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Final

Full RCRA Facility Investigation Work Plan

SWMU 9 Area B, Tank 214 Area

Naval Activity Puerto Rico
RCRA/HSWA Permit No. PR2170027203
Ceiba, Puerto Rico

Prepared for

Department of the Navy
Atlantic Division
Naval Facilities Engineering Command

Norfolk, Virginia

Contract No. N62470-02-D-3052
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February 29, 2008

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FINAL
FULL RCRA FACILITY INVESTIGATION WORK PLAN
SWMU 9 AREA B, TANK 214 AREA

NAVAL ACTIVITY PUERTO RICO
RCRA/HSWA PERMIT NO. PR2170027203
CEIBA, PUERTO RICO

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FEBRUARY 29, 2008

Prepared for:

DEPARTMENT OF THE NAVY
NAVAL FACILITIESENGINEERING COMMAND
ATLANTIC DIVISION
Norfolk, Virginia

Under the:

LANTDIV CLEAN Program
Contract N62470-02-D-3052

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I certify under penalty of law that I have examined and am familiar with the information submitted in this document and all attachments and that this document and its attachments were prepared either by me personally or under my direction or supervision in a manner designed to ensure that qualified and knowledgeable personnel properly gather and present the information contained therein. I further certify, based on my personal knowledge or on my inquiry of those individuals immediately responsible for obtaining the information, that the information is true, accurate and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fines and imprisonment for knowingly and willfully submitting a materially false statement.

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LIST OF ACRONYMS AND ABBREVIATIONS

AOC	Area of Concern
AVGAS	Aviation Gasoline
Baker	Baker Environmental, Inc.
bgs	below ground surface
BRAC	Base Realignment and Closure
BTEX	Benzene, toluene, ethylbenzene, and xylene
CERCLA	Comprehensive Environmental Response Conservation and Liability Act
CLEAN	Comprehensive Long-Term Environmental Action Navy
CMS	Corrective Measures Study
COC	Chemical of Concern
CTO	Contract Task Order
DoN's	Department of the Navy's
DRMO	Defense Reutilization and Marketing Office
DRO	Diesel Range Organics
EM	Electromagnetic
ERA	Ecological Risk Assessment
FMTUD	Facility Management Transportation and Utility Division
GIS	Geographic Information System
GPS	Global Positioning System
GRO	Gasoline Range Organics
GPR	Ground Penetrating Radar
HHRA	Human Health Risk Assessment
HQ	Hazard Quotient
HSA	Hollow-stem augers
HSWA	Hazardous and Solid Waste Amendments
ICM	Interim Corrective Measure
IDW	Investigation Derived Waste
IR	Installation Restoration Program
LANTDIV	Naval Facilities Engineering Command Atlantic Division
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
MCL	Maximum Contaminant Level
mg/kg	Milligram per Kilogram
MS/MSD	Matrix Spike/Matrix Spike Duplicate

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

NAPR	Naval Activity Puerto Rico
NSSR	Naval Station Roosevelt Roads
NTR	Navy Technical Representative
OUs	Operable Units
PAH	Polynuclear Aromatic Hydrocarbons
PID	Photoionization Detector
PMO	Project Management Office
PREQB	Puerto Rico Environmental Quality Board
PRG	Preliminary Remediation Goal
PVC	Polyvinyl Chloride
PWD	Public Works Department
QA/QC	Quality Assurance/Quality Control
RCI	Reactivity, Corrosivity, Ignitibility
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
SE	Southeast
SOP	Standard Operating Procedure
SWMU	Solid Waste Management Unit
TCA	1,1,2-Trichloroethane
TCLP	Toxicity Characteristic Leaching Procedure
TPH	Total Petroleum Hydrocarbons
USEPA	United States Environmental Protection Agency
USTs	Underground Storage Tanks
VOCs	Volatile Organic Compounds

1.0 INTRODUCTION

This document presents the activities required for the performance of a full Resource Conservation Recovery Act (RCRA) Facility Investigation (RFI) at the Solid Waste Management Unit (SWMU) 9, Area B, Tank 214 Area, located at Naval Activity Puerto Rico (NAPR), Ceiba, Puerto Rico (Figure 1-1).

This document was prepared by Baker Environmental, Inc. (Baker), for the Naval Facilities Engineering Command Atlantic Division (LANTDIV). This work plan is being developed under Contract Task Order (CTO) 147 under the LANTDIV Comprehensive Long-Term Environmental Action Navy (CLEAN) Program, Contract Number N62470-02-D-3052. The work will be implemented in accordance with the Final RFI Management Plans (Baker, 1995), with updates to appropriate sampling and analytical methods.

1.1 Site History

This section provides a description of the site and its history. A description of regional and, where applicable, area-specific physiographic features, including climate, topography, geology, and hydrology was previously presented in the *Draft Phase I RCRA Facility Investigation Report for SWMU 9, Area B (Tank 214), Naval Station Roosevelt Roads, Ceiba, Puerto Rico* (Baker, 2007). As of August 21, 2007 the United States Environmental Protection Agency (USEPA) has deemed this report as complete.

NAPR occupies over 8,600 acres on the East Coast of Puerto Rico, along Vieques Passage, with Vieques Island lying approximately ten miles to the east. NAPR was commissioned in 1943 as a Naval Operations Base and re-designated a Naval Station in 1957. Naval Station Roosevelt Roads (NSRR) operated as a Naval Station until March 31, 2004 when NSRR underwent operational closure. On April 1, 2004 NSRR was re-designated as NAPR. The current primary mission of NAPR is to protect the physical assets remaining, comply with environmental regulations, and sustain the value of the property until final disposal of the property.

On October 20, 1994, a Final RCRA Part B permit was issued by the USEPA Region II to NSRR. This permit contained requirements for RFI activities at 24 SWMUs and three areas of concern (AOC). Prior to 1993, environmental activities at NSRR, exclusive of underground storage tanks (USTs), were conducted in compliance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) regulations under the Department of the Navy's (DoN's) Installation Restoration (IR) Program. The RCRA Part B permit, issued for the Defense Reutilization and Marketing Office (DRMO) at NSRR, included provisions for corrective action under the Hazardous and Solid Waste Amendments (HSWA) provisions of RCRA.

The various SWMUs and AOCs at NAPR have been grouped together into Operable Units (OUs) based on similarity of investigation scope, geography, or similarity of contaminants potentially released. This work plan pertains to SWMU 9 Area B - Tank 214 Area, a fuel management area within OU 2. OU 2 consists of SWMUs 7 and 8 (Tow Way Fuel Farm) and SWMU 9 (Tanks 212-217).

SWMU 9 is comprised of six USTs, pipelines, and ancillary facilities. For investigation purposes, the SWMU had been divided into three separate areas:

- Area A – Tanks 212 to 213
- Area B – Tanks 214 to 215
- Area C – Tanks 216 and 217

Areas A and B are located north of Forrestal Drive, along Manila Bay Street (see Figure 1-2). Area C is located approximately 4,000 feet southwest of Areas A and B, north of Forrestal Drive along Antietam Road. The USTs were constructed in the 1940's for the storage of aviation gasoline (AVGAS) for piston-driven airplanes. Most recently, Tanks 212 and 213 (Area A) were used for the storage of diesel fuel and unleaded gasoline. Tanks 214 and 215 (Area B) were changed from AVGAS storage to diesel fuel marine, while Tank 216 (Area C) was most recently used for the storage of unleaded gasoline. In addition to AVGAS, Tank 217 (Area C) may have been used for the storage of diesel fuel marine and JP-5. All tanks were cleaned and put out of service in 2001.

Previous reports indicate that each UST was cleaned of petroleum-based sludge every five years. Sludge material collected during tank cleaning activities prior to 1978 was reportedly disposed of onsite in unlined earthen pits. Since 1978, any sludge materials generated during tank cleaning activities have been removed and disposed off-site by a licensed contractor. A geophysical investigation, using a combination of both electromagnetic (EM) terrain conductivity and ground penetrating radar (GPR), conducted during Phase I of the SWMU 9 RFI, as well as test pits excavated during Phases I and II of the SWMU 9 RFI did not identify the presence of the suspected sludge disposal pits (Baker, 2000).

Following the Phase II RFI, an ecological risk assessment (ERA) was undertaken to determine the impact of Navy activities on ecological receptors. Steps 3b and 4 of the ERA process were finalized in January, 2006 (Baker, 2006a), and sampling associated with Step 5 of the ERA was performed in August 2005. Prior to publication of the results of the work performed for Steps 5 and 6, however, an interim corrective measure (ICM) was undertaken at three locations at SWMU 9 Area B in the Tank 214 area in order to remove lead contaminated soil. During the ICM in May 2006, petroleum-impacted soil was discovered at one location at the floor of the excavation at a depth of approximately 1 foot below ground surface. One soil sample was collected from the suspected petroleum-contaminated soils and analyzed for total petroleum hydrocarbons (TPH) diesel range organics (DRO) and TPH gasoline range organics (GRO), and Appendix IX volatile organic compounds (VOCs). Results of this sample (S3-SW01-FL01) indicated TPH-GRO at 690 mg/kg, TPH-DRO at 144 mg/kg, 1,1,2-trichloroethene (112-TCE) at 46J micrograms per kilogram (µg/kg), and acetone at 103 J µg/kg. It was decided to halt the ERA process in order to determine the extent of the petroleum-impacted soil. This resulted in the preparation of a Phase I RFI *for the SWMU 9 Area B, Tank 214 Area. Since the Phase I RFI Report (Baker, August 14, 2007) confirmed that releases of solid and/or hazardous wastes or hazardous constituents are present at the site, USEPA in a letter* dated August 21, 2007 directed that a full RFI Work Plan be developed to fully characterize the nature and extent of contamination associated with the site. This Work Plan is the result of the USEPA directive.

1.2 Objectives

The objectives of this Full RFI for SWMU 9, Area B, Tank 214 are based on the EPA Region II comment letter dated August 21, 2007, which recommended that the soil, sediment, and groundwater at the Tank 214 area be fully characterized to determine the nature and extent of contamination associated with:

- TPH present in the soils surrounding Tank 214
- TPH present in the sediments near the shore-line north of Tank 214
- Benzene and other organic constituents, including 1,1,2-Trichloroethane (TCA), present in the groundwater around Tank 214.

In addition, EPA comments (which included TechLaw Technical Review of the November 28, 2007 Draft Full RFI Work Plan for SWMU 9 Area B, Tank 214) were received by the Navy on January 17, 2008. Based on those comments the following additional analytes will be included with the sampling plan:

- Appendix IX metals present in the surface soil and sediment.
- Methyl tertiary butyl ether (MTBE) present in the subsurface soils and groundwater.

The Project Quality Objectives (PQOs) defining the type, quantity, and quality of data needed to specifically address each of the overall objectives stated above. Although the seven step DQO process was not rigorously applied in the SWMU 9 work plan, elements essential to the process (with the exception of statistically determining the number of samples) have been considered in the development of the sampling design. The work plan was developed with input from human health and ecological risk assessors to assure that the investigation will provide the data that is needed for risk management decisions. The human health and ecological risk assessors have reviewed the sampling program (number, frequency, location and collection methods) and analytical programs (analytical methods, parameter lists, detection limits) and have compared applicable screening values to method performance limits to maximize the usability of the resultant data.

1.3 Organization of the RFI Work Plan

This work plan is organized into seven sections. Section 1.0 of this document includes the site history and objectives of this RFI. Section 2.0 provides a description of the current conditions and usage of the site, as well as a summary of previous investigations. Section 3.0 provides a description of the scope of investigations that will be utilized during the upcoming fieldwork. The proposed scope of investigations include a soil sampling and analysis program, temporary and permanent monitor well installation programs, a groundwater sampling and analysis program, a sediment sampling and analysis program, and collection/analysis of quality assurance/quality control (QA/QC) samples, as well as other investigation considerations. The reporting activities that will be conducted following the completion of the field investigation are described in Section 4.0. Section 5.0 discusses the proposed project schedule that will be followed for this data collection investigation. The site management structure that will be utilized during this investigation, including project team responsibilities and field reporting requirements, is presented in Section 6.0, while Section 7.0 presents the Work Plan references.

2.0 CURRENT CONDITIONS AND BASIS FOR A FULL RFI

The following sections provide a discussion of the current conditions that exist at SWMU 9 Area B – Tank 214 Area along with any previous investigations that have been conducted.

2.1 Current Site Conditions/Usage

The USTs were constructed in the 1940's for the storage of AVGAS for piston-driven airplanes. Most recently, Tanks 214 and 215 were changed from AVGAS storage to diesel fuel marine. Previous reports indicate that each UST was cleaned of petroleum-based sludge every five years. Sludge material collected during tank cleaning activities prior to 1978 was reportedly disposed of onsite in unlined earthen pits. Since 1978, any sludge materials generated during tank cleaning activities have been removed and disposed off-site by a licensed contractor.

All tanks were cleaned and put out of service in 2001. No ongoing activities are occurring at the present time at this SWMU.

2.2 Previous Investigations/Interim Corrective Measures

Sampling activities at SWMU 9 (Areas A, B, and C) have been conducted under six separate investigations and Interim Corrective Measures:

- RFI: Phase I (April 1996), Phase II (September/October 1997), and Phase III (June 1999) at Areas A, B, and C;
- Corrective Measures Study (CMS) Investigation in December 2000 at Areas A, B, and C;
- Additional Data Collection Field Investigation in support of the ERA in July 2003 at Area B;
- Steps 5 and 6 of the BERA (conducted in August 2005 and January 2006, respectively at Area B), and;
- ICM (conducted in May 2006 at Area B)
- RFI: Phase I RCRA Facility Investigation at SWMU 9, Area B, Tank 214 Area (conducted in March, 2007)

RCRA Facility Investigation

The RFI field investigations and associated analytical data were presented and discussed in the *Revised Draft RCRA Facility Investigation Report for SWMU 9, Naval Station Roosevelt Roads, Ceiba, Puerto Rico* (Baker, 2000). The RFI indicated that there was some evidence of the impact of past site operations on subsurface soil and groundwater. Total petroleum hydrocarbons (TPH) Diesel-Range Organics (DRO) and TPH Gasoline-Range Organics (GRO) were detected in samples. SVOC were also detected, but at low levels and did not exceed screening criteria. The inorganics detected in subsurface soil samples above background screening criteria were not associated with fuel. Lead was associated with gasoline; however, detects above background were limited. There is evidence of the impact of past site operations on groundwater. Benzene, toluene, ethylbenzene, and xylene (BTEX) compounds were detected in several of the temporary monitoring wells located downgradient of Tanks 214. There is limited evidence of the impact of past site operations on

surface water and sediment. Several Volatile Organic Compounds (VOCs) were detected in sediments, but all were below screening criteria. Many inorganic compounds were detected in surface water and sediment, and many exceeded the background screening criteria; however, most of the inorganic compounds were determined not to be associated with fuels. Lead was associated with fuel, and was detected in surface water and sediment above screening criteria.

The human health risk assessment (HHRA) did not identify an incremental lifetime cancer risk greater than the acceptable USEPA limits. There were no unacceptable non-carcinogenic risks associated with exposures to contaminants detected (as estimated in the HHRA). The screening-level ERA indicated that the assessment endpoints were not met. As such, the results of the screening-level ERA were determined not to be sufficient to conclude that risks to the ecological receptors were negligible. For all receptor species, there were multiple chemicals with Hazard Quotient (HQ) values greater than 1.0. These receptor species included sediment-associated biota for copper and vanadium, aquatic life for copper and cyanide, earthworms for chromium, plants for chromium and lead, Belted Kingfisher for chromium lead, vanadium, American Robin for lead, and the Red-Tailed Hawk for lead.

Corrective Measures Study Investigation

The CMS field investigation and associated analytical data were presented and discussed in the *Final Corrective Measures Study Investigation Report for SWMU 9, Naval Station Roosevelt Roads, Ceiba, Puerto Rico* (Baker, 2003). A screening-level ERA and Step 3a of the baseline ERA was conducted at SWMU 9 for this CMS. The CMS indicated uncertainties associated with the analytical data, and the data were deemed to be unacceptable. Therefore, a decision was made to collect additional surface water, sediment, and surface soil samples and re-evaluate potential risks to ecological receptors. A sampling plan was prepared by Baker and approved by the USEPA in 2001 (Baker, 2001). Based on the additional sampling and re-evaluation of ERA Step 3a, it was recommended that no further evaluation of ecological risk need be conducted for Area B surface water. The CMS did indicate that there appeared to be a potential risk to both soil invertebrates and upper trophic level receptors from lead and zinc in surface soil. There also appeared to be a potential risk to benthic invertebrates and upper trophic level receptors from lead. It was stated that these metals represent those chemicals that could not be dismissed from posing potential risk to ecological receptors after evaluating the weight of evidence for each chemical. Due to the potential risks to invertebrates and upper trophic level receptors from the surface soils, it was recommended that additional sampling be conducted in the vicinity of Tank 214 to characterize the extent of lead and zinc contamination. Also, due to the potential risk to benthic invertebrates and upper trophic level receptors from lead in sediment, it was also recommended that additional characterization be performed. This characterization was specific to two locations (9SD19 and 9SD20). Once the characterization was completed, Step 3a of the ERA was to be reevaluated before making a decision of whether or not this site should move forward to Step 3b or move into the CMS stage.

Additional Data Collection Field Investigation

The additional data collection field investigation and associated analytical data were presented and discussed in the *Final Additional Data Collection Investigation Report, SWMU 9, Naval Activity Puerto Rico, Ceiba, Puerto Rico* (Baker, 2004). Given the limited surface soil and sediment data available for these two metals, the CMS recommended the collection of additional surface soil samples at Area B (in the vicinity of Tank 214) for lead and zinc analysis, as well as the collection of additional sediment samples from the estuarine wetland system downgradient from Tank 214 for lead analysis prior to making a decision on whether the SWMU should move forward in the ERA process (i.e., the baseline risk assessment problem formulation). A work plan presenting the technical approach for conducting the additional data collection was prepared and submitted to the USEPA in

2003 (Baker, 2003). The report for the investigation contained risk calculations and a risk characterization for the lead and zinc surface soil data and lead sediment data (unified data sets containing surface soil and sediment data from the RFI, CMS, and additional data collection field investigations). Based on the risk calculations and characterization, lead was retained as an ecological chemical of concern (COC) for surface soil and terrestrial avian omnivore food web exposures. Lead also was retained as an ecological COC for aquatic invertebrates and avian invertebrate consumer populations.

Based on the risk calculations and risk characterization summarized, it was recommended that SWMU 9 Area B move forward in the ERA process (Step 3b baseline risk assessment problem formulation). The results of the surface soil sampling at SWMU 9 (Area B) identified levels of lead in surface soils above screening criteria.

Baseline Ecological Risk Assessment

The collection and analysis of sediment samples conducted in August 2005 for the BERA field verification (Step 5) and January 2006 for the BERA field investigation (Step 6) of the ERA process is complete. However, the results of that investigation have not been published as part of the ERA at this time due to the finding of the petroleum stained soils during the ICM and the postponement of the ERA process.

Interim Corrective Measure

The screening level ERA and Step 3a of the BERA indicated an ecological risk to invertebrates and upper trophic level receptors from lead and zinc in surface soil. In addition lead was detected in soil above the USEPA Region IX Residential Preliminary Remediation Goal (PRG) for lead in soil (400 mg/kg). Thus, the Navy evaluated the option of performing an ICM for the removal of soils contaminated with lead in excess of the USEPA action level of 400 mg/kg. To determine if surface soil remediation to address human health would also address potential ecological risks at the SWMU, the Navy conducted an evaluation of ecological risks (post remediation). The evaluation concluded that remediation of surface soils in excess of 400 mg/kg lead would reduce the magnitude and spatial extent of potential risks to acceptable levels, thereby eliminating the need to perform a terrestrial baseline ERA at SWMU 9, Area B. The USEPA agreed to the approach and conclusions. Three areas exhibiting lead contamination in surface soil above 400 mg/kg were excavated in May of 2006.

During the ICM in May 2006, petroleum-impacted soil was discovered at one location at the floor of the excavation at a depth of approximately 1 foot below ground surface. One soil sample was collected from the suspected petroleum-contaminated soils and analyzed for TPH-DRO and TPH GRO, and Appendix IX VOCs. Results of this sample (S3-SW01-FL01) indicated TPH-GRO at 690 mg/kg, TPH-DRO at 144 mg/kg, 1,1,2-trichloroethene (112-TCE) at 46J micrograms per kilogram (µg/kg), and acetone at 103 J µg/kg. It was decided to halt the ERA process in order to determine the extent of the petroleum-impacted soil with a Phase I RFI.

Phase I RCRA Facility Investigation at SWMU 9, Area B, Tank 214 (March 2007)

A Phase I RFI investigation was conducted in March 2007. The purpose of the Phase I RFI was to determine whether or not the environment has been impacted (i.e., to confirm a release) from past operations at SWMU 9, Area B, Tank 214 Area. The results of the investigation were documented in the Phase I RFI Report (Baker, August 2007) and indicated the following:

- TPH-DRO was mainly detected in surface soils and sediments. As shown on Figure 2-1 an

elongated hot spot is evident near the shore line north of the Tank (in the vicinity of samples SB01, SB02, and SB05). Detections of PAHs (benzo[g,h,i]perylene, chrysene, and pyrene) above screening criteria correspond with this hot spot. The extent of TPH-DRO in surface soil and sediment above Puerto Rico Environmental Quality Board (PREQB) Screening Values is broader.

- TPH-GRO was mainly detected in subsurface soils above screening criteria in a broad area generally north of the Tank (see Figure 2-2). A TPH-GRO hot spot is apparent in a more-narrow band north and east of the Tank. The highest levels of ethylbenzene and total xylenes correspond with this hot spot, but are below screening criteria.

- The distribution pattern of TPH-DRO and TPH-GRO appear different indicating different sources:

  - The elongated pattern of TPH-DRO in surface soil is consistent with pit disposal or surface dumping along the shore line.

  - The distribution pattern of TPH-GRO suggests a leak or multiple leaks from Tank 214, with significant lateral dispersion.

- Benzene is the predominant fuel-related compound detected in groundwater above human health screening criteria. As shown on Figure 2-3, the benzene detections correspond to the TPH-GRO source in subsurface soil immediately above the groundwater table. In addition to benzene, 1,1,2-trichloroethane, 2-toluidine, methacrylonitirle, and naphthalene were detected above human health screening criteria.

- In order to evaluate potential human health risks from benzene, 1,1,2-trichloroethane, 2-toluidine, methacrylonitirle, and naphthalene in SWMU 9 groundwater, preliminary risk calculations were performed under a future residential (adult and young child) exposure scenario. Preliminary carcinogenic and noncarcinogenic risk calculations under a future residential exposure scenario exceed USEPA's acceptable criteria (specifically, for carcinogens a risk range of 1×10^{-06} to 1×10^{-04} and noncarcinogens a hazard index of 1.0). Benzene and methacrylonitrile contributed over 95% of the risk presented from potential exposure to groundwater.

- Lead was observed in surface soil beyond the 2006 excavation at concentrations greater than the USEPA Region IX Residential PRG of 400 mg/kg, which was used as a remediation goal for surface soils for the May 2006 ICM. This metal also was detected in one fine sand/silt subsurface soil sample (9SB03-01) at a concentration (790J mg/kg) greater than the ICM remediation goal. The extent of lead detections greater than 400 mg/kg is located immediately to the south of the TPH-DRO hot spot.

- Thallium also was detected at concentrations greater than the ecological soil screening value. Descriptive and/or distributional statistics show that detected concentrations exceed background; however, no discernible pattern is evident in surface soil suggesting it is site related.

- Barium, lead, thallium, and vanadium were detected in SMWU 9 sediment at concentrations exceeding ecological sediment screening values. Statistical evaluations (i.e., descriptive and distributional statistics) show that detected concentrations are elevated above background concentrations.

The Phase I RFI confirmed that releases of solid and/or hazardous wastes or hazardous constituents have occurred at SMWU 9, Area B, Tank 214. Based on these results, USEPA recommended, in a comment letter dated August 21, 2007, that a Full RFI be conducted at SWMU 9, Area B, Tank 214 to further identify and delineate the extent of contamination as it pertains to TPH-DRO/GRO, benzene (and other organic constituents, including the chlorinated solvent 1,1,2-trichloroethane (TCA)) in the surface soils, sediment and groundwater around Tank 214 and near the shore-line north of the tank.

2.3 Area of Investigation at SWMU 9 Area B – Tank 214 Area

The investigation for this Full RFI focuses on further determination of the extent of contamination around the areas where petroleum impacted soil was found during previous investigations. Although analytical results for sediment, groundwater and surface soils at several locations in the nearby area are available from those previous investigations, additional investigation and sampling is needed in order to determine the amount of contamination beyond what has been conducted to date.

3.0 SCOPE OF INVESTIGATION

Surface soil, subsurface soil, groundwater and sediment samples will be collected from the vicinity SMWU 9, Area B, Tank 214 during this Full RFI. Potential sampling locations for this investigation were selected based on:

1) TPH-DRO hot spots in surface soil and sediment evident near the shore line north of the Tank (in the vicinity of previous samples 9SB01, 9SB02, 9SB05 and 9SD53).

2) TPH-GRO hot spots detected in intermediate subsurface soils and deep subsurface soil at or above a 100 mg/kg threshold in broad areas generally north of the Tank. Within the intermediate subsurface soil, Figure 2-5 shows three localized hot spots around 9SB04 (710 mg/kg), 9TW/SB13 (580 mg/kg) , 9SB22 (200 mg/kg), and 9SB27 (580 mg/kg). Finally, in the deep subsurface soil, a considerably larger hot spot was associated with 9SB18 (2,000 mg/kg), 9SB26 (1,300 mg/kg), 9SB25 (2,000 mg/kg), and 9SB29 (1,200 mg/kg).

3) Benzene detected in groundwater and corresponding to the TPH-GRO source in subsurface soil immediately above the groundwater table as shown on Figure 2-3.

4) Previous detections of barium lead, thallium and vanadium in site sediments (which were above background concentrations). In addition to site sediments, surface soil samples will also be analyzed for Appendix IX metals based on the presence of Thallium at concentrations greater than the ecological surface soil screening value. This metal is also statistically elevated above background.

In selecting the sampling locations, consideration was also given to previous sampling locations, site topography, anticipated groundwater flow direction, and contaminant migration potential to the estuarine wetland.

A summary of the sampling and analytical program for this investigation is provided as Table 3-1. The potential soil boring/monitor well locations are shown on Figure 3-1, while the potential sediment sample locations are shown on Figure 3-2. The various investigation elements are bulleted below and described in detail in the subsections that follow.

- Up to 20 surface soil samples will be collected from 20 soil boring locations and will be analyzed at a fixed-base laboratory

- Up to 40 subsurface soil samples will be collected from the 23 boring locations identified above and will be analyzed at a fixed-base laboratory. Two samples will be collected from different depths at each boring location. It is expected that a maximum depth of 15 to 25 feet will be reached at 16 locations, and a maximum depth of 3 feet will be reached for the hand-augered locations (estimated at seven locations), depending on the proximity to the estuarine wetland.

- Up to 13 groundwater samples will be collected from permanent (seven samples) and temporary (six samples) monitor wells installed at various locations identified on Figure 3-1. All groundwater samples will be analyzed at a fixed-base laboratory. Groundwater flow at the site is radial toward the estuarine wetland (Figure 3-1).
- Up to forty two sediment samples will be collected in the estuarine wetland using a stratified random sampling scheme by establishing 50-foot by 50-foot sampling grids (see Figure 3-2). In most cases, a single sediment sample will be collected from the center point of each grid.

However, existing sample locations from previous investigations (i.e., Steps 3b and 4 of the Baseline Ecological Risk Assessment for SWMU 9 – Area B (Tanks 214 – 215) have been overlayed onto Figure 3-2 in order to ensure that Appendix IX VOC;s, Low Level polynuclear aromatic hydrocarbons (PAH's), TPH DRO/GRO, and Appendix IX metals data is analyzed at those same locations for this investigation.

Sample locations and procedures are discussed in more detail in the following sections. Updated Standard Operating Procedures (SOPs) that were previously provided in the Final RFI Management Plans (Baker Environmental, Inc., 1995) will be followed for the proposed field work. These SOPs are provided in Appendix A.

3.1 Soil Sampling and Analysis Program

Surface and subsurface soil samples will be collected from a total of 20 boring locations to meet the objectives of characterizing the extent of contamination in the vicinity of SWMU 9, Area B, Tank 214. The surface and subsurface soil sampling program is discussed in the following sections.

3.1.1 Surface and Subsurface Soil Sampling

The subsurface soil samples will be obtained with either a hand auger (near the wetland) or a 66DT Geoprobe® drill rig capable of direct push and augering. Soil samples will be collected continuously from the ground surface to the water table (from approximately 5 to 25 feet) using a 5-foot long Macro Core Sampler when the 66DT Geoprobe® drill rig is used to advance the borings (an estimated 15 borings using this method). During soil boring installation, care will be taken to achieve maximum recovery so that a good stratigraphic profile can be developed. Soil samples will initially be screened at 6-inch intervals with a photoionization detector (PID) to develop a semi-quantitative profile of contaminated zones. A boring log will be maintained indicating, among other things, lithology, water occurrence, PID measurements and other observations. One surface soil sample (0 to 1 foot below ground surface [bgs]) and two subsurface soil samples will be collected for fixed-base laboratory analysis. (Alternately, the surface soil sample may be collected using a spoon.) The two subsurface soil samples per boring will be collected from the depth of suspected contamination (based on flame ionization detector [FID]/PID measurements, olfactory and/or visual screening), and directly above the water table. Surface and subsurface soil samples will be collected following Baker SOP F102 (see Appendix A). Borehole logging will be prepared in accordance with Baker SOP F101 (see Appendix A).

It is expected that a few soil borings (estimated five borings) will be advanced using hand-augers in the vicinity of the estuarine wetland. Because of the likely shallow depth to water in this area, it is expected that no more than 3 feet depth will be achieved. Soil samples will be placed in aluminum pie pans. Samples for VOC analysis will be containerized and all pertinent sampling information such as soil description (e.g., color and texture), sample number and location, presence or absence of soil discoloration, and the time of sample collection will be recorded in the field logbook. The remaining soil will be thoroughly homogenized with a stainless steel spoon following the removal of debris (e.g., rocks or twigs) prior to placement in the appropriate jars for laboratory-based chemical analysis.

3.1.2 Fixed Base Laboratory Soil Analysis

The surface and subsurface soil samples collected from each boring location will be submitted to a fixed base laboratory for analysis of:

- Appendix IX VOCs
- Low-level PAHs
- TPH DRO and GRO
- Appendix IX metals (analyzed for surface soil samples only).

Table 3-1 summarizes the samples that will be collected and the associated analyses. All analyses at the laboratory will be performed using current methodologies as presented in Table 3-2. It should be noted that MTBE is included in the Appendix IX VOCs list for analysis in Table 3-2. All analytical work conducted on the mainland of the United States of America must be certified by a Puerto Rico licensed chemist. The specific laboratory and third party validator, as well as a certified licensed chemist from Puerto Rico, will be determined at a later date. Standard Operating Procedures (SOPs) used by the analytical laboratory will be requested from the laboratory after selection. Soil borings will be labeled consecutively (beginning with 9SB36 and ending with 9SB54) in a manner consistent with previous sample designations at NAPR. Extensions to the sample identification will reflect the depth at which the sample was obtained. For the purposes of this work plan, two-foot discrete depths will be used. Sample identification extensions will follow the pattern shown below.

9SB36-00 -	SMWU 9 Sample
9SB36-00 -	Soil Boring Sample
9SB36-00 -	Soil boring location identifier
9SB36-00 -	0 to 12 inches bgs (surface soil) sampling interval

Subsurface soil samples will be designated as follows:

9SB36-01 -	First subsurface sampling interval, 1 to3 feet bgs
9SB36-02 -	Second subsurface sampling interval, 3 to5 feet, bgs and so on.

Sample identification extensions will follow the pattern shown above. However, the actual sample depth will be determined in the field.

Samples will be packed in ice and shipped next day air to the fixed-base laboratory. At least one member of the field team will remain on the island until verification by the laboratory of receipt of all shipments. This will minimize any potential re-sampling costs associated with mobilization. Tracking numbers for each shipment will be forwarded to the project manager for assisting in verification of receipt of samples by the laboratory.

3.2 Monitor Well Installation Program

Six permanent and six temporary monitor wells will be installed at the soil boring locations at SWMU 9, Area B, Tank 214. The locations of these wells are shown on Figure 3-1.

Temporary wells installed in soil borings advanced with the 66DT Geoprobe rig will consist of a 2-inch diameter, Schedule 40 polyvinyl chloride (PVC), riser with a five-foot screen. Each temporary well will be sealed with plastic sheeting at the surface to prevent inflow of surface water or accidental introduction of foreign material into the hole. A groundwater sample will be obtained from each temporary well after allowing the groundwater to enter the screen overnight. The temporary wells will not be developed.

The appropriate method for installation of the temporary monitoring point at the hand-augered locations near the wetland will be determined in the field. If the formation will stay open, the hole may be allowed to fill overnight with water from the formation. If it appears to collapse, a PVC

screen may be installed at the appropriate depth. As noted above, these temporary wells will also be sealed with plastic sheeting at the surface to prevent inflow of surface water or accidental introduction of foreign material into the hole.

After completion of groundwater sampling and surveying, as discussed in Section 3.3 and 3.6.5, respectively, each temporary well will be abandoned by extricating the PVC riser and screen and backfilling with the soil removed from the borehole to the extent practicable, in order to minimize the waste disposal burden. The surface of the borehole will then be patched with bentonite grout.

Permanent monitor wells will be installed using hollow-stem augers (HSAs). The wells will be constructed of 2-inch ID, Schedule 40 PVC, with flush joint threads. Well screens will be 10-feet long and installed to straddle the water table.

For all well locations, soil sampling will be conducted in order to classify the soil during well installation. Upon completion of soil sampling, the borehole will be reamed as necessary to the desired depth using the prescribed drilling method. The well construction materials will be installed through the HSAs, casing, or in an open borehole. For the permanent wells, the well screen and bottom cap will be set at the bottom of the borehole. The screen will be connected to threaded, flush-joint, riser. An expandable, water tight locking cap or 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 HSAs or casing are being withdrawn from the borehole. The sand will extend to approximately 2 feet above the top of the screened interval. The thickness of the sand above the screened interval may be reduced if the well is too shallow to allow for placement of adequate sealing material. An approximate 2-foot thick bentonite seal (minimum of 6 inches for very shallow wells) will be placed above the sand pack. If bentonite pellets or chips are used, they will be sized appropriately given the well and borehole diameter and placed in a careful manner that will prevent bridging. The bentonite will be hydrated with potable water, as necessary. The annular space above the bentonite seal will be backfilled with cement/bentonite grout to prevent surface and near subsurface water from infiltrating into the screened groundwater monitoring zone. The grout will consist of five to ten percent (by dry weight) of bentonite powder and seven gallons of potable water per 94-pound bag of portland cement. For very shallow wells, the cement/bentonite grout may be omitted. 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.

Wells will be provided with 2 to 3 feet of "stickup" above ground surface. Steel protective casing will be placed over the riser and surrounded by a concrete pad. The pad will be a minimum of 2 feet by 2 feet (length x width) and 6 inches in thickness (with 2 inches set into the ground outside the casing), and extending 2 feet bgs inside the annular space around the well. If water table conditions prevent having a 24-inch thick bentonite seal, the concrete pad depth in the annular space around the well may be decreased. Steel bollards will be installed around the concrete pad as additional protection and painted a bright color to aid in visibility.

All permanent wells will have a locking cap installed on the PVC riser or protective steel casing.

Each new permanent monitor well will be developed using pumping and surging methods after allowing suitable time for the cement/bentonite grout to cure (typically a minimum of 24 hours). The purpose of well development is 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/accumulated in the well or filter pack. The wells will be developed until the discharged water runs relatively clear of fine-grained materials. It should be noted that the water in some wells does not clear with continued development. Typical limits placed on well development may include any one or a combination of the following:

- Clarity of water based on visual determination
- A maximum time period (typically two hours for shallow wells)
- A maximum borehole volume (typically three to five borehole volumes plus the amount of any water added during the drilling or installation process)
- Stability of pH, specific conductance, and temperature measurements (typically less than 10 percent change between three successive measurements)
- Clarity based on turbidity measurements [typically less than 20 Nephelometric Turbidity Units (NTU)]

A record of the well development will be completed to document the development process. Monitoring well installation and well development procedures will be conducted in accordance with Baker SOP F103 (see Appendix A).

3.3 Groundwater Sampling and Analysis Program

Groundwater sampling will be used to determine the extent of groundwater contamination at SWMU 9. Thirteen groundwater samples will be collected from the temporary and permanent wells and submitted to the laboratory for analysis of:

- Appendix IX VOCs
- Low-level PAHs
- TPH DRO and GRO

Table 3-1 summarizes the samples that will be collected and the associated analyses. All analyses at the laboratory will be performed using current methodologies as presented in Table 3-2. All analytical work conducted on the mainland of the United States of America must be certified by a Puerto Rico licensed chemist. The specific laboratory and third party validator, as well as a certified licensed chemist from Puerto Rico, will be determined at a later date. Standard Operating Procedures (SOPs) used by the analytical laboratory will be requested from the laboratory after selection.

The groundwater will be sampled using a low-flow sampling technique. Appendix B includes a detailed description of the USEPA Region II low flow sampling technique. Field parameters of pH, temperature, turbidity, conductivity, dissolved oxygen, and oxidation-reduction potential will be obtained with appropriate instrumentation during sampling if enough volume of groundwater is present. The groundwater samples will be placed into appropriate laboratory supplied containers. The groundwater flow direction is expected to be radial toward the estuary. Prior to sampling, a synoptic set of static water levels will be recorded in order to obtain data to more accurately interpret the groundwater flow direction at SWMU 9.

The groundwater sample designations will correspond to the soil boring location (refer to Figure 3-1 and Table 3-1). For example, groundwater collected from soil boring location 9SB41 will have a groundwater sample identification of 9PW41. Sample identification extensions will follow the pattern below.

9PW41 -	SMWU 9 Sample
9PW41 -	PW = Permanent Monitor Well, TW = Temporary Monitor Well

9PW41 - Soil boring location identifier

Samples will be packed in ice and shipped next day air to the "fixed base" laboratory. At least one member of the field team will remain on the island until verification by the laboratory of receipt of all shipments. This will minimize any potential re-sampling costs associated with mobilization. Tracking numbers for each shipment will be forwarded to the project manager for assisting in verification of receipt or samples by the laboratory.

3.4 Sediment Sampling and Analysis Program

Forty three sediment samples will be obtained from the estuarine wetland at locations depicted on Figure 3-2. The samples will be obtained using disposable, stainless steel spoons. The samples will be obtained by placing the sediment in a disposable aluminum pan. Samples for VOC analysis will be containerized, and the remaining sediment will be thoroughly homogenized following the removal of debris (e.g., vegetation/roots). All pertinent sampling information such as sediment description (e.g., color and texture), sample number and location, presence or absence of aquatic invertebrates, and the time of sample collection will be recorded in the field logbook. After homogenization, the sediment samples will be placed into appropriate jars for laboratory-based chemical analysis. Sediment sampling will be conducted following Baker SOP F107 (see Appendix A).

The 43 sediment samples will be submitted for analysis of:

- Appendix IX VOCs
- Low-level PAHs
- TPH DRO and GRO
- Appendix IX Metals

Table 3-1 summarizes the samples that will be collected and the associated analyses. As discussed previously, all analyses at the laboratory will be performed using current methodologies as presented in Table 3-2. All analytical work conducted on the mainland of the United States of America must be certified by a Puerto Rico licensed chemist. The specific laboratory and third party validator, as well as a certified licensed chemist from Puerto Rico, will be determined at a later date. Standard Operating Procedures (SOPs) used by the analytical laboratory will be requested from the laboratory after selection.

A portion of the proposed sediment samples will be labeled consecutively beginning with 9SD80 and ending with 9SD108. However, some of the existing sample locations from the Baseline Ecological Risk Assessment for SWMU 9 – Area B (Tanks 214 – 215) will also be used (and analyzed for the parameters outlined in Table 3-1). Those previous sample locations include 9SD39, 9SD41, 9SD45, 9SD47, 9SD54, 9SD59, 9SD70, 9SD71, 9SD72, 9SD75, 9SD77, 9SD78, and 9SD79.

Samples will be packed in ice and shipped next day air to the "fixed base" laboratory. At least one member of the field team will remain on the island until verification by the laboratory of receipt of all shipments. This will minimize any potential re-sampling costs associated with mobilization. Tracking numbers for each shipment will be forwarded to the project manager for assisting in verification of receipt or samples by the laboratory.

3.5 Quality Assurance/Quality Control Samples

Field specific QA/QC procedures are given below. QA/QC samples will be analyzed for parameters as shown in Table 3-3 by methods presented in Table 3-2. QA/QC samples collected during these

investigations will include trip blanks, equipment rinsate samples, field blank samples, field duplicate samples and matrix spike/matrix spike duplicates (MS/MSD), as discussed below.

3.5.1 Trip Blanks

Trip blank samples will be required to accompany the samples submitted to the laboratory for volatile organic and/or TPH GRO analysis. One trip blank sample will accompany each cooler containing samples requiring the Appendix IX VOC and/or TPH GRO analysis.

3.5.2 Equipment Rinsates

Equipment rinsate samples are collected from analyte-free water rinse of decontaminated equipment. Equipment rinsate blanks will be collected on a daily basis and submitted to a fixed-base analytical laboratory for analysis. The total number of equipment rinsate samples to be collected will be dependent on the length of the field investigation. The results from the blanks will be used to determine if the sampling equipment was free of contamination. The equipment rinsate samples are analyzed for the same parameters as the related samples. It is anticipated that a total of three equipment rinsates will be collected. These samples will be associated with the surface and subsurface soil, sediment, and groundwater sampling equipment. The samples will be obtained from a stainless steel spoon for collection of soil and sediment, a split spoon sampler or macro core liner for collection of subsurface soil, and from the polyethylene and silicon tubing used during the collection of groundwater. These samples will be analyzed for the analytes presented in Table 3-3.

3.5.3 Field Blanks

Field blank samples consist of the source water used in equipment decontamination procedures. At a minimum, one field blank for each source of water must be collected and analyzed for the same parameters as the related samples. It is anticipated that three different sources of water (i.e., NAPR potable water source, store-bought distilled water, and laboratory-grade de-ionized water) will be utilized for this investigation as shown in Table 3-3.

3.5.4 Field Duplicates

Field duplicate samples of the surface soil, subsurface soil, groundwater, and sediment samples will be collected during the same time the corresponding environmental sample is collected. One duplicate sample will be collected at a frequency of 10 percent of environmental samples collected per media as shown on Table 3-1.

3.5.5 Matrix Spike/Matrix Spike Duplicates

Matrix Spike/Matrix Spike Duplicates (MS/MSDs) are laboratory derived and are collected to evaluate the matrix effect of the sample upon the analytical methodology. One MS/MSD will be collected for every 20 samples collected of a similar matrix as shown on Table 3-1.

3.6 Other Investigation Considerations

During the investigation, the following activities will be performed:

- Clearing and Grubbing
- Utility Clearance
- Investigation Derived Waste (IDW) Management

- Decontamination
- Surveying
- Health and Safety Procedures
- Chain of Custody

Each of these activities is discussed in the following sections.

3.6.1 Clearing and Grubbing

It may be necessary for site clearing to be performed so the Geoprobe 66DT rig can gain access to delineate the suspected contamination. One day of site clearing will be performed by the direct push subcontractor.

3.6.2 Utility Clearance

If this work plan is initiated while NAPR is still under operation, the following procedure must be followed to obtain utility clearances. Fifteen days prior to the initiation of the proposed fieldwork, a digging permit request will be submitted by Baker to the Facility Management Transportation and Utility Division (FMTUD) of the Public Works Department (PWD) at NAPR. Some fuel lines are identified on the Geographic Information System (GIS) utility layer. All proposed soil borings and monitor well locations will be cleared by the base utility department.

If this work plan is initiated after NAPR is no longer maintaining the facility, then the party conducting the implementation of this work plan will be responsible for clearing all proposed soil boring and well locations.

3.6.3 Investigation Derived Wastes (IDW) Management

The generation of IDW associated with soil sampling and temporary monitor well installation, including soil cuttings and decontamination fluids, will be collected and stored temporarily in 55-gallon drums. However, the soil cuttings from the subsurface soil sampling, as well as from the temporary monitoring wells, will be placed back into the boring from which they came, unless contamination is present. As much as possible, soils last out of the hole will be returned first, thereby, approximating original stratigraphy.

Two IDW samples will be collected during this investigation. One composite aqueous sample will be collected from all drums containing decontamination fluid (from sampling equipment and drill rig), and one composite soil sample will be collected from all drums containing drill cuttings. The soil and water samples will be analyzed for TPH DRO and GRO, Toxicity Characteristic Leaching Procedure (TCLP) VOCs , and reactivity, corrosivity, and ignitibility (RCI) as shown in Table 3-3, as well as by methods presented in Table 3-2. These samples will provide the necessary data to be able to dispose of the generated IDW at an appropriate disposal facility. Upon completion of the field program, the drums will be moved and stored per the direction of PWD personnel. The soil and water IDW will be removed and disposed of from the site by an approved vendor upon receipt and review of the IDW sample analytical data.

3.6.4 Decontamination

All reusable (non-dedicated and non-disposable) soil sampling and monitoring well installation equipment (i.e. augers, bits, split-spoon samplers, etc.), will be decontaminated between each sampling location in accordance with SOPs F501 and F502 (see Appendix A). The drill rigs will be

decontaminated before arriving at the site and before leaving the site. The remaining contaminant-free sampling equipment and materials utilized during this investigation will be disposable.

3.6.5 Surveying

All sampling locations are pre-determined and presented on a figure prior to entering the field. This figure will be loaded into the global positioning system (GPS) unit for locating purposes in the field. This methodology reduces the need for a surveyor to identify the sampling locations in the field. Any of the locations that may need to be field modified will be located utilizing a survey grade GPS unit. Traditional survey equipments or a survey GPS unit will be used to obtain vertical (+/- 0.01 foot) and horizontal (+/- 0.1 foot) locations and top of PVC elevations for the permanent and temporary wells for generating groundwater contours

3.6.6 Health and Safety Procedures

The health and safety procedures previously presented in the RFI Management Plans (Baker, 1995) will be employed during this investigation.

3.6.7 Chain-of-Custody

Chain-of-Custody procedures will be followed to ensure a documented, traceable link between measurement results and the sample/parameter that they represent. These procedures are intended to provide a legally acceptable record of sample preparation, storage, and analysis.

A chain-of-custody form will be completed for each shipment in which the samples are shipped. After the samples are properly packaged, the shipping container will be sealed and prepared for shipment to the analytical laboratory.

3.7 Data Validation

All mainland laboratory data generated by this investigation will be subjected to independent, third party validation. The USEPA Region II Data Validation Standard Operating Procedures will be followed. The specific data validator will be determined at a later date.

4.0 REPORTING

This section outlines the reporting activities that are associated with the field investigation. In accordance with Attachment III of the RCRA § 7003 Administrative Order on Consent mentioned in Section 1 the Full RFI report will address the following:

- Environmental Setting
- Source Characterization (as applicable)
- Contaminant Characterization
- Potential Receptor Identification
- Investigation Analysis

The RFI report sections that will address these requirements are discussed in the following subsections.

4.1 Introduction

The introduction will consist of a discussion of the historical background of any investigations conducted at the SWMU. The introduction will also provide a regulatory framework for NAPR and the SWMU, as well as a discussion of current conditions.

4.2 Facility Investigation

This section will summarize the results of the previous investigation and describe the basis for the most recent investigation. This section will also describe the field activities of the most recent investigation to fulfill the Full RFI work plan objectives for the SWMU. This will include a description of the sample locations, sample collection and handling procedures, QA/AC procedures, and analytical methods used. This section will also discuss any problems encountered including any deviations from the work plan and problem resolution.

4.3 Physical Characteristics of Study Area

This section will provide the environmental setting, including the regional and site-specific geology and hydrogeology. Regional and local climatic conditions that may be relevant to the environmental impacts of the contaminated media at the site will also be discussed, as relevant.

4.4 Nature and Extent of Contamination

The nature and extent of contamination section will present analytical results of the environmental media and interpretation of the data, to characterize the contaminants present in the soil, and groundwater. The surface and subsurface soil analytical data will be screened against USEPA Region IX Preliminary Remediation Goals (PRGs). Analytical data for surface soil and subsurface soil collected from the 0 to 1-foot depth interval also will be compared to ecological soil screening values previously developed for use in ecological risk assessments (ERAs) at NAPR (Baker, 2006b and 2006c). The ecological soil screening values will be updated as necessary to reflect current information from the literature (i.e., ecological soil screening levels [Eco-SSLs] available at http://www.epa.gov/ecotox/ecossl/). Analytical data for subsurface soil collected from deeper depth intervals (e.g., 3 to 5-feet bgs) will not be compared to ecological soil screening values since these depths are not likely to represent a significant exposure point for ecological receptors (most heterotrophic activity and soil invertebrates occur on the surface or within the oxidized root zone [Suter II, 1995]). The sediment analytical data will be compared to ecological sediment screening

values. As is the case with the to the ecological soil screening values, ecological sediment screening values used in the comparison will be those previously developed for use in ERAs at NAPR (Baker, 2006a and 2006b). The groundwater analytical data will be compared to USEPA Region IX Tap Water PRGs, the Federal Maximum Contaminant Levels (MCLs), and ecological surface water screening values. Identical to the ecological soil screening values, ecological surface water screening values used in the comparison will be those previously developed for use in ERAs at NAPR (Baker, 2006a and 2006b). These values will be updated as necessary to reflect current information from the literature.

The results of the screening and statistical evaluations will be presented on tables and figures with textual explanation. Results of QA/QC procedures also will be presented within the nature and extent of contamination section.

Also, an evaluation and recommendation of whether or not additional permanent wells will need to be installed based on the findings of the temporary wells will be conducted. However, it should be noted that some of the locations at SWMU 9 would not be conducive for the installation of additional permanent wells due to the shallow depth of groundwater and their location adjacent to the estuarine wetland.

4.5 Conclusions and Recommendations

Information from the nature and extent of contamination will be synthesized into conclusions regarding site conditions. Recommendations will be made from these conclusions as to whether a CMS is needed or the SWMU can proceed toward corrective action complete. Actual or potential receptors under the current or future likely site uses will be identified during the risk analysis in either the RFI or the follow up CMS.

4.6 References

Source material used in the development of the RFI Report will be documented in the References section of the report.

5.0 SCHEDULE

A schedule for the implementation of this work plan, and follow-up reports for SWMU 9 is provided as Figure 5-1.

It should be noted that this schedule is dependent upon USEPA review time. Many other factors can also extend the schedule such as resampling if further re-characterization is required, weather delays in the field, or consensus cannot be reached on how the USEPA's comments are to be incorporated.

6.0 SITE MANAGEMENT

An organizational chart presenting the proposed staffing for this project is provided on Figure 6-1. This section also outlines the responsibilities and reporting requirements of field personnel and staff.

6.1 Project Team Responsibilities

Mr. Mark Kimes, P.E., Activity Coordinator for all work in Puerto Rico, will manage the Baker Project Team. His responsibilities will be to direct the technical performance of the project staff, costs and schedule, ensuring that QA/QC procedures are followed during the course of the project. He will maintain communication with the BRAC PMO SE, Navy Technical Representative (NTR), Mr. Jeffrey G. Meyers. Mr. John Mentz will administer overall QA/QC for this project.

The field activities of this project will consist of one field team managed by the Geologist, Mr. Mark DeJohn. Mr. DeJohn's responsibilities include directing the field team and subcontractors. Mr. Rick Aschenbrenner, P.E. will direct the reporting effort associated with the field investigation, ensuring that all necessary staffing is utilized to assist in developing the RFI Report for SWMU 9 Area B – Tank 214 Area.

6.2 Field Reporting Requirements

The Geologist will maintain a daily summary of each day's field activities. The following information will be included in this summary:

- Baker and subcontractor personnel on site
- Major activities of the day
- Samples collected
- Problems encountered
- Other pertinent site information

The Geologist will receive direction from the Activity Manager regarding any changes in scope of the investigation.

7.0 REFERENCES

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TABLES

TABLE 3-1

SUMMARY OF SAMPLING AND ANALYTICAL PROGRAM
ENVIRONMENTAL SAMPLES
FULL RFI WORK PLAN, SWMU 9 TANK 214 AREA
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

		Fixed Based Analytical Lab Analysis					
Media	**Sample Depth (ft bgs)**	App IX VOCs	Low Level PAHs	TPH DRO	TPH GRO	App IX Metals	**Comment**
Surface Soil Samples							
9SB36-00	0.0 - 1.0	X	X	X	X	X	
9SB36-00D	0.0 - 1.0	X	X	X	X	X	Duplicate
9SB36-00MS/MSD	0.0 - 1.0	X	X	X	X	X	Matrix Spike/Matrix Spike Duplicate
9SB37-00	0.0 - 1.0	X	X	X	X	X	
9SB38-00	0.0 - 1.0	X	X	X	X	X	
9SB39-00	0.0 - 1.0	X	X	X	X	X	
9SB40-00	0.0 - 1.0	X	X	X	X	X	
9SB41-00	0.0 - 1.0	X	X	X	X	X	
9SB42-00	0.0 - 1.0	X	X	X	X	X	
9SB43-00	0.0 - 1.0	X	X	X	X	X	
9SB44-00	0.0 - 1.0	X	X	X	X	X	
9SB45-00	0.0 - 1.0	X	X	X	X	X	
9SB46-00	0.0 - 1.0	X	X	X	X	X	
9SB46-00D	0.0 - 1.0	X	X	X	X	X	Duplicate
9SB47-00	0.0 - 1.0	X	X	X	X	X	
9SB48-00	0.0 - 1.0	X	X	X	X	X	
9SB49-00	0.0 - 1.0	X	X	X	X	X	
9SB50-00	0.0 - 1.0	X	X	X	X	X	
9SB49-00	0.0 - 1.0	X	X	X	X	X	
9SB51-00	0.0 - 1.0	X	X	X	X	X	
9SB52-00	0.0 - 1.0	X	X	X	X	X	
9SB53-00	0.0 - 1.0	X	X	X	X	X	
9SB54-00	0.0 - 1.0	X	X	X	X	X	
Subsurface Soil Samples							
9SB36-01(1	TBD	X	X	X	X		
9SB36-01D(1)	TBD	X	X	X	X		Duplicate
9SB36-01MS/MSD(1)	TBD	X	X	X	X		Matrix Spike/Matrix Spike Duplicate
9SB36-02(1)	TBD	X	X	X	X		
9SB37-01(1)	TBD	X	X	X	X		
9SB37-02(1)	TBD	X	X	X	X		
9SB38-01(1)	TBD	X	X	X	X		
9SB38-02(1)	TBD	X	X	X	X		
9SB39-01(1)	TBD	X	X	X	X		
9SB39-02(1)	TBD	X	X	X	X		

TABLE 3-1

SUMMARY OF SAMPLING AND ANALYTICAL PROGRAM
ENVIRONMENTAL SAMPLES
FULL RFI WORK PLAN, SWMU 9 TANK 214 AREA
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

		Fixed Based Analytical Lab Analysis					
Media	**Sample Depth (ft bgs)**	App IX VOCs	Low Level PAHs	TPH DRO	TPH GRO	App IX Metals	**Comment**
Subsurface Soil Samples (continued)							
9SB40-01(1)	TBD	X	X	X	X		
9SB40-01D(1)	TBD	X	X	X	X		Duplicate
9SB40-02(1)	TBD	X	X	X	X		
9SB41-01(1)	TBD	X	X	X	X		
9SB41-02(1)	TBD	X	X	X	X		
9SB42-01(1)	TBD	X	X	X	X		
9SB42-02(1)	TBD	X	X	X	X		
9SB43-01(1)	TBD	X	X	X	X		
9SB43-02(1)	TBD	X	X	X	X		
9SB44-01(1)	TBD	X	X	X	X		
9SB44-02(1)	TBD	X	X	X	X		
9SB45-01(1)	TBD	X	X	X	X		
9SB45-01D(1)	TBD	X	X	X	X		Duplicate
9SB45-01MS/MSD(1)	TBD	X	X	X	X		Matrix Spike/Matrix Spike Duplicate
9SB45-02(1)	TBD	X	X	X	X		
9SB46-01(1)	TBD	X	X	X	X		
9SB46-02(1)	TBD	X	X	X	X		
9SB47-01(1)	TBD	X	X	X	X		
9SB47-02(1)	TBD	X	X	X	X		
9SB48-01(1)	TBD	X	X	X	X		
9SB48-02(1)	TBD	X	X	X	X		
9SB49-01(1)	TBD	X	X	X	X		
9SB49-02(1)	TBD	X	X	X	X		
9SB50-01(1)	TBD	X	X	X	X		
9SB50-01D(1)	TBD	X	X	X	X		Duplicate
9SB50-02(1)	TBD	X	X	X	X		
9SB51-02(1)	TBD	X	X	X	X		
9SB51-02(1)	TBD	X	X	X	X		
9SB52-02(1)	TBD	X	X	X	X		
9SB52-02(1)	TBD	X	X	X	X		
9SB53-02(1)	TBD	X	X	X	X		
9SB53-02(1)	TBD	X	X	X	X		
9SB54-02(1)	TBD	X	X	X	X		
9SB54-02(1)	TBD	X	X	X	X		

TABLE 3-1

SUMMARY OF SAMPLING AND ANALYTICAL PROGRAM
ENVIRONMENTAL SAMPLES
FULL RFI WORK PLAN, SWMU 9 TANK 214 AREA
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

		Fixed Based Analytical Lab Analysis					
Media	**Sample Depth (ft bgs)**	App IX VOCs	Low Level PAHs	TPH DRO	TPH GRO	App IX Metals	**Comment**
Sediment Samples							
9SD39	0.0 - 0.5	X	X	X	X	X	
9SD39D	0.0 - 0.5	X	X	X	X	X	Duplicate
9SD39MS/MSD	0.0 - 0.5	X	X	X	X	X	Matrix Spike/Matrix Spike Duplicate
9SD41	0.0 - 0.5	X	X	X	X	X	
9SD45	0.0 - 0.5	X	X	X	X	X	
9SD47	0.0 - 0.5	X	X	X	X	X	
9SD54	0.0 - 0.5	X	X	X	X	X	
9SD59	0.0 - 0.5	X	X	X	X	X	
9SD70	0.0 - 0.5	X	X	X	X	X	
9SD71	0.0 - 0.5	X	X	X	X	X	
9SD72	0.0 - 0.5	X	X	X	X	X	
9SD75	0.0 - 0.5	X	X	X	X	X	
9SD77	0.0 - 0.5	X	X	X	X	X	
9SD77D	0.0 - 0.5	X	X	X	X	X	Duplicate
9SD78	0.0 - 0.5	X	X	X	X	X	
9SD79	0.0 - 0.5	X	X	X	X	X	
9SD80	0.0 - 0.5	X	X	X	X	X	
9SD81	0.0 - 0.5	X	X	X	X	X	
9SD82	0.0 - 0.5	X	X	X	X	X	
9SD83	0.0 - 0.5	X	X	X	X	X	
9SD84	0.0 - 0.5	X	X	X	X	X	
9SD85	0.0 - 0.5	X	X	X	X	X	
9SD86	0.0 - 0.5	X	X	X	X	X	
9SD87	0.0 - 0.5	X	X	X	X	X	
9SD87D	0.0 - 0.5	X	X	X	X	X	Duplicate
9SD87MS/MSD	0.0 - 0.5	X	X	X	X	X	Matrix Spike/Matrix Spike Duplicate
9SD88	0.0 - 0.5	X	X	X	X	X	
9SD89	0.0 - 0.5	X	X	X	X	X	
9SD90	0.0 - 0.5	X	X	X	X	X	
9SD91	0.0 - 0.5	X	X	X	X	X	
9SD92	0.0 - 0.5	X	X	X	X	X	
9SD93	0.0 - 0.5	X	X	X	X	X	
9SD94	0.0 - 0.5	X	X	X	X	X	
9SD95	0.0 - 0.5	X	X	X	X	X	
9SD96	0.0 - 0.5	X	X	X	X	X	
9SD97	0.0 - 0.5	X	X	X	X	X	
9SD97D	0.0 - 0.5	X	X	X	X	X	Duplicate
9SD98	0.0 - 0.5	X	X	X	X	X	
9SD99	0.0 - 0.5	X	X	X	X	X	
9SD100	0.0 - 0.5	X	X	X	X	X	

TABLE 3-1

SUMMARY OF SAMPLING AND ANALYTICAL PROGRAM
ENVIRONMENTAL SAMPLES
FULL RFI WORK PLAN, SWMU 9 TANK 214 AREA
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

		Fixed Based Analytical Lab Analysis					
Media	**Sample Depth (ft bgs)**	App IX VOCs	Low Level PAHs	TPH DRO	TPH GRO	App IX Metals	**Comment**
Sediment Samples (continued)							
9SD101	0.0 - 0.5	X	X	X	X	X	
9SD102	0.0 - 0.5	X	X	X	X	X	
9SD103	0.0 - 0.5	X	X	X	X	X	
9SD104	0.0 - 0.5	X	X	X	X	X	
9SD105	0.0 - 0.5	X	X	X	X	X	
9SD106	0.0 - 0.5	X	X	X	X	X	
9SD107	0.0 - 0.5	X	X	X	X	X	
9SD107D	0.0 - 0.5	X	X	X	X	X	Duplicate
9SD107MS/MSD	0.0 - 0.5	X	X	X	X	X	Matrix Spike/Matrix Spike Duplicate
9SD108	0.0 - 0.5	X	X	X	X	X	
9SD109	0.0 - 0.5	X	X	X	X	X	
Groundwater Samples							
9TW37	NA	X	X	X	X		
9TW39	NA	X	X	X	X		
9TW40	NA	X	X	X	X		
9PW41	NA	X	X	X	X		
9PW41D	NA	X	X	X	X		Duplicate
9PW41MS	NA	X	X	X	X		Matrix Spike
9PW41MSD	NA	X	X	X	X		Matrix Spike Duplicate
9TW42	NA	X	X	X	X		
9PW44	NA	X	X	X	X		
9PW47	NA	X	X	X	X		
9TW48	NA	X	X	X	X		
9TW50	NA	X	X	X	X		
9PW52	NA	X	X	X	X		
9PW53	NA	X	X	X	X		
9PW53D	NA	X	X	X	X		Duplicate
9PW54	NA	X	X	X	X		
13GW05	NA	X	X	X	X		

Notes:
(1) - Two subsurface samples will be collected at depths to be established in the field and reported with analytical results. The actual sampling interval will be determined in the field.
ft bgs - feet below ground surface.
NA - Not Applicable.

TABLE 3-2

Revised: February 29, 2008

METHOD PERFORMANCE LIMITS
APPENDIX IX COMPOUND LIST AND CONTRACT
REQUIRED QUANTITATION LIMITS (CRQL)
FULL RFI WORK PLAN, SWMU 9 TANK 214 AREA
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

Volatiles	Quantitation Limits*		Method Number
	(µg/L)	(µg/kg)	
Acetone	25	50	8260B (5030)(low level)
Acetonitrile	40	200	8260B (5030)(low level)
Acrolein	20	100	8260B (5030)(low level)
Acrylonitrile	20	100	8260B (5030)(low level)
Benzene	1.0	5.0	8260B (5030)(low level)
Bromodichloromethane	1.0	5.0	8260B (5030)(low level)
Bromoform	1.0	5.0	8260B (5030)(low level)
Bromomethane	1.0	5.0	8260B (5030)(low level)
Carbon Disulfide	2.0	5.0	8260B (5030)(low level)
Carbon Tetrachloride	1.0	5.0	8260B (5030)(low level)
Chlorobenzene	1.0	5.0	8260B (5030)(low level)
Chloroethane	1.0	5.0	8260B (5030)(low level)
Chloroform	1.0	5.0	8260B (5030)(low level)
Chloromethane	1.0	5.0	8260B (5030)(low level)
Chloroprene	1.0	5.0	8260B (5030)(low level)
3-Chloro-1-propene	1.0	5.0	8260B (5030)(low level)
1,2-Dibromo-3-chloropropane	1.0	10	8260B (5030)(low level)
Dibromochloromethane	1.0	5.0	8260B (5030)(low level)
1,2-Dibromoethane	1.0	5.0	8260B (5030)(low level)
Dibromomethane	1.0	5.0	8260B (5030)(low level)
trans-1,4-Dichloro-2-butene	2.0	10	8260B (5030)(low level)
Dichlorodifluoromethane	1.0	5.0	8260B (5030)(low level)
1,1-Dichloroethane	1.0	5.0	8260B (5030)(low level)
1,2-Dichloroethane	1.0	5.0	8260B (5030)(low level)
trans-1,2-dichloroethene	1.0	5.0	8260B (5030)(low level)
1,1-Dichloroethene	1.0	5.0	8260B (5030)(low level)
Methylene Chloride	5.0	5.0	8260B (5030)(low level)
1,2-Dichloropropane	1.0	5.0	8260B (5030)(low level)
cis-1,3-Dichloropropene	1.0	5.0	8260B (5030)(low level)
trans-1,3-Dichloropropene	1.0	5.0	8260B (5030)(low level)
Ethyl benzene	1.0	5.0	8260B (5030)(low level)
Ethyl methacrylate	1.0	5.0	8260B (5030)(low level)
2-Hexanone	10	25	8260B (5030)(low level)
Iodomethane	5.0	5.0	8260B (5030)(low level)
Isobutanol	40	200	8260B (5030)(low level)
Methacrylonitrile	20	100	8260B (5030)(low level)
2-Butanone	10	25	8260B (5030)(low level)
Methyl methacrylate	1.0	5.0	8260B (5030)(low level)
4-Methyl-2-pentanone	10	25	8260B (5030)(low level)

METHOD PERFORMANCE LIMITS
APPENDIX IX COMPOUND LIST AND CONTRACT
REQUIRED QUANTITATION LIMITS (CRQL)
FULL RFI WORK PLAN, SWMU 9 TANK 214 AREA
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

Volatiles (Cont.)	Quantitation Limits*		Method Number
	Water (µg/L)	Low Soil (µg/kg)	
Pentachloroethane	5.0	25	8260B (5030)(low level)
Propionitrile	20	100	8260B (5030)(low level)
Stryene	1.0	5.0	8260B (5030)(low level)
1,1,1,2-Tetrachloroethane	1.0	5.0	8260B (5030)(low level)
1,1,2,2-Tetrachloroethane	1.0	5.0	8260B (5030)(low level)
Tetrachloroethene	1.0	5.0	8260B (5030)(low level)
Toluene	1.0	5.0	8260B (5030)(low level)
1,1,1-Trichloroethane	1.0	5.0	8260B (5030)(low level)
1,1,2-Trichloroethane	1.0	5.0	8260B (5030)(low level)
Trichloroethene	1.0	5.0	8260B (5030)(low level)
Trichlorofluoromethane	1.0	5.0	8260B (5030)(low level)
1,2,3-Trichloropropane	1.0	5.0	8260B (5030)(low level)
Vinyl Acetate	2.0	10	8260B (5030)(low level)
Vinyl Chloride	1.0	5.0	8260B (5030)(low level)
Xylenes (total)	2.0	10	8260B (5030)(low level)
Methyl Tertiary Butyl Ether (MTBE)	10.0	50	8260B (5030)(low level)
Low Level PAHs	**Quantitation Limits***		**Method Number**
	Water (µg/L)	**Low Soil (µg/kg)**	
Acenaphthene	0.2	6.7	8270C
Acenaphthylene	0.2	6.7	8270C
Anthracene	0.2	6.7	8270C
Benzo(a)anthracene	0.2	6.7	8270C
Benzo(b)fluoranthene	0.2	6.7	8270C
Benzo(k)fluoranthene	0.2	6.7	8270C
Benzo(g,h,i)perylene	0.2	6.7	8270C
Benzo(a)pyrene	0.2	6.7	8270C
Chrysene	0.2	6.7	8270C
Dibenzo(a,h)anthracene	0.2	6.7	8270C
Fluoranthene	0.2	6.7	8270C
Fluorene	0.2	6.7	8270C
Indeno(1,2,3-cd)pyrene	0.2	6.7	8270C
1-Methylnaphthalene	0.2	6.7	8270C
2-Methylnaphthalene	0.2	6.7	8270C
Naphthalene	0.2	6.7	8270C
Phenanthrene	0.2	6.7	8270C
Pyrene	0.2	6.7	8270C

METHOD PERFORMANCE LIMITS
APPENDIX IX COMPOUND LIST AND CONTRACT
REQUIRED QUANTITATION LIMITS (CRQL)
FULL RFI WORK PLAN, SWMU 9 TANK 214 AREA
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

Metals	Quantitation Limits* Water (µg/L)	Quantitation Limits* Low Soil (mg/kg)	Method Number
Antimony	20	2.0	6010
Arsenic	10	1.0	6010
Barium	10	1.0	6010
Beryllium	4.0	0.4	6010
Cadmium	5.0	0.5	6010
Chromium	10	1.0	6010
Cobalt	10	1.0	6010
Copper	20	2.0	6010
Lead	5.0	0.5	6010
Mercury	0.2	0.02	7470A/7471A
Nickel	40	4.0	6010
Selenium	10	1.0	6010
Silver	10	1.0	6010
Thallium	10	1.0	6010
Tin	10	5.0	6010
Vanadium	10	1.0	6010
Zinc	20	2.0	6010
Total Petroleum Hydrocarbons	**Quantitation Limits* Water (µg/L)**	**Quantitation Limits* Soil (µg/kg)**	**Method Number**
TPH DRO	100	3300	5030B/8015B
TPH GRO	50	250	3550B/8015B
Toxicity Characteristic Leaching Procedure	**Quantitation Limits* Water (µg/L)**	**Quantitation Limits* Soil (µg/kg)**	**Method Number**
TCLP Volatiles	20	NA	1311
RCRA Metals	**Quantitation Limits* Soil (mg/kg)**	**Quantitation Limits* Water (µg/L)**	**Method Number**
Arsenic	1.0	10	6010(3050/3010)
Barium	1.0	10	6010(3050/3010)
Cadmium	0.50	5	6010(3050/3010)
Chromium	1.0	10	6010(3050/3010)
Lead	0.50	5.0	6010(3050/3010)
Mercury	0.020	0.20	7471A/7470A
Selenium	1.0	10	6010(3050/3010)
Silver	1.0	10	6010(3050/3010)
Reactivity, Corrosivity, Ignitability	**Quantitation Limits* Water**	**Quantitation Limits* Soil**	**Method Number**
RCI	various	various	9014/9040/9034/9045/ 1010

µg/L- micrograms per liter; µg/kg- micrograms per kilogram; NA- not applicable
* Quantitation limits listed for soil/sediment are based on wet weight. The quanitiation limits calculated by the laboratory for soil/sediment, calculated on dry weight basis, will be higher.

Revised: February 29, 2008

TABLE 3-3

SUMMARY OF SAMPLING AND ANALYTICAL PROGRAM
QA/QC AND IDW SAMPLES
FULL RFI WORK PLAN, SWMU 9 TANK 214 AREA
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

	Samples Analysis Requested								
Media	App IX VOCs	Low Level PAHs	TPH GRO	TPH DRO	App IX Metals	TCLP Volatiles	RCI	RCRA Metals	**Comment**
Trip Blank Samples									
9RFI-TB01	X(1)		X(1)						
9RFI-TB02	X(1)		X(1)						
9RFI-TB03	X(1)		X(1)						
9RFI-TB04	X(1)		X(1)						
9RFI-TB05	X(1)		X(1)						
9RFI-TB06	X(1)		X(1)						
Equipment Rinsate Samples									
9RFI-ER01	X	X	X	X	X				Stainless Steel Spoon
9RFI-ER02	X	X	X	X	X				Macro Core Liner
9RFI-ER03	X	X	X	X	X				Polyethylene and Silicon Tubing
Field Blank Samples									
9RFI-FB01	X	X	X	X	X				Lab Grade Deionized Water
9RFI-FB02	X	X	X	X	X				Store Bought Distilled Warer
9RFI-FB03	X	X	X	X	X				NAPR Potable Water
IDW Samples									
9RFI-IDW01			X	X		X	X	X	Aqueous
9RFI-IDW02			X	X		X	X	X	Solid

Note:

(1) - The analysis required for this sample will be dependent on which samples are being accompanied in the cooler.

FIGURES

K:_CH2M Hill CLEAN III\CTO 147 (110045)\3.0 Deliverables\3.1 Deliverables\SWMU 9 Full RFI Work Plan\CAD\110045RFI_01

4 0 2 4 8

1 inch = 4 miles

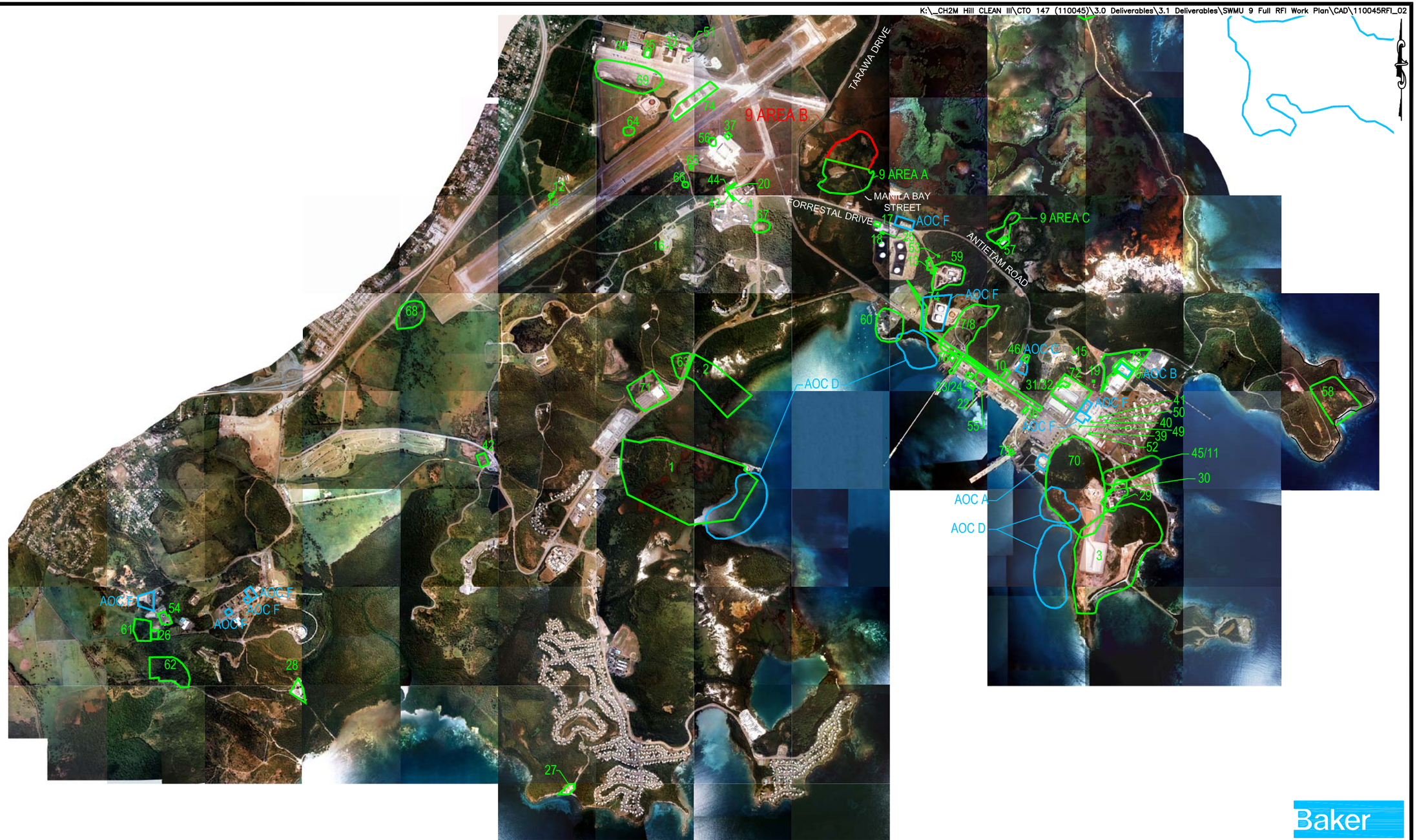
Baker

FIGURE 1-1
GENERAL LOCATION MAP
SWMU 9 AREA B (TANK 214)
FULL RCRA FACILITY INVESTIGATION

SOURCE: METRODATA, INC., 1999.

NAVAL ACTIVITY PUERTO RICO

K:_CH2M Hill CLEAN III\CTO 147 (110045)\3.0 Deliverables\3.1 Deliverables\SWMU 9 Full RFI Work Plan\CAD\110045RFI_02



Baker

LEGEND

1 – SWMUs

9 – AREA OF THIS INVESTIGATION

AOC D – AOCs

SOURCE: GEO-MARINE, INC., SEPTEMBER 6, 2000.

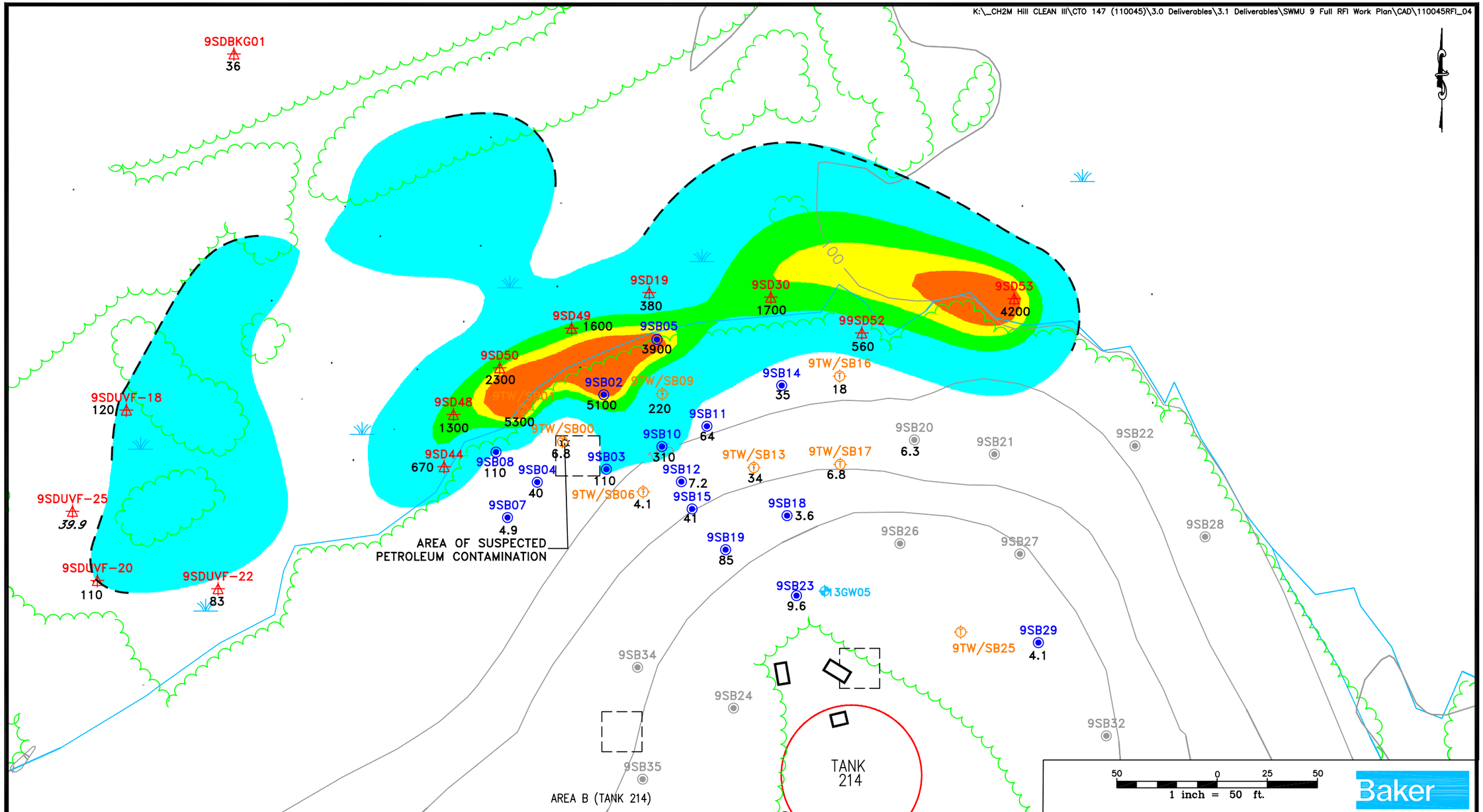
2500 0 1250 2500

1 inch = 2500 ft.

FIGURE 1-2
SWMU LOCATION MAP
SWMU 9 AREA B (TANK 214)
FULL RCRA FACILITY INVESTIGATION WORK PLAN

NAVAL ACTIVITY PUERTO RICO

K:_CH2M Hill CLEAN III\CTO 147 (110045)\3.0 Deliverables\3.1 Deliverables\SWMU 9 Full RFI Work Plan\CAD\110045RFI_04



NOTE:
1. ITALICS – USED UVF-3100 DATA
2. BAKER, 2007. DRAFT PHASE I RCRA FACILITY INVESTIGATION REPORT FOR SWMU 9 AREA B, (TANK 214), NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO. BAKER ENVIRONMENTAL, INC. AUGUST 14, 2007.

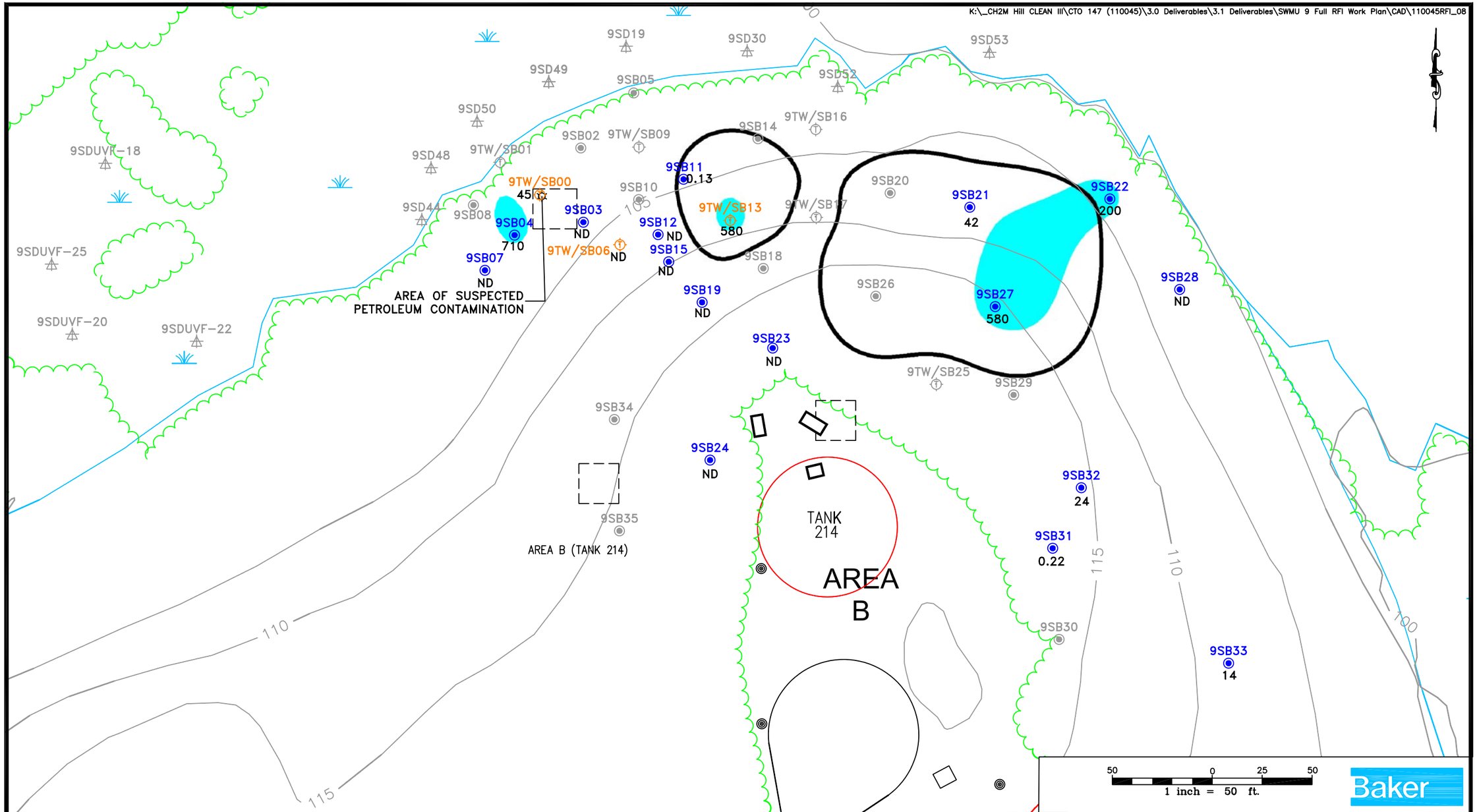
COLOR SCALE
- 3,000 mg/kg
- 2,000 mg/kg
- 1,000 mg/kg
- 100 mg/kg

LEGEND
- EXISTING MONITORING WELL LOCATION
- TEMPORARY WELL AND SOIL BORING LOCATION
- SOIL BORING
- SEDIMENT SAMPLE LOCATION
- TELEPHONE POLE
- MAY 2006 EXCAVATION (INTERIM CORRECTIVE MEASURE)
- AREA OF SUSPECTED PETROLEUM CONTAMINATION
- MANGROVE
- TREES
- 115 – GROUND SURFACE ELEVATION CONTOUR
- PROJECTED EXTENT

FIGURE 2-1
EXTENT OF TPH-DRO ABOVE PREQB CRITERIA
IN SURFACE SOIL AND SEDIMENT
SWMU 9 AREA B (TANK 214)
RCRA FACILITY INVESTIGATION WORK PLAN

NAVAL ACTIVITY PUERTO RICO

K:_CH2M Hill CLEAN III\CTO 147 (110045)\3.0 Deliverables\3.1 Deliverables\SWMU 9 Full RFI Work Plan\CAD\110045RFI_08



NOTE:
1. ITALICS – USED UVF-3100 DATA
2. BAKER, 2007. DRAFT PHASE I RCRA FACILITY INVESTIGATION REPORT FOR SWMU 9 AREA B, (TANK 214), NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO. BAKER ENVIRONMENTAL, INC. AUGUST 14, 2007.

COLOR SCALE

- 3,000 mg/kg
- 2,000 mg/kg
- 1,000 mg/kg
- 100 mg/kg

LEGEND

- TEMPORARY WELL AND SOIL BORING LOCATION
- SOIL BORING
- SEDIMENT SAMPLE LOCATION
- TELEPHONE POLE
- MAY 2006 EXCAVATION (INTERIM CORRECTIVE MEASURE)
- AREA OF SUSPECTED PETROLEUM CONTAMINATION
- MANGROVE
- TREES
- 115 – GROUND SURFACE ELEVATION CONTOUR
- REGIONS OF PID READINGS >1000ppm

FIGURE 2-2
EXTENT OF TPH-GRO ABOVE PREQB CRITERIA
IN INTERMEDIATE SUBSURFACE SOIL
SWMU 9 AREA B (TANK 214)
RCRA FACILITY INVESTIGATION WORK PLAN
NAVAL ACTIVITY PUERTO RICO
CEIBA,PUERTO RICO

K:_CH2M Hill CLEAN III\CTO 147 (110045)\3.0 Deliverables\3.1 Deliverables\SWMU 9 Full RFI Work Plan\CAD\110045RFI_10

9SD19
9SD30
9SD53
9SD49
9SB05
9SD52
9SD50
9SB14
9GW16
ND
9SB02
9GW09
ND
1.3
9SDUVF-18
9SD48
9GW01
ND
9GW00
ND
9SB11
9SB20
9SB21
9SB22
9SB10
9SB08
9SD44
9SB03
9SB04
9SB12
9GW13
17
9GW17
24
9GW06
ND
9SB15
9SDUVF-25
9SB07
9SB18
9SB28
9SB19
9SB26
9SB27
AREA OF SUSPECTED
PETROLEUM CONTAMINATION
9SDUVF-20
9SDUVF-22
9SB23
9GW25
330
9SB29
9SB34
9SB24
9SB32
AREA B (TANK 214)
9SB35
TANK
214
9SB31
AREA
B
9SB30
ND
9SB33
5
50
100
200
105
110
115
110
115
100

50 0 25 50
1 inch = 50 ft.

Baker

LEGEND

- TEMPORARY WELL GROUNDWATER SAMPLE
- SOIL BORING
- SEDIMENT SAMPLE LOCATION
- TELEPHONE POLE
- MAY 2006 EXCAVATION (INTERIM CORRECTIVE MEASURE)
- AREA OF SUSPECTED PETROLEUM CONTAMINATION
- 115 – GROUND SURFACE ELEVATION CONTOUR
- MANGROVE – TREES
- ESTIMATED EXTENT OF BENZENE (ug/L)
- PROJECTED EXTENT OF BENZENE (ug/L)

COLOR SCALE
SOIL

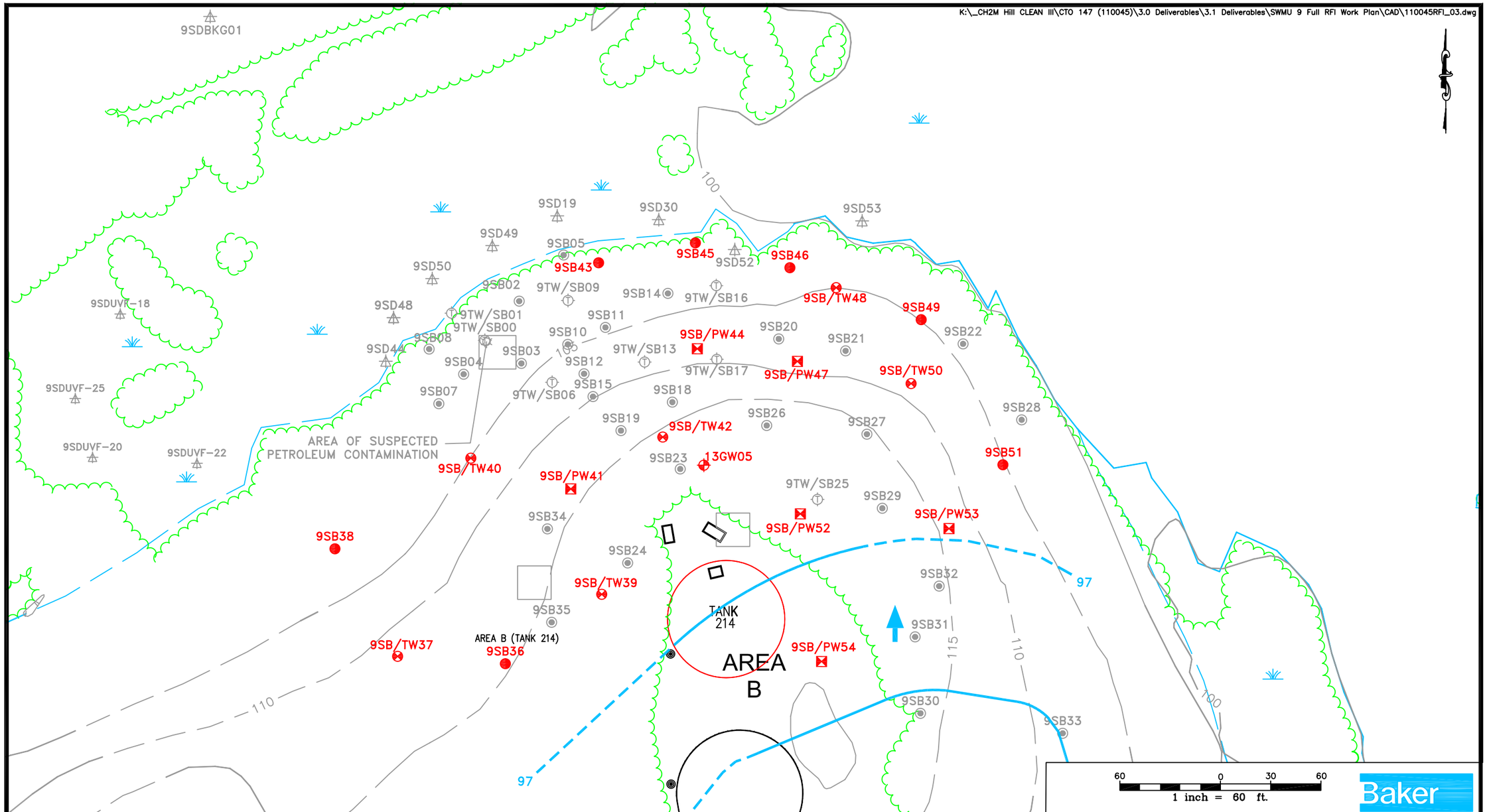
- 3,000 mg/kg
- 2,000 mg/kg
- 1,000 mg/kg
- 100 mg/kg

NOTE:
1. BAKER, 2007. DRAFT PHASE I RCRA FACILITY INVESTIGATION REPORT FOR SWMU 9 AREA B, (TANK 214), NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO. BAKER ENVIRONMENTAL, INC. AUGUST 14, 2007.

FIGURE 2-3
EXTENT OF BENZENE ABOVE MCL IN GROUNDWATER COMPARED WITH TPH-GRO IN DEEP SUBSURFACE SOIL
SWMU 9 AREA B (TANK 214)
RCRA FACILITY INVESTIGATION WORK PLAN

NAVAL ACTIVITY PUERTO RICO

K:_CH2M Hill CLEAN III\CTO 147 (110045)\3.0 Deliverables\3.1 Deliverables\SWMU 9 Full RFI Work Plan\CAD\110045RFI_03.dwg

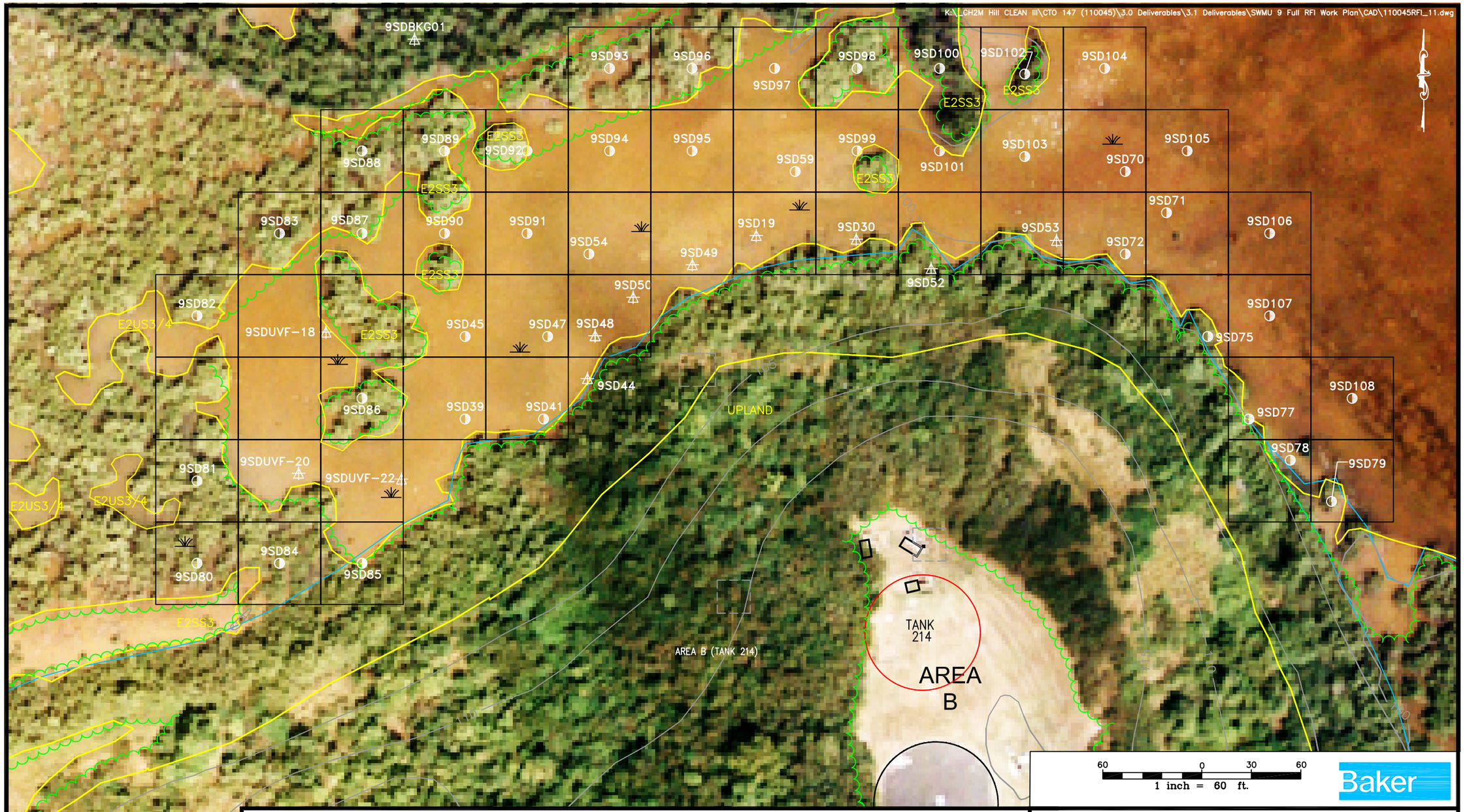


LEGEND

- EXISTING MONITORING WELL LOCATION
- EXISTING SOIL BORING (PHASE I RFI 2007)
- EXISTING TEMPORARY WELL GROUNDWATER SAMPLE (PHASE I RFI 2007)
- EXISTING SEDIMENT SAMPLE LOCATION (PHASE I RFI 2007)
- EXISTING MAY 2006 EXCAVATION (INTERIM CORRECTIVE MEASURE)
- EXISTING AREA OF SUSPECTED PETROLEUM CONTAMINATION
- PROPOSED SOIL BORING
- PROPOSED SOIL BORING AND TEMPORARY WELL
- PROPOSED PERMANENT WELL
- PROPOSED SOIL BORING AND PERMANENT WELL
- PROPOSED TEMPORARY WELL
- MANGROVE
- TREES
- 115 – GROUND SURFACE ELEVATION CONTOUR
- TELEPHONE POLE
- 97 – GROUNDWATER ELEVATION CONTOUR (MAY 10, 1996)
- GROUNDWATER FLOW (MAY 10, 1996)

FIGURE 3-1
PROPOSED AND PREVIOUS
UPLAND SAMPLE LOCATION MAP
FULL SWMU 9 AREA B (TANK 214)
RCRA FACILITY INVESTIGATION

NAVAL ACTIVITY PUERTO RICO



LEGEND

- EXISTING SEDIMENT SAMPLE LOCATION
- EXISTING MAY 2006 EXCAVATION (INTERIM CORRECTIVE MEASURE)
- PROPOSED SEDIMENT SAMPLE
- MANGROVE
- TREES
- 115 – GROUND SURFACE ELEVATION CONTOUR
- E2SS3 – WETLANDS BOUNDARIES

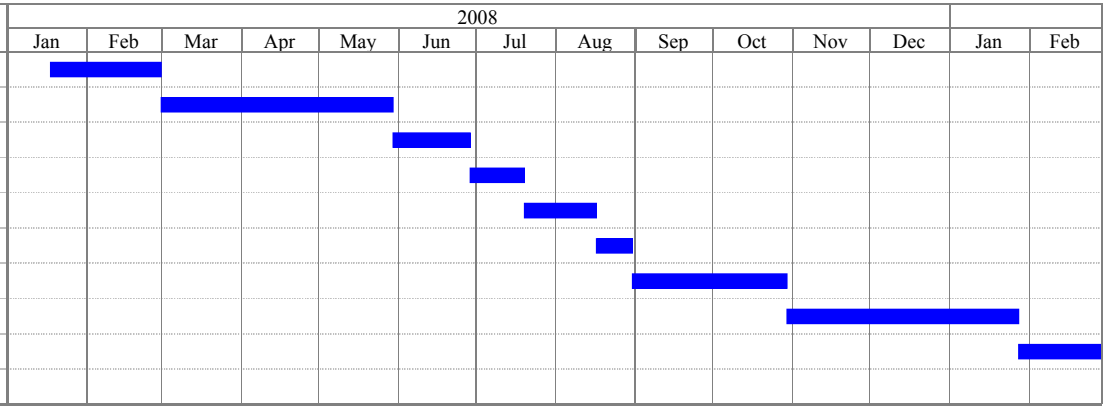
FIGURE 3-2
PROPOSED AND PREVIOUS
SEDIMENT SAMPLE LOCATION MAP
FULL SWMU 9 AREA B (TANK 214)
RCRA FACILITY INVESTIGATION

NAVAL ACTIVITY PUERTO RICO

Revised: February 29, 2008

FIGURE 5-1
FULL RFI WORK PLAN
SWMU 9 AREA B TANK 214
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO
PROPOSED PROJECT SCHEDULE

Task Name	Duration	Start	Finish
Final Full RFI Work Plan to the EPA	43 edays	1/17/08	2/29/08
EPA Review and approval	90 edays	2/29/08	5/29/08
Initiate Field Work	30 edays	5/29/08	6/28/08
Field Investigation	21 edays	6/28/08	7/19/08
Laboratory Analysis	28 edays	7/19/08	8/16/08
Data Validation	14 edays	8/16/08	8/30/08
Draft Full RFI Report for SWMU 9 Tank 214 to EPA	60 edays	8/30/08	10/29/08
EPA Review	90 edays	10/29/08	1/27/09
Final Full RFI Report for SWMU 9 Tank 214 to EPA	45 edays	1/27/09	3/13/09
EPA Review & Approval	90 edays	3/13/09	6/11/09

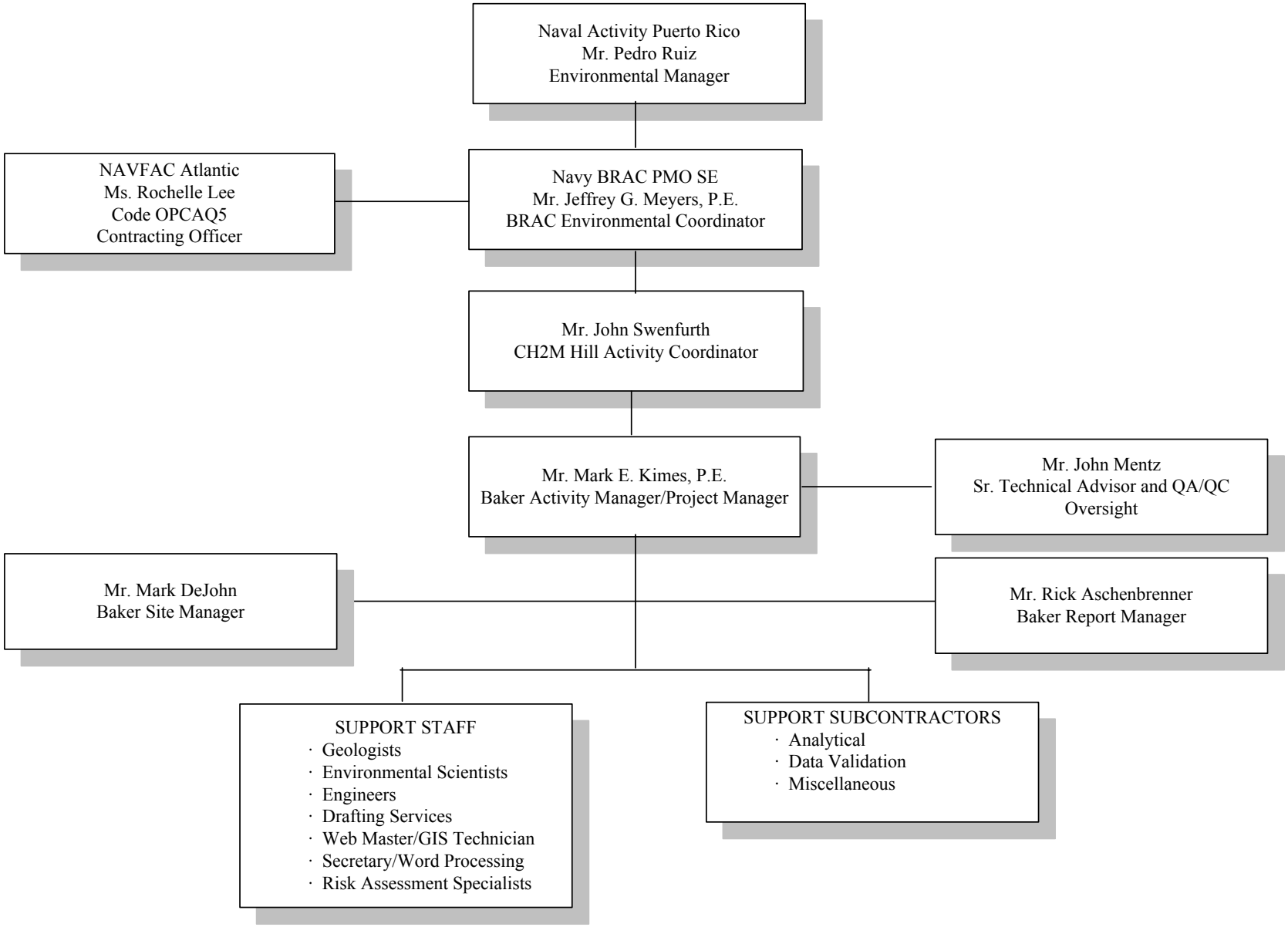


Project: Full RFI Work Plan
Date: February 29, 2008

Task

Revised: February 29, 2008

FIGURE 6-1
PROJECT ORGANIZATION
FULL RFI WORK PLAN – SWMU 9
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO



APPENDIX A
BAKER STANDARD OPERATING PROCEDURES

STANDARD OPERATING PROCEDURES
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F102 - Soil and Rock Sample Acquisition

F103 - Monitoring Well Installation

F107 - Surface Water and Sediment Sample Acquisition

F501 - Decontamination of Heavy Equipment and Associated Sampling Equipment

F502 - Decontamination of Sampling and Monitoring Equipment

SOP F101
BOREHOLE AND SAMPLING LOGGING

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ATTACHMENT B -- UNIFIED SOIL CLASSIFICATION SYSTEM
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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 drilling inspector correctly and completely fill out the appropriate documents (e.g., test boring logs, field logbooks, etc.).

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 logbooks to the Project File via the Project Manager, 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). Furthermore, the drilling inspector typically also is responsible for health and safety issues during on-site drilling and sampling activities.

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 (Attachment A) and/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 logbook so that all boring logs recorded (by each drilling inspector) are located in one source. The use of a field logbook precludes the possibility of losing individual test boring log sheets. Furthermore, use of the field logbook 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 logbook. The Field Test Boring Records must be completely filled out prior to demobilization from the site. Because personnel other than the drilling inspector may be interpreting the boring records, the Field Test Boring Records must also be legible. Completed Field Test Boring Records shall be converted to report format using a Test Boring Record (excel format) or 'Log Draft' software.

The data that are to be included on the Test Boring Records, when applicable, are listed below:

1. Project name, location, and Project and Task Number.
2. Date(s).
3. Identifying number and location of the boring.
4. Soil classifications in accordance with the Unified Soil Classification System (USCS) (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 (if performed). Both field determined USCS and a detailed soil description shall be included on the Test Boring Record.
5. Depth, type, and number of samples taken (geologic and environmental).
6. The number of blows required for each 6-inch penetration of a split-spoon sampler (not applicable for direct-push technology). The percentage of sample recovered, hammer weight, and fall length.
7. Depth to water as first encountered during drilling operations, along with the method of determination. Any distinct water bearing zones (aquifers) shall also be delineated vertically, if possible.
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. Name of the drilling company and the driller.
11. Size and length of the casing used in each boring.
12. Observations of visual contamination (free product, odor, etc.).
13. 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/depth of each stratigraphic unit. The descriptions should contain color, grain-size distribution, consistency, plasticity, moisture, etc., in addition to the USCS classification category (Section 5.3.7).

Each sample collected for chemical or geotechnical analysis shall be handled as described in SOP F102.

5.2 Soil Classification

The data shall be recorded on a Field Test Boring Record and/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 (e.g., ML, CL, SM); 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. The generalized USCS classifications also aid in development of geologic cross sections at the conclusion of field activities.

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 (e.g., 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, PID measurements, etc. The use of Field Guides for Soil Analysis, Soil Texturing Flow Charts and Geotechnical Gauges is highly recommended for consistency of description narrative. Other tools useful for soil descriptions include a pocket knife or spatula, small hand lens, test tube with stopper (or jar with lid) and small bottle of dilute hydrochloric acid (HCL) – one part HCL added to three parts water. A summary of the soil description components is given in Attachment C.

5.3.1 Grain Size Identification

In nature, soils are comprised of varying size, shape, and combinations of the various grain types. The following terms are used to indicate soil grain size:

Size Description	Size Limits (Diameter)
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	1 to 5 percent
Few	5 to 10 percent
Little	15 to 25 percent
Some	30 to 45 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, 30 to 45 percent silt.
- Fine sandy silt, trace clay: 50 to 65 percent silt, 35 to 50 percent fine sand, and 1 to 5 percent clay.

The soil type may be classified as non-cohesive, 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/smears/swirls of different colors. Soil color charts (e.g., Muncel) 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 non-cohesive (a 6 mm diameter roll cannot be formed). Conversely, fine-grained soils (which contain predominantly silts and clays) are cohesive (a 6 mm diameter roll can be formed).

The density of non-cohesive, 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 (pneumatic or hammer drops) required to drive a split-barrel sampler with a 2-inch outside diameter 6-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 (or the middle 12 inches if the spoon is driven 24 inches). 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 are typically used in order to obtain a sufficient quantity of sample for required analysis. As presented above, the second and third 6-inch increments will be used to calculate the relative density for a 24-inch sample interval.

The relative density designations for non-cohesive soils are:

Designation	Standard Penetration Resistance (Blows per Foot)
Very loose	Less than 4
Loose	4 to 10
Medium dense	10 to 29
Dense	30 to 49
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	< 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 three categories: dry, moist, and wet:

Designation	Moisture Content
Dry	Moisture Absent
Moist	Damp, No Visible Water
Wet	Visible Water

Little or no water should appear in dry soil. Wet soils appear to contain all the water they can possibly hold (i.e., saturated). Moist is in between. 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 sampler is opened. Typically, bedding thicknesses are described as follows:

Designation	Bedding Spacing
Indistinct	No bedding apparent
Laminated	Less than 0.5 cm
Thinly Bedded	0.5 cm to 3 cm
Bedded	3 cm to 30 cm
Thickly Bedded	>30 cm
Massive	Uniform

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, non-stratified, 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. If the Log Draft program will be used to develop a digitized copy of the boring logs, the 'Description Builder' program within Log Draft will allow for consistency in geologic descriptions. This is done by "building" a geologic description of an encountered formation by choosing from a finite list of geologic properties as summarized in the bulletized list above.

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 (e.g., Muncel color chart) 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 (a.k.a., mechanical 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 and/or the Field Logbook.

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, non-uniform 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 or fractures
- 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 either hand written or in the Log Draft format.

7.0 REFERENCES

1. American Society for Testing and Materials, 2000. Standard Methods for Classification of Soils for Engineering Purposes. ASTM Method D2487-00, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.

2. American Society for Testing and Materials, 2000. Standard Practice for Description and Identification of Soils (Visual - Manual Procedure). ASTM Method D2488-00, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.

3. American Society for Testing and Materials, 1999. Standard Method for Penetration Test and Split-Barrel Sampling of Soils. ASTM Method D1586-99, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.

ATTACHMENT A

EXAMPLE TEST BORING RECORD

Baker

Baker Environmental

TEST BORING RECORD

PROJECT: Testing

PROJ. NO.: CTO-0356 BORING NO.: SB01

COORDINATES: EAST: 64789456.123 NORTH: 123456.789

ELEVATION: SURFACE: 100

Rig:	Split Spoon	Casing	Augers	Core Barrel	Date	Progress (Ft.)	Weather	Depth to Water (Ft.)
Size (ID)								
Length								
Type								
Hammer Wt.								
Fall								

Remarks:

SAMPLE TYPE

S = Split Spoon A = Auger
T = Shelby Tube W = Wash
R = Air Rotary C = Core
D = Denison P = Piston
N = No Sample

DEFINITIONS

SPT = Standard Penetration Test (ASTM D1586)
PID = Photo Ionization Detector Measurement
MSL = Mean Sea Level
BG/PS = Background/Point Source
ppm = parts per million

Depth (Ft.)		Sample Type & No.	Sample Rec. (Ft.,%)	SPT	Lab ID	PID (ppm) ps/bg	Visual Description		Elevation (Ft. MSL)
1		S-1	1.3 65%	5 6 7 6		106 1	FINE SAND, little silt & clay, trace fine gravel; brown; med dense; damp	1.5	98.50
2	2.0						CLAY, trace fine sand; gray; stiff; moist	3.4	96.60
3							COARSE GRAVEL, little med sand; tan; dense; wet	4.9	95.10
4									
5									
6									
7									
8									
9									
10							Match to Sheet 2		

DRILLING COMPANY: PennDrill BAKER REP.: Joe Standovertherig

DRILLER: Joe Deephole BORING NO.: SB01 SHEET 1 OF 6

Baker
Baker Environmental

TEST BORING RECORD

PROJECT: Testing
CTO NO.: CTO-0356 BORING NO.: SB01

SAMPLE TYPE	DEFINITIONS
S = Split Spoon A = Auger	SPT = Standard Penetration Test (ASTM D1586)
T = Shelby Tube W = Wash	PID = Photo Ionization Detector Measurement
R = Air Rotary C = Core	MSL = Mean Sea Level
D = Denison P = Piston N = No Sample	ps/bg = point source/background

Depth (Ft.)	Sample Type & No.	Sample Rec. (Ft.,%)	SPT	Lab ID	PID (ppm) ps/bg	Visual Description	Elevation (Ft. MSL)
11						Continued from Sheet 1	
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
28							
29							
30						Match to Sheet 3	

DRILLING COMPANY: PennDrill BAKER REP.: Joe Standovertherig
DRILLER: Joe Deephole BORING NO.: SB01 SHEET 2 OF 6

Baker

Baker Environmental

TEST BORING RECORD

PROJECT: Testing

CTO NO.: CTO-0356 BORING NO.: SB01

SAMPLE TYPE	DEFINITIONS
S = Split Spoon A = Auger	SPT = Standard Penetration Test (ASTM D1586)
T = Shelby Tube W = Wash	PID = Photo Ionization Detector Measurement
R = Air Rotary C = Core	MSL = Mean Sea Level
D = Denison P = Piston N = No Sample	ps/bg = point source/background

Depth (Ft.)	Sample Type & No.	Sample Rec. (Ft.,%)	SPT	Lab ID	PID (ppm) ps/bg	Visual Description	Elevation (Ft. MSL)
31						Continued from Sheet 2	
32							
33							
34							
35							
36							
37							
38							
39							
40							
41							
42							
43							
44							
45							
46							
47							
48							
49							
50						Match to Sheet 4	

DRILLING COMPANY: PennDrill BAKER REP.: Joe Standovertherig

DRILLER: Joe Deephole BORING NO.: SB01 SHEET 3 OF 6

Baker
Baker Environmental

TEST BORING RECORD

PROJECT: Testing
CTO NO.: CTO-0356 BORING NO.: SB01

SAMPLE TYPE	DEFINITIONS
S = Split Spoon A = Auger	SPT = Standard Penetration Test (ASTM D1586)
T = Shelby Tube W = Wash	PID = Photo Ionization Detector Measurement
R = Air Rotary C = Core	MSL = Mean Sea Level
D = Denison P = Piston N = No Sample	ps/bg = point source/background

Depth (Ft.)	Sample Type & No.	Sample Rec. (Ft.,%)	SPT	Lab ID	PID (ppm) ps/bg	Visual Description	Elevation (Ft. MSL)
51						Continued from Sheet 3	
52							
53							
54							
55							
56							
57							
58							
59							
60							
61							
62							
63							
64							
65							
66							
67							
68							
69							
70						Match to Sheet 5	

DRILLING COMPANY: PennDrill BAKER REP.: Joe Standovertherig
DRILLER: Joe Deephole BORING NO.: SB01 SHEET 4 OF 6

Baker
Baker Environmental

TEST BORING RECORD

PROJECT: Testing
CTO NO.: CTO-0356 BORING NO.: SB01

SAMPLE TYPE	DEFINITIONS
S = Split Spoon A = Auger	SPT = Standard Penetration Test (ASTM D1586)
T = Shelby Tube W = Wash	PID = Photo Ionization Detector Measurement
R = Air Rotary C = Core	MSL = Mean Sea Level
D = Denison P = Piston N = No Sample	ps/bg = point source/background

Depth (Ft.)	Sample Type & No.	Sample Rec. (Ft.,%)	SPT	Lab ID	PID (ppm) ps/bg	Visual Description	Elevation (Ft. MSL)
71						Continued from Sheet 4	
72							
73							
74							
75							
76							
77							
78							
79							
80							
81							
82							
83							
84							
85							
86							
87							
88							
89							
90						Match to Sheet 6	

DRILLING COMPANY: PennDrill BAKER REP.: Joe Standovertherig
DRILLER: Joe Deephole BORING NO.: SB01 SHEET 5 OF 6

Baker
Baker Environmental

TEST BORING RECORD

PROJECT: Testing
CTO NO.: CTO-0356 BORING NO.: SB01

SAMPLE TYPE	DEFINITIONS
S = Split Spoon A = Auger	SPT = Standard Penetration Test (ASTM D1586)
T = Shelby Tube W = Wash	PID = Photo Ionization Detector Measurement
R = Air Rotary C = Core	MSL = Mean Sea Level
D = Denison P = Piston N = No Sample	ps/bg = point source/background

Depth (Ft.)	Sample Type & No.	Sample Rec. (Ft.,%)	SPT	Lab ID	PID (ppm) ps/bg	Visual Description	Elevation (Ft. MSL)
91						Continued from Sheet 5	
92							
93							
94							
95							
96							
97							
98							
99							
100							
101							
102							
103							
104							
105							
106							
107							
108							
109							
110							

DRILLING COMPANY: PennDrill BAKER REP.: Joe Standovertherig
DRILLER: Joe Deephole BORING NO.: SB01 SHEET 6 OF 6

ATTACHMENT B

UNIFIED SOIL CLASSIFICATION SYSTEM

Geotechnical Gauge

Manuf. by:
W.F. McCollough
3101 Elkridge Ct.
Beltsville, MD 20705

0mm 10 20 30 40 50 60 70 80 90 100 110

Very Angular | Angular | Sub Angular | Sub Rounded | Rounded | Well Rounded

3 % | 5 % | 15 % | 25 % | 40 % | 50 %

MAJOR DIVISIONS			GRAPHIC SYMBOL	LETTER SYMBOL	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE	GRAVEL AND GRAVELLY SOILS MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL - GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES.
				GP	POORLY - GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES.
		GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL - SAND - SILT MIXTURES.
				GC	CLAYEY GRAVELS, GRAVEL - SAND - CLAY MIXTURES.
	SAND AND SANDY SOILS MORE THAN 50% OF COARSE FRACTION PASSING NO. 4 SIEVE	CLEAN SAND (LITTLE OR NO FINES)		SW	WELL - GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES.
				SP	POORLY - GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES.
		SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY - SANDS, SAND - SILT MIXTURES.
				SC	CLAYEY SANDS, SAND - CLAY MIXTURES.
FINE GRAINED SOILS MORE THAN 50% OF MATERIAL IS SMALLERTHAN NO. 200 SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY.
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS.
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY.
	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS.
				CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS.
				OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS.
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS.

Light Brown

Yellowish Orange

Greenish Gray

Olive Gray

Light Gray

Dark Gray

0 1 2 3 4 5 6 Inches

UNIFIED SOIL CLASSIFICATION SYSTEM

FOR COMMON INORGANIC AND ORGANIC SEDIMENTS

Modified from ASTM D2488

STEP 1: IS SEDIMENT COARSE-GRAINED OR FINE-GRAINED?

COARSE-GRAINED DEPOSITS (>50% coarse-grained, <50% fine sediments)

STEP 2: DETERMINE SAND VS. GRAVEL RATIO

INCREASING GRAIN SIZE

SAND | GRAVEL

FINE | MEDIUM | COARSE | FINE | COARSE

STEP 3: CONTINUE WITH "SAND" OR "GRAVEL" AND FOLLOW FLOW CHART TO ASSIGN A GROUP SYMBOL AND A GROUP NAME

				GROUP SYMBOL		GROUP NAME
GRAVEL (gravel > sand)	<5% fines	Well graded		GW	<15% sand	WELL GRADED GRAVEL
					>15% sand	WELL GRADED GRAVEL WITH SAND
		Poorly graded		GP	<15% sand	POORLY GRADED GRAVEL
					>15% sand	POORLY GRADED GRAVEL WITH SAND
	10% fines	Well graded	non-plastic fines	GW-GM	<15% sand	WELL GRADED GRAVEL WITH SILT
					>15% sand	WELL GRADED GRAVEL WITH SILT AND SAND
			plastic fines	GW-GC	<15% sand	WELL GRADED GRAVEL WITH CLAY
					>15% sand	WELL GRADED GRAVEL WITH CLAY AND SAND
		Poorly graded	non-plastic fines	GP-GM	<15% sand	POORLY GRADED GRAVEL WITH SILT
					>15% sand	POORLY GRADED GRAVEL WITH SILT AND SAND
			plastic fines	GP-GC	<15% sand	POORLY GRADED GRAVEL WITH CLAY
					>15% sand	POORLY GRADED GRAVEL WITH CLAY AND SAND
	>15% fines		non-plastic fines	GM	<15% sand	SILTY GRAVEL
					>15% sand	SILTY GRAVEL WITH SAND
			plastic fines	GC	<15% sand	CLAYEY GRAVEL
					>15% sand	CLAYEY GRAVEL WITH SAND
SAND (sand > gravel)	<5% fines	Well graded		SW	<15% gravel	WELL GRADED SAND
					>15% gravel	WELL GRADED SAND WITH GRAVEL
		Poorly graded		SP	<15% gravel	POORLY GRADED SAND
					>15% gravel	POORLY GRADED SAND WITH GRAVEL
	10% fines	Well graded	non-plastic fines	SW-SM	<15% gravel	WELL GRADED SAND WITH SILT
					>15% gravel	WELL GRADED SAND WITH SILT AND GRAVEL
			plastic fines	SW-SC	<15% gravel	WELL GRADED SAND WITH CLAY
					>15% gravel	WELL GRADED SAND WITH CLAY AND GRAVEL
		Poorly graded	non-plastic fines	SP-SM	<15% gravel	POORLY GRADED SAND WITH SILT
					>15% gravel	POORLY GRADED SAND WITH SILT AND GRAVEL
			plastic fines	SP-SC	<15% gravel	POORLY GRADED SAND WITH CLAY
					>15% gravel	POORLY GRADED SAND WITH CLAY AND GRAVEL
	>15% fines		non-plastic fines	SM	<15% gravel	SILTY SAND
					>15% gravel	SILTY SAND WITH GRAVEL
			plastic fines	SC	<15% gravel	CLAYEY SAND
					>15% gravel	CLAYEY SAND WITH GRAVEL

FINE-GRAINED DEPOSITS (>50% fines, <50% coarse-grained sediments)

STEP 2: DETERMINE PLASTICITY AND ASSIGN USCS GROUP SYMBOL

INCREASING PLASTICITY

NON PLASTIC | LOW PLASTICITY | MEDIUM PLASTICITY | HIGH PLASTICITY

ML | CL | CH

STEP 3: CONTINUE WITH GROUP SYMBOL AND FOLLOW FLOW CHART TO ASSIGN A GROUP NAME

STEP 4: DOES ORGANIC CONTENT INFLUENCE SOIL PROPERTIES?

YES → OL / OH

NO → ML / CL / CH

				GROUP NAME
ML	<30% Coarse Grained Sediments	<15% Coarse-Grained Sediment		SILT
		15-25% Coarse-Grained Sediment	% sand > % gravel	SILT WITH SAND
			% sand < % gravel	SILT WITH GRAVEL
	>30% Coarse Grained Sediments	% sand > % of gravel	<15% gravel	SANDY SILT
			>15% gravel	SANDY SILT WITH GRAVEL
		% sand < % gravel	<15% sand	GRAVELLY SILT
			>15% sand	GRAVELLY SILT WITH SAND
CL	<30% Coarse Grained Sediments	<15% Coarse-Grained Sediment		LEAN CLAY
		15-25% Coarse-Grained Sediment	% sand > % gravel	LEAN CLAY WITH SAND
			% sand < % gravel	LEAN CLAY WITH GRAVEL
	>30% Coarse Grained Sediments	% sand > % of gravel	<15% gravel	SANDY LEAN CLAY
			>15% gravel	SANDY LEAN CLAY WITH GRAVEL
		% sand < % gravel	<15% sand	GRAVELLY LEAN CLAY
			>15% sand	GRAVELLY LEAN CLAY WITH SAND
CH	<30% Coarse Grained Sediments	<15% Coarse-Grained Sediment		FAT CLAY
		15-25% Coarse-Grained Sediment	% sand > % gravel	FAT CLAY WITH SAND
			% sand < % gravel	FAT CLAY WITH GRAVEL
	>30% Coarse Grained Sediments	% sand > % of gravel	<15% gravel	SANDY FAT CLAY
			>15% gravel	SANDY FAT CLAY WITH GRAVEL
		% sand < % gravel	<15% sand	GRAVELLY FAT CLAY
			>15% sand	GRAVELLY FAT CLAY WITH SAND
OL / OH	<30% Coarse Grained Sediments	<15% Coarse-Grained Sediment		ORGANIC SOIL
		15-25% Coarse-Grained Sediment	% sand ≥ % gravel	ORGANIC SOIL WITH SAND
			% sand < % gravel	ORGANIC SOIL WITH GRAVEL
	>30% Coarse Grained Sediments	% sand ≥ % of gravel	<15% gravel	SANDY ORGANIC SOIL
			≥15% gravel	SANDY ORGANIC SOIL WITH GRAVEL
		% sand < % gravel	<15% sand	GRAVELLY ORGANIC SOIL
			≥15% sand	GRAVELLY ORGANIC SOIL WITH SAND

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ATTACHMENT C

SOIL AND ROCK DESCRIPTION SUMMARY

USDA SOIL TEXTURING FIELD FLOW CHART

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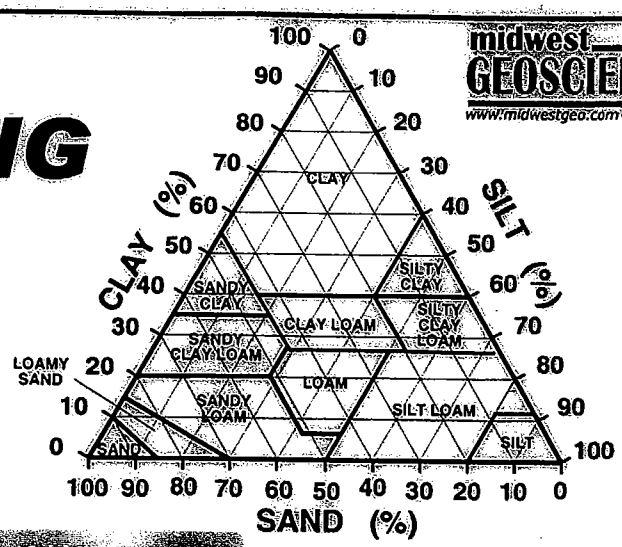


Remove any material larger than 2 mm in size and start with approximately 25g of sediment in palm. Add water dropwise and knead the soil to break down all aggregates. Stop adding water when soil is plastic and moldable.

Add dry sediment

Does soil hold together when squeezed? — NO → Is soil too dry? — NO → Is sediment too wet? — NO → SAND

YES → Place ball of soil between thumb and forefinger gently pushing the soil with the thumb, squeezing it upward into a ribbon. Form the ribbon with uniform thickness and width. Allow the ribbon to extend over the forefinger, breaking from its own weight.

YES → Does the soil form a ribbon? — NO → LOAMY SAND

YES → Is the ribbon less than 2.5cm long before breaking? — >2.5 CM? → Is the ribbon from 2.5 to 5.0cm long before breaking? — >5.0 CM? → Is the ribbon greater than 5.0cm long before breaking?

Excessively wet a small pinch of soil in palm and rub with forefinger

Is soil very sandy? — YES → SANDY LOAM	Does soil feel very gritty? — YES → SANDY CLAY LOAM	Does soil feel very gritty? — YES → SANDY CLAY
NO → Is soil moderately sandy? — YES → LOAM	NO → Does soil feel slightly gritty? — YES → SILTY CLAY LOAM	NO → Does soil feel slightly gritty? — YES → SILTY CLAY
NO → Does sample have little or no sand? — YES → SILT LOAM	NO → Does soil feel smooth? — YES → CLAY LOAM	NO → Does soil feel smooth? — YES → CLAY

TEXTURE MODIFIERS
Fragment Content % by Volume

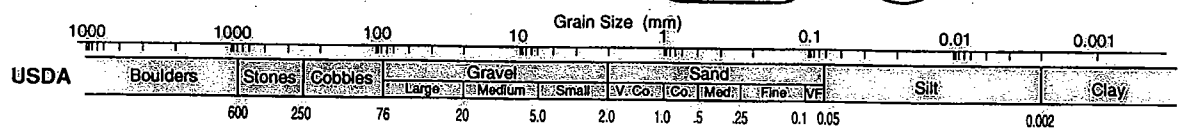
<15%	No modifier
15% to <35%	Add modifier
36% to <60%	Add "very" with modifier
60% to 90%	Add "extremely" with modifier
>90%	No modifier; use Size Class only

ROCK FRAGMENT MODIFIERS
Size Class & Quantity

Gravelly	>15% but <35% gravel
Fine Gravelly	>15% but <35% fine gravel
Medium Gravelly	>15% but <35% med. gravel
Large Gravelly	>15% but <35% large gravel
Very Gravelly	<35% but <60% gravel
Extremely Gravelly	>60% but <90% gravel
Cobbly	>15% but <35% cobbles
Very Cobbly	<35% but <60% cobbles
Extremely Cobbly	>60% but <90% cobbles
Stony	>15% but <35% stones
Very Stony	<35% but <60% stones
Extremely Stony	>60% but <90% stones
Bouldery	>15% but <35% boulders
Very Bouldery	<35% but <60% boulders
Extremely Bouldery	>60% but <90% boulders

COMPOSITIONAL TEXTURE MODIFIERS
Organic Class

Grassy	>15% grassy fibers
Herbaceous	>15% herbaceous fibers
Mossy	>15% moss fibers
Mucky	Minerals >10% but <17% fibers
Peaty	Minerals >10% but >17% fibers
Woody	>15% wood fragments or fiber



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FIELD GUIDE FOR SOIL AND STRATIGRAPHIC ANALYSIS

midwest GEOSCIENCES group
www.midwestgeo.com

START HERE

DENSITY OR CONSISTENCY

COARSE GRAINED DEPOSITS	N-VALUE	
	0-4	► VERY LOOSE
	5-10	► LOOSE
	11-29	► MEDIUM DENSE
	30-49	► DENSE
	>50	► VERY DENSE

FINE GRAINED DEPOSITS	N-VALUE	q_u (tsf)	
	0-2	<0.25	► VERY SOFT
	3-4	0.25-0.50	► SOFT
	5-8	0.50-1.0	► MEDIUM
	9-15	1.0-2.0	► STIFF
	16-30	2.0-4.0	► VERY STIFF
	>30	>4.0	► HARD

COLOR
Use Standard Munsell Color Notation

IS THE COLOR A MATRIX COLOR?
- YES ► **MATRIX COLOR** — List in sequence, dominant first
- NO ► IS THE COLOR FROM A COATING OR CONCENTRATION?
  - YES ► **COATING or CONCENTRATION** — Note frequency, color, and size
  - NO ► **MOTTLE** — Note contrast, color, and size

CLASSIFICATION
Unified Soil Classification System - adopted ASTM D2488

STEP 1: IS SEDIMENT COARSE-GRAINED OR FINE-GRAINED?

COARSE-GRAINED DEPOSITS
>50% coarse-grained sediments, <50% fines

STEP 2: DETERMINE SAND VS. GRAVEL RATIO

INCREASING GRAIN SIZE

SAND			GRAVEL		
FINE	MEDIUM	COARSE	FINE	COARSE	

0.075 MM, 0.425 MM, 2.0 MM, 4.75 MM, 19.0 MM, 75.0 MM

STEP 3: CONTINUE WITH SAND OR GRAVEL ON FLOW CHART (REVERSE)

FINE-GRAINED DEPOSITS
(organic and inorganic)
>50% fines, <50% coarse-grained sediments

STEP 2: DETERMINE PLASTICITY AND ASSIGN USCS GROUP SYMBOL

INCREASING PLASTICITY

NON PLASTIC	LOW PLASTICITY	MEDIUM PLASTICITY	HIGH PLASTICITY
ML	CL		CH

STEP 3: CONTINUE WITH GROUP SYMBOL ON FLOW CHART (REVERSE)

MOISTURE

MOISTURE ABSENT	► DRY
DAMP, NO VISIBLE WATER	► MOIST
VISIBLE WATER	► WET

PLASTICITY
(Use with CLASSIFICATION)

WILL NOT SUPPORT 6mm DIAMETER ROLL IF HELD ON END	► NON-PLASTIC
6mm DIA. ROLL CAN BE REPEATEDLY ROLLED AND SUPPORTS ITSELF, 4mm DIA. ROLL DOES NOT	► LOW PLASTICITY
4mm DIA. ROLL CAN BE REPEATEDLY ROLLED AND SUPPORTS ITSELF, 2mm DIA. ROLL DOES NOT	► MEDIUM PLASTICITY
2mm DIA. ROLL CAN BE REPEATEDLY ROLLED AND SUPPORTS ITSELF	► HIGH PLASTICITY

6mm, 4, 2

COHESIVENESS

6mm DIAMETER ROLL CANNOT BE FORMED	► NONCOHESIVE
6mm DIAMETER ROLL CAN BE FORMED	► COHESIVE

SEDIMENTARY STRUCTURE

UNIFORM	
BEDS >30cm	► MASSIVE
BEDS 3cm to 30cm	► THICKLY BEDDED
BEDS 0.5cm to 3cm	► BEDDED
BEDS <0.5cm	► THINLY BEDDED
	► LAMINATED

SECONDARY SOIL STRUCTURE (IN SOLUM ONLY)	
Spheroidal peds or granules usually packed loosely	► GRANULAR
Irregular, roughly cubelike peds with planar faces (angular or subangular)	► BLOCKY
Flat and horizontal peds	► PLATY
Vertical, pillarlike peds with flat tops	► PRISMATIC
Vertical, pillarlike peds with curved tops (which are commonly "bleached")	► COLUMNAR

WEATHERING ZONE ABBREVIATION

MODIFIER SYMBOL (if present)		1st SYMBOL		2nd SYMBOL		LAST SYMBOL (if present)	
MOTTLED	► M	OXIDIZED	► O	LEACHED	► L	SECONDARY CARBONATE	► 2
JOINTED	► J	REDUCED	► R	UNLEACHED	► U		
		UNOXIDIZED	► U				

EXAMPLE: solum OJL, MOJL, MOJL2, MOJU ↓ MRJU, RJU, RU, UU

SECONDARY GRAIN SIZE INFORMATION

<5%	► TRACE	0.075mm to 0.425mm (powdered sugar)	► FINE SAND
6% to 15%	► LITTLE	0.425mm to 2.0mm (sugar to table salt)	► MEDIUM-GRAINED SAND
16% to 30%	► FEW	2.0mm to 4.75mm (rocksalt)	► COARSE-GRAINED SAND
31% to 45%	► SOME	4.75mm to 19.0mm (pea to grape)	► FINE GRAVEL
		19.0mm to 75.0mm (grape to lemon)	► COARSE GRAVEL

FOR GLACIAL DIAMICTONS ► CLAST FRACTION ► CLAST LITHOLOGY

DEPOSITIONAL ENVIRONMENT

VARIOUS DEPOSITIONAL ENVIRONMENTS (interpretation)
- ► EOLIAN (LOESS)
- ► FLUVIAL
- ► ALLUVIAL
- ► LACUSTRINE
- ► COASTAL
- ► RESEDIMENTED

GLACIAL DEPOSITIONAL PROCESSES
- ► SUBGLACIAL
- ► GLACIOFLUVIAL
- ► GLACIOLACUSTRINE
- ► RESEDIMENTED

GENERALIZED RESEDIMENTATION PROCESSES
- ► MASS SLUMP
- ► SEDIMENT FLOW
- ► COLLUVIUM

STRATIGRAPHIC NAME

USE FORMAL STATE GEOLOGICAL SURVEY NOMENCLATURE WHEN POSSIBLE;
IF NOT POSSIBLE, ASSIGN SITE-SPECIFIC UNIT NAME ACCORDING TO DEPOSITIONAL ENVIRONMENT / FACIES ASSEMBLAGE

STRATIGRAPHIC CONTACT

< 2 cm	► SHARP (or ABRUPT for pedogenic alternation)
> 2 cm (Note transition interval)	► GRADATIONAL

0110103

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SOIL DESCRIPTION

GRAIN SIZE IDENTIFICATION

NAME	SIZE LIMITS
Boulder	12" OR MORE
Cobbles	3" - 12"
Coarse Gravel	3/4" - 3"
Fine Gravel	4.76 mm (#4) - 3/4"
Coarse Sand	2 mm (#10) - 4.76 mm (#4)
Medium Sand	0.42 mm (#40) - 2 mm (#10)
Fine Sand	0.074 mm (#200)-0.42 mm (#40)
Silt	0.002 mm-0.074 mm (#200)
Clay	Less than 0.002 mm

RELATIVE DENSITY

NONCOHESIVE SOIL

TERM	SPT (Blows/ft)
Very Loose	Below 4
Loose	4-10
Medium Dense	10-30
Dense	30-50
Very Dense	OVER 50

COHESIVE SOILS

TERM	SPT (Blows/ft)
Very Soft	BELOW 2
Soft	2-4
Medium Stiff	4-8
Stiff	8-15
Very Stiff	15-30
Hard	OVER 30

MOISTURE	DESCRIPTIVE TERMS	
Dry	Trace	0-10%
Damp	Little	10-20%
Moist	Some	20-35%
Wet	And	35-50%

CONTACTS:

_____ = DEFINITE

____ ____ = INDEFINITE

. . . . . = GRADATIONAL

ROCK DESCRIPTIONS

HARDNESS

Very Soft -	Easily gouged by knife, easily scratched by fingernail, easily broken by hand
Soft -	Gouged by knife, scratched by fingernail, difficult to break by hand, powders with hammer
Medium Hard -	Easily scratched by knife, easily broken with hammer
Hard -	Difficult to scratch, breaks with hammer
Very Hard -	Difficult to break, rings when struck

WEATHERING

Decomposed -	Soft to Very soft, bedding and fractures indistinct, no cementation.
Highly Weathered -	Very soft to soft, with medium hard relict rock fragments: little to moderate cementation. Vugs, openings in bedding and fractures (may be filled).
Weathered -	Soft to medium hard. Good cementation. bedding and fractures are pronounced. Uniformly stained.
Slightly Weathered -	Medium hard. Fractures pronounced, non-uniform staining, bedding distinct.
Fresh -	Medium hard to hard. No staining. Fractures may be present. Bedding may or may not be indistinct.

BEDDING AND FRACTURES:

SPACING	BEDDING	FRACTURES
	Indistinct	
LESS THAN 1/2" (1 cm)	Laminated	Fissile
1/2" to 1" (1cm-3cm)	Very Thin	Very Close
1" TO 4" (3cm-10cm)	Thin	Close
4" TO 1' (10cm-30cm)	Moderate	Moderate
1' TO 3' (30 cm-1m)	Thick	Wide
3' TO 10' (1m-3m)	Massive	Very Wide

SAMPLE TYPE

S = Split Spoon
T = Shelby Tube
R = Air Rotary
D = Denison
A = Auger
W = Wash (Roller Bit)
C = Core
P = Piston
N = No Sample Taken

ABBREVIATIONS

HS = Hollow Stem
NP = Non Plastic
-PL = Below the Plastic Limit
PL = At the Plastic Limit
+PL = Above the Plastic Limit
+LL = Above the Liquid Limit
SPT = Standard Penetration Test
RQD = Rock Quality Designation

ROCK SYMBOLS

- CONGLOMERATE
- BRECCIA
- SANDSTONE
- SILTSTONE
- SHALE
- CLAYSTONE
- LIMESTONE
- DOLOMITE
- COAL
- VOID
- UNDIFFERENTIATED

HARDNESS

V. SOFT - CORE RECOVERY <30%, EASILY GOUGED BY KNIFE OR SCREWDRIVER, EASILY SCRATCHED BY FINGERNAIL, EASILY BROKEN BY HAND

SOFT - CORE RECOVERY 30 - 75%, GOUGED BY KNIFE OR SCREWDRIVER, SCRATCHED BY FINGERNAIL, DIFFICULT TO BREAK BY HAND, POWDERS w/HAMMER

MED. HD. - CORE RECOVERY > 75%, EASILY SCRATCHED BY KNIFE OR SCREWDRIVER, EASILY BROKEN BY HAMMER

HD. - DIFFICULT TO SCRATCH, BREAKS w/HAMMER

V. HD. - DIFFICULT TO BREAK, RINGS WHEN STRUCK

SPACING	BEDDING	FRACTURES
	INDISTINCT	
LESS THAN ½" (1cm)	LAMINATED	FISSILE
½" To 1" (1cm-3cm)	VERY THIN	VERY CLOSE
1" To 4" (3cm-10cm)	THIN	CLOSE
4" To 1' (10cm-30cm)	MODERATE	MODERATE
1' To 3' (30cm-1m)	THICK	WIDE
3' To 10' (1m-3m)	MASSIVE	VERY WIDE

WEATHERING

DECOMPOSED - SOFT - V. SOFT, BEDDING AND FRACTURES INDISTINCT, NO CEMENTATION

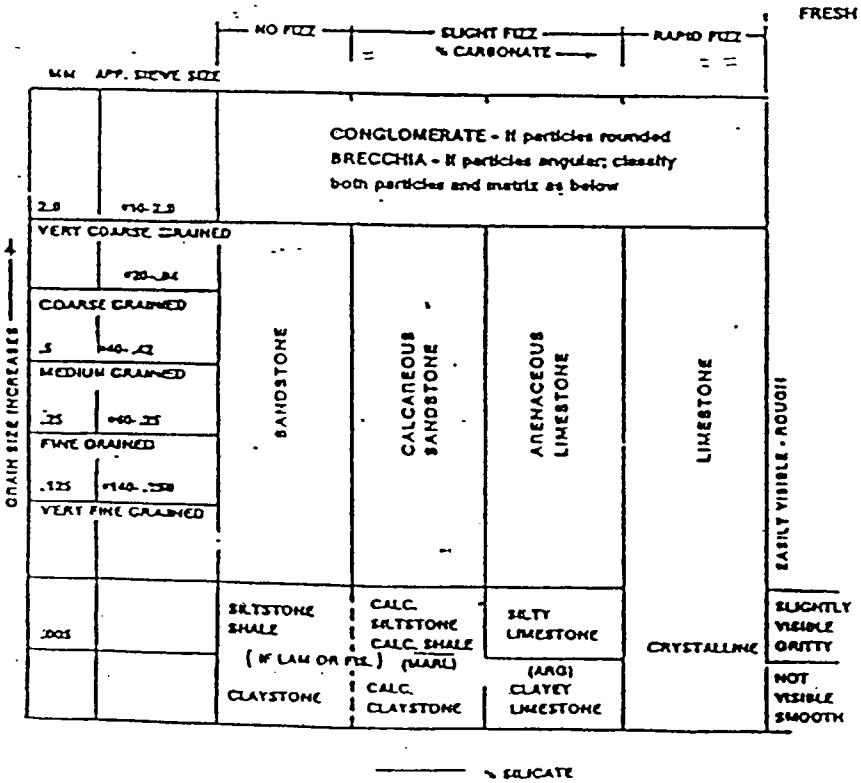
HI. WTHR. - V. SOFT - SOFT, w/MED. HD. RELICT ROCK FRAGMENTS; LITTLE TO MOD. CEMENTATION, VUGS, OPENINGS IN BEDDING AND FRACTURES (MAY BE CLAY OR CALC. FILLED)

WTHR. - SOFT TO MED. HD., GOOD CEMENTATION, BEDDING AND FRACTURES ARE PRONOUNCED, UNIFORMLY STAINED

SL. WTHR. - MED. HD., FRACTURES PRONOUNCED, NON-UNIFORM STAINING, BEDDING DISTINCT

FRESH - MED. HD. TO HD., NO STAINING, FRACTURES MAY BE PRESENT, BEDDING MAY OR MAY NOT BE DISTINCT

COMMON LOCAL SEDIMENTARY ROCK CLASSIFICATIONS



ROCK DESCRIPTIONS

$$RQD = \frac{L}{R}$$ - NTYPE CORE ONLY

L = TOTAL LENGTH IN A RUN OF CORE PIECES LONGER THAN 4"

R = LENGTH OF THE RUN

SOP F102
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 "Rock Core Drilling for Site Investigation" and "Direct Push Soil Sampling" are referenced in Section 7.0 of this SOP.

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.

Split-Barrel Sampler - A steel tube, split in half lengthwise (along its axis), with the halves held together by threaded collars at both ends 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 or the drill rig hydraulics. 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 lengths providing either 20-inch (uncommon) or 26-inch (common) internal longitudinal clearance for obtaining 18-inch long (typical for geotechnical) or 24-inch long (typical for environmental) 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 (grab) 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.

- Encore® Sampler – A syringe-type sampler (Encore® being a common brand) used to collect Volatile Organic Compound (VOC) samples in accordance with SW 846 Method 5035. The Encore® sampler

is inserted into the soil core using a T-handle. The soil displaces a piston that retains an approximate 5-gram soil core (25-gram size is also available). The sampler is then capped, labeled, and placed in a re-sealable storage bag that comes with the sampler. Typically, two to three Encore® samplers are required for each VOC sample.

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 that deviate from those presented herein.

Field Team Leader - The Field Team Leader is responsible for selecting and detailing the specific sampling techniques and equipment to be used, and documenting these in accordance with 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, preservation, and shipment of samples to the laboratory.

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 and/or the origin of a contaminant release. These samples may be collected during initial site screening to determine gross contamination levels, levels of personal protection for future 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 four methods for collecting subsurface soil samples: (1) split-spoon sampling; (2) Shelby tube sampling; (3) bucket auger sampling; and (4) direct push sampling. All four methods yield samples suitable for laboratory analysis. The ASTM procedures for split-spoon sampling, Shelby tube sampling and direct push sampling are referenced in Section 7.0 of this SOP.

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 or bottom-discharge bits are permissible. 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 split-barrel sampler should be driven with blows from a 140-pound hammer falling 30 inches in accordance with ASTM D1586-99, 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 or Work Plan.

5. Record on the Field Test Boring Record and/or field logbook the number of blows required to drive the sampler each six inches of penetration (or fraction there of if refusal is encountered). 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 percentage 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 Standard Penetration Test 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. Retrieve 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, if possible. Describe carefully the recovery (length in feet), composition, structure, consistency, color, condition, etc. of the recovered soil according to SOP F101 before placing into jars without ramming (compacting). 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 5.1.1.

2. Screen the length of the soil core with a photoionization detector (PID). PID readings are recorded on the Field Test Boring Log. The portion of the core exhibiting the highest PID readings may be selected for VOC analysis, if designated in the Work Plan.

3. If VOC analysis is required, the sample shall be collected immediately after screening with the PID, and shall be collected using SW 846 Method 5035 (syringe-type piston sampler - Encore® or similar). If the Work Plan does not require Method 5035, sample containers for VOCs analyses provided by the laboratory should be filled completely without headspace remaining in the container to minimize volatilization.

4. After VOC 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. This is typically performed by mixing the soils in either a disposable pie tin (to avoid the need for decontamination) or a decontaminated stainless steel bowl. Soil samples for VOCs should not be mixed to avoid further volatilization.

5. When all environmental sampling has been completed and the samples have been properly preserved (typically placed on ice in a cooler at approximately 4 degrees Celsius), 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 and/or the field logbook. In addition, label, tag, and number the sample bottle(s).

6. Decontaminate the split-spoon sample as described in SOP F501 and SOP F502. Replace disposable latex gloves between sample intervals to prevent cross-contaminating samples.

7. At the completion of sampling activities, pack the samples for shipping to avoid breakage (see SOP F301). Attach a custody seal to the shipping package for quality control purposes. Make sure that Chain-of-Custody Forms (and Sample Request Forms, if necessary) are properly filled out and enclosed within the shipment cooler (see SOP F302).

For obtaining composite soil samples (see Section 3.0), 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 VOCs should be collected. However, a composite VOC sample is rarely requested in the environmental industry. 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. Only side discharge bits are permitted.

3. 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 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 borehole, 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 one 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 liquid (hot) 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 to 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.

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. Other appropriate devices 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 geologic classification purposes.

5.1.3 Bucket (Hand) Auger Sampling

Hand augering is the most common manual method used to collect shallow 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 sand, augering is usually easily accomplished, but the depth of investigation is controlled by the depth at which sands begin to cave into the augered borehole. At this point, auger boreholes 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, twisting of hand auger extensions becomes so severe that in resistant materials powered methods must be used.

When a vertical sampling interval has been established, one auger bucket is used to advance the auger borehole 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 borehole, as well collect subsequent samples in the same borehole. 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 and bottom 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 maximum depth range for this equipment. It is used to advance a borehole to the required sample depth, at which point a hand auger is usually used to collect the sample.

5.1.4 Direct Push Sampling

Direct push sampling has become a widely used technique for collecting environmental samples of soil and groundwater. There are multiple sampling devices and different sized samplers used in direct push methods. This is a general procedure for sampling and could change depending on work plan and type of sampling being done.

1. The sampler should be driven to desired depth for sample.

2 Bring the sampler to the surface and remove the acetate soil liner from the stainless steel outer sampler. 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 and/or field logbook. In addition, label, tag, and number the sample bottle(s). Affix labels to the jar and complete Chain-of-Custody and other required sample data forms (see SOP F302).

3. After recording the pertinent information, slice the liner with a cutting tool or drill small holes along the length (axis) of the liner in order to screen the soil core with the PID. PID readings are also recorded on the Field Test Boring Log. The portion of the core exhibiting the highest PID readings may be selected for VOC analysis, if required.

4. If VOC analysis is required, they shall be collected immediately after screening with the PID, and shall be collected using SW 846 Method 5035 (Encore® or similar). If the Work Plan does not require Method 5035, sample containers for VOCs analyses should be filled completely without headspace remaining in the container to minimize volatilization. After VOC sample collection, remove the soil from the liner. Prior to filling laboratory containers, the soil sample should be mixed thoroughly as possible to ensure that the sample is as representative as possible of the sample interval. Soil samples for volatile organic compounds should not be mixed. Further, sample containers for volatile organic compounds analyses should be filled completely without headspace remaining in the container to minimize volatilization.

5. Pack the samples for shipping (see SOP F301). 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 F302).

6. Decontaminate the sampler as described in SOP F501 and SOP F502. Replace disposable latex gloves between sample stations to prevent cross contaminating samples.

5.2 Surface Soil Samples

Surface soils are generally classified as soils between the ground surface and 6 to 12 inches below ground surface (Note: the depth considered to be "surface soil" varies by regulatory agency; if the Work Plan does not specify the depth for surface soil samples, verify the appropriate sample depth with the Project Manager). 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 sample identification label (completed in indelible ink) to the sample container. Record all required information in the field logbook (SOP F303) and on the chain-of-custody record (SOP F302), 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 a decontaminated sampling utensil for each sample collected.

5. Preserve, pack, and ship the surface soil samples as described in SOP F301.

6. Mark the location with a numbered stake, pin flag, or similar if possible and locate sample points on a sketch of the site or on a sketch in the field logbook. If available for the project, collect the sample location using GPS technology for future placement on a digitized, scaled base map.

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 bowl (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. However, as presented previously, the request for a composited VOC soil sample is observed in a Work Plan.

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 (left to right, top row to bottom row). 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 shifting of the cores in the box during transportation.

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

- Project name and number
- Date
- 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 project name, 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 at the 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

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2. American Society for Testing and Materials, 2000. Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes. Method D1587-00, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.

3. American Society for Testing and Materials, 1999. Standard Practice for Rock Core Drilling and Sampling for Site Investigation. Method D2113-99, Annual Book of Standards ASTM, Philadelphia, Pennsylvania.

4. American Society for Testing and Materials, 1999. Standard Practice for Direct Push Soil Sampling for Environmental Site Characterizations. Method D6282-98, Annual Book of Standards ASTM, Philadelphia, Pennsylvania.

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

SOP F103
MONITORING WELL INSTALLATION

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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 logbooks 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, and typically also is responsible for health and safety issues. 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.

Placement 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, and/or information supplied by local drilling companies will provide information for placement of the 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 and/or Work Plan. These modifications may include larger diameter shallow wells, extraction wells, deep monitoring wells requiring surface casing and other specially constructed well types. Guidelines for monitoring well construction are given in Attachment A. Typical shallow monitoring well construction details are shown in Figures A-1 and A-2 in Attachment A for wells with flush-mounted and stick-up wells, respectively.

Note that these procedures discuss well installation using a PVC screen and riser pipe. Other materials such as stainless steel or Teflon® also are available. These items are used when the contaminant being investigated is known to exist in high concentrations in the soil/groundwater and is reactive with PVC (i.e., solvent).

Generally PVC is less expensive and easier to work with than either stainless steel or Teflon®. Thus, PVC is the most commonly used well construction material used today.

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 typically composed of Schedule 40 PVC, threaded, flush-joint riser (casing) with a #10 slot (0.010-inch diameter), threaded, flush-joint PVC screen. A larger or smaller diameter screen may be used to accommodate site-specific geologic conditions. A 6-inch long PVC threaded end cap may be placed at the bottom of each screen to act as a settling cup for fine grained material (e.g., silt) that may pass through the filter pack and screen. 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 5 to 20 feet depending on site-specific conditions. For light non-aqueous 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 the floating free product can enter the well. Should very shallow water table conditions be encountered or if the focus is on a specific thin water-bearing zone, the screened interval may be reduced. If this situation is expected, it should be addressed in the project plans, as necessary.

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 or near the base of the aquifer. Depending on the location of the monitoring well, the riser pipe may extend from the top of the screened interval to either approximately 6 inches below the ground surface (for flush-mounted wells) to between approximately one to three feet above the ground surface for wells completed with ‘stick-up’ casings.

The annular space between the well screen and the open borehole (annular space) is to be backfilled with a well-sorted (uniform size) quartz sand 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 borehole to approximately 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 shallow to allow enough vertical distance for placement of the sealing materials and protective casing.

A sodium bentonite seal at least 2-foot thick shall be place above the sand pack. The bentonite seal shall be hydrated with potable water if it lies above the water table. For deeper wells, a bentonite slurry may be more appropriate than pellets or chips due to problems with bridging in the annular space. Currently, a large number of monitoring well construction projects are modifying the typical construction of the past to include a thicker bentonite seal and a thinner grout zone. The use of a bentonite seal from the top of the sand pack to near grade minimizes the potential for downward migration of contaminants from the near surface. This minimization is due to the bentonite’s expansive properties (swells extensively when moist or wet) versus the tendency of cement-bentonite grout to shrink upon curing (forming a small annulus for potential downward vertical migration of near-surface contaminants).

The annular space above the bentonite seal will be backfilled with a cement-bentonite grout consisting of 3 to 4 percent granular or powder bentonite (by dry weight) to the grout. The grout mixture shall be specified in the project plans. The grout will be tremied into the annular space if greater than 20 feet deep. If the annular space is less than 20 feet deep, 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 0.1foot and recorded on the Field Well Construction Record (Attachment B) and/or in a field logbook.

5.2 Drive Points

Drive points are typically used as temporary monitoring points of groundwater elevations and/or groundwater quality. 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 drive point 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 F105, "Groundwater Sample Acquisition."

5.3 Surface Completion

There are several methods for surface completion of monitoring wells. Two typical methods are presented below.

The first method considers wells completed above grade (stick-up casing). The aboveground section of the PVC riser pipe will be protected by installation of a 4- to 6-inch diameter, 5-foot long steel casing (with locking cap and lock) into either concrete or cement grout. The bottom of the surface casing will be placed at a minimum of 2-1/2, but not more than 3-1/2 feet below the ground surface. For very shallow wells, a steel casing of less than five feet in length may be used, as space permits. The protective steel casing shall not fully penetrate the bentonite seal. A concrete apron (typically a 2' x 2' pad) shall be constructed around the steel casing. Furthermore, in areas of potential damage, protective bollards may also be installed at the corners of the concrete pad to mitigate potential damage to the well casing itself.

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" manhole-type cover. The well shall be completed by construction of a concrete apron (typically 2' x 2'). 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 may be required to be firmly attached to each well. Alternately, well identification information may either be stamped on a metal plate and attached to the well protective steel casing, painted on the casing, or embedded in the concrete apron, as appropriate.

5.4 Well Development

There are two stages of well development; initial and sampling. Sampling development is described in SOP F105, 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 aquifer. 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 should 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. However, if the entire grout column within the annulus does not contact the aquifer (including confined conditions), the well may be developed soon after construction completion. Wells typically are developed using bailers, pumps, or surging with a surge block or air. The appropriate method shall be specified in the project plans.

In general, wells shall be developed until groundwater 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 to five borehole volumes) or until the 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 requirements 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 F503, 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 or Work Plan. In general, all site investigation derived wastes (IDW) shall be containerized unless otherwise specified in the Sampling and Analysis Plan or Work Plan. The disposition of these wastes shall be determined after receipt of the appropriate analytical results.

5.6 Well Construction Records

The Drilling Inspector shall complete Field Well Construction Records 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 or digitally recorded using Log Draft software.

Field Well Construction Records (in Attachment B) shall include not only well construction information, but also information pertaining to the amount of materials used for construction. Quantifying the amount of materials used during the well construction activities (as well as labor hours) will facilitate the review of the subcontractor invoices. Some of the following items shall be recorded on the Field Well Construction Record, the field logbook, or in Log Draft, as appropriate:

- Project name and location.
- Project and Task number.
- Date and weather.
- Well identification number
- Drilling company and driller.
- Pay items including amount of screen and riser pipe used, amounts of cement, bentonite and sand used, and other well construction items.
- Well casing, augers, and borehole diameters.
- Elevations of (and depth to) top of steel casing, PVC casing, bottom of well, top of filter pack, top of bentonite seal, top of screen (elevations calculated post field from survey results).

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. Furthermore, the field boring and well construction logs may also be placed in a digitized format using Log Draft. An example of all three documents is presented in Attachment B.

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 should 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.

5. American Society for Testing and Materials, 2004. Standard Practice for Design and Installation of Ground Water Monitoring Wells. Method D5092-04, Annual Book of Standards ASTM, Philadelphia, Pennsylvania.

ATTACHMENT A

MONITORING WELL CONSTRUCTION

ATTACHMENT A

UST MONITORING WELL CONSTRUCTION AND FIELD OPERATIONS

SPECIFICATIONS

Well permits required by state agencies are the responsibility of the contractor. All monitoring wells will be installed in accordance with the specifications set forth in the site-specific sampling and analysis plan. The wells will be constructed of either a 2-inch or 4-inch inside diameter (I.D.) flush joint threaded PVC well screen and riser casing depending on conditions encountered during borehole completion.

DRILLING

During the drilling program, boreholes will be advanced using conventional hollow-stem auger drilling methods. If it is the opinion of the contractor that air or mud rotary drill methods are necessary, approval must be obtained from the Investigation Manager. Presentation of justification for a boring method change shall be presented prior to drilling.

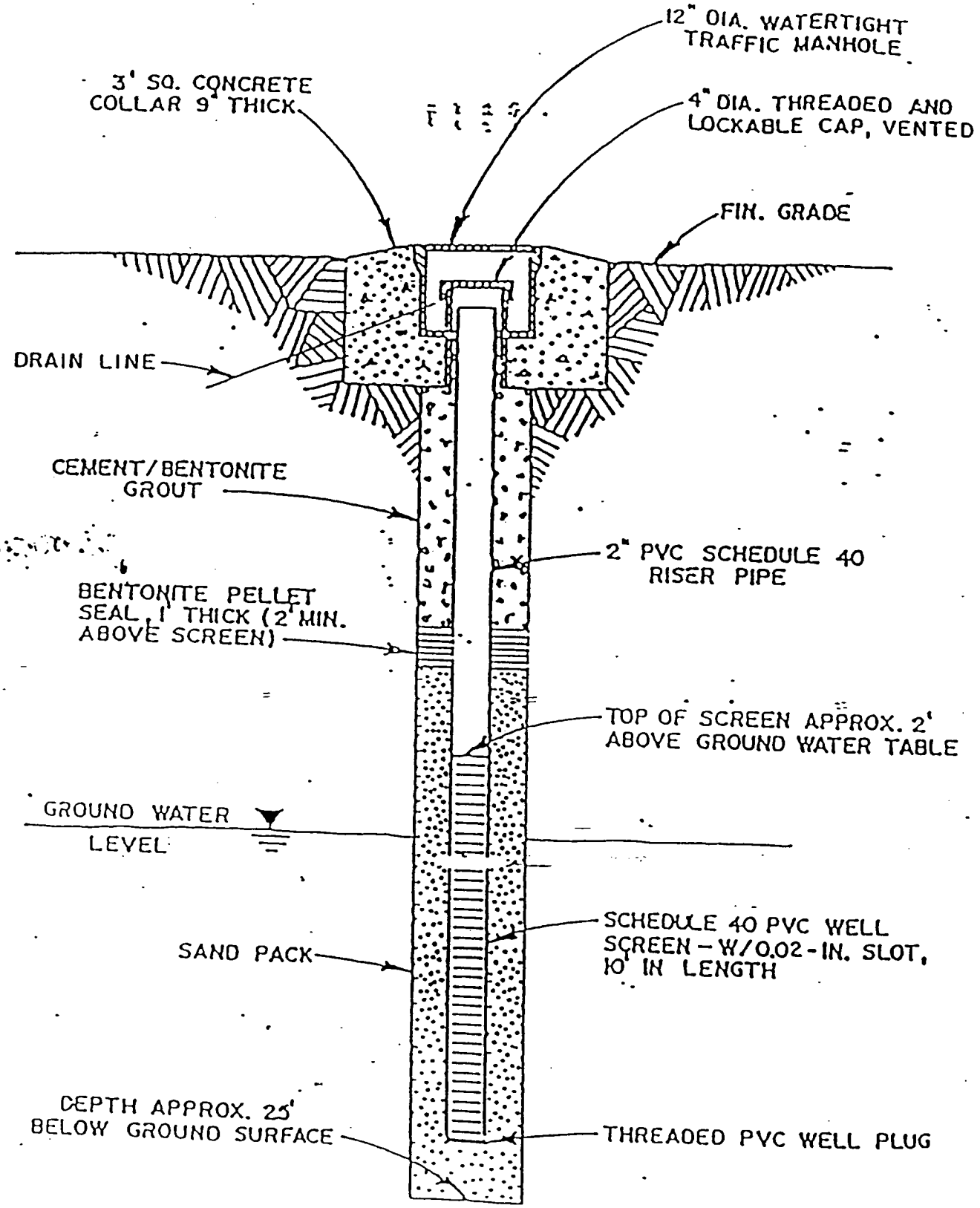
Well construction details are shown in Figures A-1 and A-2. A drill mounted on an All-Terrain-Vehicle (ATV) may be required for access to remote areas. Each rig will use necessary tools, supplies and equipment supplied by the contractor to drill each site. Drill crews should consist of an experienced driller and a driller assistant for work on each rig. A geologist, experienced in hazardous waste site investigations, shall be on site to monitor the drillers efforts and for air monitoring/safety control. Additional subcontractor personnel may be needed to transport water to the rigs, clean tools, assist in the installation of the security and marker pipes, construct the concrete aprons/collars and develop the wells. A potable water source in the plant will be designated by U.S. Steel.

Standard Penetration Tests (SPTs) will be performed in accordance with ASTM D-1586. Standard penetration tests will be performed at the following depths: 0.0-1.5 feet; 1.5-3.0 feet; 3.0-4.5 feet; and 5-foot centers thereafter. In cases where soil sampling for environmental analytical analysis is required, 24-inch spoon barrels may be used in the SPT to obtain a sufficient amount of sample for required analysis. A boring log of the soil type, stratification, consistency, and groundwater level will be prepared.

SAMPLING

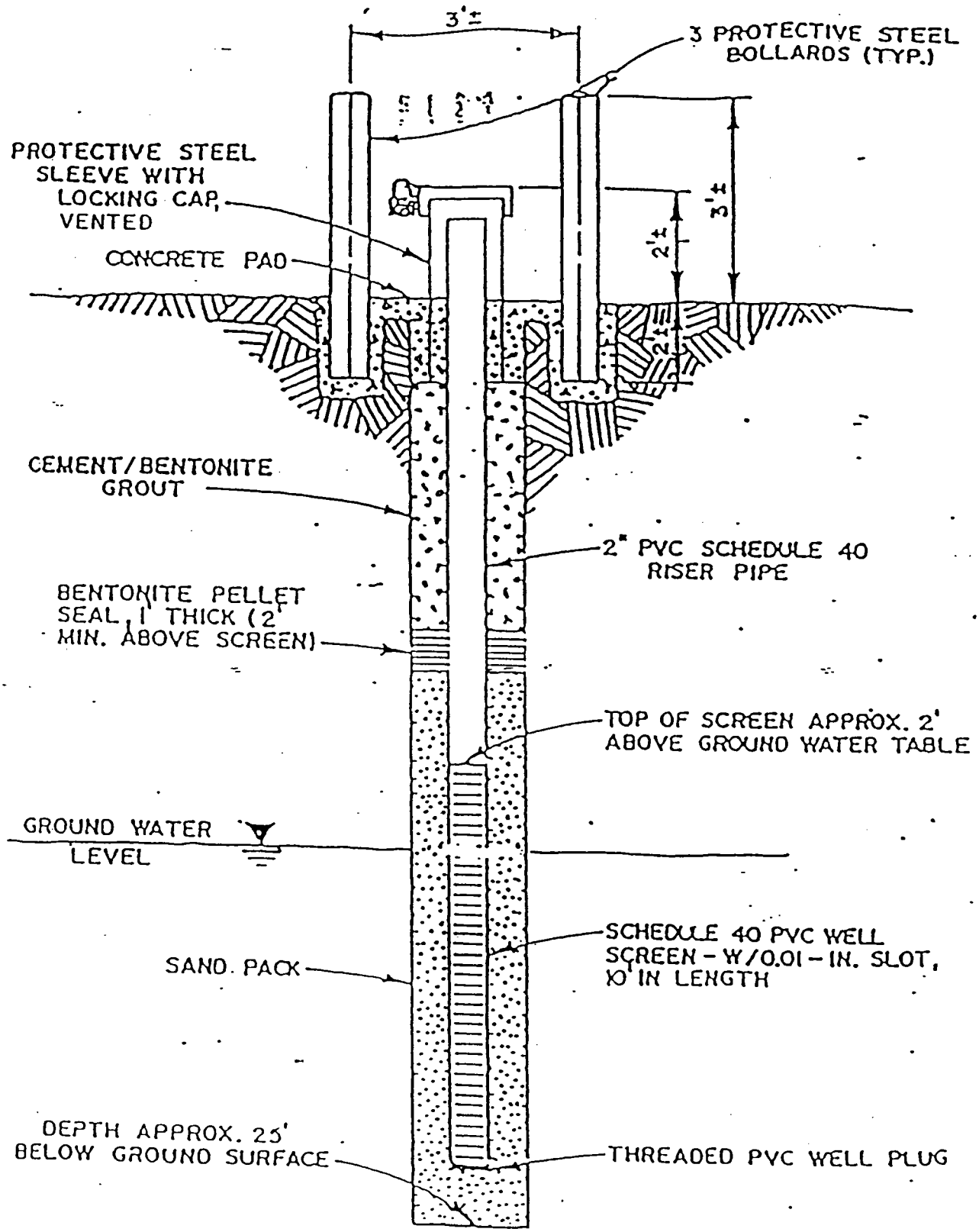
Soil samples of the subsurface materials will be collected at the interval specified in the Sample and Analysis Plan throughout the borehole in accordance with ASTM Method D-1586. Each soil sample will be screened in the field using an Hnu photoionizer, organic vapor detector or similar type direct readout instrument to identify the presence of volatile organic vapors within the soils. This field screening will provide a preliminary indication of the vertical and horizontal extent of contamination in order to select the optimum locations of other monitoring wells during the drilling program. Based on the field screening, two-inch or four-inch diameter monitoring wells will be installed at the locations where the most significant accumulation of contamination is encountered.

FIGURE A-1



MONITORING WELL CONSTRUCTION DETAIL
(TRAFFIC AREA)
NOT TO SCALE

FIGURE A-2



MONITORING WELL CONSTRUCTION DETAIL
(NON TRAFFIC AREA)
NOT TO SCALE

WELL INSTALLATION

After completion of soil sampling and drilling to the specified depth, two-inch and/or four-inch (as required in the Sample and Analysis Plan) inside-diameter, flush-threaded Schedule 40 PVC (Schedule 80 in traffic areas) monitoring wells with slotted screens and well casings will be installed in the borehole. A 5- to 15-foot section of 0.01-inch slotted PVC well screen shall be used in each well. A sand pack will be placed around the slotted well screen extending to 2 feet above the top of the screen. A bentonite seal (minimum thickness of 1 foot) will be placed on top of the sand pack. Finally, a grout mixture of three to four percent bentonite powder (by dry weight) and seven gallons of water per 94 pound bag of cement, thoroughly mixed, will be placed in the borehole to insure a proper seal.

WELL DEVELOPMENT

All wells will be developed not less than 24 hours following their installation to remove fine ground materials that may have entered the well during construction. Wells shall be developed until water runs relatively clear of fine-grained materials. Note that the water in some wells do not clear with continued development. Typical limits placed on well development may include any one of the following:

- Clarity of water based on visual determination.
- A maximum time period (typically one hour for shallow wells, well depth of 10 to 30 feet).
- A maximum well volume (typically three to five well volumes).
- Stability of specific conductance and temperature measurements (typically less than 10 percent change between three successive measurements).
- Clarity based on turbidity measurements (typically less than 50 NTU).

In addition, a volume equal to any water added during drilling will be removed above and beyond the requirement specified above.

Figure A-3 presents the Field Well Development Log used to document development data. This will be accomplished by either bailing or continuous, low-yield pumping. Equipment used for well installation that may have come in contact with potentially contaminated material will be decontaminated with a high pressure steam wash followed by a potable water rinse. SOPF503, 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.

Supplies and equipment will be transported to the lay-down area designated by U.S. Steel. Any office space, trailers, etc., required for drilling, subsequent sampling and shipping shall be arranged and provided by the contractor.

WELLHEAD COMPLETION

A four-inch diameter security pipe with a hinged locking cap will be installed over the well casing top and will be embedded approximately 2.5 feet into the grout.

There are two acceptable methods of completing the wellheads.

In traffic areas (and non-traffic areas where required), a "flush" mount type cover shall be built into a concrete pad as shown in Figure A-1. If the well is installed through a paved or concrete surface, the annular space between the casing and the borehole shall be grouted to a depth of at least 2.5 feet and finished with

a concrete collar. If the well is not installed through a concrete or paved medium and still finished as a high traffic area, a concrete apron measuring 5-foot by 5-foot by 0.5 foot will be constructed around each well. This apron/collar will be constructed of 3,000 psi ready-mixed concrete. The concrete will be crowned to provide and to meet the finished grade of surrounding pavement as required. The concrete pads can be constructed within five days after all of the wells have been installed.

In non-traffic areas the acceptable method of finishing a wellhead is shown in Figure A-2. Each well will be marked with three, Schedule 40 steel pipes, three-inch I.D., embedded in a minimum of 2.5-foot of 3,000 psi concrete. (The concrete used to secure the three pipes will be poured at the same time and be an integral part of the 5-foot by 5-foot by 0.5-foot concrete apron described above.) The security pipes will extend a minimum of 2.5 feet and maximum of 4.0 feet above the ground surface. The steel marker pipes will be filled with concrete and painted day-glo yellow or an equivalent. Attachment C presents Sample Field Test Boring Records and Field Well Construction Record Forms.

In all finished methods, the well covers will be properly labeled on the exterior of the security pipe locking cap and by labeling vertically on the exterior of the security pipe or manhole cover, as appropriate. The labeling shall consist of the identification specific to each well as described in the Sampling and Analysis Plan.

A sign reading "NOT FOR POTABLE USE OR DISPOSAL" shall be firmly attached to each well.

* The contractor or project team may supplement these requirements, but may not modify or delete them, in total or in part, without prior approval of the USEPA.

If any part of the above specifications is in conflict with the regulations set forth by the State, the State regulations take precedent.

FIGURE A-3

FIELD WELL DEVELOPMENT RECORD

Baker

Baker Environmental, Inc.

PROJECT: _____

CTO NO.: _____ WELL NO.: _____

DATE: _____

GEOLOGIST/ENGINEER: _____

E START	
E FINISH	
AL WATER LEVEL (FT)	
AL WELL DEPTH (TD)	
L DIAMETER (INCHES)	
CULATED WELL VOLUME	
EHOLE DIAMETER (INCHES)	
EHOLE VOLUME	
UNT OF WATER ADDED NG DRILLING	
ELOPMENT METHOD	
P TYPE	
L TIME (A)	
AGE FLOW (GPM)(B)	
L ESTIMATED DRAWAL AxB =	
OVA READING	

DEVELOPMENT DATA

TIME	CUMULATIVE VOLUME (gallons)	pH	TEMP (°C)	SPEC. COND. (µmhos/cm)	TEMP (°C)	COLOR AND TURBIDITY

OBSERVATIONS/NOTES

ATTACHMENT B

FIELD TEST BORING RECORDS AND FIELD WELL CONSTRUCTION RECORD FORMS

Baker Environmental

TEST BORING AND WELL CONSTRUCTION RECORD

PROJECT: Columbia Gas of Pennsylvania - Charleroi Service Center
PROJ. NO.: 17280-070-0000-08020 BORING NO.: CMW-11
COORDINATES: EAST: 991.50 NORTH: 1,200.86
ELEVATION: SURFACE: TOP OF PVC CASING: 107.89

Rig: CMW-45	Split Spoon	Casing	Augers	Core Barrel	Date	Progress (Ft.)	Weather	Depth to Water (Ft.)
Size (ID)	2"		4-1/4"		#######	0 - 26.1	sunny, 50	
Length	2'		5'	5'				
Type	Std.		HS	NX				
Hammer Wt.	140 #							
Fall	30"							

Remarks
Bedrock reamed with 4" roller bit

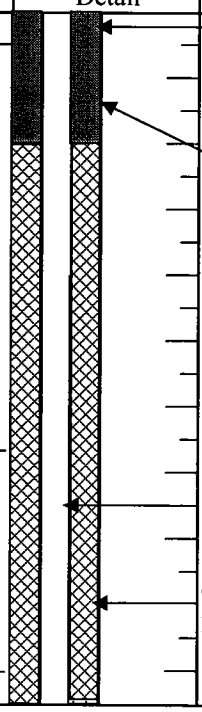
SAMPLE TYPE
S = Split Spoon A = Auger
T = Shelby Tube W = Wash
R = Air Rotary C = Core
D = Denison P = Piston
N = No Sample

WELL INFORMATION

Type	Diam.	Top Depth (Ft.)	Bottom Depth (Ft.)
Schedule 40 PVC Casing	2"	0.0	16.1
Sch. 40 PVC, 10-Slot Well Screen	2"	16.1	26.1

Depth (Ft.)	Sample Type & No.	Sample Rec. (Ft.,%)	SPT RQD	Lab ID	PID (ppm) ps/bg	Visual Description
1, 2, 3, 4, 5 (5')	A-N					
6, 7 (7')	S-1	1.0' 50%	1-5-5-13		0	CLAYEY SILT, gray and brown, stiff, damp (6.8')
8, 9, 10	A-N					SILTY SAND, brown, dry

Well Installation Detail / Elevation (Ft. MSL)



Match to Sheet 2

DRILLING CO.: Rindfuss Drilling Company BAKER REP.: Christopher H. Kupfer, P.G.
DRILLER: Jeff Rindfuss BORING NO.: CMW-11 SHEET 1 OF 2

Baker Environmental

TEST BORING AND WELL CONSTRUCTION RECORD

PROJECT: Columbia Gas of Pennsylvania - Charleroi Service Center
SO NO.: 17280-070-0000-08020 BORING NO.: CMW-11

SAMPLE TYPE
S = Split Spoon A = Auger
T = Shelby Tube W = Wash
R = Air Rotary C = Core
D = Denison P = Piston N = No Sample

DEFINITIONS
SPT = Standard Penetration Test (ASTM D1586)
PID = Photo Ionization Detector Measurement
MSL = Mean Sea Level
ps/bg = point source/background

Depth (Ft.)		Sample Type & No.	Sample Rec. (Ft.,%)	SPT RQD	Lab ID	PID (ppm)	Visual Description	Well Installation Detail	Elevation (Ft. MSL)
11	11.3'	S-2	0.8'	7-20-50/4		0	CLAYEY SILT, some gravel, dry		Cement/ bent. Slurry
12							LIMESTONE, very weathered to decomposed, lt. Gray, laminated friable, no structure, dry		
13		A-N							
14									Bentonite Seal
15	15.0								
	15.3	S-3	0.3	50/4		0			Riser Pipe
16	16.1	A-N							
17							LIMESTONE (competent), gray water bearing fractures every 4" to 17.8'		
18							highly weathered water bearing zone		
19		C-1	3.6' 72%	0.9' 18%		0	from 17.8 to 18.4'		
20							weathered water bearing zone from 20 to 21.1 feet		well screen
21	21.1								
22							non-water bearing fractures at 21.6', 22.6', 24.6', 23', 23.5',		
23		C-2	3.7' 74%	1.6' 32%		0			
24									
25							degraded, clayey, friable dry zone from 25 to 26 feet		
26	26.1								
27							Well CMW-11 set at 26.1 feet		
28									
29									
30									

DRILLING CO.: Rindfuss Drilling Company BAKER REP.: Christopher H. Kupfer, P.G.
DRILLER: Jeff Rindfuss BORING NO.: CMW-11 SHEET 2 OF 3

Baker Environmental

TEST BORING AND WELL CONSTRUCTION RECORD

PROJECT:	GTAC - Puritan Cleaners Site		
PROJ. NO.:	104286 - 3010	WELL NO.:	BMW-1
COORDINATES:	EAST: 1,787,481.46	NORTH:	415,667.67
ELEVATION:	SURFACE: 1,073.98	TOP OF PVC CASING:	1,073.74

Rig: CME-750 Track Rig

	Split Spoon	Casing	Augers	Core Barrel	Date	Progress (Ft.)	Weather	Depth to Water (Ft.)
Size (ID)	2"	4"	6-1/4" ID	1-3/4"	1/30/2006	0 - 28'	Clear, 50 deg. F	
Length	2'	28'	5.0'		1/31/2006	28' - 44.5'	Flurries, 32 deg. F	
Type	Std.	Steel	HS	NX				
Hammer Wt.	140#							
Fall	30"							

Remarks: Auger refusal at 25 ft. bgs

SAMPLE TYPE

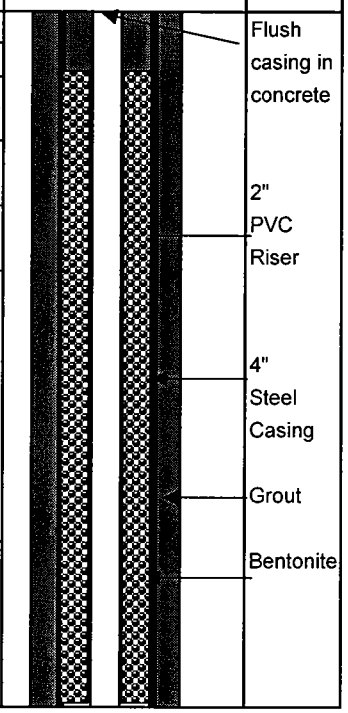
S = Split Spoon A = Auger
T = Shelby Tube W = Wash
R = Air Rotary C = Core
D = Denison P = Piston
MR = Mud Rotary N = No Sample

WELL INFORMATION

Type	Diam. (in.)	Top Depth (Ft.)	Bottom Depth (Ft.)
Schedule 40, PVC Riser	2	0.0	39.5
10-Slot, Schedule 40, PVC Screen	2	39.5	44.5

Depth (Ft.)	Sample Type & No.	Sample Rec. (Ft.)	SPT	Lab ID	PID (ppm)	Visual Description
1	S-1	0.9	6 9 13 5		0	CLAY and GRAVEL, damp, gray-brown
2						CLAY; trace sand and coal frags., no plasticity, stiff, damp, dark brown
3	S-2	0.7	7 6 8 9		0	
4						
5	S-3	1.7	4 8 6 8		0	grades moist and some plasticity
6						
7	S-4	2.0	4 7 5 7		0	
8						
9	S-5	1.9	5 8 8 9		0	
10						grades stiff, no plasticity, mottled brown and orange-brown
			3			Match to Sheet 2

Well Installation Detail



DRILLING CO.:	Frontz Drilling, Inc.	BAKER REP.:	David Schilling
DRILLER:	Aaron Mackey	BORING NO.:	BMW-1 SHEET 1 OF 3

Baker Environmental

TEST BORING AND WELL CONSTRUCTION RECORD

PROJECT: GTAC - Puritan Cleaners Site
CTO NO.: 104286 - 3010 BORING NO.: BMW-1

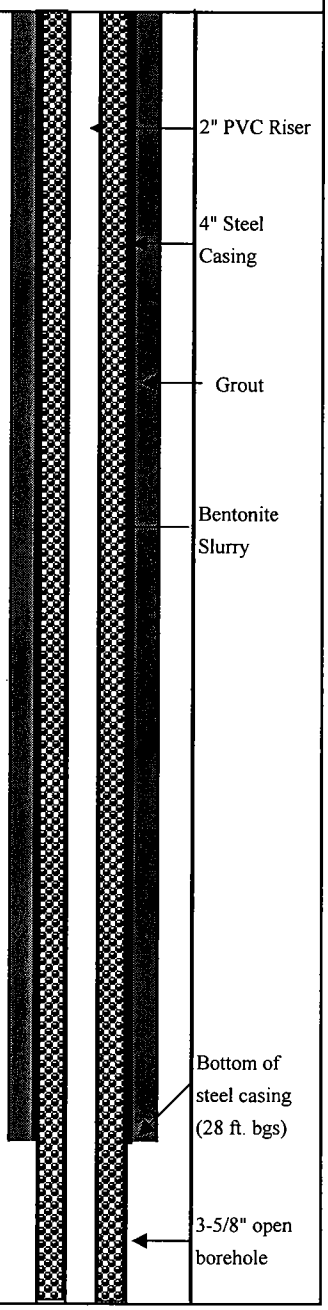
SAMPLE TYPE
S = Split Spoon A = Auger
T = Shelby Tube W = Wash
R = Air Rotary C = Core
MR = Mud Rotary N = No Sample

DEFINITIONS
SPT = Standard Penetration Test (ASTM D1586)
PID = Photo Ionization Detector Measurement
MSL = Mean Sea Level

Depth (Ft.)	Sample Type & No.	Sample Rec. (Ft.,%)	SPT	Lab ID	PID (ppm)	Visual Description
11	S-6	1.5	5, 12, 10		0	Continued from Sheet 1 11.2'; SAND and CLAY, fine grained, moist, loose, red-brown 11.5'
12, 13, 14	S-7	1.6	12, 12, 10, 7		0	SAND, little clay, fine grained, moist, loose, red-brown; grades wet from 14 - 14.9 '
15, 16	S-8	1.1	2, 2, 3, 3		0	SHALE, weathered, little clay, moist, brown
17, 18	S-9	0.8	7, 9, 14, 15		0	grades to some clay and sandstone fragments
19, 20	S-10	0.4	12, 15, 19, 17		0	
21, 22	S-11	0.6	2, 7, 11, 9		0	CLAY, some sandstone, trace shale, moist, some plasticity, brown
23, 24	S-12	2	9, 12, 15, 17		0	
25, 26	S-13	1.2	4, 23, 14, 50/5		0	SAND and CLAY, fine grained, moist, loose, brown; CLAY, some shale, dense, damp, light gray-brown
27, 28	A-N					
29, 30	C-1	9.5' 95%			0	LIMESTONE; weathered, highly fractured, gray, wet (28-28.3') wet from 29.1 to 29.2'

Match to Sheet 3

Well Installation Detail



DRILLING CO.: Frontz Drilling, Inc. BAKER REP.: David Schilling
DRILLER: Aaron Mackey BORING NO.: BMW-1 SHEET 2 OF 3

Baker Environmental

TEST BORING AND WELL CONSTRUCTION RECORD

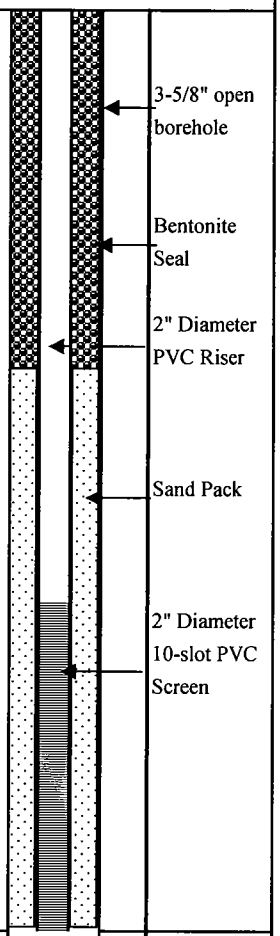
PROJECT: GTAC - Puritan Cleaners Site
CTO NO.: 104286 - 3010 BORING NO.: BMW-1

SAMPLE TYPE
S = Split Spoon A = Auger
T = Shelby Tube W = Wash
R = Air Rotary C = Core
MR = Mud Rotary N = No Sample

DEFINITIONS
SPT = Standard Penetration Test (ASTM D1586)
PID = Photo Ionization Detector Measurement
MSL = Mean Sea Level

Depth (Ft.)	Sample Type & No.	Sample Rec. (Ft.,%)	SPT	Lab ID	PID (ppm)	Visual Description
31						wet zone from 30.8 to 30.9'
32						(same limestone as above) weathered, gray, fractured, grades less fractured with depth
33	C-1	9.5' 95%			0	
34						
35						
36						moist zone from 36 to 36.1'
37						moist zone from 37.4 to 37.5' near horizontal fractures
38						
39						
40						moist zone from 39.8 to 40'
41	C-2	6.0' 100%			0	moist zone from 41.2 to 41.6'
42						moist zone from 41.8 to 42'
43						
44						highly weathered, wet, good water zone from 43.4 t0 44'
	R-N					near horizontal fractures
45						End boring at 44.5 feet bgs
46						
47						
48						
49						
50						

Well Installation Detail



DRILLING CO.: Frontz Drilling, Inc. BAKER REP.: David Schilling
DRILLER: Aaron Mackey BORING NO.: BMW-1 SHEET 3 OF 3

Michael Baker Jr., Inc.

TEST BORING AND WELL CONSTRUCTION RECORD

PROJECT: American Plate Glass (APG) Site
PROJ. NO.: 104416 BORING NO.: MW-2
COORDINATES: EAST: N/A NORTH: N/A
ELEVATION: SURFACE: N/A TOP OF PVC CASING: N/A

Rig: AMS Powerprobe 9635 Deluxe								
	Sampler	Casing	Augers	Core Barrel	Date	Progress (Ft.)	Weather	Depth to Water (Ft.)
Size (ID)	2"		4-1/4"		12/8/2005	0.0 - 17.0	Very cold, sunny, 1 F	
Length	4'		5.0'		12/13/2005	0.0 - 12.0	Cold, sunny, 20 F	8.0
Type	Macrocore	Hollow Stem			12/14/2005	12.0 - 16.5	Very cold, sunny, -5 F	4.1
Hammer Wt.	N/A		N/A					
Fall	N/A		N/A					

Remarks: AMS Powerprobe mounted on a Takeuchi skid loader
Drill test boring for lithology on 12/8/05 and redrill with augers and set well on 12/13/05 and 12/14/05.

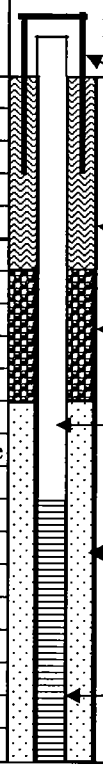
SAMPLE TYPE
S = Split Spoon A = Auger
T = Shelby Tube W = Wash
R = Air Rotary C = Core
D = Direct Push P = Piston
N = No Sample

WELL INFORMATION

Type	Diam.	Top Depth (Ft. bgs)	Bottom Depth (Ft. bgs)
Schedule 40 PVC Riser (Stickup)	2"	+1.9	6.5
Schedule 40 PVC, 10-Slot Screen	2"	6.5	16.5

Depth (Ft.)	Sample Type & No.	Sample Rec. (Ft.)	SPT	Lab ID	PID (ppm)	Visual Description
1, 2, 3, 4	D-1	3.0				SILT; trace to little clay, medium brown, well sorted, damp grades moist and light brown SILTY CLAY; some plasticity, soft, medium brown, moist
5, 6, 7, 8	D-2	4.0				CLAYEY SILTS; some sandstone gravels, friable, stiff, dry
9, 10	D-3	4.0				SANDSTONE; decomposed to highly weathered, much silt,

Well Installation



DRILLING CO.: Allprobe Environmental, Inc. BAKER REP.: C. Kupfer, P.G.
DRILLER: Greg Baker BORING NO.: MW-2 SHEET 1 OF 2

Michael Baker Jr., Inc.

TEST BORING AND WELL CONSTRUCTION RECORD

PROJECT: American Plate Glass (APG) Site

PROJ. NO.: 104416 BORING NO.: MW-2

SAMPLE TYPE

S = Split Spoon A = Auger
T = Shelby Tube W = Wash
R = Air Rotary C = Core
D = Denison P = Piston N = No Sample

DEFINITIONS

SPT = Standard Penetration Test (ASTM D1586)
PID = Photo Ionization Detector Measurement
MSL = Mean Sea Level
ps/bg = point source/background

Depth (Ft.)	Sample Type & No.	Sample Rec. (Ft.)	SPT	Lab ID	PID (ppm)	Visual Description	Well Installation Detail	Elevation (Ft. MSL)
11						dry, some laminations, light brown.		
12								Sand Pack
13						grades wet with more competent sandstone gravels and some laminations from 13 to 14 ft. bgs		10-Slot PVC Well Screen
14	D-4	4.0						
15								
16						SAND; some silt, fine grained, well sorted, black/brown, dry		Well
17	D-5	1.0				SANDSTONE; decomposed to highly weathered, laminated, dry	16.5'	Bottom
18						Direct Push refusal at 17 feet bgs Auger refusal at 16.5 feet bgs		
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								

DRILLING CO.: Allprobe Environmental, Inc. BAKER REP.: C. Kupfer, P.G.

DRILLER: Greg Baker BORING NO.: MW-2 SHEET 2 OF 2

ENGINEERS WELL INSTALLATION LOG

BKRWELLE (LD4)
(02/01 Baker)

BORING NO.	MW-1
SHEET	1 OF 1
DATE: START	1/12/04
END	1/12/04
O.G. ELEV.	922.34

PROJECT NAME URA - Homewood
LOCATION
STATION **OFFSET** **BASELINE**
COORDINATES: NORTH: 416435.12 **EAST:** 1371794.97
INSPECTOR (SIGNED) C. Kupfer, P.G. **DRILLERS NAME/COMPANY** R. Parsons/Geo-Enviromental, Inc.
EQUIPMENT USED Acker Soil Max
DRILLING METHODS 4-1/4" ID HSA
CASING: SIZE: None **DEPTH:** N/A **WATER: DEPTH:** **TIME:** **DATE:**
CHECKED BY: CHK **DATE:** 1/12/04 **DEPTH:** **TIME:** **DATE:**
S.O. NUMBER: **FILE:** URA Homewood **NOT ENCOUNTERED** ☐ **INCLINATION (DEGREES):**

PROFILE	DEPTH (FEET)	WELL DETAIL ELEV	WELL DETAIL DEPTH	WELL NOTES
	0	922.34	0.00	8" diameter flush-mounted protective casing
		922.24	0.10	
		922.14	0.20	
		921.34	1.00	Lockable, expandable cap
		919.34	3.00	
	5			
	10			
	15			
		904.34	18.00	
		902.84	19.50	
	20			
	25			
		892.84	29.50	
	30		31.00	

EXTENDED READINGS

WELL DEVELOPMENT

3 well volumes removed by dedicated, disposable bailer

Well is in SE corner of property - Lot #2

SOP F107
SURFACE WATER AND SEDIMENT SAMPLE ACQUISITION

TABLE OF CONTENTS

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4.0 RESPONSIBILITIES
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5.1.2 Location of Sampling Stations
5.1.3 Frequency of Sampling
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5.2.2 Lakes, Ponds and Reservoirs
5.2.3 Estuaries
5.2.4 Surface Water Sampling Equipment
5.2.5 Surface Water Sampling Techniques
5.3 Sediment Sampling
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SURFACE WATER AND SEDIMENT SAMPLE ACQUISITION

1.0 PURPOSE

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

2.0 SCOPE

The information presented in this SOP is generally applicable to all environmental sampling of surface waters (Section 5.2) and aquatic sediments (Section 5.3), except where the analyte(s) may interact with the sampling equipment.

Specific sampling problems may require the adaptation of existing equipment or design of new equipment. Such innovations shall be documented and presented in the Sampling and Analysis Plan (SAP) and/or Work Plan.

3.0 DEFINITIONS

Grab Sample - An individual sample collected from a single location at a specific time or period of time generally not exceeding 15 minutes.

Composite Sample - A sample collected over time that typically consists of a series of discrete or grab samples which are combined or composited.

4.0 RESPONSIBILITIES

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

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

Sampling Personnel - It is the responsibility of the field sampling personnel to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team Leader and/or the Project Manager. The sampling personnel are responsible for the proper acquisition of surface water and sediment samples, and their subsequent preservation and shipment to a designated laboratory.

5.0 PROCEDURES

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

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

5.1 Defining the Sampling Program

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

5.1.1 Sampling Program Objectives

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

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

A more subtle consideration in designing the sampling program is the potential for dispersion of dissolved or sediment-associated contaminants away from the source. The dispersion could lead to a more homogeneous distribution of contamination at low or possibly non-detectable concentrations. Such dispersion does not,

however, always readily occur throughout the entire body of water; the mixing may be limited to specific flow streams within the water body. For example, obtaining a representative sample of contamination from the center of a channel immediately below an outfall or a tributary is difficult because the inflow frequently follows a stream bank with little lateral mixing for some distance. Sampling alternatives to overcome this situation are: (1) move the site far enough downstream to allow for adequate mixing, or (2) collect integrated samples in a cross section. Also, non-homogeneous distribution is a particular problem with regard to sediment-associated contaminants which may accumulate in low-energy environments while higher-energy areas (main stream channels) near the source may show no contaminant accumulation.

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

The first step in selecting sampling locations is to review site history, define hydrologic boundaries and features of the site, and identify the sources, pathways and potential distribution of contamination based on these considerations. After performing these tasks, the numbers, types, and general locations of samples up gradient, on site, and down gradient can then be identified.

5.1.2 Location of Sampling Stations

Accessibility is the primary factor affecting sampling costs. The desirability and utility of a sample for analysis and description of site conditions must be balanced against the costs of collection as controlled by accessibility. Wading or sampling from a stream bank often is sufficient for springs, seeps, and small streams. Bridges or piers are the first choice for locating a sampling station on a larger stream or small river; they provide ready access and also permit the sampling technician to sample any point across the stream or river. A boat or pontoon (with an associated increase in cost) may be needed to sample locations on lakes and reservoirs (especially if a sample grid is utilized), as well as those on larger rivers. Frequently, however, a boat will take longer to cross a water body and will hinder manipulation of the sampling equipment.

If it is necessary to wade into the water body to obtain a sample, the sampler shall be careful to minimize disturbance of bottom sediments and must enter the water body downstream of the sampling location. If necessary, the sampling technician shall wait for the sediments to settle before taking a sample. Use of boats or wading to collect samples requires the use of U. S. Coast Guard approved personal flotation devices (PFDs).

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

The availability of stream flow and sediment discharge records can be an important consideration in choosing sampling sites in streams. Stream flow data in association with contaminant concentration data are essential for estimating the total contaminant load carried and/or deposited by the stream. If a gauging station is not conveniently located on a selected stream, obtaining stream flow data by direct or indirect methods shall be explored.

5.1.3 Frequency of Sampling

The sampling frequency and the objectives of the sampling event will be defined by the Sampling and Analysis Plan and/or Work Plan. If valid data are available on the distribution of the contaminant between the solid and aqueous phases, it may be appropriate to sample only one phase, although this often is not recommended. If samples are collected primarily for monitoring purposes, consisting of repetitive, continuing measurements to define variations and trends at a given location, water samples shall be collected at established and consistent intervals, as specified in the Sampling and Analysis Plan and/or Work Plan (often monthly or quarterly), and during droughts and floods. Samples of sediment shall be collected from fresh deposits at least yearly, and preferably during both spring and fall seasons.

The variability in available water quality data over an extended period of time (if available) shall be evaluated before deciding on the number and collection frequency of samples required to maintain an effective monitoring program.

5.2 Surface Water Sample Collection

This section presents methods for collection of samples from various surface water bodies, as well as a description of types of surface water sampling equipment. The guidance in this section should be used to develop specific sampling procedures based on site conditions and investigation goals. A summary of sampling techniques and procedures is given in Section 5.2.5.

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

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

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

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

For larger streams greater than three feet in depth, two samples at each station shall be collected from just below the surface, and just above the bottom.

5.2.2 Lakes, Ponds and Reservoirs

Lakes, ponds, and reservoirs have a much greater tendency to stratify according to physical or chemical differences than rivers and streams. The relative lack of mixing requires that more samples be obtained to provide a true representation of the quality of the water body. The number of water sampling locations on a lake, pond, or impoundment will vary with the size and shape of the basin. In ponds and small lakes, a single vertical composite at the deepest point may be sufficient. Similarly, the measurement of DO, pH, temperature, etc., is conducted on each aliquot of the vertical composite. In naturally-formed ponds, the deepest point may have to be determined empirically; in impoundments, the deepest point is usually near the dam.

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

As it is likely that poor mixing may occur in lakes with irregular shape (with bays and coves that are protected from the wind), separate composite samples may be needed to adequately represent water quality. Similarly, additional samples are recommended where discharges, tributaries, land use characteristics, and other such factors are suspected of influencing water quality.

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

5.2.3 Estuaries

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

- Mixed estuary - characterized by the absence of a vertical halocline (gradual or no marked increase in salinity in the water column) and a gradual increase in salinity seaward. Typically this type of estuary is shallow and is found in major freshwater sheetflow areas. Being well mixed, the sampling locations are not critical in this type of estuary.

- Salt wedge estuary - characterized by a sharp vertical increase in salinity and stratified freshwater flow along the surface. In these estuaries the vertical mixing forces cannot override the density differential between fresh and saline waters. In effect, a salt wedge tapering inland moves horizontally, back and forth, with the tidal phase. If contamination is

being introduced into the estuary from upstream, water sampling from the salt wedge may miss it entirely.

- Oceanic estuary - characterized by salinities approaching full strength oceanic waters. Seasonally, freshwater inflow is small with the preponderance of the fresh-saline water mixing occurring near, or at, the shore line.

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

5.2.4 Surface Water Sampling Equipment

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

- Dip sampler
- Weighted bottle
- Kemmerer
- Depth-Integrating Sampler

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

The criteria for selecting a sampler include:

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

Each sample (grab or each aliquot collected for compositing) shall be measured for: specific conductance; temperature; pH; and dissolved oxygen (optional) as soon as it is recovered. These analyses will provide information on water mixing/stratification and potential contamination.

5.2.4.1 Dip Sampling

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

5.2.4.2 Weighted Bottle Sampling

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

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

- Gently lower the sampler to the desired depth so as not to remove the stopper prematurely (watch for bubbles).
- Pull out the stopper with a sharp jerk of the sampler line.
- Allow the bottle to fill completely, as evidenced by the absence of air bubbles.
- Raise the sampler and cap the bottle.
- Decontaminate the outside of the bottle. The bottle can be used as the sample container (as long as original bottle is an approved container).

5.2.4.3 Kemmerer

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

5.2.5 Surface Water Sampling Techniques

Most samples taken during site investigations are grab samples. Typically, surface water sampling involves immersing the sample container directly in the body of water. The following suggestions are applicable to sampling springs, seeps, ditches, culverts, small streams and other relatively small bodies of water, and are presented to help ensure that the samples obtained are representative of site conditions:

- The most representative samples will likely be collected from near mid-stream, the center of flow in a culvert, etc.
- Downstream samples shall be collected first, with subsequent samples collected while moving upstream. Care shall be taken to minimize sediment disturbance while collecting surface water samples. If necessary, sediment samples shall be collected after the corresponding surface water sample.

- Samples may be collected either by immersing the approved sample container or decontaminated glassware into the water.

- Care shall be taken to avoid excessive agitation of the water which may result in the loss of volatile constituents. Additionally, samples for volatile organic analyses shall be collected first, followed by the samples for other constituents.

- Measurements for temperature, pH, specific conductance, or other field parameters, as appropriate, shall be collected immediately following sample collection for laboratory analyses.

- All samples shall be handled as described in SOP F301.

- The sampling location shall be marked via wooden stake or pin flag placed at the nearest bank or shore. The sampling location number shall be marked with indelible ink on the stake or pin flag.

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

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

General guidelines for collection of samples from larger streams, ponds or other water bodies are as follows:

- The most <u>representative</u> samples are obtained from mid-channel at mid-stream depth in a well-mixed stream.

- For sampling running water, the farthest downstream sample should be obtained first and subsequent samples be collected progressing upstream. In addition, samples should also be collected progressing from zones suspected of low contamination to zones of high contamination.

- To sample a pond or other standing body of water, the surface area may be divided into grids. A series of samples taken from each grid is combined into one composite sample, or several grids are selected at random.

- Care should be taken to avoid excessive agitation of the water that would result in the loss of volatile constituents.

- When obtaining samples in 40 ml septum vials for volatile organics analysis, it is important to exclude any air space in the top of the bottle and to be sure that the Teflon liner faces inward. The bottle can be turned upside down to check for air bubbles after the bottle is filled and capped. Do not overfill pre-preserved vials, which can wash out the preservative. Furthermore, if air bubbles do form, do not empty out the entire vial prior to refilling. This too may wash out any preservative previously placed into the bottle.

- Do not sample at the surface unless sampling specifically for a known constituent which is immiscible and on top of the water. Instead, the sample container should be inverted, lowered to the approximate depth, and held at about a 45-degree angle with the mouth of the bottle facing upstream.

- Measurements for temperature, pH, specific conductance, and/or other field parameters, as appropriate, shall be collected immediately following sample collection for laboratory analysis.

- All samples shall be handled as described in SOP F301.

- Items to be recorded in the field logbook are the same as those described above for small streams.

5.3 Sediment Sampling

Sediment samples usually are collected at the same locations as surface water samples. If only one sediment sample is to be collected, the sample location shall be approximately at the center of the water body. If, however, multiple samples are required, sediment samples should be collected along a cross section to characterize the bed material. A common procedure for obtaining multiple samples is to sample at quarter points along the cross section of flow. As with surface water samples, sediment samples should be collected from downstream to upstream.

5.3.1 Sampling Equipment and Techniques

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

When boats are used for sampling, U. S. Coast Guard approved personal flotation devices must be provided and two individuals must undertake the sampling. An additional person shall remain on-shore in visual contact at all times.

The following samplers may be used to collect sediment samples:

- Scoop sampler
- Dredge samplers
- Bucket/hand auger

- Stainless steel spoon or trowel

5.3.1.1 Scoop Sampler

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

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

5.3.1.2 Dredges

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

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

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

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

5.3.1.3 Bucket (Hand) Auger

Bucket (hand) augering is a viable method for collecting sediment samples in narrow, intermittent streams or tidal flats. Typically, a 4-inch auger bucket with a cutting head is pushed and twisted into the ground and removed as the bucket is filled. The auger hole is advanced one bucket at a time, to a depth specified in the project plans.

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

5.3.1.4 Stainless Steel Spoon or Trowel

For loosely packed sediments, a stainless steel scoop or trowel can be used to collect a representative sediment sample, in narrow intermittent streams or tidal flats.

Use the scoop or trowel to collect the sample from the desired depth. Remove heavy debris, rocks, and twigs before collecting the sample. Immediately transfer the sample to the appropriate sample container. Attach a label completed in indelible ink. Record all required information in the field logbook, chain-of-custody record, and other required forms.

5.3.2 Sediment Sampling Procedure

The following general procedure should be used, where applicable, for sampling sediment from springs, seeps, small streams, ditches, or other similar small bodies of water. Procedures for sampling larger bodies of water (i.e., rivers, lakes, estuaries, etc.) should be developed on a project-specific basis, as needed.

- Sediment samples shall be collected only after the corresponding surface water sample has been collected, if one is to be collected.
- Sediment samples shall be collected from downstream locations to upstream locations.
- Samples shall be collected by excavating a sufficient amount of bottom material using a scoop, sample container, spoon, trowel, or auger. Samples should be collected with the sampling device facing upstream and the sample collected from downstream to upstream. Care should be taken to minimize the loss of fine-grained materials from the sample.
- The sample shall be transferred to the appropriate sample containers. Sampling personnel shall use judgment in removing large plant fragments to limit bias caused by bio-organic accumulation.
- All samples shall be preserved and handled as described in SOP F301.
- The sampling location shall be marked via a wooden stake or pin flag placed at the nearest bank or shore. The sample location number shall be marked on the stake or pin flag with indelible ink.
- The following information shall be recorded in the field logbook:

- Project location, date and time.
- Weather.
- Sample identification number.
- Flow conditions.
- Sketch of sampling location including boundaries of water body, sample location, water depth, sample collection depth, relative position with respect to the site, location of wooden identifier stake.
- Chemical analyses to be performed.
- Description of sediment

6.0 QUALITY ASSURANCE RECORDS

The description of the sampling event in the field logbook shall serve as a quality assurance record. Other records include chain-of-custody and sample analysis request forms as discussed in SOP F302.

7.0 REFERENCES

1. Feltz, H. R., 1980. Significance of Bottom Material Data in Evaluating Water Quality in Contaminants and Sediments. Ann Arbor, Michigan, Ann Arbor Science Publishers, Inc., V. 1, p. 271-287.

2. Kittrell, F. W., 1969. A Practical Guide to Water Quality Studies of Streams. U.S. Federal Water Pollution Control Administration, Washington, D.C., 135p.

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

4. U.S. Geological Survey, 1977. National Handbook of Recommended Methods for Water-Data Acquisition. Office of Water Data Coordination, USGS, Reston, Virginia.

SOP 501
DECONTAMINATION OF HEAVY EQUIPMENT AND ASSOCIATED SAMPLING EQUIPMENT

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DECONTAMINATION OF HEAVY EQUIPMENT AND ASSOCIATED SAMPLING EQUIPMENT

1.0 PURPOSE

The purpose of this SOP is to provide a general reference regarding the proper decontamination of drilling rigs, direct push (e.g., Geoprobe) rigs, backhoes, trackhoes, and associated sampling equipment used in the performance of field investigations.

2.0 SCOPE

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

3.0 DEFINITIONS

Decontamination - Decontamination is the process of removing or neutralizing contaminants and/or media (e.g., soil) which may have accumulated on field equipment. This process 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. It should be documented when project plans deviate from these procedures. If a potable water source and/or electricity are not available on site, the project manager should inform the drilling/excavating subcontractor and confirm that the subcontractor has allotted for these line items in their associated cost proposal. Furthermore, it should be verified with the subcontractor that an appropriate number of drums (or other suitable containers) will be brought on site for containerizing the accumulated decontamination wastes.

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. In addition, prior to field mobilization, the field team leader should confirm that both a potable water source and electrical source are available on site for use by the drilling/excavating subcontractor. If not available, inform the subcontractor that they will need to make arrangements to procure water and electrical power for the decontamination activities.

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

5.0 PROCEDURE

The various drilling and sampling equipment involved with test boring, test pit excavation, and subsurface soil sampling must be properly decontaminated to ensure that the findings from the investigation activities are truly representative of indigenous site conditions. These decontamination procedures will minimize the potential for cross contamination between investigation locations and the potential transfer of contamination off site.

5.1 Equipment

All heavy equipment involved in field sampling activities that comes in contact with potentially sampled material (soil, sediment, etc.) shall be decontaminated prior to drilling, excavation, or sampling activities. Such equipment includes drilling rigs, backhoes, trackhoes, augers, and downhole tools. Split-spoon soil samplers and other similar soil sampling devices shall be decontaminated according to the procedures given in SOP F502, Decontamination of Sampling and Monitoring Equipment.

5.2 Decontamination Procedures

Prior to and after drilling at each location, large equipment not directly utilized for sampling (e.g., augers, backhoe buckets, drill rods, etc.) 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. 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 or debris.

The steam cleaning area will consist of a decontamination pad capable of containing decontamination solids and waste water. The pad typically consists of either a lined excavated pit, a bermed concrete/asphalt pad, or an site-constructed pad (using a wood frame lined with plastic sheeting). If possible, the designated decontamination area should be located in an area preferably upwind from the proposed sampling areas. For each decontamination pad, a low point will be designed/constructed within the pad to allow for liquids to gravity drain to the low point for subsequent pumping into appropriate holding containers for future disposal, as applicable.

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

- Locate the steam cleaning area in a centralized area on site to minimize potential impacts.
- Enclose steam cleaning operations. For example, augers and drilling rods can be steam cleaned in drums. Plastic sheeting also can be placed around the steam cleaning area to control the spraying and splattering of wastes outside of the decontamination pad.

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

6.0 QUALITY ASSURANCE RECORDS

Rinsate samples may be collected from steam-cleaned equipment to document the effectiveness of the decontamination procedures. The frequency of the collection of rinsate samples from decontaminated equipment shall be specified in the Work Plan and/or Quality Assurance Project Plans for a given project, as appropriate.

Documentation in the field logbook also shall serve as a record of decontamination activities. In addition to documenting the method of decontamination, the location of the decontamination pad/area should also be described in the field notebook. Furthermore, because the basis of payment for decontamination by a subcontractor is typically based on a hourly rate, the duration of each decontamination activity also should be documented in the field notebook.

7.0 REFERENCES

SOP F503 – Handing of Investigation Derived Wastes (IDW)

SOP 502
DECONTAMINATION OF SAMPLING AND MONITORING EQUIPMENT

FIELD EQUIPMENT OPERATION AND MAINTENANCE PROCEDURES - 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 non-disposable sampling equipment including, but not limited to, split-barrel soil samplers (split-spoons), direct push samplers (e.g., Geoprobe), 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 and/or media (e.g., soil) which may have accumulated on non-disposable field equipment. This process 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. The Field Team Leader should notify the Project Manager immediately if there appears to be any discrepancies between procedures proposed in this SOP versus project-specific procedures proposed in the associated scope of work (e.g., work plan, sampling and analysis plan, etc.). In addition, if high concentration acids and/or solvents are being shipped or transported to the site, appropriate packing and shipping protocols must be in place (e.g., FedEx Dangerous Goods Airbill).

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 prior to demobilizing from the site. This will minimize the potential for cross-contamination between sampling locations and the transfer of contamination off site.

Generally, all equipment used for investigative activities will arrive on site in clean condition. With the exception of certified laboratory-cleaned equipment, all sampling, testing, or measuring equipment that comes in contact with potentially sampled medium (soil, concrete, groundwater) will be decontaminated prior to use, unless it arrives prepackaged from the manufacturer.

Preferably, sampling equipment should be dedicated or disposable for each sampling location. If this is not possible or cost effective, non-disposable sampling equipment must be decontaminated between sample locations. Sampling personnel also should use disposable gloves and change them between sample locations.

5.1 Sampling Equipment Decontamination Procedures

Soil, sediment, groundwater, and concrete non-disposable sampling equipment including, but not limited to, trowels, beakers, dredges, bailers, spoons, chisels, etc., that will come in contact with the sampling medium (with the exception of downhole pumps and transducers used in well sampling and aquifer testing) shall be decontaminated using the following USEPA Region procedures. For electronic equipment, solvents and/or nitric acid will not be used as a process step below unless specified by the manufacturer.

Decontamination wastes will be collected, containerized, and properly disposed unless otherwise directed in the associated work plan or sampling and analysis plan. Decontamination solvents will be collected in a separate container from any water/detergent solutions and allowed to evaporate, if weather conditions permit. If the solvents do not evaporate, they will be containerized for disposal according to SOP F504 (Handling of Site Investigative Derived Wastes). If nitric acid is used, it will be collected in a separate container from the solvents and also disposed of according to SOP F504. The ultimate fate of the waste fluids (and solids, as applicable) will be at the discretion of the Field Team Leader.

At a minimum, non-disposable sampling equipment that contacts the sample media should be washed with a detergent solution and rinsed with potable water. For programs requiring more rigorous decontamination to meet the sampling and QA/QC objectives, the decontamination procedures are likely to be as follows:

1. Clean with potable water and non-phosphate detergent (e.g., Liquinox) using a brush if necessary to remove particulate matter (e.g., soil clumps), surface films, and/or free-phase product. For badly contaminated equipment, a hot water detergent wash may be needed prior to the rinse procedure.

2. Rinse thoroughly with potable water.

3. Rinse with 10% nitric acid (reagent grade) rinse when sampling for metals. This rinse is only effective on non-metallic surfaces.

4. Rinse thoroughly with potable water.

5. Rinse with methanol or hexane (pesticide grade) when sampling for organics.

6. Rinse thoroughly with distilled or deionized water and allow to air dry, if time permits.

7. Wrap with aluminum foil, if appropriate, to prevent contamination if equipment is going to be stored for an extended period of time.

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 (e.g., groundwater in well casing prior to purging, beaker of water for field meter analysis, flow through cell, etc.). Probes which make no direct contact (e.g., PID or OVA probes) will be wiped clean with clean paper towels or an alcohol-saturated cloth, as necessary.

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 Work Plan, Sampling and Analysis, and/or Quality Assurance Project Plans. Documentation recorded in the field logbook also shall serve as a quality assurance record. Furthermore, the specific manufacturer and lot number of the decontamination fluid (e.g., distilled water, methanol, etc.) also should be recorded in the field logbook if known.

7.0 REFERENCES

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.

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APPENDIX B
USEPA REGION II GROUND WATER SAMPLING PROCEDURE
LOW STRESS (Low Flow) PURGING AND SAMPLING

U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION II

GROUND WATER SAMPLING PROCEDURE
LOW STRESS (Low Flow) PURGING AND SAMPLING

I. SCOPE & APPLICATION

This Low Stress (or Low-Flow) Purging and Sampling Procedure is the EPA Region II standard method for collecting low stress (low flow) ground water samples from monitoring wells. Low stress Purging and Sampling results in collection of ground water samples from monitoring wells that are representative of ground water conditions in the geological formation. This is accomplished by minimizing stress on the geological formation and minimizing disturbance of sediment that has collected in the well. The procedure applies to monitoring wells that have an inner casing with a diameter of 2.0 inches or greater, and maximum screened intervals of ten feet unless multiple intervals are sampled. The procedure is appropriate for collection of ground water samples that will be analyzed for volatile and semi-volatile organic compounds (VOCs and SVOCs), pesticides, polychlorinated biphenyls (PCBs), metals, and microbiological and other contaminants in association with all EPA programs.

This procedure does not address the collection of light or dense non-aqueous phase liquids (LNAPL or DNAPL) samples, and should be used for aqueous samples only. For sampling NAPLs, the reader is referred to the following EPA publications: DNAPL Site Evaluation (Cohen & Mercer, 1993) and the RCRA Ground-Water Monitoring: Draft Technical Guidance (EPA/530-R-93-001), and references therein.

II. METHOD SUMMARY

The purpose of the low stress purging and sampling procedure is to collect ground water samples from monitoring wells that are representative of ground water conditions in the geological formation. This is accomplished by setting the intake velocity of the sampling pump to a flow rate that limits drawdown inside the well casing.

Sampling at the prescribed (low) flow rate has three primary benefits. First, it minimizes disturbance of sediment in the bottom of the well, thereby producing a sample with low turbidity (i.e., low concentration of suspended particles). Typically, this saves time and analytical costs by eliminating the need for collecting and analyzing an additional filtered sample from the same well. Second, this procedure minimizes aeration of the ground water during sample collection, which improves the sample quality for VOC analysis. Third, in most cases the procedure significantly reduces the volume of ground water purged from a well and the costs associated with its proper treatment and disposal.

III. ADDRESSING POTENTIAL PROBLEMS

Problems that may be encountered using this technique include a) difficulty in sampling wells with insufficient yield; b) failure of one or more key indicator parameters to stabilize; c) cascading of water and/or formation of air bubbles in the tubing; and d) cross-contamination between wells.

Insufficient Yield

Wells with insufficient yield (i.e., low recharge rate of the well) may dewater during purging. Care should be taken to avoid loss of pressure in the tubing line due to dewatering of the well below the level of the pump=s intake. Purging should be interrupted before the water level in the well drops below the top of the pump, as this may induce cascading of the sand pack. Pumping the well dry should therefore be avoided to the extent possible in all cases. Sampling should commence as soon as the volume in the well has recovered sufficiently to allow collection of samples. Alternatively, ground water samples may be obtained with techniques designed for the unsaturated zone, such as lysimeters.

Failure to Stabilize Key Indicator Parameters

If one or more key indicator parameters fails to stabilize after 4 hours, one of four options should be considered: a) continue purging in an attempt to achieve stabilization; b) discontinue

purging, do not collect samples, and document attempts to reach stabilization in the log book; c) discontinue purging, collect samples, and document attempts to reach stabilization in the log book; or d) Secure the well, purge and collect samples the next day (preferred). The key indicator parameter for samples to be analyzed for VOCs is dissolved oxygen. The key indicator parameter for all other samples is turbidity.

Cascading

To prevent cascading and/or air bubble formation in the tubing, care should be taken to ensure that the flow rate is sufficient to maintain pump suction. Minimize the length and diameter of tubing (i.e., 1/4 or 3/8 inch ID) to ensure that the tubing remains filled with ground water during sampling.

Cross-Contamination

To prevent cross-contamination between wells, it is strongly recommended that dedicated, in-place pumps be used. As an alternative, the potential for cross-contamination can be reduced by performing the more thorough Adaily@ decontamination procedures between sampling of each well in addition to the start of each sampling day (see Section VII, below).

Equipment Failure

Adequate equipment should be on-hand so that equipment failures do not adversely impact sampling activities.

IV. PLANNING DOCUMENTATION AND EQUIPMENT

< Approved site-specific Field Sampling Plan/Quality Assurance Project Plan (QAPP). This plan must specify the type of pump and other equipment to be used. The QAPP must also specify the depth to which the pump intake should be lowered in each well. Generally, the target depth will correspond to the mid-point of the most permeable zone in the screened interval. Borehole geologic and geophysical logs can be used to help select the most permeable zone. However, in some cases, other criteria may be used to select the target depth for the pump

intake. In all cases, the target depth must be approved by the EPA hydrogeologist or EPA project scientist.

< Well construction data, location map, field data from last sampling event.

< Polyethylene sheeting.

< Flame Ionization Detector (FID) and Photo Ionization Detector (PID).

< Adjustable rate, positive displacement ground water sampling pump (e.g., centrifugal or bladder pumps constructed of stainless steel or Teflon). A peristaltic pump may only be used for inorganic sample collection.

< Interface probe or equivalent device for determining the presence or absence of NAPL.

< Teflon or Teflon-lined polyethylene tubing to collect samples for organic analysis. Teflon or Teflon-lined polyethylene, PVC, Tygon or polyethylene tubing to collect samples for inorganic analysis. Sufficient tubing of the appropriate material must be available so that each well has dedicated tubing.

< Water level measuring device, minimum 0.01 foot accuracy, (electronic preferred for tracking water level drawdown during all pumping operations).

< Flow measurement supplies (e.g., graduated cylinder and stop watch or in-line flow meter).

< Power source (generator, nitrogen tank, etc.).

< Monitoring instruments for indicator parameters. Eh and dissolved oxygen must be monitored in-line using an instrument with a continuous readout display. Specific conductance, pH, and temperature may be monitored either in-line or using separate probes. A nephalometer is used to measure turbidity.

< Decontamination supplies (see Section VII, below).

< Logbook (see Section VIII, below).

< Sample bottles.

< Sample preservation supplies (as required by the analytical methods).

< Sample tags or labels, chain of custody.

V. SAMPLING PROCEDURES

Pre-Sampling Activities

1. Start at the well known or believed to have the least contaminated ground water and proceed systematically to the well with the most contaminated ground water. Check the well, the lock, and the locking cap for damage or evidence of tampering. Record observations.

2. Lay out sheet of polyethylene for placement of monitoring and sampling equipment.

3. Measure VOCs at the rim of the unopened well with a PID and FID instrument and record the reading in the field log book.

4. Remove well cap.

5. Measure VOCs at the rim of the opened well with a PID and an FID instrument and record the reading in the field log book.
6. If the well casing does not have a reference point (usually a V-cut or indelible mark in the well casing), make one. Note that the reference point should be surveyed for correction of ground water elevations to the mean geodesic datum (MSL).

7. Measure and record the depth to water (to 0.01 ft) in all wells to be sampled prior to purging. Care should be taken to minimize disturbance in the water column and dislodging of any particulate matter attached to the sides or settled at the bottom of the well.

8. If desired, measure and record the depth of any NAPLs using an interface probe. Care should be taken to minimize disturbance of any sediment that has accumulated at the bottom of the well. Record the observations in the log book. If LNAPLs and/or DNAPLs are detected, install the pump at this time, as described in step 9, below. Allow the well to sit for several days between the measurement or sampling of any DNAPLs and the low-stress purging and sampling of the ground water.

Sampling Procedures

9. Install Pump: Slowly lower the pump, safety cable, tubing and electrical lines into the well to the depth specified for that well in the EPA-approved QAPP or a depth otherwise approved by the EPA hydrogeologist or EPA project scientist. The pump intake must be kept at least two (2) feet above the bottom of the well to prevent disturbance and resuspension of any sediment or NAPL present in the bottom of the well. Record the depth to which the pump is lowered.

10. Measure Water Level: Before starting the pump, measure the water level again with the pump in the well. Leave the water level measuring device in the well.

11. Purge Well: Start pumping the well at 200 to 500 milliliters per minute (ml/min). The water level should be monitored approximately every five minutes. Ideally, a steady flow rate should be maintained that results in a stabilized water level (drawdown of 0.3 ft or less). Pumping rates should, if needed, be reduced to the minimum capabilities of the pump to ensure stabilization of the water level. As noted above, care should be taken to maintain pump suction and to avoid entrainment of air in the tubing. Record each adjustment made to the pumping rate and the water level measured immediately after each adjustment.

12. Monitor Indicator Parameters: During purging of the well, monitor and record the field indicator parameters (turbidity, temperature, specific conductance, pH, Eh, and DO)

approximately every five minutes. The well is considered stabilized and ready for sample collection when the indicator parameters have stabilized for three consecutive readings as follows (Puls and Barcelona, 1996):

±0.1 for pH
±3% for specific conductance (conductivity)
±10 mv for redox potential
±10% for DO and turbidity

Dissolved oxygen and turbidity usually require the longest time to achieve stabilization. The pump must not be removed from the well between purging and sampling.

13. Collect Samples: Collect samples at a flow rate between 100 and 250 ml/min and such that drawdown of the water level within the well does not exceed the maximum allowable drawdown of 0.3 ft. VOC samples must be collected first and directly into sample containers. All sample containers should be filled with minimal turbulence by allowing the ground water to flow from the tubing gently down the inside of the container.

    Ground water samples to be analyzed for volatile organic compounds (VOCs) require pH adjustment. The appropriate EPA Program Guidance should be consulted to determine whether pH adjustment is necessary. If pH adjustment is necessary for VOC sample preservation, the amount of acid to be added to each sample vial prior to sampling should be determined, drop by drop, on a separate and equal volume of water (e.g., 40 ml). Ground water purged from the well prior to sampling can be used for this purpose.

14. Remove Pump and Tubing: After collection of the samples, the tubing, unless permanently installed, must be properly discarded or dedicated to the well for resampling by hanging the tubing inside the well.

15. Measure and record well depth.

16. Close and lock the well.

VI. FIELD QUALITY CONTROL SAMPLES

Quality control samples must be collected to determine if sample collection and handling procedures have adversely affected the quality of the ground water samples. The appropriate EPA Program Guidance should be consulted in preparing the field QC sample requirements of the site-specific QAPP.

All field quality control samples must be prepared exactly as regular investigation samples with regard to sample volume, containers, and preservation. The following quality control samples should be collected during the sampling event:

< Field duplicates
< Trip blanks for VOCs only
< Equipment blank (not necessary if equipment is dedicated to the well)

As noted above, ground water samples should be collected systematically from wells with the lowest level of contamination through to wells with highest level of contamination. The equipment blank should be collected after sampling from the most contaminated well.

VII. DECONTAMINATION

Non-disposable sampling equipment, including the pump and support cable and electrical wires which contact the sample, must be decontaminated thoroughly each day before use (Adaily decon@) and after each well is sampled (Abetween-well decon@). Dedicated, in-place pumps and tubing must be thoroughly decontaminated using Adaily decon@ procedures (see #17, below) prior to their initial use. For centrifugal pumps, it is strongly recommended that non-disposable sampling equipment, including the pump and support cable and electrical wires in contact with the sample, be decontaminated thoroughly each day before use (Adaily decon@).

EPA=s field experience indicates that the life of centrifugal pumps may be extended by removing entrained grit. This also permits inspection and replacement of the cooling water in centrifugal pumps. All non-dedicated sampling equipment (pumps, tubing, etc.)

must be decontaminated after each well is sampled (Abetween-well decon,@ see #18 below).

17. **Daily Decon**

A) Pre-rinse: Operate pump in a deep basin containing 8 to 10 gallons of potable water for 5 minutes and flush other equipment with potable water for 5 minutes.

B) Wash: Operate pump in a deep basin containing 8 to 10 gallons of a non-phosphate detergent solution, such as Alconox, for 5 minutes and flush other equipment with fresh detergent solution for 5 minutes. Use the detergent sparingly.

C) Rinse: Operate pump in a deep basin of potable water for 5 minutes and flush other equipment with potable water for 5 minutes.

D) Disassemble pump.

E) Wash pump parts: Place the disassembled parts of the pump into a deep basin containing 8 to 10 gallons of non-phosphate detergent solution. Scrub all pump parts with a test tube brush.

F) Rinse pump parts with potable water.

G) Rinse the following pump parts with distilled/ deionized water: inlet screen, the shaft, the suction interconnector, the motor lead assembly, and the stator housing.

H) Place impeller assembly in a large glass beaker and rinse with 1% nitric acid (HNO_3).

I) Rinse impeller assembly with potable water.

J) Place impeller assembly in a large glass bleaker and rinse with isopropanol.

K) Rinse impeller assembly with distilled/deionized water.

18. **Between-Well Decon**

A) Pre-rinse: Operate pump in a deep basin containing 8 to 10 gallons of potable water for 5 minutes and flush other equipment with potable water for 5 minutes.
B) Wash: Operate pump in a deep basin containing 8 to 10 gallons of a non-phosphate detergent solution, such as Alconox, for 5 minutes and flush other equipment with fresh detergent solution for 5 minutes. Use the detergent sparingly.

C) Rinse: Operate pump in a deep basin of potable water for 5 minutes and flush other equipment with potable water for 5 minutes.

D) Final Rinse: Operate pump in a deep basin of distilled/deionized water to pump out 1 to 2 gallons of this final rinse water.

VIII. FIELD LOG BOOK

A field log book must be kept each time ground water monitoring activities are conducted in the field. The field log book should document the following:

< Well identification number and physical condition.
< Well depth, and measurement technique.
< Static water level depth, date, time, and measurement technique.
< Presence and thickness of immiscible liquid layers and detection method.
< Collection method for immiscible liquid layers.
< Pumping rate, drawdown, indicator parameters values, and clock time, at three to five minute intervals; calculate or measure total volume pumped.
< Well sampling sequence and time of sample collection.
< Types of sample bottles used and sample identification numbers.
< Preservatives used.
< Parameters requested for analysis.

- Field observations of sampling event.
- Name of sample collector(s).
- Weather conditions.
- QA/QC data for field instruments.

IX. REFERENCES

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