AND HOLDING TIMES**

ATTACHMENT A

SUMMARY OF CONTAINERS, PRESERVATION, AND HOLDING TIMES FOR AQUEOUS SAMPLES

Parameter	Bottle Requirements	Preservation Requirements	Holding Time (1)	Analytical Method	Bottle Volume
Volatile Organic Compounds (VOA)	glass teflon lined cap	Cool to 4°C 1:1 HCl pH <2	10 days	CLP	2 x 40 ml
Semivolatile Organic Compounds (SVOA)	glass teflon lined cap	Cool to 4°C Dark	Extraction within 5 days Analyze 40 days	CLP	2 x 1 liter
PCB/Pesticides	glass teflon lined cap	Cool to 4°C Dark	Extraction within 5 days Analyze 40 days	CLP	2 x 1 liter
Cyanide	plastic/glass	NaOH to pH >12 Cool to 4°C	14 days	CLP EPA 335.2	1 x 1 liter
Metals (TAL)	plastic/glass	HNO ₃ to pH <2	180 days except Mercury is 26 days	CLP	1 x 1 liter
Total Organic Carbon	glass, teflon lined cap	Cool to 4°C H ₂ SO ₄ to pH <2	28 days	EPA 415.1	2 x 40 ml
Total Organic Halogen	plastic/glass	Cool to 4°C H ₂ SO ₄ to pH <2	28 days	EPA 450.1	250 ml
Chloride	plastic/glass	none required	28 days	EPA 325.2/325.3	250 ml
Sulfate	plastic/glass	Cool to 4°C	28 days	EPA 375.4	250 ml
Alkalinity	plastic/glass	Cool to 4°C	14 days	EPA 310.1/310.2	250 ml
Gross alpha/gross beta	plastic/glass	HNO ₃ to pH <2	6 months	9310	1 gallon
Chlorinated herbicides	glass, teflon lined cap	Cool to 4°C	14/28 days	EPA 515.1	1000 ml
Hardness	plastic/glass	HNO ₃ to pH <2	6 months	EPA 130.2	150 ml

(1) Holding times for CLP methods are based on Validated Time of Sample Receipt as stated in CLP statement of work of February, 1991.
Holding times for Non-CLP methods are based on time of sample collection.

Note: Verify this information with the laboratory that will perform the analyses.

ATTACHMENT A (Continued)

SUMMARY OF CONTAINERS, PRESERVATION, AND HOLDING TIMES FOR SOIL SAMPLES

Parameter	Bottle Requirements	Preservation Requirements	Holding Time (1)	Analytical Method	Bottle Volume
Volatile Organic Compounds (VOA)	glass teflon lined cap	Cool to 4°C	10 days	CLP	1 x 50 gm
Semivolatile Organic Compounds (SVOA)	glass teflon lined cap	Cool to 4°C	Extraction within 10 days Analyze 40 days	CLP	1 x 250 gm
PCB/Pesticides	glass teflon lined cap	Cool to 4°C	Extraction within 10 days Analyze 40 days	CLP	1 x 50 gm
Metals (TAL)	plastic/glass	Cool to 4°C	Mercury is 26 days 180 days	CLP	1 x 50 gm
Cyanide	plastic/glass	Cool to 4°C	14 days	CLP EPA 335.2M	1 x 50 gm

(1) Holding times for CLP methods are based on Validated Time of Sample Receipt as stated in CLP statement of work of February, 1991.
Holding times for Non-CLP methods are based on time of sample collection.

Note: Verify this information with the laboratory that will perform the analyses.

ATTACHMENT B

SAMPLE SHIPPING PROCEDURES

ATTACHMENT B
SAMPLE SHIPPING PROCEDURES

Introduction

Samples collected during field investigations or in response to a hazardous materials incident must be classified by the project leader, prior to shipping by air, as either environmental or hazardous substances. The guidance for complying with U.S. DOT regulations in shipping environmental laboratory samples is given in the "National Guidance Package for Compliance with Department of Transportation Regulations in the Shipment of Environmental Laboratory Samples."

Pertinent regulations for the shipping of environmental samples is given in 40 CFR 261.4(d). Samples collected from process wastewater streams, drums, bulk storage tanks, soil, sediment, or water samples from areas suspected of being highly contaminated may require shipment as dangerous goods/hazardous substance. Regulations for packing, marking, labeling, and shipping of dangerous goods by air transport are promulgated by the United Nations International Civil Aviation Organization (UN/ICAO), which is equivalent to IATA.

Individuals responsible for transportation of environmental samples or dangerous goods/hazardous substances must be tested and certified by their employer. This is required by 49 CFR Part 172 Subpart H Docket HM-126 to assure the required qualifications for individuals offering materials for transportation.

Environmental samples shall be packed prior to shipment by commercial air carrier using the following procedures:

1. Select a sturdy cooler in good repair. Secure and tape the drain plug (inside and outside) with fiber or duct tape. Line the cooler with a large heavy duty plastic bag. This practice keeps the inside of the cooler clean and minimizes cleanup at the laboratory after samples are removed.
2. Allow sufficient headspace (ullage) in all bottles (except VOAs) to compensate for any pressure and temperature changes (approximately 10 percent of the volume of the container).

3. Be sure the lids on all bottles are tight (will not leak). In many regions custody seals are also applied to sample container lids. The reason for this practice is two-fold: to maintain integrity of samples and keep lid on the container should the lid loosen during shipment. Check with the appropriate regional procedures prior to field work. In many cases, the laboratory manager of the analytical lot to be used on a particular project can also provide this information.
4. It is good practice to wrap all glass containers in bubblewrap or other suitable packing material prior to placing in plastic bags.
5. Place all bottles in separate and appropriately sized polyethylene bags and seal the bags with tape (preferably plastic electrical tape, unless the bag is a zipper-type bag). Up to three VOA bottles, separately wrapped in bubblewrap, may be packed in one plastic bag.
6. Optionally, place three to six VOA vials in a quart metal can and then fill the can with vermiculite.
7. Place two to four inches of vermiculite (ground corn cob, or other inert packing material) in the bottom of the cooler and then place the bottles and cans in the cooler with sufficient space to allow for the addition of more vermiculite between the bottles and cans.
8. Put frozen "blue ice" (or ice that has been placed in properly sealed, double-bagged, heavy duty polyethylene bags) on top of and between the samples. Fill all remaining space between the bottles or cans with packing material. Fold and securely fasten the top of the large heavy duty plastic bag with tape (preferably electrical or duct).
9. Place the Chain-of-Custody Record and the Request for Analysis Form (if applicable) into a plastic bag, tape the bag to the inner side of the cooler lid, and then close the cooler and securely tape (preferably with fiber tape) the top of the cooler unit. Wrap the tape three to four times around each side of the cooler unit. Chain-of-custody seals should be affixed to the top and sides of the cooler within the securing tape so that the cooler cannot be opened without breaking the seal.
10. Each cooler (if multiple coolers) should have its own Chain-of-Custody Record reflecting the samples shipped in that cooler.
11. Label according to 40 CFR 261.4(d). The shipping containers should be marked "THIS END UP," and arrow labels which indicate the proper upward position of the container should be affixed to the container. A label containing the name and address of the shipper and laboratory shall be placed on the outside of the container. It is good practice to secure this label with clear plastic tape to prevent removal during shipment by blurring of important information should the label become wet. The commercial carrier is not required to sign the COC record as long as the custody seals remain intact and the COC record stays in the cooler. The only other documentation required is the completed airbill, which is secured to the top of the shipping container. Please note several coolers/shipping containers may be shipped under one airbill. However, each cooler must be labeled as "Cooler 1 of 3, Cooler 2 of 3, etc.", prior to shipping. Additionally it is good practice to label each COC form to correspond to each cooler (i.e., 1 of 3, 2 of 3, etc.).

APPENDIX Q
Chain-of-Custody

SOP F302
Chain-of-Custody

**CHAIN-OF-CUSTODY
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CHAIN-OF-CUSTODY

1.0 PURPOSE

The purpose of this SOP is to provide information on chain-of-custody procedures to be used to document sample handling.

2.0 SCOPE

This procedure describes the steps necessary for transferring samples through the use of Chain-of-Custody Records. A Chain-of-Custody Record is required, without exception, for the tracking and recording of samples collected for on-site or off-site analysis (chemical or geotechnical) during program activities (except wellhead samples taken for measurement of field parameters, SOP F101). Use of the Chain-of-Custody Record Form creates an accurate written record that can be used to trace the possession and handling of the sample from the moment of its collection through analysis. This procedure identifies the necessary custody records and describes their completion. This procedure does not take precedence over region-specific or site-specific requirements for chain-of-custody.

3.0 DEFINITIONS

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

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

- It is in one's actual possession.
- It is in one's view, after being in one's physical possession.
- It was in one's physical possession and then he/she locked it up to prevent tampering.
- It is in a designated and identified secure area.

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

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for development of documentation of procedures which deviate from those presented herein. The Project Manager is responsible for ensuring that chain-of-custody procedures are implemented. The Project Manager also is responsible for determining that custody procedures have been met by the analytical laboratory.

Field Team Leader - The Field Team Leader is responsible for determining that chain-of-custody procedures are implemented up to and including release to the shipper or laboratory. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that personnel performing sampling activities have been briefed and trained to execute these procedures.

Sampling Personnel - It is the responsibility of the field sampling personnel to initiate chain-of-custody procedures, and maintain custody of samples until they are relinquished to another custodian, the sample shipper, or to a common carrier.

5.0 PROCEDURES

The term "chain-of-custody" refers to procedures which ensure that evidence presented in a court of law is valid. The chain-of-custody procedures track the evidence from the time and place it is first obtained to the courtroom, as well as providing security for the evidence as it is moved and/or passed from the custody of one individual to another.

Chain-of-custody procedures, recordkeeping, and documentation are an important part of the management control of samples. Regulatory agencies must be able to provide the chain-of-possession and custody of any samples that are offered for evidence, or that form the basis of analytical test results introduced as evidence. Written procedures must be available and followed whenever evidence samples are collected, transferred, stored, analyzed, or destroyed.

5.1 Sample Identification

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

Information which shall be recorded in the field logbook, when in-situ measurements or samples for laboratory analysis are collected, includes:

- Field Sampler(s);
- CTO Number;
- Project Sample Number;
- Sample location or sampling station number;
- Date and time of sample collection and/or measurement;
- Field observations;
- Equipment used to collect samples and measurements; and,
- Calibration data for equipment used.

Measurements and observations shall be recorded using waterproof ink.

5.1.1 Sample Label

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

- Project or Contract Task Order (CTO) Number.
- Station Location - The unique sample number identifying this sample.
- Date - A six-digit number indicating the day, month, and year of sample collection (e.g., 12/21/85).
- Time - A four-digit number indicating the 24-hour time of collection (for example: 0954 is 9:54 am., and 1629 is 4:29 p.m.).
- Medium - Water, soil, sediment, sludge, waste, etc.

- Sample Type - Grab or composite.
- Preservation - Type and quantity of preservation added.
- Analysis - VOA, BNAs, PCBs, pesticides, metals, cyanide, other.
- Sampled By - Printed name of the sampler.
- Remarks - Any pertinent additional information.

Using only the work assignment number of the sample label maintains the anonymity of sites. This may be necessary, even to the extent of preventing the laboratory performing the analysis from knowing the identity of the site (e.g., if the laboratory is part of an organization that has performed previous work on the site).

5.2 Chain-of-Custody Procedures

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

5.2.1 Field Custody Procedures

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

5.2.2 Transfer of Custody and Shipment

Samples are accompanied by a Chain-of-Custody Record Form. A Chain-of-Custody Record Form example is shown in Attachment B. When transferring the possession of samples, the individual(s) relinquishing and receiving will sign, date, and note the time on the Record. This Record documents sample custody transfer from the sampler, often through another person, to the analyst in the laboratory. The Chain-of-Custody Record is filled out as given below.

- Enter header information (CTO number, samplers, and project name).
- Enter sample specific information (sample number, media, sample analysis required and analytical method, grab or composite, number and type of sample containers, and date/time sample was collected).
- Sign, date, and enter the time under "Relinquished by" entry.
- Have the person receiving the sample sign the "Received by" entry. If shipping samples by a common carrier, print the carrier to be used in this space (i.e., Federal Express).
- If a carrier is used, enter the airbill number under "Remarks," in the bottom right corner;
- Place the original (top, signed copy) of the Chain-of-Custody Record Form in a plastic zipper-type bag or other appropriate sample shipping package. Retain the copy with field records.
- Sign and date the custody seal, a 1- by 3-inch white paper label with black lettering and an adhesive backing. Attachment C is an example of a custody seal. The custody seal is part of the chain-of-custody process and is used to prevent tampering with samples after they have been collected in the field. Custody seals shall be provided by the analytical laboratory.
- Place the seal across the shipping container opening so that it would be broken if the container was to be opened.
- Complete other carrier-required shipping papers.

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

Common carriers will usually not accept responsibility for handling Chain-of-Custody Record Forms; this necessitates packing the record in the shipping container (enclosed with other

documentation in a plastic zipper-type bag). As long as custody forms are sealed inside the shipping container and the custody seals are intact, commercial carriers are not required to sign the custody form.

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

6.0 QUALITY ASSURANCE RECORDS

Once samples have been packaged and shipped, the COC copy and airbill receipt becomes part of the Quality Assurance Record.

7.0 REFERENCES

1. USEPA. User's Guide to the Contract Laboratory Program. Office of Emergency and Remedial Response, Washington, D.C. (EPA/540/P-91/002), January 1991.

ATTACHMENT A

EXAMPLE SAMPLE LABEL

ATTACHMENT A

EXAMPLE SAMPLE LABEL

Baker	Baker Environmental Inc. Airport Office Park, Bldg. 3 420 Rouser Road Coraopolis, PA 15108
Project: <u>19026-SRN</u>	CTO No.: <u>0026</u>
Sample Description: <u>Groundwater</u>	
Date: <u>09/17/92</u>	Sampler: <u>ABC</u>
Time: <u>0944</u>	
Analysis: <u>TAL Metals (CAP)</u>	Preservation: <u>HNO₃</u>
Project Sample No.: <u>CAX-GW-04</u>	

Note: Typically, sample labels are provided by the analytical laboratory and may be used instead of the above. However, samplers should make sure all pertinent information can be affixed to the label used.

ATTACHMENT B

EXAMPLE CHAIN-OF-CUSTODY RECORD

ATTACHMENT C

EXAMPLE CUSTODY SEAL

ATTACHMENT C

EXAMPLE CUSTODY SEAL

Baker	____/____/____ Date	Baker	____/____/____ Date
	_____ Signature		_____ Signature
	CUSTODY SEAL		CUSTODY SEAL

APPENDIX R
Field Logbook

SOP F303
Field Logbook

**FIELD LOGBOOK
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FIELD LOGBOOK

1.0 PURPOSE

This SOP describes the process for maintaining a field logbook.

2.0 SCOPE

The field logbook is a document which records all major on-site activities conducted during a field investigation. At a minimum, the following activities/events shall be recorded in the field logbook by each member of the field crew.

- Arrival/departure of site workers and visitors
- Arrival/departure of equipment
- Sample pickup (sample numbers, carrier, time)
- Sampling activities
- Start or completion of boreholes, monitoring wells, or sampling activities
- Health and safety issues

The field logbook is initiated upon arrival at the site for the start of the first on-site activity. Entries are made every day that on-site activities take place. At least one field logbook shall be maintained per site.

The field logbook becomes part of the permanent site file. Because information contained in the field logbook may be admitted as evidence in legal proceedings, it is critical that this document is properly maintained.

3.0 DEFINITIONS

Field logbook - The field logbook is a bound notebook with consecutively numbered pages. Upon entry of data, the logbook requires the signature of the responsible data/information recorder.

4.0 RESPONSIBILITIES

The Field Team Leader is responsible for maintaining a master field logbook for the duration of on-site activities. Each member of the sampling crew is responsible for maintaining a complete and accurate record of site activities for the duration of the project.

5.0 PROCEDURES

The following sections discuss some of the information which must be recorded in the field logbook. In general, a record of all events and activities, as well as other potentially important information shall be recorded by each member of the field team.

5.1 Cover

The inside cover or title page of each field logbook shall contain the following information:

- Contract Task Order Number
- Project name and location
- Name of Field Team Leader
- Baker's address and telephone number
- Start date
- If several logbooks are required, a sequential field logbook number

It is good practice to list important phone numbers and points of contact here.

5.2 Daily Entries

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

- Date
- Start time
- Weather
- All field personnel present
- All visitors present
- Other pertinent information (i.e., planned activities, schedule changes, expected visitors, and equipment changes)

During the day, an ongoing record of all site activities should be written in the logbook. The master logbook kept by the field team leader need not duplicate that recorded in other field logbooks, but should summarize the information in other books and, where appropriate, reference the page numbers of other logbooks where detailed information pertaining to a subject may be found.

Some specific information which must be recorded in the logbook includes:

- Equipment used, equipment numbers, calibration, field servicing
- Field measurements
- Sample numbers, media, bottle size, preservatives, collection methods, and time
- Test boring and monitoring well construction information, including boring/well number and location
- Sketches for each sample location including appropriate measurements if required.
- Photograph log
- Drum log
- Other pertinent information

All entries should be made in indelible ink; all pages numbered consecutively; and all pages must be signed or initialed and dated by the responsible field personnel completing the log. No erasures are permitted. If an incorrect entry is made, the entry shall be crossed out with a single line, initialed, and dated.

5.3 Photographs

If photographs are permitted at a site, the record shall be maintained in the field logbook. When movies, slides or photographs are taken of any site location, they are numbered or cross-referenced to correspond to logbook entries. The name of the photographer, date, time, site location, site description, direction of view and weather conditions are entered in the logbook as the photographs are taken. Special lenses, film, or other image-enhancement techniques also must be noted in the field logbook. Once processed, photographs shall be serially numbered and labeled corresponding to the field logbook entries. Note that it may not be permitted to take photographs at all Activities; permission must be obtained from the LANTDIV EIC and the Activity responsible individual.

6.0 QUALITY ASSURANCE RECORDS

Once on-site activities have been completed, the field logbook shall be considered a quality assurance record.

7.0 REFERENCES

None.