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Phase II Confirmatory Sampling Investigation Work Plan

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Camp Lejeune, North Carolina

Prepared For

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Atlantic Division
Naval Facilities Engineering Command

Norfolk, Virginia

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QC Review Page

Phase II Confirmatory Sampling Investigation Work Plan

MCB Camp Lejeune

Jacksonville, North Carolina

Contract Task Order Number - 0143
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Prepared by

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ACRONYMS AND ABBREVIATIONS

AST	Aboveground Storage tank
ASTM	American Society for Testing and Materials
Baker	Baker Environmental, Inc.
CFR	Code of Federal Register
CLEAN	Comprehensive Long-Term Environmental Action Navy
CLP	Contract Laboratory Program
CMI	Corrective Measures Implementation
COC	Chain-of-Custody
COPC	Constituents of Potential Concern
CTO	Contract Task Order
DQO	Data Quality Objective
DoN	Department of the Navy
DOT	Department of Transportation
ECBSOPQAM	Environmental Compliance Branch Standard Operating Procedures and Quality Assurance Manual
EMD	Environmental Management Division
EQB	Environmental Quality Branch
ESD	Environmental Services Division
FS	Feasibility Study
GPR	Ground Penetrating Radar
GPS	Global Positioning System
HASP	Health and Safety Plan
ID	Inside Diameter
IDW	Investigation Derived Waste
IR	Installation Restoration
LANTDIV	Atlantic Division, Naval Facilities Engineering Command
MCB	Marine Corps Base
MSL	Mean Sea Level
MS/MSD	Matrix Spike/Matrix Spike Duplicate
NC DENR	North Carolina Department of Environment and Natural Resources
NFESC	Naval Facilities Engineering Service Center
OD	Outside Diameter
O2/LEL	Oxygen/Combustible Gas Meter
PCB	Polychlorinated Biphenyl
PID	Photo Ionization Detector
PVC	Polyvinyl Chloride

ACRONYMS AND ABBREVIATIONS
(Continued)

QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
RCRA	Resource Conservation and Recovery Act
RFA	RCRA Facility Assessment
RFI	RCRA Facility Investigation
RI	Remedial Investigation
SOP	Standard Operating Procedure
SVOCs	Semivolatile Organic Compounds
SWMU	Solid Waste Management Unit
TAL	Target Analyte List
TCL	Target Compound List
TCLP	Toxicity Characteristic Leaching Procedure
TDS	Total Dissolved Solids
TSDF	Treatment, Storage, and Disposal Facility
TSS	Total Suspended Solids
USCS	Unified Soil Classification System
USEPA	United States Environmental Protection Agency
UST	Underground Storage Tank
VOCs	Volatile Organic Compounds
WQP	Water Quality Parameter

1.0 INTRODUCTION

This Work Plan presents the proposed activities to be conducted for the Phase II Confirmatory Sampling Program at 47 Solid Waste Management Units (SWMUs) located throughout Marine Corps Base (MCB) Camp Lejeune, North Carolina (the Base). The Work Plan was prepared under Contract Task Order (CTO) 0143 of the Department of the Navy's (DoN's) Comprehensive Long-Term Environmental Action Navy (CLEAN) Program and is part of the Project Plans, which also include the Quality Assurance Project Plan (QAPP) and Health and Safety Plan (HASP). Baker Environmental, Inc. (Baker) is subcontracted to CH2M Hill for implementation of this project.

The primary purpose of this Work Plan is to provide guidance for the project field activities by describing in detail the sampling and data collection methods to be used in implementing the various field tasks. This document also will help to ensure that the project activities are carried out in accordance with the United States Environmental Protection Agency (USEPA) Region IV and Naval Facilities Engineering Service Center (NFESC) standard operating procedures (SOPs), so that data obtained during the field investigation are of sufficient quantity and quality to evaluate potential impacts to soil and groundwater at the SWMUs.

1.1 Project Objectives

The objectives of the Phase II Confirmatory Sampling Program are as follows:

- Further evaluate potential impacts to soil at the SWMUs
- Determine if groundwater has been impacted as a result of a release(s) from the SWMUs
- Attempt to determine the boundaries and approximate depth of the old landfill at SWMU 46 – Montford Point Dump Site

Upon completion of the Phase II Confirmatory Sampling Program, the SWMUs will either require additional investigation in the form of a Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) or Corrective Measures Implementation (CMI), or will be designated as requiring no further action.

2.0 BACKGROUND INFORMATION

This section presents a brief summary of pertinent background information developed for the Base. Detailed descriptions of the background information including history and conditions are presented in the Phase I SWMU Confirmatory Sampling Report (Baker, 2001) and other documents, which are referenced herein.

2.1 Location

The Base is located within the Atlantic Coastal Plain Physiographic Province in Onslow County, North Carolina, approximately 45 miles south of New Bern and 47 miles north of Wilmington (Figure 2-1). The Base covers approximately 236 square miles. The Base is bisected by the New River, which flows in a southeasterly direction and forms a large estuary before entering the Atlantic Ocean.

The Base is bordered by the City of Jacksonville, North Carolina and State Route 24 to the north; the Atlantic shoreline to the south and east; and U.S. Route 17 to the west.

2.2 Topography

The topography of the Base is generally flat and typical of the North Carolina Coastal Plain. Elevations on the Base range from sea level to approximately 72 feet above mean sea level (MSL). However, elevations on the majority of the base range from approximately 20 to 40 feet above MSL.

Drainage at the Base generally is toward the New River, except in areas near the coast, which drain through the Intracoastal Waterway. In developed areas, the natural drainage has been altered by asphalt cover, storm sewers, and drainage ditches. Approximately 70 percent of the Base is situated in broad, flat interstream areas. Drainage is poor in these areas and the soils are often wet (WAR, 1983). The U.S. Army Corps of Engineers has mapped the limits of the 100-year floodplain at the Base at 7 feet above MSL in the upper reaches of the New River increasing downstream to 11 feet above MSL near the coastal area (WAR, 1983).

2.3 Geology

The Base is located within the Tidewater region of the Atlantic Coastal Plain Physiographic Province. The sediments of the Atlantic Coastal Plain consist mostly of interbedded sands, silts, clays, calcareous clays, shell beds, sandstone, and limestone. These sediments are layered in interfingering beds and lenses that gently dip and thicken to the southeast to a combined thickness of approximately 1,500 feet. They were deposited in marine or near-shore environments and range in age from early Cretaceous to Quaternary time. Regionally, the sediments comprise ten aquifers and nine confining units, which overlie igneous and metamorphic basement rocks of the pre-Cretaceous age. Seven of these aquifers and their associated confining units are present at the Base (Cardinell, et al., 1993).

2.4 RCRA-Related History

An initial RCRA Facility Assessment (RFA) was conducted at the Base by the USEPA Region IV and the North Carolina Department of Environment and Natural Resources (NC DENR) in January 1989. The RFA included 76 SWMUs. Seven of the SWMUs required confirmatory sampling; 23 of the SWMUs required an RFI; 46 of the SWMUs required no further action. The

initial RFA was later expanded to include units such as landfills, surface impoundments, waste piles, tanks, container storage areas, septic tanks, drain fields, waste treatment units, and storm water conveyances. More than 3,500 SWMUs were identified during a preliminary review of Base records. Visual site inspections were conducted on nearly 500 of these SWMUs. The findings from the RFA are presented in the RCRA Facility Assessment Report for Marine Corps Base, Camp Lejeune, North Carolina (EnSafe, 1996).

The 1996 RFA Report identified 41 Installation Restoration (IR) sites, 112 underground storage tank (UST) sites, and 56 SWMUs that required confirmatory sampling or corrective measures. Based on further negotiations between NC DENR and the Base, 62 SWMUs required confirmatory sampling. These 62 SWMUs were investigated under the Phase I Confirmatory Sampling Program conducted by Baker in 1997. The confirmatory sampling data are presented in the Phase I SWMU Confirmatory Sampling Report (Baker, 2001).

The focus of the Phase I Confirmatory Sampling was to determine which SWMUs required additional investigation and which SWMUs required no further action. Of the 62 SWMUs investigated, 20 SWMUs required no further action, and 42 SWMUs were recommended for a Phase II Confirmatory Sampling Investigation. The 42 SWMUs requiring additional investigation are as follows:

- SWMU 43 – Pest Control Shop
- SWMU 46 – Montford Point Dump Site
- SWMU 53 – Coal Storage Area
- SWMU 89 – SLCH785 Basin
- SWMU 253 – 1205 AST
- SWMU 254 – 1408 Dumpster
- SWMU 255 – 1502 Oil/Water Separator-1
- SWMU 256 – 1700 Oil/Water Separator-1
- SWMU 257 – 1700 Oil/Water Separator-2
- SWMU 258 – S1745 Oil/Water Separator
- SWMU 261 – 1780 UST-1
- SWMU 264 – 2611 Container
- SWMU 265 – 2615 Oil/Water Separator
- SWMU 269 – 816 Oil/Water Separator
- SWMU 272 – AS137 Oil/Water Separator
- SWMU 279 – FC200 Oil/Water Separator
- SWMU 285 – S947 Oil/Water Separator
- SWMU 291 – 034 Ditch
- SWMU 293 – 1106/1107 Oil/Water Separator
- SWMU 294 – 1203 Oil/Water Separator
- SWMU 295 – 1601 AST
- SWMU 296 – 1700 Basin B
- SWMU 297 – 1780 Oil/Water Separator-2
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- SWMU 303 – AS515 AST-E
- SWMU 305 – BB224 Pile
- SWMU 306 – FC230 Oil/Water Separator-1

- SWMU 307 – G649 Rack
- SWMU 308 – GP-19 Oil/Water Separator
- SWMU 311 – S1619 Oil/Water Separator
- SWMU 312 – S1735 Oil/Water Separator
- SWMU 313 – S1753 Oil/Water Separator and AST
- SWMU 314 – SM187 Oil/Water Separator
- SWMU 315 – SM269 Oil/Water Separator
- SWMU 316 – TC773 Oil/Water Separator
- SWMU 317 – TT2453 Release
- SWMU 318 – AS515 Oil/Water Separator
- SWMU 319 – Camp Geiger Wastewater Treatment Plant
- SWMU 336 – AS4106 Paint Stripper
- SWMU 339 – AS146 Sand Blaster

It should be noted that additional investigation activities were recommended at SWMU 82. However, the additional investigation at this SWMU is currently being conducted under the Remedial Investigation (RI)/Feasibility Study (FS) at Building 45 and not the Phase II Confirmatory Sampling Program.

In addition to the above-referenced SWMUs requiring additional investigation, the following six SWMUs were included in the Phase II Confirmatory Sampling Program as requested by the Environmental Quality Branch (EQB), Environmental Management Division (EMD), Installations and Environment Department:

- SMWU 358 - Sneads Ferry Road Battery Dump
- SWMU 359 – Lot 201 Battery Dump
- SWMU 360 - Building 1817 UST
- SWMU 361 – 333-C Former UST
- SWMU 362 – Dog 11 Area
- SWMU 363 – M-21 Arresting Gear

3.0 DATA QUALITY AND SAMPLING OBJECTIVES

The site-specific objectives presented in this section have been developed using the USEPA seven-step data quality objectives (DQO) process, as presented in USEPA Guidance for the Data Quality Objectives Process (USEPA, 2000a) and USEPA Data Quality Objectives Process for Hazardous Waste Site Investigations (USEPA, 2000b).

3.1 Data Quality Objectives Process

DQOs are qualitative and quantitative statements, developed using the USEPA DQO process, that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as a basis for establishing the quality and quantity of data needed to support decisions. DQOs define the performance criteria that limit the probabilities of making decision errors by considering the purpose of collecting data, defining the appropriate type of data needed, and specifying tolerable probabilities of making decision errors. The seven-step DQO process is as follows:

- Step 1 – State the Problem
- Step 2 – Identify the Decision
- Step 3 – Identify the Inputs to the Decision
- Step 4 – Define the Boundaries of the Study
- Step 5 – Develop a Decision Rule
- Step 6 – Specify Tolerable Limits on Decision Errors
- Step 7 – Optimize the Design for Obtaining Data

In Step 1 of the DQO Process, the planning team is established, the problem is described, a conceptual model of the environmental hazard to be investigated is developed, and available resources, constraints, and deadlines are identified.

Step 2 of the DQO Process should identify the principal study question, define alternative actions, develop a decision statement, state each decision in terms of whether to take action, and organize multiple decisions into an order of priority.

Step 3 of the DQO Process should identify the kinds of information needed, identify the sources of information, determine the basis for setting the action level, and confirm the appropriateness of proposed sampling and analyses methods.

Step 4 of the DQO Process should define the target population (i.e., what is to be sampled), determine the spatial and temporal boundaries, identify practical restraints, and define the scale of decision making.

Step 5 of the DQO Process should define the population parameter, determine what action is needed, and confirm that the action level exceeds minimum detection limits.

Step 6 of the DQO Process should specify tolerable limits on decision errors.

Step 7 of the DQO Process is the review of existing environmental data, evaluation of the operational decision rules, development of general data collection design alternatives, calculation of the number of samples to be collected, and selection of the most resource-effective data collection system.

The following sections present the seven-step DQO process developed for the Phase II Confirmatory Sampling Program.

3.1.1 Step 1 - State the Problem

The first activity associated with this step is to establish the planning team. The planning team will include the NC DENR, Atlantic Division, Naval Facilities Engineering Command (LANTDIV), the Base, CH2M Hill, and Baker. These team members are decision-makers for the DQO Process.

The planning team's objectives are to evaluate impacts to soil and groundwater at the SWMUs and determine if additional action is warranted in the form of an RFI or CMI. The problem is that a sufficient quantity of data does not exist to evaluate impacts to soil and groundwater at the SWMUs.

The project team organization and project schedule are presented in Sections 9.0 and 10.0 of this Work Plan, respectively. The schedule presents the anticipated completion and/or submittal dates for specific tasks or documents.

3.1.2 Step 2 – Identify the Decision

The principal study question identified is:

- Have activities at the SWMUs impacted soil and groundwater?

Before a decision statement can be formulated, a definition of "impacted" must be clarified.

For this confirmatory sampling, soil and groundwater will be considered "impacted" if concentrations of constituents of potential concern (COPCs) exceed applicable background, NC DENR, and/or USEPA Region IX screening criteria.

Considering the principal study question and definition of impacted, the decision statement is as follows:

- Determine impacts to soil and groundwater at the SWMUs through soil/groundwater sampling and laboratory analyses of COPCs.

3.1.3 Step 3 - Identify the Inputs to the Decision

Existing information regarding impacts to soil and groundwater at the SWMUs is limited. It is evident that additional data are required to determine if additional action is warranted in the form of an RFI or CMI. The kinds of data and sources used to resolve the decision statement include:

Kinds of Information	Sources of Information
Concentrations of COPCs in soil	Laboratory analytical results from soil samples collected from borings
Concentrations of COPCs in groundwater	Laboratory analytical results from groundwater samples collected from some existing monitoring wells and new, temporary monitoring wells

The criterion for determining impacts to soil and groundwater will be based on background, NC DENR, and/or USEPA Region IX screening criteria. As described in Section 4.3, the samples will be analyzed at a fixed-based laboratory for volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), pesticides, and/or metals. The detection limits will be below the applicable screening criteria.

3.1.4 Step 4 - Define the Boundaries of the Study

Soil and/or groundwater samples will be collected at the SWMUs. Figures 4-1 through 4-38 show the proposed sampling locations within the boundaries of each SWMU. There are no figures showing the proposed sampling locations at the six new SWMUs added to this program. The sample location for these SWMUs will be located in the field and figures will be constructed as part of the Draft Phase II Confirmatory Sampling Report.

Temporal changes in the distribution of COPCs are expected to be negligible. Thus, data collection is not time dependent.

Practical constraints to sample collection are insignificant. There are no significant physical barriers or access issues at the SWMUs. Weather conditions (such as heavy rain) can delay the field activities, but is not a serious constraint.

3.1.5 Step 5 - Develop a Decision Rule

The decision rule developed for the Phase II Confirmatory Sampling Program is as follows:

- If a given concentration at a given sampling point exceeds the background screening criteria and either the NC DENR and/or USEPA Region IX screening criteria, then that sampling point will be considered to be impacted by activities associated with the SWMU.

3.1.6 Step 6 - Specify Tolerable Limits on Decision Errors

Specification of tolerable limits on the decision errors will not be performed at this time. The proposed sampling locations are flexible and include points in and around the perimeter of the SWMUs. Specification of tolerable limits on decision errors may be performed at a later date if an RFI or CMI is warranted.

3.1.7 Step 7 - Optimize the Design for Obtaining Data

There are two fundamental goals for Step 7, and both rely on the review of existing data and information:

- To evaluate the decision rule
- To design and optimize the sampling and analyses program

The decision rule developed in Step 5 has been shown to be valid following review of the existing data. In this case, a simple statistical hypothesis test will be used, broadly classified as a one-sample test. The test will involve a comparison of individual analytical data to known values (background, NC DENR, and USEPA Region IX screening criteria).

Existing information/data has been reviewed to evaluate and develop the data collection strategy for the field program. The development of alternate sampling plans is not practical given the dynamic nature of this investigation. Additionally, the flexibility of the Work Plan optimizes resources, in that the location of sampling points is determined by the existing data and field conditions.

The proposed sampling and analyses program is detailed in the following section.

4.0 SAMPLING LOCATIONS AND FREQUENCY

This section of the Work Plan describes the location and frequency of environmental samples to be collected during the field program. Support activities, sampling locations, sample matrix, constituents to be analyzed for, and Quality Assurance/Quality Control (QA/QC) requirements also are discussed. Detailed investigation procedures and sample handling and analytical requirements are provided in Sections 6.0 and 7.0, respectively. The field program described below and summarized on Tables 4-1 and 4-2 will provide data to meet the objectives presented in Section 1.1 of this Work Plan.

4.1 Soil Investigation

Approximately 181 test borings will be advanced in and around the perimeter of the SWMUs as shown on Figures 4-1 through 4-38. In general, each boring will be advanced to the water table using direct push methods. Soil samples will be collected at continuous intervals and field-screened using a photo ionization detector (PID). Up to two samples from each boring will be selected for laboratory analyses. The selection of samples for laboratory analyses will be based on sample depth, lithologic location, and field observations (e.g., elevated PID readings, discoloration, etc.). Section 6.1 presents specific details on soil sample collection.

4.2 Groundwater Investigation

Approximately 136 temporary monitoring wells will be installed at locations shown on Figures 4-1 through 4-38 to sample the shallow water-bearing zone. It is anticipated that the wells will be installed to a depth of approximately 7 feet below the groundwater table. The wells will be constructed of 1-inch inside diameter (ID), polyvinyl chloride (PVC) pipe, with 10 feet of 0.010-inch slot well screen. Section 6.2 presents specific details on temporary monitoring well construction.

One groundwater sample will be collected from each of the new, temporary monitoring wells as well as a few existing wells. The samples will be collected using low-flow purge and sampling methods. Depth to groundwater and field measurements, including pH, specific conductance, temperature, turbidity, and dissolved oxygen (Level I quality) also will be collected. Section 6.3 presents specific details on groundwater sample collection.

4.3 Analytical Requirements

The soil and groundwater samples will be analyzed for the following parameters at a fixed-base laboratory:

- Target Compound List (TCL) VOCs using SW846 Method 8260 B,
- TCL SVOCs using SW846 Method 8270 C,
- TCL pesticides using SW846 Method 8081 A, and/or
- RCRA metals using SW846 6000/7000 Series.

Routine, 21-day analytical turnaround time will be requested from the laboratory. A summary of sampling, analytical, and DQOs is presented on Table 4-3.

4.4 Quality Assurance/Quality Control Samples

Specific QA/QC requirements are presented in the QAPP. The following QA/QC samples will be collected during the field sampling activities:

Equipment Rinsate Blanks

Equipment rinsate blanks will be collected by running laboratory-supplied distilled/deionized water over/through the sampling equipment and placing it into the appropriate sample containers for laboratory analyses. One equipment rinsate blank per media sampled per day will be collected. Initially, equipment rinsate samples from every other day will be analyzed. If analytes pertinent to the project are detected in the rinsates, the remaining samples will be analyzed, as necessary. The results will be used to verify that the sampling equipment has not contributed to contamination of the samples.

Field Blanks

One field blank will be collected from each source of water used in decontamination. It is anticipated that a total of three field blanks will be collected. The field blanks will be collected by pouring the water from the original container directly into the sample bottle set. Field blanks will not be collected in dusty environments and/or from areas where volatile organics are present in the atmosphere or originating from a source other than the source being sampled. The results will be used to verify that the water used in decontamination has not contributed to contamination of the samples.

Trip Blanks

Trip blanks are samples of analyte-free water prepared by the laboratory, taken to the sampling site, kept with the investigative samples throughout the sampling event, and returned to the laboratory with the samples to be analyzed for VOCs. One trip blank will be included in each cooler containing samples for VOC analyses. The trip blanks will only be analyzed for VOCs. The results will be used to verify that the sample containers and method of sample container handling used throughout the sampling program have not contributed to contamination of the samples.

Field Duplicate Samples

Field duplicate samples will consist of one unique sample, split into two aliquots, and analyzed independently. Duplicate soil samples analyzed for parameters other than VOCs will be homogenized, and split. Samples for VOC analyses will not be mixed, but select segments of the soil will be collected from the length of the core using Encore™ samplers. Duplicate water samples will be collected simultaneously. The duplicate samples will be analyzed to verify the reproducibility of the laboratory results and degree of variability of reported concentrations. Duplicate samples will be collected at a frequency of 10 percent.

Matrix Spike/Matrix Spike Duplicate Samples

Matrix spike/matrix spike duplicate (MS/MSD) samples will be prepared in the field to address aliquoting reproducibility and to provide information on matrix reproducibility otherwise unobtainable from samples reported below analytically reproducible and statistically valid levels. Due to the limited number of samples at each SWMU, MS/MSD samples will be prepared at a frequency of 5 percent for each group of samples of a similar matrix.

4.5 Geophysical Survey

A geophysical survey is proposed to be conducted at SWMU 46 – Montford Point Dump Site. This investigation will be conducted to determine the boundaries and approximate depth of the old landfill. The geophysical methods proposed for the investigation include ground penetrating radar (GPR), magnetometry, electromagnetic induction, and/or earth resistivity survey methods. It has been Baker's experience that a multi-method geophysical investigation is the best non-intrusive method for evaluating the condition of landfills. Each survey method responds to different physical characteristics of the earth or landfill materials. In a landfill, particularly and old abandoned landfill, a variety of conditions might exist that one survey method cannot fully evaluate. Therefore, a multi-method geophysical survey provides the best overall evaluation of conditions in and around an abandoned landfill. Section 6.7 presents specific details on the geophysical survey.

5.0 SAMPLE DESIGNATION

In order to identify and accurately track the various samples, all samples collected during the Phase II Confirmatory Sampling Program, including QA/QC samples, will be designated with a unique number. The number will serve to identify the SWMU, sample media, sampling location, depth/round (for groundwater samples), and QA/QC qualifiers.

The sample designation format is as follows:

SWMU#-Media/Station#-Depth/Round or QA/QC

An explanation of each of these identifiers is given below.

SWMU# — This will be the number assigned to each SWMU in the RFA report (EnSafe, 1996).

Media SS = Surface Soil Sample
SB = Soil Boring (soil sample from a boring)
TW = Temporary Well (groundwater sample from a temporary well)
MW = Monitoring Well (groundwater sample from an existing monitoring well)

Station# — Each sample location will be identified with a unique identification number.

Depth/Round — Depth indicators will be used for soil samples. The number will reference the depth interval of the sample. For example:

00 = Ground surface to 2 feet below ground surface
01 = 2 to 4 feet below ground surface
02 = 4 to 6 feet below ground surface
03 = 6 to 8 feet below ground surface

A two digit number followed by a character (A through D) will indicate the year and quarter the sample was collected. For example:

02A = First Quarter (January-March) of 2002.
02B = Second Quarter (April-June) of 2002.

QA/QC
FB = Field Blank
TB = Trip Blank
D = Duplicate Sample (following depth/round)
ER = Equipment Rinsate Blank
MS/MSD = Matrix Spike/Matrix Spike Duplicate

Under this sample designation format, the sample number SWMU258-SB05-00D refers to:

SWMU258-SB05-00D	SWMU 258
SWMU258-SB05-00D	Soil sample from a boring
SWMU258-SB05-00D	Soil boring #5
SWMU258-SB05-00D	Sample depth interval 0 to 2 feet
SWMU258-SB05-00D	Duplicate (QA/QC) sample

The sample number SWMU 258-GW01TW-02A refers to:

SWMU258-GW01TW-02A	SWMU 258
SWMU258-GW01TW-02A	Groundwater sample from temporary well #1
SWMU258-GW01TW-02A	First Quarter of 2002

The sample designation SWMU258-ER01-02A refers to:

SWMU258-ER01-02A	SWMU 258
SWMU258-ER01-02A	Equipment rinsate blank
SWMU258-ER01-02A	Equipment rinsate sample #1
SWMU258-ER01-02A	First Quarter of 2002

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

6.0 INVESTIGATIVE PROCEDURES

The investigative procedures to be used for the Phase II Confirmatory Sampling Program are discussed in the subsections that follow. These procedures include soil sample collection, temporary monitoring well construction, groundwater sample collection, decontamination, temporary monitoring well abandonment, geophysical survey, and handling of investigation derived wastes (IDW). These procedures will comply with the field methods described in the USEPA, Region IV, Environmental Services Division (ESD), Environmental Compliance Branch Standard Operating Procedures and Quality Assurance Manual (ECBSOPQAM), (USEPA, 1997). Additional guidance from other sources such as the American Society for Testing and Materials (ASTM) may be used, but if the ASTM and ESD methods conflict, the ESD procedure will be used. Additionally, in instances where the ESD has no SOP, other guidance sources will be used, such as manufacturer's SOP manuals. Field deviations will be recorded in the field logbook and discussed in the text of the report.

The field program is summarized on Table 4-1 and 4-2; the proposed sample locations are presented on Figures 4-1 through 4-38.

6.1 Soil Sample Collection

Surface and subsurface soil samples will be collected from borings advanced using a truck-mounted rig (or by hand) and direct-push methods. Some borings locations may be difficult to access by truck. As a result, samples will be collected at these locations by hand using a tripod system. Appendix A presents the SOP for soil sample acquisition. Appendices A through C present SOPs for borehole and sample logging, monitoring well installation, and soil sample acquisition.

Prior to sampling, the presence of underground utilities will be determined by an independent utility locating service. Soil samples from borings advanced either by a direct-push rig or by hand will be collected using a GeoProbe "Macro-Core Sampler" or "Large Bore Soil Sampler", respectively. The Macro-Core Sampler is a 48-inch long, stainless-steel tube with a 2-inch outside diameter (OD). A 1-1/2-inch ID cutting shoe is threaded to the base. Soil samples are collected in a 45-inch long by 1-1/2-inch wide acetate liner that is inserted into the tube. The Large Bore Soil Sampler is a 24-inch long, stainless-steel tube with a 1-3/8-inch OD. A 1-1/16-inch ID cutting shoe is threaded to the base. Soil samples are collected in a 22-inch long by 1-1/8-inch wide acetate liner that is inserted into the tube.

Soil samples will be collected continuously from the ground surface to the water table. Soils will be classified according to the Unified Soil Classification System (USCS). Soil descriptions, including estimates of grain size, relative density, moisture content, discoloration, odor, and other visual observations will be recorded in the field logbook.

Soil samples will be field-screened for total VOCs using a PID as follows:

- The acetate liner will be cut across the entire length of the liner.
- The two edges of the liner will be separated using gloved hands while the entire length of the soil core is field-screened for total VOCs using the PID. Any elevated PID readings and the depth that the readings were observed will be noted in the field logbook.

Up to two soil samples from each boring will be collected and submitted to the laboratory for chemical analyses. The samples will be selected based on sample depth, lithologic location, and field observations (e.g., elevated PID readings, discoloration, etc.).

Soil for volatile organics analysis will be collected using EnCore samplers to minimize loss of VOCs in the sample. Soil for all other analyses will be placed into an aluminum pan, thoroughly homogenized, and placed into the appropriate sample container(s). All pertinent sampling information including sample depth, sample number and location, and time of sample collection will be recorded in the field logbook. The sample containers will be stored on ice in a cooler at approximately 4 degrees Celsius (or less) until shipped to the laboratory. Chain-of-Custody (COC) Forms and Sample Analyses Request Forms will be properly filled out and enclosed in the shipping package. COC seals will be attached to the package prior to shipping. Sample preservation and handling procedures are outlined in Section 7.0.

Subsequent to sampling, borings not converted to temporary monitoring wells will be backfilled with a mixture of its soil cuttings and sodium bentonite. The surface will be plugged with asphalt or material similar to the existing surface. In addition, each boring will be surveyed for horizontal position using a Global Positioning System (GPS).

6.2 Temporary Monitoring Well Construction

Temporary monitoring wells will be installed in some of the borings at the SWMUs to sample the shallow water-bearing zone (see Tables 4-1 and 4-2). The wells will be constructed as follows:

- Subsequent to soil sampling as described in Section 6.1, the borehole will be reamed to approximately 7 feet below the groundwater table using 3-1/4-inch ID hollow-stem augers.

- Upon completion of the borehole to the desired depth, the well construction materials will be installed through the hollow-stem augers.

- 10 feet of 1-inch ID, Schedule 40, 0.010-slot, PVC screen with a bottom cap will be set at the bottom of the borehole. The top of the well screen will be placed such that approximately 3 feet of the screen (as subsurface conditions permit) extends above the groundwater table to allow for fluctuations in the groundwater table. The screen will be connected to threaded, flush-joint, PVC riser. The casing will be installed to be approximately 2 feet above the ground surface. A PVC riser slip-cap with a vent hole will be placed at the top of the casing.

- The annular space around the well screen will be backfilled with a well-graded, fine to medium sand as the hollow-stem augers are being withdrawn from the borehole. The sand will extend to approximately 2 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 material.

- A sodium bentonite seal (minimum of 6 inches) will be placed above the sand pack and extended to the ground surface to prevent surface and near subsurface water from infiltrating into the screened groundwater monitoring zone. The bentonite will be hydrated with potable water, as necessary.

- The depth intervals of all backfilled materials will be measured with a weighted measuring tape to the nearest 0.1-foot and recorded in the field logbook.

Figure 6-1 depicts a typical temporary monitoring well construction diagram. The wells will be surveyed for horizontal position using a GPS and topographic elevation relative to MSL using a registered surveyor so that groundwater elevations can be determined.

6.3 Groundwater Sample Collection

The monitoring wells will be sampled using a peristaltic pump and low-flow purge and sampling methods. The procedure for collecting groundwater samples is detailed in this section, and is based on ECBSOPQAM procedures.

6.3.1 Selection of Water Quality Indicator Parameters

ECBSOPQAM SOPs specify using pH, specific conductance, temperature, and turbidity as water quality indicator parameters (WQPs) for stabilization. This field program will include those WQPs plus dissolved oxygen. Use of dissolved oxygen has precedence in USEPA and other studies. Dissolved oxygen and turbidity are more sensitive indicators of "fresh" groundwater than pH, specific conductance, and temperature (Puls and Powell, 1992). Barcelona et. al., 1994, suggest that dissolved oxygen and specific conductance are good indicators of stabilization.

6.3.2 Purging and Sampling Procedure

The following low-flow purge and sampling procedure will be used to collect the groundwater samples:

- The well cap will be removed and escaping gasses will be measured at the wellhead using a PID. This will determine the need for respiratory protection.

- The static water level will be measured. The total depth of the monitoring well will not be measured, as not to stir up any sediment. The total well depth will be obtained from test boring and well construction records. The water volume in the well will then be calculated.

- The sampling device intake (new, 1/4-inch ID, polyethylene tubing) will be slowly lowered until the bottom end is 2 to 3 feet below the top of the well screen or the top of the water level, whichever is greater. Next, the water level probe will be placed into the monitoring well just above the water.

- Purging will begin using a peristaltic pump. The pumping rate will be set to create a sustainable flow (approximately 1 liter/minute or less) without causing a significant drop in water level in the well. The static water level will be periodically measured throughout purging to verify that a significant drop in water level has not occurred.

- The WQPs, including pH, specific conductance, temperature, turbidity, and dissolved oxygen will be measured frequently.

- Purging will be complete when a minimum of three well volumes have been removed and three successive WQP readings have stabilized within 10 percent (0.1 Standard Units for pH), or there is no further discernable upward or downward trend. It is Baker's

experience that at low values, certain WQPs (such as turbidity) may vary by more than 10 percent, but have reached a stable plateau.

- Upon WQP stabilization, groundwater samples will be collected from the end of the tubing and placed into the sample containers.

- The following information will be recorded in the field logbook:

  Project location, date, and time
  Weather
  Sample location, number, round, and identification number
  Static water level
  Calculation of amount of water to be purged
  WQPs during purging
  Visual description of water (i.e., clear, cloudy, muddy, etc.)
  Names of sampling personnel
  Names of visitors on site
  Purging and sampling technique, procedure and equipment used
  Sampling remarks and observations
  QA/QC samples collected

- The sample jars will be stored on ice in a cooler at approximately 4 degrees Celsius (or less) until shipped to the laboratory.

- The samples will be packed for shipping in the same manner as the soil samples. COC Forms and Sample Analyses Request Forms will be properly filled out and enclosed in the shipping package. COC seals will be attached to the package prior to shipping.

Sample preservation and handling procedures are outlined in Section 7.0. Appendix D presents the SOP for groundwater sample acquisition.

6.4 Monitoring and Data Collection Equipment

Field measurements, including pH, specific conductance, temperature, turbidity, and dissolved oxygen will be recorded during groundwater sampling. Appendix E presents specific procedures for on-site water quality testing.

Additional monitoring well information may be obtained using water level meters and well depth meters. The operation and various uses of this data collection equipment is provided in Appendix F.

Health and safety monitoring and environmental media screening will be conducted using a PID and an oxygen/combustible gas (O2/LEL) meter. The operation and use of the PID and O2/LEL meter are described in Appendices G and H, respectively.

6.5 Decontamination

Equipment and materials that will require decontamination are as follows:

- Field measurement, sampling, and monitoring equipment (e.g. water level meters, pH meters, etc.)

- Machinery, equipment, and materials (e.g. drilling rigs, drilling equipment, monitoring well materials, etc.)

Appendices I and J presents procedures for decontaminating the aforementioned equipment and materials, respectively.

6.6 Temporary Monitoring Well Abandonment

Subsequent to completion of the groundwater sampling activities, the temporary monitoring wells will be abandoned as follows:

- To the extent feasible, the well casing and screen materials will be removed.
- The borehole will be backfilled with sodium bentonite and hydrated with potable water.
- The surface will be completed with like material (e.g., grass, dirt, concrete).
- Waste materials (e.g., well casing/screen) will be disposed of in on-site trash dump boxes.

6.7 Geophysical Survey

A geophysical survey is proposed to be conducted at SWMU 46 – Montford Point Dump Site. This investigation will be conducted to determine the boundaries and approximate depth of the old landfill. The geophysical methods proposed for the investigation include GPR, magnetometry, electromagnetic induction, and/or earth resistivity survey methods. It has been Baker's experience that a multi-method geophysical investigation is the best non-intrusive method for evaluating the condition of landfills. Each survey method responds to different physical characteristics of the earth or landfill materials. In a landfill, particularly and old abandoned landfill, a variety of conditions might exist that one survey method cannot fully evaluate. Therefore, a multi-method geophysical survey provides the best overall evaluation of conditions in and around an abandoned landfill.

The approximate area of investigation is shown on Figure 4-2. The locations of the geophysical lines will be located by Baker using a pre-established site grid. The following sections provide a brief discussion of the geophysical survey techniques.

6.7.1 Ground Penetrating Radar

The GPR survey technique produces a graphic cross-sectional view of layered materials below the ground surface. Changes in the character (smooth, well-defined horizons to broken, irregular point reflections) of the GRP record will be used to define the limits and depth of the landfill. The GPR depth of investigation is related to the conductivity of the soils being investigated (high conductivity – limited penetration/low conductivity – deeper penetration). Appendix K presents specific procedures for conducting the GPR survey.

6.7.2 Magnetometry

The magnetometry survey will be used to delineate areas where metals may be buried. Shallow buried metal (iron, steel) objects tend to distort the earth's magnetic field, resulting in anomalous total field measurements. Often the edges of landfills can be defined by the change from irregular

to consistent total field magnetic values. By evaluating the magnetic data obtained over the investigation area, a background range of magnetic values is established. Zones of anomalous total magnetic field values are differentiated as being higher or lower than the background range. Appendix L presents specific procedures for conducting the magnetometry survey.

6.7.3 Electromagnetic Induction

The electromagnetic induction survey provides an indication of the apparent conductivity of materials within the exploration depth. If several layers are present, the apparent conductivity is a composite of the layer's conductivities. High conductivity values often are associated with landfilled areas. Appendix M presents specific procedures for conducting the electromagnetic induction survey.

6.7.4 Earth Resistivity

Earth resistivity measurements obtained at the ground surface may be used to evaluate subsurface materials. The resisitivity of earth materials is inversely proportional to their temperature, permeability, porosity, water content, and salinity or ion content. The apparent resistivity value of a particular material, as measured in the field, is a function of the material's true resistivity, the thickness of the unit, thickness and resistivities of adjacent layers, and the electrode spacing. Apparent resistivity values are calculated based on the configuration of current and potential electrodes. Interpretation of electrical resistivity data is based on either comparison of field-derived apparent resistivity values with an appropriate theoretical case or inverse modeling performed by a computer. The results will be used to determine approximate depths of conductive layers associated with the landfill materials to determine the depth of filling. Appendix N presents specific procedures for conducting the earth resistivity survey.

6.8 Investigation Derived Waste Handling

The subsections that follow discuss the responsibilities, sources, containerization, sampling and analyses, and disposal of IDW. These wastes include soil from borings, groundwater from purging of monitoring wells, decontamination fluids, and personal protection equipment.

6.8.1 Responsibilities

LANTDIV - LANTDIV or the Base must ultimately be responsible for the final disposition of the IDW. As such, a LANTDIV or a Base representative will sign waste disposal manifests as the generator of the material in the event off-site disposal is required. However, it may be the responsibility of Baker, depending on the contingency discussions during execution of the investigation, to provide assistance to LANTDIV in arranging for final disposition and preparing manifests.

Baker Project Manager - It is the responsibility of the Baker Project Manager to work with the LANTDIV-Technical Representative in determining the final disposition of the IDW. The Baker Project Manager will relay the results and implications of the chemical analyses of the IDW, and advise on the regulatory requirements and prudent measures appropriate to the disposition of the material. The Baker Project Manager also is responsible for ensuring that field personnel involved in the IDW handling are familiar with the procedures to be implemented in the field, and that all required field documentation has been completed.

Baker Field Team Leader - The Baker Field Team Leader or Site Manager is responsible for the on-site supervision of the IDW handling procedures during implementation of the field program. The Baker Field Team Leader also is responsible for ensuring that all other field personnel are familiar with these procedures.

6.8.2 Sources of Investigation Derived Wastes

The field investigation activities will result in the generation and handling of potentially contaminated materials that must be properly managed to protect the public and the environment, as well as to meet legal requirements. These wastes may be either hazardous or non-hazardous in nature. The nature of the waste (i.e., hazardous or non-hazardous) will determine how the wastes will be handled during the field investigation.

The following sections discuss the types of IDW that will be generated as a result of the field investigation and methods used to handle the IDW.

Soil Cuttings

Soil cuttings will be generated during soil sample acquisition and augering of the well borings. The soil cuttings will be field-screened using a PID. Soil containing no PID readings above background or evidence of gross contamination will be mixed with bentonite and placed back into the respective borehole. Alternatively, the soil may be spread on the ground surface at the boring/well head, as appropriate. Soil containing elevated PID readings or evidence of gross contamination will be containerized in Department of transportation (DOT) approved 55-gallon drums for analytical testing, temporary storage on site, and subsequent treatment and/or disposal.

Monitoring Well Purge Water and Decontamination Fluids

Monitoring well purge water and decontamination fluids collected from decontamination/wash pads will be containerized in DOT-approved 55-gallon drums for analytical testing, temporary storage on site, and subsequent treatment and/or disposal.

Personal Protective Equipment

All personal protective equipment (i.e., Tyvek coveralls, gloves, and other health and safety disposables) will be placed in garbage bags and disposed of in on-site trash dump boxes.

6.8.3 Investigation Derived Waste Sampling and Analyses

One composite sample will be collected from the drums containing soil cuttings. The sample will be analyzed for Toxicity Characteristic Leaching Procedure (TCLP) organics and inorganics and RCRA hazardous waste characterization (ignitability, corrosivity, and reactive cyanide and sulfide).

One composite sample will be collected from the drums containing monitoring well purge water and decontamination fluids. The sample will be analyzed for TCL organics, Target Analyte List (TAL) metals (total), total suspended solids (TSS), total dissolved solids (TDS), and RCRA hazardous waste characterization (ignitability, corrosivity, and reactive cyanide and sulfide).

6.8.4 Labeling

The drums will be labeled by the field team during the field investigation. Information will be written on a plaque and affixed to the prominent side of the drum. The labels will include, at a minimum:

- LANTDIV CTO number
- Camp Lejeune point-of-contact name and phone number
- Project name
- Contractor name and Project Manager name
- Drum number
- Date
- Source
- Contents

If laboratory analyses reveals that containerized materials are hazardous, additional labeling of containers may be required. Baker will be responsible for additional labeling procedures, with assistance from the Base and/or LANTDIV as needed. These additional labeling procedures will be based on the identification of material present and USEPA regulations applicable to labeling hazardous and polychlorinated biphenyl (PCB) containing wastes, which are contained in 40 CFR Parts 261, 262, and 761.

6.8.5 Container Log

A container log will be maintained in the field logbook. The container log will contain the same information as the container label plus any additional remarks or information. Such additional information may include the identification number of a representative laboratory sample. The EQB will be informed of the status of all IDW storage containers on a regular basis.

6.8.6 Container Storage

Containers of IDW will be stored on site or in a specially designated secure area that is managed by the EQB until disposition is determined.

If the laboratory analyses reveals that the IDW is hazardous, additional storage security may be implemented. Baker will coordinate, with LANTDIV and/or the Base, any additional measures that may need to be taken to insure that the containerized IDW is secure and meets applicable Federal regulations.

Baker will assist LANTDIV in devising the storage requirements as required. Weekly inspections by facility personnel of the temporary storage area also may be required. These inspections may assess the structural integrity of the containers and proper container labeling. Also, precipitation that may accumulate in the storage area may need to be removed. These weekly inspections and whatever precipitation removal is necessary will be recorded in the field logbook.

6.8.7 Container Disposition

The disposition of the containers of IDW will be determined by LANTDIV, with the assistance of Baker, as necessary. Container disposition will be based on quantity of materials, types of materials, and analytical results. If necessary, specific samples of contained materials may be

collected to identify further characteristics that may affect disposition. Typically, container disposition will not be addressed until after receipt of applicable analytical results, which are usually not available until long after completion of the field investigation.

6.8.8 Disposal of Contaminated Materials

Actual disposal methods for IDW will be determined following receipt of the analytical results. The usual course will be a contractor specialist retained to conduct the disposal. However, regardless of the mechanism used, all applicable Federal, state, and local regulations will be observed. USEPA regulations applicable to generating, storing, and transporting hazardous wastes are contained in 40 CFR Parts 262, 263.

For the Phase II Confirmatory Sampling Program, any soil determined to be non-hazardous will be transported to the on-base landfull and used as soil cover. Soil determined to be hazardous will be taken to a Treatment, Storage, and Disposal Facility (TSDF). Monitoring well purge water and decontamination fluids may be taken to one of the on-base groundwater treatment plants designed handle solvent and petroleum contamination.

7.0 SAMPLE HANDLING, ANALYSES, AND VALIDATION

Field activities will be conducted in accordance with the USEPA Region IV ESD's ECBSOPQAM (USEPA, 1997). Procedures for sample preservation, labeling, handling, and maintaining a field logbook are detailed in SOPs. Because these procedures are not specific to this project, they are provided as appendices, rather than detailed herein. Major components of sample handling and analyses are discussed in the following subsections.

A sample analyses summary is presented on Table 4-2 and a summary of sampling, analytical, and DQOs is presented on Table 4-3.

7.1 Sample Preservation and Handling

Sample preservation, sample bottle packing, and shipping are important components to maintaining the integrity of the samples. Preservation and handling procedures to be used during the Phase II Confirmatory Sampling Program are detailed in Appendix O and Section 6.1 of the QAPP.

7.2 Chain-of-Custody

COC is another important component to maintaining sample integrity. COC procedures to be followed during the Phase II Confirmatory Sampling Program are detailed in Appendix P. This SOP also details sample bottle labeling procedures.

COC procedures 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 analyses.

7.3 Field Logbook

Field logbooks will be used to record sampling activities and information. Entries will include general and specific sampling information so that the field activities may be reconstructed. Appendix Q describes a general format for the field logbook.

Each field person will have and maintain a logbook. Logbooks will be copied and stored in the project files as backup in case the original is lost or destroyed.

7.4 Sample Analyses and Validation

This section discusses efforts relating to the following activities:

- Sample Management
- Laboratory Analyses
- Data Validation

Sample management activities involve coordination with the laboratory, tracking of samples submitted for analyses, tracking of analyses received, and tracking of information related to samples submitted and received from a third party validator. Sample management also involves resolving technical or administrative problems (e.g., reanalysis, resubmission of information) as necessary.

Laboratory analyses begins when the samples are shipped from the field and received by the laboratory. For the Phase II Confirmatory Sampling Program, the soil and groundwater samples will be analyzed for the following parameters:

- TCL VOCs using SW846 Method 8260 B,
- TCL SVOCs using SW846 Method 8270 C,
- TCL pesticides using SW846 Method 8081 A, and/or
- RCRA metals using SW846 6000/7000 Series.

Validation begins when the validator receives the "raw" laboratory data. Baker will also receive the data from the laboratory, and enter it into a database for tracking purposes. A validation report will be expected within three weeks following receipt of laboratory data packages by the validator. The data will be validated in accordance with the Contract Laboratory Program (CLP) criteria as outlined in the following documents:

- USEPA, National Functional Guidelines for Organic Data Review (October, 1999)

- USEPA, Hazardous Site Evaluation Division, Laboratory Data Validation Functional Guidelines for Evaluating Inorganics Analyses (February, 1994)

8.0 DATA EVALUATION AND REPORT PREPARATION

This task involves efforts related to the data once it is received from the laboratory and is validated. It also involves the evaluation of any field-generated data, including water level measurements, Test Boring and Well Construction Records, and other field notes. Efforts under this task will include the tabulation of validated data and field data, generation of Test Boring and Well Construction Records, and generation of other diagrams associated with field notes or data received from the laboratory (e.g., sampling location maps).

The laboratory analytical results will be compared to background, NC DENR, and USEPA Region IX screening criteria.

A report will be prepared to include, but not be limited to, the following:

- A summary of the investigation/sampling activities
- A discussion of investigation procedures that deviated from the Work Plan
- A discussion of the analytical results and comparison to the applicable screening criteria (e.g. background, NC DENR, and/or USEPA Region IX)
- A summary of recommendations including SWMUs that either will require additional investigation in the form of an RFI or CMI, or will be designated as requiring no further action.
- A complete analytical results package

9.0 PROJECT MANAGEMENT AND STAFFING

Mr. Christopher Bozzini, CH2M Hill Project Manager, will provide overall coordination, project administration, and senior QA/QC functions. In addition, Mr. Bozzini will keep abreast of all project activities and will maintain close communication with the Navy Technical Representative and the Base.

Mr. Jim Culp and Mr. Scott Moffett will co-manage the Baker Project Team. Their primary responsibilities will include guiding, monitoring, and coordination of the technical aspects of the project. Mr. Culp and Mr. Moffett also will be responsible for Baker project administration and the overall QA/QC of project deliverables.

Mr. Richard Bonelli, the Baker Activity Coordinator, will serve as an essential member of the management team, maintaining communication with CH2M Hill, LANTDIV, and the Base.

The Baker Project Team will include a Site Manager, an Assistant Project Geologist, and technical support staff as shown in Figure 9-1 and discussed below.

9.1 Field Team Responsibilities

The field investigation portion of this project will be conducted in conjunction with the Background Groundwater Study and consist of one field team. A Site Manager will coordinate all field activities and serve as the Site Health and Safety Officer. The Site Manager will ensure that all field activities are conducted in accordance with the project plans which include the Work Plan, the QAPP, and the HASP.

The Field Team will employ one drilling rig for the soil sampling and monitoring well installation. An Assistant Project Geologist will supervise the drilling rig work.

9.2 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 fax. 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 the scope of the investigation. All changes in the scope will be discussed and agreed upon by CH2M Hill, LANTDIV, and NC DENR.

10.0 SCHEDULE

A proposed schedule for the deliverables and milestones associated with the Phase II Confirmatory Sampling Program is presented on Figure 10-1 and detailed below. The assumed start date is February 11, 2002. The day in the "()" represents the proposed deliverable or end date for each task/activity.

- Receive NC DENR's concurrence on the proposed Phase II Confirmatory Sampling Work Plan (Day 1)
- Submit the Final Phase II Confirmatory Sampling Work Plan (Day 14)
- Procurement of Subcontractors (Day 14)
- Mobilize to the field (Day 21)
- Conduct the field investigation (61)
- Demobilize from the field (Day 62)
- Receive analytical results (Day 83)
- Receive validated analytical results (97)
- Submit the Draft Phase II Confirmatory Sampling Report/Results (Day 158)
- Receive NCDENR comments on the Draft Phase II Confirmatory Sampling Report/Results (Day 188)
- Respond to NCDENR comments on the Draft Phase II Confirmatory Sampling Report and submit Final Report (Day 218)

11.0 REFERENCES

Baker Environmental, Inc. (Baker). Phase I SWMU Confirmatory Sampling Report. Baker November 2001.

Barcelona, M.J., Wehrmann, H.A., Varljen, M.D. "Reproducible Well-Purging Procedures and VOC Stabilization Criteria for Groundwater Sampling." Ground Water, Vol. 32, No. 1. January-February, 1994.

Cardinell, Alex P. et al. Hydrogeologic Framework of U.S. Marine Corps Base at Camp Lejeune, North Carolina. U.S. Geological Survey, Water-Resources Investigations Report 93-4049. 1993.

Environmental and Safety Designs, Inc. (EnSafe). 1996. RCRA Facility Assessment Report for Marine Corps Base Camp Lejeune, North Carolina. Final. EnSafe. July, 1996.

United States Environmental Protection Agency (USEPA), Region IV. Environmental Compliance Branch Standard Operating Procedures and Quality Assurance Manual. USEPA, Region IV. 1997.

Puls, R.W. and Powel, R.M. "Acquisition of Representative Ground Water Quality Samples for Metals." Groundwater Monitoring and Remediation. Summer, 1992.

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

United States Environmental Protection Agency (USEPA). National Functional Guidelines for Organic Data Review. USEPA. October, 1999.

United States Environmental Protection Agency (USEPA). Hazardous Site Evaluation Division, Laboratory Data Validation Functional Guidelines for Evaluating Inorganics Analyses. USEPA. February, 1994.

United States Environmental Protection Agency (USEPA). USEPA Guidance for the Data quality Objectives Process. USEPA. 2000a.

United States Environmental Protection Agency (USEPA). USEPA Data Quality Objectives Process for Hazardous Waste Site Investigations. USEPA. 2000b.

TABLES

Table 4-1
Summary of Proposed Sampling Under Phase II
Phase II Confirmatory Sampling, CTO-0143
MCB Camp Lejeune, North Carolina

SWMU Designation	Compounds Exceeding Screening Criteria	Proposed Sampling Under Phase II					Additional Actions/Comments	Comparison Criteria
		Number of Borings	Number of Surface Soil Samples	Number of Subsurface Soil Samples	Number of Surface Water/ Sediment Samples	Number of Temporary Monitoring Wells		
SWMU 43 - Pest Control Shop	Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Dibenz(a,h)anthracene, 4,4'-DDD, 4,4'-DDT, Chlordane, Arsenic, Chromium	6	7	6		3	One surface soil sample to be collected from drainage ditch	Industrial
SWMU 46 - Montford Point Dump Site	Cadmium, Lead, Arsenic	6	6	6		6	Geophysical survey also is recommended to establish the boundary of the historic landfill	Industrial
SWMU 53 - Coal Storage Area	Benzo(a)pyrene, Arsenic	4	4	4		2	SWMU256-TW03 will serve as the 3rd well	Industrial
SWMU 253 - 1205 AST	Benzo(a)pyrene, Arsenic	3	3	3		3		Industrial
SWMU 254 - 1408 Dumpster	Benzo(a)anthracene, Benzo(a)Pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, Dibenz(a,h)anthracene, Carbazole	3	4	3		3	One surface soil sample to be collected from drainage ditch	Industrial
SWMU 255 - 1502 O/W-1	Benzo(a)pyrene, Pentachlorophenol	1		2		1	One soil sample to be collected immediately beneath concrete and one soil sample to be collected at soil/groundwater interface	Industrial
SWMU 256/257 - 1700 O/W-1 & 2	Benzo(a)pyrene	5	5	5		4	SWMUs 256 and 257 were combined for the Phase II Confirmatory Sampling	Industrial
SWMU 258 - S1745 O/W	Acetone, Cadmium, Mercury	3	4	3		3	Resample SWMU258-IS05-00 for VOCs only	Industrial

Table 4-1
Summary of Proposed Sampling Under Phase II
Phase II Confirmatory Sampling, CTO-0143
MCB Camp Lejeune, North Carolina

SWMU Designation	Compounds Exceeding Screening Criteria	Proposed Sampling Under Phase II					Additional Actions/Comments	Comparison Criteria
		Number of Borings	Number of Surface Soil Samples	Number of Subsurface Soil Samples	Number of Surface Water/ Sediment Samples	Number of Temporary Monitoring Wells		
SWMU 261 - 1780 UST-1	Cadmium, Chromium, Lead	4	2	4		4	Two surface soil samples to be collected from drainage ditch	Industrial
SWMU 264 - 2611 Container	Arsenic, Pentachlorophenol	3	3	3		3		Residential
SWMU 265 - 2615 O/W	Benzo(a)pyrene	3	3	3		3		Residential
SWMU 269 - 816 O/W	Arsenic	3	3	3		3		Residential
SWMU 272 - AS137 O/W	Benzo(a)pyrene, 2-Chlorophenol, 4-Chloro-3-methylphenol, Pentachlorophenol, Arsenic	5	5	5		2	One groundwater sample to be collected from existing monitoring well MW09	Industrial
SWMU 279 - FC200 O/W	Benzo(a)pyrene	3		3		3		Residential
SWMU 285 - S947 O/W	Methylene chloride, Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Indeno(1,2,3-cd)pyrene, Dibenz(a,h)anthracene	3	2	2		3	One of the three recommended monitoring wells to be installed at boring location SWMU 285-IS03	Industrial
SWMU 291 - 034 Ditch	Chromium	3	3	3		3		Industrial
SWMU 293 - 1106/1107 O/W	Lead	3	3	3		3		Industrial
SWMU 294 - 1203 O/W	Mercury, Benzo(a)pyrene	6	9	6		6	Three surface soil samples to be collected from drainage ditch	Industrial
SWMU 295 - 1601 AST	2-Methylnaphthalene, Naphthalene, Arsenic	5	5	5		3	Groundwater sample also to be collected from existing monitoring well 78GW09-1	Industrial
SWMU 296 - 1700 Basin B	Benzo(a)pyrene, Arsenic						See SWMU 53	Industrial
SWMU 297 - 1780 O/W-2							See SMWU 261	Industrial
SWMU 299 - AS114 AST	Benzo(a)anthracene, Benzo(b)fluoranthene, Benzo(a)pyrene, Benzo(k)fluoranthene, Dibenz(a,h)anthracene, Indeno(1,2,3-cd)pyrene Arsenic, Cadmium, Chromium, Lead, Silver	8	8	8		4		Residential

Table 4-1
Summary of Proposed Sampling Under Phase II
Phase II Confirmatory Sampling, CTO-0143
MCB Camp Lejeune, North Carolina

SWMU Designation	Compounds Exceeding Screening Criteria	Proposed Sampling Under Phase II					Additional Actions/Comments	Comparison Criteria
		Number of Borings	Number of Surface Soil Samples	Number of Subsurface Soil Samples	Number of Surface Water/ Sediment Samples	Number of Temporary Monitoring Wells		
SWMU 300 - AS118 AST	Benzo(a)pyrene, Benzo(b)fluoranthene	3	3	3		3		Residential
SWMU 302 - AS504 AST	Cadmium, Benzo(a)pyrene, Dibenz(a,h)anthracene	3	3	3		3		Industrial
SWMU 303 - AS515 AST-E	Acetone, Arsenic, Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene	5	6	5		3	Resample soil boring SWMU303-IS04 for VOCs only; the remaining samples to be analyzed for SVOCs and metals only	Industrial
SWMU 305 - BB224 Pile	Arsenic	3	3	3		3		Residential
SWMU 306 - FC230 O/W-1	Silver	3	3	3		3		Residential
SWMU 307 - G649 Rack	Mercury, Arsenic	3	3	3		3		Residential
SWMU 308 - GP-19 O/W	Bis(2-chloroethyl) ether	3	3	3		3		Residential
SWMU 311 - S1619 O/W	Chlorobenzene, Arsenic, Cadmium, Chromium, Lead, Mercury	6	6	6		3		Industrial
SWMU 312 - S1735 O/W	Benzo(a)pyrene, Arsenic	5	5	5		3		Industrial
SWMU 313 - S1753 O/W & AST	Silver, Arsenic	5	5	5		3		Industrial
SWMU 314 - SM187 O/W	Arsenic, Benzo(a)pyrene	3	3	3		3		Residential
SWMU 315 - SM269 O/W	Pentachlorophenol, Arsenic, Mercury, Silver	4	4	4		3		Residential
SWMU 316 - TC773 O/W	Arsenic, Benzo(a)pyrene	3	3	3		3		Residential
SWMU 317 - TT2453 Release	Lead	3	3	3		3		Residential
SWMU 318 - AS515 O/W	1,2-Dichlorobenzene, 1,4-Dichlorobenzene, Benzo(a)anthracene, Benzo(a)Pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Dibenz(a,h)anthracene, Indeno(1,2,3-cd)pyrene, Naphthalene, Cadmium, Chromium, Mercury, Silver, Arsenic	3	5	3		3	Two surface soil samples to be collected from drainage ditch	Industrial

Table 4-1
Summary of Proposed Sampling Under Phase II
Phase II Confirmatory Sampling, CTO-0143
MCB Camp Lejeune, North Carolina

SWMU Designation	Compounds Exceeding Screening Criteria	Proposed Sampling Under Phase II					Additional Actions/Comments	Comparison Criteria
		Number of Borings	Number of Surface Soil Samples	Number of Subsurface Soil Samples	Number of Surface Water/ Sediment Samples	Number of Temporary Monitoring Wells		
SWMU 319 - Camp Geiger Wastewater Treatment Plant	Benzo(a)pyrene, Benzo(a)anthracene, Benzo(b)fluoranthene, Dibenz(a,h)anthracene, Mercury	1	1	1				Residential
SWMU 336 - AS4106 Paint Stripper		2	2	2		2	Samples could not be collected from floor drains during Phase I; Borings to be advanced outside building during Phase II; Samples to be analyzed for VOCs, SVOCs, and metals	Industrial
SWMU 339 - AS146 Sandblaster	Acetone, 4-Methylphenol	4	3	4		3	Resample VOCs and SVOCs in boring SWMU339-IS01	Industrial
SWMU 359 - Lot 201 Battery Dump	Zinc	2		2		2		Industrial
SWMU 360 - Building 1817 UST	Unknown	4	4	4		4		Residential
SWMU 361 - UST Site 333-C	Unknown	6	6	6		1	Groundwater samples also to be collected from existing monitoring wells MW02 through MW06	Residential
SWMU 362 - Dog 11 Area	Unknown	1	4	1	3			Residential
SWMU 363 - M-21 Arresting Gear	Unknown	3	2	2		3	Groundwater samples to be collected from two of the wells; the 3rd well will be for determination of groundwater elevation only	Industrial

Table 4-2
Sample Analyses Summary
Phase II Confirmatory Sampling, CTO-0143
MCB Campl Lejeune, North Carolina

SWMU Designation	Boring/Temporary Well Designation	Surface Soil/Sediment Samples				Subsurface Soil Samples				Groundwater/Surface Water Samples				Investigation Derived Waste Characterization
		VOCs	SVOCs	Pesticides	Metals	VOCs	SVOCs	Pesticides	Metals	VOCs	SVOCs	Pesticides	Metals	
SWMUs 256/257	SWMU256-SB01		1				1							
	SWMU256-TW01		1				1				1			
	SWMU256-TW02		1				1				1			
	SWMU256-TW03		1		1		1		1		1		1	
	SWMU256-TW04		1				1				1			
SWMUs 53/296	Sharing SWMU256-TW03													
	SWMU53-SB01		1		1		1		1					
	SWMU53-SB02		1		1		1		1					
	SWMU53-TW01		1		1		1		1		1		1	
	SWMU53-TW02		1		1		1		1		1		1	
SWMU 43	SWMU43-SB01		1	1	1		1	1	1					
	SWMU43-SB02		1	1	1		1	1	1					
	SWMU43-SB03		1	1	1		1	1	1					
	SWMU43-TW01		1	1	1		1	1	1		1	1	1	
	SWMU43-TW02		1	1	1		1	1	1		1	1	1	
	SWMU43-TW03		1	1	1		1	1	1		1	1	1	
	SWMU43-SS04		1	1	1									
SWMU 46	SWMU46-TW01				1				1				1	
	SWMU46-TW02				1				1				1	
	SWMU46-TW03				1				1				1	
	SWMU46-TW04				1				1				1	
	SWMU46-TW05				1				1				1	
	SWMU46-TW06				1				1				1	
SWMU 253	SWMU253-TW01		1		1		1		1		1		1	
	SWMU253-TW02		1		1		1		1		1		1	
	SWMU253-TW03		1		1		1		1		1		1	
SWMU 254	SWMU254-SS02		1											
	SWMU254-TW01		1				1				1			
	SWMU254-TW02		1				1				1			
	SWMU254-TW03		1				1				1			
SWMU 255	SWMU255-TW01						2				1			
SWMU 258	SWMU258-TW01				1				1				1	
	SWMU258-TW02				1				1				1	
	SWMU258-TW03				1				1				1	
	Resample SWMU258-IS05-00	1												

Table 4-2
Sample Analyses Summary
Phase II Confirmatory Sampling, CTO-0143
MCB Campl Lejeune, North Carolina

SWMU Designation	Boring/Temporary Well Designation	Surface Soil/Sediment Samples				Subsurface Soil Samples				Groundwater/Surface Water Samples				Investigation Derived Waste Characterization
		VOCs	SVOCs	Pesticides	Metals	VOCs	SVOCs	Pesticides	Metals	VOCs	SVOCs	Pesticides	Metals	
SWMUs 261/297	SWMU261-TW01								1				1	
	SWMU261-TW02								1				1	
	SWMU261-TW03								1				1	
	SWMU261-TW04								1				1	
	SWMU261-SS02				1									
	SWMU261-SS03				1									
SWMU 264	SWMU264-TW01		1		1		1		1		1		1	
	SWMU264-TW02		1		1		1		1		1		1	
	SWMU264-TW03		1		1		1		1		1		1	
SWMU 265	SWMU265-TW01		1				1				1			
	SWMU265-TW02		1				1				1			
	SWMU265-TW03		1				1				1			
SWMU 269	SWMU269-TW01				1				1				1	
	SWMU269-TW02				1				1				1	
	SWMU269-TW03				1				1				1	
SWMU 272	SWMU272-SB01		1		1		1		1					
	SWMU272-SB02		1		1		1		1					
	SWMU272-SB03		1		1		1		1					
	SWMU272-TW01		1		1		1		1		1		1	
	Existing Well MW09										1		1	
	SWMU272-TW03		1		1		1		1		1		1	
SWMU 279	SWMU279-TW01						1				1			
	SWMU279-TW02						1				1			
	SWMU279-TW03						1				1			
SWMU 285	SWMU285-TW01	1	1			1	1			1	1			
	SWMU285-TW02	1	1			1	1			1	1			
	SWMU285-TW03									1	1			
SWMU 291	SWMU291-TW01				1				1				1	
	SWMU291-TW02				1				1				1	
	SWMU291-TW03				1				1				1	
SWMU 293	SWMU293-TW01				1				1				1	
	SWMU293-TW02				1				1				1	
	SWMU293-TW03				1				1				1	

Table 4-2
Sample Analyses Summary
Phase II Confirmatory Sampling, CTO-0143
MCB Campl Lejeune, North Carolina

SWMU Designation	Boring/Temporary Well Designation	Surface Soil/Sediment Samples				Subsurface Soil Samples				Groundwater/Surface Water Samples				Investigation Derived Waste Characterization
		VOCs	SVOCs	Pesticides	Metals	VOCs	SVOCs	Pesticides	Metals	VOCs	SVOCs	Pesticides	Metals	
SWMU 294	SWMU294-TW01		1		1		1		1		1		1	
	SWMU294-TW02		1		1		1		1		1		1	
	SWMU294-TW03		1		1		1		1		1		1	
	SWMU294-TW04		1		1		1		1		1		1	
	SWMU294-TW05		1		1		1		1		1		1	
	SWMU294-TW06		1		1		1		1		1		1	
	SWMU294-SS01		1		1									
	SWMU294-SS02		1		1									
	SWMU294-SS03		1		1									
SWMU 295	SWMU295-SB01		1		1		1		1					
	SWMU295-SB02		1		1		1		1					
	SWMU295-TW01		1		1		1		1		1		1	
	SWMU295-TW02		1		1		1		1		1		1	
	SWMU295-TW03		1		1		1		1		1		1	
	Existing Well 78GW09-1										1		1	
SWMU 299	SWMU299-SB01		1		1		1		1					
	SWMU299-SB02		1		1		1		1					
	SWMU299-SB03		1		1		1		1					
	SWMU299-SB04		1		1		1		1					
	SWMU299-TW01		1		1		1		1		1		1	
	SWMU299-TW02		1		1		1		1		1		1	
	SWMU299-TW03		1		1		1		1		1		1	
	SWMU299-TW04		1		1		1		1		1		1	
SWMU 300	SWMU300-TW01		1				1				1			
	SWMU300-TW02		1				1				1			
	SWMU300-TW03		1				1				1			
SWMU 302	SWMU302-TW01		1		1		1		1		1		1	
	SWMU302-TW02		1		1		1		1		1		1	
	SWMU302-TW03		1		1		1		1		1		1	
SWMU 303	SWMU303-SB01		1		1		1		1					
	SWMU303-SB02		1		1		1		1					
	SWMU303-TW01		1		1		1		1		1		1	
	SWMU303-TW02		1		1		1		1		1		1	
	SWMU303-TW03		1		1		1		1		1		1	
	Resample SWMU303-IS04-00	1												
SWMU 305	SWMU305-TW01				1				1				1	
	SWMU305-TW02				1				1				1	
	SWMU305-TW03				1				1				1	

Table 4-2
Sample Analyses Summary
Phase II Confirmatory Sampling, CTO-0143
MCB Campl Lejeune, North Carolina

SWMU Designation	Boring/Temporary Well Designation	Surface Soil/Sediment Samples				Subsurface Soil Samples				Groundwater/Surface Water Samples				Investigation Derived Waste Characterization
		VOCs	SVOCs	Pesticides	Metals	VOCs	SVOCs	Pesticides	Metals	VOCs	SVOCs	Pesticides	Metals	
SWMU 306	SWMU306-TW01				1				1				1	
	SWMU306-TW02				1				1				1	
	SWMU306-TW03				1				1				1	
SWMU 307	SWMU307-TW01				1				1				1	
	SWMU307-TW02				1				1				1	
	SWMU307-TW03				1				1				1	
SWMU 308	SWMU308-TW01		1				1				1			
	SWMU308-TW02		1				1				1			
	SWMU308-TW03		1				1				1			
SWMU 311	SWMU311-SB01	1			1	1			1					
	SWMU311-SB02	1			1	1			1					
	SWMU311-SB03	1			1	1			1					
	SWMU311-TW01	1			1	1			1	1			1	
	SWMU311-TW02	1			1	1			1	1			1	
	SWMU311-TW03	1			1	1			1	1			1	
SWMU 312	SWMU312-SB01		1		1		1		1					
	SWMU312-SB02		1		1		1		1					
	SWMU312 -TW01		1		1		1		1		1		1	
	SWMU312-TW02		1		1		1		1		1		1	
	SWMU312-TW03		1		1		1		1		1		1	
SWMU 313	SWMU313-SB01				1				1					
	SWMU313-SB02				1				1					
	SWMU313-TW01				1				1				1	
	SWMU313-TW02				1				1				1	
	SWMU313-TW03				1				1				1	
SWMU 314	SWMU314-TW01		1		1		1		1		1		1	
	SWMU314-TW02		1		1		1		1		1		1	
	SWMU314-TW03		1		1		1		1		1		1	
SWMU 315	SWMU315-SB01		1		1		1		1					
	SWMU315-TW01		1		1		1		1		1		1	
	SWMU315-TW02		1		1		1		1		1		1	
	SWMU315-TW03		1		1		1		1		1		1	
SWMU 316	SWMU316-TW01		1		1		1		1		1		1	
	SWMU316-TW02		1		1		1		1		1		1	
	SWMU316-TW03		1		1		1		1		1		1	

Table 4-2
Sample Analyses Summary
Phase II Confirmatory Sampling, CTO-0143
MCB Campl Lejeune, North Carolina

SWMU Designation	Boring/Temporary Well Designation	Surface Soil/Sediment Samples				Subsurface Soil Samples				Groundwater/Surface Water Samples				Investigation Derived Waste Characterization
		VOCs	SVOCs	Pesticides	Metals	VOCs	SVOCs	Pesticides	Metals	VOCs	SVOCs	Pesticides	Metals	
SWMU 317	SWMU317-TW01				1				1				1	
	SWMU317-TW02				1				1				1	
	SWMU317-TW03				1				1				1	
SWMU 318	SWMU318-SS02	1	1		1									
	SWMU318-SS03	1	1		1									
	SWMU318-TW01	1	1		1	1	1		1	1	1		1	
	SWMU318-TW02	1	1		1	1	1		1	1	1		1	
	SWMU318-TW03	1	1		1	1	1		1	1	1		1	
SWMU 319	SWMU319-SB01		1		1		1		1					
SWMU 336	SWMU336-TW01	1	1		1	1	1		1	1	1		1	
	SWMU336-TW02	1	1		1	1	1		1	1	1		1	
SWMU 339	Resample SWMU339-IS01-01					1	1							
	SWMU339-TW01	1	1			1	1			1	1			
	SWMU339-TW02	1	1			1	1			1	1			
	SWMU339-TW03	1	1			1	1			1	1			
SWMU 359	SWMU359-TW01								1				1	
	SWMU359-TW02								1				1	
SWMU 360	SWMU360-TW01	1	1	1	1	1	1	1	1	1	1	1	1	
	SWMU360-TW02	1	1	1	1	1	1	1	1	1	1	1	1	
	SWMU360-TW03	1	1	1	1	1	1	1	1	1	1	1	1	
	SWMU360-TW04	1	1	1	1	1	1	1	1	1	1	1	1	
SWMU 361	SWMU361-TW01	1	1	1	1	1	1	1	1	1	1	1	1	
	SWMU361-SB02	1	1	1	1	1	1	1	1					
	SWMU361-SB03	1	1	1	1	1	1	1	1					
	SWMU361-SB04	1	1	1	1	1	1	1	1					
	SWMU361-SB05	1	1	1	1	1	1	1	1					
	SWMU361-SB06	1	1	1	1	1	1	1	1					
	Existing Well MW02									1	1	1	1	
	Existing Well MW03									1	1	1	1	
	Existing Well MW04									1	1	1	1	
	Existing Well MW05									1	1	1	1	
	Existing Well MW06									1	1	1	1	

Table 4-2
Sample Analyses Summary
Phase II Confirmatory Sampling, CTO-0143
MCB Campl Lejeune, North Carolina

SWMU Designation	Boring/Temporary Well Designation	Surface Soil/Sediment Samples				Subsurface Soil Samples				Groundwater/Surface Water Samples				Investigation Derived Waste Characterization
		VOCs	SVOCs	Pesticides	Metals	VOCs	SVOCs	Pesticides	Metals	VOCs	SVOCs	Pesticides	Metals	
SWMU 362	SWMU362-SB01	1	1	1	1	1	1	1	1					
	SWMU362-SS01	1	1	1	1									
	SWMU362-SS02	1	1	1	1									
	SWMU362-SS03	1	1	1	1									
	SWMU362-SW01									1	1	1	1	
	SWMU362-SD01	1	1	1	1									
	SWMU362-SW02									1	1	1	1	
	SWMU362-SD02	1	1	1	1									
	SWMU362-SW03									1	1	1	1	
	SWMU362-SD03	1	1	1	1									
SWMU 363	SWMU363-TW01	1	1	1	1	1	1	1	1	1	1	1	1	
	SWMU363-TW02	1	1	1	1	1	1	1	1	1	1	1	1	
	SWMU363-TW03													
Investigation Derived Wastes	Soil (1)													1
	Water (2)													1
Total Environmental Samples		39	117	26	138	30	110	19	130	29	92	18	109	2
Field Duplicate Samples		4	12	3	14	3	11	2	13	3	10	2	11	
Matrix Spike Samples		2	6	2	7	2	6	1	7	2	5	1	6	
Matrix Spike Duplicate Samples		2	6	2	7	2	6	1	7	2	5	1	6	
Field Blanks										3	3	3	3	
Equipment Rinsate Blanks										24	24	24	24	
Trip Blanks										16				
Total Samples		47	141	33	166	37	133	23	157	79	139	49	159	2

Notes:
The number of equipment rinsate blanks and trip blanks are estimated. The actual number of samples collected will be determined in the field in accordance with the Work Plan.
(1) Soil to be analyzed for TCLP VOCs, SVOCs, pesticides, and metals; corrosivity; reactivity; and ignitability.
(2) Water to be analyzed for VOCs, SVOCs, pesticides, metals, total suspended solids, and total dissolved solids.
SVOCs = Semivolatile Organic Compounds
SWMU = Solid Waste Management Unit
VOCs = Volatile Organic Compounds

Table 4-3
Summary of Sampling, Analytical, and Data Quality Objectives
Phase II Confirmatory Sampling, CTO-0143
MCB Camp Lejeune, North Carolina

Study Area	Media	Analyses	Analytical Method	Data Quality Objective	Laboratory Turnaround
SWMUs	Soil	TCL VOCs	CLP/SOW (SW846 8260B)	Level IV	28 Days
		TCL SVOCs	CLP/SOW (SW846 8270C)		
		TCL Pesticides	CLP/SOW (SW846 8081A)		
		RCRA Metals	CLP/SOW (SW846 6000/7000 Series)		
	Water	TCL VOCs	CLP/SOW (SW846 8260B)	Level IV	28 Days
		TCL SVOCs	CLP/SOW (SW846 8270C)		
		TCL Pesticides	CLP/SOW (SW846 8081A)		
		RCRA Metals	CLP/SOW (SW846 6000/7000 Series)		
Investigation Derived Wastes	Soil Cuttings	TCLP VOCs	SW846 1311/8260B	Level III	28 Days
		TCLP SVOCs	SW846 1311/8270C		
		TCLP Pesticides	SW846 8081A		
		TCLP Metals	SW846 6000/7000 Series		
		Ignitability	SW846 1010		
		Corrosivity	SW846 1110		
		Reactive Cyanide	7.3.3.2/9010		
		Reactive Sulfide	7.3.4.2/9030		
	Purge Water/ Decontamination Fluids	TCL VOCs	SW846 8260B	Level III	28 Days
		TCL SVOCs	SW846 8270C		
		TCL Pesticides	SW846 8081A		
		TAL Metals	SW846 6000/7000 Series		
		Ignitability	SW846 1010		
		Corrosivity	SW846 1110		
		Reactive Cyanide	7.3.3.2/9010		
		Reactive Sulfide	7.3.4.2/9030		
		Total Suspended Solids	EPA 160.2		
		Total Dissolved Solids	EPA 160.1		

Notes:
CLP = Contract Laboratory Program
RCRA = Resource Conservation and Recovery Act
SOW = Statement of Work
SVOCs = Semivolatile Organic Compounds
SWMU = Solid Waste Management Unit
TCL = Target Compound List
TCLP = Toxicity Characteristic Leaching Procedure
VOCs = Volatile Organic Compounds

FIGURES

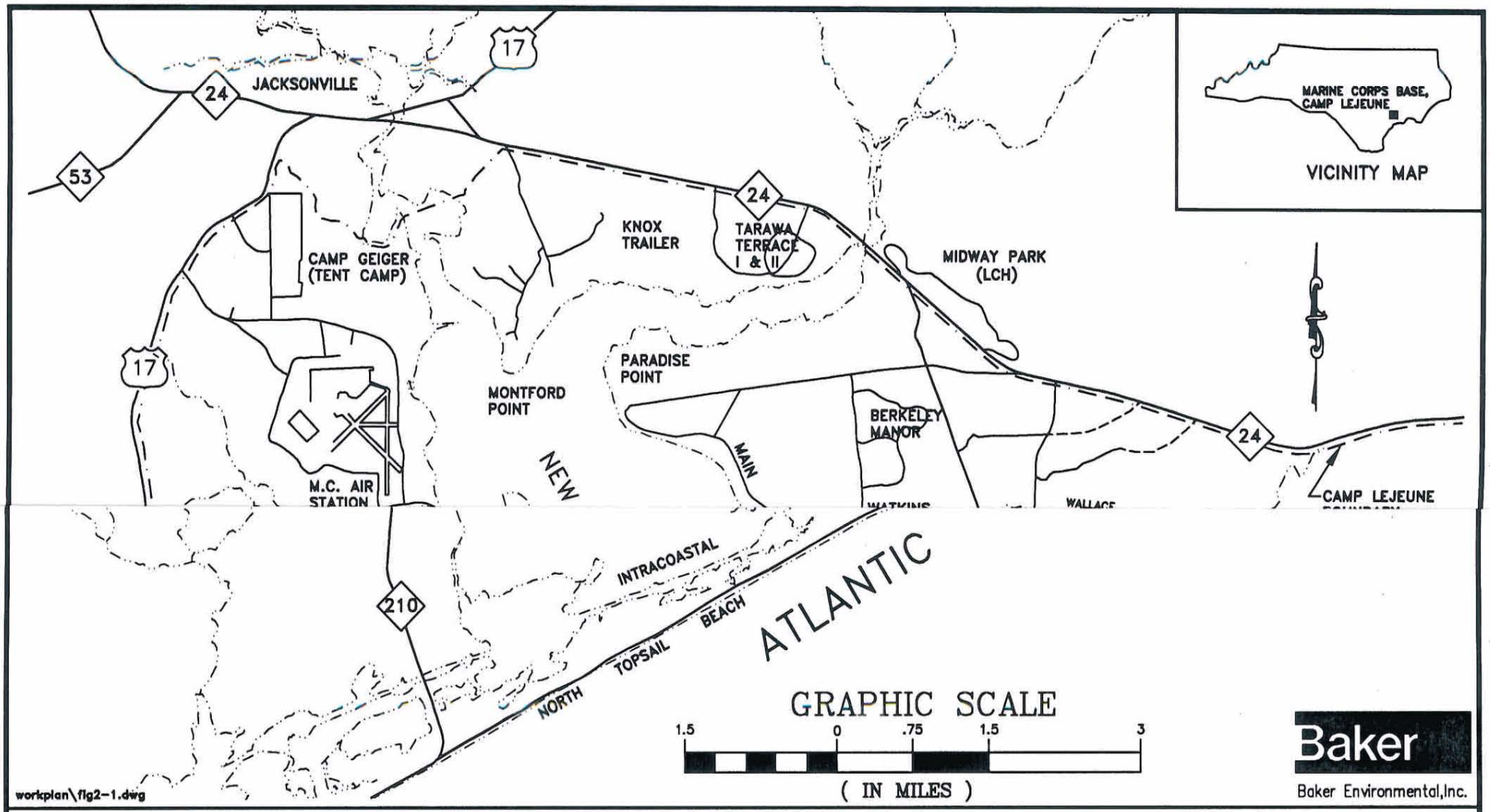
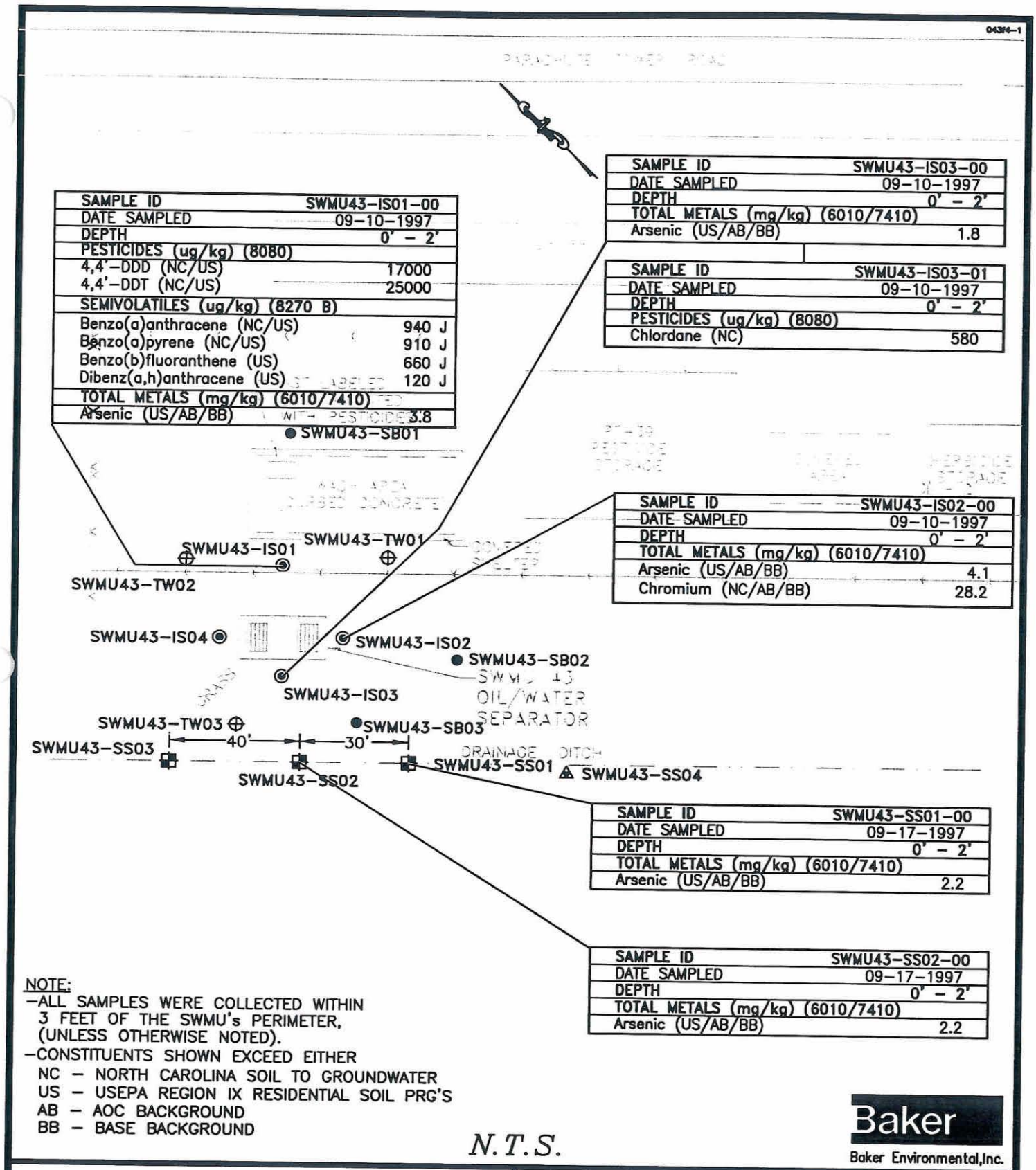


FIGURE 2-1
GENERAL LOCATION MAP
PHASE II CONFIRMATORY SAMPLING WORKPLAN

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



SAMPLE ID	SWMU43-IS01-00
DATE SAMPLED	09-10-1997
DEPTH	0' - 2'
PESTICIDES (ug/kg) (8080)	
4,4'-DDD (NC/US)	17000
4,4'-DDT (NC/US)	25000
SEMIVOLATILES (ug/kg) (8270 B)	
Benzo(a)anthracene (NC/US)	940 J
Benzo(a)pyrene (NC/US)	910 J
Benzo(b)fluoranthene (US)	660 J
Dibenz(a,h)anthracene (US)	120 J
TOTAL METALS (mg/kg) (6010/7410)	
Arsenic (US/AB/BB)	3.8

SAMPLE ID	SWMU43-IS03-00
DATE SAMPLED	09-10-1997
DEPTH	0' - 2'
TOTAL METALS (mg/kg) (6010/7410)	
Arsenic (US/AB/BB)	1.8

SAMPLE ID	SWMU43-IS03-01
DATE SAMPLED	09-10-1997
DEPTH	0' - 2'
PESTICIDES (ug/kg) (8080)	
Chlordane (NC)	580

SAMPLE ID	SWMU43-IS02-00
DATE SAMPLED	09-10-1997
DEPTH	0' - 2'
TOTAL METALS (mg/kg) (6010/7410)	
Arsenic (US/AB/BB)	4.1
Chromium (NC/AB/BB)	28.2

SAMPLE ID	SWMU43-SS01-00
DATE SAMPLED	09-17-1997
DEPTH	0' - 2'
TOTAL METALS (mg/kg) (6010/7410)	
Arsenic (US/AB/BB)	2.2

SAMPLE ID	SWMU43-SS02-00
DATE SAMPLED	09-17-1997
DEPTH	0' - 2'
TOTAL METALS (mg/kg) (6010/7410)	
Arsenic (US/AB/BB)	2.2

NOTE:
- ALL SAMPLES WERE COLLECTED WITHIN 3 FEET OF THE SWMU's PERIMETER, (UNLESS OTHERWISE NOTED).
- CONSTITUENTS SHOWN EXCEED EITHER
  - NC – NORTH CAROLINA SOIL TO GROUNDWATER
  - US – USEPA REGION IX RESIDENTIAL SOIL PRG'S
  - AB – AOC BACKGROUND
  - BB – BASE BACKGROUND

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LEGEND
- ● PROPOSED SOIL BORING
- ▲ PROPOSED SURFACE SOIL SAMPLE
- ⊕ PROPOSED TEMPORARY MONITORING WELL
- ● EXISTING SOIL BORING SAMPLE
- ▲ EXISTING SURFACE SOIL SAMPLE

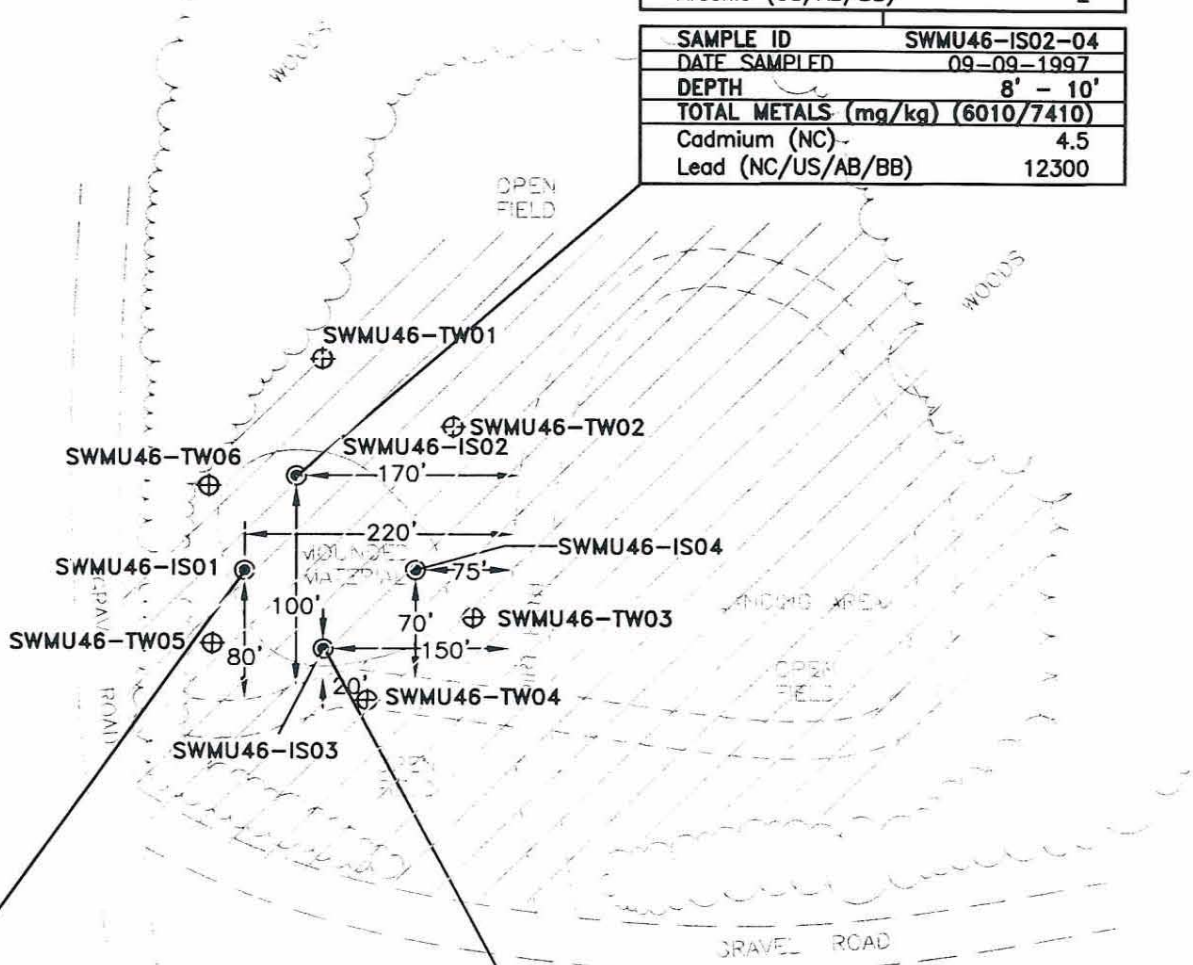
mg/kg – MILLIGRAM/KILOGRAM
ug/kg – MICROGRAM/KILOGRAM

FIGURE 4-1
PROPOSED PHASE II SWMU INVESTIGATION PLAN
SWMU 43
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

NOTE:
- ALL SAMPLES WERE COLLECTED WITHIN 3 FEET OF THE SWMU's PERIMETER, (UNLESS OTHERWISE NOTED).
- CONSTITUENTS SHOWN EXCEED EITHER
  - AB – AOC BACKGROUND
  - BB – BASE BACKGROUND
  - NC – NORTH CAROLINA SOIL TO GROUNDWATER
  - US – USEPA REGION IX RESIDENTIAL SOIL PRGs

SAMPLE ID	SWMU46-IS02-00
DATE SAMPLED	09-09-1997
DEPTH	0' – 2'
TOTAL METALS (mg/kg) (6010/7410)	
Arsenic (US/AB/BB)	2

SAMPLE ID	SWMU46-IS02-04
DATE SAMPLED	09-09-1997
DEPTH	8' – 10'
TOTAL METALS (mg/kg) (6010/7410)	
Cadmium (NC)	4.5
Lead (NC/US/AB/BB)	12300



SAMPLE ID	SWMU46-IS03-04
DATE SAMPLED	09-09-1997
DEPTH	8' – 10'
TOTAL METALS (mg/kg) (6010/7410)	
Arsenic (US/AB/BB)	6.1

SAMPLE ID	SWMU46-IS01-00
DATE SAMPLED	09-09-1997
DEPTH	0' – 2'
TOTAL METALS (mg/kg) (6010/7410)	
Arsenic (US/AB/BB)	1.3

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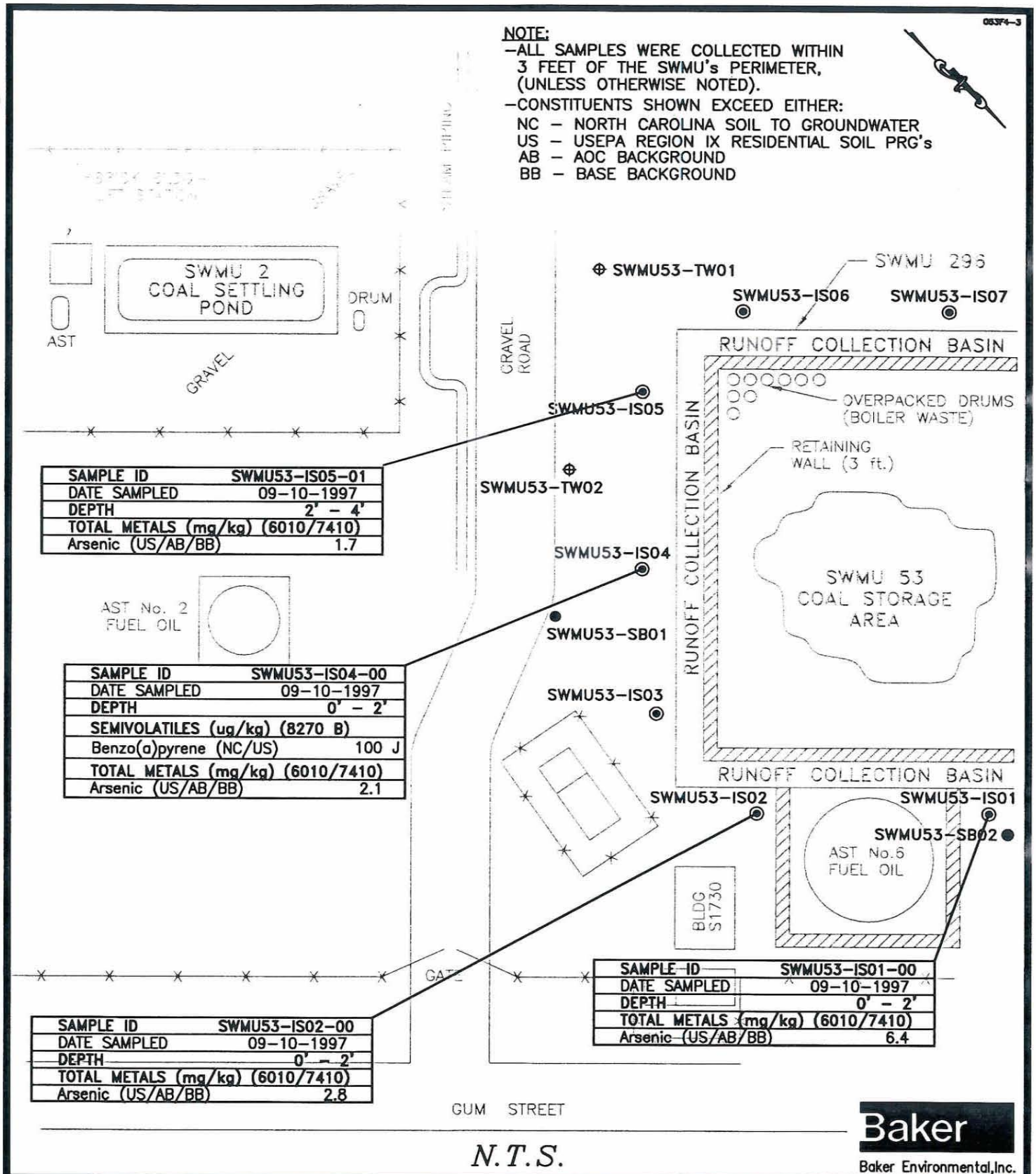
LEGEND

- ⊕ PROPOSED TEMPORARY MONITORING WELL
- ◉ EXISTING SOIL BORING SAMPLE
- GEOPHYSICAL SURVEY AREA
- mg/kg MILLIGRAM/KILOGRAM

FIGURE 4-2
PROPOSED PHASE II SWMU INVESTIGATION PLAN
SWMU 46
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



SAMPLE ID	SWMU53-IS05-01
DATE SAMPLED	09-10-1997
DEPTH	2' - 4'
TOTAL METALS (mg/kg) (6010/7410)	
Arsenic (US/AB/BB)	1.7

SAMPLE ID	SWMU53-IS04-00
DATE SAMPLED	09-10-1997
DEPTH	0' - 2'
SEMIVOLATILES (ug/kg) (8270 B)	
Benzo(a)pyrene (NC/US)	100 J
TOTAL METALS (mg/kg) (6010/7410)	
Arsenic (US/AB/BB)	2.1

SAMPLE ID	SWMU53-IS01-00
DATE SAMPLED	09-10-1997
DEPTH	0' - 2'
TOTAL METALS (mg/kg) (6010/7410)	
Arsenic (US/AB/BB)	6.4

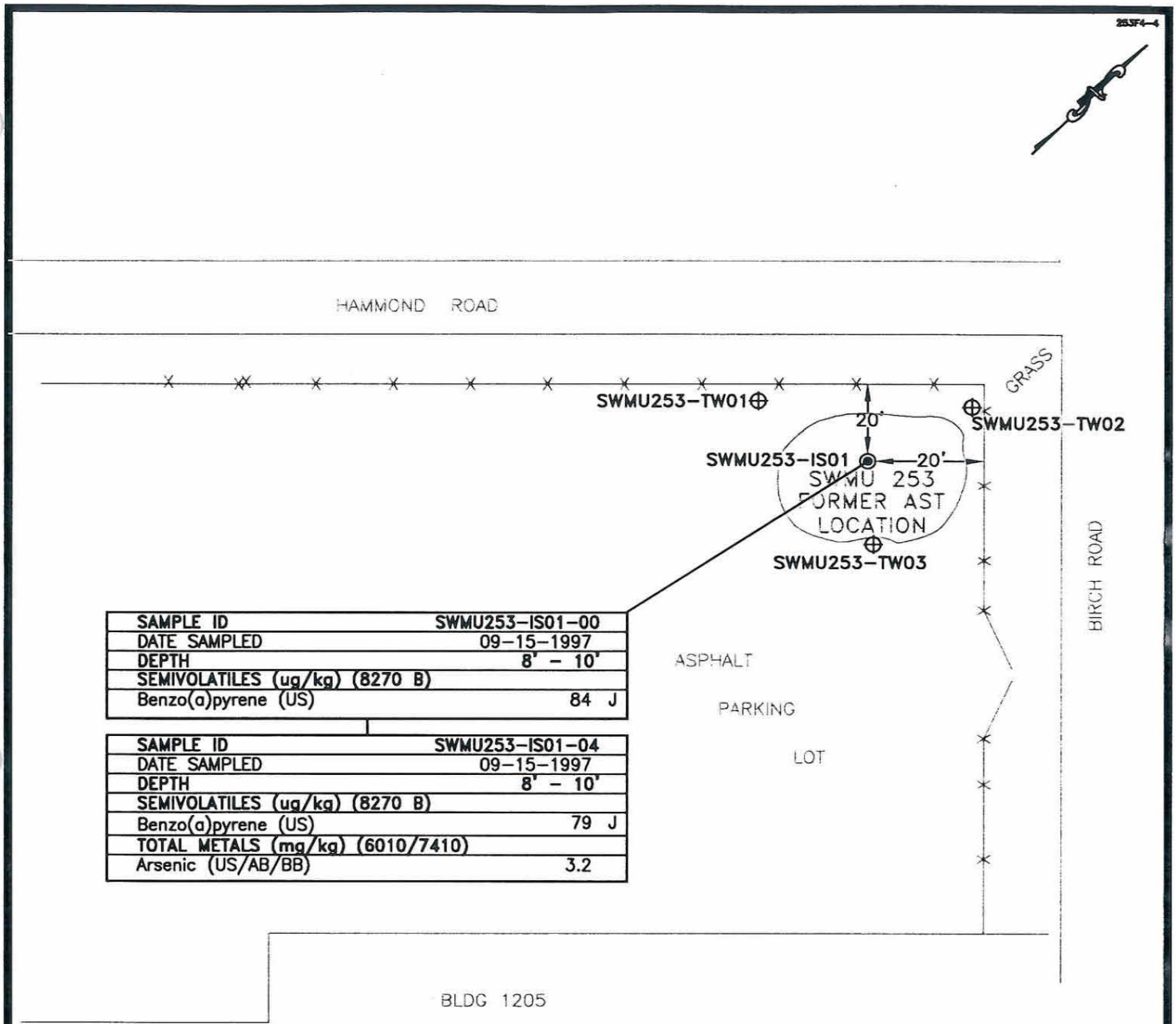
SAMPLE ID	SWMU53-IS02-00
DATE SAMPLED	09-10-1997
DEPTH	0' - 2'
TOTAL METALS (mg/kg) (6010/7410)	
Arsenic (US/AB/BB)	2.8

LEGEND

- ● PROPOSED SOIL BORING
- ⊕ PROPOSED TEMPORARY MONITORING WELL
- ◉ EXISTING SOIL BORING SAMPLE

mg/kg MILLIGRAM/KILOGRAM
ug/kg MICROGRAM/KILOGRAM

FIGURE 4-3
PROPOSED PHASE II SWMU INVESTIGATION PLAN
SWMUs 53 & 296
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



SAMPLE ID	SWMU253-IS01-00
DATE SAMPLED	09-15-1997
DEPTH	8' - 10'
SEMIVOLATILES (ug/kg) (8270 B)	
Benzo(a)pyrene (US)	84 J

SAMPLE ID	SWMU253-IS01-04
DATE SAMPLED	09-15-1997
DEPTH	8' - 10'
SEMIVOLATILES (ug/kg) (8270 B)	
Benzo(a)pyrene (US)	79 J
TOTAL METALS (mg/kg) (6010/7410)	
Arsenic (US/AB/BB)	3.2

NOTE:
-ALL SAMPLES WERE COLLECTED WITHIN 3 FEET OF THE SWMU's PERIMETER, (UNLESS OTHERWISE NOTED).
-CONSTITUENTS SHOWN EXCEED EITHER:
AB - AOC BACKGROUND
BB - BASE BACKGROUND
US - USEPA REGION IX RESIDENTIAL SOIL PRG's

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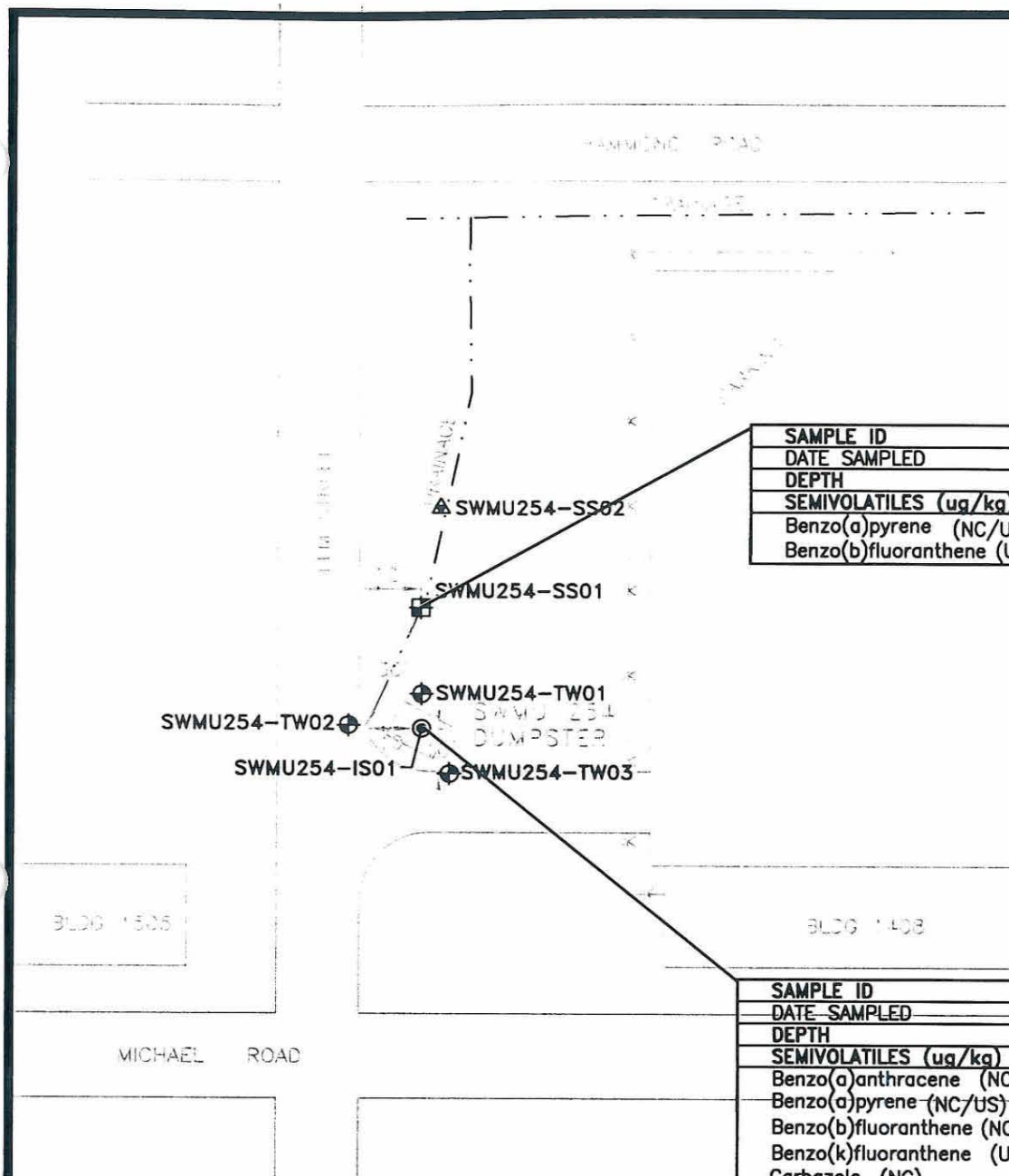
LEGEND

⊕ PROPOSED TEMPORARY MONITORING WELL
◉ EXISTING SOIL BORING SAMPLE
mg/kg MILLIGRAM/KILOGRAM
ug/kg MICROGRAM/KILOGRAM

FIGURE 4-4
PROPOSED PHASE II SWMU INVESTIGATION PLAN
SWMU 253
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



SAMPLE ID	SWMU254-SS01-00
DATE SAMPLED	09-12-1997
DEPTH	0' - 2'
SEMIVOLATILES (ug/kg) (8270 B)	
Benzo(a)pyrene (NC/US)	500
Benzo(b)fluoranthene (US)	770

SAMPLE ID	SWMU254-IS01-00
DATE SAMPLED	09-12-1997
DEPTH	0' - 2'
SEMIVOLATILES (ug/kg) (8270 B)	
Benzo(a)anthracene (NC/US)	6000
Benzo(a)pyrene (NC/US)	9000
Benzo(b)fluoranthene (NC/US)	15000
Benzo(k)fluoranthene (US)	7200
Carbazole (NC)	2100 J
Dibenz(a,h)anthracene (NC/US)	2800
Indeno(1,2,3-cd)pyrene (US)	7400

NOTE:
- ALL SAMPLES WERE COLLECTED WITHIN 3 FEET OF THE SWMU's PERIMETER, (UNLESS OTHERWISE NOTED).
- CONSTITUENTS SHOWN EXCEED
  NC – NORTH CAROLINA SOIL TO GROUNDWATER
  US – USEPA REGION IX RESIDENTIAL SOIL PRGs

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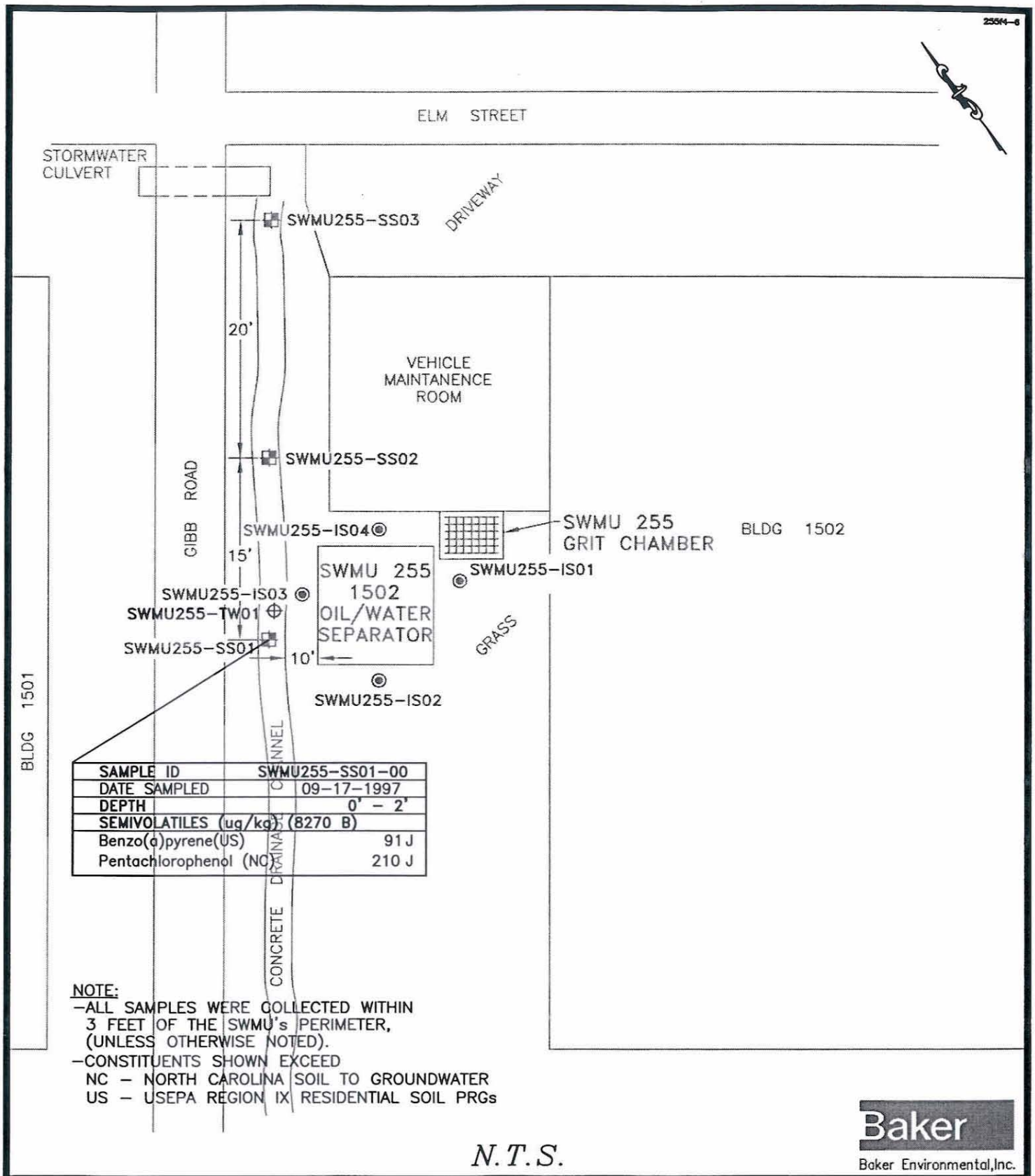
LEGEND
- PROPOSED TEMPORARY MONITORING WELL
- PROPOSED SURFACE SOIL SAMPLE
- EXISTING SOIL BORING SAMPLE
- EXISTING SURFACE SOIL SAMPLE

ug/kg MICROGRAM/KILOGRAM

FIGURE 4-5
PROPOSED PHASE II SWMU INVESTIGATION PLAN
SWMU 254
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



SAMPLE ID	SWMU255-SS01-00
DATE SAMPLED	09-17-1997
DEPTH	0' - 2'
SEMIVOLATILES (ug/kg) (8270 B)	
Benzo(a)pyrene(US)	91 J
Pentachlorophenol (NC)	210 J

NOTE:
-ALL SAMPLES WERE COLLECTED WITHIN 3 FEET OF THE SWMU's PERIMETER, (UNLESS OTHERWISE NOTED).
-CONSTITUENTS SHOWN EXCEED
NC - NORTH CAROLINA SOIL TO GROUNDWATER
US - USEPA REGION IX RESIDENTIAL SOIL PRGs

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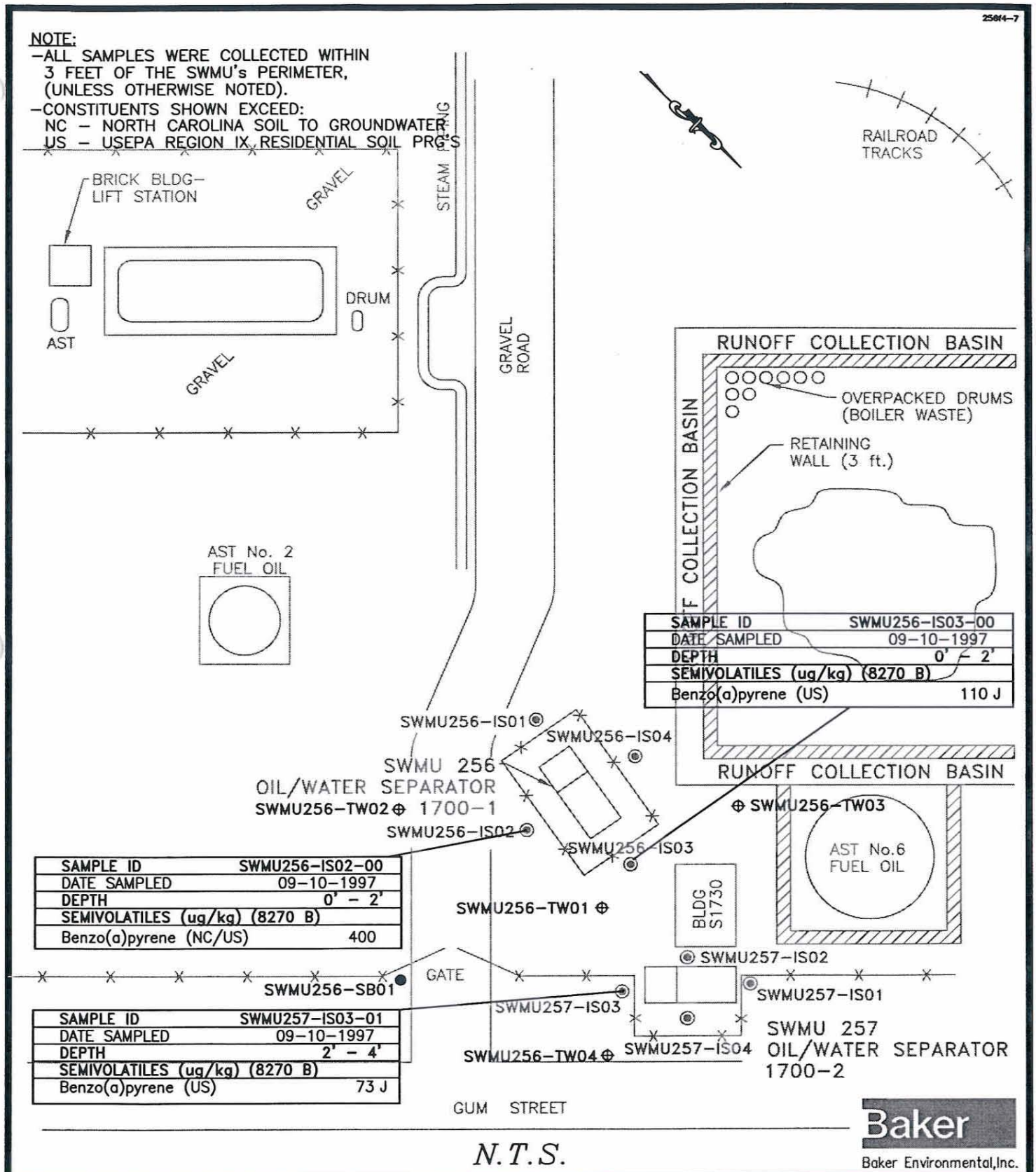
LEGEND

- ⊕ PROPOSED TEMPORARY MONITORING WELL
- ◉ SOIL BORING AND SAMPLE PLAN
- SURFACE SOIL LOCATION
- ug/kg MICROGRAM/KILOGRAM

FIGURE 4-6
PROPOSED PHASE II SWMU INVESTIGATION PLAN
SWMU 255
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



LEGEND

- ● PROPOSED SOIL BORING
- ⊕ PROPOSED TEMPORARY MONITORING WELL
- ◉ EXISTING SOIL BORING SAMPLE

ug/kg MICROGRAM/KILOGRAM

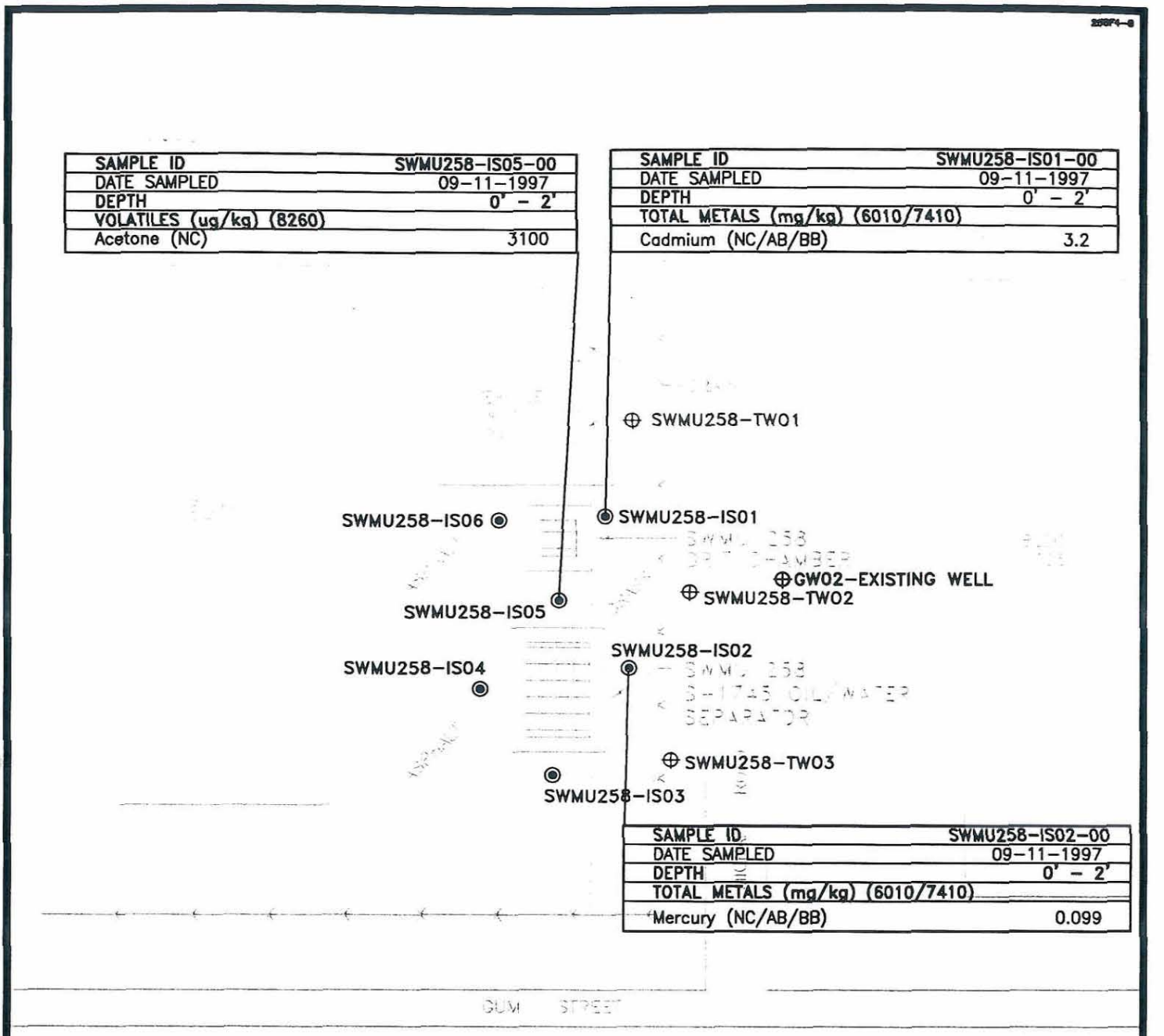
FIGURE 4-7

PROPOSED PHASE II SWMU INVESTIGATION PLAN

SWMUs 256 AND 257

MARINE CORPS BASE, CAMP LEJEUNE

NORTH CAROLINA



SAMPLE ID	SWMU258-IS05-00
DATE SAMPLED	09-11-1997
DEPTH	0' - 2'
VOLATILES (ug/kg) (8260)	
Acetone (NC)	3100

SAMPLE ID	SWMU258-IS01-00
DATE SAMPLED	09-11-1997
DEPTH	0' - 2'
TOTAL METALS (mg/kg) (6010/7410)	
Cadmium (NC/AB/BB)	3.2

SAMPLE ID	SWMU258-IS02-00
DATE SAMPLED	09-11-1997
DEPTH	0' - 2'
TOTAL METALS (mg/kg) (6010/7410)	
Mercury (NC/AB/BB)	0.099

NOTES:
-ALL SAMPLES WERE COLLECTED WITHIN 3' OF THE SWMU PERIMETER UNLESS OTHERWISE NOTED
-CONSTITUENTS SHOWN EXCEED EITHER
AB - AOC BACKGROUND
BB - BASE BACKGROUND
NC - NORTH CAROLINA SOIL TO GROUNDWATER

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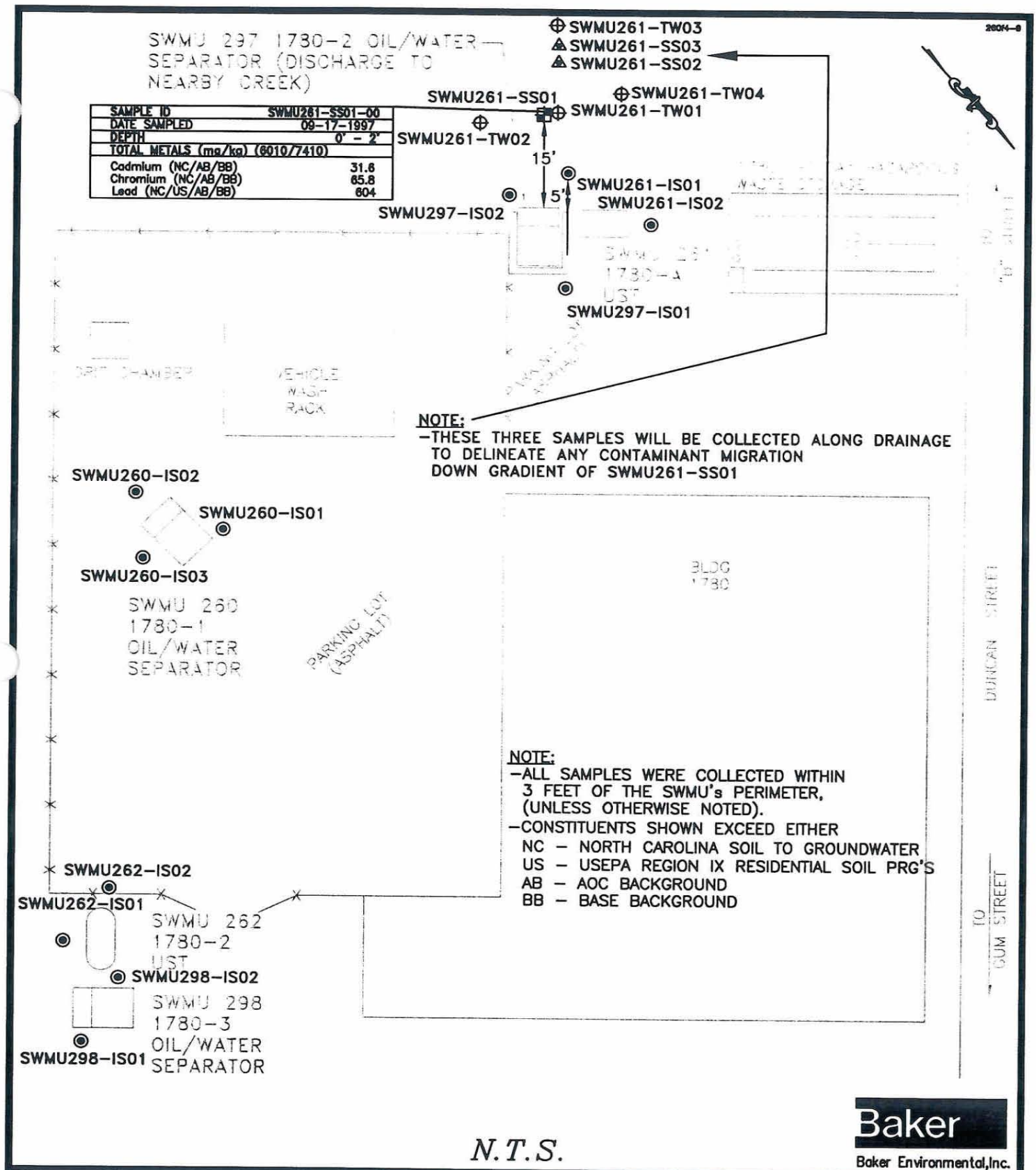
LEGEND
⊕ PROPOSED TEMPORARY MONITORING WELL
◉ SOIL BORING AND SAMPLE LOCATION
mg/kg MILLIGRAM/KILOGRAM

FIGURE 4-8
PROPOSED PHASE II SWMU INVESTIGATION PLAN
SWMU 258
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



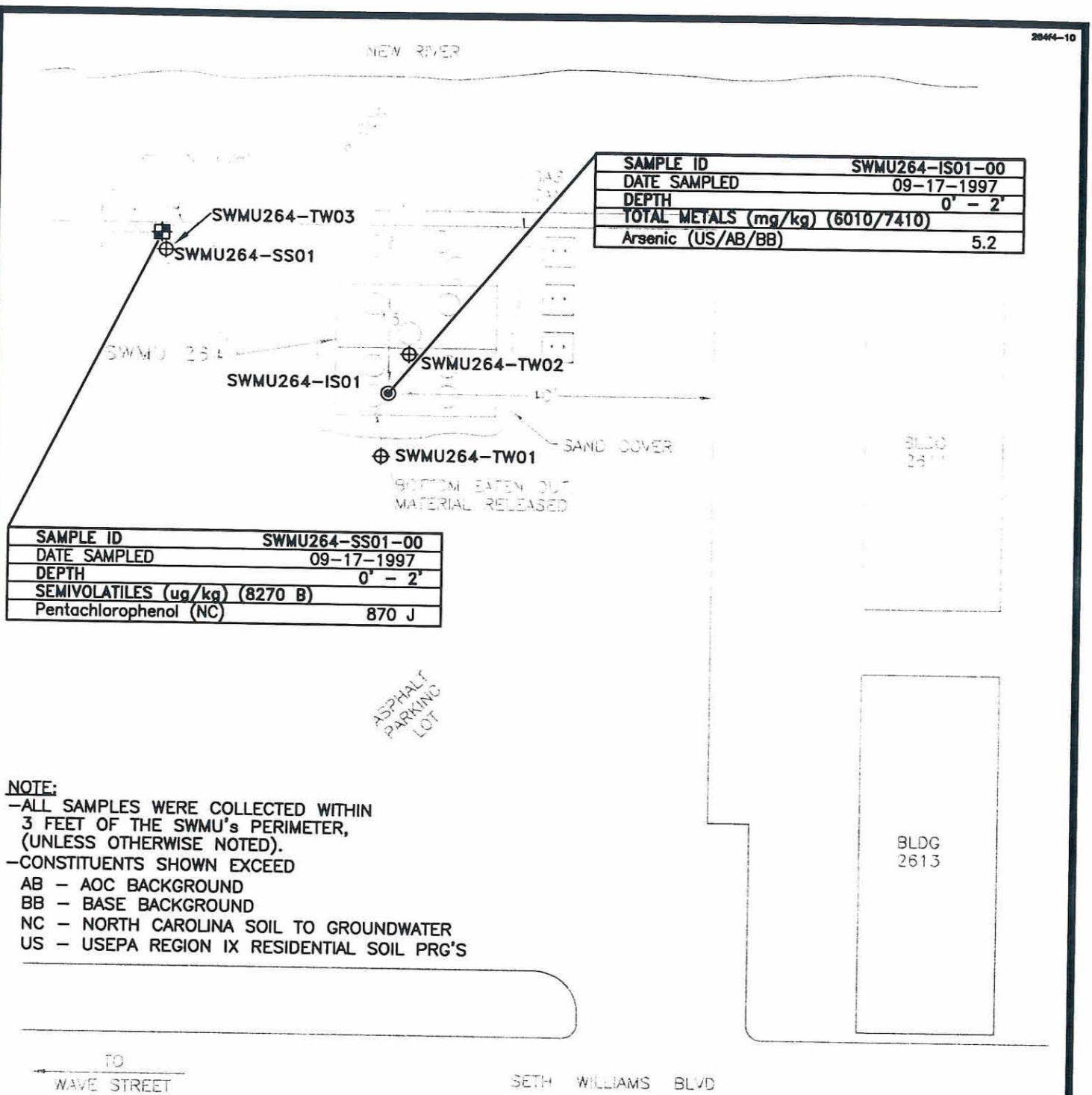
SAMPLE ID	SWMU261-SS01-00
DATE SAMPLED	09-17-1997
DEPTH	0' - 2'
TOTAL METALS (mg/kg) (6010/7410)	
Cadmium (NC/AB/BB)	31.6
Chromium (NC/AB/BB)	65.8
Lead (NC/US/AB/BB)	604

LEGEND

- ▲ PROPOSED SURFACE SOIL SAMPLE
- ⊕ PROPOSED TEMPORARY MONITORING WELL
- ● EXISTING SOIL BORING SAMPLE
- ⊞ EXISTING SURFACE SOIL SAMPLE

mg/kg MILLIGRAM/KILOGRAM

FIGURE 4-9
PROPOSED PHASE II SWMU INVESTIGATION PLAN
SWMUs 261 AND 297
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



SAMPLE ID	SWMU264-IS01-00
DATE SAMPLED	09-17-1997
DEPTH	0' - 2'
TOTAL METALS (mg/kg) (6010/7410)	
Arsenic (US/AB/BB)	5.2

SAMPLE ID	SWMU264-SS01-00
DATE SAMPLED	09-17-1997
DEPTH	0' - 2'
SEMIVOLATILES (ug/kg) (8270 B)	
Pentachlorophenol (NC)	870 J

NOTE:
- ALL SAMPLES WERE COLLECTED WITHIN 3 FEET OF THE SWMU's PERIMETER, (UNLESS OTHERWISE NOTED).
- CONSTITUENTS SHOWN EXCEED
  - AB – AOC BACKGROUND
  - BB – BASE BACKGROUND
  - NC – NORTH CAROLINA SOIL TO GROUNDWATER
  - US – USEPA REGION IX RESIDENTIAL SOIL PRG'S

- DURING THE OCTOBER 1996 VISIT, THE ENTIRE PARKING LOT AT SWMU 264 WAS COVERED WITH WOOD CHIPS AND NO DETAILS WERE VISIBLE. THE DETAILS IN THIS DRAWING WERE NOTED BY ENSAFE, INC. IN NOVEMBER 1993.

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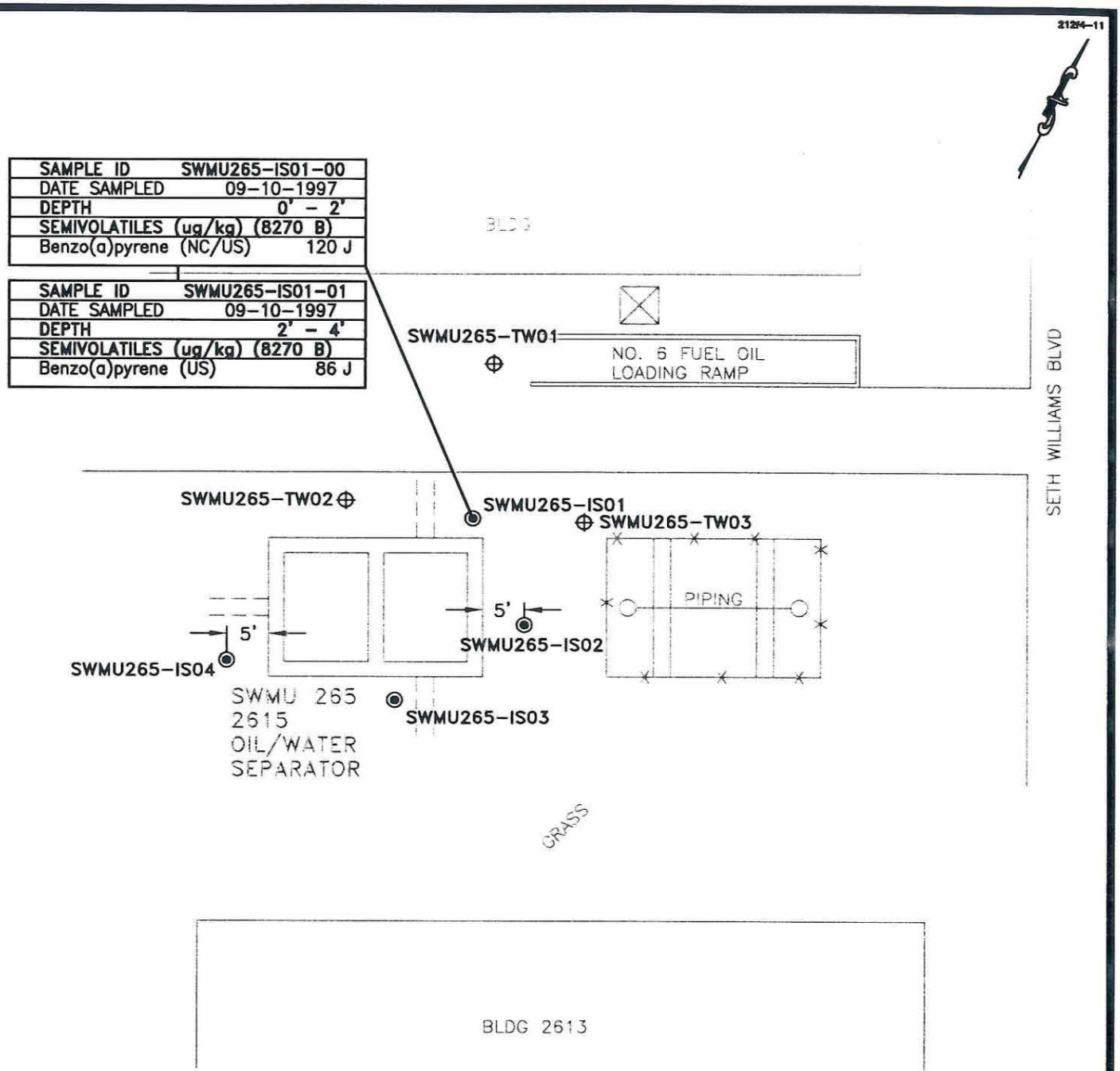
LEGEND
- PROPOSED TEMPORARY MONITORING WELL
- EXISTING SOIL BORING SAMPLE
- EXISTING SURFACE SOIL SAMPLE
- mg/kg MILLIGRAM/KILOGRAM
- FORMER LOCATIONS OF STEEL DRUMS
- FORMER LOCATIONS OF BATTERIES

FIGURE 4-10
PROPOSED PHASE II SWMU INVESTIGATION PLAN
SWMU 264
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



NOTES:
-ALL SAMPLES WILL BE COLLECTED WITHIN 3 FEET OF THE SWMU's PERIMETER, (UNLESS OTHERWISE NOTED).

-CONSTITUENTS SHOWN EXCEED EITHER:
NC - NORTH CAROLINA SOIL TO GROUNDWATER
US - USEPA REGION IX RESIDENTIAL SOIL PRG's

N.T.S.

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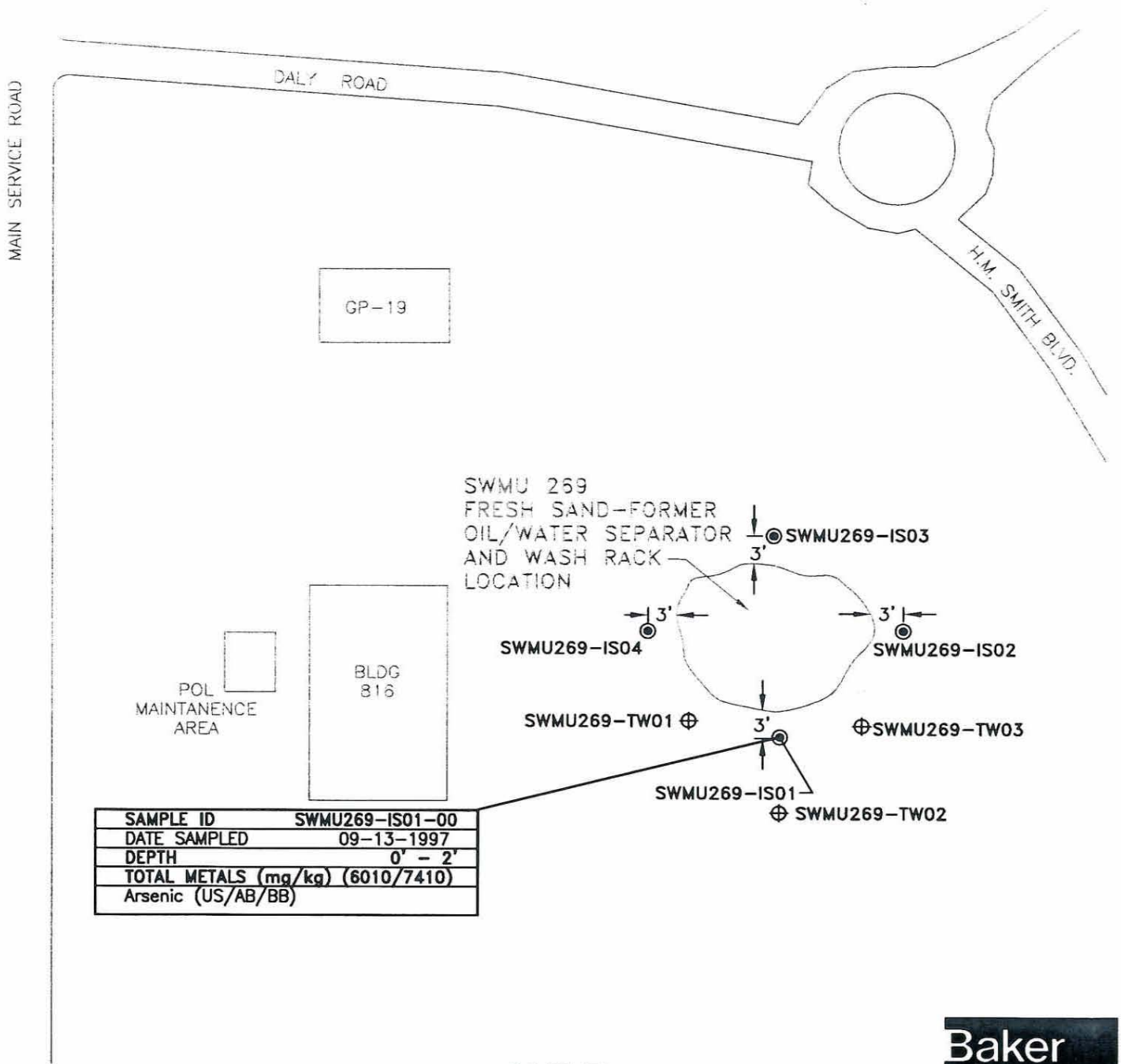
LEGEND
⊕ PROPOSED TEMPORARY MONITORING WELL
◉ EXISTING SOIL BORING SAMPLE
ug/kg MICROGRAM/KILOGRAM

FIGURE 4-11
PROPOSED PHASE II SWMU INVESTIGATION PLAN
SWMU 265
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

NOTE:
- ALL SAMPLES WERE COLLECTED WITHIN 3 FEET OF THE SWMU's PERIMETER, (UNLESS OTHERWISE NOTED).
- CONSTITUENTS SHOWN EXCEED EITHER:
  - AB – AOC BACKGROUND
  - BB – BASE BACKGROUND
  - US – USEPA REGION IX RESIDENTIAL SOIL PRG'S



SAMPLE ID	SWMU269-IS01-00
DATE SAMPLED	09-13-1997
DEPTH	0' – 2'
TOTAL METALS (mg/kg) (6010/7410)	
Arsenic (US/AB/BB)	

N.T.S.

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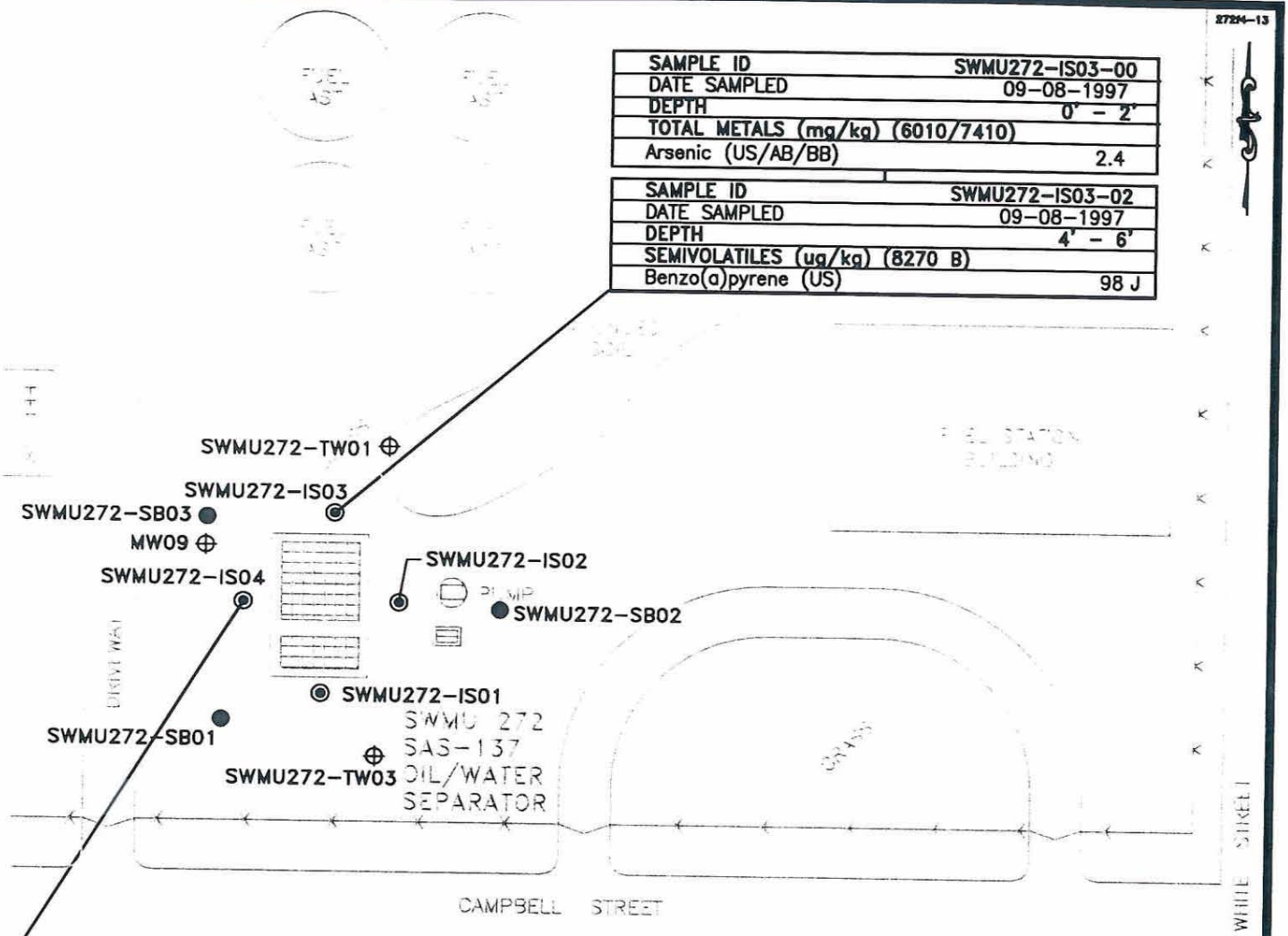
LEGEND

⊕ PROPOSED TEMPORARY MONITORING WELL

◉ EXISTING SOIL BORING SAMPLE

mg/kg MILLIGRAM/KILOGRAM

FIGURE 4-12
PROPOSED PHASE II SWMU INVESTIGATION PLAN
SWMU 269
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



SAMPLE ID	SWMU272-IS03-00
DATE SAMPLED	09-08-1997
DEPTH	0' - 2'
TOTAL METALS (mg/kg) (6010/7410)	
Arsenic (US/AB/BB)	2.4

SAMPLE ID	SWMU272-IS03-02
DATE SAMPLED	09-08-1997
DEPTH	4' - 6'
SEMIVOLATILES (ug/kg) (8270 B)	
Benzo(a)pyrene (US)	98 J

SAMPLE ID	SWMU272-IS04-02
DATE SAMPLED	09-08-1997
DEPTH	4' - 6'
SEMIVOLATILES (ug/kg) (8270 B)	
2-Chlorophenol (NC)	58 J
4-Chloro-3-methylphenol (NC)	90 J
Pentachlorophenol (NC)	440 J
TOTAL METALS (mg/kg) (6010/7410)	
Arsenic (US/AB/BB)	13.4

NOTE:
- ALL SAMPLES WERE COLLECTED WITHIN 3 FEET OF THE SWMU's PERIMETER, (UNLESS OTHERWISE NOTED).
- CONSTITUENTS SHOWN EXCEED EITHER
  - AB – AOC BACKGROUND
  - BB – BASE BACKGROUND
  - NC – NORTH CAROLINA SOIL TO GROUNDWATER
  - US – USEPA REGION IX RESIDENTIAL SOIL PRG'S

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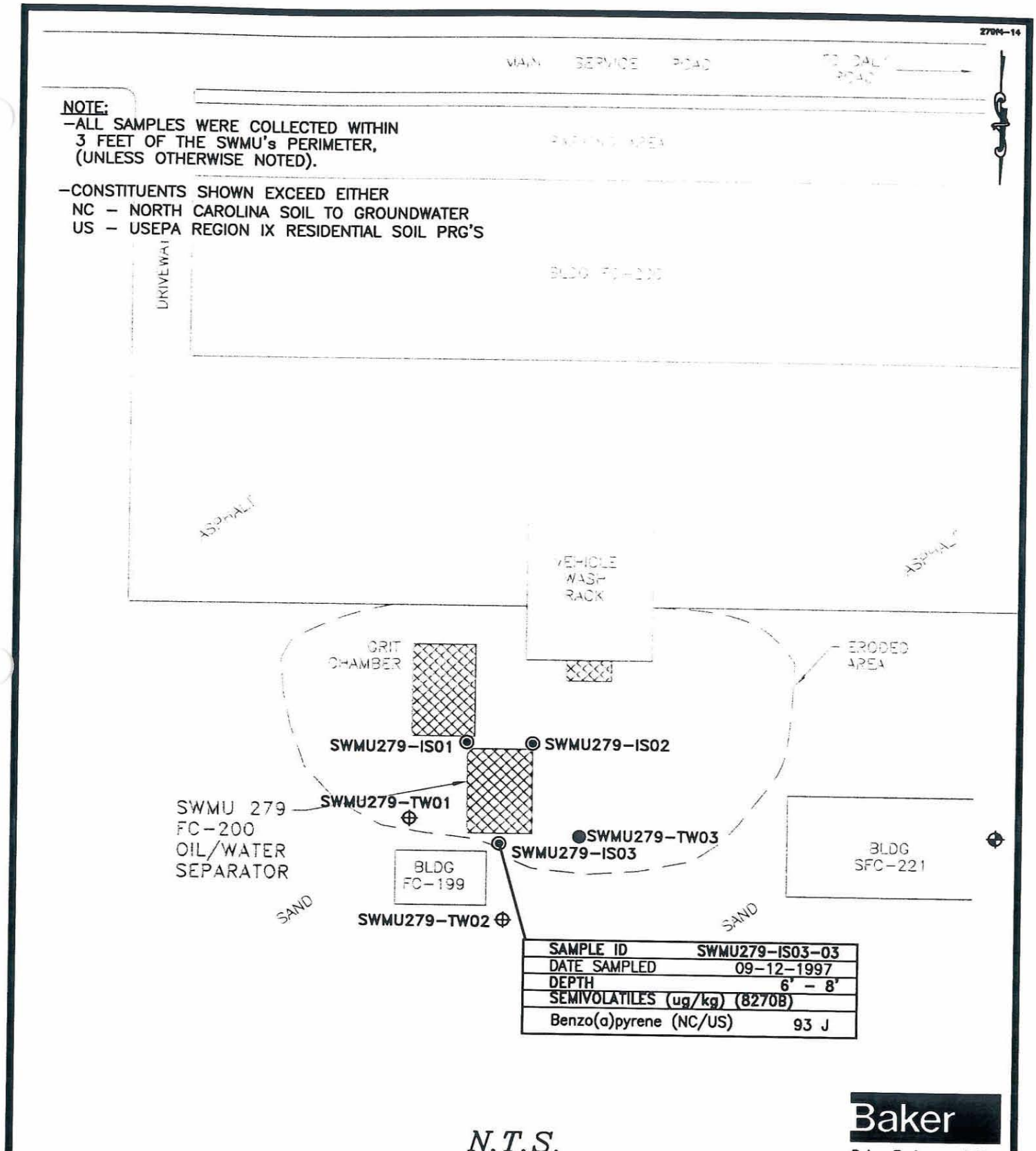
LEGEND

- ● PROPOSED SOIL BORING
- ⊕ PROPOSED TEMPORARY MONITORING WELL
- ◉ EXISTING SOIL BORING SAMPLE
- ⊕ EXISTING MONITORING WELL

mg/kg MILLIGRAM/KILOGRAM
ug/kg MICROGRAM/KILOGRAM

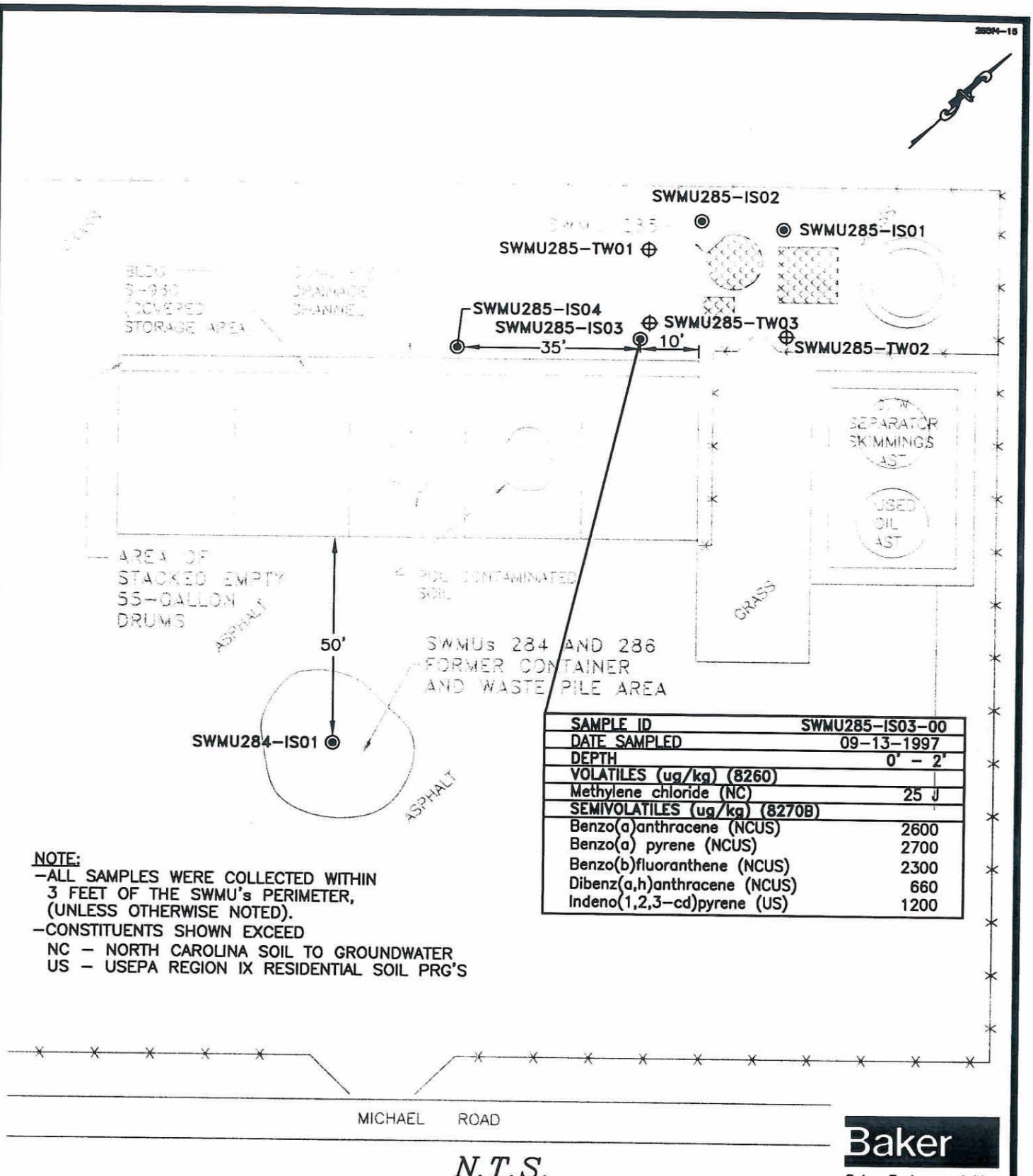
FIGURE 4-13
PROPOSED PHASE II SWMU INVESTIGATION PLAN
SWMU 272
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



LEGEND

- ● PROPOSED SOIL BORING
- ⊕ PROPOSED TEMPORARY MONITORING WELL
- ◉ EXISTING SOIL BORING SAMPLE
- ⊕ EXISTING MONITORING WELL
- ug/kg MICROGRAM/KILOGRAM

FIGURE 4-14
PROPOSED PHASE II SWMU INVESTIGATION PLAN
SWMU 279
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



SAMPLE ID	SWMU285-IS03-00
DATE SAMPLED	09-13-1997
DEPTH	0' - 2'
VOLATILES (ug/kg) (8260)	
Methylene chloride (NC)	25 J
SEMIVOLATILES (ug/kg) (8270B)	
Benzo(a)anthracene (NCUS)	2600
Benzo(a) pyrene (NCUS)	2700
Benzo(b)fluoranthene (NCUS)	2300
Dibenz(a,h)anthracene (NCUS)	660
Indeno(1,2,3-cd)pyrene (US)	1200

NOTE:
- ALL SAMPLES WERE COLLECTED WITHIN 3 FEET OF THE SWMU's PERIMETER, (UNLESS OTHERWISE NOTED).
- CONSTITUENTS SHOWN EXCEED
  NC - NORTH CAROLINA SOIL TO GROUNDWATER
  US - USEPA REGION IX RESIDENTIAL SOIL PRG'S

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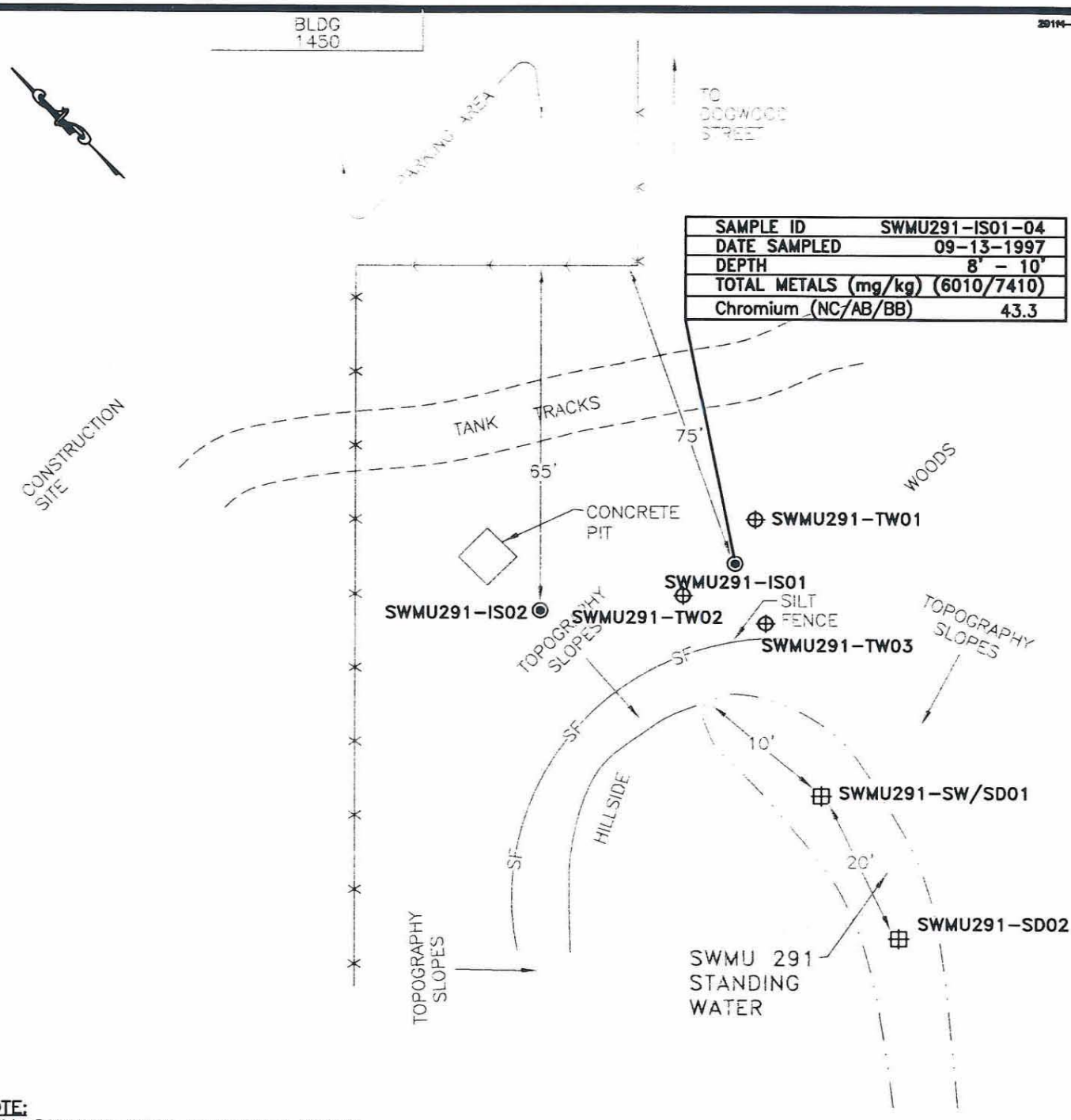
LEGEND

⊕ PROPOSED TEMPORARY MONITORING WELL

◉ EXISTING SOIL BORING SAMPLE

ug/kg MICROGRAM/KILOGRAM

FIGURE 4-15
PROPOSED PHASE II SWMU INVESTIGATION PLAN
SWMU 285
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



NOTE:
- ALL SAMPLES WERE COLLECTED WITHIN 3 FEET OF THE SWMU's PERIMETER, (UNLESS OTHERWISE NOTED).
- CONSTITUENTS SHOWN EXCEED EITHER
  - NC – NORTH CAROLINA SOIL TO GROUNDWATER
  - AB – AOC BACKGROUND
  - BB – BASE BACKGROUND

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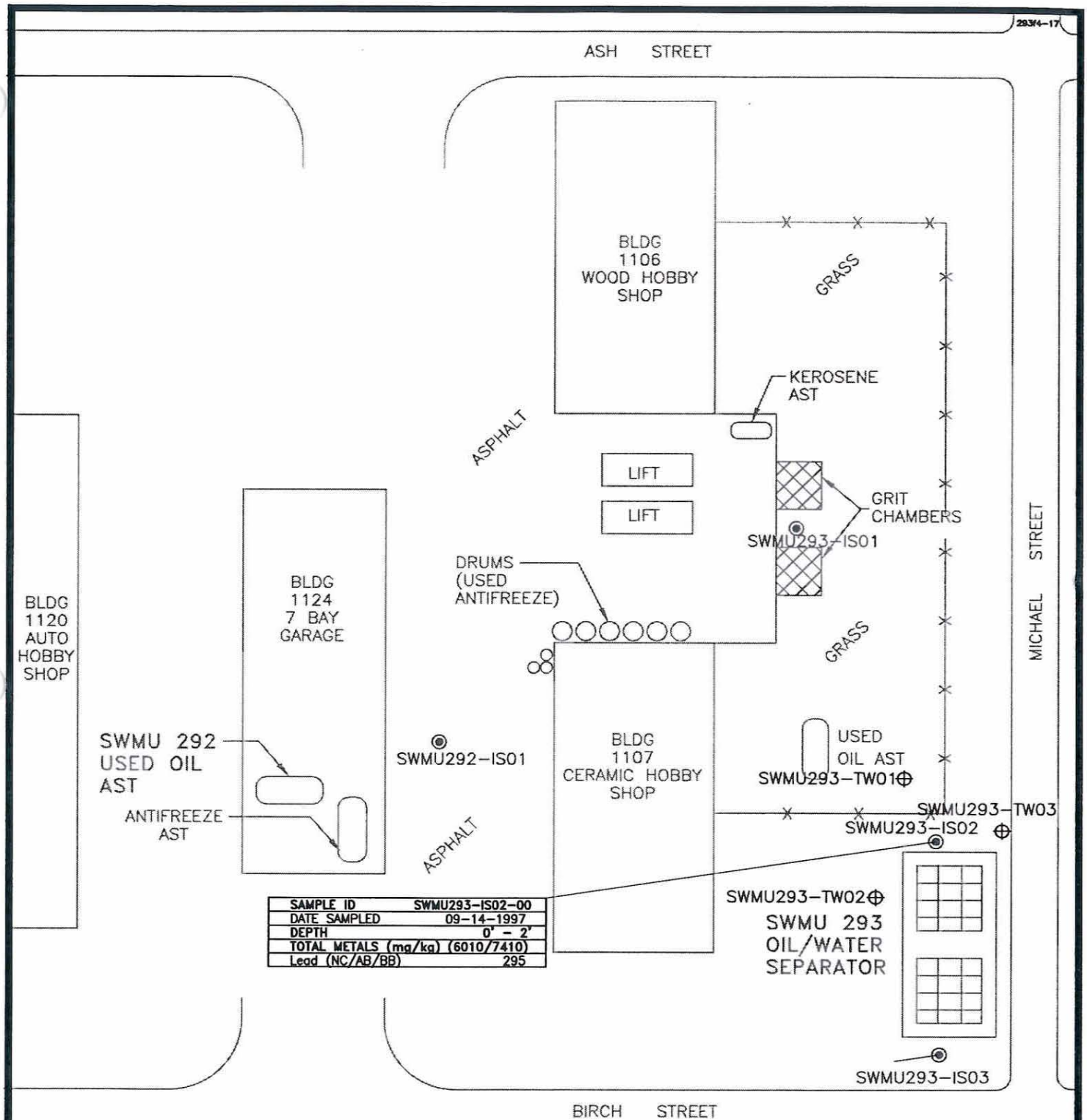
LEGEND

- ⊕ PROPOSED TEMPORARY MONITORING WELL
- ◉ EXISTING SOIL BORING SAMPLE
- ⊞ EXISTING SURFACE WATER/SEDIMENT SAMPLE
- mg/kg – MILLIGRAM/KILOGRAM

FIGURE 4-16
PROPOSED PHASE II SWMU INVESTIGATION PLAN
SWMU 291
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



NOTE:
CONSTITUENTS SHOWN EXCEED EITHER
NC – NORTH CAROLINA SOIL TO GROUNDWATER
AB – AOC BACKGROUND
BB – BASE BACKGROUND

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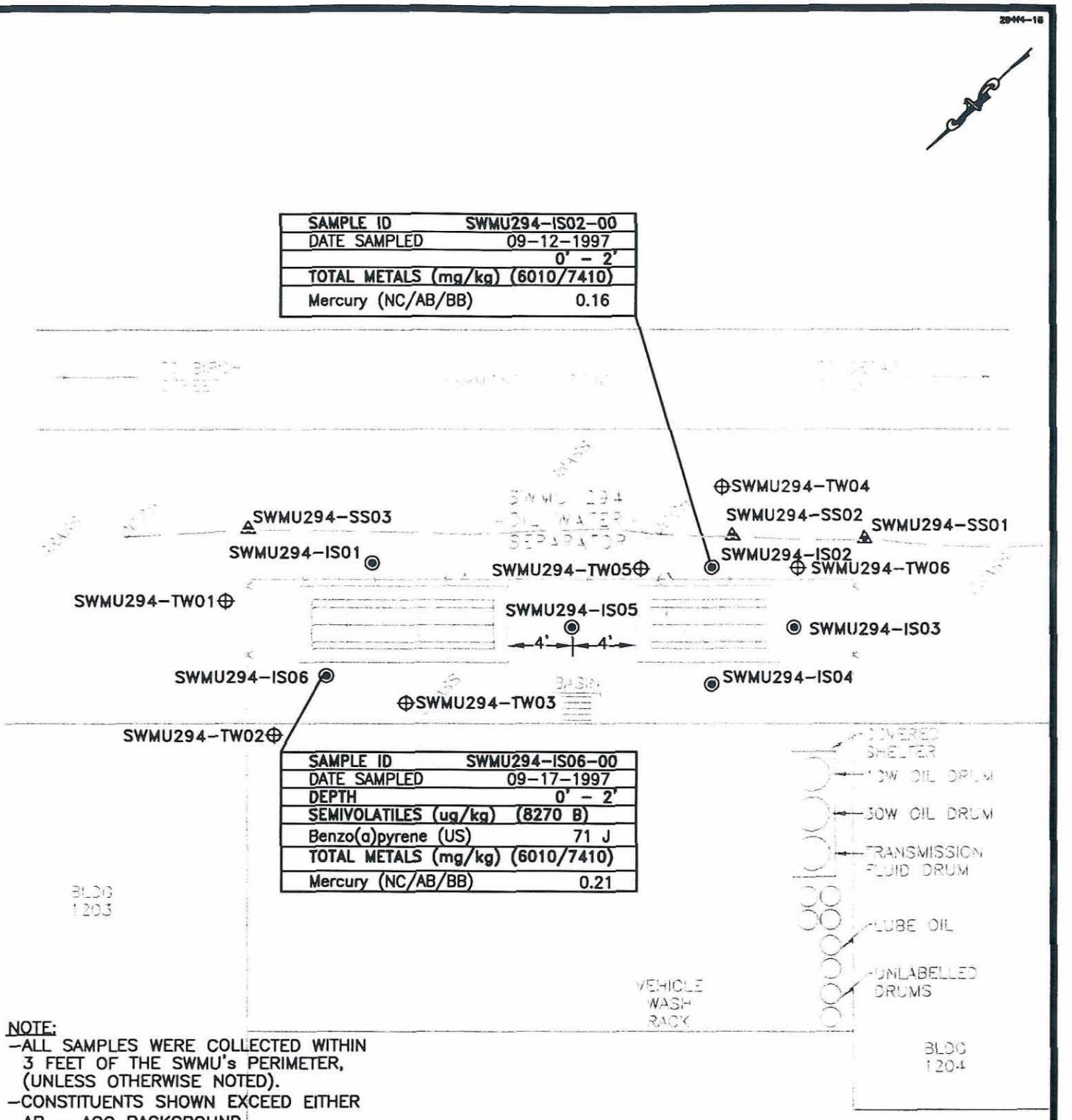
LEGEND

⊕ PROPOSED TEMPORARY MONITORING WELL

◉ EXISTING SOIL BORING SAMPLE

mg/kg MILLIGRAMS/KILOGRAM

FIGURE 4-17
PROPOSED PHASE II SWMU INVESTIGATION PLAN
SWMU 293
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



SAMPLE ID	SWMU294-IS02-00
DATE SAMPLED	09-12-1997
	0' - 2'
TOTAL METALS (mg/kg) (6010/7410)	
Mercury (NC/AB/BB)	0.16

SAMPLE ID	SWMU294-IS06-00
DATE SAMPLED	09-17-1997
DEPTH	0' - 2'
SEMIVOLATILES (ug/kg) (8270 B)	
Benzo(a)pyrene (US)	71 J
TOTAL METALS (mg/kg) (6010/7410)	
Mercury (NC/AB/BB)	0.21

NOTE:
- ALL SAMPLES WERE COLLECTED WITHIN 3 FEET OF THE SWMU's PERIMETER, (UNLESS OTHERWISE NOTED).
- CONSTITUENTS SHOWN EXCEED EITHER
  - AB – AOC BACKGROUND
  - BB – BASE BACKGROUND
  - NC – NORTH CAROLINA SOIL TO GROUNDWATER
  - US – USEPA REGION IX RESIDENTIAL SOIL PRG's

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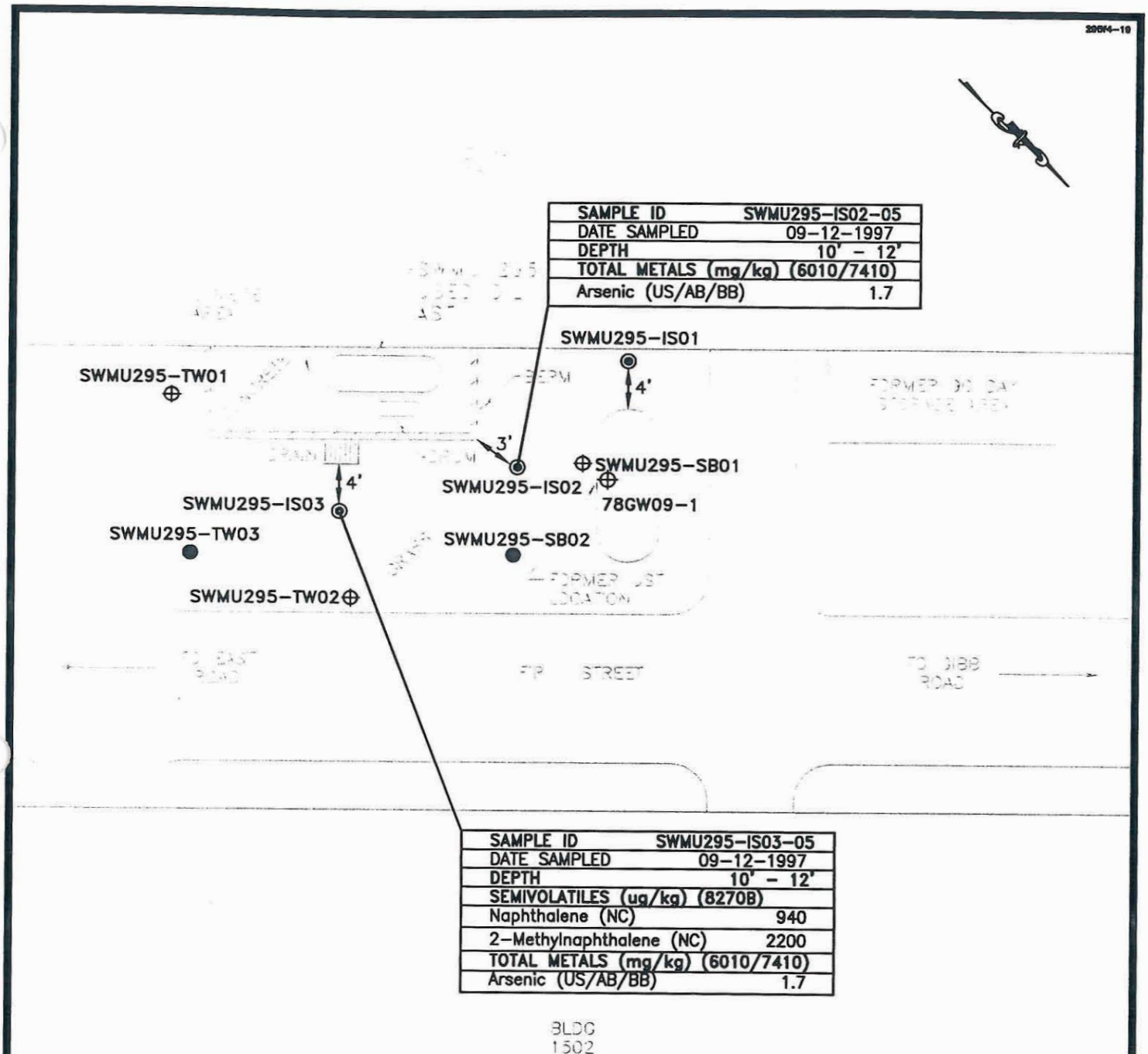
LEGEND
- ⊕ PROPOSED TEMPORARY MONITORING WELL
- ◉ EXISTING SOIL BORING SAMPLE
- ▲ PROPOSED SURFACE SOIL SAMPLE
- mg/kg – MILLIGRAM/KILOGRAM
- ug/kg – MICROGRAM/KILOGRAM

FIGURE 4-18
PROPOSED PHASE II SWMU INVESTIGATION PLAN
SWMU 294
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



NOTE:
- ALL SAMPLES WERE COLLECTED WITHIN 3 FEET OF THE SWMU's PERIMETER, (UNLESS OTHERWISE NOTED).
- CONSTITUENTS SHOWN EXCEED EITHER
  - AB – AOC BACKGROUND
  - BB – BASE BACKGROUND
  - NC – NORTH CAROLINA SOIL TO GROUNDWATER
  - US – USEPA REGION IX RESIDENTIAL SOIL PRGs

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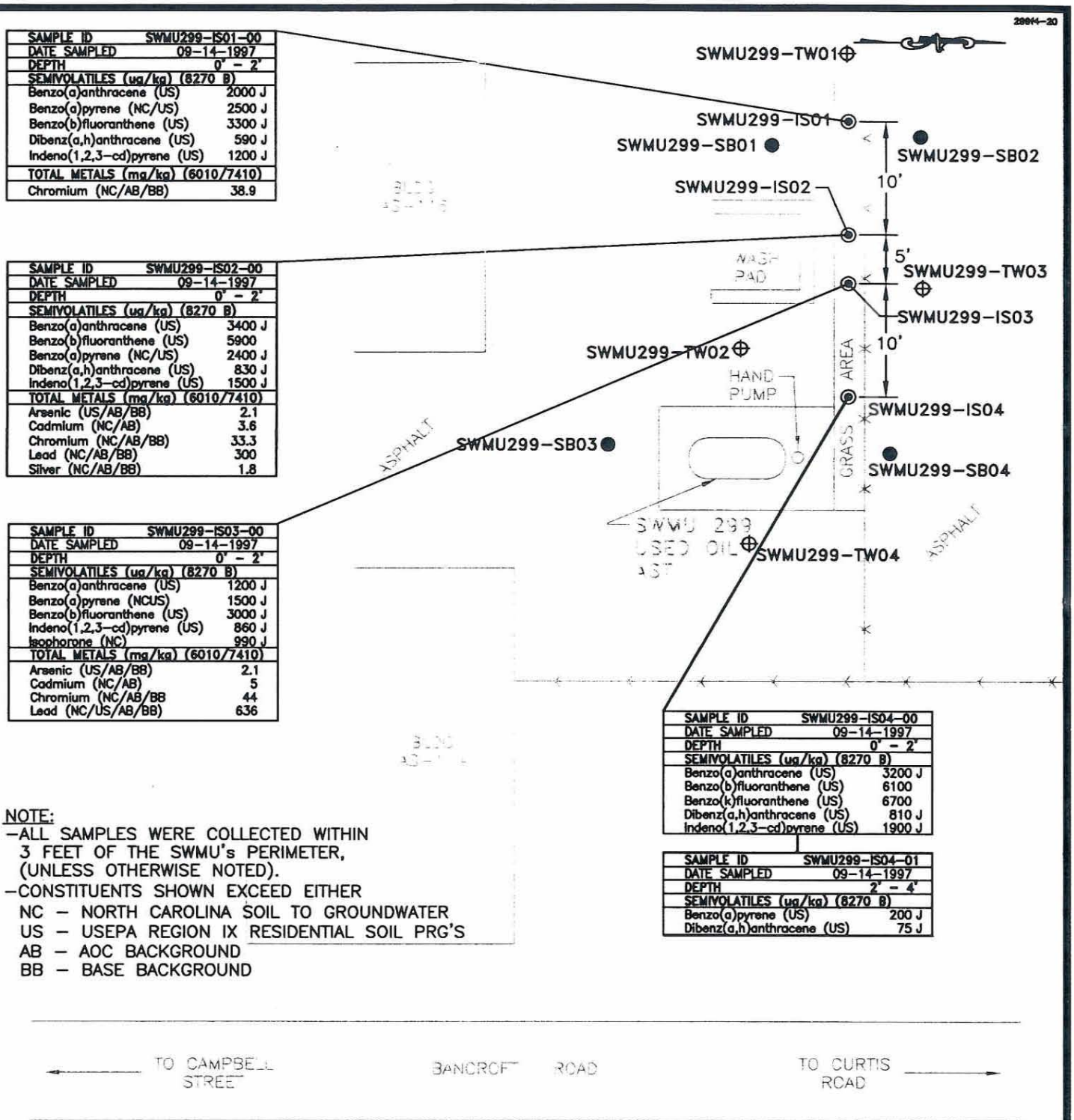
LEGEND
- ● PROPOSED SOIL BORING
- ⊕ PROPOSED TEMPORARY MONITORING WELL
- ◉ EXISTING SOIL BORING SAMPLE
- ⊕ EXISTING MONITORING WELL LOCATION
- mg/kg MILLIGRAM/KILOGRAM
- ug/kg MICROGRAM/KILOGRAM

FIGURE 4-19
PROPOSED PHASE II SWMU INVESTIGATION PLAN
SWMU 295
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



SAMPLE ID	SWMU299-IS01-00
DATE SAMPLED	09-14-1997
DEPTH	0' - 2'
SEMIVOLATILES (ug/kg) (8270 B)	
Benzo(a)anthracene (US)	2000 J
Benzo(a)pyrene (NC/US)	2500 J
Benzo(b)fluoranthene (US)	3300 J
Dibenz(a,h)anthracene (US)	590 J
Indeno(1,2,3-cd)pyrene (US)	1200 J
TOTAL METALS (mg/kg) (6010/7410)	
Chromium (NC/AB/BB)	38.9

SAMPLE ID	SWMU299-IS02-00
DATE SAMPLED	09-14-1997
DEPTH	0' - 2'
SEMIVOLATILES (ug/kg) (8270 B)	
Benzo(a)anthracene (US)	3400 J
Benzo(b)fluoranthene (US)	5900
Benzo(a)pyrene (NC/US)	2400 J
Dibenz(a,h)anthracene (US)	830 J
Indeno(1,2,3-cd)pyrene (US)	1500 J
TOTAL METALS (mg/kg) (6010/7410)	
Arsenic (US/AB/BB)	2.1
Cadmium (NC/AB)	3.6
Chromium (NC/AB/BB)	33.3
Lead (NC/AB/BB)	300
Silver (NC/AB/BB)	1.8

SAMPLE ID	SWMU299-IS03-00
DATE SAMPLED	09-14-1997
DEPTH	0' - 2'
SEMIVOLATILES (ug/kg) (8270 B)	
Benzo(a)anthracene (US)	1200 J
Benzo(a)pyrene (NCUS)	1500 J
Benzo(b)fluoranthene (US)	3000 J
Indeno(1,2,3-cd)pyrene (US)	860 J
Isophorone (NC)	990 J
TOTAL METALS (mg/kg) (6010/7410)	
Arsenic (US/AB/BB)	2.1
Cadmium (NC/AB)	5
Chromium (NC/AB/BB	44
Lead (NC/US/AB/BB)	636

SAMPLE ID	SWMU299-IS04-00
DATE SAMPLED	09-14-1997
DEPTH	0' - 2'
SEMIVOLATILES (ug/kg) (8270 B)	
Benzo(a)anthracene (US)	3200 J
Benzo(b)fluoranthene (US)	6100
Benzo(k)fluoranthene (US)	6700
Dibenz(a,h)anthracene (US)	810 J
Indeno(1,2,3-cd)pyrene (US)	1900 J

SAMPLE ID	SWMU299-IS04-01
DATE SAMPLED	09-14-1997
DEPTH	2' - 4'
SEMIVOLATILES (ug/kg) (8270 B)	
Benzo(a)pyrene (US)	200 J
Dibenz(a,h)anthracene (US)	75 J

NOTE:
- ALL SAMPLES WERE COLLECTED WITHIN 3 FEET OF THE SWMU's PERIMETER, (UNLESS OTHERWISE NOTED).
- CONSTITUENTS SHOWN EXCEED EITHER
  - NC – NORTH CAROLINA SOIL TO GROUNDWATER
  - US – USEPA REGION IX RESIDENTIAL SOIL PRG'S
  - AB – AOC BACKGROUND
  - BB – BASE BACKGROUND

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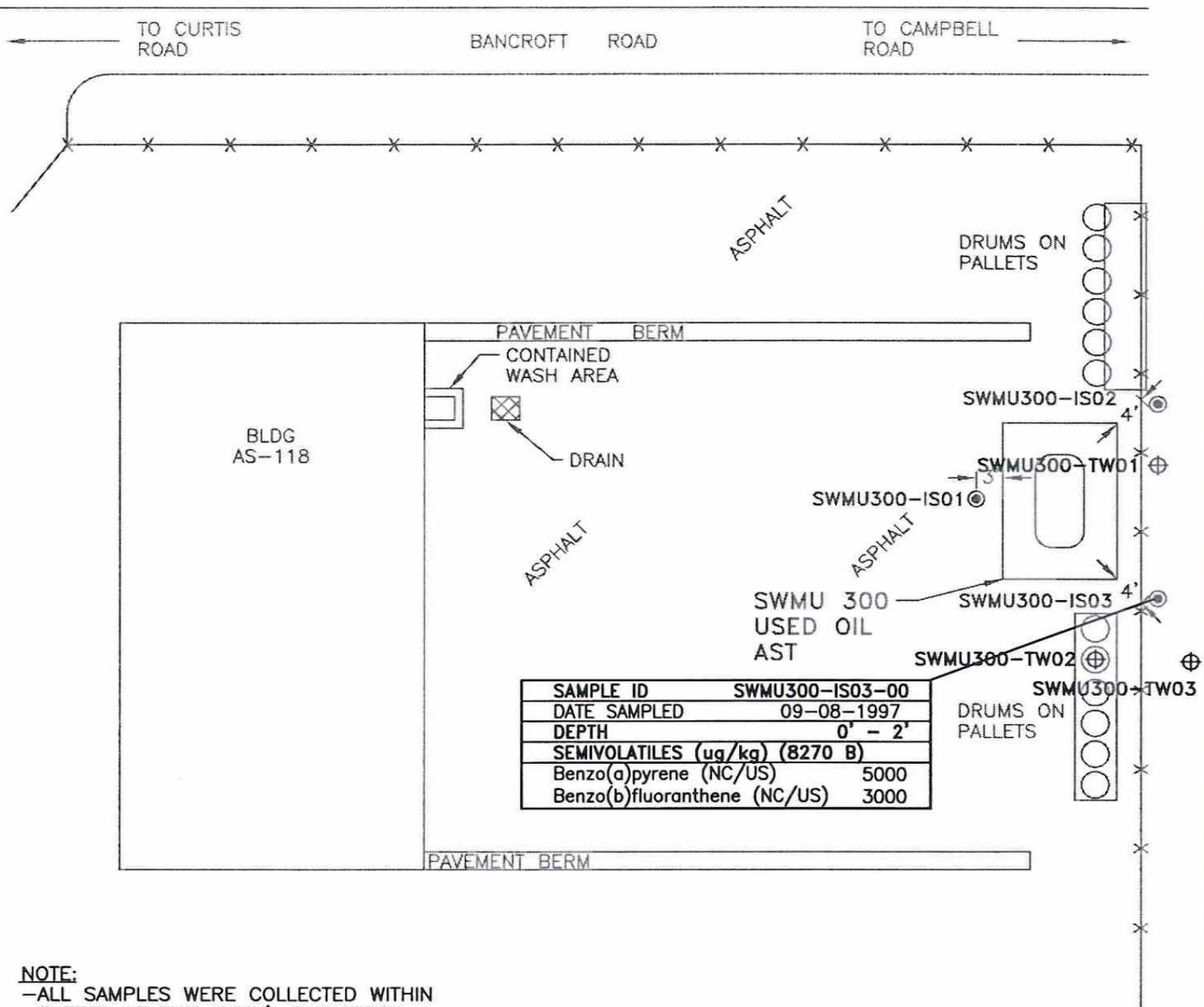
LEGEND
- ● PROPOSED SOIL BORING
- ⊕ PROPOSED TEMPORARY MONITORING WELL
- ◉ EXISTING SOIL BORING SAMPLE
- mg/kg MILLIGRAM/KILOGRAM
- ug/kg MICROGRAM/KILOGRAM

FIGURE 4-20
PROPOSED PHASE II SWMU INVESTIGATION PLAN
SWMU 299
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



SAMPLE ID	SWMU300-IS03-00
DATE SAMPLED	09-08-1997
DEPTH	0' - 2'
SEMIVOLATILES (ug/kg) (8270 B)	
Benzo(a)pyrene (NC/US)	5000
Benzo(b)fluoranthene (NC/US)	3000

NOTE:
- ALL SAMPLES WERE COLLECTED WITHIN 3 FEET OF THE SWMU's PERIMETER, (UNLESS OTHERWISE NOTED).
- CONSTITUENTS SHOWN EXCEED:
  - NC – NORTH CAROLINA SOIL TO GROUNDWATER
  - US – USEPA REGION IX RESIDENTIAL SOIL PRG's

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LEGEND

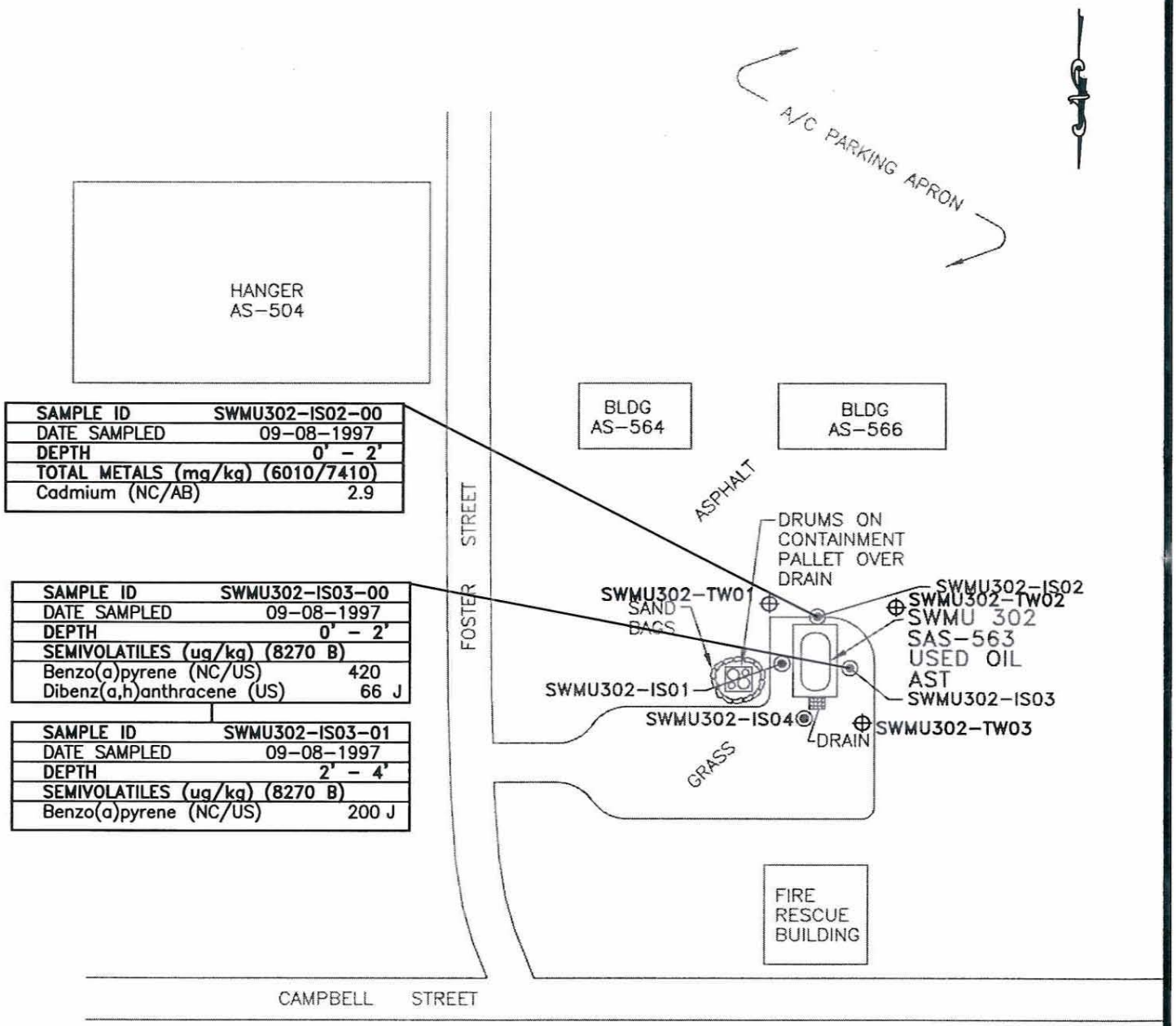
⊕ PROPOSED TEMPORARY MONITORING WELL

◉ EXISTING SOIL BORING SAMPLE

ug/kg – MICROGRAM/KILOGRAM

FIGURE 4-21
PROPOSED PHASE II SWMU INVESTIGATION PLAN
SWMU 300
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

30214-22



SAMPLE ID	SWMU302-IS02-00
DATE SAMPLED	09-08-1997
DEPTH	0' - 2'
TOTAL METALS (mg/kg) (6010/7410)	
Cadmium (NC/AB)	2.9

SAMPLE ID	SWMU302-IS03-00
DATE SAMPLED	09-08-1997
DEPTH	0' - 2'
SEMIVOLATILES (ug/kg) (8270 B)	
Benzo(a)pyrene (NC/US)	420
Dibenz(a,h)anthracene (US)	66 J

SAMPLE ID	SWMU302-IS03-01
DATE SAMPLED	09-08-1997
DEPTH	2' - 4'
SEMIVOLATILES (ug/kg) (8270 B)	
Benzo(a)pyrene (NC/US)	200 J

NOTE:
- ALL SAMPLES WERE COLLECTED WITHIN 3 FEET OF THE SWMU's PERIMETER, (UNLESS OTHERWISE NOTED).
- CONSTITUENTS SHOWN EXCEED EITHER
  - AB – AOC BACKGROUND
  - NC – NORTH CAROLINA SOIL TO GROUNDWATER
  - US – USEPA REGION IX RESIDENTIAL SOIL PRG's

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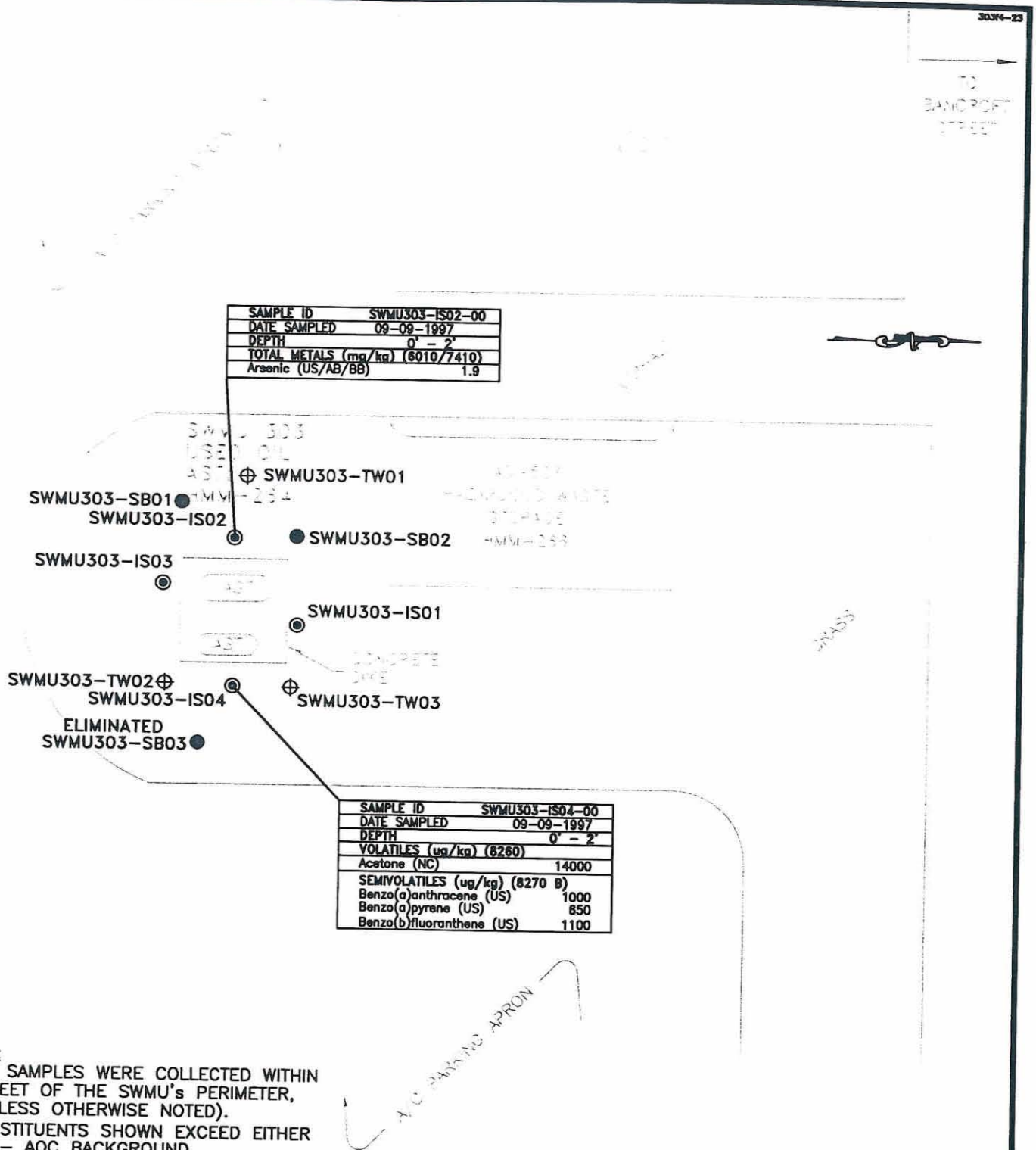
LEGEND
- ⊕ PROPOSED TEMPORARY MONITORING WELL
- ◉ EXISTING SOIL BORING SAMPLE

mg/kg – MILLIGRAM/KILOGRAM
ug/kg – MICROGRAM/KILOGRAM

FIGURE 4-22
PROPOSED PHASE II SWMU INVESTIGATION PLAN
SWMU 302
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



NOTE:
- ALL SAMPLES WERE COLLECTED WITHIN 3 FEET OF THE SWMU's PERIMETER, (UNLESS OTHERWISE NOTED).
- CONSTITUENTS SHOWN EXCEED EITHER
  - AB – AOC BACKGROUND
  - BB – BASE BACKGROUND
  - NC – NORTH CAROLINA SOIL TO GROUNDWATER
  - US – USEPA REGION IX RESIDENTIAL SOIL PRG's

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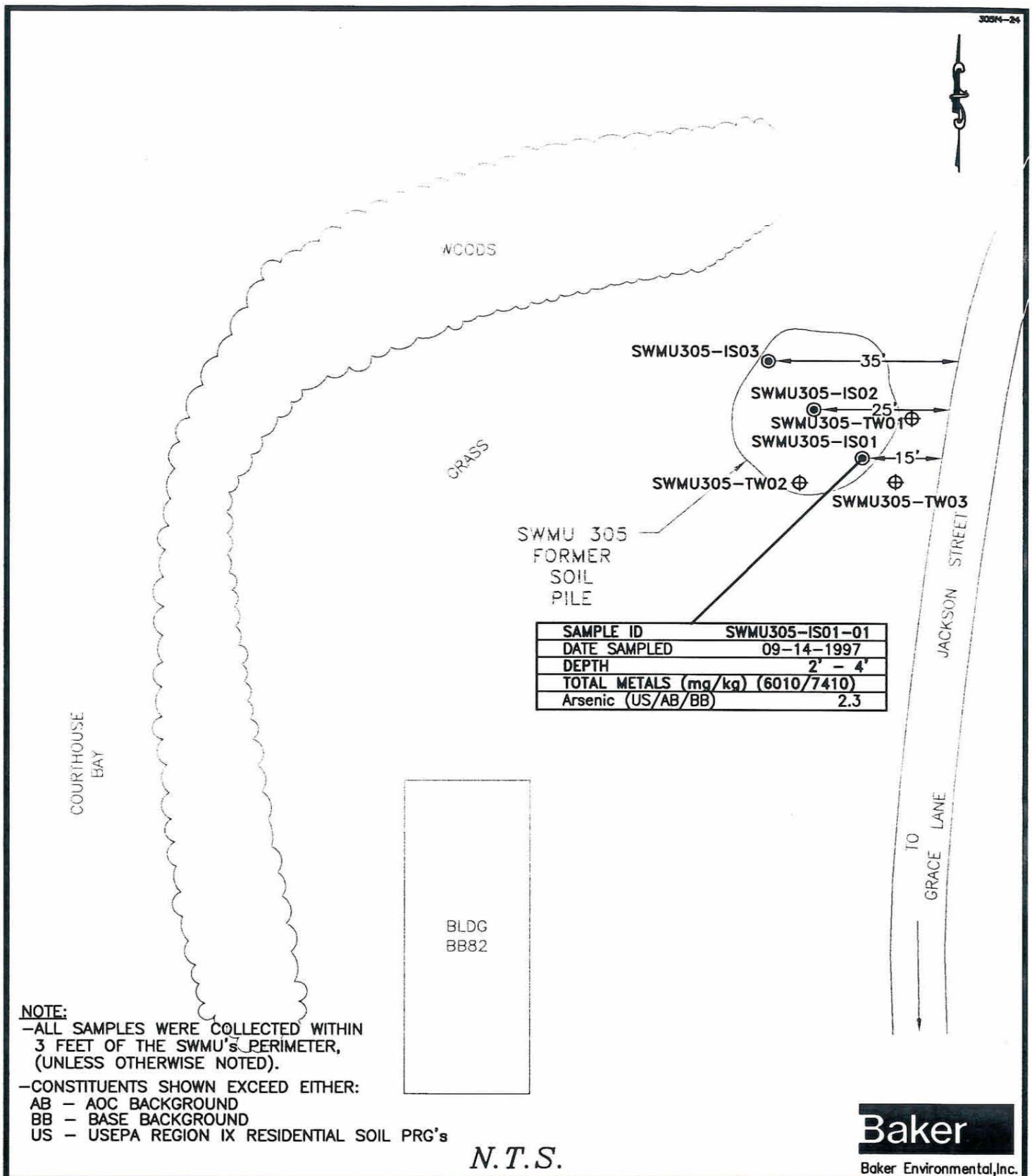
LEGEND
- ● PROPOSED SOIL BORING
- ⊕ PROPOSED TEMPORARY MONITORING WELL
- ◉ EXISTING SOIL BORING SAMPLE
- mg/kg – MILLIGRAM/KILOGRAM
- ug/kg – MICROGRAM/KILOGRAM

FIGURE 4-23
PROPOSED PHASE II SWMU INVESTIGATION PLAN
SWMU 303
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



SAMPLE ID	SWMU305-IS01-01
DATE SAMPLED	09-14-1997
DEPTH	2' - 4'
TOTAL METALS (mg/kg) (6010/7410)	
Arsenic (US/AB/BB)	2.3

NOTE:
- ALL SAMPLES WERE COLLECTED WITHIN 3 FEET OF THE SWMU's PERIMETER, (UNLESS OTHERWISE NOTED).
- CONSTITUENTS SHOWN EXCEED EITHER:
  AB – AOC BACKGROUND
  BB – BASE BACKGROUND
  US – USEPA REGION IX RESIDENTIAL SOIL PRG's

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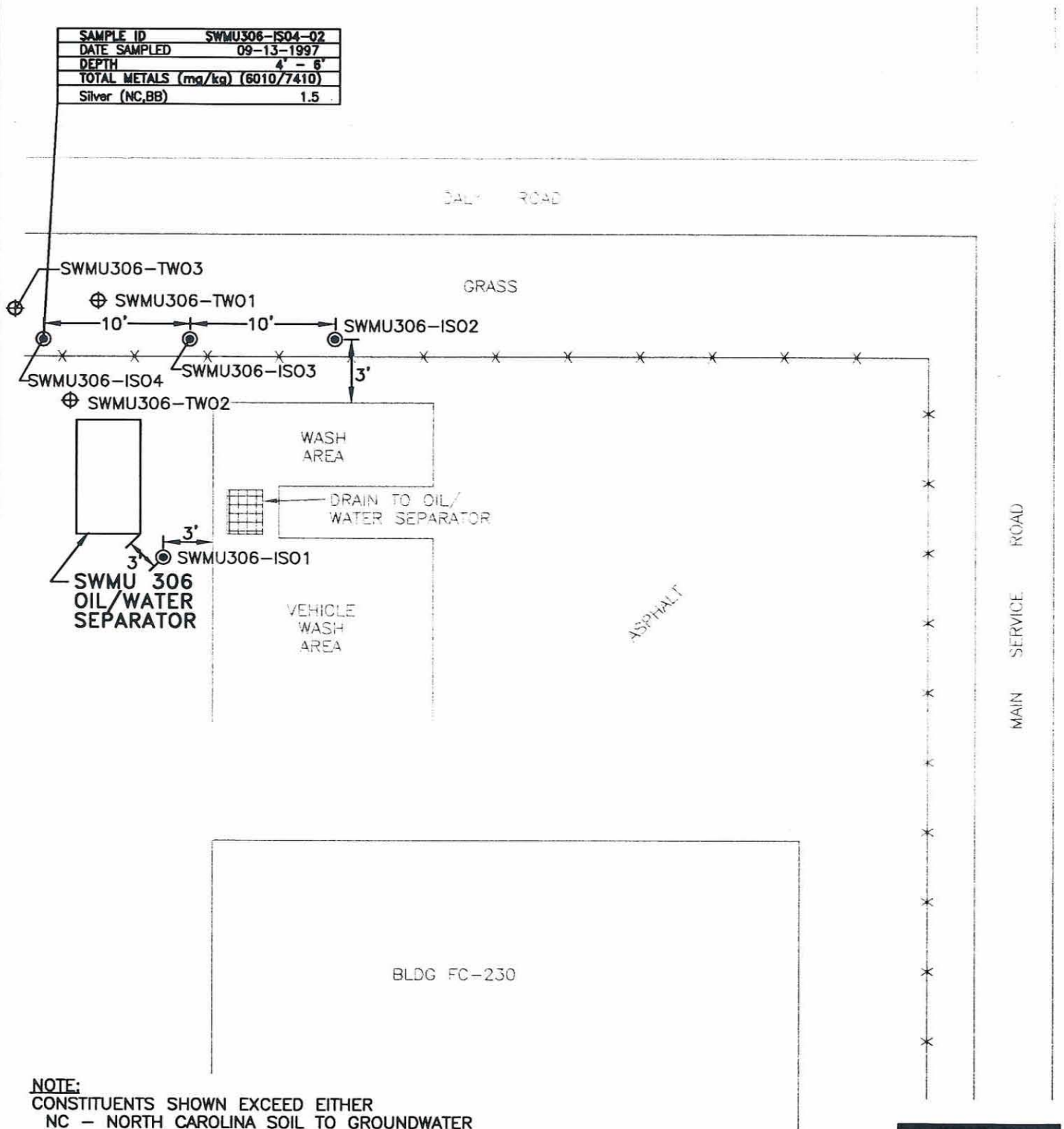
LEGEND

⊕ PROPOSED TEMPORARY MONITORING WELL

◉ EXISTING SOIL BORING SAMPLE

mg/kg – MILLIGRAM/KILOGRAM

FIGURE 4-24
PROPOSED PHASE II SWMU INVESTIGATION PLAN
SWMU 305
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



NOTE:
CONSTITUENTS SHOWN EXCEED EITHER
NC – NORTH CAROLINA SOIL TO GROUNDWATER
BB – BASE BACKGROUND

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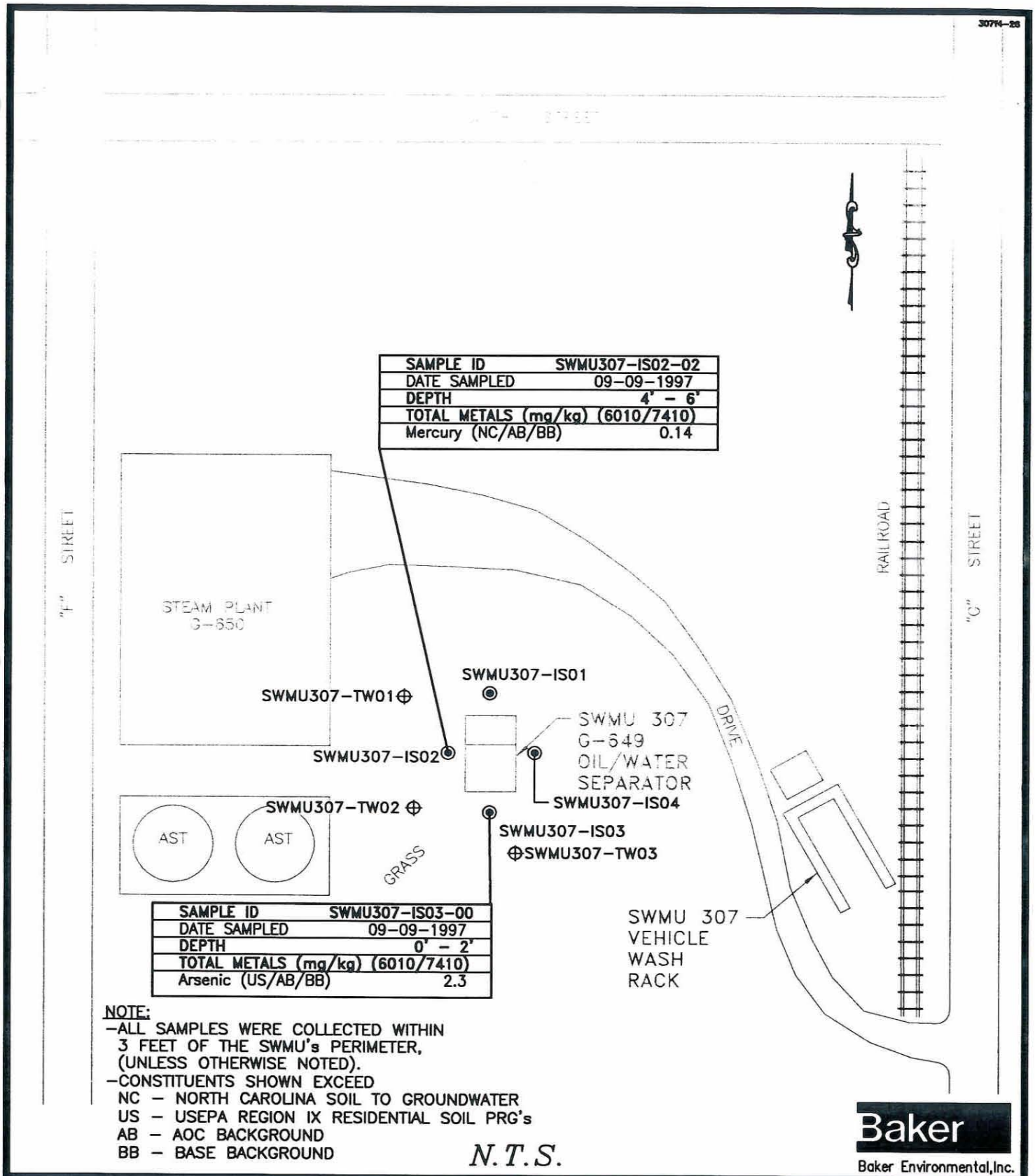
LEGEND

⊕ PROPOSED TEMPORARY MONITORING WELL
◉ EXISTING SOIL BORING SAMPLE
mg/kg MILLIGRAMS/KILOGRAM

FIGURE 4-25
PROPOSED PHASE II SWMU INVESTIGATION PLAN
SWMU 306
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



LEGEND

⊕ PROPOSED TEMPORARY MONITORING WELL

◉ EXISTING SOIL BORING SAMPLE

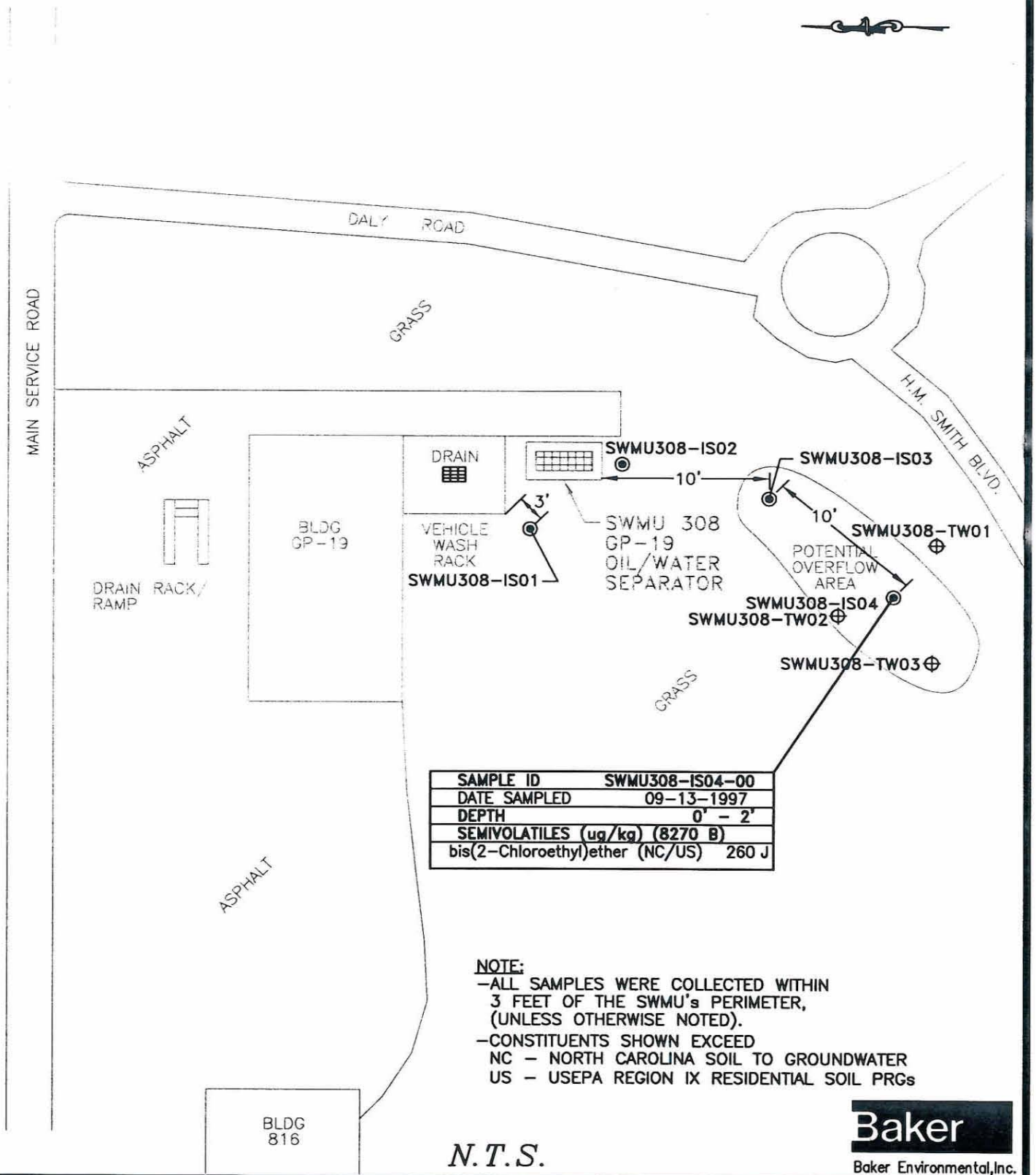
mg/kg - MILLIGRAM/KILOGRAM

FIGURE 4-26

PROPOSED PHASE II SWMU INVESTIGATION PLAN

SWMU 307

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



SAMPLE ID	SWMU308-IS04-00
DATE SAMPLED	09-13-1997
DEPTH	0' - 2'
SEMIVOLATILES (ug/kg) (8270 B)	
bis(2-Chloroethyl)ether (NC/US)	260 J

NOTE:
- ALL SAMPLES WERE COLLECTED WITHIN 3 FEET OF THE SWMU's PERIMETER, (UNLESS OTHERWISE NOTED).
- CONSTITUENTS SHOWN EXCEED
  NC – NORTH CAROLINA SOIL TO GROUNDWATER
  US – USEPA REGION IX RESIDENTIAL SOIL PRGs

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LEGEND

⊕ PROPOSED TEMPORARY MONITORING WELL

◉ EXISTING SOIL BORING SAMPLE

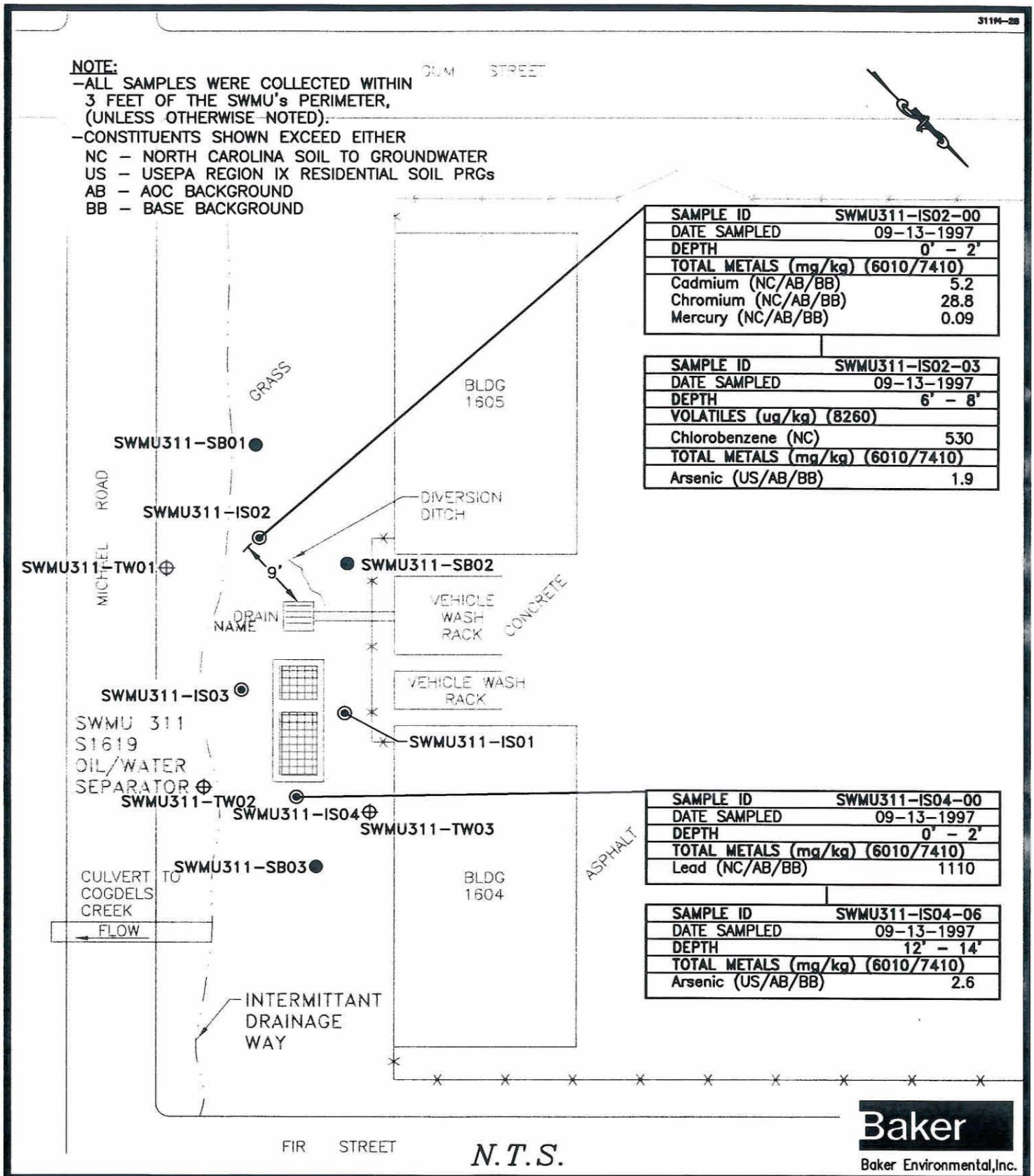
ug/kg – MICROGRAM/KILOGRAM

FIGURE 4-27

PROPOSED PHASE II SWMU INVESTIGATION PLAN

SWMU 308

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



SAMPLE ID	SWMU311-IS02-00
DATE SAMPLED	09-13-1997
DEPTH	0' - 2'
TOTAL METALS (mg/kg) (6010/7410)	
Cadmium (NC/AB/BB)	5.2
Chromium (NC/AB/BB)	28.8
Mercury (NC/AB/BB)	0.09

SAMPLE ID	SWMU311-IS02-03
DATE SAMPLED	09-13-1997
DEPTH	6' - 8'
VOLATILES (ug/kg) (8260)	
Chlorobenzene (NC)	530
TOTAL METALS (mg/kg) (6010/7410)	
Arsenic (US/AB/BB)	1.9

SAMPLE ID	SWMU311-IS04-00
DATE SAMPLED	09-13-1997
DEPTH	0' - 2'
TOTAL METALS (mg/kg) (6010/7410)	
Lead (NC/AB/BB)	1110

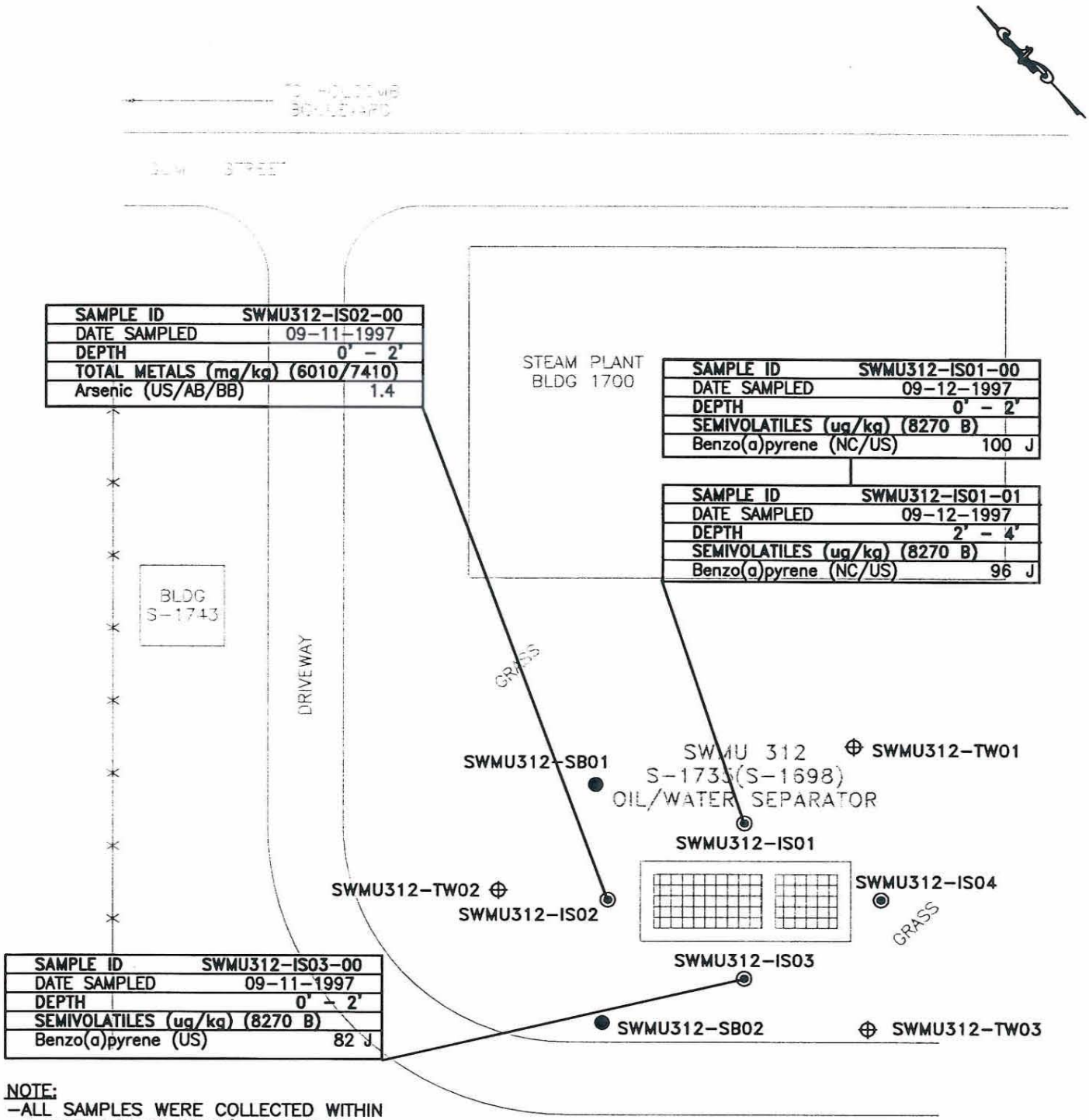
SAMPLE ID	SWMU311-IS04-06
DATE SAMPLED	09-13-1997
DEPTH	12' - 14'
TOTAL METALS (mg/kg) (6010/7410)	
Arsenic (US/AB/BB)	2.6

LEGEND

- ● PROPOSED SOIL BORING
- ⊕ PROPOSED TEMPORARY MONITORING WELL
- ◉ EXISTING SOIL BORING SAMPLE

mg/kg - MILLIGRAM/KILOGRAM
ug/kg - MICROGRAM/KILOGRAM

FIGURE 4-28
PROPOSED PHASE II SWMU INVESTIGATION PLAN
SWMU 311
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



SAMPLE ID	SWMU312-IS02-00
DATE SAMPLED	09-11-1997
DEPTH	0' - 2'
TOTAL METALS (mg/kg) (6010/7410)	
Arsenic (US/AB/BB)	1.4

SAMPLE ID	SWMU312-IS01-00
DATE SAMPLED	09-12-1997
DEPTH	0' - 2'
SEMIVOLATILES (ug/kg) (8270 B)	
Benzo(a)pyrene (NC/US)	100 J

SAMPLE ID	SWMU312-IS01-01
DATE SAMPLED	09-12-1997
DEPTH	2' - 4'
SEMIVOLATILES (ug/kg) (8270 B)	
Benzo(a)pyrene (NC/US)	96 J

SAMPLE ID	SWMU312-IS03-00
DATE SAMPLED	09-11-1997
DEPTH	0' - 2'
SEMIVOLATILES (ug/kg) (8270 B)	
Benzo(a)pyrene (US)	82 J

NOTE:
- ALL SAMPLES WERE COLLECTED WITHIN 3 FEET OF THE SWMU's PERIMETER, (UNLESS OTHERWISE NOTED).
- CONSTITUENTS SHOWN EXCEED EITHER
  - NC – NORTH CAROLINA SOIL TO GROUNDWATER
  - US – USEPA REGION IX RESIDENTIAL SOIL PRG'S
  - AB – AOC BACKGROUND
  - BB – BASE BACKGROUND

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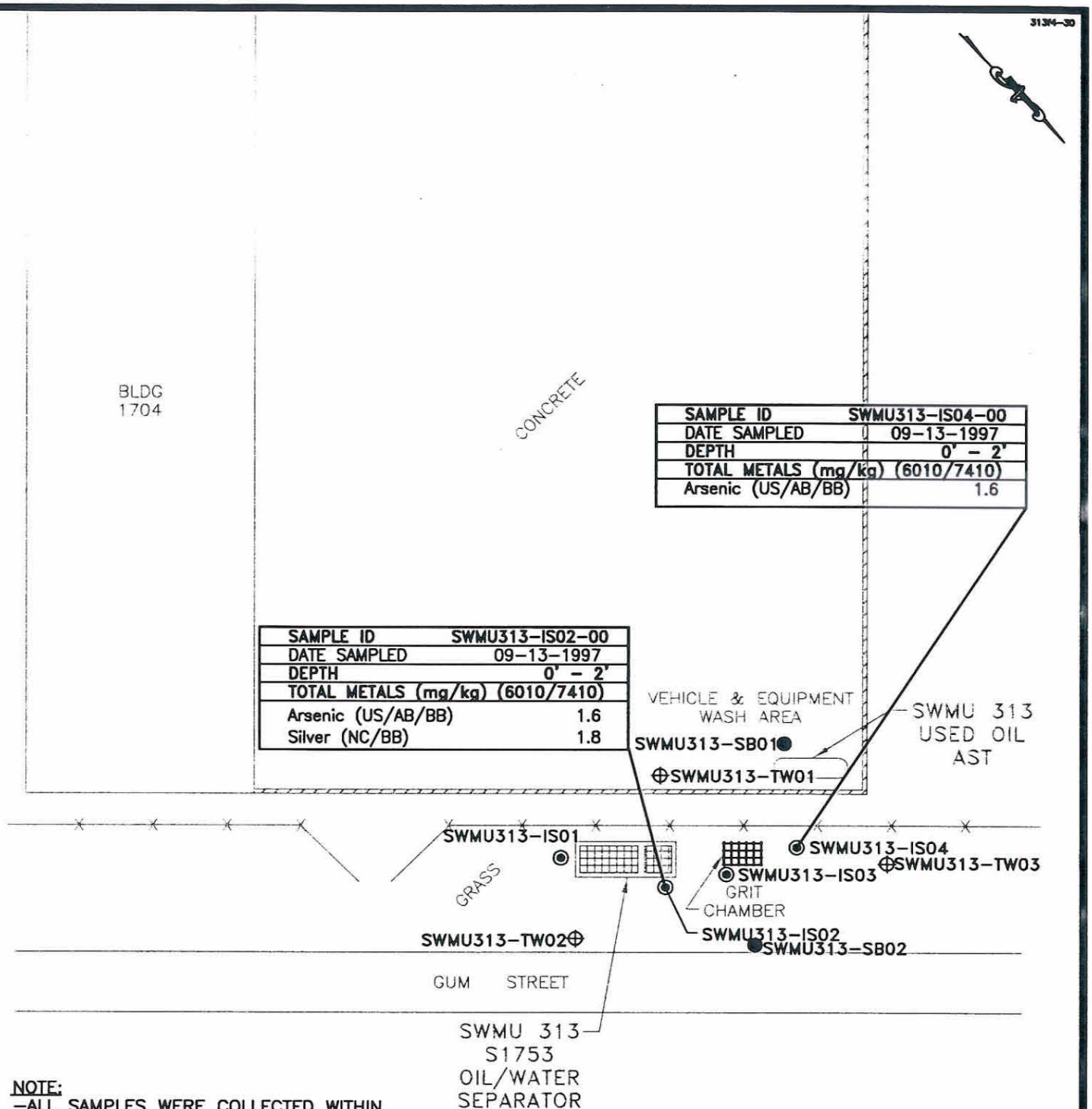
LEGEND

- ● PROPOSED SOIL BORING
- ⊕ PROPOSED TEMPORARY MONITORING WELL
- ◉ EXISTING SOIL BORING SAMPLE
- mg/kg – MILLIGRAM/KILOGRAM
- ug/kg – MICROGRAM/KILOGRAM

FIGURE 4-29
PROPOSED PHASE II SWMU INVESTIGATION PLAN
SWMU 312
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



NOTE:
- ALL SAMPLES WERE COLLECTED WITHIN 3 FEET OF THE SWMU's PERIMETER, (UNLESS OTHERWISE NOTED).
- CONSTITUENTS SHOWN EXCEED EITHER
  - NC – NORTH CAROLINA SOIL TO GROUNDWATER
  - US – USEPA REGION IX RESIDENTIAL SOIL PRGs
  - AB – AOC BACKGROUND
  - BB – BASE BACKGROUND

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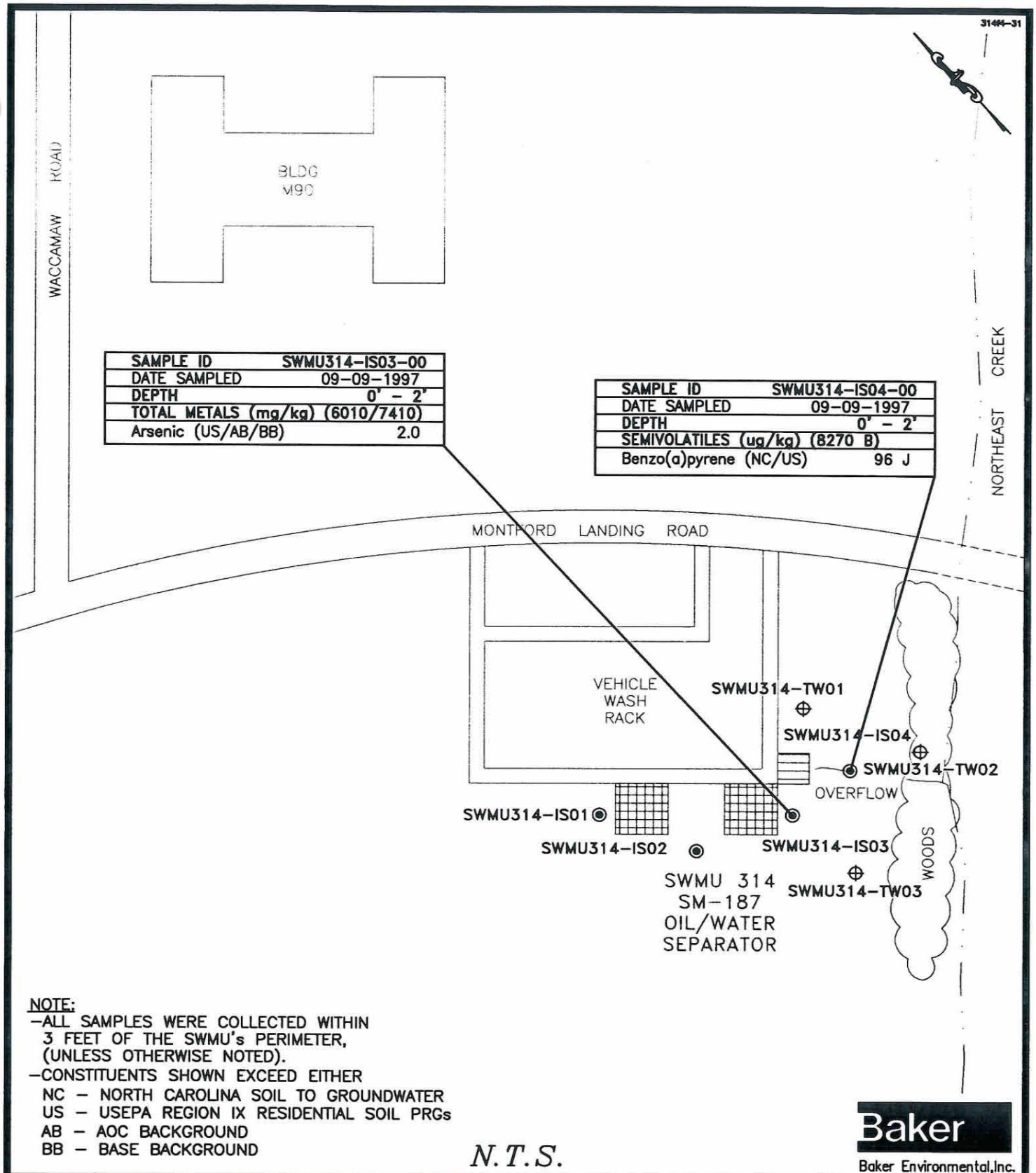
LEGEND

- ● PROPOSED SOIL BORING
- ⊕ PROPOSED TEMPORARY MONITORING WELL
- ◉ EXISTING SOIL BORING SAMPLE
- mg/kg MILLIGRAM/KILOGRAM

FIGURE 4-30
PROPOSED PHASE II SWMU INVESTIGATION PLAN
SWMU 313
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



NOTE:
- ALL SAMPLES WERE COLLECTED WITHIN 3 FEET OF THE SWMU's PERIMETER, (UNLESS OTHERWISE NOTED).
- CONSTITUENTS SHOWN EXCEED EITHER
  - NC – NORTH CAROLINA SOIL TO GROUNDWATER
  - US – USEPA REGION IX RESIDENTIAL SOIL PRGs
  - AB – AOC BACKGROUND
  - BB – BASE BACKGROUND

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LEGEND

⊕ PROPOSED TEMPORARY MONITORING WELL

◉ EXISTING SOIL BORING SAMPLE

mg/kg – MILLIGRAM/KILOGRAM

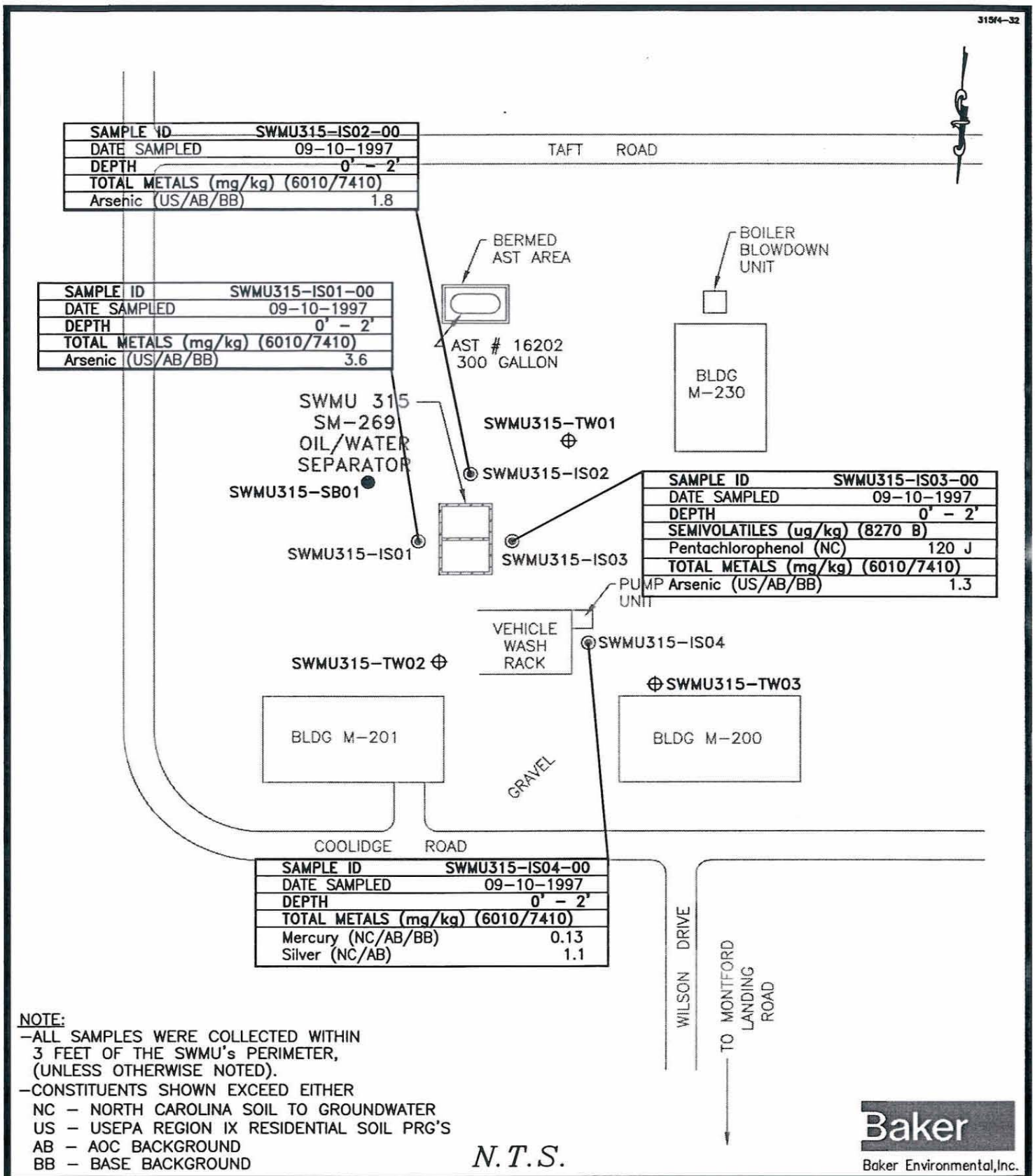
ug/kg – MICROGRAM/KILOGRAM

FIGURE 4-31

PROPOSED PHASE II SWMU INVESTIGATION PLAN

SWMU 314

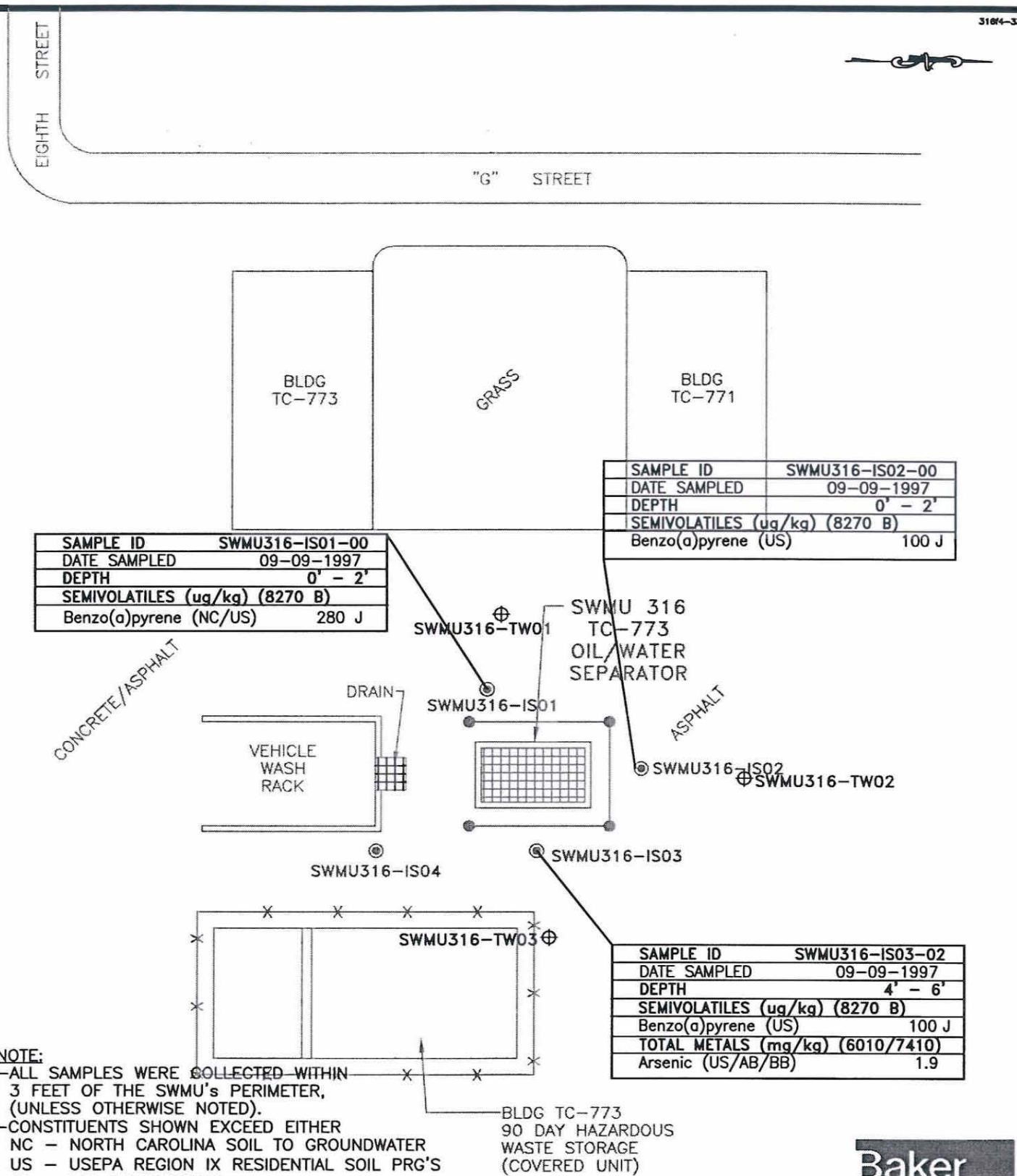
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



LEGEND

- ● PROPOSED SOIL BORING
- ⊕ PROPOSED TEMPORARY MONITORING WELL
- ◉ EXISTING SOIL BORING SAMPLE
- mg/kg MILLIGRAM/KILOGRAM
- ug/kg MICROGRAM/KILOGRAM

FIGURE 4-32
PROPOSED PHASE II SWMU INVESTIGATION PLAN
SWMU 315
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



NOTE:
- ALL SAMPLES WERE COLLECTED WITHIN 3 FEET OF THE SWMU's PERIMETER, (UNLESS OTHERWISE NOTED).
- CONSTITUENTS SHOWN EXCEED EITHER
  - NC – NORTH CAROLINA SOIL TO GROUNDWATER
  - US – USEPA REGION IX RESIDENTIAL SOIL PRG'S
  - AB – AOC BACKGROUND
  - BB – BASE BACKGROUND

N.T.S.

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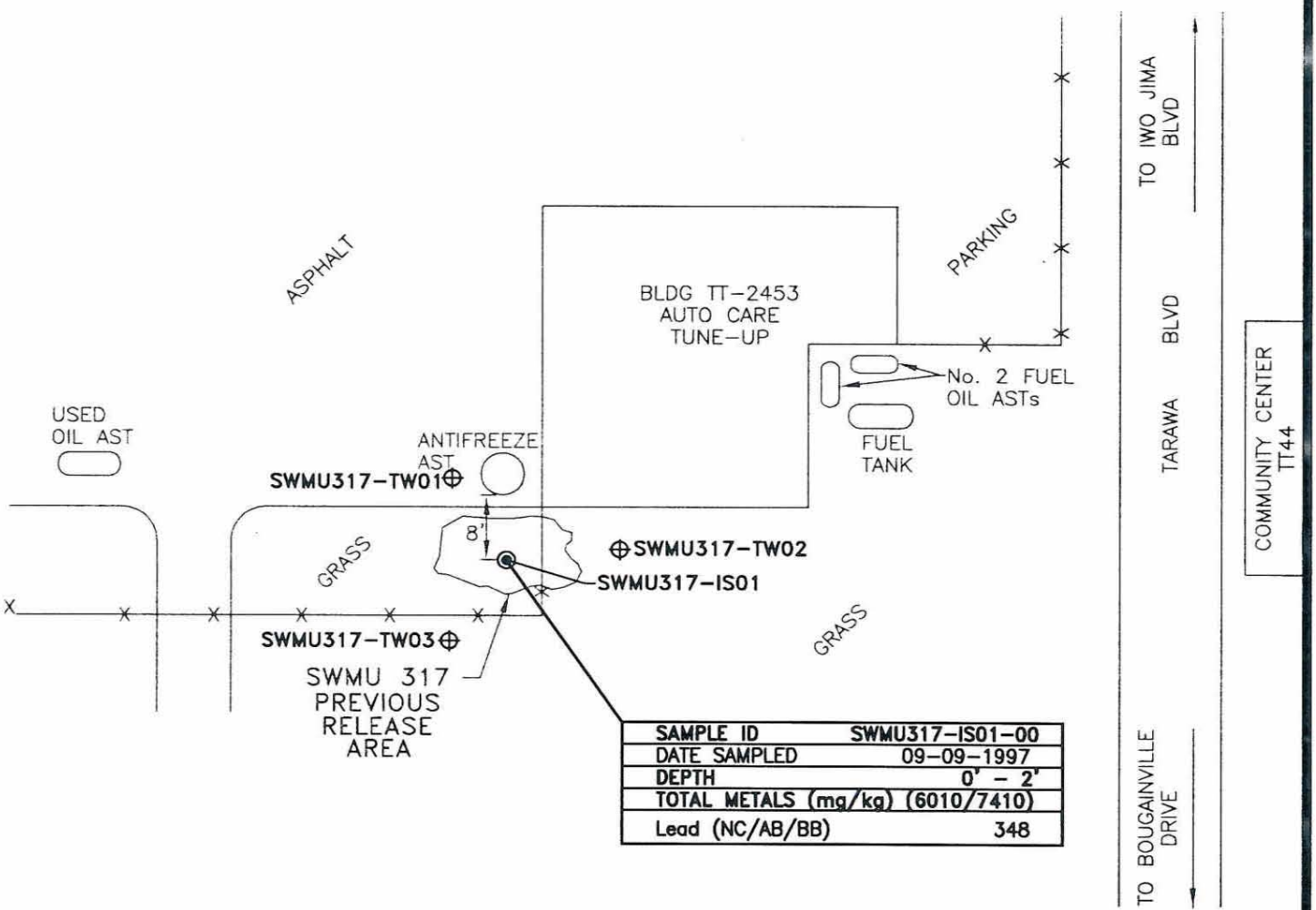
LEGEND

- ⊕ PROPOSED TEMPORARY MONITORING WELL
- ◉ SOIL BORING
- ●—● FENCE AND BOLLARDS
- mg/kg – MILLIGRAM/KILOGRAM
- ug/kg – MICROGRAM/KILOGRAM

FIGURE 4-33
PROPOSED PHASE II SWMU INVESTIGATION PLAN
SWMU 316
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



SAMPLE ID	SWMU317-IS01-00
DATE SAMPLED	09-09-1997
DEPTH	0' - 2'
TOTAL METALS (mg/kg) (6010/7410)	
Lead (NC/AB/BB)	348

NOTE:
- ALL SAMPLES WERE COLLECTED WITHIN 3 FEET OF THE SWMU's PERIMETER, (UNLESS OTHERWISE NOTED).
- CONSTITUENTS SHOWN EXCEED EITHER
  NC - NORTH CAROLINA SOIL TO GROUNDWATER
  AB - AOC BACKGROUND
  BB - BASE BACKGROUND

N.T.S.

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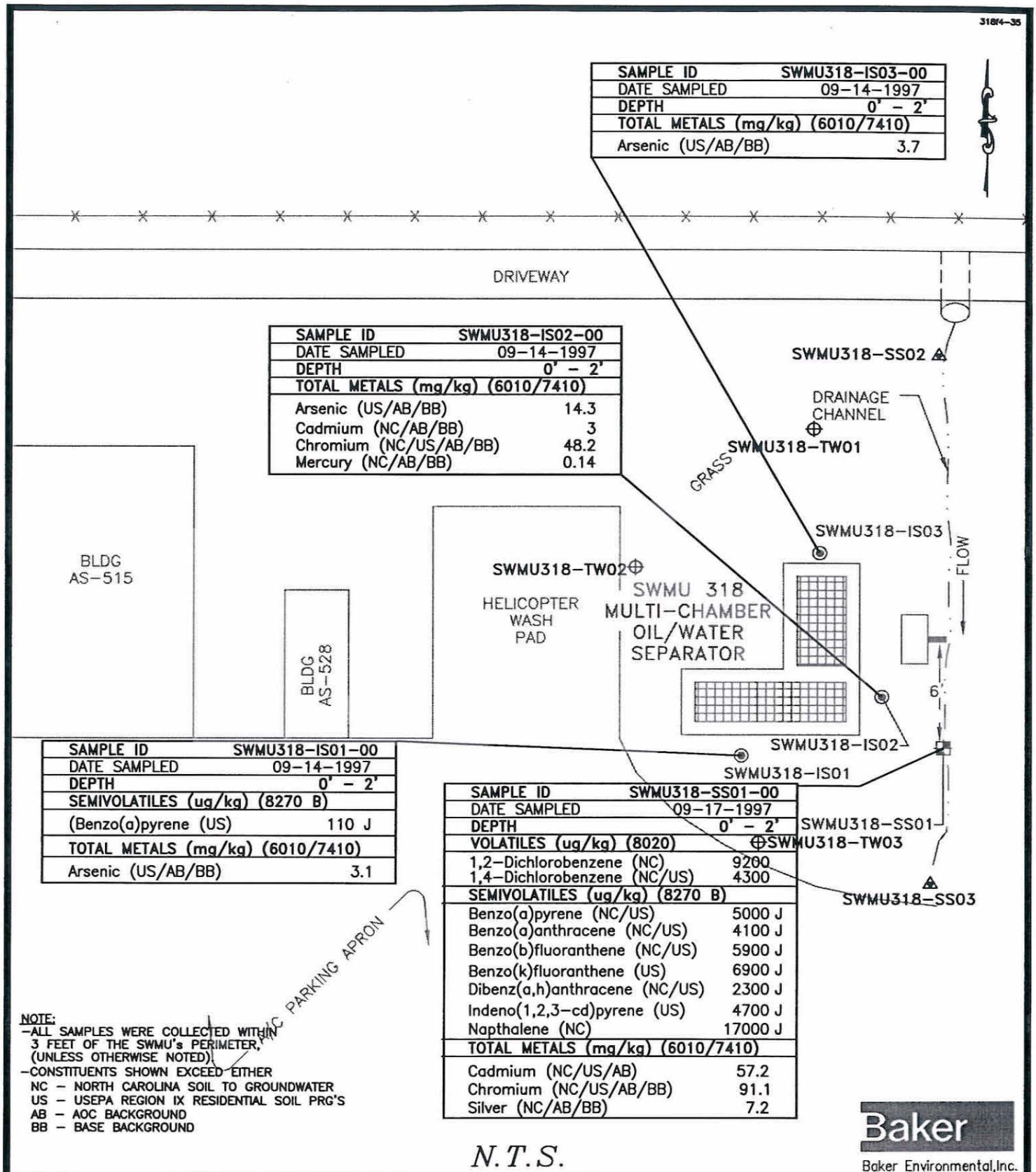
LEGEND

⊕ PROPOSED TEMPORARY MONITORING WELL

◉ SOIL BORING

mg/kg MILLIGRAM/KILOGRAM

FIGURE 4-34
PROPOSED PHASE II SWMU INVESTIGATION PLAN
SWMU 317
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



SAMPLE ID	SWMU318-IS03-00
DATE SAMPLED	09-14-1997
DEPTH	0' - 2'
TOTAL METALS (mg/kg) (6010/7410)	
Arsenic (US/AB/BB)	3.7

SAMPLE ID	SWMU318-IS02-00
DATE SAMPLED	09-14-1997
DEPTH	0' - 2'
TOTAL METALS (mg/kg) (6010/7410)	
Arsenic (US/AB/BB)	14.3
Cadmium (NC/AB/BB)	3
Chromium (NC/US/AB/BB)	48.2
Mercury (NC/AB/BB)	0.14

SAMPLE ID	SWMU318-IS01-00
DATE SAMPLED	09-14-1997
DEPTH	0' - 2'
SEMIVOLATILES (ug/kg) (8270 B)	
(Benzo(a)pyrene (US)	110 J
TOTAL METALS (mg/kg) (6010/7410)	
Arsenic (US/AB/BB)	3.1

SAMPLE ID	SWMU318-SS01-00
DATE SAMPLED	09-17-1997
DEPTH	0' - 2'
VOLATILES (ug/kg) (8020)	
1,2-Dichlorobenzene (NC)	9200
1,4-Dichlorobenzene (NC/US)	4300
SEMIVOLATILES (ug/kg) (8270 B)	
Benzo(a)pyrene (NC/US)	5000 J
Benzo(a)anthracene (NC/US)	4100 J
Benzo(b)fluoranthene (NC/US)	5900 J
Benzo(k)fluoranthene (US)	6900 J
Dibenz(a,h)anthracene (NC/US)	2300 J
Indeno(1,2,3-cd)pyrene (US)	4700 J
Napthalene (NC)	17000 J
TOTAL METALS (mg/kg) (6010/7410)	
Cadmium (NC/US/AB)	57.2
Chromium (NC/US/AB/BB)	91.1
Silver (NC/AB/BB)	7.2

NOTE:
- ALL SAMPLES WERE COLLECTED WITHIN 3 FEET OF THE SWMU's PERIMETER, (UNLESS OTHERWISE NOTED).
- CONSTITUENTS SHOWN EXCEED EITHER
  - NC - NORTH CAROLINA SOIL TO GROUNDWATER
  - US - USEPA REGION IX RESIDENTIAL SOIL PRG'S
  - AB - AOC BACKGROUND
  - BB - BASE BACKGROUND

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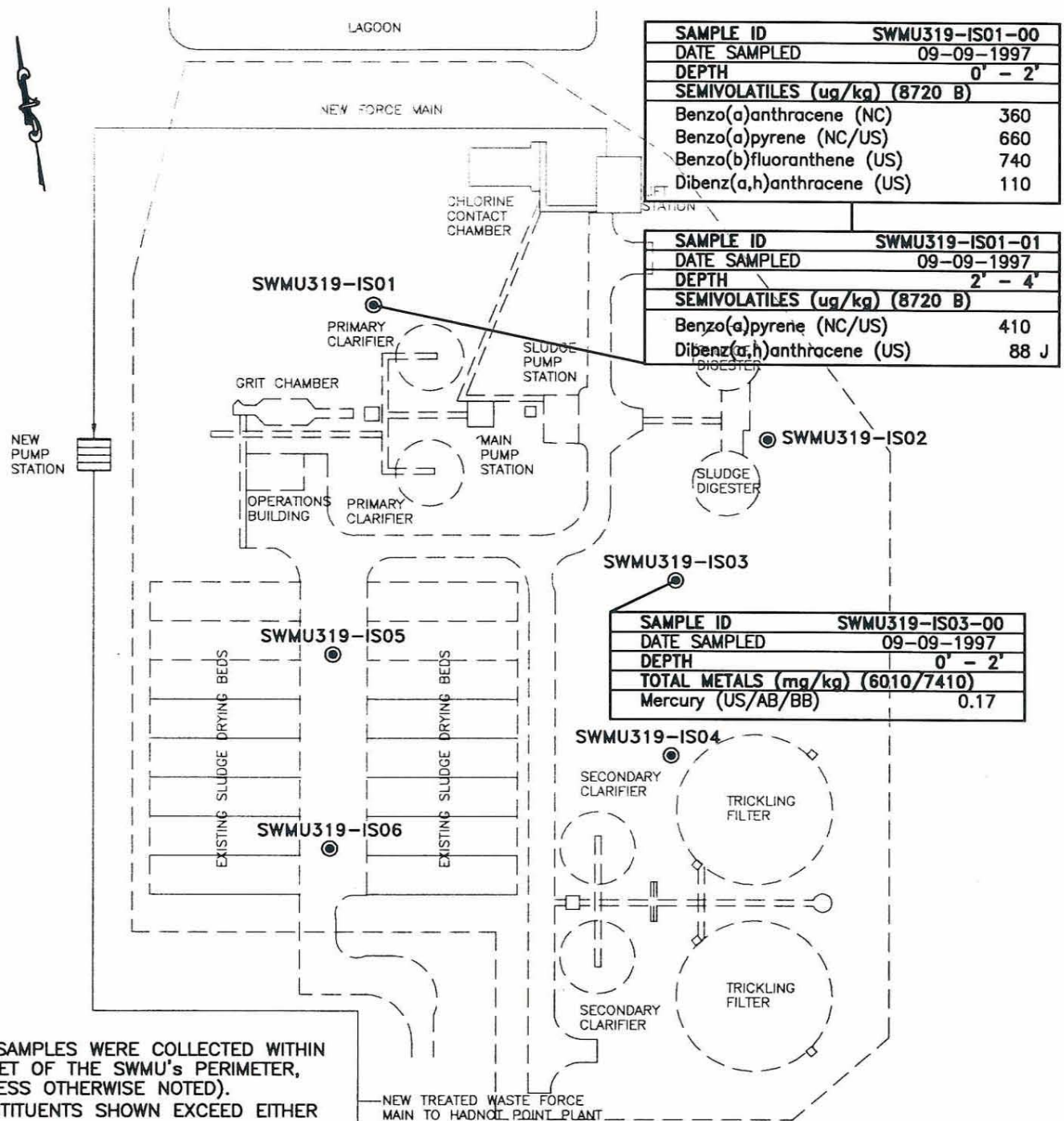
LEGEND
- PROPOSED SURFACE SOIL SAMPLE
- PROPOSED TEMPORARY MONITORING WELL
- EXISTING SOIL BORING SAMPLE
- EXISTING SURFACE SOIL SAMPLE

mg/kg MILLIGRAM/KILOGRAM
ug/kg MICROGRAM/KILOGRAM

FIGURE 4-35
PROPOSED PHASE II SWMU INVESTIGATION PLAN
SWMU 318
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



SAMPLE ID	SWMU319-IS01-00
DATE SAMPLED	09-09-1997
DEPTH	0' - 2'
SEMIVOLATILES (ug/kg) (8720 B)	
Benzo(a)anthracene (NC)	360
Benzo(a)pyrene (NC/US)	660
Benzo(b)fluoranthene (US)	740
Dibenz(a,h)anthracene (US)	110

SAMPLE ID	SWMU319-IS01-01
DATE SAMPLED	09-09-1997
DEPTH	2' - 4'
SEMIVOLATILES (ug/kg) (8720 B)	
Benzo(a)pyrene (NC/US)	410
Dibenz(a,h)anthracene (US)	88 J

SAMPLE ID	SWMU319-IS03-00
DATE SAMPLED	09-09-1997
DEPTH	0' - 2'
TOTAL METALS (mg/kg) (6010/7410)	
Mercury (US/AB/BB)	0.17

NOTE:
- ALL SAMPLES WERE COLLECTED WITHIN 3 FEET OF THE SWMU's PERIMETER, (UNLESS OTHERWISE NOTED).
- CONSTITUENTS SHOWN EXCEED EITHER
  - NC – NORTH CAROLINA SOIL TO GROUNDWATER
  - US – USEPA REGION IX RESIDENTIAL SOIL PRG'S
  - AB – AOC BACKGROUND
  - BB – BASE BACKGROUND

SOURCE:
- FINAL RCRA FACILITY ASSESSMENT REPORT, MARINE CORPS BASE CAMP LEJEUNE (ENSAFE, JULY 25, 1996)

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LEGEND

◉ EXISTING SOIL BORING SAMPLE

mg/kg MILLIGRAM/KILOGRAM

ug/kg MICROGRAM/KILOGRAM

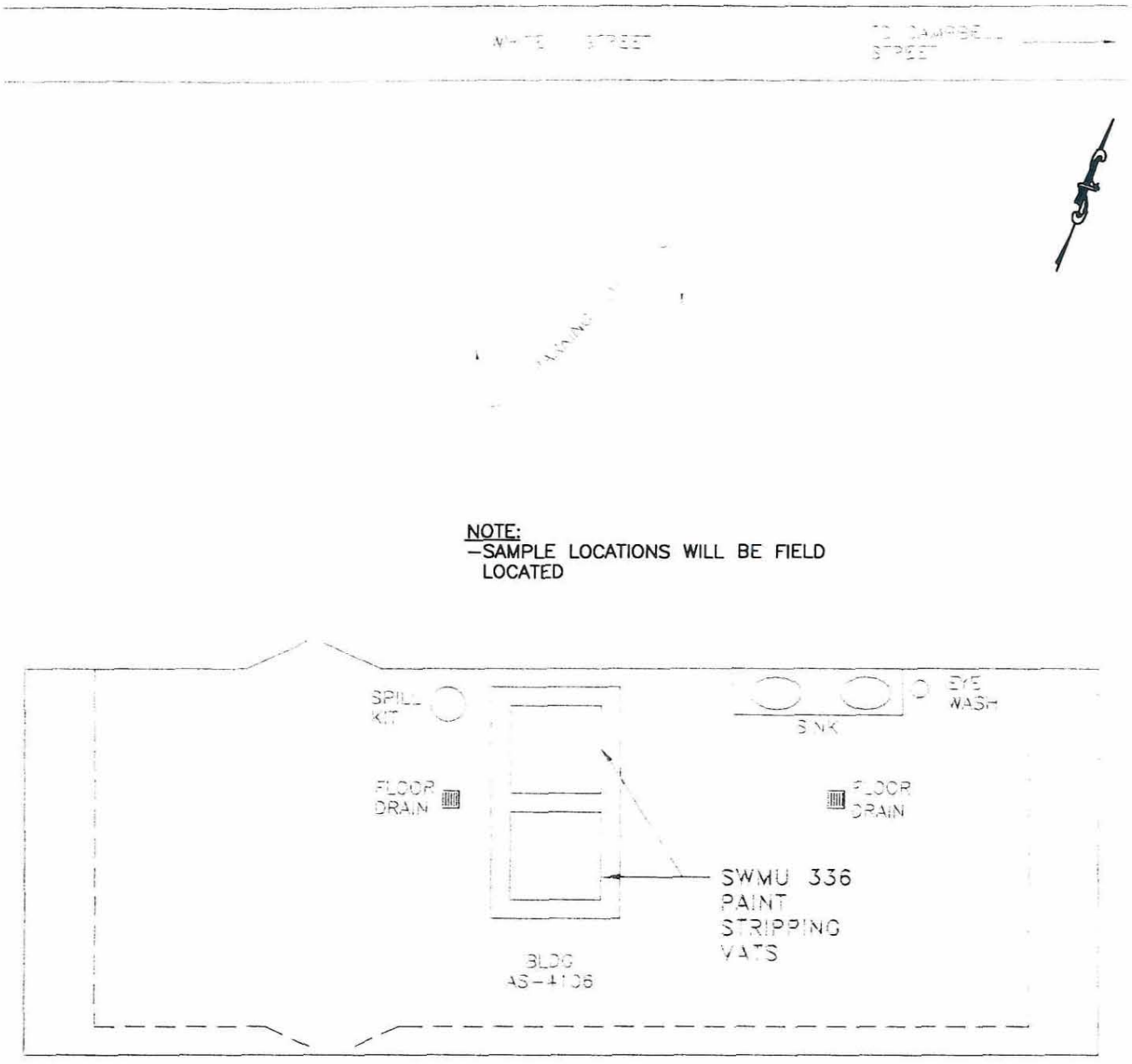
FIGURE 4-36

PPROPOSED PHASE II SWMU INVESTIGATION PLAN

SWMU 319

MARINE CORPS BASE, CAMP LEJEUNE

NORTH CAROLINA



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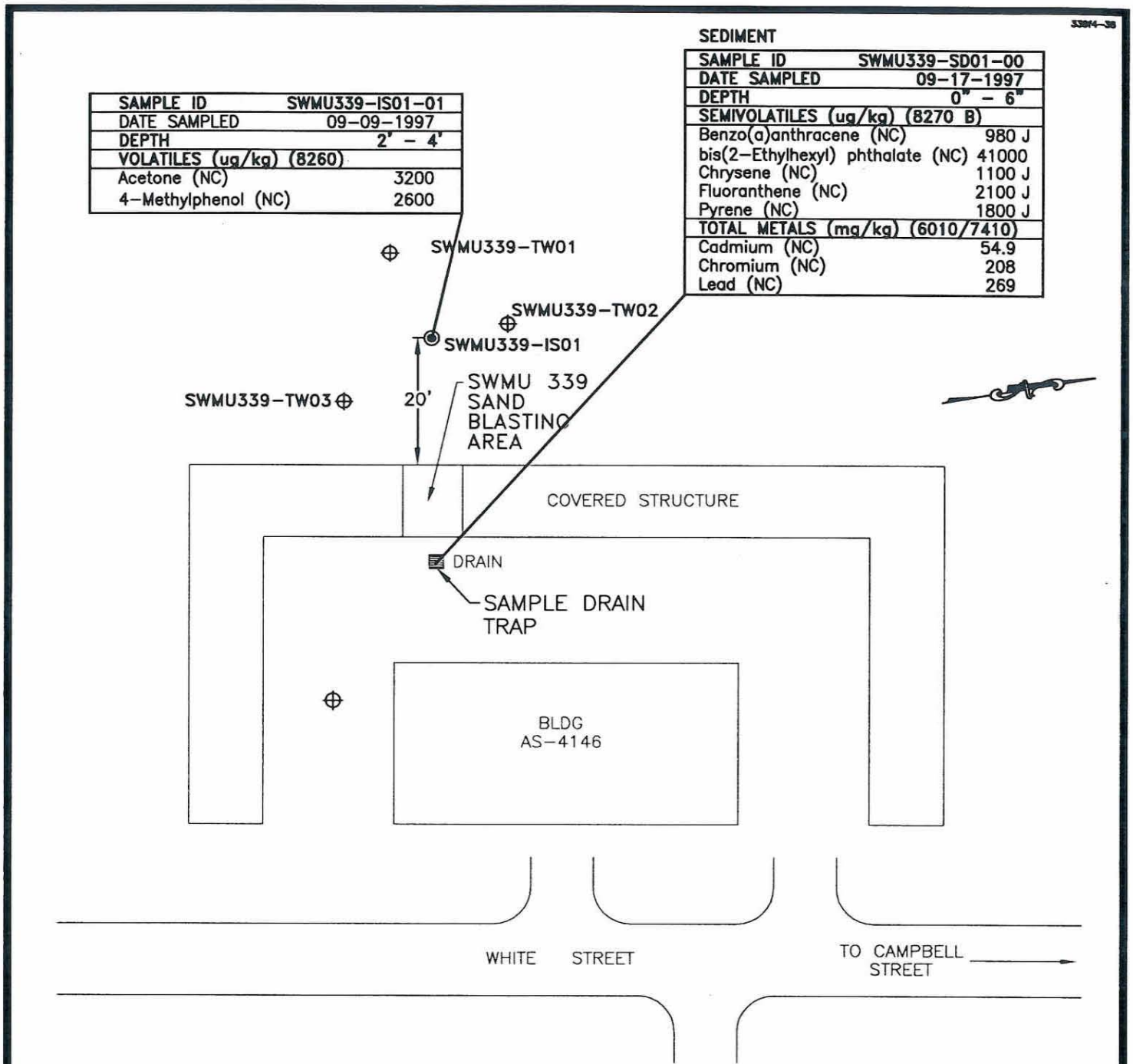
NOTE: SEDIMENT FROM THE FLOOR DRAINS WAS TO BE SAMPLED; HOWEVER, NO SEDIMENT WAS PRESENT IN THE DRAINS. AS A RESULT, NO SAMPLES WERE COLLECTED FROM THE SWMU DURING PHASE I.

FIGURE 4-37
PROPOSED PHASE II SWMU INVESTIGATION PLAN
SWMU 336
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

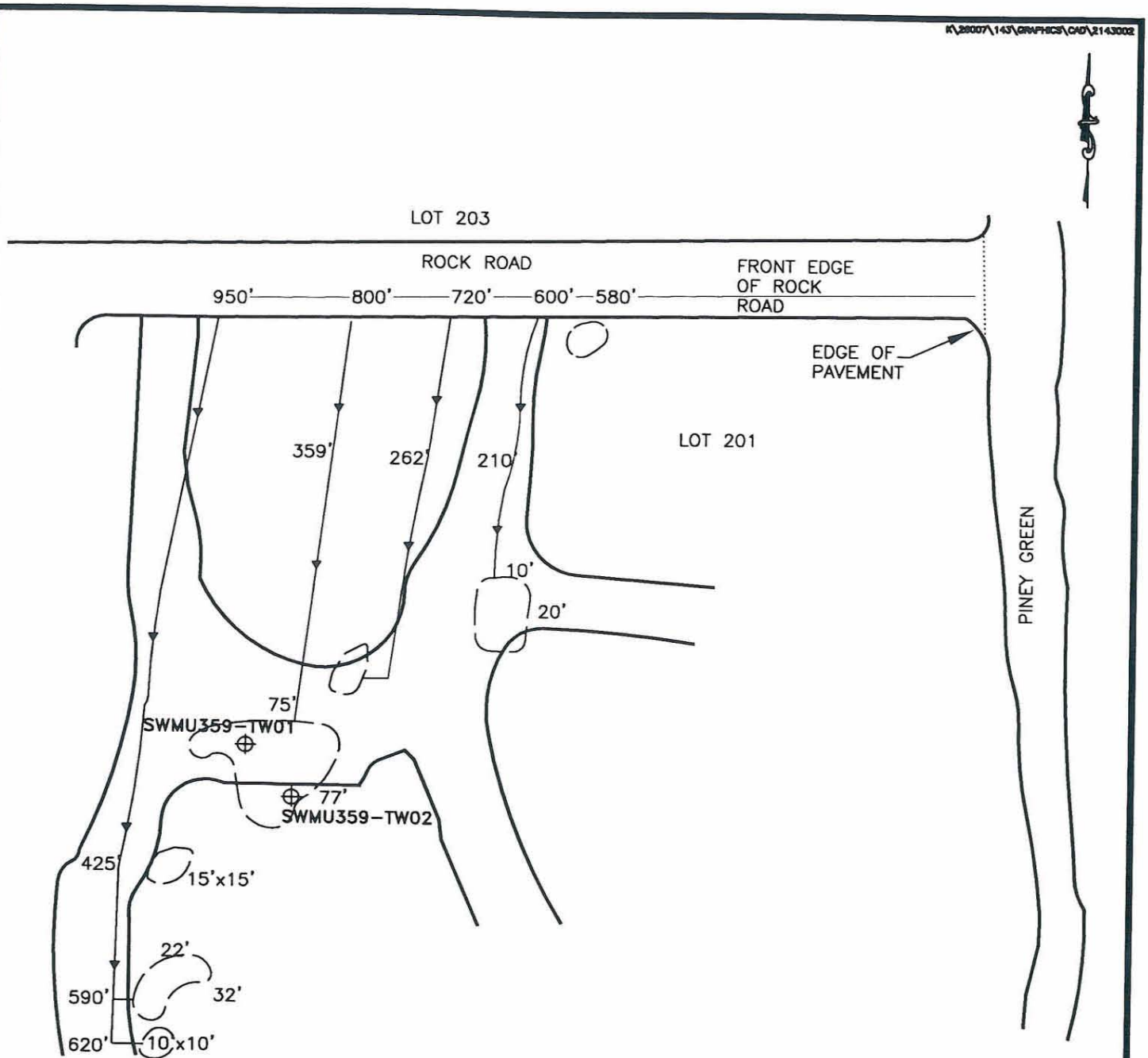


NOTE:
- ALL SAMPLES WERE COLLECTED WITHIN 3 FEET OF THE SWMU's PERIMETER, (UNLESS OTHERWISE NOTED).
- CONSTITUENTS SHOWN EXCEED EITHER NC - NORTH CAROLINA SOIL TO GROUNDWATER

LEGEND

⊕	PROPOSED TEMPORARY MONITORING WELL
◉	EXISTING SOIL BORING SAMPLE
⊕	EXISTING MONITORING WELL
mg/kg	MILLIGRAM/KILOGRAM
ug/kg	MICROGRAM/KILOGRAM

FIGURE 4-38
PROPOSED PHASE II SWMU INVESTIGATION PLAN
SWMU 339
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



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LEGEND

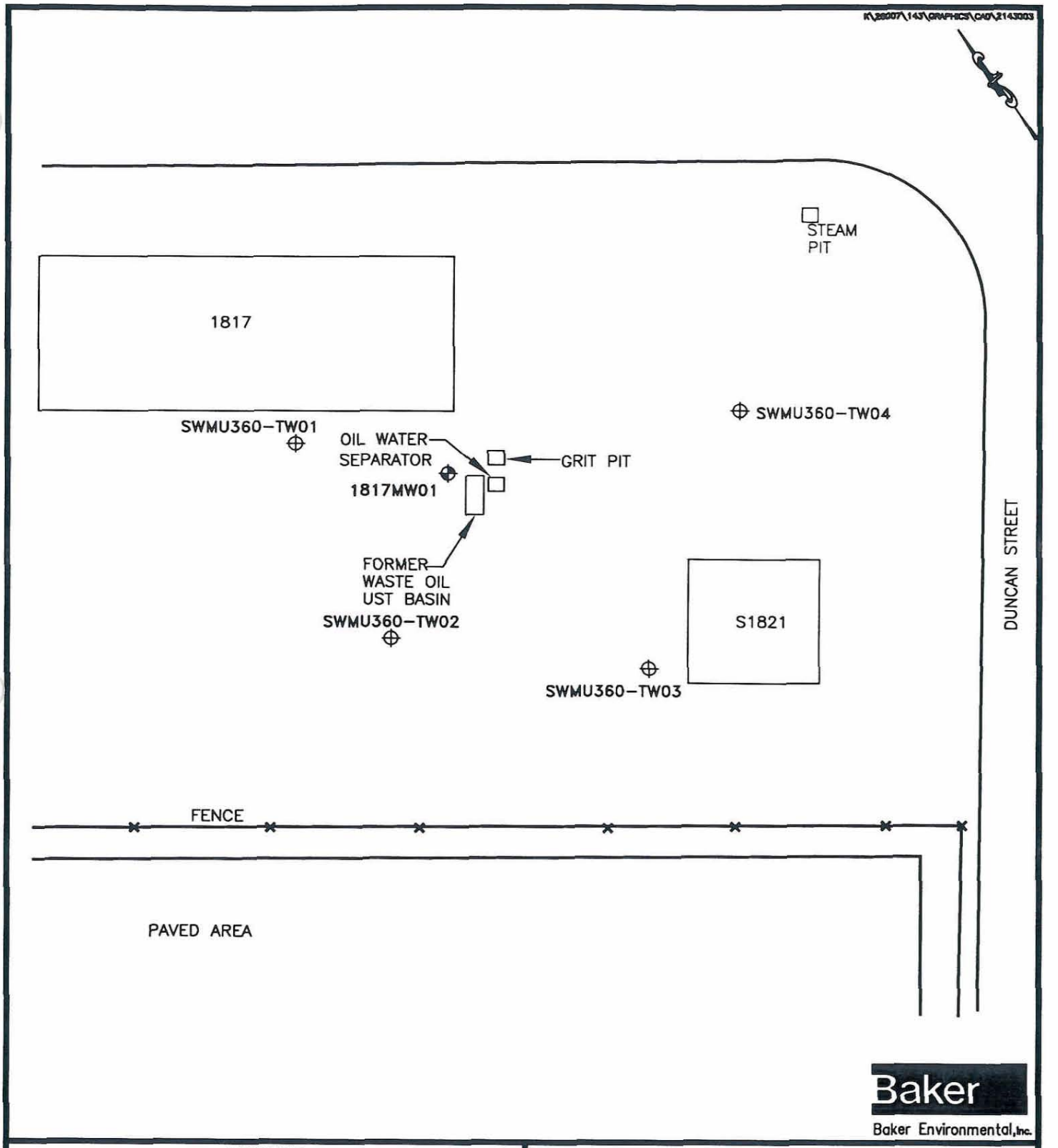
- FORMER EXCAVATION AREA
- PROPOSED TEMPORARY MONITORING WELL

FIGURE 4-39

PROPOSED PHASE II SWMU INVESTIGATION PLAN

SWMU 359

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



LEGEND

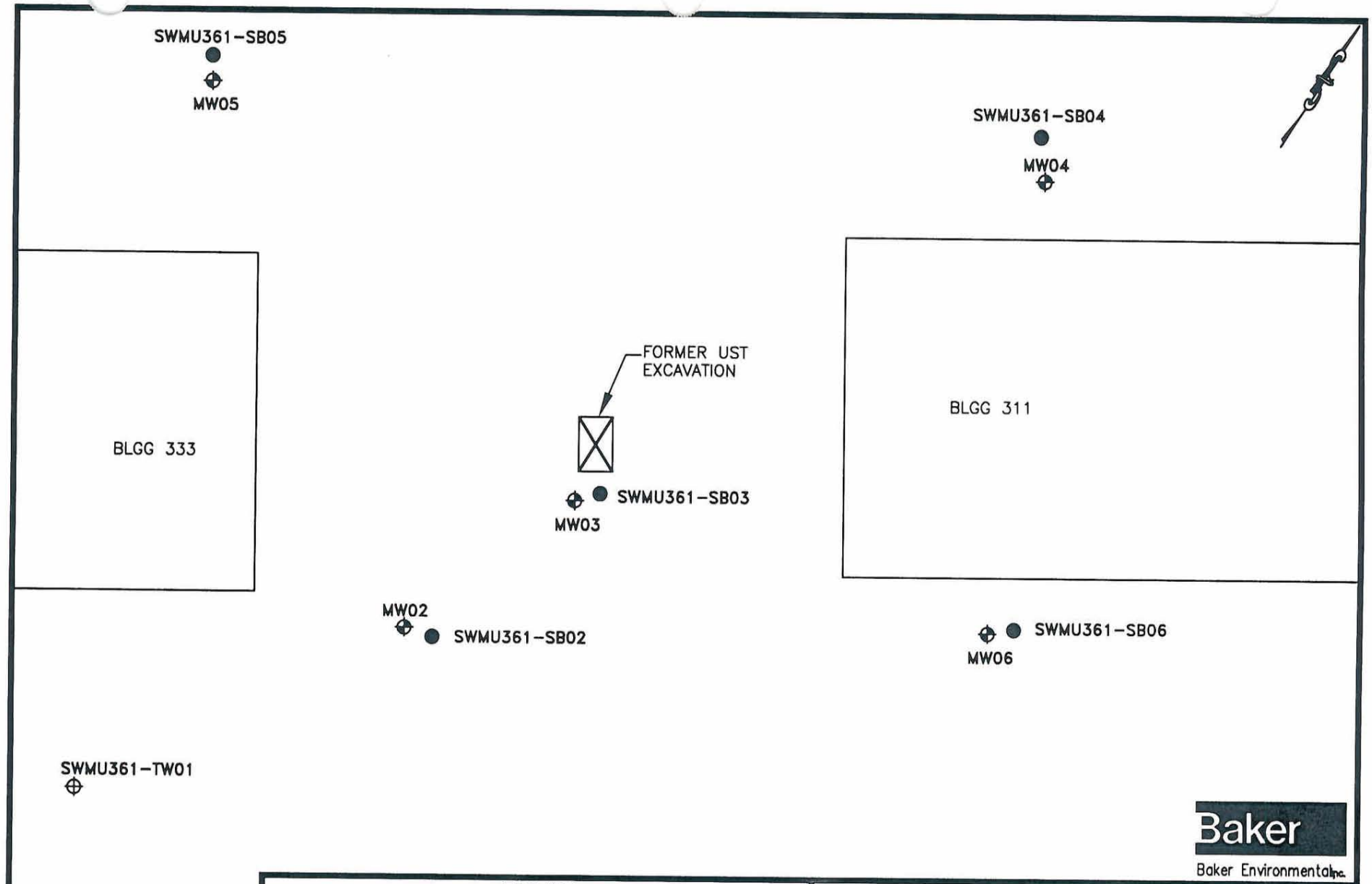
- EXISTING MONITORING WELL
- PROPOSED TEMPORARY MONITORING WELL

FIGURE 4-40

PROPOSED PHASE II SWMU INVESTIGATION PLAN

SWMU 360

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



LEGEND

- EXISTING MONITORING WELL
- PROPOSED SOIL BORING
- PROPOSED TEMPORARY MONITORING WELL

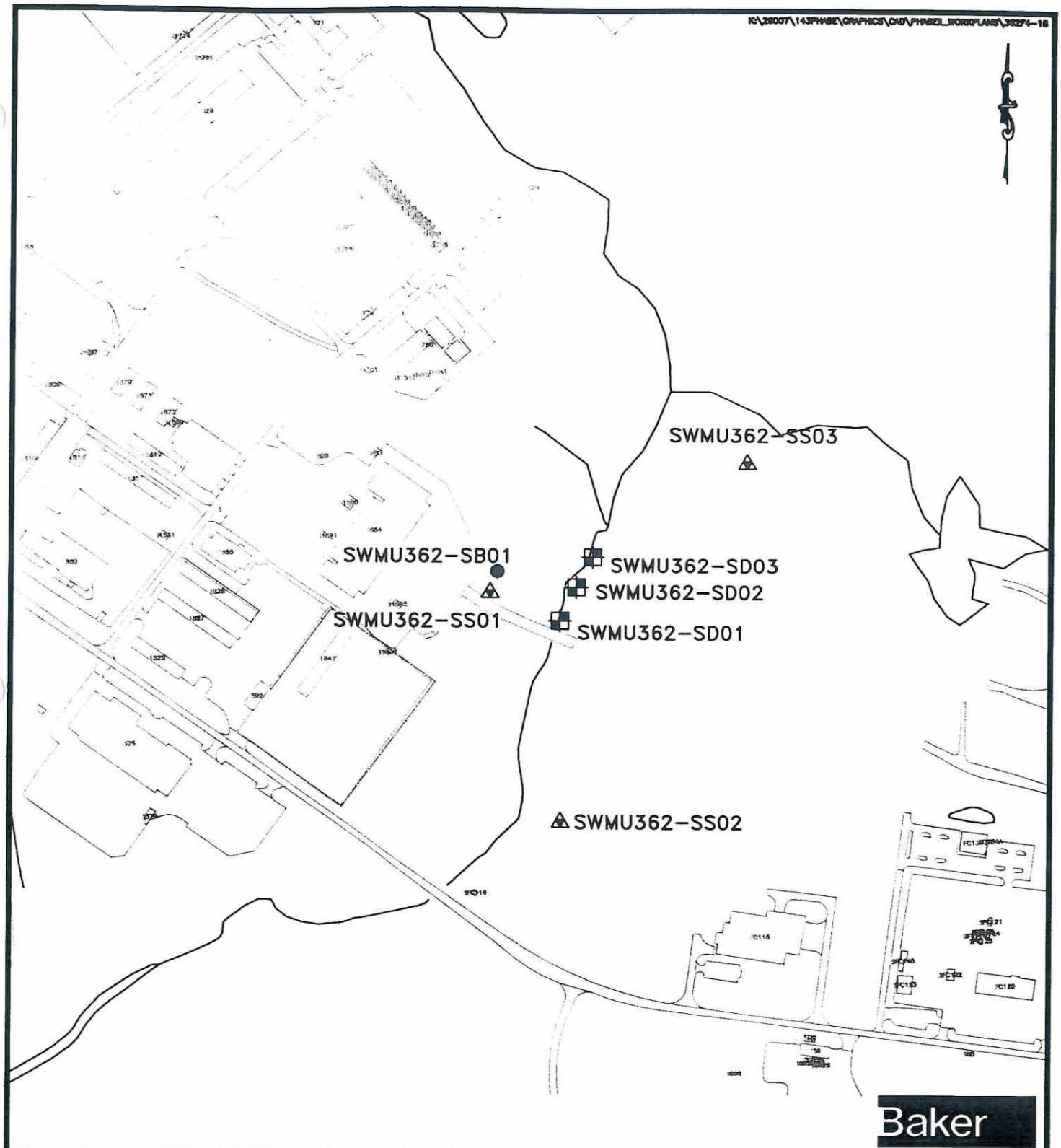
FIGURE 4-41

PROPOSED PHASE II SWMU INVESTIGATION PLAN

SWMU 361

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

K\26007\143\GRAPHICS\CAD\361f4-41



LEGEND

- ▲ PROPOSED SURFACE SOIL SAMPLE
- ● PROPOSED SOIL BORING
- ⊞ PROPOSED SURFACE WATER AND SEDIMENT SAMPLE

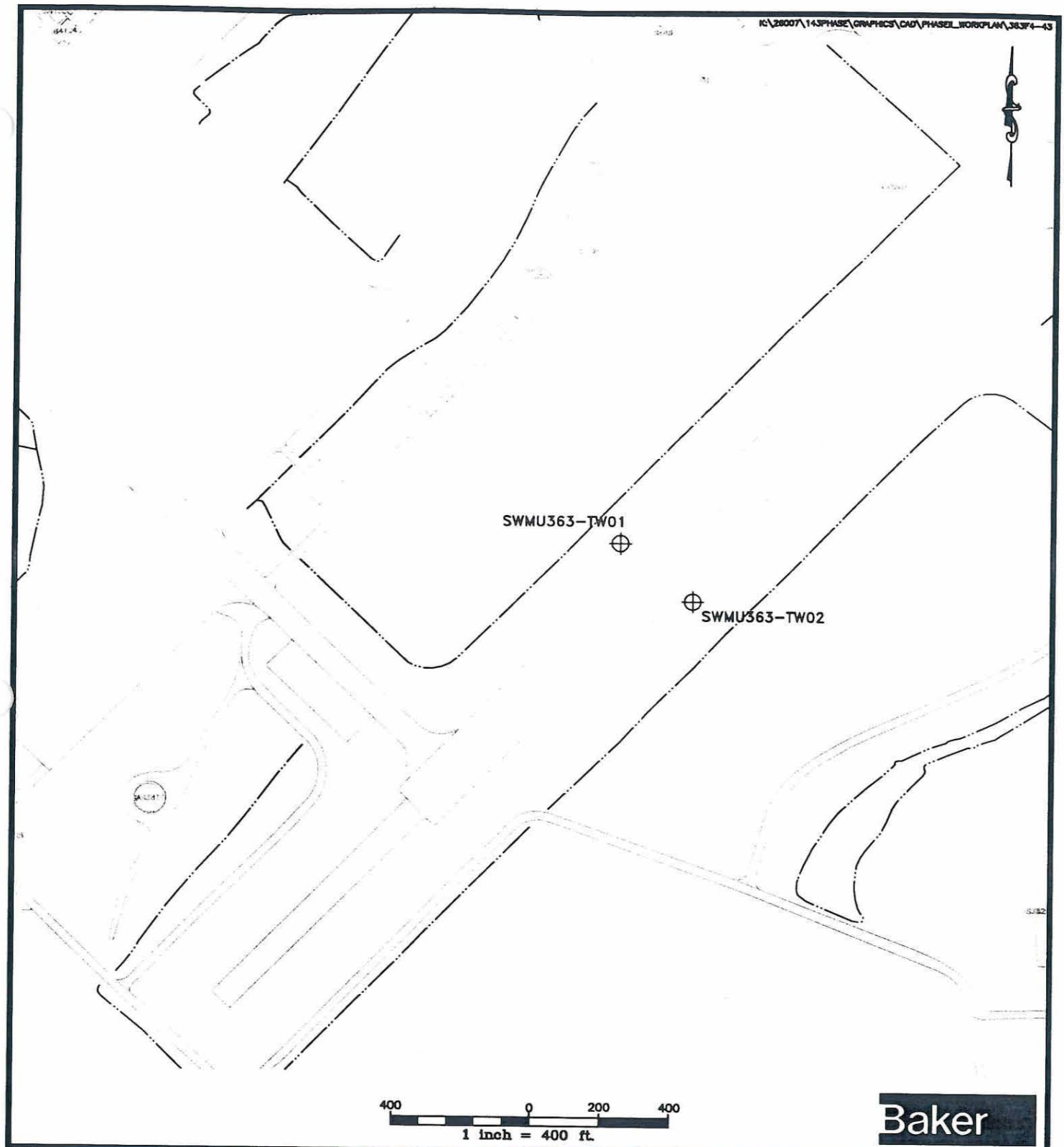
SOURCE: MCB, CAMP LEJEUNE MARCH 2000.

FIGURE 4-42

PROPOSED PHASE II SWMU INVESTIGATION PLAN

SWMU 362

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



LEGEND

⊕ – PROPOSED TEMPORARY MONITORING WELL

SOURCE: MCB, CAMP LEJEUNE MARCH 2000.

FIGURE 4-43

PROPOSED PHASE II INVESTIGATION PLAN

SWMU 363

MARINE CORPS AIR STATION, NEW RIVER
JACKSONVILLE, NORTH CAROLINA

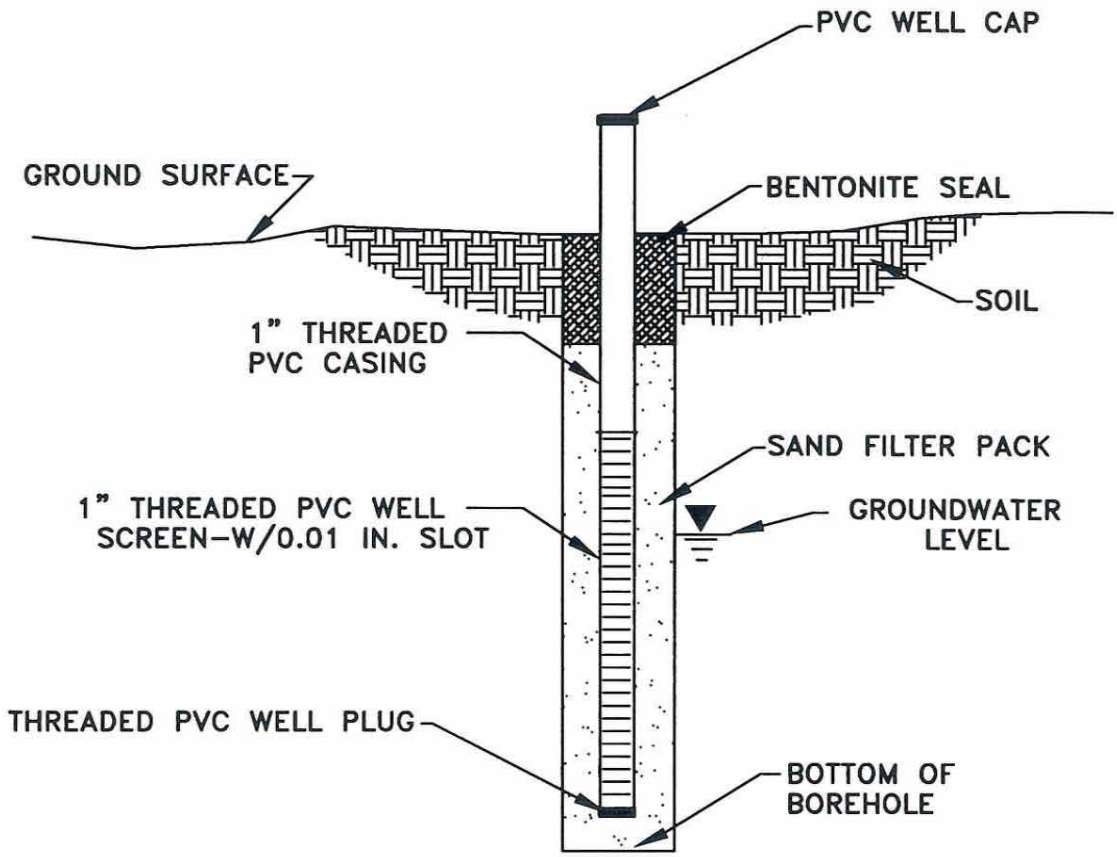


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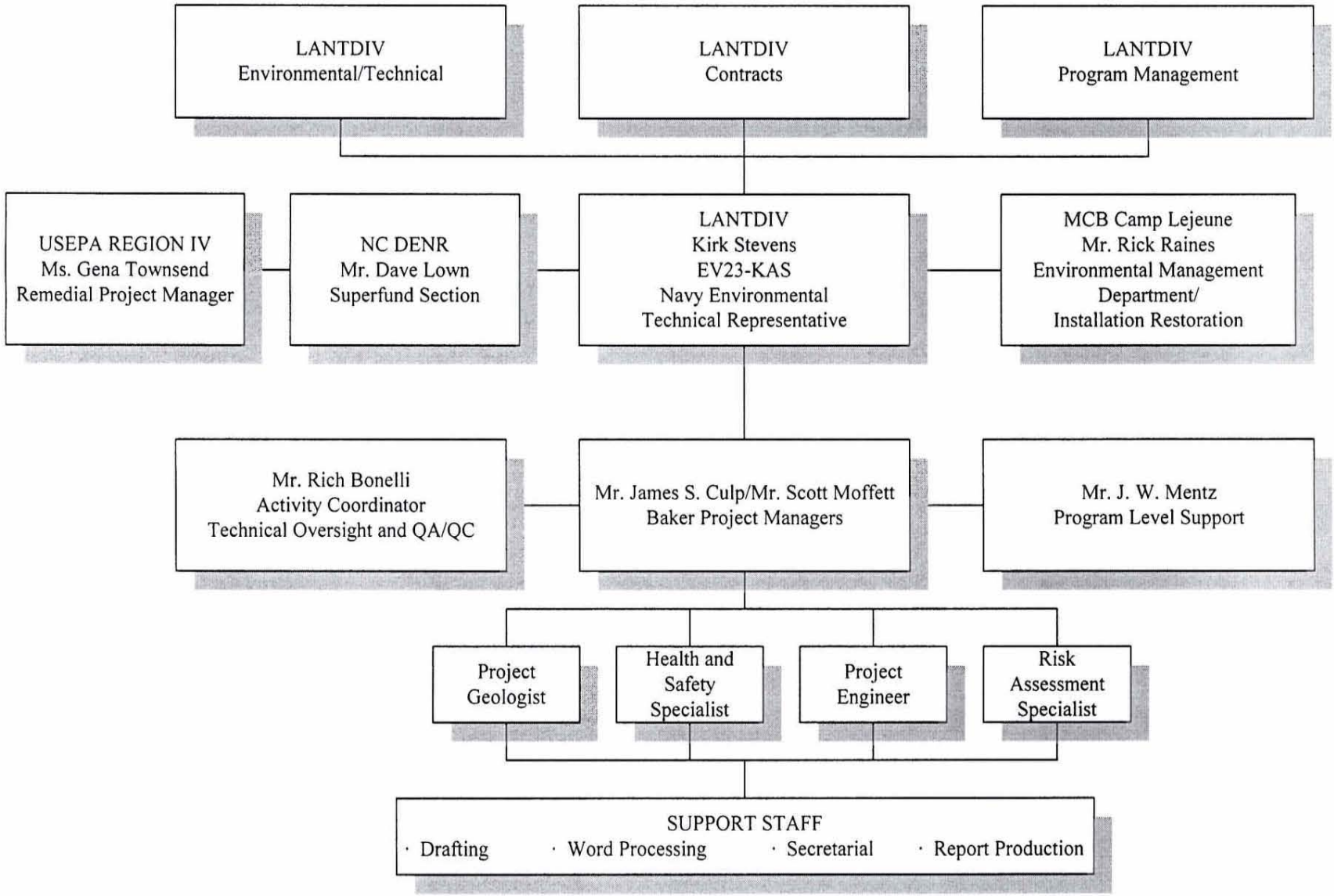
FIGURE 6-1

TEMPORARY MONITORING WELL CONSTRUCTION DIAGRAM
PHASE II CONFIRMATORY SAMPLING WORKPLAN

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

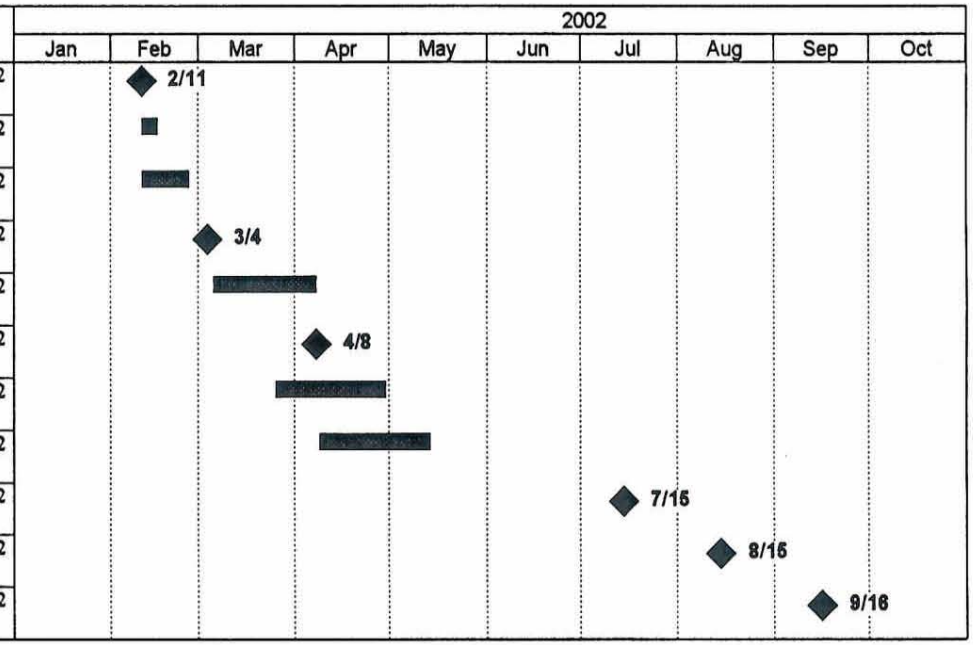
FIGURE 9-1

PROJECT TEAM ORGANIZATION
BACKGROUND GROUNDWATER STUDY (CTO-0143)
MCB, CAMP LEJEUNE, NORTH CAROLINA



Phase II Confirmatory Sampling Investigation Schedule
CTO-0143
MCB Camp Lejeune

Task Name	Duration	Start	Finish
Receive NC DENR's Concurrence on Work Plan	1 day?	2/11/02	2/11/02
Submit Final Background Groundwater Study Work Plan	5 days?	2/11/02	2/15/02
Procure Subcontractors	11 days?	2/11/02	2/25/02
Mobilize to Field	1 day?	3/4/02	3/4/02
Conduct Field Investigation	24 days?	3/6/02	4/7/02
Demobilize from Field	1 day?	4/8/02	4/8/02
Receive Analytical Results	26 days?	3/26/02	4/29/02
Receive Validated Results	25 days?	4/9/02	5/13/02
Submit Draft Report	1 day?	7/15/02	7/15/02
Receive Comments on Draft Report	1 day?	8/15/02	8/15/02
Submit Final Report	1 day?	9/16/02	9/16/02



Project: CTO-0143
Date: 12/12/01

Task Progress Milestone

APPENDIX A
BOREHOLE AND SAMPLE LOGGING

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2.0 SCOPE
3.0 DEFINITIONS
4.0 RESPONSIBILITIES
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  - 5.3.1 Grain Size Identification
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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. The field team leader is responsible for providing copies of the test boring 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 - 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 or the field notebook.

5.1 Test Boring Record

Each boring shall be fully described in a Field Test Boring Record. 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 so that all boring logs recorded (by each drilling inspector) are located in one source. The use of a field log book precludes the possibility of losing individual test boring log sheets. Furthermore, use of the field log book allows for the recording of additional information (i.e. notes) for which space is not allocated on the Field Test 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 site. Field Test Boring Records must also be legible. Completed Field Test Boring Records shall be converted to report format using a Test Boring Record.

The data which is to be included on the Test Boring Records, when applicable is listed below.

1. Project name, location, and Project and Task Number.
2. Date(s).
3. Identifying number and location of each boring.
4. Soil classifications 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 laboratory analysis and review. Both field determined USCS soil classification and a soil description shall be included on the Test Boring Record.
5. Depth limits, and the type and number of samples taken.
6. The number of blows required for each 6-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 (indicative of subsurface voids) and the interval over which it was observed.
9. Identification of equipment used, including model and type of drilling rig, size of split spoon samplers, 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 distribution, consistency moisture, etc., in addition to the USCS classification category (Section 5.3.7).

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 USCS. The USCS 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.

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:

Size	Size Limits
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-spoon (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 2-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 6-inch increments will be used to calculate the relative density.

The relative density designations for noncohesive soils are:

Designation	Standard Penetration Resistance (Blows per Foot)
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:

Designation	Standard Penetration Resistance (Blows per Foot)
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:

Designation	Moisture Content
Dry	0 to 10 percent
Damp	10 to 20 percent
Moist	20 to 35 percent
Wet	35 to 50 percent

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 analysis should be performed if it is necessary to accurately determine the natural water content.

5.3.5 Stratification

Stratification can only be determined after the split-barrel sampler is opened. Typically, bedding thicknesses are described as follows:

Designation	Bedding Spacing
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 to the USCS. 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 types of 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:

Designation	Grain Size Diameter
Cobbles	Greater than 64 mm (2.5-inches)
Pebbles	4 mm (0.16-inches) to 64 mm
Granules	2 mm (0.08-inches) to 4 mm
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 sample is silt. If the grains are not distinguishable with a hand lens, the sample 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 2-inch spacing between fractures
- Broken - A 2-inch to 1-foot spacing between fractures
- Blocky - A 1-foot to 3-foot spacing between fractures
- Massive - A 3-foot to 10-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 4 inches, and have resulted from natural breaks. Natural breaks include slickenslides, 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.

APPENDIX B
MONITORING WELL INSTALLATION

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ATTACHMENT A -- ALTERNATE WELL CASING MATERIAL JUSTIFICATION

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.

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.

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. Generally PVC is 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 A 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 2-inch or 4-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 light nonaqueous phase liquid (LNAPL) applications, the screen should be installed such that at least 2 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 6-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 6 inches below the ground surface (for flush-mounted wells) to between approximately one and 2 feet above the ground surface for wells completed with stick-up.

The annular space around the screen is to be successively 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 from the bottom of the boring to a minimum of 2 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-foot thick shall be place above the sand pack. 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 3 to 4 percent bentonite powder (by dry weight) or equivalent grout. The grout mixture shall be specified in the project plans. The grout will be tremied into the annular space greater than 20 feet high. If the annular space is less than 20 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 Well Construction Record (Attachment C) 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). The drive points will be sampled according to SOP F104, "Groundwater Sample Acquisition."

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 4- or 6-inch diameter, 5-foot long steel casing into the cement grout with locking cap and lock. 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. A concrete apron shall be constructed around the steel casing.

The second method considers flush-mounted wells, typically installed where a stick-up installation would present a traffic hazard. 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 concrete apron. 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 or locking cap. 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. 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 three borehole volumes) or until well goes dry.
- Stability of specific conductance, turbidity, 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 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. 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 Sampling and Analysis Plan. In general, all site investigation generated wastes shall be containerized unless otherwise specified by the Sampling and Analysis Plan. The disposition of these wastes shall be determined after receipt of the appropriate analytical results.

5.6 Well Construction Records

Field Well Construction Records shall be completed by the Drilling Inspector for each monitoring well installed. These records 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 Field Well Construction Record. If well construction information is recorded in the field logbook, it must be transferred to the appropriate form within 5 days, and prior to demobilization from the field.

Field Well Construction Records 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 Record, or in the field logbook, as appropriate:

- Project name and location.
- Project and Task 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 Record will be used to generate a final Well Construction Record which combines the Field Boring and Well Construction Logs into one package.

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., 1986, Groundwater and Wells , Johnson division. St. Paul, Minnesota. 2nd ed..

2. Roscoe Moss Company, 1990, Handbook of Ground Water Development. John Wiley & Sons. New York.

3. USEPA, September, 1986, RCRA Ground-Water Monitoring Technical Enforcement Guidance Document.

4. Aller, L. et al. , June 1989, Handbook of Suggested Practices for the Design and Installation of Ground Water Monitoring Wells. National Water Well Association. Dublin, Ohio.

ATTACHMENT A

ALTERNATE WELL CASING MATERIAL JUSTIFICATION

ATTACHMENT A

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.

APPENDIX C
SOIL 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) shelby 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 shelby-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 <u>not</u> 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

Designation: D 1586 – 84 (Reapproved 1992)[ε1]

Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils[1]

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 Purposes[2]

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

D 4220 Practices for Preserving and Transporting Soil Samples[2]

D 4633 Test Method for Stress Wave Energy Measurement for Dynamic Penetrometer Testing Systems[2]

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.

Current edition approved Sept. 11, 1984. Published November 1984. Originally published as D 1586 – 58 T. Last previous edition D 1586 – 67 (1974).

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

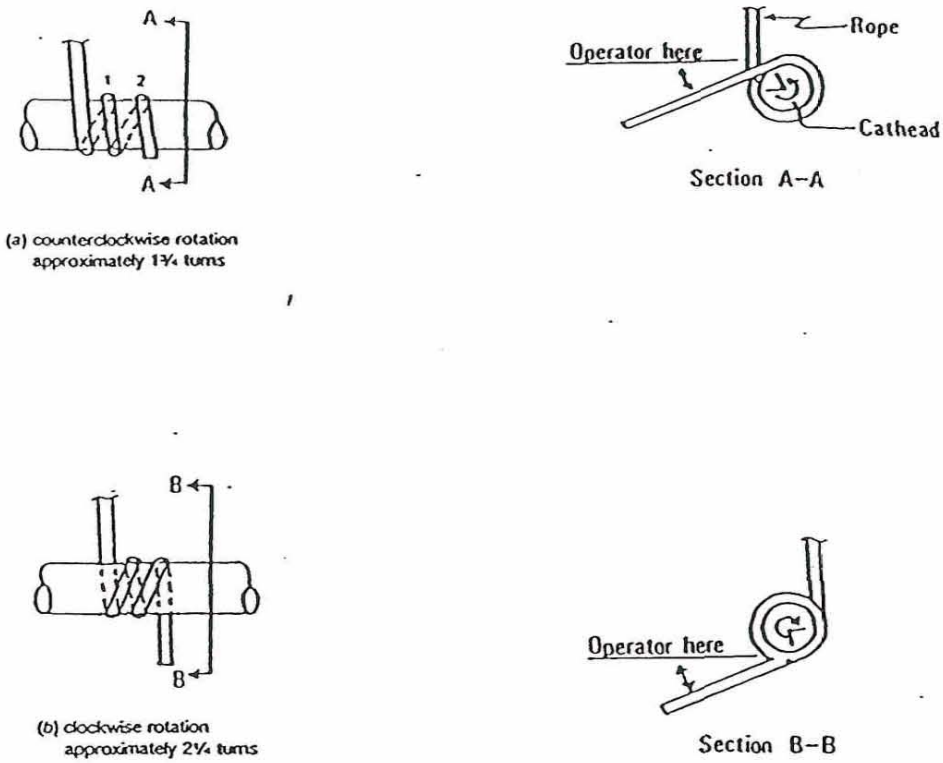


FIG. 1 Definitions of the Number of Rope Turns and the Angle for (a) Counterclockwise Rotation and (b) Clockwise Rotation of the Cathead

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 conjuction 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 1⅝ in. (41.2 mm) and an inside diameter of 1⅛ 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 1⅜ 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.

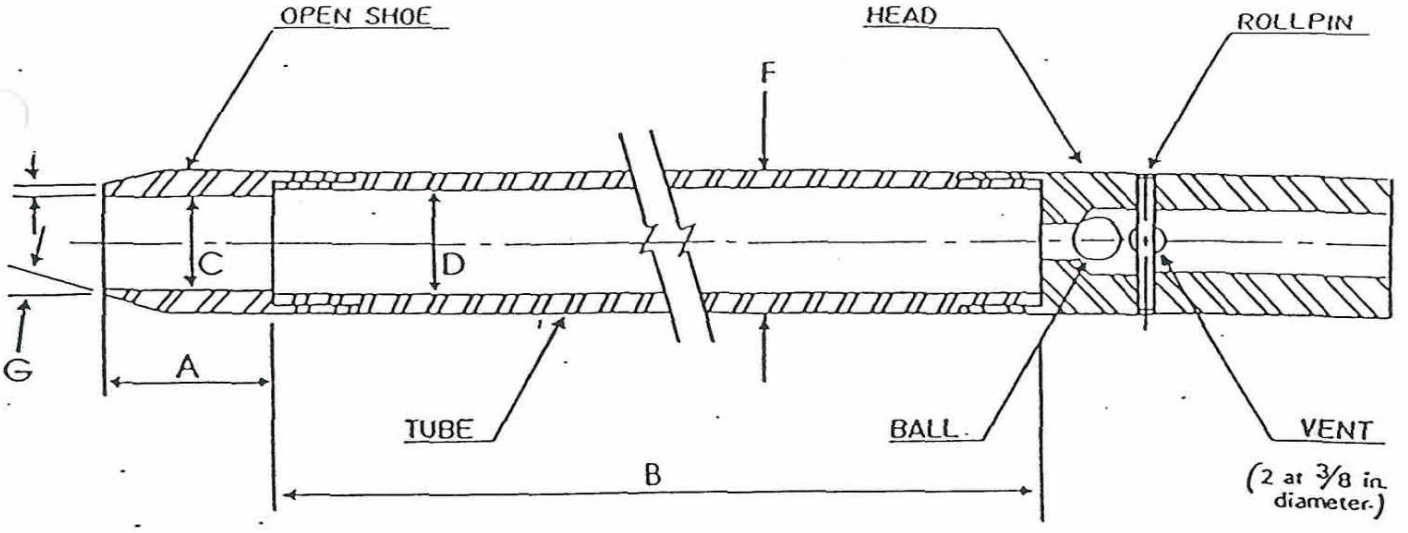
NOTE 2—Both theory and available test data suggest that *N*-values may increase between 10 to 30 % when liners are used.

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 mm) 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 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 ± 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 2¼ 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 1¾ or 2¼ rope turns, depending upon whether or not the rope comes off the top (1¾ turns) or the bottom (2¼ turns) of the cathead. It is generally known and accepted that 2¾ 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 lubricate 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 mpler and adjusting N on the basis of comparative gies. 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 Soils[1]

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 Soils[2]

D 4220 Practices for Preserving and Transporting Soil Samples[2]

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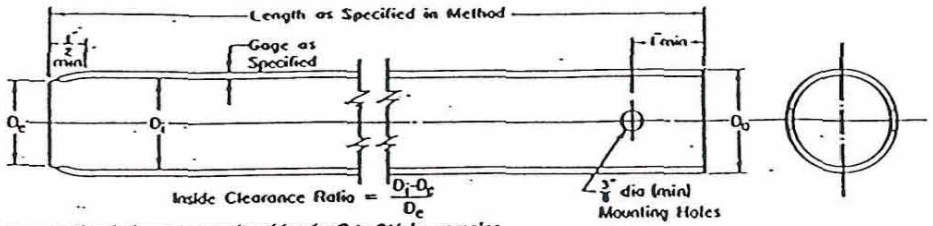
[2] *Annual Book of ASTM Standards*, Vol 04.08.



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
¼	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:			
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
[illegible]	0.91	0.91	1.45
[illegible]rance ratio, %	1	1	1

[A] The three diameters recommended in Table 1 are indicated for purposes of [illegible]andardization, 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

Nominal Tube Diameters from Table 1[A] Tolerances, in.			
Size Outside Diameter	2	3	5
Outside diameter	+0.007 −0.000	+0.010 −0.000	+0.015 −0.000
Inside diameter	+0.000 −0.007	+0.000 −0.010	+0.000 −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 [illegible]ttom of the hole. Advance the sampler without rotation by [illegible]continuous relatively rapid motion.

6.4 Determine the length of advance by the resistance and [illegible]ondition 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 Investigation[1]

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 Soils[2]

D 1587 Practice for Thin-Walled Tube Sampling of Soils[2]

D 3550 Practice for Ring-Lined Barrel Sampling of Soils[2]

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 determinations.

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: 2¾ in. (69.85 mm) by 3⅞ in. (98.43 mm), 4 in. (101.6 mm) by 5½ in. (139.7 mm), and 6 in. (152.4 mm) by 7¾ 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 thin 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 required 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	44.6
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
2¾ × 3⅞	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 × 5½	5.44	138.0	3.97	100.8
6 × 7¾	7.66	194.4	5.97	151.6

TABLE 2 Casing Sizes

Size Designation	Outside Diameter		Inside Diameter		Threads per in.	Will 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 × 5½
PW	5.50	139.7	5.00	127.0	3	6 × 7¾
SW	6.63	168.2	6.00	152.4	3	6 × 7¾
UW	7.63	193.6	7.00	177.8	2	. . .
ZW	8.63	219.0	8.00	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	1.34	34.1	0.63	16.0	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 event 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.

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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.

SAMPLING EXCERPTS FROM SW-846 METHOD 5035

6.0 SAMPLE COLLECTION, PRESERVATION, AND HANDLING

Refer to the introductory material in this chapter, Organic Analytes, Sec. 4.1, for general sample collection information. The low concentration portion of this method employs sample vials that are filled and weighed in the field and never opened during the analytical process. As a result, sampling personnel should be equipped with a portable balance capable of weighing to 0.01 g.

6.1 Preparation of sample vials

The specific preparation procedures for sample vials depend on the expected concentration range of the sample, with separate preparation procedures for low concentration soil samples and high concentration soil and solid waste samples. Sample vials should be prepared in a fixed laboratory or other controlled environment, sealed, and shipped to the field location. Gloves should be worn during the preparation steps.

6.1.1 Low concentration soil samples

The following steps apply to the preparation of vials used in the collection of low concentration soil samples to be analyzed by the closed-system purge-and-trap equipment described in Method 5035.

6.1.1.1 Add a clean magnetic stirring bar to each clean vial. If the purge-and-trap device (Sec. 4.2) employs a means of stirring the sample other than a magnetic stirrer (e.g., sonication or other mechanical means), then the stir bar is omitted.

6.1.1.2 Add preservative to each vial. The preservative is added to each vial prior to shipping the vial to the field. Add approximately 1 g of sodium bisulfate to each vial. If samples markedly smaller or larger than 5 g are to be collected, adjust the amount of preservative added to correspond to approximately 0.2 g of preservative for each 1 g of sample. Enough sodium bisulfate should be present to ensure a sample pH of ≤ 2.

6.1.1.3 Add 5 mL of organic-free reagent water to each vial. The water and the preservative will form an acid solution that will reduce or eliminate the majority of the biological activity in the sample, thereby preventing biodegradation of the volatile target analytes.

6.1.1.4 Seal the vial with the screw-cap and septum seal. If the double-ended, fritted, vials are used, seal both ends as recommended by the manufacturer.

6.1.1.5 Affix a label to each vial. This eliminates the need to label the vials in the field and assures that the tare weight of the vial includes the label. (The weight of any markings added to the label in the field is negligible).

6.1.1.6 Weigh the prepared vial to the nearest 0.01 g, record the tare weight, and write it on the label.

6.1.1.7 Because volatile organics will partition into the headspace of the vial from the aqueous solution and will be lost when the vial is opened, surrogates, matrix spikes, and internal standards (if applicable) should only be added to the vials after the sample has been added to the vial. These standards should be introduced back in the

laboratory, either manually by puncturing the septum with a small-gauge needle or automatically by the sample introduction system, just prior to analysis.

6.1.2 High concentration soil samples collected without a preservative

When high concentration samples are collected without a preservative, a variety of sample containers may be employed, including 60-mL glass vials with septum seals (see Sec. 4.4).

6.1.3 High concentration soil samples collected and preserved in the field

The following steps apply to the preparation of vials used in the collection of high concentration soil samples to be preserved in the field with methanol and analyzed by the aqueous purge-and-trap equipment described in Method 5030.

6.1.3.1 Add 10 mL of methanol to each vial.

6.1.3.2 Seal the vial with the screw-cap and septum seal.

6.1.3.3 Affix a label to each vial. This eliminates the need to label the vials in the field and assures that the tare weight of the vial includes the label. (The weight of any markings added to the label in the field is negligible).

6.1.3.4 Weigh the prepared vial to the nearest 0.01 g, record the tare weight, and write it on the label.

NOTE: Vials containing methanol should be weighed a second time on the day that they are to be used. Vials found to have lost methanol (reduction in weight of >0.01 g) should not be used for sample collection.

6.1.3.5 Surrogates, internal standards and matrix spikes (if applicable) should be added to the sample after it is returned to the laboratory and prior to analysis.

6.1.4 Oily waste samples

When oily waste samples are known to be soluble in methanol or PEG, sample vials may be prepared as described in Sec. 6.1.3, using the appropriate solvent. However, when the solubility of the waste is unknown, the sample should be collected without the use of a preservative, in a vial such as that described in Sec. 6.1.2.

6.2 Sample collection

Collect the sample according to the procedures outlined in the sampling plan. As with any sampling procedure for volatiles, care must be taken to minimize the disturbance of the sample in order to minimize the loss of the volatile components. Several techniques may be used to transfer a sample to the relatively narrow opening of the low concentration soil vial. These include devices such as the EnCore™ sampler, the Purge-and-Trap Soil Sampler ™, and a cut plastic syringe. Always wear gloves whenever handling the tared sample vials.

6.2.1 Low concentration soil samples

6.2.1.1 Using an appropriate sample collection device, collect approximately 5 g of sample as soon as possible after the surface of the soil or other solid material has been exposed to the atmosphere: generally within a few minutes at most. Carefully wipe the exterior of the sample collection device with a clean cloth or towel.

6.2.1.2 Using the sample collection device, add about 5 g (2 - 3 cm) of soil to the sample vial containing the preservative solution. Quickly brush any soil off the vial threads and immediately seal the vial with the septum and screw-cap. Store samples on ice at 4°C.

NOTE: Soil samples that contain carbonate minerals (either from natural sources or applied as an amendment) may effervesce upon contact with the acidic preservative solution in the low concentration sample vial. If the amount of gas generated is very small (i.e., several mL), any loss of volatiles as a result of such effervescence may be minimal if the vial is sealed quickly. However, if larger amounts of gas are generated, not only may the sample lose a significant amount of analyte, but the gas pressure may shatter the vial if the sample vial is sealed. Therefore, when samples are known or suspected to contain high levels of carbonates, a test sample should be collected, added to a vial, and checked for effervescence. If a rapid or vigorous reaction occurs, discard the sample and collect low concentration samples in vials that do not contain the preservative solution.

6.2.1.3 When practical, use a portable balance to weigh the sealed vial containing the sample to ensure that 5.0 ± 0.5 g of sample were added. The balance should be calibrated in the field using an appropriate weight for the sample containers employed (Sec. 4.5.5). Record the weight of the sealed vial containing the sample to the nearest 0.01 g.

6.2.1.4 Alternatively, collect several trial samples with plastic syringes. Weigh each trial sample and note the length of the soil column in the syringe. Use these data to determine the length of soil in the syringe that corresponds to 5.0 ± 0.5 g. Discard each trial sample.

6.2.1.5 As with the collection of aqueous samples for volatiles, collect at least two replicate samples. This will allow the laboratory an additional sample for reanalysis. The second sample should be taken from the same soil stratum or the same section of the solid waste being sampled, and within close proximity to the location from which the original sample was collected.

6.2.1.6 In addition, since the soil vial cannot be opened without compromising the integrity of the sample, at least one additional aliquot of sample must be collected for screening, dry weight determination, and high concentration analysis (if necessary). This third aliquot may be collected in a 60-mL glass vial or a third 40-mL soil sample vial. However, this third vial must *not* contain the sample preservative solution, as an aliquot will be used to determine dry weight. If high concentration samples are collected in vials containing methanol, then two additional aliquots should be collected, one for high concentration analysis collected in a vial containing methanol, and another for the dry weight determination in a vial without either methanol or the low concentration aqueous preservative solution.

6.2.1.7 If samples are known or expected to contain target analytes over a wide range of concentrations, thereby requiring the analyses of multiple sample aliquots, it may be advisable and practical to take an additional sample aliquot in a low concentration soil vial containing the preservative, but collecting only 1-2 g instead of the 5 g collected in Sec. 6.2.1.1. This aliquot may be used for those analytes that exceed the instrument calibration range in the 5-g analysis.

6.2.1.8 The EnCore™ sampler has not been thoroughly evaluated by EPA as a sample storage device. While preliminary results indicate that storage in the EnCore™ device may be appropriate for up to 48 hours, samples collected in this device should be transferred to the soil sample vials as soon as possible, or analyzed within 48 hours.

6.2.1.9 The collection of low concentration soil samples in vials that contain methanol is not appropriate for samples analyzed with the closed-system purge-and-trap equipment described in this method (see Sec. 6.2.2).

6.2.2 High concentration soil samples preserved in the field

The collection of soil samples in vials that contain methanol has been suggested by some as a combined preservation and extraction procedure. However, this procedure is not appropriate for use with the low concentration soil procedure described in this method.

NOTE: The use of methanol preservation has not been formally evaluated by EPA and analysts must be aware of two potential problems. First, the use of methanol as a preservative and extraction solvent introduces a significant dilution factor that will raise the method quantitation limit beyond the operating range of the low concentration direct purge-and-trap procedure (0.5-200 µg/kg). The exact dilution factor will depend on the masses of solvent and sample, but generally exceeds 1000, and may make it difficult to demonstrate compliance with regulatory limits or action levels for some analytes. Because the analytes of interest are volatile, the methanol extract cannot be concentrated to overcome the dilution problem. Thus, for samples of unknown composition, it may still be necessary to collect an aliquot for analysis by this closed-system procedure and another aliquot preserved in methanol and analyzed by other procedures. The second problem is that the addition of methanol to the sample is likely to cause the sample to fail the ignitability characteristic, thereby making the unused sample volume a hazardous waste.

6.2.2.1 When samples are known to contain volatiles at concentrations high enough that the dilution factor will not preclude obtaining results within the calibration range of the appropriate determinative method, a sample may be collected and immediately placed in a sample vial containing purge-and-trap grade methanol.

6.2.2.2 Using an appropriate sample collection device, collect approximately 5 g of sample as soon as possible after the surface of the soil or other solid material has been exposed to the atmosphere: generally within a few minutes at most. Carefully wipe the exterior of the sample collection device with a clean cloth or towel.

6.2.2.3 Using the sample collection device, add about 5 g (2 - 3 cm) of soil to the vial containing 10 mL of methanol. Quickly brush any soil off the vial threads and immediately seal the vial with the septum and screw-cap. Store samples on ice at 4°C.

6.2.2.4 When practical, use a portable balance to weigh the sealed vial containing the sample to ensure that 5.0 ± 0.5 g of sample were added. The balance should be calibrated in the field using an appropriate weight for the sample containers employed (Sec. 4.5.5). Record the weight of the sealed vial containing the sample to the nearest 0.01 g.

6.2.2.5 Alternatively, collect several trial samples with plastic syringes. Weigh each trial sample and note the length of the soil column in the syringe. Use these data to determine the length of soil in the syringe that corresponds to 5.0 ± 0.5 g. Discard each trial sample.

6.2.2.6 Other sample weights and volumes of methanol may be employed, provided that the analyst can demonstrate that the sensitivity of the overall analytical procedure is appropriate for the intended application.

6.2.2.7 The collection of at least one additional sample aliquot is required for the determination of the dry weight, as described in Sec. 6.2.1.6. Samples collected in methanol should be shipped as described in Sec. 6.3, and must be clearly labeled as containing methanol, so that the samples are not analyzed using the closed-system purge-and-trap equipment described in this procedure.

6.2.3 High concentration soil sample <u>not</u> preserved in the field

The collection of high concentration soil samples that are not preserved in the field generally follows similar procedures as for the other types of samples described in Secs. 6.2.1 and 6.2.2, with the obvious exception that the sample vials contain neither the aqueous preservative solution nor methanol. However, when field preservation is not employed, it is better to collect a larger volume sample, filling the sample container as full as practical in order to minimize the headspace. Such collection procedures generally do not require the collection of a separate aliquot for dry weight determination, but it may be advisable to collect a second sample aliquot for screening purposes, in order to minimize the loss of volatiles in either aliquot.

6.2.4 Oily waste samples

The collection procedures for oily samples depend on knowledge of the waste and its solubility in methanol or other solvents.

6.2.4.1 When an oily waste is <u>known</u> to be soluble in methanol or PEG, the sample may be collected in a vial containing such a solvent (see Sec. 6.1.4), using procedures similar to those described in Sec. 6.2.2.

6.2.4.2 When the solubility of the oily waste is <u>not</u> known, the sample should either be collected in a vial without a preservative, as described in Sec. 6.2.3, or the solubility of a trial sample should be tested in the field, using a vial containing solvent. If the trial sample is soluble in the solvent, then collect the oily waste sample as described in Sec. 6.2.2. Otherwise, collect an unpreserved sample as described in Sec. 6.2.3.

6.3 Sample handling and shipment

All samples for volatiles analysis should be cooled to approximately 4°C, packed in appropriate containers, and shipped to the laboratory on ice, as described in the sampling plan.

6.4 Sample storage

6.4.1 Once in the laboratory, store samples at 4°C until analysis. The sample storage area should be free of organic solvent vapors.

6.4.2 All samples should be analyzed as soon as practical, and within the designated holding time from collection. Samples not analyzed within the designated holding time must be noted and the data are considered minimum values.

6.4.3 When the low concentration samples are strongly alkaline or highly calcareous in nature, the sodium bisulfate preservative solution may not be strong enough to reduce the pH of the soil/water solution to below 2. Therefore, when low concentration soils to be sampled are known or suspected to be strongly alkaline or highly calcareous, additional steps may be required to preserve the samples. Such steps include: addition of larger amounts of the sodium bisulfate preservative to non-calcareous samples, storage of low concentration samples at -10°C (taking care not to fill the vials so full that the expansion of the water in the vial breaks the vial), or significantly reducing the maximum holding time for low concentration soil samples. Whichever steps are employed, they should be clearly described in the sampling and QA project plans and distributed to both the field and laboratory personnel. See Sec. 6.2.1.2 for additional information.

APPENDIX D
GROUNDWATER SAMPLE ACQUISITION

GROUNDWATER SAMPLE ACQUISITION
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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 lenses) or by contrasts in permeability (for example, between a layer of silty, fine sand and a layer of medium sand).

Purging 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: PID; Thermometer; pH meter; specific conductivity meter; appropriate keys (for locked wells) or bolt-cutter; tape measure; plastic sheeting; water-level indicator; calibrated buckets and, where applicable, flow meter.

3. Pumps

   a. Shallow-well pumps: Centrifugal, Packer Pumps, 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, Packer Pumps, 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 equipment and materials: 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 purging and sample collection.

5.2 Calculations of Well Volume for Purging

The volume of the cylinder of water in a well is given by:

Where: V =volume of standing water in well (in cubic feet)

r=well radius (in feet)
h=standing water in well (in feet)

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 (D).

3. Measure and record static water level (DW-depth to water 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 (TD) to the nearest 0.01-foot by sounding using a clean, decontaminated weighted tape measure, referenced to the top of PVC casing or ground surface.

5. Calculate number of linear feet of static water (total well depth minus the depth to static water level).

6. Calculate the volume of water in the casing:

$$V_{gal} = V_W \times 7.48 \text{ gallons/ft}^3$$

$$V_{purge} = Vgal\ (\ \#\ \text{Well Vol})$$

Where:

V_W	=	Volume of water standing in well in cubic feet (i.e., one well volume)
π	=	pi, 3.14
r	=	Well radius in feet
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
# 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.)

Table 5-1 lists gallons and cubic feet of water per standing foot of water for a variety of well diameters.

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

5.3 Evacuation of Static Water (Purging)

The amount of purging 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.

If a well is dewatered before the required volume is purged, the sample should be collected from the well once as a sufficient volume of water has entered the well. In order to avoid stagnation, the well should not be allowed to fully recharge before the sample is collected. The field parameters (pH, conductance, and temperature) should be recorded when the well was dewatered.

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 and use.

Limitations on the use of bailers include the following:

- Limited volume of sample.
- Time consuming to remove stagnant water using a bailer.
- Collection and transfer of sample may cause aeration.
- Use of bailers is physically demanding, especially in warm temperatures at protection levels above Level D.
- Unable to collect depth-discrete sample.

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 Samples - 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, measure the total depth and water level (with 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 distance just 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. Record the method of discharge measurement.

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 that the groundwater level has stabilized. Generally, these measurements are made after the removal of 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 groundwater recovery time is very slow (e.g., 24 hours), sample collection can be delayed until the following day. However, it is preferred that such a well be bailed early in the morning so that sufficient volume of 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. Volatile organics septum 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. If the second attempt still produces air bubbles, note on Chain-of-Custody form and in field notebook and submit sample to the laboratory.

    Fill the remaining sample containers in order of decreasing volatilability (semi-volatiles next, then pesticides, PCBs, inorganics, etc.).

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 for dissolved inorganics 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 analyzed as "total metals" and preserved unfiltered. In Regions III and IV, samples collected for metals analysis are also to be unfiltered. However, if metals analysis of groundwater 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

Designation: D 4448 – 85a

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Standard Guide for Sampling Groundwater Monitoring Wells[1]

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 the concentration levels are prime factors for selecti sampling devices (1, 2).[2] The sampling device and materials and devices the water contacts must be construct of materials that will not introduce contaminants or alter t analyte chemically in any way.

2.4 The method of sample withdrawal can vary with t parameters of interest. The ideal sampling scheme wou employ a completely inert material, would not subject t sample to negative pressure and only moderate positi pressure, would not expose the sample to the atmosphere, preferably, any other gaseous atmosphere before conveying to the sample container or flow cell for on-site analysis.

2.5 The degree and type of effort and care that goes into sampling program is always dependent on the chemic species of interest and the concentration levels of interest. the concentration level of the chemical species of analytic interest decreases, the work and precautions necessary f sampling are increased. Therefore, the sampling objecti must clearly be defined ahead of time. For example, prepare equipment for sampling for mg/L (ppm) levels Total Organic Carbon (TOC) in water is about an order magnitude easier than preparing to sample for μg/L (ppb levels of a trace organic like benzene. The specific precau tions to be taken in preparing to sample for trace organics a different from those to be taken in sampling for trace metal No final Environmental Protection Agency (EPA) protocol available for sampling of trace organics. A short guidanc manual, (3) and an EPA document (4) concerning mon toring well sampling, including considerations for trac organics are available.

2.6 Care must be taken not to cross contaminate sample or monitoring wells with sampling or pumping devices c materials. All samples, sampling devices, and containe must be protected from the environment when not in us Water level measurements should be made before the well i flushed. Oxidation-reduction potential, pH, dissolved ox ygen, and temperature measurements and filtration shoul all be performed on the sample in the field, if possible. A but temperature measurement must be done prior to an significant atmospheric exposure, if possible.

2.7 The sampling procedures must be well planned and a sample containers must be prepared and labeled prior t going to the field.

3. Significance and Use

3.1 The quality of groundwater has become an issue c national concern. Groundwater monitoring wells are one c

[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.

Current edition approved Aug. 23 and Oct. 25, 1985. Published May 1986.

[2] The boldface numbers in parentheses refer to a list of references at the end 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 % $K_2Cr_2O_7$	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_2SO_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_2SO_4 to pH <2	24 h 28 days
Pesticides, herbicides and total organic halogen (TOX)	1000–4000	G/TFE-fluorocarbon lined cap solvent rinsed	cool, 4°C	7 days/extraction +30 days/analysis
Extractable organics	1000–2000	G/TFE-fluorocarbon-lined cap solvent rinsed	cool, 4°C	7 days/extraction +30 days/analysis
Organic purgeables acrolein/acrylonitrile	25–120	G/vial TFE-fluorocarbon-lined septum	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.

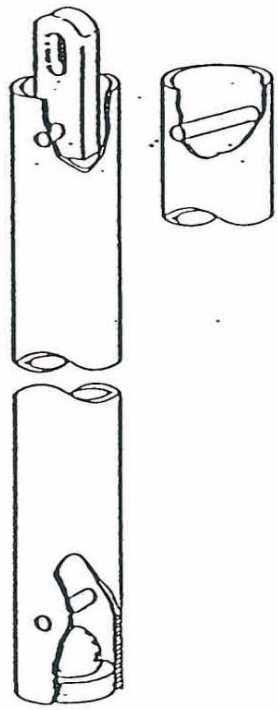
4. Well Flushing (Purging)

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 sample with stored water is minimized.



NOTE—Taken from Ref (15).

FIG. 1 Single Check Valve Bailer

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.

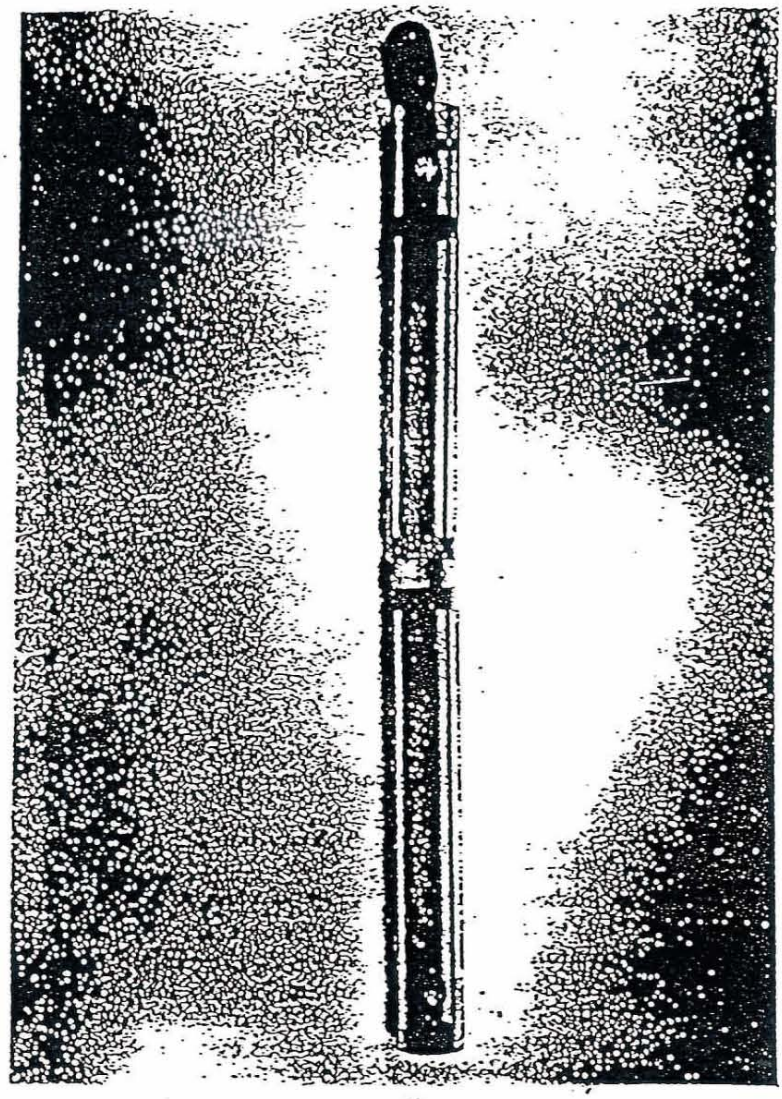
4.7 In any flushing approach, a withdrawal rate that minimizes drawdown while satisfying time constraints should be used. Excessive drawdown distorts the natural flow patterns around a well and can cause contaminants that were not present originally to be drawn into the well.

5. Materials and Manufacture

5.1 The choice of materials used in the construction c sampling devices should be based upon a knowledge of wha compounds may be present in the sampling environmen and how the sample materials may interact via leachin adsorption, or catalysis. In some situations, PVC or som other plastic may be sufficient. In others, an all gla apparatus may be necessary.

5.2 Most analytical protocols suggest that the devices use in sampling and storing samples for trace organics analys (μg/L levels) must be constructed of glass c TFE–fluorocarbon resin, or both. One suggestion advance by the EPA is that the monitoring well be constructed so th only TFE–fluorocarbon tubing be used in that portion of th sampling well that extends from a few feet above the wat table to the bottom of the borehole. (3, 5) Although this typ of well casing is now commercially available, PVC we casings are currently the most popular. If adhesives a avoided, PVC well casings are acceptable in many cas although their use may still lead to some problems if trac organics are of concern. At present, the type of backgroun presented by PVC and interactions occurring between PV and groundwater are not well understood. Tin, in the form c an organotin stabilizer added to PVC, may enter sampl taken from PVC casing. (9)

5.3 Since the most significant problem encountered i trace organics sampling, results from the use of PV adhesives in monitoring well construction, threaded join might avoid the problem (3, 5). Milligram per litre (parts p million) levels of compounds such as tetrahydrofura methyl-ethyl-ketone, and toluene are found to leach in



NOTE—Taken from Ref (17).

FIG. 2 Acrylic Point Source Bailer

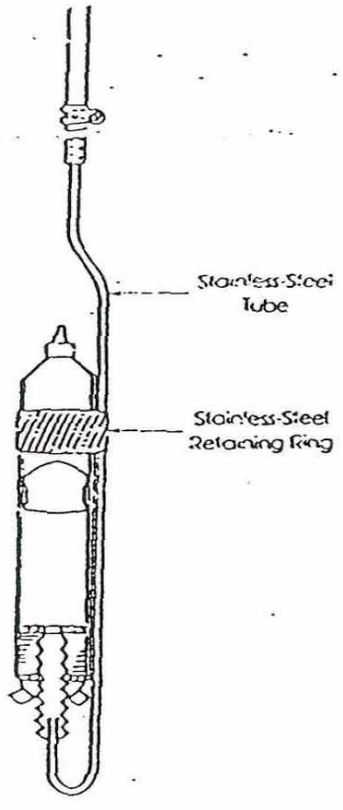
groundwater samples from monitoring well casings sealed with PVC solvent cement. Pollutant phthalate esters (8, 10) are often found in water samples at ppb levels; the EPA has found them on occasion at ppm levels in their samples. The ubiquitous presence of these phthalate esters is unexplained, except 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 no require this extrusion aid and may be suitable for samp tubing as well. Unsintered thread-sealant tape of TFE fluorocarbon is available in an "oxygen service" grade an contains no extrusion aid and lubricant.

5.6 Louneman, et al. (11) alludes to problems caused by lubricating oil used during TFE-fluorocarbon tubing extru sion. This reference also presents evidence that a fluorinate ethylene-propylene copolymer adsorbed acetone to a degre that later caused contamination of a gas sample.

5.7 Glass and stainless steel are two other materia generally considered inert in aqueous environments. Glass probably among the best choices though it is not inconsei able it could adsorb some constituents as well as release oth contaminants (for example, Na, silicate, and Fe). Of cou glass sampling equipment must be handled carefully in field. Stainless steel is strongly and easily machined



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 nonplastic (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 Chemical Society's committee on environmental improvem published guidelines for data acquisition and data eva which should be useful in such environmental eval (10, 12).

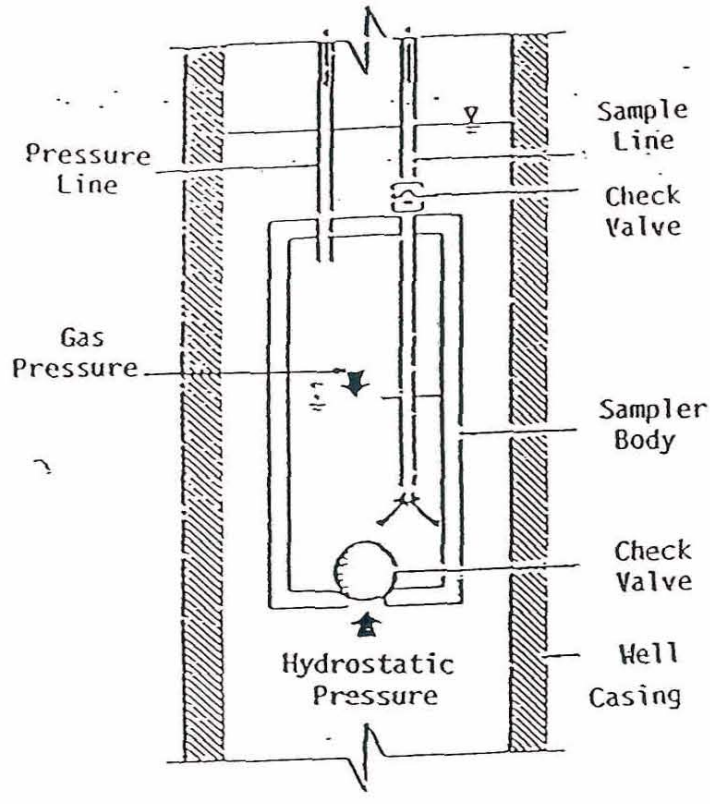
6. Sampling Equipment

6.1 There is a fairly large choice of equipment p available for groundwater sampling from single s wells and well clusters. The sampling devices can be rized into the following eight basic types.

6.1.1 *Down-Hole Collection Devices:*

6.1.1.1 Bailers, messenger bailers, or thief samp 14) are examples of down-hole devices that probably valid samples once the well has been flushed. They practical for removal of large volumes of wate devices can be constructed in various shapes and size variety of materials. They do not subject the sa pressure extremes.

6.1.1.2 Bailers do expose part of the sampl atmosphere during withdrawal. Bailers used for sar volatile organic compounds should have a sampl draft valve in or near the bottom of the sampler withdrawal of a sample from the well below the surface of the water or the first few inches of th should be discarded. Suspension lines for bailers samplers should be kept off the ground and free contaminating materials that could be carried into Down-hole devices are not very practical for us



NOTE—Taken from Ref (5).

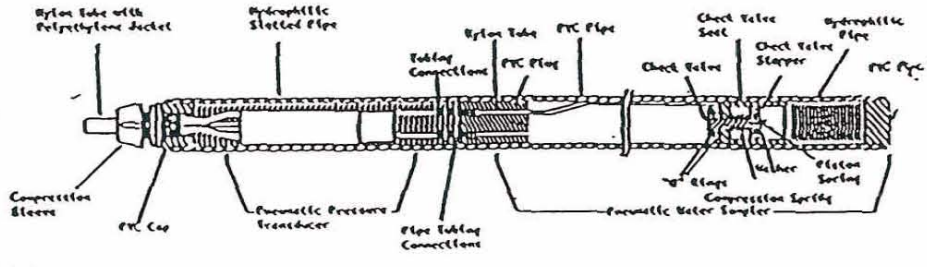
FIG. 4 The Principal of Gas Displacement Pumping

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).

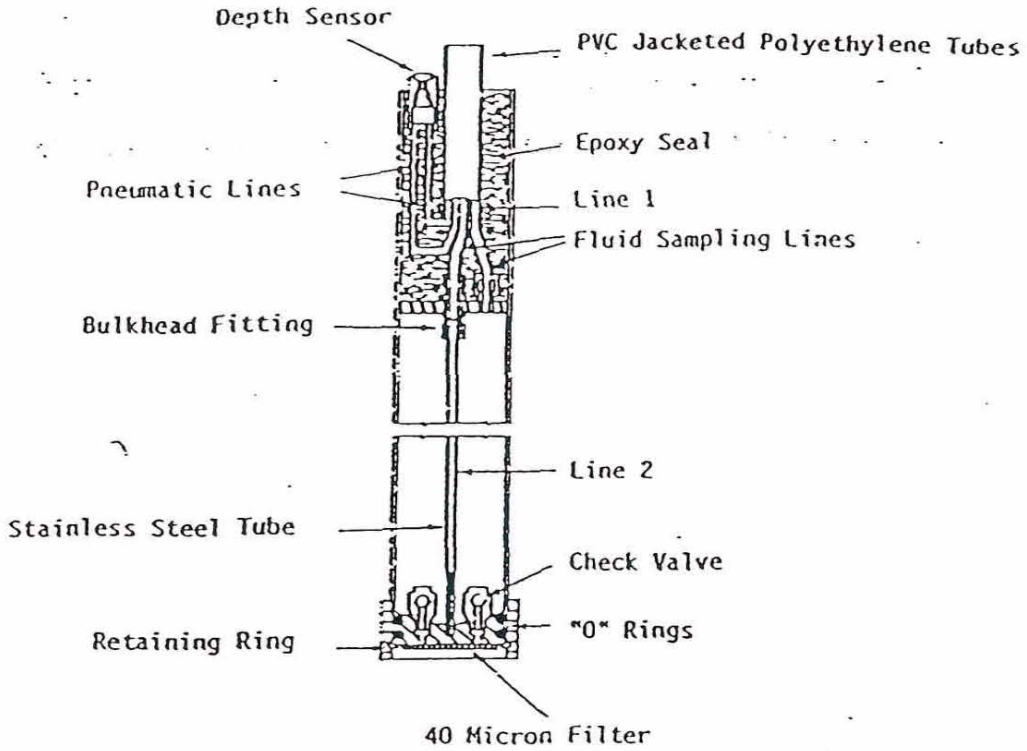
6.1.1.4 In operation, the single check valve bailer is lowered into the well, water enters the chamber through the bottom, and the weight of the water column closes the check valve upon bailer retrieval. The specific gravity of the ball should be about 1.4 to 2.0 so that the ball almost sits on the check 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.

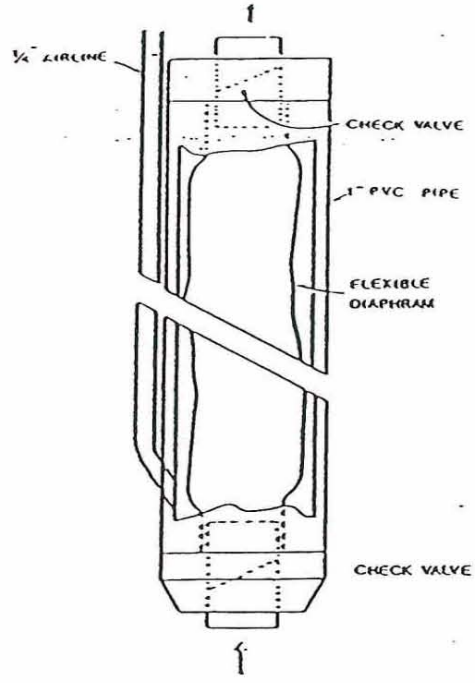
6.1.1.6 Another approach for obtaining point source samples employs a weighted messenger or pneumatic change to "trip" plugs at either end of an open tube (for example, tube water sampler or thief sampler) to close the chamber (18). Foerst, Kemmerer, and Bacon samplers are of this variety (14, 17, 19). 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 va materials and shapes.

6.1.2 *Suction Lift Pumps:*

6.1.2.1 Three types of suction lift pumps are the d line, centrifugal, and peristaltic. A major disadvantage of suction pump is that it is limited in its ability to raise v by the head available from atmospheric pressure. Thus, i surface of the water is more than about 25 ft below pump, water may not be withdrawn. The theoretical suc limit is about 34 ft, but most suction pumps are capab maintaining a water lift of only 25 ft or less.

6.1.2.2 Many suction pumps draw the water thr some sort of volute in which impellers, pistons, or c devices operate to induce a vacuum. Such pumps probably unacceptable for most sampling purposes bec they are usually constructed of common materials suc brass or mild steel and may expose samples to lubric They often induce very low pressures around rotating v or other such parts such that degassing or even cavita may occur. They can mix air with the sample via small l in the casing, and they are difficult to adequately c between uses. Such pumps are acceptable for purgin wells, but should not generally be used for sampling.

6.1.2.3 One exception to the above statements is a staltic pump. A peristaltic pump is a self-priming, volume suction pump which consists of a rotor with bearing rollers (21). Flexible tubing is inserted around pump rotor and squeezed by heads as they revolve circular pattern around the rotor. One end of the tubi placed into the well while the other end can be conn



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 Viton[3] 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.

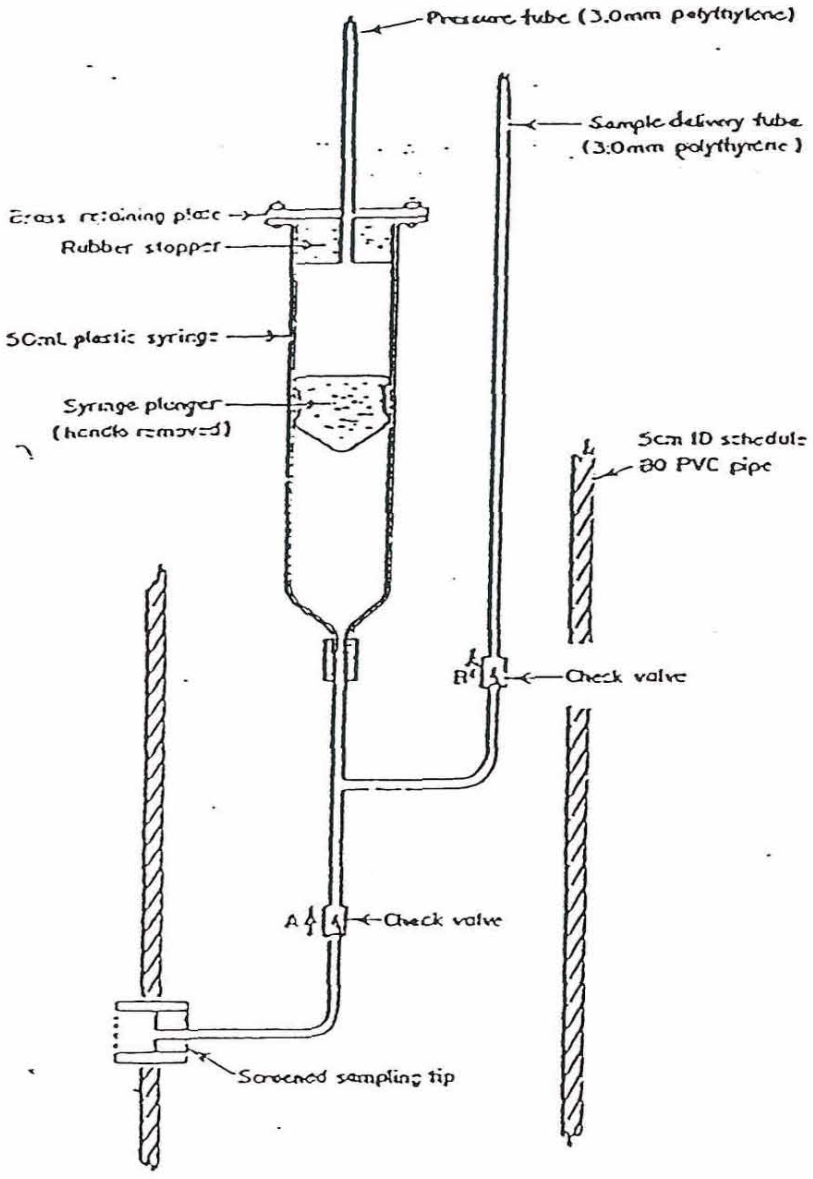
6.1.2.8 All three systems can be specially designed so that the water sample contacts only the TFE flourocarbon or silicone tubing prior to sample bottle entry. Separate tubing is recommended for each well or piezometer sampled.

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

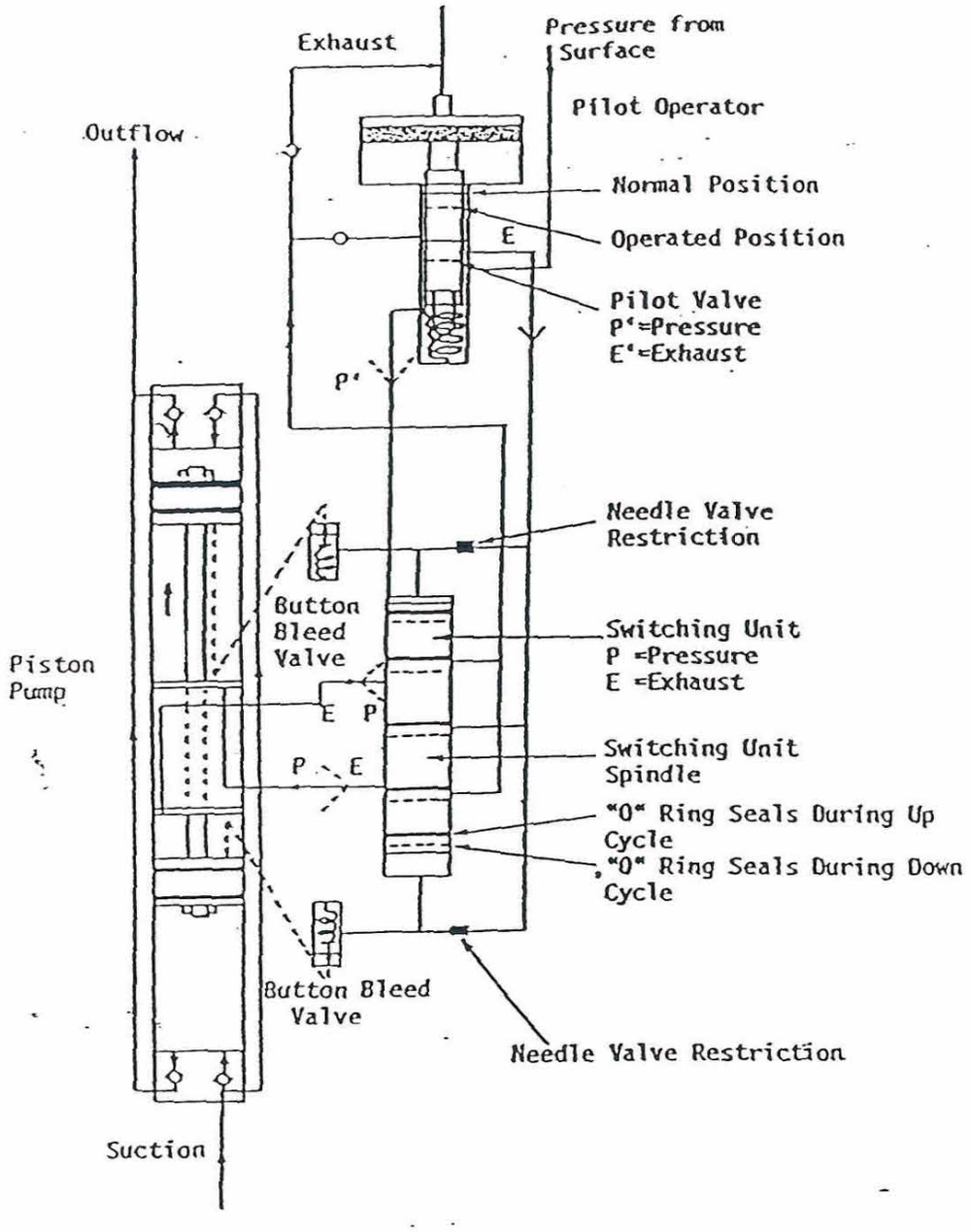
lift capabilities. A battery operated unit 3.6 cm (1.4 in.) in diameter and with a 4.5 Lpm (1.2 gpm) flow rate at 33.5 m (110 ft) has been developed (27). Another submersible pump has an outer diameter of 11.4 cm (4.5 in.) and can pump water from 91 m (300 ft). Pumping rates vary up to 53.0 Lpm (14 gpm) 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 wate sample to the surface. Water is forced up an eductor pip that may be the outer casing or a smaller diameter pip inserted into the well annulus below the water level (30, 31)

6.1.4.2 A similar principle is used for a unit that consist of a small diameter plastic tube perforated in the lower end This tube is placed within another tube of slightly large diameter. Compressed air is injected into the inner tube; th air bubbles through the perforations, thereby lifting the wate sample via the annulus between the outer and inner tubin (32). In practice, the eductor line should be submerged to depth equal to 60 % of the total submerged eductor lengt during pumping (26). A 60 % ratio is considered optima although a 30 % submergence ratio is adequate.



NOTE—Taken from Ref (49).

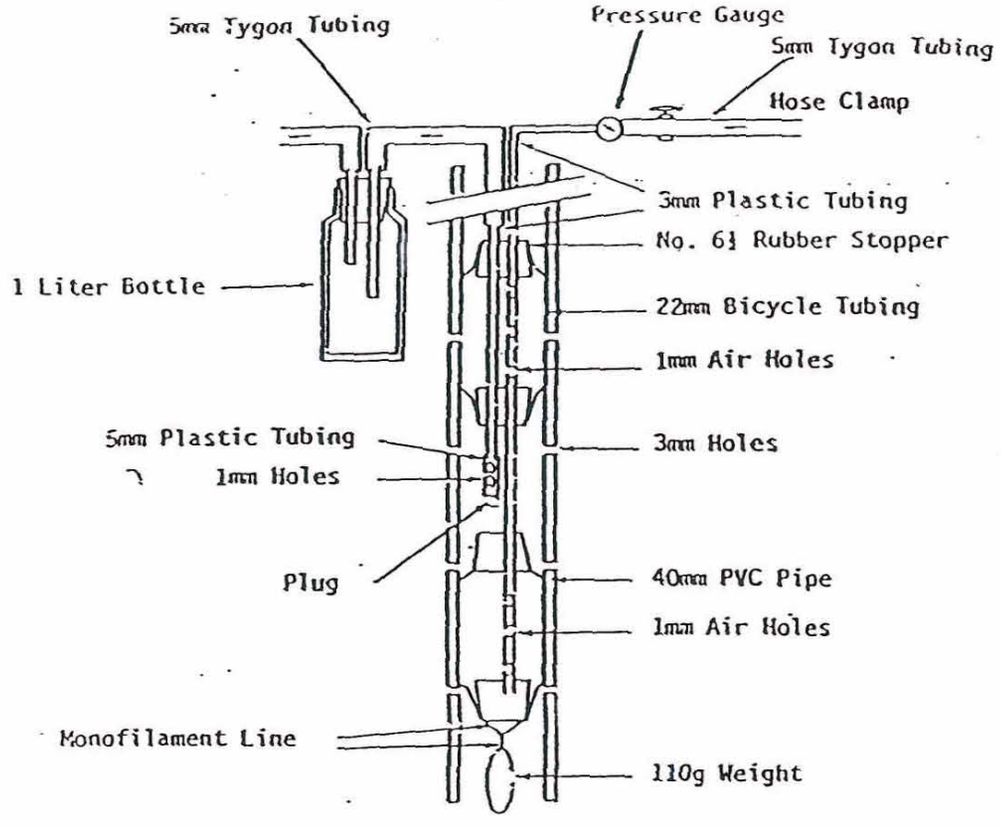
FIG. 9 Gas Driven Piston Pump

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 constan changes resulting from stripping, oxidation, and pressur changes.

6.1.5 *Gas Displacement Pumps:*

6.1.5.1 Gas displacement or gas drive pumps are distin guished from gas-lift pumps by the method of samp transport. Gas displacement pumps force a discrete colum of water to the surface via mechanical lift without extensi mixing of the pressurized gas and water as occurs with air-l equipment. The principle is shown schematically in F Water fills the chamber. A positive pressure is applied t



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 sample in Fig. 5 provides piezometric data measurements with an internally mounted transducer (40). A sample 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-operat squeeze pumps, consist of a flexible membrane enclosed by rigid housing. Water enters the membrane through a che valve in the vessel bottom; compressed gas injected into t cavity between the housing and bladder forces the samp through a check valve at the top of the membrane and into discharge line (Fig. 7). Water is prevented from re-enteri the bladder by the top check valve. The process is repeated cycle the water to the surface. Samples taken from depths 30.5 m (100 ft) have been reported.

6.1.6.2 A variety of design modifications and materi are available (43, 44). Bladder materials include neopre rubber, ethylene propylene terpolymer (E.P.T.), nitrile, a the fluorocarbon Viton.[3] A bladder made of TFE-fluo carbon is also under development (45). Automated sampl systems have been developed to control the time betw pressurization cycles (46).

6.1.6.3 Bladder pumps provide an adaptable samp tool due primarily to the number of bladder shapes that feasible. These devices have a distinct advantage over displacement pumps in that there is no contact with driving gas. Disadvantages include the large gas volu required, low pumping rates, and potential contamina from many of the bladder materials, the rigid housing 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 th best preservation technique available, but it is not the on measure nor is it applicable in all cases. There may be speci cases where it might be prudent to include a record thermometer in the sample shipment to verify the maximu and minimum temperature to which the samples we exposed. Inexpensive devices for this purpose are available

7.2 All bottles and containers must be specially pr cleaned, pre-labelled, and organized in ice-chests (isolatin samples and sampling equipment from the environmen before one goes into the field. Otherwise, in any comprehen sive program utter chaos usually develops in the field c laboratory. The time in the field is very valuable and shoul be spent on taking field notes, measurements, and i documenting samples, not on labelling and organizing sam ples. Therefore, the sampling plan should include clea instructions to the sampling personnel concerning the infor mation required in the field data record logbook (notebook the information needed on container labels for identifica tion, the chain-of-custody protocols, and the methods fo preparing field blanks and spiked samples. Example c detailed plans and documentation procedures have bee published (14, 53).

7.3 The exact requirements for the volumes of sampl needed and the number of containers to use may vary fror laboratory to laboratory. This will depend on the specifi analyses to be performed, the concentration levels of interes and the individual laboratory protocols. The manager of th sampling program should make no assumptions about th laboratory analyses. He should discuss the analytical require ments of the sampling program in detail with the laborat coordinator beforehand. This is especially the case si some analyses and preservation measures must be performe 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 availabl which list the containers and preservation techniques appro priate for water and soils (13, 14, 50, 54, 55, 56). Th "Handbook for Sampling and Sample Preservation of Wate and Wastewater" is an excellent reference and perhaps th most comprehensive one (14). Some of this information i summarized in Table 1.

7.5 Sample containers for trace organic samples requir special cleaning and handling considerations (57). Th sample container for purgeable organics consist of a screw cap vial (25 to 125 mL) fitted with a TFE-flourocarbon face silicone septum. The vial is sealed in the laboratory immedi ately after cleaning and is only opened in the field just pric to pouring sample into it. The water sample then must b sealed into the vial headspace free (no air bubbles) an immediately cooled (4°C) for shipment. Multiple sample (usually about four taken from one large sample containe are taken because leakage of containers may cause losse may allow air to enter the containers, and may caus erroneous analysis of some constituents. Also, some analyse are best conducted on independent protected samples.

7.6 The purgeable samples must be analyzed by th laboratory within 14 days after collection, unless they are t be analyzed for acrolein or acrylonitrile (in which case t are to be analyzed within 3 days). For samples for solv extractions (extractable organics-base neutrals, acids an

pesticides), the sample bottles are narrow mouth, screw cap quart bottles or half-gallon bottles that have been precleaned, 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 the concentration of each specific dissolved componen the total concentration of each. Samples for these typ measurements should be filtered through 0.45 μm r brane filters ideally in the field or possibly at an o laboratory as soon as possible. Analyses often requ filtered samples include all metals, radioactivity param total organic carbon, dissolved orthophosphate (if nec and total dissolved phosphorous (if needed) (13, 1 metals are to be analyzed, filter the sample prior to preservation. For TOC organics, the filter material shou tested to assure that it does not contribute to the TOC type or size of the filter to be used is not well unders However, if results of metal, TOC or other parameter could be effected by solids are to be compared, the filtering procedure must be used in each case. Rep analytical results should state whether the samples filtered and how they were filtered.

7.8 Shipment and receipt of samples must be coordi with the laboratory to minimize time in transit. All sa for organic analysis (and many other parameters), s arrive at the laboratory within one day after it is shippe be maintained at about 4°C with wet ice. The best way them to the laboratory in good condition is to send th sturdy insulated ice chests (coolers) equipped with dividers. 24-h courier service is recommended, if pe 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., Scalf, 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) Scalf, 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) Lounsman, 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, "Guideli Data Acquisition and Data Quality Evaluation in Environ Chemistry," *Analytical Chemistry*, Vol 52, 1980, pp. 2242–

(13) *Procedures Manual for Ground Water Monitoring at Solid Disposal Facilities*, EPA/530/SW-611, August 1977.

(14) *Handbook for Sampling and Sample Preservation of Wa Wastewater*, U.S. Dept. of Commerce NTIS PB-259 94 tember 1976.

(15) Timco Manufacturing Co., Inc., "Variable Capacity Bailer," *Geotechnical Catalogue*, Prairie du Sac, WI, 1982.

(16) deVera, E., Simmons, B., Stephens, R., Storm, D., *Sampl Sampling Procedures for Hazardous Waste Streams*, E mental Protection Agency, EPA-600/2-80-018, 1980, p. 51

(17) Morrison, R., *Ground Water Monitoring Technology*, Manufacturing Co., 1982, p. 276.

(18) Eijelkamp, "Equipment for Soil Research," *General Ca* Geisbeek, The Netherlands, 1979, pp. 82–83.

(19) Wood, W., "Guidelines for Collection and Field Ana Ground-Water Samples for Selected Unstable Constituents *niques of Water-Resources Investigations of the Unitec Geological Survey*, Chapter D2, 1976, p. 24.

(20) Gilham, R. W., "Syringe Devices for Groundwater Moni *Ground Water Monitoring Review*, Vol 2 (2), Spring 1982.

(21) Masterflex, *Masterflex Pump Catalogue*, Barnant Barrington, IL, 1981.

(22) "Guidelines for Contracting Sampling and Analyses for Pollutants in Pulp and Paper Industry Effluents," *NCASI Improvement Technical Bulletin*, No. 335, August 1980.

(23) Allison, L., "A Simple Device for Sampling Ground V Auger Holes," *Soil Science Society of America Proceed* 844–45, 1971.

(24) Willardson, L., Meek, B., Huber, M., "A Flow Path Grour

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-60017-80-134, 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 197[illegible]

(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 E
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 inacurracy 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 fraction 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
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

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
22.7	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

Temperature °C	2.Dissolved Oxygen mg/l 2.1.Chloride Concentration in Water 2.1.1.0 2.1.2.5,000 2.1.3.10,000 2.1.4.15,000 2.1.5.20,000 2.2.Difference/ 100 mg chloride					
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

Temperature °C	2.Dissolved Oxygen mg/l 2.1.Chloride Concentration in Water 2.1.1.0 2.1.2.5,000 2.1.3.10,000 2.1.4.15,000 2.1.5.20,000 2.2.Difference/ 100 mg chloride					
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
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

APPENDIX F
WATER LEVEL, WATER-PRODUCT LEVEL MEASUREMENTS, AND WELL DEPTH MEASUREMENTS

WATER LEVEL, WATER-PRODUCT LEVEL MEASUREMENTS, AND WELL DEPTH MEASUREMENTS
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- 5.4 Decontamination of Measuring Devices

6.0 QUALITY ASSURANCE RECORDS

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. A permanent notch, placed on the inner PVC or stainless steel casing by the surveyor will facilitate consistent water level measurements.

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 permanent point indicated at the top of the inner casing (the surveyed elevation point, as marked by the surveyor), unless otherwise specified in the project plans, using an electronic water level measuring device (water level indicator). The point of measurement will be documented in the field logbook if different from the top of the inner casing. The reason for deviating from the measurement point should also be noted.

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 Isopropanol

- 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.

APPENDIX G
PHOTO IONIZATION DETECTOR

PHOTOIONIZATION DETECTOR (PID)
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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 terpines 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 or wiped down daily or after each use, as appropriate.

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).

7.0 REFERENCES

HNu Systems, Inc. Instruction Manual. Model PI 101, 1986.
HNu Systems, Inc. Operator's Manual. Model DL 101, 1991.

APPENDIX H
BACHARACH OXYGEN/COMBUSTIBLE GAS METER

BACHARACH COMBUSTIBLE GAS/ OXYGEN METER PERSONAL GAS MONITOR TABLE OF CONTENTS

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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 O_2 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:

   % calibration gas (i.e., methane) x 20% LEL (meter alarm setting) = % LEL calibration setting

   If meter indication is within ±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 O_2 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

Function	Frequency
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 I
DECONTAMINATION OF SAMPLING AND MONITORING EQUIPMENT

DECONTAMINATION OF SAMPLING AND MONITORING EQUIPMENT

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DECONTAMINATION OF SAMPLING AND MONITORING EQUIPMENT

1.0 PURPOSE

The purpose of this SOP is to provide a general methodology and protocol, and to reference information for the proper decontamination of field chemical sampling and analytical equipment.

2.0 SCOPE

This procedure applies to all field sampling equipment including, but not limited to, split-barrel soil samplers (split-spoons), bailers, beakers, trowels, filtering apparatus, and pumps. This procedure should be consulted when decontamination procedures are being developed as part of project-specific plans. Additionally, current USEPA regional procedures and decontamination guidance as well as state guidance should be reviewed.

3.0 DEFINITIONS

Decontamination - Decontamination is the process of removing or neutralizing contaminants which may have accumulated on field equipment. This process ensures protection of personnel from penetrating substances, reduces or eliminates transfer of contaminants to clean areas, prevents mixing of incompatible substances, and minimizes the likelihood of sample cross-contamination.

4.0 RESPONSIBILITIES

Project Manager - It is the responsibility of the Project Manager to ensure that project-specific plans are in accordance with these procedures. Documentation should be developed for areas where project plans deviate from these procedures.

Field Team Leader - It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field. The Field Team Leader is responsible for ensuring field personnel performing decontamination activities have been briefed and trained to execute these procedures.

Sampling Personnel - It is the responsibility of field sampling personnel to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team Leader.

5.0 PROCEDURES

In order to ensure that chemical analysis results reflect actual concentrations present at sampling locations, sampling equipment must be properly decontaminated prior to the field effort, during the sampling program (i.e., between sampling locations) and at the conclusion of the sampling program. This will minimize the potential for cross-contamination between sampling locations and the transfer of contamination off site.

Preferably, sampling equipment should be dedicated to a given sampling location. If this is not possible, equipment must be decontaminated between sampling locations. Sampling personnel also must use disposable gloves and change them between sampling locations.

5.1 Sampling Equipment Decontamination Procedures

Soil and sediment sampling equipment including, but not limited to trowels, beakers, dredges, etc., shall be decontaminated using the following USEPA Region procedures.

The following sections summarize decontamination procedures for USEPA Regions I through IV for overall comparison. Each region should be contacted prior to initiation of sampling activities to assure that the most recent, accepted decontamination procedures are used.

USEPA Region I

Prior to use, all sampling equipment should be carefully cleaned using the following procedure:

1. A dilute hydrochloric acid rinse
2. Deionized water rinse
3. Methanol or acetone rinse; and,
4. Distilled, organic-free water rinse.

For badly contaminated equipment, a hot water detergent wash may be needed prior to the rinse procedure. Additionally, a hexane rinse also may be needed, prior to the final distilled water rinse, when sampling for low-level organic pollutants.

USEPA Region II

Prior to use, all sampling equipment will be decontaminated using the following procedure:

1. Low-phosphate detergent wash (i.e., Alconox or Liquinox)
2. Tap water rinse
3. 10 percent nitric acid solution rinse
4. Tap water rinse
5. Methanol followed by a hexane or an acetone rinse
6. Analyte-free deionized water rinse
7. Air dry
8. Wrap in aluminum foil, shiny side out, for storage or transport

If the samples will not be analyzed for metals, then steps 3 and 4 may be omitted; if samples will not be analyzed for organics, then step 5 may be omitted. All solvents must be pesticide-grade.

USEPA Region III

Prior to use, all sampling equipment will be decontaminated using the following procedure:

1. Potable water rinse
2. Alconox or Liquinox detergent wash
3. Scrubbing, as necessary
4. Potable water rinse
5. 10 percent nitric acid rinse
6. Distilled-deionized water rinse
7. Methanol or hexane rinse
8. Distilled-deionized water rinse
9. Air dry

USEPA Region IV

Prior to use, all sampling equipment will be decontaminated using the following procedures:

1. Clean with tap water and laboratory detergent using a brush if necessary to remove particulate matter and surface films.

2. Rinse thoroughly with tap water.

3. Rinse thoroughly with deionized water.

4. Rinse twice with pesticide grade isopropanol.

5. Rinse thoroughly with organic-free water and allow to air dry as long as possible.

6. If organic-free water is not available, allow equipment to air dry as long as possible. Do not rinse with deionized or distilled water.

7. Wrap with aluminum foil, if appropriate, to prevent contamination if equipment is going to be stored or transported.

* Portable power augers (such as the Little Beaver®) or large soil boring/drill rigs should be cleaned before boring or drilling operations.

5.2 Field Analytical Equipment Decontamination

Field analytical equipment which may come in direct contact with the sample or sample media, including, but not limited to water level meters, water/product level meters, pH or specific ion probes, specific conductivity probes, thermometers, and/or borehole geophysical probes must be decontaminated before and after use, according to the procedures outlined in Section 5.1, unless manufacturers instructions indicate otherwise. Probes that contact water samples not used for laboratory analyses may be rinsed with distilled water. Probes which make no direct contact (e.g. HNu or OVA probes) will be wiped clean with clean paper towels or an alcohol-saturated cloth.

6.0 QUALITY ASSURANCE RECORDS

Decontamination procedures are monitored through the collection of equipment rinsate samples and field blanks. Collection of these samples shall be specified in the project-specific Sampling and Analysis and Quality Assurance Plans following the requirements of NEESA 20.2-047B. Documentation recorded in the field logbook also shall serve as a quality assurance record.

7.0 REFERENCES

NEESA 20.2-047B. Sampling and Chemical Analysis Quality Assurance Requirements for the Navy Installation Restoration Program. Naval Energy and Environmental Support Activity. Port Hueneme, CA. June 1988.

U. S. EPA Office of Waste Program Enforcement. RCRA Ground Water Monitoring Technical Enforcement Guidance Document (TEGD). OSWER Directive 9950.1. 1986.

U. S. EPA. Standard Operating Procedures and Quality Assurance Manual. Environmental Compliance Branch, U. S. EPA Environmental Services Division, Athens, Georgia. 1991.

Micham, J. T., R. Bellandi, E. C. Tifft, Jr. "Equipment Decontamination Procedures for Ground Water and Vadose Zone Monitoring Programs: Status and Prospects." in Ground Water Monitoring Review. Spring 1989.

APPENDIX J
DECONTAMINATION OF DRILL RIGS AND MONITORING WELL MATERIALS

DECONTAMINATION OF DRILLING RIGS AND MONITORING WELL MATERIALS

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DECONTAMINATION OF DRILLING RIGS AND MONITORING WELL MATERIALS

1.0 PURPOSE

The purpose of this SOP is to provide a general reference regarding the proper decontamination of drilling rigs and monitoring well materials used in the performance of field investigations.

2.0 SCOPE

This procedure addresses drilling equipment, test pit equipment (i.e. backhoe) and monitoring well material decontamination and should be consulted during the preparation of project-specific plans. This procedure does not pertain to personnel decontamination, or to chemical sampling or field analytical equipment decontamination.

3.0 DEFINITIONS

Decontamination - Decontamination is the process of removing or neutralizing contaminants which may have accumulated on field equipment. This process ensures protection of personnel from penetrating substances, reduces or eliminates transfer of contaminants to clean areas, prevents mixing of incompatible substances, and minimizes the likelihood of sample cross-contamination.

4.0 RESPONSIBILITIES

Project Manager - It is the responsibility of the Project Manager to ensure that project-specific plans are in accordance with these procedures. Documentation should be developed for areas where project plans deviate from these procedures.

Field Team Leader - It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field. The Field Team Leader is responsible for ensuring the field personnel overseeing decontamination activities, and personnel conducting the activities have been briefed and trained to execute these procedures.

Drilling Inspector (Site Geologist, Rig Geologist etc.) - It is the responsibility of the drilling inspector to ensure that the drilling subcontractor follows these, or other project-specific procedures as directed by the Field Team Leader.

5.0 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.

5.1 Equipment

All drilling equipment involved in field sampling activities shall be decontaminated prior to drilling, excavation, or sampling activities. Such equipment includes drilling rigs, backhoes, augers, downhole tools, well casings, and screens. Split-spoon soil samplers and other similar soil sampling devices shall be decontaminated according to the procedures given in SOP F502.

5.2 Decontamination Procedures

Prior to drilling, or leaving the site, large equipment not directly utilized for sampling will be decontaminated by steam-cleaning in a designated area. The decontamination procedure consists of steam-cleaning the equipment, using potable water as the steam source, to remove visible signs of soils or wastes, and allowing the equipment to air dry. If necessary, the equipment may be cleaned with a scrub brush and alconox/liquinox-water solution prior to steam cleaning to remove visible signs of contamination.

The steam cleaning area will be designed to contain decontamination wastes and waste waters, and can be a lined, excavated pit or a bermed concrete or asphalt pad. For the latter, a floor-drain must be provided which is connected to a holding tank. A shallow, above-surface tank may be used or a pumping system with discharge to a waste tank may be installed.

At certain sites, due to the type of contaminants or proximity to residences, concerns may exist about air emissions from steam cleaning operations. These concerns can be alleviated by utilizing one or more of the following practices:

- Locate the steam cleaning area on site to minimize potential impacts.
- Enclose steam cleaning operations. For example, augers and drilling rods can be steam cleaned in drums. Tarpaulins also can be placed around the steam cleaning area to control emissions.

For a given project, the location of the steam cleaning area will be identified in the Sampling and Analysis Plan.

Decontamination wastes will be collected and contained unless otherwise directed by LANTDIV. The eventual disposition of these wastes will be determined on a project-specific basis, but may include on-site treatment and/or transport off site to an approved treatment/disposal facility.

6.0 QUALITY ASSURANCE RECORDS

Rinsate samples may be collected from steam-cleaned equipment as quality assurance records. The frequency of rinsate samples from either drilling tools or well casings/screens shall be specified in the Sampling and Analysis and Quality Assurance Project Plans for a given project, as appropriate.

Documentation in the field logbook also shall serve as a quality assurance record of decontamination activities.

7.0 REFERENCES

None.

APPENDIX K
GROUND PENETRATING RADAR SURVEY

GEOPHYSICS: GROUND PENETRATING RADAR (GPR)
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GEOPHYSICS: GROUND PENETRATING RADAR (GPR)

1.0 PURPOSE

The purpose of this SOP is to provide general reference information and technical guidance on the methods and techniques of ground penetrating radar (GPR).

2.0 SCOPE

These procedures provide overall technical guidance.

3.0 DEFINITIONS

Bistatic Antenna - An antenna system in which transmitting and receiver coils are housed in separate antenna units.

Deconvolution - A computer processing method. The process of undoing the effect of another filter (in this instance the "earth"). A process that removes ringing, multiples, ghosts, and some background noise (Sheriff, 1973).

Dielectric Permittivity - (Also known as the relative dielectric permittivity): 1. A complex number consisting of a real and imaginary part, which uniquely describes the propagation and attenuation of electromagnetic energy in every material. The real dielectric permittivity (dielectric constant) characterizes the propagation and reflection of electromagnetic (EM) waves, while the imaginary part (dielectric loss) characterizes the attenuation of EM signal (Kutrubes and Olhoeft, 1987). 2. A measure of the capacity of a material to store charge when an electric field is applied (Sheriff, 1973).

Electromagnetic Waves - One of the waves that are propagated by simultaneous periodic variations of electric and magnetic field intensity and that include radio waves, infrared, visible light, ultraviolet, X-rays and gamma rays (Webster's New Collegiate Dictionary. 1979).

Migration - here velocity varies laterally, data will migrate (relative to the time versus antenna distance plot), and ray tracing is used to determine migrated positions (Sheriff, 1973).

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that the project-specific plans are in accordance with these procedures, where applicable, or that other approved procedures are developed. The Project Manager is responsible for ensuring that the personnel operating and interpreting the geophysical data are trained, skilled in that endeavor, so far as to receiving documentation on the training and experience of the operating personnel.

Field Team Leader - The Field Team Leader is responsible for selecting and detailing the geophysical technique and equipment to be used. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that the field investigation personnel performing the activities have been briefed and trained to execute these procedures.

5.0 PROCEDURES

5.1 Overview

Ground penetrating radar (GPR) is an active geophysical system which transmits high frequency electromagnetic (EM) waves into the ground and detects the energy reflected back to the surface. GPR operates on a similar principle as seismic reflection, except, instead of acoustic waves, electromagnetic waves of radio and microwave frequencies (80 MHz to 1,000 MHz) are utilized. Electromagnetic signals are reflected back to the surface from interfaces with differing electrical properties, such as dielectric permittivity and conductivity. The greater the contrast in the real dielectric permittivity (dielectric constant) between two materials, the more energy is reflected to the surface. Reflections typically occur at lithologic changes, subsurface discontinuities, and internal soil structures such as:

- Top of bedrock surfaces
- Soil and rock stratification
- Water table
- Seepage and leachate zones
- Buried metal objects such as drums and utilities
- Open and water filled voids
- Bedrock fractures
- Archaeological structures

The depth of penetration of GPR is site specific, being limited by the attenuation of the electromagnetic energy. Signal attenuation is controlled by four different mechanisms listed below, any or all of which may be present at a site.

- Scattering losses
- Conduction losses
- Water losses
- Clay losses

Energy losses due to scattering occur when signals are dispersed in random directions, away from the receiving antenna, by large irregularly shaped objects, such as boulders and tree stumps.

Signal attenuation due to conduction is a function of the conductivity of a material, which varies with mineral composition, the amount of water, and the total dissolved solids (salt, heavy metals) within the water. The greater the electrical conductivity values of materials at a site, the more signal attenuation (hence less penetration) there will be.

Energy losses attributed to water occur when water molecules polarize in the presence of the applied electromagnetic field. Electromagnetic energy is lost to the radar system when it is converted to kinetic and thermal energy as a result of the rotation of water molecules.

Signal attenuation due to clay losses occurs when electrochemically charged ions polarize along clay surfaces in the presence of the electromagnetic field induced by the radar system. The migration and subsequent collision of these charged particles causes electromagnetic energy to be converted to kinetic and thermal energy, which is lost to the radar system.

Signal penetration is also dependent on the frequency of the transmitting antenna used in the radar system. Higher frequency antennas produce waves with shorter wave lengths, which are attenuated more rapidly with depth, but give better resolution. Specially designed 2 MHz antennas have been used to detect the ice-rock boundary of a 2 km thick glacier. Penetration of up to 75 feet has been reported for water saturated, clean sands in a Massachusetts glacial delta using a commercial antenna. Signal penetration in saturated clays, on the other hand, is on the order of magnitude of a few inches. Olhoeft (1986a) determined that even 5% clay added to a clean sand and gravel will cause a decrease in penetration by a factor of 20. Salt water is also a high loss substance, as signal penetration in sea water is less than a foot. It is important to note that in a layered medium a single, highly reflective layer alone can limit signal penetration by preventing the propagation of energy through it. In this instance the apparent loss of energy is caused by reflection rather than by signal attenuation.

5.2 Applications and Uses

Ground penetrating radar (GPR) is a shallow penetrating geophysical profiling system used where rapid and accurate surveys are desired. GPR can be used for both area and source detection studies. GPR has been used to locate underground pipes, buried drums, foundations, voids in rock and concrete, lithologic contacts, determine stratigraphy, depth to the water table, and depth to bedrock, locate buried archaeological artifacts, excavations, filled pits and lagoons, and numerous other site specific applications. GPR has been used successfully to delineate the lateral extent of plumes. Haeni et al. (1985) used GPR to investigate the thickness, type, and extent of sediments beneath a frozen lake with a 80 MHz antenna. The information acquired with GPR was used to help map the lateral extent of an aquiclude, and better estimate inputs to the mass balance equation for water budget calculations.

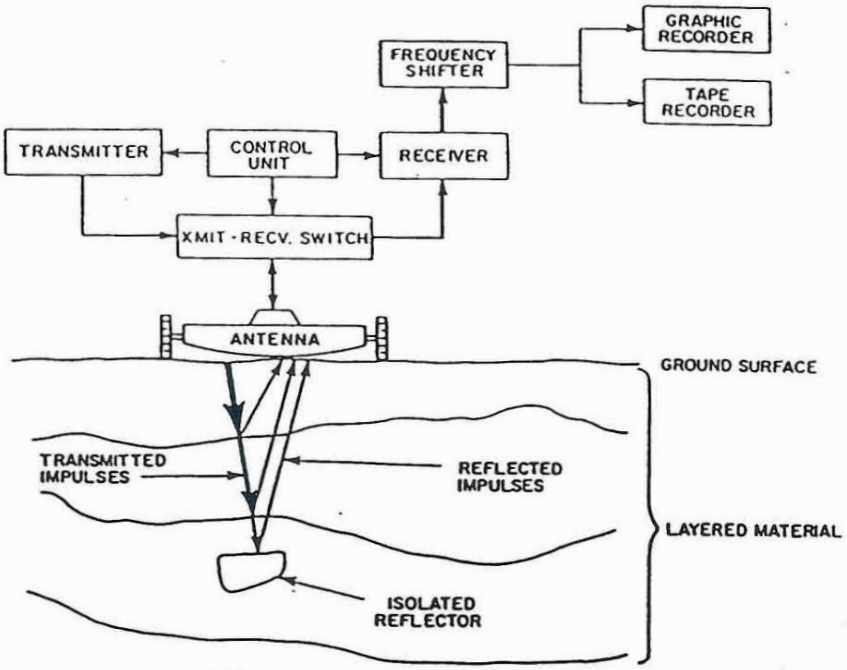
A GPR system can be used to determine depths to reflecting discontinuities by conducting a depth calibration. Typically, calibration is performed by moving the radar antenna over a metal target of known depth, such as a buried metal plate. Also, if transmitting and receiving antennas are housed in different units, designated as a bistatic antenna system, a common depth point (CDP) survey, identical to surveys conducted with seismic reflection, can be used to calculate the velocity of the medium, and hence depth to the reflector. Sakayama and others (1988) describe another method to calculate velocity from bistatic antennas where the receiving antenna is continually moved away from the stationary transmitting antenna. The velocities of the direct arrival and the first strong reflector are recalculated from the inverse slope of the time-distance display (antenna separation) on the GPR record in a similar manner as seismic refraction.

To verify GPR results, other geophysical or ground truth methods can be utilized. Haeni et al. (1985) utilized seismic refraction to correlate calculated depths of stratigraphic horizons and water tables with radar reflections. Magnetometry and electromagnetic induction methods have been utilized to verify the presence of buried drums and fuel tanks. Electromagnetic induction and electrical resistivity have been utilized to verify the lateral extent of conductive plumes. The depth to a particular reflector or target can also be verified by boreholes and/or test pit excavation.

5.3 Equipment

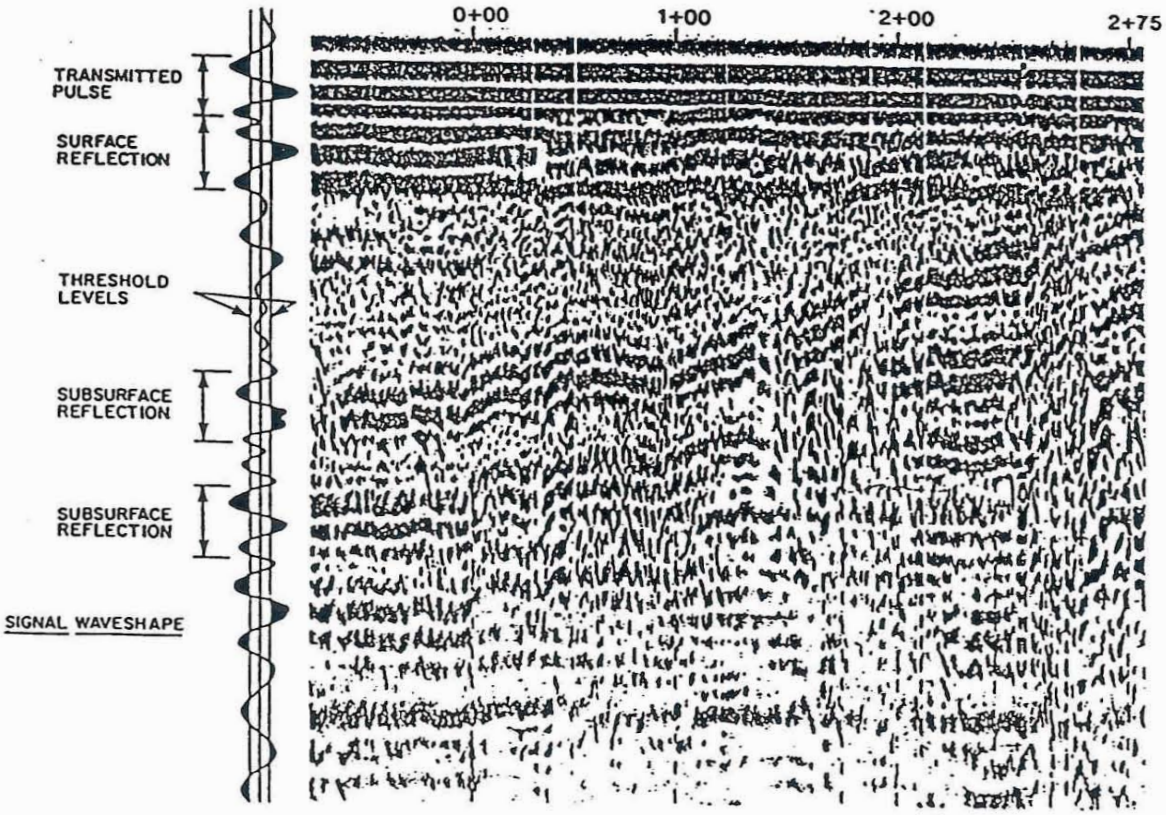
A ground penetrating radar system, shown on Figure 1, consists of:

- AC/DC power supply
- Control unit (pulse transmitter)
- Antenna(s)



RADAR SYSTEM BLOCK DIAGRAM

FIGURE 1



TYPICAL RADAR RECORD

GROUND PENETRATING RADAR SET-UP

- Graphic recorder
- Digital recorder (optional)
- Magnetic tape recorder (optional)
- Coaxial cable which connects the control unit to the antenna

Typically, radar antennas contain both the transmitter and receiver within one fiberglass unit. Once a radar impulse is transmitted, the antenna switches to the receiver mode and records reflected radar impulses. The pulse receiver contains an amplifier which increase the amplitude of reflected signals. Bistatic antennas (transmitter-receiver are separate) allow the coverage of larger areas with one pass, and multi-receiver combinations allow the "stacking" of radar data which increases the signal to noise ratio.

Field data are generally printed by a graphic recorder and simultaneously can be stored on magnetic tape or diskette. The graphic recorder produces a continuous time (vertical) versus distance (horizontal) profile of the subsurface for field quality control and qualitative interpretations. Radar impulses are synchronized with the swept-stylus type graphic recorder, producing a dark band proportional to the amplitude of reflected radar signal. Because the antenna is moving, each pass of the stylus represents a slightly different antenna position. Gradually, as the recorder paper advances under the moving stylus, a pattern of reflective interfaces emerges.

Storage of data on diskette or magnetic tape allows opportunity of additional printing and/or computer processing for the refinement of data. Deconvolution of stored data enhances stratigraphic reflections from the water table and soil structures (Olhoeft, 1988). Migration of data allows easier resolution of metallic targets, such as buried drums, and delineation of excavations and sinkholes (Hogan, 1988).

Radar systems are designed to use antennas of various electrical characteristics. Selection of the antenna is dictated by the requirements of the survey. If high resolution, near-surface data are desired, a small, high frequency antenna is used; if the survey requires deeper probing, a larger, lower frequency antenna is used (80, 120, 250, 300, 400, 500, 900, and 1,000 MHz antennas are commercially available). The drawback of using the lower frequency antennas is that resolution of data is sacrificed for penetration. Also, the low frequency antennas (less than 250 MHz) are generally not shielded, making them susceptible to overhead power line noise and spurious reflections from passing cars. The 900 and 1,000 MHz antennas are used almost exclusively for short penetration projects such as the detection of rebar in concrete, as their penetration is generally limited to 2 to 3 feet.

5.4 Field Procedures

The majority of time involved with any GPR survey is spent establishing survey lines in the area of investigation so that detected anomalies can be easily located and excavated. Survey lines should be set to maximize coverage, while maintaining a grid spacing proportional to the presumed target dimensions. A minimum survey line spacing of 10 feet is desired when looking for a 1,000 gallon fuel tank, while a larger spacing of 50 feet or more may be used to define the lateral extent of a conductive plume.

At the onset of any GPR survey the radar control unit should be adjusted for the anticipated depth of penetration. Adjustments of the time window of exploration should be made by estimating the velocity of the medium and desired depth of penetration. Most surveys can be effectively conducted with a minimum time window of 50 nanoseconds.

Accurate determination of the depth to any layer requires calibration of the radar system. The easiest way of calibrating the GPR system to specific settings is by burying a plate at a measured depth, and moving the antenna slowly along the survey line. The plate will produce on the GPR record a thick, dark band, parabolic or flat in shape, with many multiple reflections beneath it. Once a certain confidence level is attained from depth calibration, the survey is conducted by slowly pulling the antenna along survey lines. A slow walking pace increases the horizontal resolution as radar signals are propagated in a 15 to 45 degree cone from the bottom of the antenna. A slow walking pace is recommended for hazardous waste investigations as targets are better defined and easier to resolve. On the other hand, the radar antenna can be towed from the back of a car or truck at speeds up to 10 miles an hour if the "target" is a continuous reflector, such as the water table.

5.5 Interpretation

A typical GPR record is shown on Figure 1. A representation of a single GPR signal pulse is shown along the side of the record. The horizontal scale of the record is maintained by marking on the record the locations of survey stations as they are reached by the antenna. Accurate determination of the vertical scale (i.e., conversion of a time into a depth) requires calibration of the radar system. If the depth to a known reflector can not be determined through calibration or verification using boreholes and test pits, the velocity of the medium can be approximated from relationships involving the velocity of the medium, and the dielectric constant (real dielectric permittivity) of the medium. Values of the dielectric constant can be found in GSSI (1974), and Kutrubes (1986). It is important to note that the relationship is no longer valid when signal losses are great. The depth to the reflector can be calculated from time and velocity values.

Interpretation of GPR data is subjective, even among experienced interpreters. The strength of a reflected signal and/or the continuity of that reflector across the record may be indicative of a stratigraphic contact. The water table in an unconfined sand and gravel aquifer may also produce a similar signature on the GPR record. The strong continuous reflector shown in Figure 2 delineates the contact between bedrock and unconsolidated materials. Point targets, such as buried drums, pipes, boulders, tree stumps, etc., create a distinctive parabolic feature on GPR records. Positive identification of point targets are subjective, as the GPR signature of a pipe is similar to that of a large boulder.

Figure 3 shows the characteristic parabolic signal created by a point target, underground storage tanks in this instance, which are situated in a clean sand and gravel deposit. Metallic objects, such as buried drums and pipes, also produce a characteristic parabolic signal on the record, and sometimes produces a "ringing" noise, denoted by the heavy, dark banding, as shown in Figure 3.

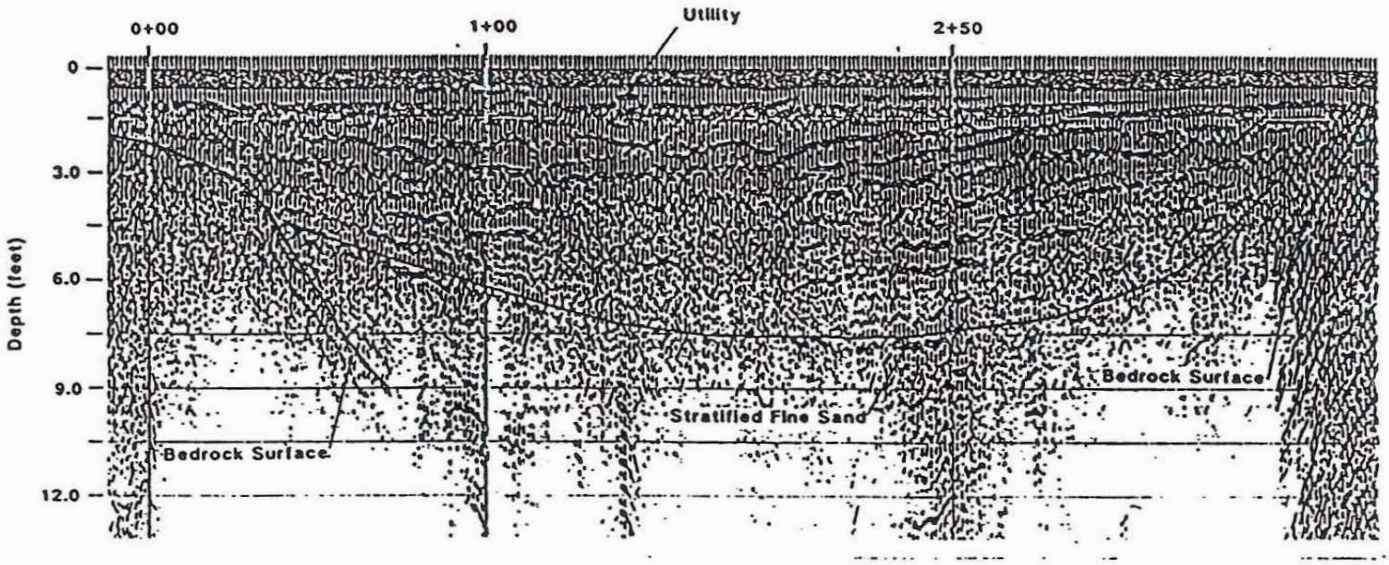
Recorded data from diskettes or magnetic tapes can be enhanced using numerous computer processing methods to remove constant noise problems, such as ringing, or to sharpen up geologic contact features and point target boundaries. Such methods are described in detail by Hogan (1988) and Olhoeft (1988). Computer processing is costly and generally not necessary in most instances.

5.6 Advantages/Disadvantages

Advantages of ground penetrating radar systems include:

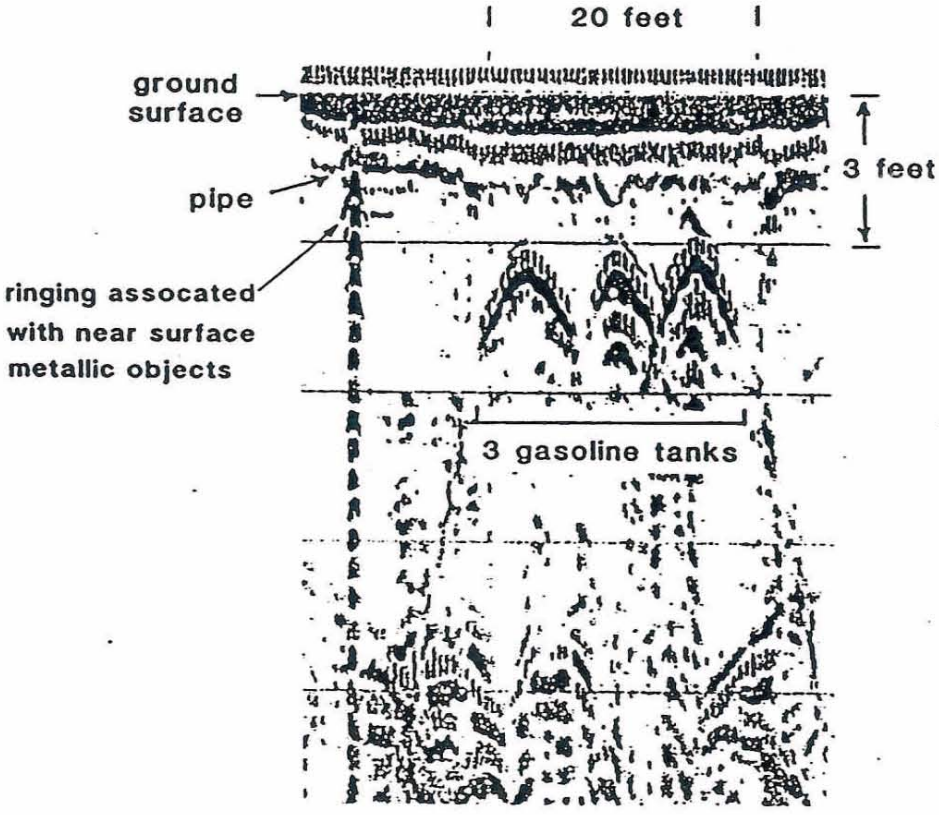
- Rapid coverage of an area
- GPR is a non-destructive technique
- Portable equipment
- Provides high vertical resolution profiles in the field for immediate interpretation

FIGURE 2



GROUND PENETRATING RADAR RECORD
OF A BURIED RIVER CHANNEL

FIGURE 3



GROUND PENETRATING RADAR RECORD
OF BURIED FUEL TANKS

Ground penetrating radar provides a cost effective way of evaluating a large site in a short amount of time. One day of work coverage completed by GPR may be equivalent to four or five days of work with seismic refraction or electrical resistivity. The GPR method is "non-destructive" in that it does not require any excavation or probing of the overburden materials, although verification of anomalies should be conducted.

Equipment can be easily loaded in the back of a truck as most pieces comprising the radar system weigh under 40 pounds. The 80 MHz antenna weighs about 100 pounds and is less portable as it is approximately 4 feet wide.

Limitations of radar systems include:

- Survey lines must be cleared to ground level
- Multiple receiver antennas are generally required to stack and process radar data
- Penetration is site specific, requiring data corroboration using alternative geophysical methods and/or verification
- Interpretations are subjective

To maximize resolution and minimize scattering losses, survey lines must be as level as possible to prevent the bouncing and jarring of the radar antenna. Survey lines cleared of debris also allow the antenna to be pulled at an even, continuous pace, permitting the easy determination of horizontal scale.

Application of GPR to a site is limited by soil type and presence of high loss materials. In New England, the presence of glacial tills, and lacustrine and marine clays limit the depth of penetration. Delineation of buried drums beneath a conductive plume also may not be possible. The unpredictability of radar effectiveness requires that site investigations be conducted with alternative geophysical methods, such as electromagnetic induction, seismic refraction, magnetometry, and/or electrical resistivity.

6.0 QUALITY ASSURANCE RECORDS

All data will be recorded in field log books with the following information: date, location, personnel on site, start and finish times (in military time), instrument gain and time settings, and Contract Task Order number.

7.0 REFERENCES

Benson, R.C., and Glaccum, R.A., 1979, Remote Assessment of Pollutants in Soil and Ground Water, in the Proceedings of the 1979 Conference on Hazardous Material Risk Assessment, Disposal and Management: Information Transfer Inc., Miami Beach, April 25-27, p. 188-194.

Haeni, F.P., McKeegan, D.K., and Capron, D.R., 1987, Ground Penetrating Radar Study of the Thickness and Extent of Sediments Beneath Silver Lake, Berlin and Meriden, Connecticut: U.S.G.S. Water Resources Investigations Report 85-4108, 19 p.

Hogan, G., 1988, Migration of GPR Data: A Technique for Locating Subsurface Targets, in Proceedings of the Second International Symposium on Geotechnical Applications of Ground Penetrating Radar: West Gainesville, Florida, March 6-10 sponsored by the U.S. Dept. of Agriculture, Washington, DC, p. 164-179.

IEEE Wave Propagation Standards Committee, 1977, IEEE Standard Definitions of Terms for Radio Wave Propagation: IEEE Standard No. 277, Piscataway, NJ, IEEE Inc., 14 p.

Kutrubes, D.L. and Olhoeft, G.R., 1987, Dielectric Permittivity Measurements; Applications to GPR: Presented at the AGU Fall Meeting, December 7-12, 1987, American Geophysical Union Transactions, v. 68, no. 44, p. 1282-1283.

Kutrubes, D.L., 1986, Dielectric Permittivity Measurements of Soils Saturated with Hazardous Fluids: H.Sc. Thesis, Colorado School of Mines, Golden, CO, 300 p.

Olhoeft, G.R., 1988, Applications and Limitations of Computer-Processed Ground Penetrating Radar Data, in Abstracts for the Second International Symposium on Geotechnical Applications of Ground Penetrating Radar: West Gainesville, Florida, March 6-10, sponsored by the U.S. Dept. of Agriculture, Washington, DC, p. 37.

Olhoeft, G.R., 1986a, Electrical Properties From 103 to 109 Hz-Physics and Chemistry, in Proceedings of the Second International Symposium on the Physics and Chemistry of Porous Media: Houston, Texas, Schlumberger-Doll, October, 18 p.

Olhoeft, G.R., 1986b, Direct Detection of Hydrocarbon and Organic Chemicals with Ground Penetrating Radar and Complex Resistivity, in Proceedings of the Conference on Petroleum Hydrocarbons and Organic Chemicals in Ground Water - Prevention, Detection and Restoration: held Nov. 12-l4, Houston, National Water Well Association, Worthington, Ohio, 22 p.

Sakayama, T., Osada, M., and Tamura, K., 1988, Some Examples of Archaeological Investigations Using Ground Probing Radar, in Proceedings of the Second International Symposium on Geotechnical Applications of Ground Penetrating Radar: West Gainesville, Florida, March 6-10, sponsored by U.S. Dept. of Agriculture, Washington, DC, p. 57-61.

Sheriff, R.E., 1973, Encyclopedic Dictionary of Exploration Geophysicists: Tulsa, OK, Society of Exploration Geophysicists, 266 p.

APPENDIX L
MAGNETOMETRY SURVEY

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GEOPHYSICS: MAGNETOMETRY

1.0 PURPOSE

This SOP provides general reference information and standard techniques for using magnetometry.

2.0 SCOPE

This SOP provides a description of the field procedures, equipment, and interpretation methods necessary to fully utilize this procedure.

3.0 DEFINITIONS

Diurnal variations - daily changes in the total magnetic field strength due to solar activity and which (may be as large as 100 gammas or more)

Gradient - change in magnetic field strength in a given vertical or horizontal distance

Magnetic storm - sudden and simultaneous variations of up to several hundred gammas throughout the world. Magnetic storms can occur as often as several times a month and can last one to several days.

Total magnetic field intensity - a scaler measurement of the magnitude of the earth's magnetic field vector independent of its direction.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that the project-specific plans are in accordance with these procedures, where applicable, or that other approved procedures are developed. The Project Manager is responsible for ensuring that the personnel operating and interpreting the geophysical data are trained, skilled in that endeavor, so far as to receiving documentation on the training and experience of the operating personnel.

Field Team Leader - The Field Team Leader is responsible for selecting and detailing the geophysical technique and equipment to be used. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that the field investigation personnel performing the activities have been briefed and trained to execute these procedures.

5.0 PROCEDURES

5.1 Overview

Magnetic surveying is a passive geophysical technique which measures the strength of the earth's magnetic field. The earth's field is a vector quantity having a unique magnitude and direction at every point on the earth's surface. A magnetometer is the instrument which measures the magnetic field strength in units of gammas or nanoteslas. In order to recognize a magnetic anomaly, it must be several times larger than the background noise level along that profile. Buried ferrous metal objects such as steel drums or tanks cause local variations or anomalies in the earth's magnetic field that can be detected by a magnetometer. Geologic features such as igneous intrusion or iron rich sands can also be mapped using magnetic surveying.

The earth's magnetic field is not completely stable. It undergoes long-term (secular) variations over centuries; small, daily (diurnal) variations (less than 1% of the total field magnitude); and transient fluctuations called magnetic storms resulting from solar flare phenomena. Both naturally-occurring and manmade magnetic materials can modify the earth's magnetic field locally.

Analysis of magnetic data by an experienced geophysicist can provide an estimate of the areal extent and quantity of buried ferrous objects. Depth of burial approximations can be made using graphical methods of interpretation such as slope techniques and half-width rules as described in Nettleton (1976).

5.2 Application and Uses

Buried ferrous metal objects such as pipelines, barrels, tanks, etc., generally produce a perturbation in the earth's naturally occurring magnetic field. The size (amplitude) of this perturbation is related to the size of, distance to, susceptibility and remanent magnetization of the buried object. The magnetic survey method, therefore, is a useful tool for site studies to locate and identify buried ferrous metal. Figures 1 and 2 shows magnetic profiles and contour maps over buried metal objects. Non-anomalous magnetic data acquired over EM conductivity anomalies is an indication of the existence buried conductive, non-ferrous metal (copper, aluminum, brass) objects.

Magnetic data also can be helpful in determining the size and geometry of geologic features such as fault zones, mineralized zones, and bedrock valleys and depressions. These features are characterized generally by longer wavelength anomalies and are readily distinguishable from anomalies associated with buried metal. In many areas, such geologic features may control or affect the direction and magnitude of groundwater flow.

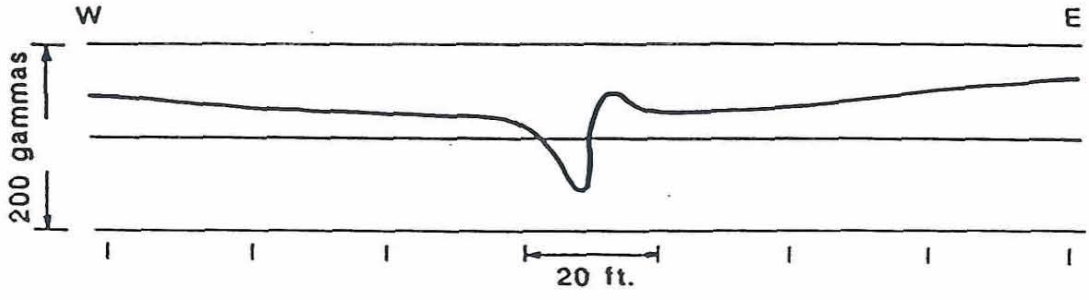
The total field proton precession magnetometer, the fluxgate magnetometer, and the magnetic gradiometer are commonly used magnetometers in environmental site investigations. The total field proton precession magnetometer is the most commonly used magnetometer because they are easy to operate, have no instrumental drift, and can acquire data rapidly. The fluxgate magnetometer can better define the boundaries of buried ferrous objects than the proton precession magnetometer but is subject to instrument drift, and needs to be exactly oriented. Magnetic gradiometer measurements enhance anomalies resulting from shallow magnetic sources.

5.3 Equipment

Magnetometers commonly used in hazardous waste site investigations include the total field proton procession magnetometer, the flux gate magnetometer, and the magnetic gradiometer. Text books such as Telford (1976) and Nettleton (1976) discuss in detail the operation and construction of these and other magnetometers.

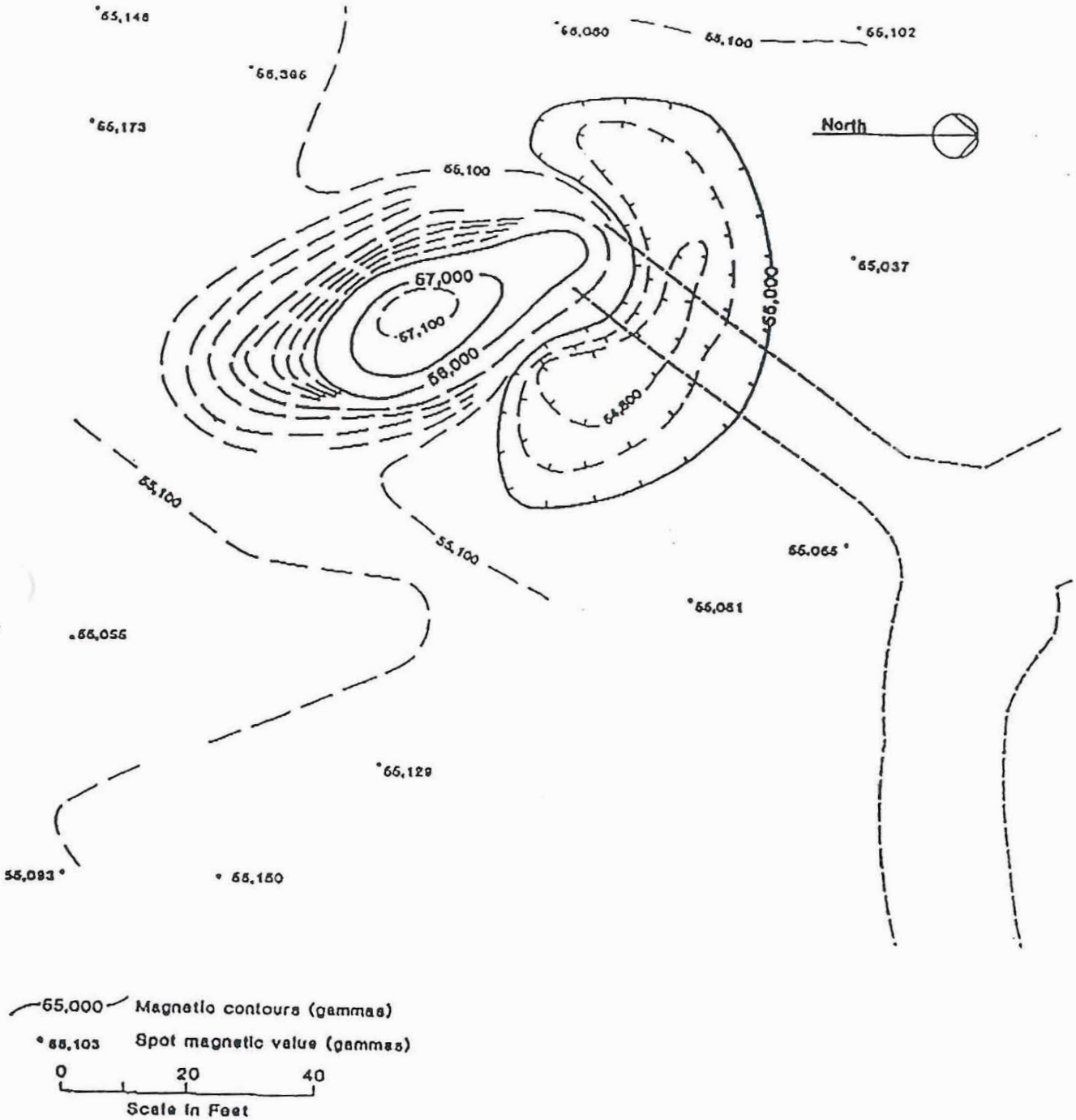
The total field proton procession magnetometer is the most commonly used magnetometer in hazardous waste investigations. This instrument utilizes the precession of spinning protons of hydrogen atoms in a sample fluid (kerosene, alcohol or water) to measure the total magnetic field intensity. Total field proton precession magnetometers are portable and do not require precise orientation and leveling; the sensor must be oriented with one side facing approximately north and the sensor held stationary during the cycling period. Proton precession magnetometers have no

FIGURE 1



MAGNETIC ANOMALY FROM A SINGLE BARREL
BURIED AT A DEPTH OF 6-7 FT.

FIGURE 2



65,000 Magnetic contours (gammas)

• 65,103 Spot magnetic value (gammas)

0 20 40

Scale in Feet

MAGNETIC ANOMALY CAUSED BY 75 BARRELS BURIED 4 TO 10 FEET DEEP

instrument drift, do not require calibrations, are easy to operate, and have an accuracy of 0.1 gamma. Most modern proton precession magnetometers have digital readouts and electronic storage of data.

Vertical magnetic gradiometers are magnetometers that measure vertical differences of the earth's total magnetic field. Gradient measurements enhance magnetic anomalies resulting from near surface magnetic source and discrimination between neighboring magnetic anomalies is also enhanced. These measurements are generally made using an instrument similar to a total field magnetometer that has two or more sensors mounted on a staff. The sensors are vertically separated by a constant distance, usually one to three feet. Gradient readings are adversely affected by ferrous metal surface debris since signals from this surface debris are also amplified. Consequently, removal of surface metal should be considered before conducting a gradiometer survey.

The flux gate magnetometer was developed during World War II as a submarine detector. Text books such as Telford (1976), RAO and Murthy (1978) explain in detail the principals of operation of the flux gate magnetometer. A fluxgate magnetometer can define the boundaries of regions of buried ferrous metal objects more precisely than the proton precession magnetometer. There are several sources of errors in flux gate magnetometers including unbalance in the two coils, thermal and shock noise, circuit drift and temperature sensitivity. The advantages are direct readout, no azimuth orientation, coarse leveling required, light weight and portability (Telford, 1976).

5.4 Field Procedures

Magnetic data are generally acquired at relatively close station spacings (5 to 50 foot intervals) along closely spaced (10 to 50 feet) parallel survey lines.

Magnetic data can be acquired in a rectangular grid pattern or along traverses. Grid data are readings acquired at the nodes of a rectangular grid; traverse data is acquired at fixed intervals along a line. Traverse data is often preferable to grid data because it generally is less expensive to acquire (heavily vegetated sites require time consuming brush cutting to establish a complete grid) and more useful for interpretation than an equal number of grid readings. Traverse lines generally ought to be oriented in a north-south direction so that the maximum amplitude of an anomaly can be detected. However, line orientations are often more dependent on site obstacles and sources of magnetic noise.

Station and line spacing intervals are determined on the basis of the desired resolution of the survey. If individual drums or clusters of deeply (greater than 25 feet) buried drums are the objective of the survey, then a detailed magnetic survey with relatively close station spacings (approximately 5 to 10 feet) and line spacings (approximately 10 to 25 feet) should be used. If large metal objects such as 10,000 gallon tanks or trenches filled with barrels are the objective of the magnetic survey, then a reconnaissance or screening survey with longer station spacings (25, 50, or 100 feet) and line spacings of (25, 50, or 100 feet) may be appropriate.

In conducting a survey, the field operator must avoid or note any sources of high magnetic gradients and alternating currents, such as power lines, buildings, and any large iron or steel objects. It is also important that the operator be relatively free of magnetic materials on his/her person and the magnetometer sensor be kept clean to avoid possible magnetic-bearing dirt. Periodically during a survey, and particularly when an anomaly is detected, it is important to establish that the magnetometer is providing valid readings and not random, meaningless instrument noise. The simplest means of verifying magnetometer field readings is to take several successive readings at one location. These readings should repeat to within ±1 gamma. Readings are taken at

predetermined intervals which depend on the nature of the survey and which may have to be modified depending on the gradients encountered. For detailed surveys, a base station or the reoccupation of a set of stations several times a day or a continuous monitoring station (within 100 miles) is established to check for diurnal variations and magnetic storms. At the height of a magnetic storm, magnetic surveying may be impractical due to the large instantaneous changes in the total magnetic field.

5.5 Interpretation

5.5.1 Data Analysis

Magnetic data can be corrected for diurnal variations; however, diurnal changes are generally very gradual and linear and should not have the extreme fluctuations associated with buried ferrous metal objects. Magnetic data can be plotted in profile form or contoured depending upon the survey coverage. Noise sources (surface ferrous metal objects, fences, power lines, etc.) should be noted on the profiles or contour map so that anomalies due to these known sources can be accounted for. The amplitudes of similar sized surface metal objects should be compared. If similar sized ferrous metal surface objects have extremely different anomaly amplitudes, it may be an indication that buried ferrous metal objects exist in the vicinity of the higher amplitude anomalies.

5.5.2 Presentation of Results

The results of a magnetic survey should be presented in profile and/or contour map form. The orientation of the traverses should be indicated on profiles and lines of coverage on contour maps. Locations of observed ferrous metal and other cultural features (hills, valleys, streams, etc.) should be noted on both the profile and the contour maps.

5.5.3 Interpretation

Magnetic anomalies can be analyzed both qualitatively and quantitatively. The shape and gradient of an anomaly (slope, wave-length, amplitude, etc.) contains enough information to draw qualitative conclusions regarding the location and depth of the causative source.

Quantitative computer modeling interpretations of magnetic data are complicated both by the inherent complexity of dipole magnetic behavior and by the fact that a number of different types and configurations of sources can cause the same anomaly. Where the properties of the earth's field and the local geologic materials (inclination, declination, susceptibility, and remanent magnetization) are well known, reasonable assumptions regarding the nature of the source can be made, and a fairly accurate model of the source generally can be derived.

5.6 Advantages and Limitations

Advantages of the magnetic survey method include:

- Rapid operation
- Low expense
- Identification of buried metal (ferrous)
- Sensitivity to small ferrous objects

Limitations of the magnetic survey method include:

- Susceptible to effects of manmade structures, utilities, buildings, fences, etc.
- Detection is limited to the distance to and quantity of ferrous metal present

6.0 QUALITY ASSURANCE RECORDS

All data will be recorded in log books and/or data logging sheets designed for this procedure. All data will be entered with the following basic information: date, start and end times (military time), location, personnel on site, Contract Task Order number, and weather.

7.0 REFERENCES

Dobrin, M.B., 1976, "Introduction to Geophysical Prospecting," McGraw-Hill Inc., New York, 630 p.

Grant, F.S. and West, G.F., 1965, Interpretation Theory in Applied Geophysics: New York, McGraw-Hill.

Nettleton, L.L., 1976, "Gravity and Magnetics in Oil Prospecting, "McGraw-Hill Book Company, New York, 453 p.

Nettleton, L.L., 1973, "Elementary Gravity and Magnetics For Geologists and Seismologists," Society of Exploration Geophysicists, Monograph no.I, Tulsa, Oklahoma, 121 p.

Telford, W.M., Geldart, L.P., Sheriff, R.E., Keys, D.A., 1976, "Applied Geophysics," Cambridge University Press, New York, 860 p.

RAO and Murthy, "Gravity and Magnetic Methods of Prospecting, " Safdarjang Enclave, New Delhi-1100166 390 p.

APPENDIX M
ELECTROMAGNETIC INDUCTION SURVEY

GEOPHYSICS: ELECTROMAGNETIC INDUCTION METHOD
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1.0 PURPOSE

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- 5.5 Interpretation
- 5.6 Advantages and Limitations

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7.0 REFERENCES

GEOPHYSICS: ELECTROMAGNETIC INDUCTION METHOD

1.0 PURPOSE

The purpose of this SOP is to provide general reference information for using electromagnetic induction (EM) methods.

2.0 SCOPE

This SOP provides a description of field procedures, equipment, and interpretation methods necessary to fully utilize this procedure.

3.0 DEFINITIONS

Conductivity - Ability of a material to transmit an electrical current. Inverse of resistivity.

Horizontal dipole mode - Transmitter and receiver coils oriented vertically.

Vertical dipole mode - Transmitter and receiver coils oriented horizontally.

Vertical sounding - Multiple EM measurements centered at a point with varying coil spacings.

Vertical profiling - EM measurements along a traverse with a fixed coil spacing and coil orientation.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that the project-specific plans are in accordance with these procedures, where applicable, or that other approved procedures are developed. The Project Manager is responsible for ensuring that the personnel operating and interpreting the geophysical data are trained, skilled in that endeavor, so far as to receiving documentation on the training and experience of the operating personnel.

Field Team Leader - The Field Team Leader is responsible for selecting and detailing the geophysical technique and equipment to be used. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that the field investigation personnel performing the activities have been briefed and trained to execute these procedures.

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 and the Project Manager. Field personnel are responsible for the proper acquisition of geophysical data.

5.0 PROCEDURES

5.1 Overview

Electromagnetic Induction (EM) methods are non-intrusive geophysical techniques of measuring the apparent conductivity of the subsurface materials. Electrical conductivity values of subsurface materials are determined by transmitting a high frequency electromagnetic (primary) field into the earth and measuring the secondary electromagnetic field produced by the eddy current as illustrated

in Figure 1. The transmitter and receiver coils do not require direct ground contact thus permitting continuous profiling and rapid data acquisition.

The strength of the secondary field is a function of the inter coil spacing, operating frequency and ground conductivity. The ratio of the secondary to the primary magnetic field is directly proportional to the terrain conductivity which enables direct instrument readout of apparent conductivity values (measured conductivity values are the bulk average conductivity for the area or volume of earth sampled). Conductivity ranges typical of various earth materials are shown on Figure 2. EM conductivity values are usually expressed in units of milliohms per meter. Conductivity values are converted to resistivity values in ohm-meters by use of the following relationship:

$$\textit{resistivity (ohm - meters)} = \frac{1{,}000}{\textit{EM instrument readout (milliohms per meter)}}$$

The apparent conductivity of the subsurface materials is dependent upon subsurface conditions such as:

- Lithology
- Porosity
- Permeability
- Conductivity of subsurface pore fluids

Changes in these parameters causing measurable variations in electromagnetic conductivity can result from:

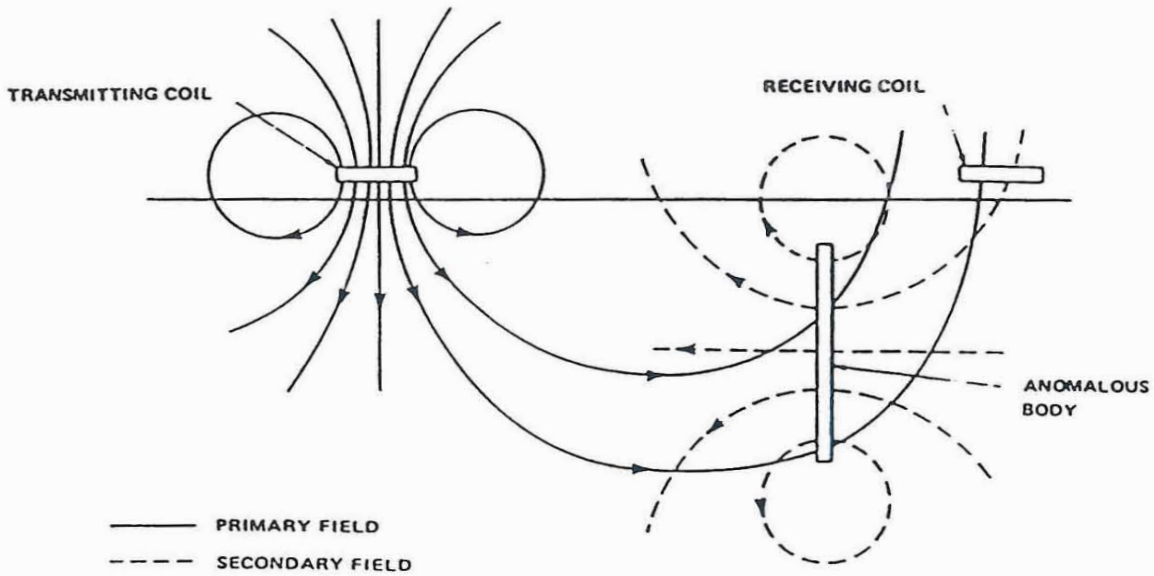
- Conductive contaminant plumes
- Abandoned trenches and lagoons
- Lateral changes such as backfill or landfill materials
- Bedrock fracture zones
- Lithological variations
- Buried metallic objects

The sampling depth or depth of investigation is related to the coil spacing and coil mode. The two coil modes used are the vertical dipole mode (coils horizontal) and the horizontal dipole mode (coils vertical). Figure 3 shows the relationship of the coil spacings, mode and relative responses.

Two common terrain conductivity meter are EM-31 and the EM-34-3. The EM-31 has a fixed intercoil spacing of 3.7 meters and an effective depth of penetration of approximately 6 meters. The EM-34-3 has two coils which can be separated by 10, 20, or 40 meters and can be oriented in either the horizontal or vertical dipole modes. Intercoil separations increase the effective depth of investigation as shown below.

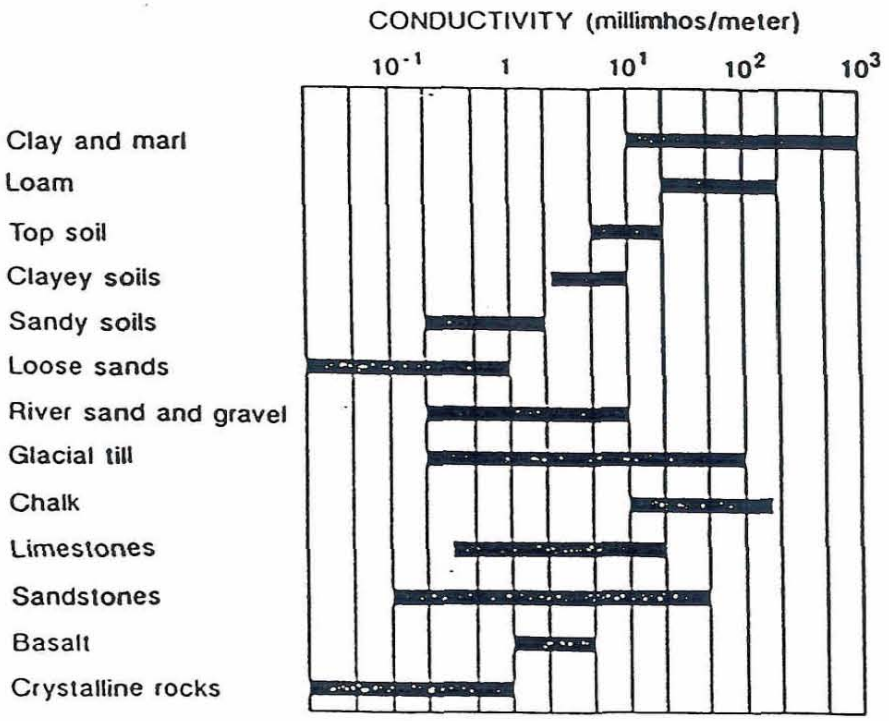
Intercoil Spacing (meters)	Depth of Investigation (meters)	
	Horizontal Dipole	Vertical Dipoles
10	7.5	15
20	15	30
40	30	60

Figure 1



Source: Griffith and King, 1981

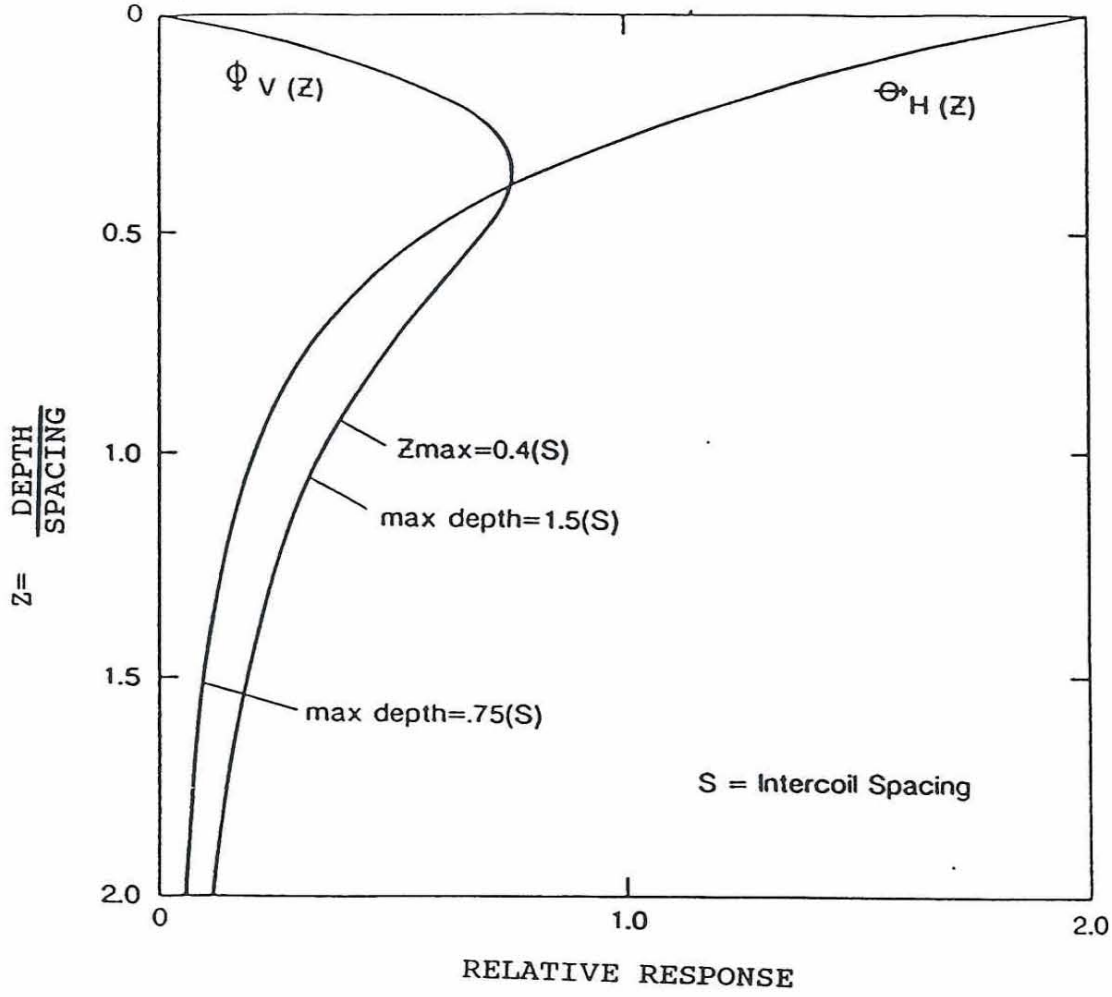
Figure 2



(after Culley et al.)

CONDUCTIVITY RANGES FOR COMMON EARTH MATERIALS

Figure 3



COMPARISON OF RELATIVE RESPONSES FOR VERTICAL AND HORIZONTAL DIPOLES

The coil orientation (horizontal or vertical) allows the EM-34-3 to respond to materials of different depths.

Vertical sounding and horizontal profiling are the two EM survey techniques. Vertical profiling is accomplished by multiple measurements about a point with varying coil spacing. Horizontal profiling is performed by making measurements along traverses with a fixed coil spacing. General discussions of electromagnetic induction methods are presented in texts by Grant and West (1965), Telford and others (1976), and Griffiths and King (1981).

5.2 Applications and Uses

The measurement of subsurface conductivity at a hazardous waste site provides a valuable contribution to site characterization. The conductivity (resistivity) of the hydrogeologic section is predominantly influenced by the pore fluids. Consequently, conductivity measurements provide indirect information on the porosity and permeability of subsurface materials, the degree of saturation, and the conductivity of the pore fluids. The conductivity of the pore fluid is influenced by the presence of dissolved electrolytes. Contaminant plumes in the unsaturated and saturated zones can be mapped provided there is a sufficient change in the conductivity to be detected by the EM instrument. Generally, contaminant plumes of inorganic waste are easily detected because the pore fluids often have conductivity values as much as three orders of magnitude above background values. Figure 4 illustrates an EM anomaly associated contamination plume. EM conductivity measurements can also be used to detect the presence of buried waste; filled disposal trenches, and buried metal objects such as drums, tanks or metal debris. Figure 5 illustrates an EM anomaly over a buried metal object. Electromagnetic surveys can be used to locate conductive as well as and non-conductive bodies. The many applications include:

- Contaminant plume mapping
- Locating abandoned trenches and lagoons
- Delineating bedrock fracture zones
- Determining thickness of weathered layers
- Lithology mapping
- Locating buried metallic objects
- Lateral anomalies such as pockets or pits of different materials

Examples of EM applications at sites where groundwater is contaminated are presented by Duran (1982), Greenhouse (1983), and Greenhouse and Slaine (1983).

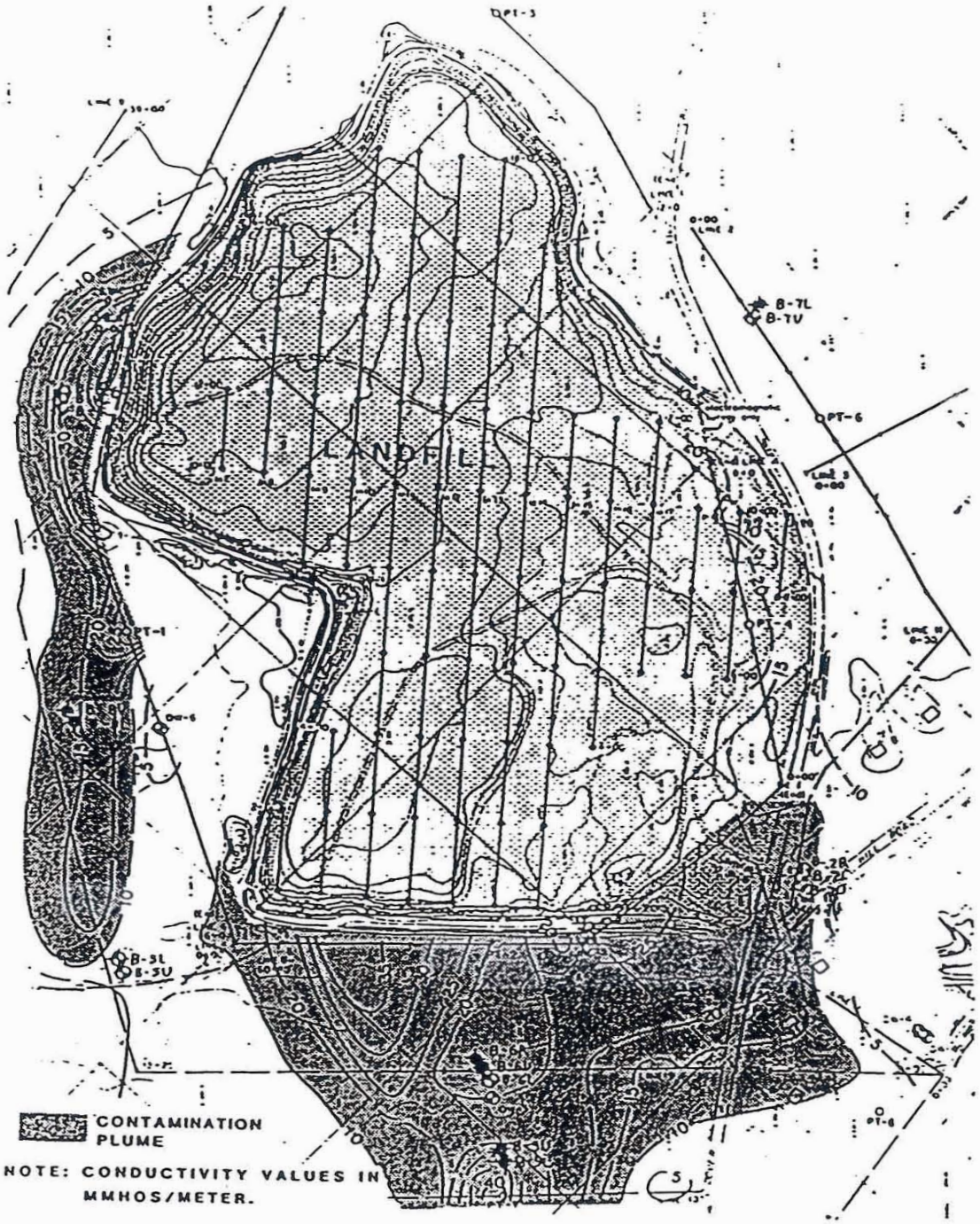
5.3 Equipment

The two-coil EM instrument and the VLF (very low frequency) instrument are basically the two different types of electromagnetic surveying instruments in use; each is capable of sensing to different depths. There are several models and manufacturers of this equipment.

The two-coil system consists of a transmitter coil and a receiver coil. Refer to Figure 1 which illustrates the basics of a two-coil electromagnetic induction apparatus. The transmitter coil induces an electromagnetic field of known strength and the receiver coil measures the resulting quadrature, or ratio of primary to secondary fields resulting from subsurface features. Each instrument is read directly in units of milliohms per meter (conductivity). EM readings represent the average bulk conductivity at a point halfway between the two coils.

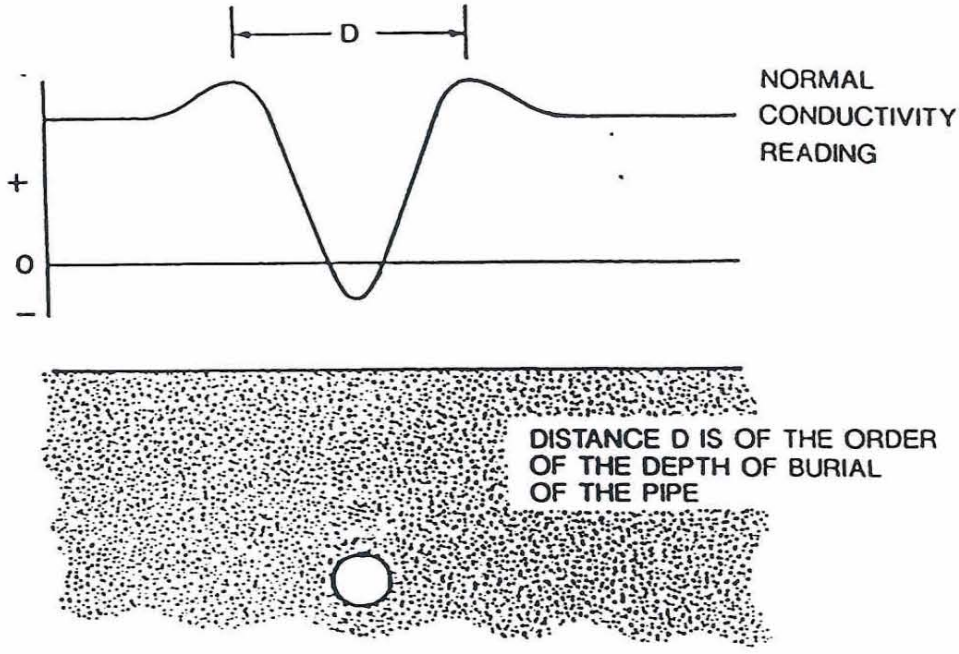
Figure 4

SOP F702
Revision No.: 1
Date: 1993



CONDUCTIVITY CONTOUR MAP

Figure 5



Source: Geonics Limited, Operating Manual for
EM31 Terrain Conductivity Meter, 1979

TYPICAL EM RESPONSE OVER A METAL PIPE

The VLF instrument is a receiver which relies on specialized, very low frequency communication antennas for induction of an electromagnetic field. Surveying with the VLF or equivalent instrumentation is commonly referred to as VLF surveying.

The VLF Instrumentation is a small, lightweight hand-held instrument which can be operated by one person. Principal components of the instrument are a pair of mutually perpendicular coils and a receiving crystal with a frequency specific to a transmitting antenna. The two receiving coils are used to measure local characteristics of the primary induced field and any secondary fields emanating from bodies of variable conductivity. Typical sources of induced electromagnetic fields for VLF surveying are the very low frequency antennas used for submarine communications.

5.4 Data Acquisition

The advantage of the EM survey method is the speed and accuracy with which lateral changes of terrain conductivity can be measured. The EM conductivity data can be acquired using sounding and profiling techniques similar to those used in electrical resistivity. EM profiling is accomplished by traversing an area with a fixed coil spacing and orientation; EM sounding is accomplished by expanding the inter-coil spacings in a manner similar to that used by electrical resistivity soundings. Some commonly used EM equipment is limited in the number of available inter-coil spacings that can be used; however, there are other EM instruments available that can operate at many coil spacings and frequency ranges to provide numerous sounding data points necessary for accurate computer modeling and profiling.

The factors determining which instrument is used and what the grid spacing should be at particular sites are:

- Depth to target and size of target
- Accessibility of the site
- Effects of manmade structures and utilities, such as electric power lines
- Conductivity of the earth materials

EM induction instruments may have a depth of investigation of up to 200 feet depending upon coil spacing and orientations used (see Figure 3). The very low frequency VLF device has the greatest depth of investigation and is generally used to evaluate large geologic structures.

In conducting a VLF survey, VLF readings should be acquired with the instrument oriented perpendicular to a straight line from the site to the transmitter antennas. This orientation is necessary to ensure optimum data quality. All readings from a particular VLF station must be obtained with the instrument oriented in the same direction.

For an EM induction survey, a regular pattern of survey stations will provide coverage of the area in question. Typically, use of a grid spacing which is approximately equal to the size of the target sought by the survey, and a coil spacing with a maximum response for the depth of interest will produce satisfactory results. Specific needs for local detail, however, may require a refined coverage. The chosen spacing should always be site and target specific.

In conducting an EM survey, the field operator must avoid or note any potential sources of anomalous (noise) conductivity values such as power lines, buildings, fences, buried pipelines or any other large metal objects. Noise sources should be noted on the profiles or contour maps accounting for anomalies due to these known sources.

Important information that should be known for planning and before conducting an EM conductivity survey are: assumed hydrogeologic characteristics of the site, potential source locations and migration paths, characteristics of the hazardous substance of interest, and depths of interest. The level of detail necessary (size of object of interest and detail of resolution) determines the number of lines and station spacings of readings required.

EM data, if not recorded on a strip chart or digital recording instrument, should be recorded on standardized data sheets. At a minimum all data (strip chart, digital disks, or standard forms) should have the following information listed:

- Project/site location identification
- Company
- Date and time
- Operators name
- Instrument make, model
- Coil spacings and configuration
- Line and station numbers
- Instrument reading scales
- Weather conditions/temperature

5.5 Interpretation

5.5.1 Data Analysis

In general, electromagnetic survey data require relatively little processing before they can be interpreted. This is especially true for fixed coil spacing surveys because the data are recorded in units of conductivity; preliminary interpretations are made by comparison of conductivity values. A contour map can be prepared from the data and compared with results of other surveys. EM instruments also can be used for vertical soundings similar to resistivity sounding. Vertical sounding with EM equipment, however, has lower resolution than that performed with the resistivity technique. As a result, EM data are generally more useful for continuous profiling surveys.

VLF instruments do not read directly in units of conductivity. The in-phase measurement (the tilt of primary induced field) is read in terms of the tangent to the angle of tilt and is given as a percentage. Quadrature measurements, which are the ratios of voltage required to equalize the primary to secondary signal strengths, are also given as percentages. For field interpretation these two sets of data can be plotted in profile form, percentage versus distance. Greenhouse and Slaine (1983) describe a simple mathematical conversion so that VLF data can be presented in contour format and compared to other available data such as resistivity and magnetics. Digital data acquisition systems are now available that allow calculation of conductivity.

5.5.2 Presentation of Results

Results of an EM conductivity survey can be presented in profile and/or contour map form. The orientation of the traverses should be indicated on profiles in lines of coverage on contour maps. Locations of observed surface metal and other cultural features such as topography, buildings, fences, power lines etc. should be noted on both the profiles and the contour maps.

5.5.3 Interpretation

EM conductivity data can be analyzed qualitatively and quantitatively. Generally, profiling data are presented as a contour map or profiles. Profile lines should be stacked and aligned. A qualitative analysis of the contour map or aligned profiles usually can allow an interpreter to identify any conductivity trends that may be indicative of buried metal, groundwater flow and contaminant transport. A comparison of available geologic data, cultural ferrous metal and debris maps prepared during data acquisitions should be made to evaluate the causes of any conductivity trends observed.

Computer or chart comparisons of EM sounding data with available theoretical models can be made. This type of interpretation is similar to that used in electrical resistivity, but in EM sounding it is limited to relatively simple hydrogeologic conditions.

5.6 Advantages and Limitations

Advantages of the electromagnetic induction method include:

- No ground contact required
- Rapid data acquisition (faster than resistivity)
- Lightweight, one or two man operation
- Wide range of applications
- High lateral resolution
- Field interpretation possible

Limitations of the electromagnetic induction method include:

- Limited dynamic range 1-1,000 milliohm/meter
- Susceptible to effects of man-made structures, utilities, etc.
- Less vertical resolution than resistivity
- Limited penetration
- Does not distinguish even simple layering without more complex application and interpretation
- Setting and maintaining instrument at zero

6.0 QUALITY ASSURANCE RECORDS

Field data will be recorded in log books and/or data recording sheets accompanying the monitoring equipment. Data recorded in a field log book will be entered with the following data: date, site location, Contract Task Order number, personnel conducting the investigation, time (military time), start time and end time, weather.

7.0 REFERENCES

Duran, P.B. and Haeni, F.P., 1982, The use of electromagnetic conductivity techniques in the delineation of groundwater contamination plumes, in Novitzki, R.P. and Levine, G., eds., The impact of waste storage and disposal on groundwater resources: A Northeast Conference, presented by U.S. Geological Survey and Cornell University Center for Environmental Research, June 18 - July 1, 1982, Ithaca, New York, p. 8.4.1 to 8.4.33.

Geonics Limited, EM 31 Operating Manual: Mississauga, Ontario, Canada, 58 p.

Geonics Limited, EM 16 VLF Electromagnetic Unit, Operating Instructions: Mississauga, Ontario, Canada.

Grant, F.S., and West, G.G., 1965, Interpretation theory in applied geophysics: New York, McGraw-Hill 583 p.

Greenhouse, J.P., 1983, Surface geophysics in contaminant hydrogeology, in Field methods in contaminant hydrogeology: Proceedings of a hydrogeology field school sponsored by The Groundwater Research Institute, University of Waterloo, April 18-22, 1983, Canadian Forces Base, Borden, Ontario, Canada, 53 p.

Greenhouse, J.P., and Slaine, D.D., 1983, The use of reconnaissance electromagnetic methods to map contaminant migration: Ground Water Monitoring Review, v. 3, no. 2, p. 47-59.

Griffiths, D.H., and King, R.F., 1981, Applied geophysics for geologists and engineers, 2nd ed.: Elmsford, New York, Pergamon Press, 230 p.

Telford, W.M., Geldart, L.P., Sheriff, R.E. and Keys, D.A., 1976, Applied geophysics: New York, Cambridge University Press, 860 p.

Zohdy, A.A.R., Eaton, G.P., and Mabey, D.R., 1974, Application of surface geophysics to groundwater investigations: U.S. Geological Survey, Techniques of Water-Resources Investigations, Book 2, Chapter D1, 116 p.

APPENDIX N
EARTH RESISTIVITY SURVEY

GEOPHYSICS: RESISTIVITY METHOD

1.0 PURPOSE

2.0 SCOPE

3.0 DEFINITIONS

4.0 RESPONSIBILITIES

5.0 PROCEDURES
- 5.1 Overview
- 5.2 Applications
- 5.3 Equipment
- 5.4 Field Procedures
- 5.5 Interpretation
- 5.6 Advantages and Disadvantages

6.0 QUALITY ASSURANCE RECORDS

7.0 REFERENCES

GEOPHYSICS: RESISTIVITY METHOD

1.0 PURPOSE

The purpose of this SOP is to provide general reference information for using and interpreting electrical resistivity surveying.

2.0 SCOPE

This SOP indicates the normal methods of interpreting and implementing resistivity data. The description of field implementation methods, data acquisition and recording are described herein.

3.0 DEFINITIONS

Finite-element modeling - A numerical method of approximating a solution to differential equations.

Hertz - A unit of frequency. One hertz equals one cycle per second.

Impedance - The apparent resistance to the flow of alternating current; analogous to resistance in a direct current circuit.

Milliamp - A unit of electric current flow, equal to one thousandth of an ampere.

Sinusoidal - An adjective describing a curve in the pattern of a sine function (mathematics).

Sounding - Measurement of geoelectrical properties as they vary with depth.

Square wave - A waveform consisting of alternating positive and negative portions.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that the project-specific plans are in accordance with these procedures, where applicable, or that other approved procedures are developed. The Project Manager is responsible for ensuring that the personnel operating and interpreting the geophysical data are trained, skilled in that endeavor, so far as to receiving documentation on the training and experience of the operating personnel.

Field Team Leader - The Field Team Leader is responsible for selecting and detailing the geophysical technique and equipment to be used. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that the field investigation personnel performing the activities have been briefed and trained to execute these procedures.

5.0 PROCEDURES

5.1 Overview

Electrical resistivity surveying is an active geophysical technique that utilizes electrical measurements obtained on the ground surface to determine physical properties of subsurface materials. Typically an electric current is applied to the earth using two electrodes (current electrodes C_1 and C_2); the resulting potential difference or voltage is measured between a second pair of electrodes (potential electrodes P_1 and P_2) as shown on Figure 1. An "apparent resistivity" is then calculated using values for the applied current, measured voltage, and electrode separation.

The values measured during a field program are known as "apparent" resistivities because they can be a composite of resistivity values for several layers. For a single isotropic homogeneous material, the apparent resistivity would equal the true resistivity.

Resistivity and its reciprocal, electrical conductivity (1/resistivity = conductivity), are inherent properties of soil, rock, and groundwater. The resistivity of an earth material depends on the following:

- Material composition
- Water content (porosity and degree of saturation)
- Salinity or ion content of the water
- Permeability
- Temperature

Most soil and rock materials are relatively poor electrical conductors (i.e., exhibit high resistivities) compared with groundwater. An applied electrical current is conducted almost entirely by water in the pore spaces or fractures of soil or rock rather than by the soil or rock alone. This applies to the unsaturated and vadose zones, because in general there is some moisture in unsaturated media. Pure water is non-conductive, but most groundwater contains dissolved salts and hence is somewhat conductive.

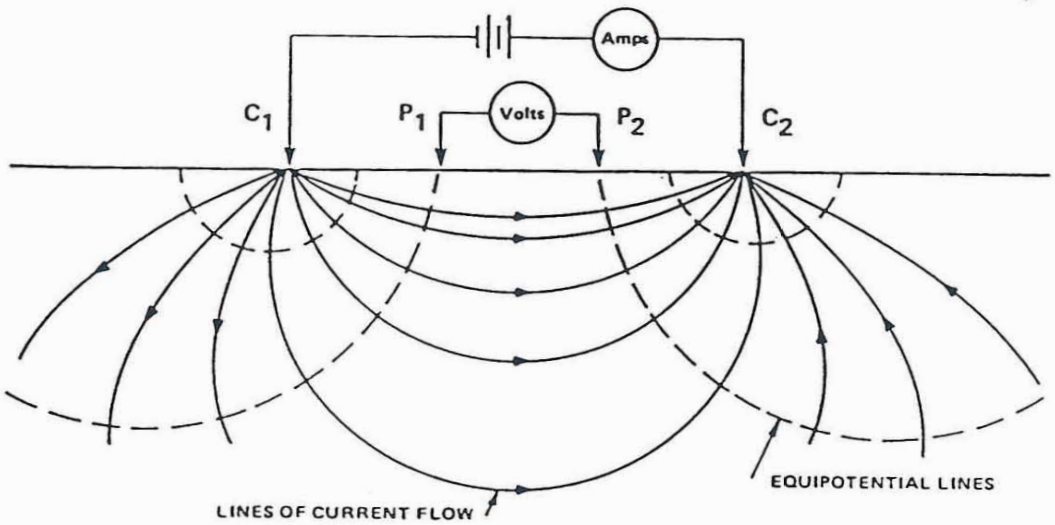
The approximate ranges of resistivity for common soil and rock types are shown on Figure 2. The ranges of resistivity values for a single material generally indicate resistivity variations between dry and water-saturated conditions. Dry sands, gravels, and massive unweathered rock typically exhibit relatively high resistivities; whereas, clays, clayey tills, water-saturated sediments, and weathered rock (chemically broken down to clays) tend to have lower resistivities.

Resistivity measurements are commonly used to delineate either changes in resistivity with depth or lateral variations in resistivity. These applications are known respectively as:

- Vertical electrical soundings (VES)
- Horizontal profiling

In VES surveys the center of an electrode array is kept at a fixed position, and resistivity measurements are obtained at successively larger electrode spacings. Measurements at the longer electrode separations sense deeper into the earth to identify geoelectrical layering in soil and rock. These data are often used to identify the water table, clay layers, and the bedrock surface, and to select optimum electrode spacings for horizontal profiling surveys.

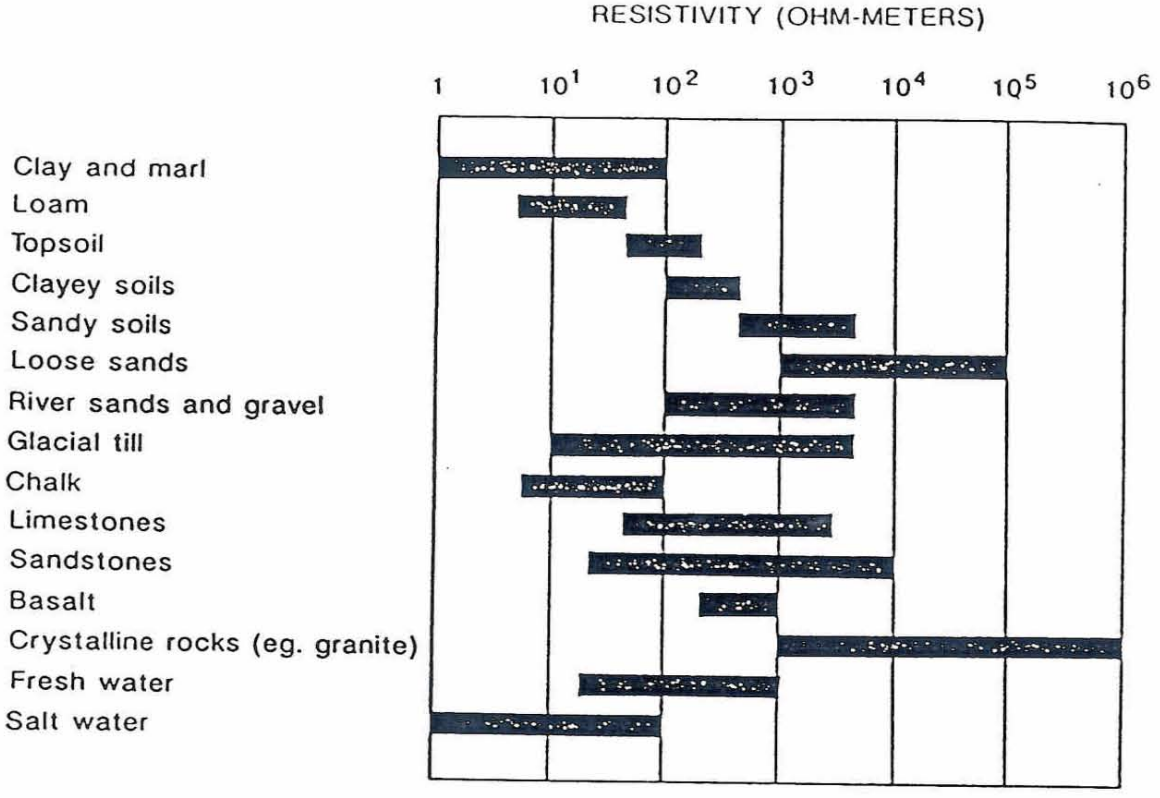
FIGURE 1



Electric current is applied to the earth between current electrodes, C_1 and C_2. Potential field generated by the current is measured between potential electrodes, P_1 and P_2. Source: U.S. Army Corps of Engineers, 1979.

BASIC CONFIGURATION OF AN ELECTRICAL RESISTIVITY SURVEY

FIGURE 2



Ranges of values reflect influence of variations in porosity, saturation, and ground-water conductivity.

Source: Benson, Glaccum, and Noel, 1983.

TYPICAL RESISTIVITIES FOR COMMON ROCKS AND SOILS

In horizontal profiling, the electrode spacing is kept constant and the array is moved across the survey area. Profiling measurements are often repeated with at least two different electrode separations to identify lateral variations at more than one depth.

A variety of electrode arrays are used for resistivity surveys. The most common ones will be discussed in this section. In all of the arrays listed below, the electrodes are arranged in a straight line. Differences between the arrays consist of variations in electrode spacing and relative position. The most commonly used electrode arrays (see Figure 3) are:

- Wenner (and Lee modification of Wenner)
- Schlumberger
- Dipole-dipole

These three arrays measure the induced electrical (potential) field differently, thus the arrays have different applications. The Wenner array measures an "average" of the induced potential because its potential electrodes are relatively far apart. This averaged measurement renders the Wenner array suitable for VES surveys, but it is less sensitive to horizontal variations in resistivity.

The Lee modification of the Wenner array involves the addition of a third potential electrode halfway between P_1 and P_2 (see Figure 3). Three potential measurements are taken, using electrodes P_1 - P_2 (normal), P_1 - P_0 (Lee left), and P_2 - P_0 (Lee right). Apparent resistivities are calculated for the Lee left and right measurements. If the left and right measurements do not each equal one-half of the normal measurement, there is either a measurement error or a lateral variation in resistivity in the vicinity of the potential electrodes.

In the Schlumberger array the potential electrodes are relatively close together compared to the current electrodes, and the array measures the first derivative of the induced potential field. The Schlumberger array's performance is comparable to that of the Wenner array for VES applications, but has greater sensitivity in horizontal profiling. Generally, only the current electrodes are moved in a Schlumberger VES survey. This is simpler than Wenner VES measurements, in which four electrodes must be moved, but it can result in larger measurement errors. Because of the closely-spaced potential electrodes the voltages measured in a Schlumberger survey are smaller than those measured in a Wenner survey, and an error in potential measurement has a greater effect on Schlumberger-calculated resistivities. At sites where many local variations in resistivity occur near the ground surface, Schlumberger results may be less noisy because the potential electrodes are kept in the same material for several readings. Wenner results for the same area will be more noisy because the potential electrodes are in different media for each reading.

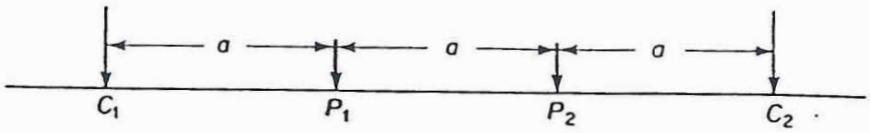
The Wenner and Schlumberger arrays have some similarities. Both can be used for profiling or VES surveys, and both have a maximum depth of investigation related to the current electrode separation (approximately one-third of the Wenner "a-spacing" or one-ninth of the Schlumberger current electrode separation). Schlumberger profiling measurements have greater sensitivity to lateral resistivity changes, and Schlumberger VES data have less error due to heterogeneous near-surface materials. Wenner measurements are more accurate at sites where small potential voltages are induced, including sites with low resistivity (high conductivity) clays. Either Wenner or Schlumberger arrays may be used for reconnaissance and detailed measurements by varying the spacing between profile traverses or sounding locations. Widely spaced traverses or soundings are used for reconnaissance surveys or for delineation of large targets (horizontally extensive clay or gravel layers). Closely spaced data are required for identification of localized features such as discrete zones of leachate migration, etc.

FIGURE 3

Ia WENNER

$\rho_a = 2\pi a \, \Delta V / I$

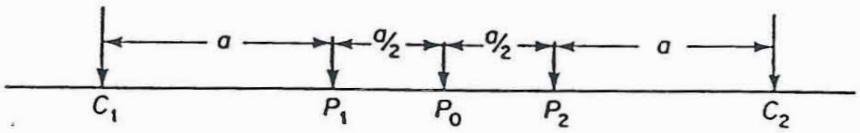
ΔV taken between $P_1 P_2$



Ib LEE MODIFICATION OF WENNER

$\rho_a = 4\pi a \, \Delta V / I$

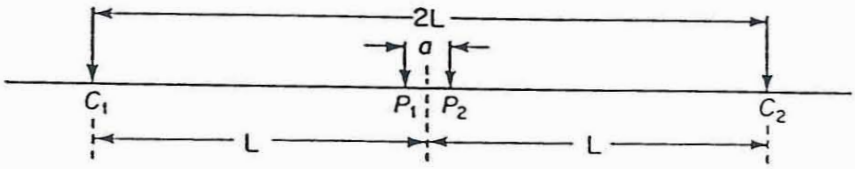
ΔV taken between $P_1 P_0$ and $P_0 P_2$



II SCHLUMBERGER

$\rho_a = \frac{\pi L^2}{a} \frac{\Delta V}{I}$

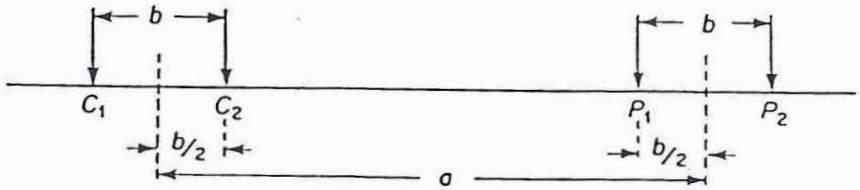
ΔV taken between $P_1 P_2$



III DIPOLE - DIPOLE

$\rho_a = \pi (a^3/b^2 - a) \Delta V / I$

ΔV taken between $P_1 P_2$



ELECTRODE ARRAYS USED IN SOUNDING AND PROFILING SURVEYS

Dipole-dipole measurements represent the second derivative of the induced potential field; they are thus more sensitive to lateral changes in resistivity than the Wenner or Schlumberger arrays, but less sensitive to changes with depth. A dipole-dipole survey is better-suited to locating discrete features (buried metal, igneous dikes, solution cavities), and should not be used for identification of soil and rock layering.

5.2 Applications

Contrasts in resistivity for some geologic materials (see Figure 2) make resistivity surveying a valuable technique for many applications including:

- Depth to groundwater
- Delineation of conductive contaminant plumes and/or buried wastes
- Locating fresh/salt water interfaces
- Detecting a perched water table
- Distinguishing bedrock and sediment lithologic types and contacts
- Identification of zones of weathered bedrock, fractures, and possibly solution cavities

Examples of resistivity applications including identification of buried stream channels, mapping the groundwater table, and clay layers may be found in Zhody et al. (1974) and Yazicigil and Sendlein (1982).

Resistivity surveys have occasionally been applied to the problem of detecting electrically resistive contaminants; however, this procedure is generally not possible. Successful applications of resistivity in organic contaminant identification requires (1) conductive contaminants (landfill leachate, chlorides, iron oxides, dissolved nitrates and salts) associated with the organic compounds, or (2) a layer of organic product (hydrocarbons including gasoline, PCBs) several feet thick which displaces the groundwater table.

Resistivity data are well-suited for correlation and verification by a variety of geophysical techniques and/or test borings. Possible correlative geophysical techniques for the applications listed above include seismic retraction, electromagnetic terrain conductivity, ground penetrating radar (GPR), and magnetometry.

5.3 Equipment

Basic field equipment needed for resistivity surveying includes:

- Two current electrodes
- Two or three potential electrodes
- Insulated connecting cables
- Non-conductive fiberglass measuring tapes
- Source of electric current
- Voltage measurement device

Resistivity instrumentation comes in a variety of designs with widely varying capabilities. Advantages and limitations of four popular designs will be discussed in this section.

The simplest resistivity instruments are known as "DC" (direct current) devices. They apply a direct current to the earth and measure the resulting DC potential with a high-impedance (at least 1×10^6

ohm) volt meter. Because SP (self-potential) voltages can adversely affect the accuracy of simple DC resistivity measurements, these instruments usually contain a "nulling" or "balancing" circuit to remove the SP effect; although SP constitutes a form of noise in a resistivity survey, SP measurements can also be used as a geophysical exploration technique (see Section 8.50). If SP is varying rapidly in the area of investigation, then its effect is nearly impossible to remove or compensate; for this reason, simple DC resistivity measurements are not suitable for all field areas (see Section 8.5.1 for a discussion of SP sources).

A more versatile resistivity meter is known as the low-frequency "AC" (alternating current) type. This instrument uses a sinusoidal applied current, usually of only a few hertz, to avoid some of the interference caused by SP. Both the DC and low-frequency AC meters are best-suited for relatively shallow investigations, with depths of investigation less than about 100 feet, in soils that are neither highly conductive nor highly resistive. These limitations are imposed by the small battery-powered current transmitters used. Current output of these units is measured in tens of milliamps at less than one thousand volts.

More powerful resistivity equipment is also available, using sinusoidal AC or square-wave DC transmitters powered by portable electric generators. These units often have a transmitter and receiver mounted in separate housings to provide greater versatility and to minimize electrical interference between the transmitting and receiving circuits. They also have the capability of producing up to tens of amperes of current at several thousand volts, sufficient for surveys in highly resistive or conductive media at maximum depths much greater than battery powered instruments.

Recent innovations in electronics design have resulted in a fourth type of resistivity meter that fills a niche between the standard battery and generator powered AC instruments. These units are also battery-powered, but produce electric currents with unique waveforms. Voltage measuring circuits in these devices are designed to recognize the specific waveform produced by the transmitter, thus enabling measurement of weak potentials in somewhat noisy conditions. Signal enhancement (summing of a few voltage measurements) is usually offered with these instruments and also contributes to improved resolution. This type of resistivity meter is capable of operation in more resistive or conductive media than the low-frequency AC meters, and can also be used to investigate deeper structures.

5.4 Field Procedures

Field procedures involve placing electrodes at the intended separations, connecting the electrodes to the transmitter and receiver, and obtaining current and potential measurements. Electrode locations should be determined with non-conductive measuring tapes to avoid providing an alternative path for the applied current. Fiberglass tapes are commonly used. Most resistivity surveys are performed with metal electrodes which are driven into the ground. Steel and copper-clad steel are common electrode materials, although other metals may be used. Electrodes of dissimilar metals should not be used during a survey (e.g. three steel electrodes and one aluminum electrode) because unusually large self-potentials can be generated. Electrodes are usually driven one to three feet into the ground. Water is poured around each electrode, if needed, to decrease the resistance between the electrode and earth materials. Copper sulfate solutions have historically been used to improve electrode contact, but tap water is usually sufficient.

At sites with strong self-potential noise effects, use of DC resistivity instrumentation may necessitate non-polarizing electrodes. These special electrodes are commonly of the porous-pot type, consisting of an unglazed ceramic pot containing a metal electrode and a saturated electrolytic solution. The solution must be of a salt of the same metal as the central electrode; e.g., a solution of copper sulfate

is often used with a copper electrode. The porous pot is placed on the ground surface, and electrical contact with the earth is achieved by seepage of the electrolytic solution through the porous ceramic. Finally, the electrode is connected to the resistivity instrumentation by insulated wire.

Quality assurance is important in resistivity field procedures. This entails careful measurement of electrode positions, checking resistances across potential and current electrodes to ensure good contact with the earth, and plotting calculated apparent resistivities in the field to quickly make identification of spurious readings. Instrument calibration is not usually of concern because the equipment is calibrated by its manufacturer. Verification of the equipment's operating condition can be obtained by repeating resistivity measurements at a known location prior to conducting field work.

Careful planning is another significant factor in conducting resistivity surveys. Parallel lines should be tied together with a perpendicular line, or by using another geophysical technique such as EM or seismic. To minimize errors from fences or other cultural features, electrode arrays should be placed perpendicular to metal fences or other linear conductive objects. Topographic effects are minimized if the electrodes are maintained at nearly the same elevation; a VES survey is best performed along hillside contours, not up and down the hill.

5.5 Interpretation

5.5.1 Data Analysis

Analysis of resistivity data involves different procedures for horizontal profiling, VES surveys, and dipole-dipole surveys. Horizontal profiling data is contoured or plotted on linear graph paper, with apparent resistivity values on the y-axis and distance along the traverse on the x-axis. The contour map or profiles are then examined for relative variations in resistivity which may be indicative of the intended target body. An example of Wenner profiling data is provided on Figure 4.

Wenner and Schlumberger VES data are plotted on log-log graph paper with apparent resistivity values on the y-axis and Wenner a-spacings or the Schlumberger current electrode separations on the x-axis (Figure 5). Until a few years ago, interpretation would have next been accomplished by comparison of the field data with published master curves. Examples of the curves and their use may be found in Orellana and Mooney (1966), Keller and Frischknecht (1966), Dobrin (1976), Telford et al. (1976), Van Nostrand and Cook (1966), and Zhody et al. (1974). This technique is slow, inaccurate, and limited in application because curves are available only for two and three layer cases at a few resistivity contrasts.

Currently, VES interpretations are performed using a computer and the linear filter algorithm described by Ghosh (1971a and 1971b) and Koefoed (1979). This algorithm operates very quickly on any computer, from a mainframe to a Laptop, and provides greater accuracy and versatility than is possible with curve matching techniques. A contractor should clearly identify the modeling technique used in the interpretation.

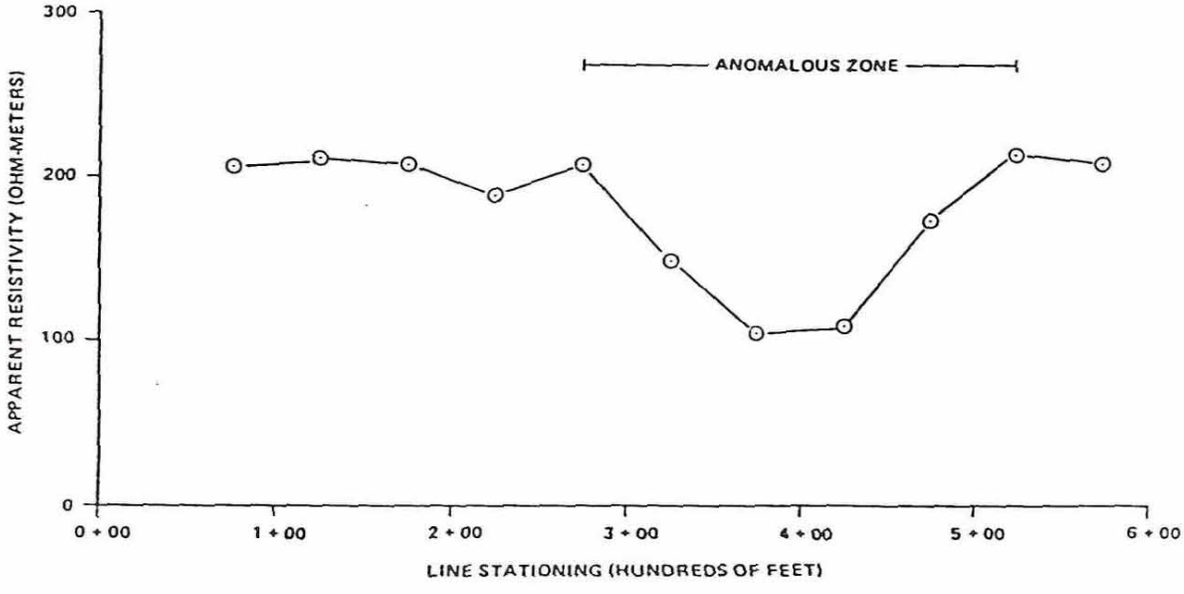
Computer-aided modeling can be performed in two manners. Forward modeling entails computation of theoretical resistivity values from a layer thickness/resistivity model supplied by the interpreter. Agreement between the field and theoretical curves in the model is obtained by subsequent trial and error refinement of the layer parameters (thicknesses and resistivities). Boring or test pit logs, if available, should be used to confirm the resistivity modeling results.

FIGURE 4

A.) DATA:

CURRENT ELECTRODE LOCATIONS (50 FOOT "A" SPACING)	CENTER OF ARRAY	APPARENT RESISTIVITY (OHM-FEET)
0 + 00 – 1 + 50	0 + 75	672
0 + 50 – 2 + 00	1 + 25	692
1 + 00 – 2 + 50	1 + 75	679
1 + 50 – 3 + 00	2 + 25	613
2 + 00 – 3 + 50	2 + 75	672
2 + 50 – 4 + 00	3 + 25	482
3 + 00 – 4 + 50	3 + 75	341
3 + 50 – 5 + 00	4 + 25	351
4 + 00 – 5 + 50	4 + 75	567
4 + 50 – 6 + 00	5 + 25	695
5 + 00 – 6 + 50	5 + 75	679

B.) INTERPRETATION:



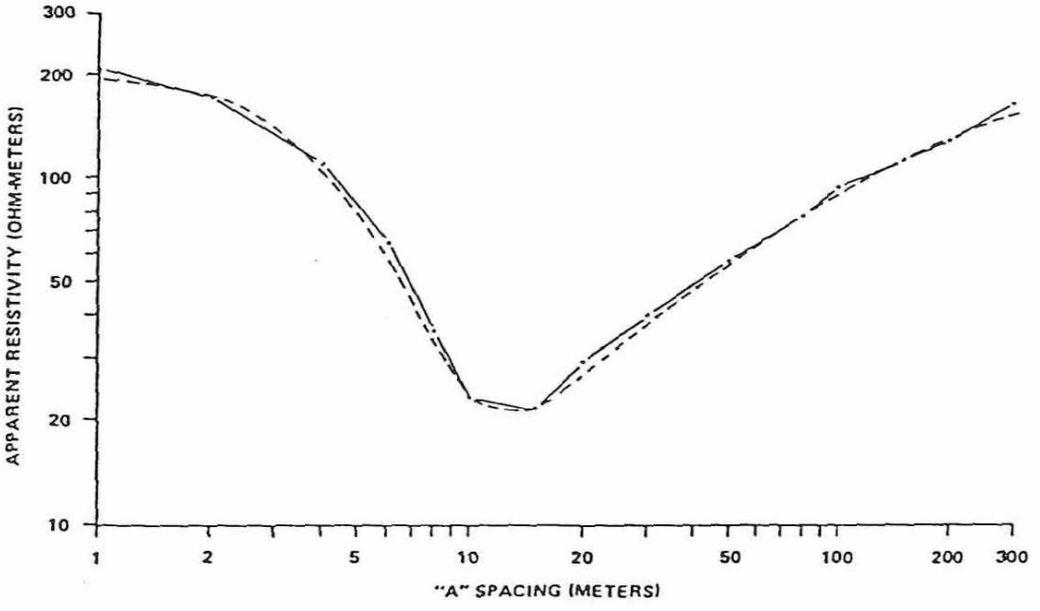
EXAMPLE OF WENNER PROFILING RESISTIVITY DATA (A) AND INTERPRETATION (B)

FIGURE 5

A.) DATA:

"A" SPACING (METERS)	APPARENT RESISTIVITY (OHM-METERS)
1	205
2	172
4	110
6	64
8	36
10	23
15	22
20	30
30	40
60	69
80	79
100	95
150	111
200	130
300	165

B.) INTERPRETATION:



		1st LAYER	2nd LAYER	3rd LAYER
------ THEORETICAL MODEL	RESISTIVITY RATIOS	1	0.05	1
	THICKNESS RATIOS	1	3	

·———· FIELD CURVE

INTERPRETATION

	THICKNESS	RESISTIVITY
1st LAYER	3 METERS	200 OHM-METERS
2nd LAYER	9 METERS	10 OHM-METERS
3rd LAYER	——	200 OHM-METERS

EXAMPLE OF WENNER VES DATA (A)
AND INTERPRETATION (B)

Inverse modeling also begins with computation of theoretical resistivity values from layer parameters supplied by the interpreter, but refinement of the layer parameters is automatically performed by the computer code. The final product of an inverse modeling session is a set of layer parameters and a corresponding theoretical curve which provide the best possible fit to the field data. This "numerically correct" interpretation must be examined by a geologist or geophysicist to ensure that the model is geologically reasonable. Again, actual field data from a boring or test pit should be used to check the model.

Dipole-dipole resistivity analysis is considerably different from horizontal profiling or VES analysis. Dipole-dipole data are displayed in a two-dimensional pseudosection format (Figure 6), and the analysis is thus performed by two-dimensional numerical modeling. An example of finite-element modeling of dipole-dipole data may be found in Rijo (1977). Note that the complexity of this finite-element modeling requires a well-trained interpreter and a mini-computer; these restrictions will limit the number of contractors qualified to perform dipole-dipole interpretation.

5.5.2 Presentation of Results

Horizontal profiling data are contoured or presented as linear-linear plots of apparent resistivity versus distance along a traverse. An example of the profiling plotting technique is provided on Figure 4.

VES data are plotted on log-log graphs with apparent resistivity values on the y-axis and Wenner a-spacings or the Schlumberger current electrode separations on the x-axis. See Figure 5 for an example. Layer parameters used in VES modelling, i.e. layer thicknesses and resistivities, must be included with each VES plot, as shown on Figure 5.

Dipole-dipole data are shown as pseudosection plots, usually with resistivity values contoured (see Figure 6). A cross section of the inferred geologic model should accompany the pseudosection plot.

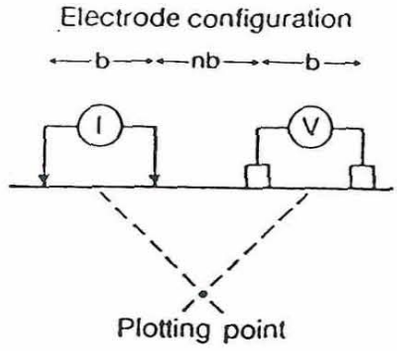
5.3.3 Interpretation of Results

Interpretation of resistivity data entails comparing resultant ranges of resistivity values with natural earth materials or manmade objects likely to be present. Horizontal profiling data and VES modelling results are directly indicative of the resistivities of the materials encountered: higher resistivity values represent more electrically resistive materials (such as sands or gravels). Figure 4 shows Wenner profiling data over a localized zone of anomalously low resistivity soil. Figure 5 shows Wenner resistivity sounding data over a clay seam that occurs between more resistive soil layers.

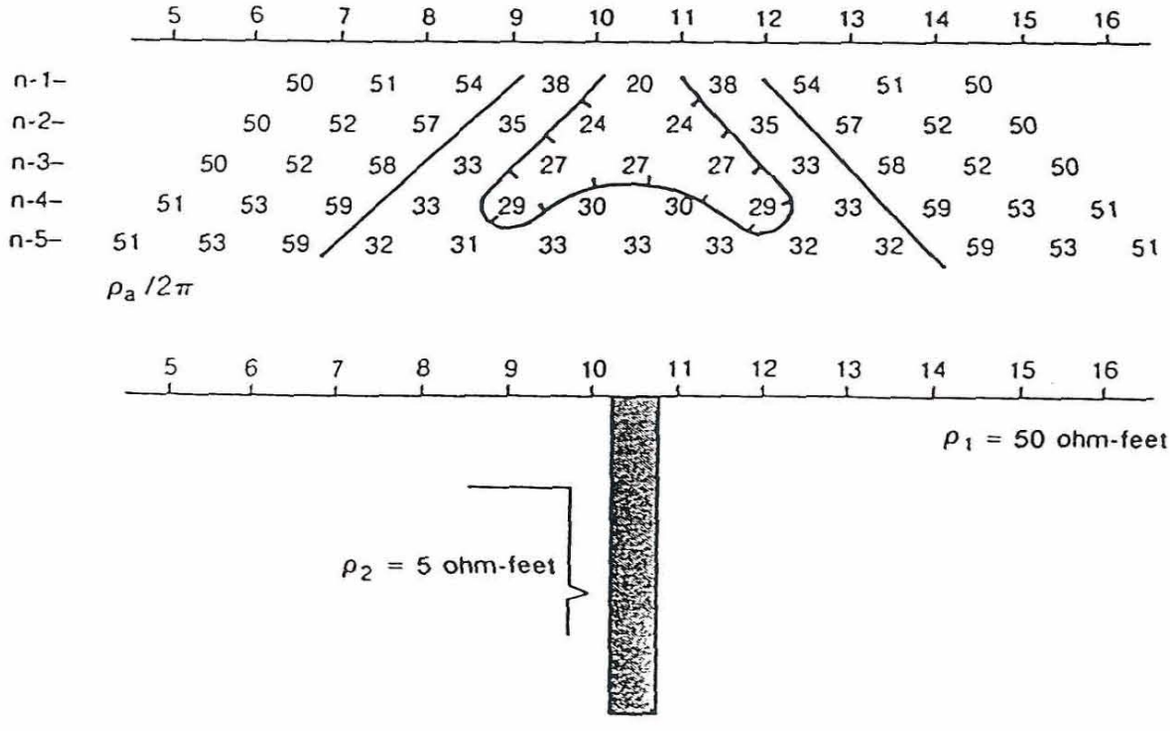
Dipole-dipole interpretation is more subjective, and requires an experienced interpreter. The complexity of dipole-dipole interpretation arises from the lack of correspondence between a dipole-dipole pseudosection and the actual resistivities of the earth materials investigated. As a simple example, a low-resistivity vertical dike will produce a dipole-dipole anomaly in the shape of an inverted letter "V". Although the dike has low resistivity, the anomaly will contain both low and high resistivity values which could be misinterpreted by inexperienced personnel.

Correlation of resistivity data with other geophysical data sets, borehole geologic logs, or borehole cores and samples, is necessary to more accurately identify the materials or structures inferred from the resistivity results. Estimates of layering thicknesses from resistivity modeling typically have to

FIGURE 6



PSEUDOSECTION PLOTTING FORMAT



EXAMPLE PSEUDOSECTION AND GEOLOGIC MODEL

EXAMPLE OF DIPOLE-DIPOLE RESISTIVITY PSEUDOSECTION FORMAT

be compared with seismic refraction or geologic data because of the imprecision inherent in resistivity layer calculations. The imprecision is caused by the non-uniqueness of resistivity data: many different models can produce theoretical curves which nearly fit the field data. A knowledgeable interpreter is thus needed to successfully integrate the resistivity results with other data, including geologic information regarding the site of interest.

5.6 Advantages and Disadvantages

Some of the advantages of resistivity surveying include the general portability of the equipment, the potential for in-field data reduction by using portable computers with horizontal profiling and VES surveys, and the generation of information which cannot be obtained with other methods at a similar cost. Equally important are the limitations inherent in resistivity surveying, which will be reviewed below. Knowledge of these limitations is critical to avoid misapplication of the resistivity technique.

First, the resistivity surveying methods can be carried out only in media which are neither extraordinarily conductive or resistive. If electrodes are placed in very conductive material, e.g., a clay layer, then the applied current flow is trapped in the conductive layer. A bedrock layer underlying the clay, could remain undetected because virtually none of the current would pass through the rock.

In very resistive materials, such as talus, resistivity surveying often cannot be performed because poor electrode contact prevents introduction of current into the earth. Marginal cases may be aided by wetting the electrodes to decrease earth resistance, but in severe cases the resistivity method must be replaced with another technique.

Another limitation is the size of a target body which can be detected by resistivity surveys. Thin layers, or targets of limited lateral extent, may be undetectable because the measured potentials integrate the effects of a large volume of material. This difficulty can be reduced if the minimum size and resistivity contrast of the expected target is known before the field measurements are begun. Numerical modelling can then be performed to select the most effective electrode array and spacing to identify the desired target. This approach is particularly effective in planning VES and dipole-dipole surveys.

Cultural interference is another serious limitation of resistivity surveying. Interference from metal fences can be minimized by orienting electrode arrays perpendicular to the fence. The same approach can be used with underground utilities, but in general an area of utilities is best avoided altogether.

All reports must include a statement of the field and computer methods used, including calibrations and correlations with other geologic or geophysical data.

6.0 QUALITY ASSURANCE RECORDS

All data will be recorded in log books and/or data logging sheets designed for this procedure. All data will be entered with the following basic information: date, start and end times (military time), location, personnel on site, Contract Task Order number, and weather.

7.0 REFERENCES

Dobrin, M.B., 1976, Introduction to Geophysical Prospecting (2nd ed.: New York, McGraw-Hill, 446 p.

Ghosh, D.P., 1971a, The Application of Linear Filter Theory to the Direct Interpretation of Geoelectrical Resistivity Sounding Measurements: Geophysical Prospecting, v. 19, no. 2, p. 192-217.

Ghosh, D.P., 1971b, Inverse Filter Coefficients for the Computation of Apparent Resistivity Standard Curves for a Horizontally Stratified Earth: Geophysical Prospecting, v. 19, no. 4, p. 769-775.

Keller, G.V., and Frischknecht, F.C., 1966, Electrical Methods in Geophysical Prospecting: New York, Pergamon Press, Elmsford, 523 p.

Koefoed, 0., 1979, Geosounding Principles, 1 - Resistivity Sounding Measurements: New York, Elsevier, 276 p.

Orellana, E., and Mooney, H.M., 1966, Master Tables and Curves for Vertical Electrical Sounding over Layered Structures: Interciencia, Madrid, Spain, 150 p. (Available from: U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, 39180).

Rijo, L., 1977, Modelling of Electrical and Electromagnetic Data: Ph.D. dissertation, University of Utah, Department of Geology and Geophysics, 242 p.

Telford, U.n., Geldart, L.P., Sheriff, R.E. and Keys, D.A., 1976, Applied Geophysics: New York, Cambridge University Press, 860 p.

U.S. Army Corps of Engineers, 1979, Geophysical Exploration: Engineer Manual No. EM-1110-1-1802, Vicksburg, Mississippi, 313 p.

Van Nostrand, R.G., and Cook, K.L., 1966, Interpretation of Resistivity Data: U.S. Geological Survey Professional Paper 499, 310 p.

Yazicigil, H. and Sendlein, L.V.A., 1982, Surface Geophysical Techniques in Groundwater Monitoring, Part II: Ground Water Monitoring Review, v. 1, no. 1, p. 56-62.

Zhody, A.A.R., et al., 1974, Application of Surface Geophysics to Groundwater Investigations: U.S. Geological Survey, Techniques of Water Resources Investigations, Book 2, Chapter D1, 116 p.

APPENDIX O
SAMPLE PRESERVATION AND HANDLING

SAMPLE PRESERVATION AND HANDLING
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3.0 DEFINITIONS

4.0 RESPONSIBILITIES

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- 5.3 Sample Holding Times

6.0 SAMPLE HANDLING AND TRANSPORTATION

7.0 REFERENCES

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
H_2SO_4- Sulfuric Acid
HNO_3 - 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 H_2SO_4 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 the 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_2SO_4 to pH <2	28 days	EPA 415.1	2 x 40 ml
Total Organic Halogen	plastic/glass	Cool to 4°C H_2SO_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.

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 P
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
- 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

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 A

EXAMPLE SAMPLE LABEL

Baker

Baker Environmental Inc.
Airport Office Park, Bldg. 3
420 Rouser Road
Coraopolis, PA 15108

Project: 19026-SRN CTO No.: 0026

Sample Description: Groundwater

Date: 09/17/92 Sampler: ABC

Time: 0944

Analysis: TAL Metals (CAP) Preservation: HNO_3

Project Sample No.: CAX-GW-04

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

Baker Environmental, Inc.
Airport Office Park, Bldg. 3
420 Rouser Road
Coraopolis, PA 15108
412-269-6000
412-269-6097 (fax)

CHAIN-OF-CUSTODY RECORD

Pg. __ of __

Project Number: _____
Project Name: _____
Field Team: _____
SEND RESULTS TO: _____

Analytical Methods / Preservatives

Type of Container(s) (3)

Number of Container(s)

General Comments

Sample Number	Date	Time	Sample Location	Matrix Type (1) GB (2)	Matrix Type (1) COM. (2)													Remarks

Relinquished By: _____ Date: _____ Time: _____
Received By: _____ Date: _____ Time: _____
Shipped by (check one): Hand ☐ Overnight ☐ Other ☐ _____

Relinquished By: _____ Date: _____ Time: _____
Received By: _____ Date: _____ Time: _____
Shipped by (check one): Hand ☐ Overnight ☐ Other ☐ _____

Relinquished By: _____ Date: _____ Time: _____
Received By: _____ Date: _____ Time: _____
Shipped by (check one): Hand ☐ Overnight ☐ Other ☐ _____

Sample Stored at 4°C: Yes ☐ No ☐
Chain-of-custody seal on cooler: Yes ☐ Number: _____ No ☐
Analysis turnaround: Priority ☐ _____ hrs. Regular ☐
See Work Order ☐
See Analysis Request Form ☐

Sample Disposal: Return to Baker ☐ Lab Disposal ☐
Archive until: _____ (date)

NOTES:

(1) A - Air; GW - Groundwater; S - Spring; SO - Soil; SW - Surface water; W - Waste; WP - Wipe; WW - Wastewater

(2) GB - Grab; COM - Composite

(3) P - Plastic; G - Glass

ATTACHMENT C

EXAMPLE CUSTODY SEAL

ATTACHMENT C

EXAMPLE CUSTODY SEAL

Baker ____/____/____ Date _____ Signature CUSTODY SEAL	Baker ____/____/____ Date _____ Signature CUSTODY SEAL

APPENDIX Q
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.

APPENDIX P
CHAIN-OF-CUSTODY

CHAIN-OF-CUSTODY
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1.0 PURPOSE

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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
- 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

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 A

EXAMPLE SAMPLE LABEL

Baker

Baker Environmental Inc.
Airport Office Park, Bldg. 3
420 Rouser Road
Coraopolis, PA 15108

Project: 19026-SRN CTO No.: 0026

Sample Description: Groundwater

Date: 09/17/92 Sampler: ABC

Time: 0944

Analysis: TAL Metals (CAP) Preservation: HNO_3

Project Sample No.: CAX-GW-04

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

Baker Environmental, Inc.
Airport Office Park, Bldg. 3
420 Rouser Road
Coraopolis, PA 15108
412-269-6000
412-269-6097 (fax)

CHAIN-OF-CUSTODY RECORD

Pg. __ of __

Project Number: _____
Project Name: _____
Field Team: _____
SEND RESULTS TO: _____

Analytical Methods / Preservatives

Type of Container(s) (3)

Number of Container(s)

General Comments

Sample Number	Date	Time	Sample Location	Matrix Type (1) GB (2)	Matrix Type (1) COM. (2)													Remarks

Relinquished By: _____ Date: _____ Time: _____
Received By: _____ Date: _____ Time: _____
Shipped by (check one): Hand ☐ Overnight ☐ Other ☐ _____

Relinquished By: _____ Date: _____ Time: _____
Received By: _____ Date: _____ Time: _____
Shipped by (check one): Hand ☐ Overnight ☐ Other ☐ _____

Relinquished By: _____ Date: _____ Time: _____
Received By: _____ Date: _____ Time: _____
Shipped by (check one): Hand ☐ Overnight ☐ Other ☐ _____

Sample Stored at 4°C: Yes ☐ No ☐
Chain-of-custody seal on cooler: Yes ☐ Number: _____ No ☐
Analysis turnaround: Priority ☐ _____ hrs. Regular ☐
See Work Order ☐
See Analysis Request Form ☐

Sample Disposal: Return to Baker ☐ Lab Disposal ☐
Archive until: _____ (date)

NOTES:

(1) A - Air; GW - Groundwater; S - Spring; SO - Soil; SW - Surface water; W - Waste; WP - Wipe; WW - Wastewater

(2) GB - Grab; COM - Composite

(3) P - Plastic; G - Glass

ATTACHMENT C

EXAMPLE CUSTODY SEAL

ATTACHMENT C

EXAMPLE CUSTODY SEAL

Baker ____/____/____ Date _____ Signature CUSTODY SEAL	Baker ____/____/____ Date _____ Signature CUSTODY SEAL