Work Plan

for

Basewide Background Study

Naval Station Newport
Newport, Rhode Island

Engineering Field Activity Northeast
Naval Facilities Engineering Command

Contract Number N62472-03-D-0057
Contract Task Order 43

May 2006

TETRA TECH NUS, INC.

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WORK PLAN
FOR
BASEWIDE BACKGROUND STUDY

NAVAL STATION NEWPORT
NEWPORT, RHODE ISLAND

COMPREHENSIVE LONG-TERM
ENVIRONMENTAL ACTION - NAVY (CLEAN) CONTRACT

Submitted to:
Environmental Branch, (Code EV2)
Engineering Field Activity, Northeast
Naval Facilities Engineering Command
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ACRONYMS

ASTM	American Society for Testing Materials
Ba	Beach soils
Bc	Birchwood sandy loam soil type
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLEAN	Comprehensive Long Term Environmental Action Navy
CTO	Contract Task Order
DIUF	De-Ionized Ultra-Filtrated
DPT	Direct Push Technology
DQO	Data Quality Objective
EGIS	Environmental Geographic Information System
EPA	U. S. Environmental Protection Agency
FOL	Field Operations Leader
FSP	Field Sampling Plan
ft	Feet
GPS	Global Positioning System
IR	Installation Restoration
Ma	Mansfield mucky silt loam soil type
MA	Master Agreement
MmA	Merrimack sandy loam soil type
NAVSTA	Naval Station
NeA	Newport silt loam soil type
NeB	Newport silt loam soil type
NeC	Newport silt loam soil type
NFESC	Naval Facilities Engineering Service Center
NP	Newport silt loam soil type
OFFTA	Old Fire Fighting Training Area
PARCC	Precision and accuracy, representativeness, completenesss, and comparability
PM	Project Manager
PmA	Pittstown silt loam soil type
PmB	Pittstown silt loam soil type
PsB	Poquonock loamy fine sand soil type
QA	Quality Assurance
QA/QC	Quality Assurance/Quality Control
QC	Quality Control
RI	Remedial Investigation
RIDEM	Rhode Island Department of Environmental Management
RFM	Request for Field Modification
RPM	Remedial Project Manager
RQD	Rock Quality Designation
Se	Stissing silt loam soil type
SER	Shore Establishment Realignment
SOP	Standard Operating Procedure
TAL	Target Analyte List

ACRONYMS (cont.)

TtNUS	Tetra Tech NUS, Inc.
UD	Udorthents soil type
Ur	Urban Land
USEPA	United States Environmental Protection Agency
UST	Underground Storage Tank
VOC	Volatile Organic Compound
WgB	Windsor loam sand soil type

1.0 INTRODUCTION

This work plan has been prepared by Tetra Tech NUS, Inc. (TtNUS) for the U.S. Department of the Navy (Navy), to direct the Basewide Background Study at the Naval Station (NAVSTA) Newport in Newport, Rhode Island. This work plan was prepared for the Navy's Engineering Field Activity Northeast (EFANE), Naval Facilities Engineering Command (NAVFAC) under the Comprehensive Long-Term Environmental Action Navy (CLEAN) Contract No. N62472-03-D-0057, Contract Task Order 43.

This Basewide Background Study is being conducted to determine background metals concentrations for soils at the NAVSTA Newport Base (the Base). In previous environmental investigations, it has been observed that the arsenic concentrations in soils at NAVSTA have been consistently higher than the anticipated levels, and higher than the Rhode Island Department of Environmental Management (RIDEM) direct exposure criteria of 7.0 milligrams per kilogram (mg/kg), and ceiling level of 15 mg/kg. Given the Navy's expectation that site soils cleanup should not be based solely on elevated levels of metals that are equal to or lower than natural background levels, it was determined that this investigation was needed to determine basewide background metals concentrations in soils. The study will be conducted according to the Naval Facilities Engineering Command Guidance, *Environmental Background Analysis, Volume 1*: *Soil*, April 2002, to meet the objectives described in Section 1.1 below.

The background study will culminate in a report that will identify metals concentrations in different types of soils in the area, and will discuss the geochemical origins of these metals. The final report is anticipated to present an evaluation of metals concentrations that are related to natural parent materials (local bedrock, etc.), versus those that are more likely the result of anthropogenic activities.

This work plan describes the procedures for performing the Basewide Background Study. The purpose of this plan is to describe the background location selection process, field tasks to be performed, analytical parameters, sampling techniques, methods for data interpretation, and reporting aspects of the investigation.

1.1 SPECIFIC INVESTIGATION OBJECTIVES

Previous investigations for NAVSTA Installation Restoration (IR) sites and sampling of background areas near the IR sites within NAVSTA indicate that the background (naturally-occurring) levels of some metals may be higher in soils at and near NAVSTA than in other background areas of Rhode Island (TtNUS, 2000; TtNUS, 2004). The primary objective of this study is to establish background concentrations of metals in soils for the NAVSTA IR sites by determining the occurrence, geochemical abundance, and variability (scatter) of surface and subsurface soil metals concentrations at undisturbed locations within or near the NAVSTA Base. The background levels for these metals will then be used to assist in the evaluation of onsite analytical data for current and future NAVSTA sites under investigation as a part of the IR Program, Underground Storage Tank (UST) Program, and other programs, as applicable. An additional objective is to characterize the concentrations of metals in the bedrock beneath the Base. The bedrock data will support interpretations of the background soil results.

Navy policy requires that there is a clear and concise understanding of chemicals released from a site in order to assure proper focus and remediation of the release. To this end, background evaluations are needed during the site investigations in order to differentiate between the site conditions and background sources. These evaluations should include naturally-occurring chemicals and anthropogenic chemicals (CNO, 2004).

The (EPA defines “background” as substances or locations that are not influenced by releases from a site, and are usually described as naturally-occurring (not influenced by human activity) or anthropogenic (present as a result of human activity) (EPA, 2002).

The RIDEM Site Remediation Regulations (DEM-DSR-01-93), defines “background” as the ambient concentrations of hazardous substances present in the environment that have not been influenced by human activities, ***or*** the ambient concentrations of hazardous substances consistently present in the environment in the vicinity of the contaminated site, which are the result of human activities unrelated to releases at the contaminated site.

Additionally, RIDEM regulations state that background samples provide baseline measurements to determine what the concentrations of chemicals would be at a site if no releases occurred there. Rhode Island regulations provide an allowance for determining background conditions under the Site Remediation Regulations, Section 8.06 A:

> “Sampling of hazardous substances in background areas may be conducted to distinguish concentrations related to the contaminated site from concentrations of hazardous substances not related to activities at the contaminated site or to support the development of soil objectives under the provisions of Rule 8.02 (Soil Objectives).”

Since the definitions for background are consistent between the Navy, EPA and RIDEM, the background conditions to be sought during the field work described in this work plan include both naturally-occurring and anthropogenic chemical contributions to the soils at NAVSTA IR sites. This data will be compared with the data collected from NAVSTA IR sites in order to distinguish site-related metal contaminants from non-site-related background (naturally occurring and anthropogenic) metal contaminants. These comparisons will be provided in the Remedial Investigation (RI) Reports to be prepared for these IR sites after field investigations are completed.

The background study activities will include: historical research to evaluate the proposed background sampling locations described in this work plan; sampling and analysis of soil and bedrock; a global positioning system (GPS) survey of the background sample locations; data review; and statistical analysis of the data, to be described in a final report.

1.2 PROJECT DELIVERABLES

Project deliverables to be submitted during this project will include:

- A report of the background investigation including:
    - Summary of NAVSTA Base background information,
    - Description of field investigation activities,
    - Summary and interpretation of the data,
    - Summary of statistical analysis of the data, and
    - Conclusions and recommendations for use of background data.

- Supporting documentation, including:
    - Maps depicting sampling points and other significant features,
    - Results from laboratory analysis of samples,
    - Statistical analysis supporting documentation, and
    - Photographs of sample locations.

1.3 WORK PLAN ORGANIZATION

Section 1.0 of this work plan consists of this introductory section.

Section 2.0 of this work plan describes the background information (brief history of NAVSTA-Newport and selection of background sampling areas) and provides the basis for the Data Quality Objectives (DQOs) developed for this project.

Section 3.0 presents a field sampling plan that describes the field work planned for this investigation. Sample collection procedures and analytical parameters are also included in this section.

Section 4.0 presents the Quality Assurance/Quality Control (QA/QC) Plan which includes a description of the QA/QC sample collection procedures and frequencies, data quality protocols, and analytical data validation requirements.

Section 5.0 presents a general outline of the data analysis and statistical testing that will be conducted following completion of the field work (described in Section 3.0).

Section 6.0 presents a brief description of information to be included in the final report.

Appendix A to this work plan presents a site-specific Health and Safety Plan, which will be observed for the field work presented in this work plan. Appendix B presents applicable TtNUS Standard Operating Procedures for field activities, and Appendix C presents documentation forms to be used during execution of the activities described in this work plan.

1.4 CHANGES TO THE WORK PLAN

During implementation of the proposed background soil investigation it may become necessary to modify some portion(s) of the work described in this work plan. If the plan for collecting data needs to be altered, the work plan may be amended through the use of a Field Modification Record (FMR) form. If required, this form will be prepared by the TtNUS Field Operations Leader (FOL) and forwarded to the TtNUS Project Manager (PM). The PM will make a recommendation to the Navy Remedial Project Manager (RPM), who will forward the FMR to the regulatory oversight RPMs, if necessary. Time limits on acceptance of, or comment to, the FMRs will be stated. An example of the FMR form is presented in Appendix C.

1.5 SCHEDULE AND REGULATORY OVERSIGHT

A schedule for field investigations will be prepared and submitted to the regulatory agencies upon development of the cost/schedule for the fieldwork. This schedule will be updated as needed prior to actual initiation of the fieldwork. Notification of changes in scheduled field activities will be given to the regulatory agencies one week prior to initiating. Cancellation of field activities, if applicable, will also be provided in a timely manner.

2.0 BACKGROUND INFORMATION AND DATA QUALITY OBJECTIVES

The following sections present a brief historical description of NAVSTA Newport, a basis for selection of the locations for background sample collection, and the data quality objectives (DQOs) to be followed for this project.

2.1 SITE DESCRIPTION AND HISTORY

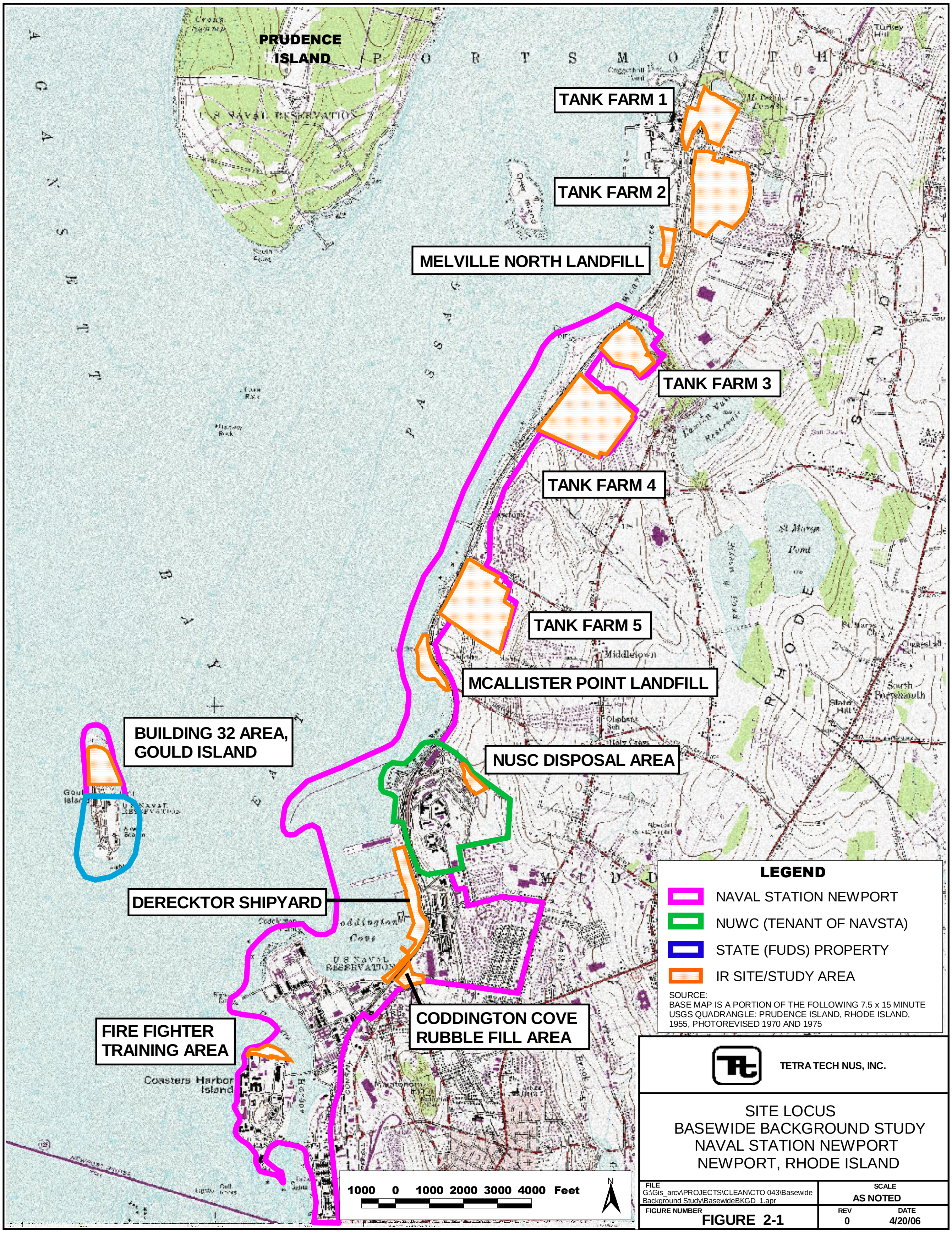
NAVSTA Newport is located approximately 60 miles southwest of Boston, Massachusetts and 25 miles south of Providence, Rhode Island. It occupies approximately 1,063 acres, with portions of the Base located in the City of Newport and Towns of Middletown and Portsmouth, Rhode Island. The facility layout is long and narrow, following the western shoreline of Aquidneck Island for nearly 6 miles, facing the east passage of Narragansett Bay (Figure 2-1).

The NAVSTA Newport facility has been in use by the Navy since the era of the Civil War. During World Wars I and II, military activities at the facility increased significantly and the Base provided housing for many servicemen. In subsequent peacetime years, use of on-site facilities was slowly phased out until Newport became the headquarters of the Commander Cruiser-Destroyer Force Atlantic in 1962. In April 1973, the Shore Establishment Realignment (SER) Program resulted in the reorganization of naval forces, and activity again declined.

Information on the NAVSTA IR Sites is presented in the “Five-Year Review for Naval Station Newport” (TtNUS, 2004).

2.2 DATA QUALITY OBJECTIVES

The DQOs for this project were developed in accordance with the EPA Guidance for Data Quality Objective Process (EPA, 2000), which recommends seven steps to develop project DQOs. The intended use(s) of the data resulting from a field investigation is a determining factor in defining the DQOs for that data. To be certain that the data are consistent with the goals of the investigation, the seven steps for defining DQOs are presented in the following subsections.



PRUDENCE ISLAND
PORTSMOUTH
TANK FARM 1
TANK FARM 2
MELVILLE NORTH LANDFILL
TANK FARM 3
TANK FARM 4
TANK FARM 5
MCALLISTER POINT LANDFILL
BUILDING 32 AREA, GOULD ISLAND
NUSC DISPOSAL AREA
DERECKTOR SHIPYARD
CODDINGTON COVE RUBBLE FILL AREA
FIRE FIGHTER TRAINING AREA
LEGEND
NAVAL STATION NEWPORT
NUWC (TENANT OF NAVSTA)
STATE (FUDS) PROPERTY
IR SITE/STUDY AREA
SOURCE:
BASE MAP IS A PORTION OF THE FOLLOWING 7.5 x 15 MINUTE USGS QUADRANGLE: PRUDENCE ISLAND, RHODE ISLAND, 1955, PHOTOREVISED 1970 AND 1975
1000 0 1000 2000 3000 4000 Feet
N
TETRA TECH NUS, INC.
SITE LOCUS
BASEWIDE BACKGROUND STUDY
NAVAL STATION NEWPORT
NEWPORT, RHODE ISLAND
FILE
G:\Gis_arcv\PROJECTS\CLEAN\CTO 043\Basewide Background Study\BasewideBKGD_1.apr
SCALE
AS NOTED
FIGURE NUMBER
FIGURE 2-1
REV
0
DATE
4/20/06

2.2.1 Statement of the Problem

RIDEM regulations require that concentrations of contaminants on hazardous waste sites be compared to "RIDEM direct exposure criteria," in part, to determine if remedial actions need to be taken at each site. Current Navy policy states that site-specific risk is determined through evaluation of background or upgradient conditions (CNO, 2004). Recent site investigations conducted at the NAVSTA Newport IR Sites, including the Melville North Landfill, Old Firefighting Training Area (OFFTA), NUSC Disposal Area, and, in general, on the west side of Aquidneck Island, indicate that RIDEM direct exposure criteria may not reflect naturally-occurring concentrations of arsenic in soil. Additionally, the site history and use of abutting properties indicate that upgradient properties may have contributed chemical contaminants to the Base through agricultural activities. Therefore, background conditions must be measured to properly evaluate IR site data for exposure and risk.

The objective of this investigation is to determine basewide background concentrations for metals through evaluation of selected undisturbed areas of the Base, which represent background conditions for the soils at the NAVSTA IR Sites. Navy policy and guidance requires that background conditions be assessed at areas with similar geological and physical conditions. EPA guidance for background evaluations indicates that the background reference areas should have the same physical, chemical, geological, and biological conditions as the site to be investigated (EPA, 2002). Therefore, potential background sampling areas are evaluated in terms of soil type, as well as land use history.

2.2.2 Identification of the Decision

At the completion of this study, a determination will be made regarding the background metals concentrations in both the surface and subsurface soils for the following soil types: Mansfield mucky silt loam (Ma); Merrimac sandy loam (MmA); Newport silt loam (NeA, NeB, NeC, NP); Pittstown silt loam (PmA, PmB); Stissing silt loam (Se); and beach soils (Ba). This determination will be supported by the calculation of various test statistics. Background metals concentrations for the Udorthents (UD) soil type will be determined using the approach outlined in Section 2.2.3, below.

2.2.3 Inputs to the Decision

Inputs to the decision are the elements used in the decision process. Inputs to the decision stated in Section 2.2.2 are as follows:

- Soil types and characteristics
- Bedrock types and characteristics

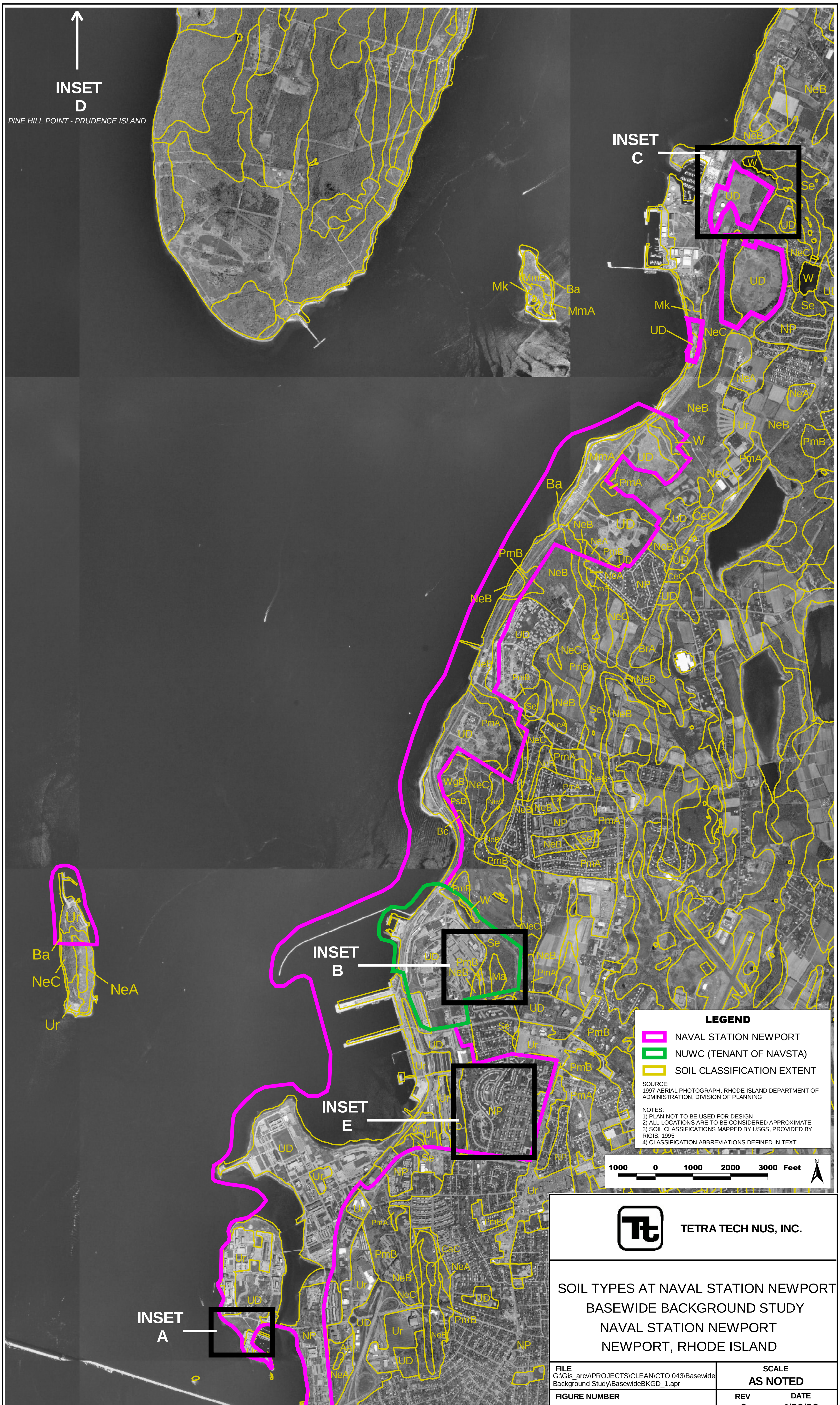
- Land use of areas evaluated and represented
- Actual concentrations of metals detected
- Results of multiple statistical analyses performed in a manner to ensure a 95% confidence level for decision-making

<u>Soil Types:</u>

The purpose of the sampling program is to collect adequate numbers of samples from the soil types that cover the majority of the NAVSTA sites. According to the *Soil Survey of Rhode Island* (Rector, 1981), the vast majority of the Base includes seven soil types: Mansfield mucky silt loam (Ma), Merrimack sandy loam (MmA), Newport silt loam (NeA, NeB, NeC, NP), Pittstown silt loam (PmA, PmB), Stissing silt loam (Se), beach soils (Ba), and Udorthents (UD) (Figure 2-2). Four additional map units occur within the base boundary, but one of them, Urban land (Ur), is not a soil type, and the other three: the Birchwood sandy loam (Bc), Poquonock loamy fine sand (PsB), and Windsor loamy sand (WgB), are only found in a small area along the eastern border of the Base, near the McAllister Point Landfill as detailed in the *Soil Survey of Rhode Island* (Rector, 1981), the seven prominent soil types are described below.

Mansfield mucky silt loam (Ma). This very poorly-drained soil formed in compact glacial till derived mainly from dark gray phyllite, shale, conglomerate, and schist bedrock types, and it occurs in nearly level depressions and small drainage ways of drumlins. Typically the surface layer is black mucky silt loam about eight inches thick. The subsoil is dark gray silt loam, seven inches thick. The substratum is dark gray and olive gray silt loam that contains flat rock fragments and extends to a depth of 60 inches or more. Included in this map unit are small areas of poorly-drained Stissing (Se) soils. The permeability of the soil is moderate in the surface layer and subsoil, and slow or very slow in the substratum. Available water capacity is moderate, and runoff is slow. This soil has a seasonal high water table at or near the surface from late fall through mid-summer. Many areas have poor drainage and standing water during wet seasons. The soil is extremely acid through medium acid.

Merrimac sandy loam (MmA). This somewhat excessively-drained soil formed in outwash deposits derived from schist, gneiss, and phyllite rock types, and it occurs on nearly level portions of outwash plains and terraces. Typically the surface layer is dark brown sandy loam, about eight inches thick. The subsoil is yellowish brown and dark yellowish brown sandy loam, 17 inches thick. The substratum is light yellowish brown gravelly sand to a depth of 60 inches or more. About ten percent of the map unit consists of other soils. The permeability of the soil is moderately rapid in the surface layer and upper part of the subsoil, moderately rapid to rapid in the lower part of the subsoil, and rapid in the substratum. Available water capacity is moderate, and runoff is slow. The soil is extremely acid through medium acid.


INSET D
PINE HILL POINT - PRUDENCE ISLAND
INSET C
INSET B
INSET E
INSET A
LEGEND
NAVAL STATION NEWPORT
NUWC (TENANT OF NAVSTA)
SOIL CLASSIFICATION EXTENT
SOURCE:
1997 AERIAL PHOTOGRAPH, RHODE ISLAND DEPARTMENT OF ADMINISTRATION, DIVISION OF PLANNING
NOTES:
1) PLAN NOT TO BE USED FOR DESIGN
2) ALL LOCATIONS ARE TO BE CONSIDERED APPROXIMATE
3) SOIL CLASSIFICATIONS MAPPED BY USGS, PROVIDED BY RIGIS, 1995
4) CLASSIFICATION ABBREVIATIONS DEFINED IN TEXT
1000 0 1000 2000 3000 Feet
N
TETRA TECH NUS, INC.
SOIL TYPES AT NAVAL STATION NEWPORT
BASEWIDE BACKGROUND STUDY
NAVAL STATION NEWPORT
NEWPORT, RHODE ISLAND
FILE
G:\Gis_arcv\PROJECTS\CLEAN\CTO 043\Basewide Background Study\BasewideBKGD_1.apr
SCALE
AS NOTED
FIGURE NUMBER
FIGURE NO. 2-2
REV
0
DATE
4/20/06

Newport silt loam (NeA, NeB, NeC, NP). These well-drained soils are found on the crests and side slopes of drumlins and glacial till plains. These soils formed in compact glacial till derived mainly from dark sandstone, conglomerate, argillite, and phyllite rock types. Typically, the surface layer is very dark brown silt loam, about eight inches thick. The subsoil is olive brown and olive silt loam, 16 inches thick. The substratum is olive gray silt loam that contains flat rock fragments and extends to a depth of 60 inches or more. Ten to 15 percent of the NeA, NeB, and NeC map units, and thirty percent of the NP map unit consist of other soils (Bc, Ps, Pm, and UD). Permeability is moderate or moderately rapid in the surface layer and subsoil, and slow or very slow in the substratum. Available water capacity is moderate, and runoff is medium to rapid, depending on the slope. The soil is very strongly acid through medium acid.

Pittstown silt loam (PmA, PmB). These soils are moderately well-drained and are found on the side slopes and crests of glacial upland hills and drumlins. These soils formed in compact glacial till derived mainly from dark phyllite, slate, shale, and schist rock types. Typically, the surface layer is very dark grayish brown silt loam, about eight inches thick. The subsoil is dark yellowish brown and olive brown silt loam, 20 inches thick, and mottled in the lower part. The substratum is olive gray, mottled silt loam that contains flat rock fragments and extends to a depth of 60 inches or more. About ten percent of the Pittstown map units consists of other soils (Ma, Ne, Se, and stony soils). The permeability of the soil is moderate in the surface layer and subsoil and slow in the substratum. Available water capacity is moderate, and runoff is slow to medium, depending on the slope. The soil has a seasonal high water table at a depth of about 20 inches from late fall through mid-spring. The soil is very strongly acid through medium acid.

Stissing silt loam (Se). This poorly-drained soil formed in compact glacial till derived from dark gray phyllite, slate, shale, and schist, and it occurs on nearly level areas or depressions of drumlins and glacial upland hills. Typically the surface layer is very dark gray silt loam, about eight inches thick. The subsoil is dark grayish brown, mottled silt loam that is seven inches thick. The substratum is dark gray, mottled silt loam to a depth of 60 inches or more. About ten percent of the Se map unit consists of other soils. The permeability of the soil is moderate in the surface layer and subsoil and slow in the substratum. Available water capacity is moderate, and runoff is slow. The soil has a seasonal high water table near the surface from late fall through spring. The soil is extremely acid through medium acid.

Beaches (Ba). This Ba map unit consists of long, narrow areas of sand dunes or escarpments. It also includes sandy, gravelly, or cobbly areas that are exposed during low tide, which are common along the NAVSTA shoreline. Slopes range from zero to eight percent. About five percent of the Ba map unit includes rock outcrops, Matunuck mucky peat (Mk) soils, and Udipsamments (sandy soils that lack distinct subsurface horizons and occur in sand dune and blowout areas that have been stabilized by beach grasses).

Udorthents-Urban land complex (UD). Seventy percent of the complex consists of Udorthents – moderately well-drained to excessively-drained soils that have been disturbed by cutting (to a depth of two feet or more) or filling (with more than two feet of fill). Twenty percent of the UD map unit includes areas that are covered by buildings or pavement, and ten percent is comprised of other (undisturbed) soils. Udorthent is a general classification term that applies to a variety of soils that are well-drained and lack well-developed pedogenic horizons. The *Soil Survey of Rhode Island* assigns this term to soils on till plains and outwash terraces that have been disturbed by cutting or filling. Thus, the original (uncut/unfilled) soil within a UD area could have been any one or a combination of the well-drained soil types that occur in the vicinity of the base. The fill material within a UD area may consist of well-drained base soils and/or off-base fill materials. Consequently, the soil properties within and between UD areas are expected to be highly variable.

The *Soil Survey of Rhode Island* acknowledges the high variability of this map unit, and the results from the OFFTA Background Soil Investigation (TtNUS, 2000) further attest to its variable character. Although the 38 OFFTA background samples were collected from a relatively small area, several samples appear to have anomalous concentrations of one or more metals. It is possible that with additional UD samples, the potential outliers identified in the OFFTA study would fall within the expected range for this soil.

Since the UD soils have been disturbed and are highly variable, it may be difficult not only to locate UD areas that could be considered “background”, but also to collect a sufficient number of samples to adequately characterize the distribution of metals in this map unit. Therefore, an alternate approach is proposed to characterize background metals concentrations in UD areas, which would also apply to Ur (urban land) areas. The approach consists of: 1) identifying the soil types bordering a UD/Ur area; 2) assuming the original soil in the UD/Ur area is a combination of the soil types bordering the area; and 3) using the combined background distributions for the adjacent soil types to represent the background distribution of a metal in the UD/Ur area. If most or all of a UD/Ur area is not bounded by other soil types, either the combined distributions for the three well-drained soil types (Mm, Ne, Pm) could be used to represent the background distribution of a metal, or site-specific background data could be collected, provided suitable background locations could be identified.

<u>Bedrock Types:</u>

Two major bedrock formations occur on the base: the Rhode Island Formation and the Purgatory Conglomerate (Hermes et al, 1994). The Rhode Island Formation occurs beneath the vast majority of the Base, where outcrops and borings indicate the bedrock types are shale, slate, phyllite, and schist. The

Purgatory Conglomerate, which consists of quartzite clasts in a predominantly quartz sand matrix, is only found on the base along the western sides of Coasters Harbor Island and Coddington Point. Off the base, the Rhode Island Formation underlies most of the Narragansett Basin, while the Purgatory Conglomerate only occurs in a few small areas of Newport County.

Field observations of rock fragments in surface and subsurface soils and Soil Conservation Service descriptions of soil genesis strongly suggest that the soils on the base formed from rock within these two major formations. According to the Soil Conservation Service, the Ma and Ne soils formed in till that was derived from conglomerate, phyllite, argillite, and/or schist. The Mm, Pm, and Se soils formed in outwash or till, derived from shale, slate, phyllite, and/or schist. Field observations indicate the Ba soils on the base were derived from the erosional debris of both rock types. Since the soils on the base appear to be derived from the rock types found beneath the base (field data from the basewide study will be used to further evaluate this assertion), the concentrations of metals in these rock types should be characterized in order to better interpret the concentrations of metals in the background soils.

For example, the OFFTA background study found that the soil in one study area on the western side of Coasters Harbor Island contained significantly lower concentrations of arsenic than the soil in another area, which was immediately to the east. Since both areas are mapped as UD soil, and since the bedrock was not evaluated, it was difficult to explain the reason(s) for the concentration differences. According to Hermes, et al. (1994), the bedrock on the western side of Coasters Harbor Island is the Purgatory Conglomerate and the bedrock on the eastern side is the Rhode Island Formation. The Purgatory Conglomerate consists of quartzite clasts in a predominantly quartz matrix, so it is likely to be arsenic-poor. On the other hand, the Rhode Island Formation contains metamorphosed silt and clay (shale, slate, etc.) that could be arsenic-rich. If the rocks within the Rhode Island Formation are arsenic-rich, and if the soils in the western study area overlie the Purgatory Conglomerate and the soils in the eastern area overlie the Rhode Island Formation, these differences in parent rock type could account for the differences in soil arsenic concentrations between the two areas.

<u>Property Use:</u>

Prior to occupation of the IR sites by the Navy, the land was used for agriculture and the soils were likely impacted by the application of pesticides and fertilizers. Metal-bearing pesticides that may have been used at these sites include lead arsenate, sodium arsenate, and arsenic trioxide. Lead arsenate was a common insecticide, and sodium arsenate and arsenic trioxide were formerly used as herbicides. Arsenic, cadmium, and other heavy metals could also have been added to the soils through the application of phosphate fertilizers. Additionally, the soils contain metals originating from the natural weathering of the parent bedrock.

The common and consistent uses of some parcels of the NAVSTA base strongly suggest that portions of these parcels exhibit conditions that could be considered “background”, as defined earlier in this section: the concentrations of compounds present in these potential reference areas are likely to reflect both naturally occurring and anthropogenic chemicals present at the NAVSTA IR sites if no releases had occurred there.

2.2.4 Definition of the Study Area Boundaries

The decision stated in Section 2.2.2 pertains to background metals concentrations in the soils encountered at NAVSTA IR sites. Background soil samples will be collected from areas on the base and on Prudence Island that are determined to be free of influence from IR sites or other non-uniformly-distributed anthropogenic sources.

Selection of Sampling Areas:

The selection of background soil and bedrock sampling areas will be based on the current and historical use of the areas and the soil and rock types present. Specifically, areas that have not undergone major change since approximately 1942 will be used. At least one sampling area for each of the six soil types and two rock formations will be selected for collection of background samples.

The soil chemistry even within a single soil designation may differ with depth, as has been demonstrated in background samples collected for the OFFTA investigation. Therefore, it is appropriate that both surface and subsurface soil samples be collected within each soil type. Further details on “surface” vs “subsurface” soils are provided in Section 3.2. Separate background soil concentrations will be established for these two soil subsets (surface and subsurface) within each soil type, following the applicable methods and tests listed in Section 5. This procedure will be modified for samples collected in the Anchorage and Coddington Cove housing areas (Figures 2-3 and 3-1D) as described in Section 3.2. All soil samples collected there will be considered composite samples that include both surface and subsurface soil, due to the extensive excavation, mixing, and resurfacing of soils at the housing development during previous construction activities.

Areas designated as A through E have been evaluated and are proposed as background sampling areas for the Basewide Background Study (see Figure 2-3). Available historical information, maps, and aerial photographs were reviewed to determine prior land uses and activities at the proposed sampling areas. In addition, the collection of two bedrock cores is proposed, one from the Purgatory Conglomerate and one from the Rhode Island Formation, in order to characterize the metals concentrations in the bedrock beneath the base. Proposed bedrock coring locations (areas seven and eight) are also shown on Figure 2-3.

2.2.5 Decision Rule

Typically, the decision rule is a clear statement defining the requirements of the investigation based on the possible outcomes of the study. The decision rule related to the primary objective of this study is to determine background concentrations for metals in soil, which can then be used for comparison with IR site data in the evaluation of the nature and extent of contamination and the determination of site-related risks. The numbers and types of samples collected must be sufficient to allow for meaningful comparisons.

According to the Navy's *Guidance for Environmental Background Analysis, Volume 1: Soil* (2002), a background dataset usually contains "more than 20 to 30 unbiased and representative measurements". Therefore, 20 surface soil samples and 20 subsurface soil samples will be evaluated for each of the six soil types: Ma, Mm, Ne, Pm, Se, and Ba. Some background data are available for evaluation in this study, from previous IR site investigations. Two Ne surface soil samples were collected and analyzed for target analyte list (TAL) metals during the background study for the Melville North Landfill (IR Site 2), and 20 Pm and 20 Se surface soil samples were collected and analyzed for TAL metals for NUSC (Site 8). As a result, a total of 208 soil samples (78 surface soil samples and 130 subsurface soil samples), excluding QA/QC samples, are proposed for collected for the Basewide Background Study (see Table 2-1).

For each soil type, the surface and subsurface soil background data sets will be compared using statistical tests, in order to answer the following questions: Are the distributions of both subgroups normal or lognormal in shape? Is the mean or median of one subgroup higher than the other, and are there differences in the right tails (largest values) of the subgroup distributions?

Within each soil type, the background data subsets will be treated as distinct populations if any tests show significant differences; otherwise, the data will be merged. Data sets from different soil types may also be merged if: 1) there are no statistically significant differences between the data sets, or 2) the information is being used to establish background concentrations for UD or Ur areas.

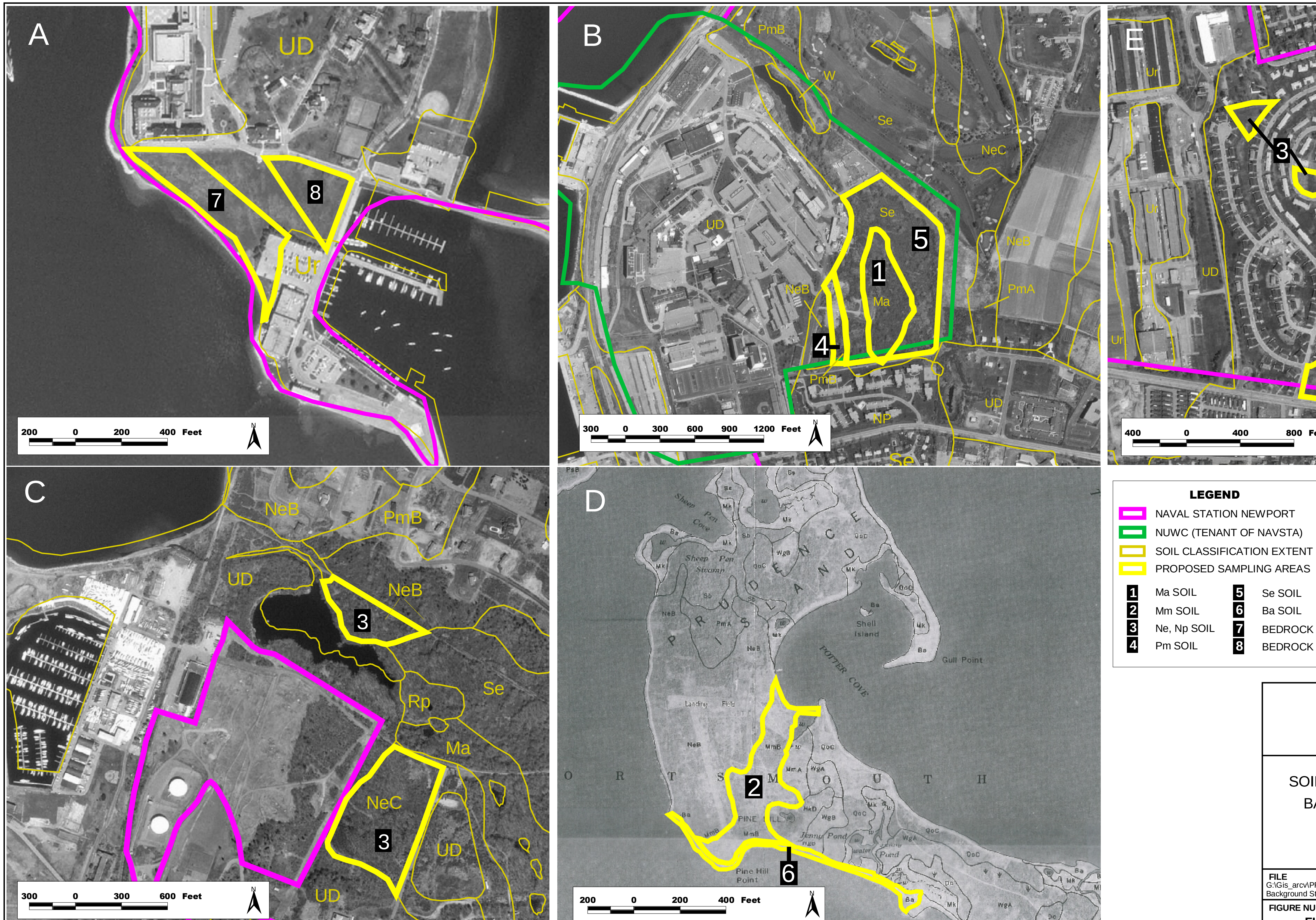
2.2.6 Limits on Decision Errors

Limits on decision errors restrict the potential for false negative and false positive decisions. This study is designed to result in a high probability of sampling soils at or near NAVSTA, from each major soil type found on the base, and with analyte concentrations that are unaffected by IR sites. Therefore, a relatively large number of background sample stations are proposed, and they target areas unlikely to have been affected by IR site activities. An alpha level of 0.05 will be used for statistical tests.

TABLE 2-1

SOIL SAMPLE SUMMARY
BASEWIDE BACKGROUND STUDY
NAVSTA NEWPORT
NEWPORT, RHODE ISLAND

Soil Type	Sampling Area(s)	Composite Sample Interval (Depth in ft)	Samples Available	Samples Needed
Mansfield mucky silt loam (Ma)	South of NUSC Disposal Area on NUWC property	0 to 1 1 to 10	0 0	20 20
Merrimack sandy loam (MmA)	Pine Hill Area on Prudence Island	0 to 1 1 to 10	0 0	20 20
Newport silt loam (NeA, NeB, NeC, NP)	Ne soil sampling areas used in Melville North Landfill Background Soil Investigation AND FROM THE Anchorage Housing and Coddington Cove Areas	0 to 1 1 to 10	2 0	18 30
Pittstown silt loam (PmA, PmB)	Pm soil sampling area used in NUSC Background Soil Investigation	0 to 1 1 to 10	20 0	0 20
Stissing silt loam (Se)	Se soil sampling area used in NUSC Background Soil Investigation	0 to 1 1 to 10	20 0	0 20
Beach Soils (Ba)	Pine Hill Area on Prudence Island	0 to 1 1 to 10	0 0	20 20
		Total	42	208



SOURCE:
1997 AERIAL PHOTOGRAPH, RHODE ISLAND DEPARTMENT OF ADMINISTRATION, DIVISION OF PLANNING

NOTES:
1) PLAN NOT TO BE USED FOR DESIGN
2) ALL LOCATIONS ARE TO BE CONSIDERED APPROXIMATE
3) SOIL CLASSIFICATIONS MAPPED BY USGS, PROVIDED BY RIGIS, 1995
4) CLASSIFICATION ABBREVIATIONS DEFINED IN TEXT
5) BACKGROUND FOR INSET D MAPPED BY USGS, SOIL SURVEY MAPS 78 AND 88, 1981

TETRA TECH NUS, INC.

SOIL AND BEDROCK SAMPLE AREAS
BASEWIDE BACKGROUND STUDY
NAVAL STATION NEWPORT
NEWPORT, RHODE ISLAND

FILE	SCALE	
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FIGURE NUMBER	REV	DATE
FIGURE NO. 2-3	0	4/20/06

To be certain, some data properties, such as population distribution shape and standard deviation, are unknown prior to collecting background data, so designating a minimum number of samples for the background study provides only partial control over the ability to adequately characterize background concentrations. For planning purposes, reasonably successful statistical performance is expected, given the assumption that background data sets are comprised of 20 samples each, based on formulas for estimating statistical performance presented in Navy guidance (NFEC, 2002). Furthermore, concentration detection limits will be set well below published background ranges for typical soils, to minimize the potential for analyte nondetects.

2.2.7 Design for Obtaining Data

The DQO process presented in the G4 DQO document assumes that data sets contain unbiased and representative measurements. Since this investigation is being performed to establish background concentration ranges for metals in soils, the design of the sampling plan can be somewhat qualitative, or "targeted" toward areas that are not impacted by site activities, in order to ensure the data are representative of background conditions. To ensure the measurements are unbiased, individual sample stations are randomly located within each sampling area. The (proposed) sampling areas are described in Section 2.2.4 of this work plan. The sampling plan for establishing background concentration ranges for metals in soils is provided in Section 3. Specifics on the precision, accuracy, etc. of the data collected are described in the Quality Assurance/Quality Control Plan, presented in Section 4. Testing of the resulting data to establish background conditions is described in Section 5.

3.0 FIELD SAMPLING PLAN

This section presents a description of the field investigation activities that are planned for the Basewide Background Study.

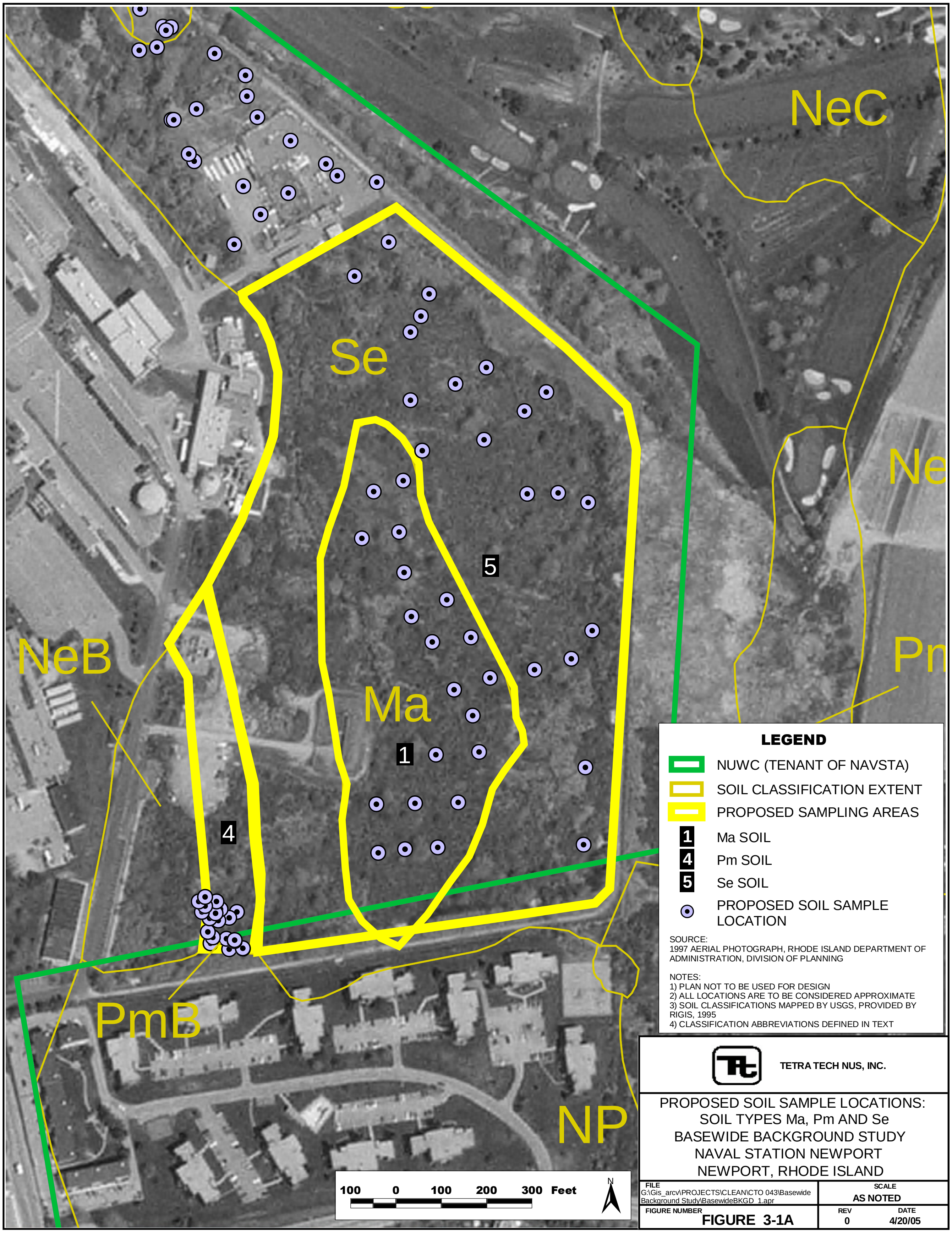
3.1 INTRODUCTION

The objective of the Field Sampling Plan (FSP) is to provide details for obtaining soil and bedrock data to establish background concentrations of metals in soils, for use in characterizing NAVSTA IR and other sites. This FSP details the soil and bedrock sampling field activities to be performed during this Basewide Background Study. Specific TtNUS Standard Operating Procedures (SOPs) will be referenced where applicable. The pertinent SOPs are included as Appendix B.

3.2 SOIL SAMPLING

The proposed soil sample locations are presented on Figures 3-1A, B, C, and D. Samples will be collected using direct push technology (DPT) in accordance with TtNUS SOP SA-2.5. Surface soil samples will be collected from the zero- to one- foot depth interval. For purposes of this study, “subsurface” soil will be considered soil collected from an interval to be selected in the field between one and ten feet below ground surface (bgs). The following guidelines will be followed, as appropriate, when selecting background locations and collecting soil samples:

- No sample location will be within 100 feet of a roadway or within 25 feet of a fence, except at the Anchorage and Coddington Cove housing areas, where samples will be collected as far from roads and fences as practical.
- Areas directly beneath pine trees, hemlocks, and oaks will be avoided, if possible, because these species increase soil acidity and may alter the distribution of metals in their immediate surroundings.
- The root mass and forest litter (leaves, needles, twigs, stems, bark) at the ground surface will be removed prior to surface soil sample collection in order to minimize the impact of pollutants from sources such as automobile emissions and road runoff.
- If refusal is encountered before a boring is advanced one foot, the location will be adjusted for additional advancement attempts.
- If refusal is encountered before a boring is advanced ten feet, a subsurface sample will not be collected at that location.



NeC
Ne
Se
5
Ma
1
NeB
Pn
4
PmB
NP
LEGEND
NUWC (TENANT OF NAVSTA)
SOIL CLASSIFICATION EXTENT
PROPOSED SAMPLING AREAS
1 Ma SOIL
4 Pm SOIL
5 Se SOIL
PROPOSED SOIL SAMPLE LOCATION
SOURCE:
1997 AERIAL PHOTOGRAPH, RHODE ISLAND DEPARTMENT OF ADMINISTRATION, DIVISION OF PLANNING
NOTES:
1) PLAN NOT TO BE USED FOR DESIGN
2) ALL LOCATIONS ARE TO BE CONSIDERED APPROXIMATE
3) SOIL CLASSIFICATIONS MAPPED BY USGS, PROVIDED BY RIGIS, 1995
4) CLASSIFICATION ABBREVIATIONS DEFINED IN TEXT
100 0 100 200 300 Feet
N
TETRA TECH NUS, INC.
PROPOSED SOIL SAMPLE LOCATIONS:
SOIL TYPES Ma, Pm AND Se
BASEWIDE BACKGROUND STUDY
NAVAL STATION NEWPORT
NEWPORT, RHODE ISLAND
FILE
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SCALE
AS NOTED
FIGURE NUMBER
FIGURE 3-1A
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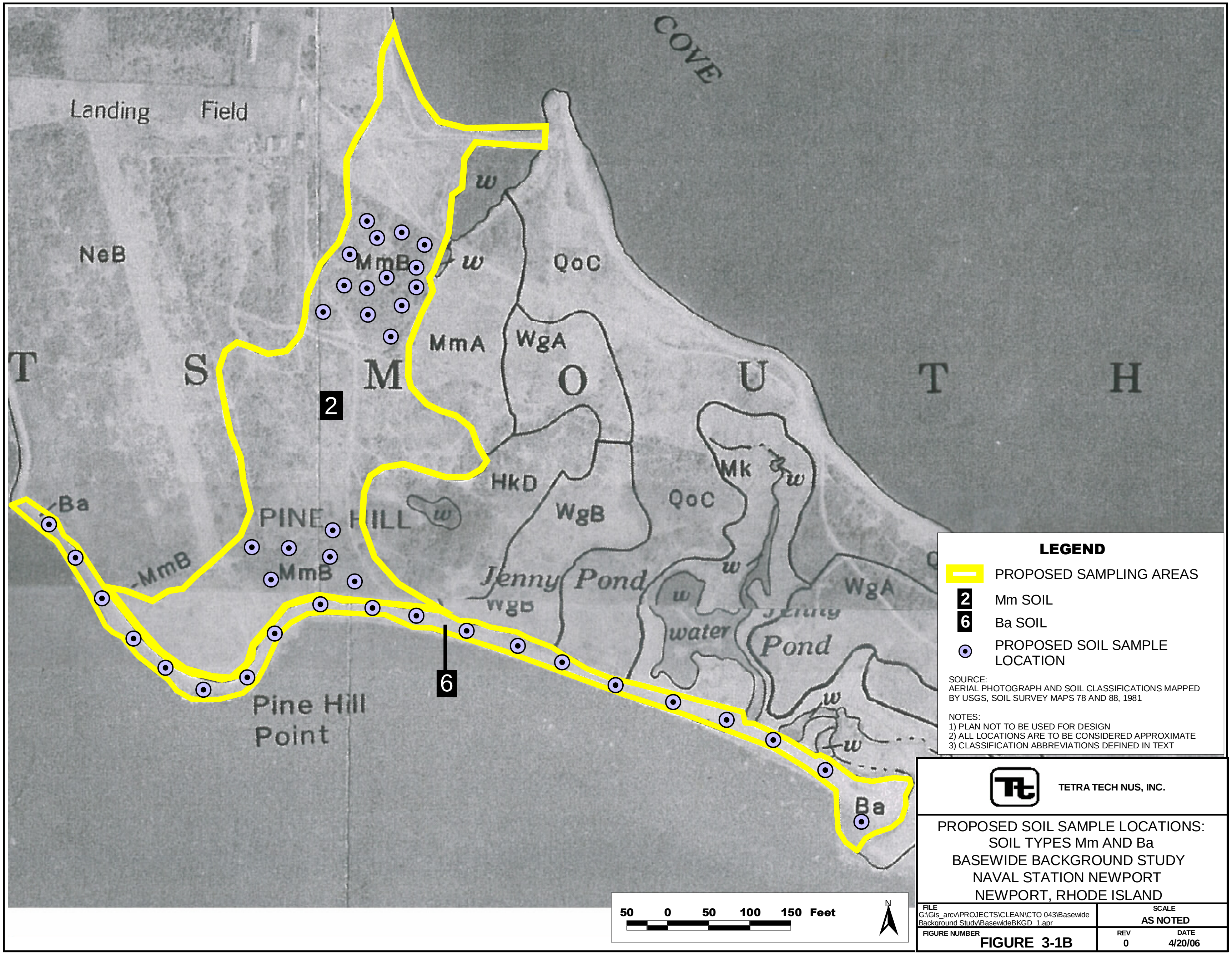
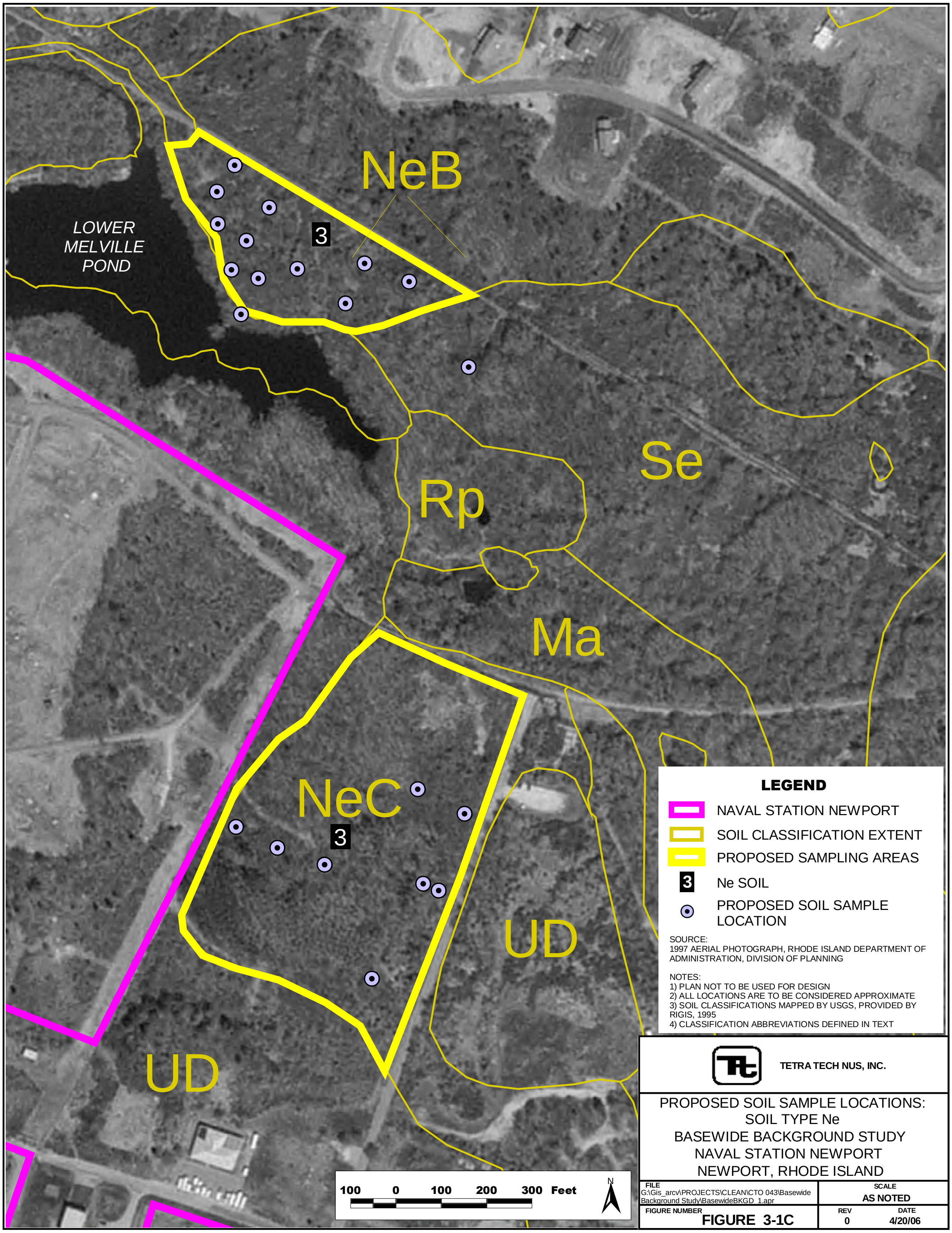
DATE
4/20/05



PROPOSED SOIL SAMPLE LOCATIONS:
SOIL TYPES Mm AND Ba
BASEWIDE BACKGROUND STUDY
NAVAL STATION NEWPORT
NEWPORT, RHODE ISLAND

FIGURE NUMBER
FIGURE 3-1B



PROPOSED SOIL SAMPLE LOCATIONS:
SOIL TYPE Ne
BASEWIDE BACKGROUND STUDY
NAVAL STATION NEWPORT
NEWPORT, RHODE ISLAND

FILE	SCALE	
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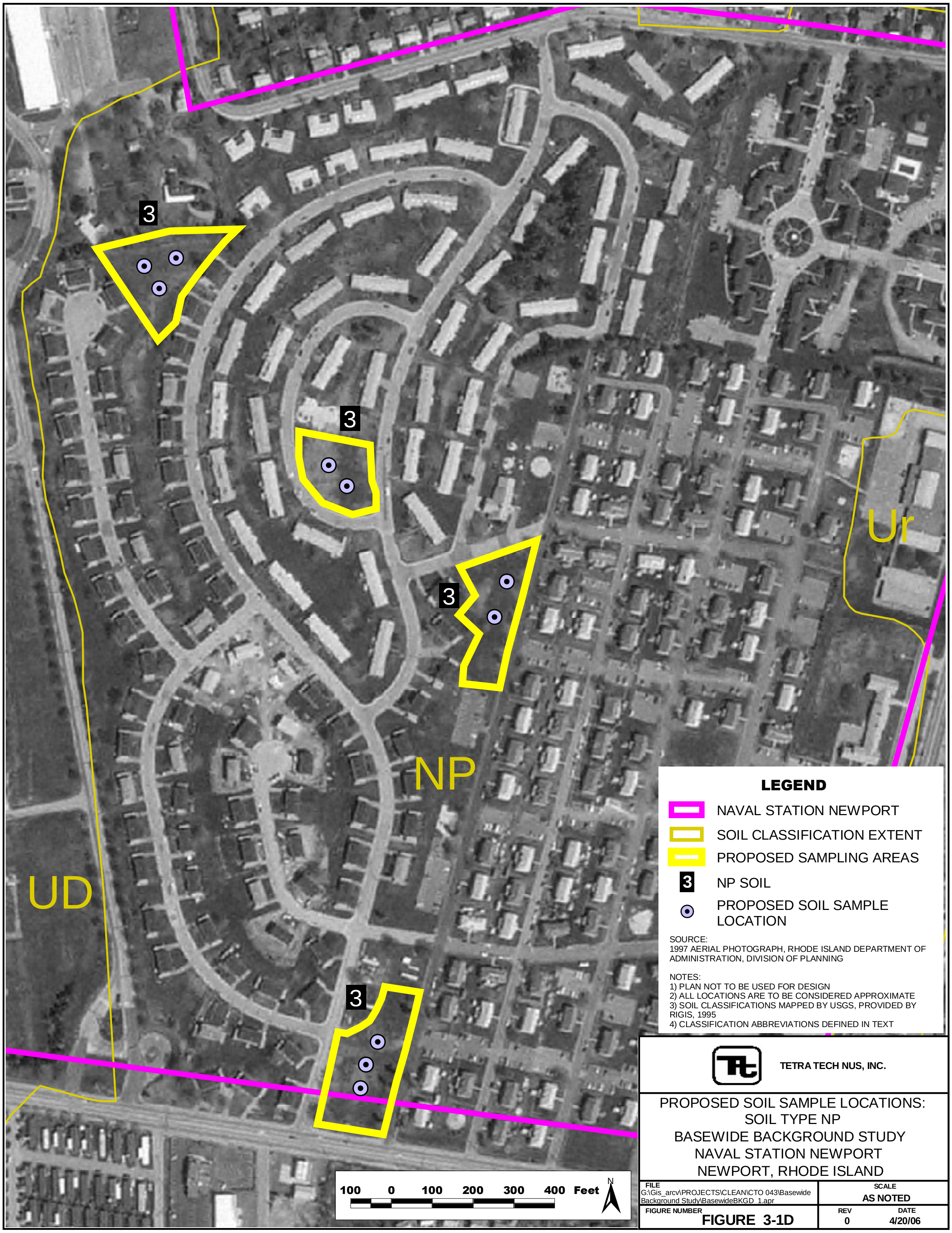
FIGURE NUMBER	REV	DATE
FIGURE 3-1C	0	4/20/06



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3
3
3
Ur
NP
UD
LEGEND
NAVAL STATION NEWPORT
SOIL CLASSIFICATION EXTENT
PROPOSED SAMPLING AREAS
NP SOIL
PROPOSED SOIL SAMPLE LOCATION
SOURCE:
1997 AERIAL PHOTOGRAPH, RHODE ISLAND DEPARTMENT OF ADMINISTRATION, DIVISION OF PLANNING
NOTES:
1) PLAN NOT TO BE USED FOR DESIGN
2) ALL LOCATIONS ARE TO BE CONSIDERED APPROXIMATE
3) SOIL CLASSIFICATIONS MAPPED BY USGS, PROVIDED BY RIGIS, 1995
4) CLASSIFICATION ABBREVIATIONS DEFINED IN TEXT
100 0 100 200 300 400 Feet
N
TETRA TECH NUS, INC.
PROPOSED SOIL SAMPLE LOCATIONS:
SOIL TYPE NP
BASEWIDE BACKGROUND STUDY
NAVAL STATION NEWPORT
NEWPORT, RHODE ISLAND
FILE
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SCALE
AS NOTED
FIGURE NUMBER
FIGURE 3-1D
REV
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DATE
4/20/06

- If refusal is encountered at a depth greater than four feet but less than ten feet (e.g. 4.9 feet), the subsurface sample will be collected from the available soil that is below ten feet (e.g. 4.0 to 4.9 feet).

At each location requiring a surface soil sample, a solid-barrel sampler, such as a MacroCore® sampler, will be advanced from zero to one foot, and the soil will be processed and jarred as described below. No surface soil samples will be collected at the Anchorage and Coddington Cove housing areas, all samples collected in this area will be subsurface due to the congested nature of the areas. For subsurface soil samples, the solid-barrel sampler will be advanced in continuous two-foot intervals, from one foot to ten feet.

The soil will be transferred from the sampler in accordance with TtNUS SOP SA-1.3. The soil will be placed in a stainless steel bowl, and particles that are too large to be sent for analysis will be removed. The remaining soil will be homogenized using a stainless steel trowel and then transferred to the sample container. Field data will be recorded in the field logbook and on appropriate field data forms. Recorded data will include soil type (e.g. Newport silt loam), soil description (structure, texture, color, consistency, etc.), and soil classification (Unified Soil Classification System). A description of any removed particles will also be included. All non-disposable sampling equipment will be decontaminated prior to each use, as described in Section 3.4. Sample locations will be backfilled with clean sand to the original grade.

Soil samples will be analyzed for TAL metals only, except samples collected in the Anchorage and Coddington Cove housing areas which will be analyzed for aluminum, iron, and arsenic. A total of 208 samples will be collected (78 surface samples and 130 subsurface samples). In addition, twenty field duplicates and approximately two field blanks and four rinsate blanks will be required. Appropriate chain-of-custody procedures will be followed (see Section 4.4.2) and samples will be labeled, packaged and shipped according to TtNUS SOP SA-6.1. Analytical parameters, sample preservation requirements, required sample containers, and a summary of quality control samples are presented in Section 4.

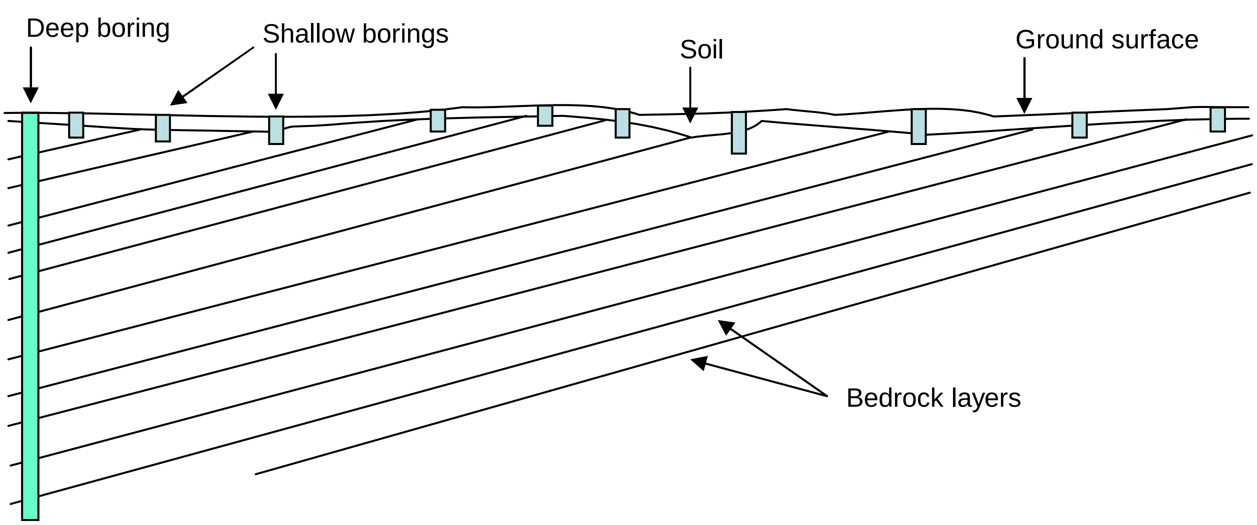
Analyses will be performed by a laboratory subcontracted to TtNUS. The analytical laboratory will provide data within 21 calendar days of sample receipt. Data will be validated using EPA Tier II validation. Validation memoranda will be provided to the project manager for review, and the data will be supplied in database format for statistical analysis and inclusion into the NAVSTA Newport IR Program Environmental Geographic Information System (EGIS).

All sample locations will be photo-documented and surveyed with global positioning system (GPS) survey equipment with sub-meter horizontal accuracy. Any stakes or flagging will be removed after surveying.

3.3 BEDROCK SAMPLING

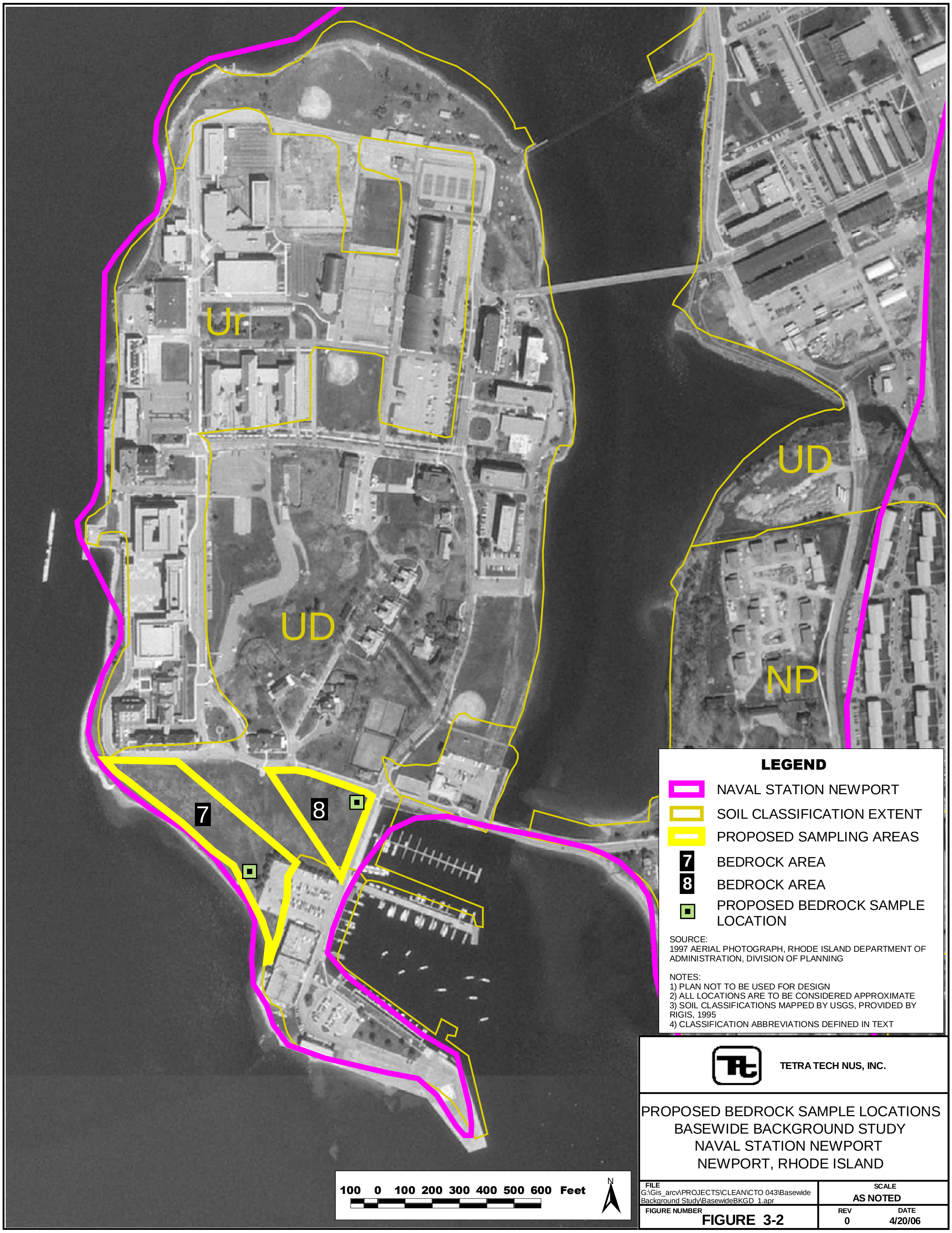
As noted in Section 2.2.3, the Purgatory Conglomerate consists primarily of quartzite clasts in a quartz sand matrix, and the Rhode Island Formation consists of layers of metamorphosed sediments (shale, slate, phyllite, schist). Within each of these formations, the texture and color (and probably the trace metal content) can vary significantly between outcrops on the Base, and between groups of layers within each outcrop. Since it is likely that the trace metal content of each formation varies spatially, multiple samples of each are needed to characterize metals concentrations.

A single deep bedrock boring is proposed for each formation. A deep boring through many layers of rock can access as much variability as several shallow bedrock borings at different locations, and is less expensive (see illustration below). As with the soil sampling, it is assumed that the metals concentrations in one background area are representative of the metals concentrations in other background areas within the same bedrock formation.



The two proposed bedrock sampling locations are shown on Figure 3-2. Both locations are within the OFFTA Background Soil Investigation study area on Coasters Harbor Island. The location on the eastern edge of bedrock sample area 8 is sited to intercept the Rhode Island Formation. The location near the southwestern edge of bedrock sample area 7 is positioned to intercept the Purgatory Conglomerate.

Bedrock borings will be advanced through the overburden to refusal or the top of bedrock using hollow-stem augers. Bedrock coring will begin at refusal or the top of bedrock and will continue in five-foot core intervals to approximately 50 feet into the bedrock, using a double-walled NX or NQ core barrel, or equivalent. Drilling fluids will consist of potable water. The driller’s water source will be pre-approved by TtNUS, and sampled as a field “source” blank. Each rock core will be reviewed and described using



Ur
UD
UD
NP
7
8
LEGEND
NAVAL STATION NEWPORT
SOIL CLASSIFICATION EXTENT
PROPOSED SAMPLING AREAS
7 BEDROCK AREA
8 BEDROCK AREA
PROPOSED BEDROCK SAMPLE LOCATION
SOURCE:
1997 AERIAL PHOTOGRAPH, RHODE ISLAND DEPARTMENT OF ADMINISTRATION, DIVISION OF PLANNING
NOTES:
1) PLAN NOT TO BE USED FOR DESIGN
2) ALL LOCATIONS ARE TO BE CONSIDERED APPROXIMATE
3) SOIL CLASSIFICATIONS MAPPED BY USGS, PROVIDED BY RIGIS, 1995
4) CLASSIFICATION ABBREVIATIONS DEFINED IN TEXT
100 0 100 200 300 400 500 600 Feet
N
TETRA TECH NUS, INC.
PROPOSED BEDROCK SAMPLE LOCATIONS
BASEWIDE BACKGROUND STUDY
NAVAL STATION NEWPORT
NEWPORT, RHODE ISLAND
FILE
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FIGURE NUMBER
FIGURE 3-2
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standard rock description methods in accordance with TtNUS SOP No. GH-1.3. At a minimum, the following information will be documented:

- Date of activity, name of person(s) overseeing activity
- Project name, project number, boring number, core run number, footage (depths)
- Percent recovery, rock quality designation (RQD %), rock type, color, extent of weathering and fracturing, and features such as contacts, grain size, sedimentary structures, and degree of cementation (where applicable)
- Rockcore Box number and total number of boxes for that boring (Example: Box 1 of 2)

For each bedrock boring, the field geologist will select the specific depth intervals to be sampled and shipped for laboratory analysis of metals, based on visual inspection of the bedrock cores. At least 10, but no more than 20, bedrock samples will be collected from each boring, depending on the range of bedrock variability (in terms of rock type [e.g. shale, schist, etc.] color, texture, etc.) observed in the cores. For each bedrock sample collected, a photograph will be taken of the applicable section of rock core, and the photograph will be documented with the applicable rock sample number. In addition, each rock sample to be shipped for analysis will be noted and described on the boring log as to sample number, rock type, features (grain size, color, etc.), etc.

All non-disposable sampling equipment will be decontaminated prior to each use, as described in Section 3.4. Borehole locations will be photo-documented and surveyed using GPS survey equipment with sub-meter horizontal accuracy, and boreholes will be abandoned by filling with neat cement or neat cement grout in accordance with TtNUS SOP GH-2.9 and State of Rhode Island guidance (RIDEM, 2005).

A total of 20 to 40 bedrock samples, two to four field duplicates, one field blank, and one rinsate blank will be collected. Appropriate chain of custody procedures will be followed (see Section 4.4.2) and samples will be labeled, packaged and shipped according to TtNUS SOP SA-6.1 (see Appendix B). Analytical parameters, sample preservation requirements, required sample containers, and a summary of quality control samples are presented in Section 4.

Bedrock samples will be analyzed for TAL metals only. Analyses will be performed by a laboratory subcontracted to TtNUS. The analytical laboratory will provide data within 21 calendar days of sample receipt. Data will be validated using EPA Tier II validation. Validation memoranda will be provided to the TtNUS project manager for review, and the data will be supplied in database format for statistical analysis and inclusion into the NAVSTA Newport IR Program EGIS.

3.4 DECONTAMINATION

The decontamination procedures described in this section were prepared in accordance with TtNUS SOP No. SA-7.1. All non-disposable equipment that will come in contact with the media to be sampled will require decontamination. If the equipment is new, the initial cleaning will consist only of a soapy water wash followed by a tap water and distilled water rinse. Sterile disposable sampling materials, which are individually packaged from the factory, will not require decontamination before sampling.

All down-hole drilling and sampling equipment and tools will be high-pressure steam-cleaned prior to the initiation of drilling activities. Initial cleaning will take place before mobilization or at a decontamination pad to be constructed at the site. In addition, for bedrock borings, any down-hole tools (augers, core barrels, etc.) that are used in the first bedrock boring and need to be reused in the second bedrock boring will be pressure-washed or steam-cleaned between the two borings.

Non-disposable sampling equipment that comes in contact with the sample medium will be decontaminated to prevent cross-contamination between sample points. This includes equipment such as DPT samplers and drive points, soil sampling spatulas, and stainless steel bowls. The following decontamination sequence will be employed:

1. Remove gross contamination by scrubbing with potable water
2. Alconox or Liquinox detergent wash
3. Rinse with potable water
4. Rinse with deionized water
5. Rinse with pesticide-grade Isopropyl alcohol
6. Rinse with deionized water
7. Air dry (to extent possible)
8. Wrap with aluminum foil, dull side toward equipment, for storage

4.0 QUALITY ASSURANCE/QUALITY CONTROL PLAN

This section provides technical guidelines and procedures for maintaining an appropriate level of quality for data to be collected during the proposed field work. The pertinent TtNUS SOPs for activities discussed in Section 3.0 are included in this work plan as Appendix B.

The sampling objective is to provide sufficient data to establish background concentrations for inorganic compounds, relative to the NAVSTA IR sites. Achieving this objective requires that the data collected from the field conform to an appropriate level of quality. The quality of a data set is measured by certain characteristics of the data, namely the precision and accuracy, representativeness, completeness, and comparability (PARCC) parameters. Some of the parameters are expressed quantitatively, while others are expressed qualitatively. The PARCC goals for a particular project are determined by the intended use of the data, defined as a part of the DQOs. DQOs are discussed in Section 2.2; the PARCC parameters are discussed below.

4.1 PARCC PARAMETERS

The PARCC goals for the work covered by this quality assurance plan are discussed in the following sections.

4.1.1 <u>Precision and Accuracy</u>

The degree of field and laboratory precision and accuracy can affect the attainment of project objectives, particularly when compliance with established criteria is based on laboratory analysis of environmental samples.

Analytical precision and accuracy will be evaluated upon receipt of the analytical data. Analytical precision will be measured as the relative percent difference from duplicate measurements and relative standard deviation from three or more replicates. Analytical accuracy measures the bias as the percent recovery from matrix spike and matrix spike duplicate samples.

Field sampling precision and accuracy are not easily measured. Field contamination, sample preservation, and sample handling will affect precision and accuracy. By following the appropriate TtNUS SOP, precision and accuracy errors associated with field activities can be minimized. Field duplicates and blanks (field and rinsate) will be used to estimate field sampling precision and accuracy for soil and rock samples submitted for laboratory analysis.

Analytical results from field duplicates and field quality control blanks will be evaluated to determine the usability of all analytical data, with respect to its intended use. In general, results that are rejected by the data review process will be disqualified from application to the intended use. Qualified data will be used to the greatest extent practicable.

4.1.2 Representativeness

Representativeness describes the degree to which analytical data accurately and precisely define the population being measured. Several elements of the sampling and sample handling process must be controlled to maximize the representativeness of the analytical data: appropriate number of samples collected, physical state of the samples, site-specific factors, sampling equipment, containers, sample preservation and storage, holding times, sample identity, and chain of custody will be defined to ensure that the samples analyzed represent the population being measured. This sampling program is designed to provide analytical data that is representative of the existing background levels of metals.

Representativeness of data is also affected by sampling techniques. Sampling techniques are described in Section 3.0 and Appendix B.

4.1.3 Completeness

Completeness describes the amount of data generated that meets the objectives for precision, accuracy, and representativeness versus the amount of data expected to be obtained. For relatively clean, homogeneous matrices, 100 percent completeness is expected. However, as matrix complexity and heterogeneity increase, completeness may decrease. Where analysis is precluded or where data quality objectives are compromised, effects on the overall investigation must be considered. Whether or not any particular sample is critical to the investigation will be evaluated in terms of the sample location, the parameter in question, the intended data use, and the risk associated with the error.

The sampling and analysis program for the study is sufficiently broad in scope to prevent a single data point or parameter from jeopardizing attainment of the study’s objectives. However, critical data points may be identified after all the analytical results are evaluated. Additionally, several sampling points, in aggregate, may be considered to be critical, either by location or by analytical results. A subsequent sampling event may be necessary if it becomes apparent that the data are of insufficient quality, either with respect to the number of samples or based on an individual sample results.

For the purposes of this effort, a data point will be determined to contribute to the completeness of the data set if the information provided is meaningful, useful, and contributes to the project objectives.

4.1.4 Comparability

One of the objectives of the sampling effort is to provide analytical data that is characterized by a level of quality that is comparable between sampling points. By specifying the use of standard analytical procedures, as well as standardizing field sampling procedures by employing TtNUS and others SOPs, the potential for variables to affect the final data quality will be effectively minimized. Analytical methods for this work are presented in Table 4-1; SOPs appear in Appendix B.

4.2 QUALITY CONTROL SAMPLES

Quality Control (QC) samples to be used during the sampling effort are identified below, and include field duplicates or replicates, laboratory duplicates or replicates, rinsate blanks, and field blanks. Each type of field quality control sample defined below will undergo the same preservation, holding times, etc., as the field samples. Table 4-1 presents a summary of the QC samples to be collected during this field sampling event.

4.2.1 Field Duplicates

Field duplicates will be submitted at the rate of one for every ten samples, or at a rate greater than one per ten samples if fewer than ten are shipped to the laboratory on a given day. Field personnel will note on the sample summary form and in the logbook which samples are field duplicates. Duplicate samples will be shipped blind to the laboratories, and shipping paperwork will be completed accordingly.

4.2.2 Rinsate Blanks

Rinsate blanks are obtained under representative field conditions by running analyte-free deionized water through sample collection equipment after decontamination, immediately before sampling, and placing it in the appropriate sample containers for analysis. These samples are used to assess the effectiveness of decontamination procedures. Rinsate blanks will be prepared at the rate of one per week per sampling procedure.

4.2.3 Field Blanks

Field blanks will consist of the source water used in decontamination (includes analyte-free deionized water, potable water from each source, and other waters used in decontamination operations). Field blanks will be prepared at the rate of one per source of water.

TABLE 4-1

ANALYTICAL METHODS AND SAMPLE SUMMARY
BASEWIDE BACKGROUND STUDY
NAVSTA NEWPORT
NEWPORT, RHODE ISLAND

MEDIA	ANALYSIS	METHOD	FIELD SAMPLES	DUPLICATES	RINSATE BLANKS	FIELD BLANKS
Ma Surface Soil	TAL Metals	6010B/7471A	20	2	(1)	(2)
Ma Subsurface Soil	TAL Metals	6010B/7471A	20	2	(1)	(2)
Mm Surface Soil	TAL Metals	6010B/7471A	20	2	(1)	(2)
Mm Subsurface Soil	TAL Metals	6010B/7471A	20	2	(1)	(2)
Ne Surface Soil	TAL Metals	6010B/7471A	18	2	(1)	(2)
Ne Subsurface Soil	TAL Metals	6010B/7471A	20	2	(1)	(2)
Pm Subsurface Soil	TAL Metals	6010B/7471A	20	2	(1)	(2)
Se Subsurface Soil	TAL Metals	6010B/7471A	20	2	(1)	(2)
Ba Surface Soil	TAL Metals	6010B/7471A	20	2	(1)	(2)
Ba Subsurface Soil	TAL Metals	6010B/7471A	20	2	(1)	(2)
Bedrock: Purgatory Conglomerate	TAL Metals	TBD	20	2	(1)	(2)
Bedrock: Rhode Island Formation	TAL Metals	TBD	20	2	(1)	(2)
NP Subsurface Soil	Aluminum, iron, arsenic	6010B	10	1	(1)	(2)
		TOTAL QUANTITY	248	25	5(est)	3(est)

(1) One rinsate blank per week per sampling procedure
(2) One field blank for each decontamination water source (e.g. deionized water, potable water, and water in driller's storage tank)
est estimated
TBD To be determined.

4.2.4 Trip Blanks

Trip blanks will not be prepared or analyzed for this sampling activity since volatile organic compound (VOC) analysis is not being conducted.

4.2.5 Matrix Spike/Matrix Spike Duplicates

A matrix spike sample will be identified by field teams at a frequency of 1 in 20 field samples collected.

4.3 SAMPLING PROCEDURES

Field sampling will be conducted in accordance with Section 3.0 of this document and the TtNUS SOPs presented in Appendix B. Allowable sample holding times and preservation requirements are shown in Table 4-2.

4.4 SAMPLE DESIGNATION AND CUSTODY

Samples will be tracked by a designated sample number for each, and by the date collected. The sample number will be the basis for maintaining chain of custody. The sample numbering system is described below.

4.4.1 Sample Numbering

Samples will be labeled as soon as they are collected. Soil and bedrock sample numbers will reflect the site project identification, sample medium, sample location, and depth interval. An alpha-numeric numbering system will be used to describe this information. This system is detailed in Table 4-3.

The site identifier for the basewide background investigation will be “BW”, and the project identifier will be “BK” for “background”. The sample medium designation will be “SS” for surface soil, “SB” for subsurface soil, “BR” for bedrock. Sample locations will be identified by the two-letter soil type or rock formation abbreviation, followed by the location number to be determined in the field. (Rock samples within each of the two formation borings will be numbered consecutively, as collected and mapped). For soils, sample depth will be indicated by expressing the actual depth interval. For example, a surface soil sample collected from location 01 within the SE sampling area at a depth interval of zero to one foot will be identified as: BWBK-SS-SE01-0001. For rock samples within each borehole the core number will be

TABLE 4-2

SAMPLE CONTAINER, PRESERVATION, AND HOLDING TIME REQUIREMENTS
BASEWIDE BACKGROUND STUDY
NAVSTA NEWPORT
NEWPORT, RHODE ISLAND

MEDIA	ANALYSIS	SAMPLE CONTAINER[1]	PRESERVATIVE	HOLDING TIME
Soil	TAL Metals	4 oz. wide-mouth jar	cool to 4°C	7 days
Rock	TAL Metals	4 oz. wide-mouth jar	cool to 4°C	7 days

[1] Sample containers shall meet specifications delineated in EPA OSWER Directive No. 9240.0-05A.

TABLE 4-3

SAMPLE NUMBERING GUIDELINES
BASEWIDE BACKGROUND STUDY
NAVSTA NEWPORT
NEWPORT, RHODE ISLAND

AAAA – (Site Identifier/Project)	**AA-** (Medium)	**AANN –** (Location Identifier)	**NNNN** (Sample Depth in feet below ground surface) Rock or Core Number for rock samples
BWBK	SS, SB, BR	Soils: MA##, MM##, etc. Bedrock: PC### or RI##	Soils: #### Bedrock: C# or C##

indicated (e.g. C1, C2, etc.). For example, if the third rock sample to be collected from the Rhode Island Formation was from rock core number 2, the sample would be identified as: BWBK-BR-RI03-C2.

Blind duplicate samples will be designated such that the location designation will be replaced with a chronological number, as shown below. The location designation for the duplicate sample will be recorded on the field sample data form to ensure the duplicate pair can be identified.

Duplicates: BWBK-SS-DUP##

Field blanks will be designated such that they can clearly be identified as field blanks. The designation will include the field blank identifier (FB) and its chronological number. The source of water for the field blank (DIUF water or potable water source) will also be included in the sample designation as well as recorded on the field sample data forms, to ensure that the sample can be tracked to its source.

Field Blanks: BWBK-A-DIUF-FB##

Rinsate blanks will be identified using a chronological number. The rinsate blank identifier (RB) and its chronological number and the sample tool used will be recorded on the field sample data form. "A" is for aqueous.

Rinsate Blanks: BWBK-A-RB##

Matrix spike samples are labeled with their appropriate routine sample identifier, and then marked as "matrix spike" on the sample containers and on the chain of custody record.

4.4.2 Sample Chain of Custody

Custody of samples must be maintained and documented at all times. To ensure the integrity of a sample from collection through analysis, an accurate written record is necessary to trace the possession and handling of the sample. This documentation is referred to as the "chain of custody". Chain of custody begins when samples are collected in the field, and is maintained by storing the samples in secure areas until custody can be passed on. All samples will be accompanied by a chain of custody form that will list the analytical parameters and the persons who are responsible for their integrity.

Once collected, samples will be placed on ice and attended by TtNUS personnel or placed in locked vehicles or designated storage areas until analysis or shipment to an off-site laboratory. Chain-of-custody procedures are described in further detail in the SOPs presented in Appendix B.

4.5 CALIBRATION PROCEDURES

Field equipment normally requiring calibration will be calibrated and operated in accordance with the manufacturer's instructions and manuals. A log will be kept onsite, documenting the periodic calibration results for each field instrument.

Calibration procedures for laboratory equipment used in the analysis of environmental samples will be performed in accordance with NFESC requirements and contract requirements under the Master Agreements (MA).

4.6 LABORATORY ANALYSIS

Soil and rock samples will be analyzed for TAL metals only except for the Anchorage and Coddington Cove and housing areas, as stated in previous sections and listed in Table 4-1. The environmental samples collected for laboratory analysis during the field investigation will be analyzed by a laboratory previously approved by the Navy. Standard analytical procedures will be employed, as listed in Table 4-1.

4.7 DATA REDUCTION, REVIEW, AND REPORTING

Laboratory analytical data will be reviewed by qualified TtNUS technical staff. Data review memoranda will be prepared and submitted to the project manager as a part of that activity. Data assessment procedures are described in Section 4.11.

Field data will be periodically reviewed by technical lead personnel and the TtNUS PM to ensure that the data collected is well documented, clearly described, and meets a standard appropriate for the investigation and its ultimate use.

4.8 INTERNAL QUALITY CONTROL

Section 4.2 discussed the types and frequency of QC samples that will be prepared during the field investigation activities for those samples that undergo laboratory analysis. The estimated quantities of various types of QC samples are shown in Table 4-1. Laboratory analysis will follow the QC criteria described in the analytical procedures.

4.9 SYSTEM AUDITS

System audits will be performed as appropriate to ensure that the work is being implemented in accordance with this work plan and the pertinent SOPs, and in an overall satisfactory manner.

- The FOL will supervise and conduct daily monitoring to ensure that the sampling equipment is thoroughly decontaminated, samples are collected and handled properly, and the field work is accurately and neatly documented.

- The data reviewer(s) will review the data to ensure it was obtained through the approved methodology, and that the appropriate levels of QC effort and reporting were conducted. The data review effort will be supervised by the TtNUS CLEAN Quality Assurance Manager or designee.

- The TtNUS PM will oversee the FOL and data reviewer, and check that management of the acquired data proceeds in an organized and expeditious manner.

4.10 PREVENTATIVE MAINTENANCE

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

- The equipment manager or supplier maintains an inventory of the equipment by model and serial number, quantity, and condition. Each item of equipment is signed out when in use, and its operating condition and cleanliness is checked upon return.

- The equipment manager or supplier conducts routine checks on the status of equipment and is responsible for stocking spare parts and for equipment readiness.

- The equipment manager or supplier maintains the equipment manual library and trains field personnel in the proper use and care of equipment.

- The FOL is responsible for ensuring that the equipment is tested, cleaned, charged, and calibrated in accordance with the manufacturer's instructions before being taken to the job site.

- While the equipment is in the field, the FOL takes responsibility for the equipment, maintains calibration records, and performs or delegates maintenance operations and checks.

4.11 DATA ASSESSMENT PROCEDURES

The following paragraphs describe the procedures used to evaluate data prior to description and inclusion in the deliverable report, described in Section 6.0 of this work plan.

4.11.1 Representativeness, Accuracy, and Precision

All laboratory data generated in the investigation will be assessed for representativeness, accuracy, and precision, as described in Section 4.1. The completeness of the data will also be assessed by comparing the acquired data to the project objectives to see that these objectives are being met.

The PARCC parameter assessment will be conducted by qualified TtNUS personnel. The representativeness of the data will be assessed by determining if the data are consistent with known or anticipated chemical conditions and accepted principles.

Field measurements will be checked for completeness and documentation of procedures and results.

Precision and accuracy will be determined using replicate samples, and blank and spiked samples, respectively. PARCC parameters are addressed in more detail in Section 4.1.

4.11.2 Analytical Data Validation

Samples will be analyzed for metals, as listed on Table 4-1. Results will be validated using a Tier II validation protocol as specified in the "National Functional Guidelines for Organic/Inorganic Data Review" (U.S. EPA December 1990, revised February 1994 [organic] and February 1993 [inorganic]). Use of these validation protocols is allowed under the Naval Facilities Engineering Service Center (NFESC) (formerly NEESA) guidelines and is described in the Navy Installation Restoration Laboratory Quality Assurance Guide, Interim Document (revised February 1996), and the NEESA 20.2047B, June 1988 guidelines.

This level of validation is appropriate for data used to perform quantitative risk evaluations under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

4.12 CORRECTIVE ACTION

The Quality Assurance (QA) program will enable problems to be identified, controlled, and corrected. Potential problems may involve non-conformance with the SOPs and/or analytical procedures established for the project, or other unforeseen difficulties. Any person identifying an unacceptable condition will notify the FOL and the PM. The PM, with the assistance of the Quality Assurance Manager and the project QA/QC officer, will be responsible for developing and initiating appropriate corrective action and verifying that the corrective action has been effective.

Corrective actions may include re-sampling and/or re-analysis of samples or modifying project procedures. If warranted by the severity of the problem (for example, if a change in the approved work plan is required), the Navy will be notified in writing and their approval will be obtained prior to implementing any change. Additional work that is dependent on a nonconforming activity will not be performed until the source of the problem has been identified and addressed.

4.13 DOCUMENTATION

A bound/weatherproof field logbook will be maintained by the FOL. The FOL or designee will record pertinent information related to sampling or field activities. This information may include sampling time, weather conditions, unusual events, field measurements, description of photographs, etc. The site logbook maintained by the FOL will contain a summary of each day's activities and will reference the other field logbooks, when applicable.

Some field documentation will be recorded on sample chain of custody forms, sample collection log sheets, boring log sheets, site entry logs, and other field forms. Examples of these forms are provided in Appendix C. At completion of the field work, this information will be bound and incorporated into the project files.

5.0 DATA ANALYSIS AND STATISTICAL TESTING

Upon completion of the work described in Sections 3 and 4, the data will be analyzed to characterize background conditions using the approach presented in the Navy's *Guidance for Environmental Background Analysis, Volume 1: Soil* (NFEC, 2002). The assessment techniques presented in the Navy guidance document closely follow the USEPA's *Guidance for the Data Quality Objectives Process* (USEPA, 2000a) and *Guidance for Data Quality Assessment: Practical Methods for Data Analysis* (USEPA, 2000b). The Navy's approach starts with a review and assessment of the data for exploratory analysis purposes. The data review and assessment process that is described below in Sections 5.1 and 5.2 results in estimates of background concentration ranges for each metal and soil type. In addition, ratios of trace metal/iron and trace metal/aluminum concentrations will be calculated, as described in Section 5.3. The background concentration range and ratio information will be used to make future comparisons with IR site data. If a metal is found in soils at an IR site, at an elevated concentration that does not fit its background concentration range or ratios, a chemical release should be suspected.

Elevated soil metals concentrations and ratios at an IR Site will also be evaluated on the basis of the biologic, geologic, and geochemical characteristics of the site, because elevated concentrations and/or ratios are not definitive proof of a release. For example, elevated arsenic concentrations in soils could be caused by localized occurrences of organic material (natural or anthropogenic) that create a local reducing environment. The reducing conditions would not mobilize all of the metals in the soil equally and could result in a preferential accumulation of arsenic along the leading edge of the reducing front. In this case, the elevated arsenic concentrations and/or ratios in soils at an IR site may be due to the occurrence of a peat lens or a fuel release – not necessarily a release of arsenic.

5.1 PRELIMINARY STEPS

The first step in the data review and assessment process is to review the available data to avoid collecting information that is not needed for the background analysis. The seven-step DQO planning process outlined in Section 2.2 was used to determine the type, quantity, and quality of data needed to support the decision-making process.

The second step in the process is to pre-treat the metal concentration results prior to conducting statistical tests. For censored data sets (i.e. data sets that contain nondetects), a value of one-half the sample quantitation limit will be assigned to nondetected (U or UJ qualified) results. Duplicate samples will be averaged together and considered as one result provided that data validation determines that the results are in reasonable agreement and can be accepted. For duplicates, where one result is positive and the other result is a nondetect, the problem of calculating an average arises whenever half the detection limit exceeds the positive result. In these situations, only the positive result will be used without averaging.

The third step is to evaluate background data sets for potential outliers. The data for metals concentrations in soils will be posted on base maps to look for anomalies in the spatial distribution of each metal. Potential outliers will be checked for calculation or reporting errors and analytical bias, and then will be checked for any pattern of localized, anthropogenic contamination that is not representative of the background area as a whole. Any potential outliers that cannot be eliminated or corrected due to proven causes of systematic error will be subjected to statistical outlier testing using either the Dixon test or the Rosner test (Table 5-1).

The fourth step is to determine which, if any, data sets for a given metal can be combined (i.e. can the surface and subsurface data for a given soil type be combined, or can data sets for different soil types be combined?). Statistically similar data sets may be merged, because the use of composite data will result in a lower chance of overlooking any significant difference that might exist in future comparisons between IR site and background populations (i.e. better statistical power). The applicable methods and tests listed below will answer the following questions: Are the distributions of both subgroups normal or lognormal in shape? Is the mean or median of one group higher than the other, and are there differences in the right tails (largest values) of the subgroup distributions?

Data sets will be compared using the following tests, as applicable:

- The Shapiro-Wilk test for determining normality/lognormality
- The student's t test for evaluating differences in the means of the two data sets, provided both sets have normal distributions and equal variances
- The Satterthwaite two-sample t test for evaluating differences in the means of the two data sets, provided both sets have normal distributions, no nondetects, and unequal variances
- The Wilcoxon Rank Sum test for evaluating differences in the medians of the two data sets
- The Gehan test for evaluating differences in the medians of the two data sets (if nondetects have multiple detection limits)
- The slippage test for evaluating differences in the largest values of the two data sets
- The quantile test for evaluating differences in the largest values of the two data sets
- The two-sample test of proportions for evaluating differences in the proportions of the two data sets above a given cut-off level

TABLE 5-1

ASSUMPTIONS, ADVANTAGES, AND DISADVANTAGES OF OUTLIER TESTS
BASWIDE BACKGROUND STUDY
NAVSTA NEWPORT
NEWPORT, RHODE ISLAND

Test Statistic	Assumptions	Advantages	Disadvantages
Dixon Test	• n <25 • Measurements are representative of the underlying population. • The measurements without the suspect outlier are normally distributed; otherwise, consult a statistician. • Test can be used to test for either one suspect large outlier or one suspect small outlier. The latter case is not considered here as it is not of interest for determining COPCs.	• Very simple to conduct the test.	• Test should be used for only one suspected outlier. Use the Rosner test if multiple suspected outliers are present. • Must conduct a test for normality on the dataset after deleting the suspect outlier and before using the Dixon test.
Rosner Test	• n $\geq$25 • Measurements are representative of underlying population. • The measurements without the suspected outliers are normally distributed; otherwise, consult a statistician.	• Can test for up to 10 outliers.	• Must conduct a test for normality after deleting the suspected outliers and before using Rosner test. • Computations are more complex than for Dixon test.

Source: NFEC, 2002.

TABLE 5-2

ASSUMPTIONS, ADVANTAGES, AND DISADVANTAGES OF NORMALITY TEST
BASEWIDE BACKGROUND STUDY
NAVSTA NEWPORT
NEWPORT, RHODE ISLAND

Test Statistic	Assumptions	Advantages	Disadvantages
Shapiro-Wilk Test	• n $\leq$ 50	• Powerful test for determining whether data have a normal or lognormal distribution.	• May not have sufficient power to detect non-normality if distribution is only slightly different than normal distribution, or if number of data in data set is too small.

Source: NFEC, 2002.

TABLE 5-3

ASSUMPTIONS, ADVANTAGES, AND DISADVANTAGES OF STATISTICAL TESTS TO DETECT DIFFERENCES BETWEEN TWO DATA SETS
BASEWIDE BACKGROUND STUDY
NAVSTA NEWPORT
NEWPORT, RHODE ISLAND

Test Statistic	Objectives/Assumptions	Advantages	Disadvantages
Slippage Test	• Objective is to test for differences in the right tail (largest values) of the surface and subsurface concentration distributions. • More less-than values are allowed than for other tests considered here. • At least one detected (quantified) back-ground measurement is present and it is larger than the largest less-than value. • No assumptions are required with regard to the shape of the two concentration distributions.	• Very simple to conduct the test. • No distribution assumptions are necessary. • Many less-than values are permitted. • Can be used in conjunction (in tandem) with tests that focus on the detecting differences in the mean or median.	• May require large number of measurements to have adequate power to detect differences in surface and subsurface concentrations.
Quantile Test	• Objective is to test for differences in the right tail (largest values) of the surface and subsurface concentration distributions. • Less-than values are not among the largest r data values in the pooled set of surface and subsurface concentration data. • No assumptions are required with regard to the shape of the two distributions.	• Relatively simple to conduct the test. • No distribution assumptions are necessary. • Can have more power to detect differences in the right tail of surface and subsurface distributions than tests like the WRS, Gehan, or two-sample t tests that focus on the mean or median. • Can be used in conjunction (in tandem) with tests that focus on detecting differences in the mean or median.	• May require large number of measurements to have adequate power to detect differences in surface and subsurface concentrations. • Test may be inconclusive if less-than values are pres-ent among the largest r data values.
Wilcoxon Rank Sum (WRS) Test	• Objective is to test for differences in the medians of the surface and subsurface populations. • Only one detection limit (all less-than values have the same value), which is less than the smallest detected datum. • No more than 40% of both data sets are less-than values. • The surface and subsurface concentra-tion distributions have the same shape (variance).	• No distribution assumptions necessary. • In general, the test has more power to detect shift in median than the two-sample t tests when both data distributions are asymmetric (skewed to the right). • Can be used in conjunction with Slippage and Quantile tests so that differences in the right tails of the distributions, as well as differences in medians, can be detected	• Too many less-than values prevent use of the test.
Gehan Test	• Objective is to test for differences in the medians of the surface and subsurface populations. • Less-than values do not have the same value (multiple detection limits exist). • The censoring mechanism that generated the less-than values is the same for both populations. • No assumptions are required with regard to the shape of the concentration distributions.	• Can be used when multiple detection limits are present. • Same advantages as for the WRS test.	• The performance of the test is not known as well as that of the WRS test. • Must assume the same censoring mechanisms apply to the surface and subsurface data.

TABLE 5-3

ASSUMPTIONS, ADVANTAGES, AND DISADVANTAGES OF STATISTICAL TESTS TO DETECT DIFFERENCES BETWEEN TWO DATA SETS
BASEWIDE BACKGROUND STUDY
NAVSTA NEWPORT
NEWPORT, RHODE ISLAND

Test Statistic	Objectives/Assumptions	Advantages	Disadvantages
Two-Sample Test of Proportions	• Objective is to test for differences in the proportions of the surface and subsurface data above a given cutoff level. • Test may be used when more than 50% of the surface or subsurface data sets are less-than values. • No assumptions are required with regard to the shape of the two concentration distributions.	• No distribution assumptions are necessary. • Relatively simple test to perform. • Can be used when many less-than values are present.	• A test based on proportions may not be what is really needed (e.g., it may be more appropriate to test for differences in means or medians).
Two-Sample t Test	• Objective is to test for differences in the means of the surface and subsurface populations. • Both surface and subsurface mean concentrations are normally distributed. • Less-than values have no significant impact on computed means (e.g., less than 15% of measurements are below detection). • Both distributions have the same shape (variance).	• Most powerful test for detecting a shift in the mean, if the surface and subsurface data are normally distributed.	• The test requires a statistical evaluation of the assumption of equal total variances for the surface and subsurface populations. • In general, the power will be less than that of the WRS test, if the data are not normally distributed. • Normal distribution assumption is often violated. • The results of the test can be affected by outliers. • Not well suited for data sets that contain less-than values.
Satterthwaite Two-Sample t Test	• Objective is to test for differences in the means of the surface and subsurface populations. • Both data sets have a normal distribution. • No less-than values are present. • Both distributions are expected or known to not have the same shape (variance).	• Test can be used when the surface and subsurface distributions have unequal variances.	• Same disadvantages as for the two-sample t test.

Source: NFEC, 2002.

The means of both subgroups will be compared if both data sets match a normal distribution. If the data sets exhibit equal standard deviations (based upon Bartlett's test for equal variances), then the student's t-test will be applied; otherwise, Satterthwaite's t-test will be performed. The t-test is valid only if: at least 85 percent of each data set contains positive detects; there are at least three sampling points in each dataset; and the pooled standard deviation is not zero. The assumptions, advantages, and disadvantages of the tests listed in this section are presented in Tables 5-1 and 5-3.

5.2 EXPLORATORY DATA ANALYSIS

Each set of metal concentration data will be evaluated using a series of statistical tools designed to determine probability distributions, descriptive statistics, and background concentration ranges.

5.2.1 Analyze Population Distributions

The underlying statistical distribution of each data set will be determined using the Shapiro-Wilk W-test. Normally distributed data exhibit a characteristic "bell-shape" curve that is symmetrical, whereas lognormal data have a skewed shape with a longer tail at the high-concentration end. The W-test will be performed twice – first using the original data, and then using the logarithms of the data. A five percent level of significance will be used to determine whether or not the data deviate from either hypothesized distribution. Data sets that conform to a normal or lognormal distribution will be evaluated with parametric statistical tests whenever possible. Data that are non-normally distributed will be evaluated solely with non-parametric tests.

5.2.2 Summarize Descriptive Statistics

Descriptive statistics will be used to quantify key attributes of each data set's distribution (e.g., its range, central tendency, and variability). The methods used to compute descriptive statistics are based on the distribution shape, number of nondetects, and total number of measurements. Calculated statistics will include the range, interquartile range, median, arithmetic mean, geometric mean, standard deviation, variance, coefficient of variation, skewness, and/or kurtosis. Alternative methods for estimating the mean and standard deviation (Table 5-4) may be used if a data set contains a large number of nondetects.

5.2.3 Graph Data

Histograms, box plots, and probability plots will be constructed for each data set in order to visually depict differences between distributions and identify background concentration ranges for target metals.

TABLE 5-4

DESCRIPTIVE STATISTICS WHEN 15% TO 50% OF THE DATA SET ARE NONDETECTS
BASEWIDE BACKGROUND STUDY
NAVSTA NEWPORT
NEWPORT, RHODE ISLAND

Method	Assumptions	Advantages	Disadvantages
Median	• The largest nondetect is less than the median of the entire dataset (detects + nondetects); that is, there are no nondetects in the upper 50% of the measurements.	• Very simple to conduct the test.	• The median cannot be determined if the assumption is not true.
100p% Trimmed Mean	• All nondetects have the same detection limit. • All detects are larger than the detection limit. • The number of nondetects is no more than np. • The underlying distribution of measurements is symmetric (not skewed).	• Trimmed mean is not affected by outliers that have been trimmed from the dataset.	• Cannot be used if the assumptions are not true.
Winsorized Mean	• $0 < p < 0.50$ • All nondetects have the same detection limit. • All detects are larger than the detection limit. • The underlying distribution of measurements is symmetric (not skewed).	• Winsorized mean is not affected by outliers that are among the largest measurements.	• Cannot be used if the assumptions are not true.
Winsorized Standard Deviation	• All nondetects have the same detection limit. • All detects are larger than the detection limit. • The underlying distribution of measurements is symmetric (not skewed). • The quantity v must be greater than 1.	• If the measurements are normally distributed, then confidence intervals for the mean can be computed.	• Cannot be used if the assumptions are not true.
Cohen Method for the Mean and Standard Deviation	• All nondetects have the same detection limit. • The underlying distribution of the measurements is normal. • Measurements obtained are representative of the underlying normal distribution.	• Has good performance if the underlying assumptions are valid and if the number of samples is sufficiently large.	• The underlying assumptions must be valid.
pth Sample Percentile	• All nondetects have the same detection limit. • All detects are larger than the detection limit. • The computed value of k must be larger than the number of nondetects plus 1.	• Provides an estimate of the value that is exceeded by 100(1 – p)% of the underlying population.	• Cannot be computed when the assumption for k is not valid.

Source: NFEC, 2002.

Histograms are bar charts of observation percentages versus concentration range intervals that show the symmetry, peakedness, spread, and central tendency of the data distribution. Box plots are box charts of concentration data that show the quartiles, symmetry, spread, and central tendency of the data, as well as extreme data values. Probability plots are graphs of concentration data versus distribution quantiles. Probability plots will be used to identify outliers – data points that produce large gaps in the probability plot and/or deviate from the line formed by the majority of points. The plots are also used to identify separate populations within the data set. A segmented probability plot suggests multiple populations, and the inflection point(s) may indicate threshold values separating the different populations. Since these plots can reveal outliers and separate populations, they can also be used to determine background concentration ranges. The background concentration range is conservatively defined as the low concentration segment of the probability plot (NFEC, 2002 – page 36).

5.2.4 <u>Conduct Spatial Data Analysis</u>

A series of univariate plots will be created for each metal and soil type in order to support conclusions based on the probability plots. First, the metal concentration data for a given soil type will be separated into three categories: data qualifier, sampling depth, and sampling location. Then, a separate chart will be created for each category by plotting the metal concentration data versus the category variables. Finally, the univariate and probability plots for a given metal and soil type will be posted side-by-side using a common y-axis scale to visualize the spatial distribution of the metal in the soil and to evaluate background concentration ranges in terms of physical, geochemical and statistical principles.

The univariate plot of metal concentration versus NQ, J, U, and UJ qualifier will provide a profile of the overall quality of the data. The plot of metal concentration versus sampling depth (surface or subsurface) should show that subsurface soil concentrations are similar to or higher than surface soil concentrations if the concentrations represent naturally-occurring (background) levels. The concentration versus sample location plot will depict metal concentration ranges that correspond to different sampling sub-areas. Small concentration differences between sub-areas will support conclusions that all of the metal concentrations reflect background conditions.

5.3 ELEMENTAL CORRELATION

Based on geological and geochemical principles and observation, certain groups of metals tend to occur together in natural soils. For example, trace metal concentrations in soils often show a high degree of correlation with aluminum and/or iron, because the sorption of trace metals is frequently controlled by aluminosilicate clay minerals and/or iron oxide grain coatings.

The elemental correlation method is based on these natural relationships between trace metals and aluminum and iron, and it uses statistical techniques founded on geochemical principles to identify background metal concentration ranges and ratios. The first step in the analysis is to construct a scatter plot of trace metal vs. reference metal (aluminum or iron) concentrations. (A log-log scatter plot can be used if the metal concentrations are lognormally distributed.) The scatter plot provides a graphic representation of the nature and strength of the relationship between the trace metal and the reference metal.

Linear regression is used to draw a best fit line through the data points. The slope and y-intercept of the line and the confidence and prediction intervals about the line define the expected relationship between the two metals. By defining and plotting the expected relationship, outliers can be identified, and the background concentration range and ratio can be estimated.

In order to establish a reliable and defensible estimate of the background concentration range, there should be a strong geochemical relationship between two metals. The strength of the relationship is evaluated by examining the amount of data scatter around the best fit line, and it is quantified by the correlation coefficient (r). The correlation coefficient is derived from the regression coefficient (r^2) which represents the fraction of the variation in the trace metal that can be explained by the regression line.

If the relationship between the trace metal and reference metal is strong, the highest concentration that fits the linear relationship represents the estimated upper bound of the background concentration range. Moreover, if the two metals are highly correlated, their concentration ratios tend to be relatively constant.

The elemental correlation analysis results can be used in future comparisons with IR site data. Concentration ratios that fit the background relationship most likely represent background conditions. Concentrations that plot as outliers on trace metal vs. reference metal scatter plots may represent contamination.

6.0 REPORTING

Following the completion of field sampling, laboratory analysis, and data analysis and statistical testing, the results will be presented in a final report. The report will contain the following information:

- A statement describing the purpose of the report.

- A description of the background investigation based on Section 3.0 of this work plan, and on modifications to the field work, if any.

- Preliminary statistical test results that demonstrate whether or not the data sets for a given metal are statistically similar. Tables will present the results of each statistical test, the hypotheses considered, the calculated false positive probabilities (P-values), and footnotes indicating the general assumptions and limitations that are applicable to each test.

- A summary of the exploratory data analysis results for each metal and soil/rock type. The summary will include a table of the descriptive statistics and distribution fit test results for each soil/rock type, as well as histograms, box plots, univariate plots, and probability plots.

- A summary of the elemental correlation analysis for each metal and soil/rock type. The summary will include a table of metal concentration ratios for each soil/rock type, as well as scatter plots with regression results.

- An interpretation of the estimated background concentration ranges for each metal and soil/rock type. Supporting information will include the results of outlier analyses, interpretations of bedrock sample data and its impact on metals concentrations in soils, maps depicting sampling points and other significant features, and photographs of sample locations.

- Conclusions and recommendations for use of the background soil and bedrock data.

- An appendix showing the metals analytical results for each soil and bedrock sample collected for this investigation.

- An appendix documenting the survey coordinates, with range of error for northing/easting/elevation.

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REFERENCES

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APPENDIX A

HEALTH AND SAFETY PLAN FOR SITE INSPECTIONS

“This section is intentionally omitted from this work plan”

APPENDIX B

STANDARD OPERATING PROCEDURES

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ATTACHMENTS

1.0 PURPOSE

This procedure discusses the methods used to collect surface, near surface, and subsurface soil samples. Additionally, it describes the method for sampling of test pits and trenches to determine subsurface soil and rock conditions, and recover small-volume or bulk samples.

2.0 SCOPE

This procedure is applicable to the collection of surface, near surface and subsurface soils for laboratory testing, which are exposed through hand digging, hand augering, drilling, or machine excavating at hazardous substance sites.

3.0 GLOSSARY

Composite Sample - A composite sample exists as a combination of more than one sample at various locations and/or depths and times, which is homogenized and treated as one sample. This type of sample is usually collected when determination of an average waste concentration for a specific area is required. Composite samples are not to be collected for volatile organics analysis.

Grab Sample - One sample collected at one location and at one specific time.

Non-Volatile Sample - A non-volatile sample includes all other chemical parameters (e.g., semivolatiles, pesticides/PCBs, metals, etc.) and those engineering parameters that do not require undisturbed soil for their analysis.

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

Thin-Walled Tube Sampler - A thin-walled metal tube (also called a Shelby tube) used to recover relatively undisturbed soil samples. These tubes are available in various sizes, ranging from 2 to 5 inches outside diameter (OD) and from 18 to 54 inches in length.

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

Test Pit and Trench - Open, shallow excavations, typically rectangular (if a test pit) or longitudinal (if a trench), excavated to determine the shallow subsurface conditions for engineering, geological, and soil chemistry exploration and/or sampling purposes. These pits are excavated manually or by machine (e.g., backhoe, clamshell, trencher excavator, or bulldozer).

Confined Space - As stipulated in 29 CFR 1910.146, a confined space means a space that: 1) is large enough and so configured that an employee can bodily enter and perform assigned work; 2) has limited or restricted means for entry or exit (for example tanks, vessels, silos, storage bins, hoppers, vaults, and pits, and excavations are spaces that may have limited means of entry.); and 3) is not designed for continuous employee occupancy. TtNUS considers all confined space as permit-required confined spaces.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for determining sampling objectives, as well as, the field procedures used in the collection of soil samples. Additionally, in consultation with other project personnel (geologist, hydrogeologist, etc.), the Project Manager establishes the need for test pits or trenches, and determines their approximate locations and dimensions.

Site Safety Officer (SSO) - The SSO (or a qualified designee) is responsible for providing the technical support necessary to implement the project Health and Safety Plan. This will include (but not be limited to) performing air quality monitoring during sampling, boring and excavation activities, and to ensure that workers and offsite (downwind) individuals are not exposed to hazardous levels of airborne contaminants. The SSO/designee may also be required to advise the FOL on other safety-related matters regarding boring, excavation and sampling, such as mitigative measures to address potential hazards from unstable trench walls, puncturing of drums or other hazardous objects, etc.

Field Operations Leader (FOL) - The FOL is responsible for finalizing the location of surface, near surface, and subsurface (hand and machine borings, test pits/trenches) soil samples. He/she is ultimately responsible for the sampling and backfilling of boreholes, test pits and trenches, and for adherence to OSHA regulations during these operations.

Project Geologist/Sampler - The project geologist/sampler is responsible for the proper acquisition of soil samples and the completion of all required paperwork (i.e., sample log sheets, field notebook, boring logs, test pit logs, container labels, custody seals, and chain-of-custody forms).

Competent Person - A Competent Person, as defined in 29 CFR 1929.650 of Subpart P - Excavations, means one who is capable of identifying existing and predictable hazards in the surroundings, or working conditions which are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them.

5.0 PROCEDURES

5.1 Overview

Soil sampling is an important adjunct to groundwater monitoring. Sampling of the soil horizons above the groundwater table can detect contaminants before they have migrated into the water table, and can establish the amount of contamination sorbed on aquifer solids that have the potential of contributing to groundwater contamination.

Soil types can vary considerably on a hazardous waste site. These variations, along with vegetation, can affect the rate of contaminant migration through the soil. It is important, therefore, that a detailed record be maintained during the sampling operations, particularly noting the location, depth, and such characteristics as grain size, color, and odor. Subsurface conditions are often stable on a daily basis and may demonstrate only slight seasonal variation especially with respect to temperature, available oxygen and light penetration. Changes in any of these conditions can radically alter the rate of chemical reactions or the associated microbiological community, thus further altering specific site conditions. As a result, samples must be kept at their at-depth temperature or lower, protected from direct light, sealed tightly in approved glass containers, and be analyzed as soon as possible.

The physical properties of the soil, its grain size, cohesiveness, associated moisture, and such factors as depth to bedrock and water table, will limit the depth from which samples can be collected and the method required to collect them. Often this information on soil properties can be obtained from published soil surveys available through the U.S. Geological Surveys and other government or farm agencies. It is the intent of this procedure to present the most commonly employed soil sampling methods used at hazardous waste sites.

5.2 Soil Sample Collection

5.2.1 Procedure for Collecting Soil Samples for Volatile Organic Compounds

The above described traditional sampling techniques, used for the collection of soil samples for volatile organic analysis, have recently been evaluated by the scientific community and determined to be ineffective in producing accurate results (biased low) due to the loss of volatile organics in the sampling stages and microbial degradation of aromatic volatiles. One of the newly adopted sampling procedures for collecting soil samples includes the field preservation of samples with methanol or sodium bisulfate to minimize volatilization and biodegradation. These preservation methods may be performed either in the field or laboratory, depending on the sampling methodology employed.

Soil samples to be preserved by the laboratory are currently being performed using method SW-846, 5035. Laboratories are currently performing low level analyses (sodium bisulfate preservation) and high level analyses (methanol preservation) depending on the end users needs.

It should be noted that a major disadvantage of the methanol preservation method is that the laboratory reporting limits will be higher than conventional testing. The reporting levels using the new method for most analytes are 0.5 µg/g for GC/MS and 0.05 µg/g for GC methods.

The alternative preservation method for collecting soil samples is with sodium bisulfate. This method is more complex to perform in the field and therefore is not preferred for field crews. It should also be noted that currently, not all laboratories have the capabilities to perform this analysis. The advantage to this method is that the reporting limits (0.001 µg/g for GC/PID or GC/ELCD, or 0.010 for GC/MS) are lower than those described above.

The following procedures outline the necessary steps for collecting soil samples to be preserved at the laboratory, and for collecting soil samples to be preserved in the field with methanol or sodium bisulfate.

5.2.1.1 Soil Samples to be Preserved at the Laboratory

Soil samples collected for volatile organics that are to be preserved at the laboratory will be obtained using a hermetically sealed sample vial such as an EnCore™ sampler. Each sample will be obtained using a reusable sampling handle provided with the EnCore™ sampler. The sample is collected by pushing the EnCore™ sampler directly into the soil, ensuring that the sampler is packed tight with soil, leaving zero headspace. Using this type of sampling device eliminates the need for field preservation and the shipping restrictions associated with preservatives.

Once the sample is collected, it should be placed on ice immediately and shipped to the laboratory within 48 hours (following the chain-of-custody and documentation procedures outlined in SOP SA-6.1). Samples must be preserved by the laboratory within 48 hours of sample collection.

If the lower detection limits are necessary, an option would be to collect several EnCore™ samplers at a given sample location. Send all samplers to the laboratory and the laboratory can perform the required preservation and analyses.

5.2.1.2 Soil Samples to be Preserved in the Field

Soil samples preserved in the field may be prepared for analyses using both the low-level (sodium bisulfate preservation) method and medium-level (methanol preservation) method.

Methanol Preservation (Medium Level):

Soil samples to be preserved in the field with methanol will utilize 40-60 mL glass vials with septum lids. Each sample bottle will be filled with 25 mL of demonstrated analyte-free purge and trap grade methanol. Bottles may be prespiked with methanol in the laboratory or prepared in the field.

Soil will be collected with the use of a decontaminated (or disposable), small-diameter coring device such as a disposable tube/plunger-type syringe with the tip cut off. The outside diameter of the coring device must be smaller than the inside diameter of the sample bottle neck.

A small electronic balance or manual scale will be necessary for measuring the volume of soil to be added to the methanol preserved sample bottle. Calibration of the scale should be performed prior to use and intermittently throughout the day according to the manufacturers requirements.

The sample should be collected by pulling the plunger back and inserting the syringe into the soil to be sampled. The top several inches of soil should be removed before collecting the sample. Approximately 10 grams ±2g (8-12 grams) of soil should be collected. The sample should be weighed and adjusted until obtaining the required amount of sample. The sample weight should be recorded to the nearest 0.01 gram in the field logbook and/or sample log sheet. The soil should then be extruded into the methanol preserved sample bottle taking care not to contact the sample container with the syringe. The threads of the bottle and cap must be free of soil particles.

After capping the bottle, swirl the sample (do not shake) in the methanol and break up the soil such that all of the soil is covered with methanol. Place the sample on ice immediately and prepare for shipment to the laboratory as described in SOP SA-6.1.

Sodium Bisulfate Preservation (Low Level):

Samples to be preserved using the sodium bisulfate method are to be prepared as follows:

Add 1 gram of sodium bisulfate to 5 mL of laboratory grade deionized water in a 40-60 mL glass vial with septum lid. Bottles may be prespiked in the laboratory or prepared in the field. The soil sample should be collected in a manner as described above and added to the sample container. The sample should be weighed to nearest 0.01 gram as described above and recorded in field logbook or sample log sheet.

Care should be taken when adding the soil to the sodium bisulfate solution. A chemical reaction of soils containing carbonates (limestone) may cause the sample to effervesce or the vial to possibly explode.

When preparing samples using the sodium bisulfate preservation method, duplicate samples must be collected using the methanol preservation method on a one for one sample basis. The reason for this is because it is necessary for the laboratory to perform both the low level and medium level analyses. Place the sample on ice immediately and prepare for shipment to the laboratory as described in SOP SA-6.1.

If the lower detection limits are necessary, an option to field preserving with sodium bisulfate would be to collect 3 EnCore™ samplers at a given sample location. Send all samplers to the laboratory and the laboratory can perform the required preservation and analyses.

5.2.2 Procedure for Collecting Non-Volatile Soil Samples

Non-volatile soil samples may be collected as either grab or composite samples. The non-volatile soil sample is thoroughly mixed in a stainless steel or disposable, inert plastic tray, using a stainless steel trowel or other approved tool, then transferred into the appropriate sample container(s). Head space is permitted in a non-volatile soil sample container to allow for sample expansion.

5.2.3 Procedure for Collecting Undisturbed Soil Samples (ASTM D1587-83)

When it is necessary to acquire undisturbed samples of soil for purposes of engineering parameter analysis (e.g., permeability), a thin-walled, seamless tube sampler (Shelby tube) will be employed. The following method will be used:

1. Remove all surface debris (e.g., vegetation, roots, twigs, etc.) from the specific sampling location and drill and clean out the borehole to the sampling depth, being careful to minimize the chance for disturbance of the material to be sampled. In saturated material, withdraw the drill bit slowly to prevent loosening of the soil around the borehole and to maintain the water level in the hole at or above groundwater level.

2. The use of bottom discharge bits or jetting through an open-tube sampler to clean out the borehole shall not be allowed. Use of any side-discharge bits is permitted.

3. A stationary piston-type sampler may be required to limit sample disturbance and aid in retaining the sample. Either the hydraulically operated or control rod activated-type of stationary piston sampler may be used. Prior to inserting the tube sampler into the borehole, check to ensure that the sampler head contains a check valve. The check valve is necessary to keep water in the rods from pushing the sample out the tube sampler during sample withdrawal and to maintain a suction within the tube to help retain the sample.

4. To minimize chemical reaction between the sample and the sampling tube, brass tubes may be required, especially if the tube is stored for an extended time prior to testing. While steel tubes coated with shellac are less expensive than brass, they're more reactive, and shall only be used when the sample will be tested within a few days after sampling or if chemical reaction is not anticipated. With the sampling tube resting on the bottom of the hole and the water level in the boring at groundwater level or above, push the tube into the soil by a continuous and rapid motion, without impacting or twisting. In no case shall the tube be pushed farther than the length provided for the soil sample. Allow about 3 inches in the tube for cuttings and sludge.

5. Upon removal of the sampling tube from the hole, measure the length of sample in the tube and also the length penetrated. Remove disturbed material in the upper end of the tube and measure the length of sample again. After removing at least an inch of soil from the lower end and after inserting an impervious disk, seal both ends of the tube with at least a 1/2-inch thickness of wax applied in a way that will prevent the wax from entering the sample. Clean filler must be placed in voids at either end of the tube prior to sealing with wax. Place plastic caps on the ends of the sample tube, tape the caps in place, and dip the ends in wax.

6. Affix label(s) to the tube as required and record sample number, depth, penetration, and recovery length on the label. Mark the "up" direction on the side of the tube with indelible ink, and mark the end of the sample. Complete Chain-of-Custody and other required forms (see SOP SA-6.3). Do not allow tubes to freeze, and store the samples vertically with the same orientation they had in the

ground, (i.e., top of sample is up) in a cool place out of the sun at all times. Ship samples protected with suitable resilient packing material to reduce shock, vibration, and disturbance.

Thin-walled undisturbed tube samplers are restricted in their usage by the consistency of the soil to be sampled. Often, very loose and/or wet samples cannot be retrieved by the samplers, and soils with a consistency in excess of very stiff cannot be penetrated by the sampler. Devices such as Dennison or Pitcher core samplers can be used to obtain undisturbed samples of stiff soils. Using these devices normally increases sampling costs, and therefore their use shall be weighed against the need for acquiring an undisturbed sample.

5.3 Surface Soil Sampling

The simplest, most direct method of collecting surface soil samples (most commonly collected to a depth of 6 inches) for subsequent analysis is by use of a stainless steel trowel. Surface soils are considered 0-12 inches bgs.

In general, the following equipment is necessary for obtaining surface soil samples:

- Stainless steel or pre-cleaned disposable trowel.
- Real-time air monitoring instrument (e.g., PID, FID, etc.).
- Latex gloves.
- Required Personal Protective Equipment (PPE).
- Required paperwork.
- Required decontamination equipment.
- Required sample container(s).
- Wooden stakes or pin flags.
- Sealable polyethylene bags (i.e., Ziploc® baggies).
- Heavy duty cooler.
- Ice (if required) double-bagged in sealable polyethylene bags.
- Chain-of-custody records and custody seals.

When acquiring surface soil samples, the following procedure shall be used:

1. Carefully remove vegetation, roots, twigs, litter, etc., to expose an adequate soil surface area to accommodate sample volume requirements.

2. Using a decontaminated stainless steel trowel, follow the procedure cited in Section 5.2.1 for collecting a volatile soil sample. Surface soil samples for volatile organic analysis should be collected from 6-12 inches bgs only.

3. Thoroughly mix (in-situ) a sufficient amount of soil to fill the remaining sample containers and transfer the sample into those containers utilizing the same stainless steel trowel employed above. Cap and securely tighten all sample containers.

4. Affix a sample label to each container. Be sure to fill out each label carefully and clearly, addressing all the categories described in SOP SA-6.3.

5. Proceed with the handling and processing of each sample container as described in SOP SA-6.2.

5.4 Near-Surface Soil Sampling

Collection of samples from near the surface (depth of 6-18 inches) can be accomplished with tools such as shovels and stainless steel or pre-cleaned disposable trowels.

The following equipment is necessary to collect near surface soil samples:

- Clean shovel.
- The equipment listed under Section 5.3 of this procedure.
- Hand auger.

To obtain near-surface soil samples, the following protocol shall be observed:

1. With a clean shovel, make a series of vertical cuts to the depth required in the soil to form a square approximately 1 foot by 1 foot.

2. Lever out the formed plug and scrape the bottom of the freshly dug hole with a decontaminated stainless steel or pre-cleaned disposable trowel to remove any loose soil.

3. Follow steps 2 through 5 listed under Section 5.3 of this procedure.

5.5 Subsurface Soil Sampling With a Hand Auger

A hand augering system generally consists of a variety of all stainless steel bucket bits (i.e., cylinders 6-1/2" long, and 2-3/4", 3-1/4", and 4" in diameter), a series of extension rods (available in 2', 3', 4' and 5' lengths), and a cross handle. A larger diameter bucket bit is commonly used to bore a hole to the desired sampling depth and then withdrawn. In turn, the larger diameter bit is replaced with a smaller diameter bit, lowered down the hole, and slowly turned into the soil at the completion depth (approximately 6"). The apparatus is then withdrawn and the soil sample collected.

The hand auger can be used in a wide variety of soil conditions. It can be used to sample soil both from the surface, or to depths in excess of 12 feet. However, the presence of rock layers and the collapse of the borehole normally contribute to its limiting factors.

To accomplish soil sampling using a hand augering system, the following equipment is required:

- Complete hand auger assembly (variety of bucket bit sizes).
- Stainless steel mixing bowls.
- The equipment listed under Section 5.3 of this procedure.

To obtain soil samples using a hand auger, the following procedure shall be followed:

1. Attach a properly decontaminated bucket bit to a clean extension rod and further attach the cross handle to the extension rod.

2. Clear the area to be sampled of any surface debris (vegetation, twigs, rocks, litter, etc.).

3. Begin augering (periodically removing accumulated soils from the bucket bit) and add additional rod extensions as necessary. Also, note (in a field notebook or on standardized data sheets) any changes in the color, texture or odor of the soil.

4. After reaching the desired depth, slowly and carefully withdraw the apparatus from the borehole.

5. Remove the soiled bucket bit from the rod extension and replace it with another properly decontaminated bucket bit. The bucket bit used for sampling is commonly smaller in diameter than the bucket bit employed to initiate the borehole.

6. Carefully lower the apparatus down the borehole. Care must be taken to avoid scraping the borehole sides.

7. Slowly turn the apparatus until the bucket bit is advanced approximately 6 inches.

8. Discard the top of the core (approximately 1"), which represents any loose material collected by the bucket bit before penetrating the sample material.

9. Fill volatile sample container(s), using a properly decontaminated stainless steel trowel, with sample material directly from the bucket bit. Refer to Section 5.2.1 of this procedure.

10. Utilizing the above trowel, remove the remaining sample material from the bucket bit and place into a properly decontaminated stainless steel mixing bowl and thoroughly homogenize the sample material prior to filling the remaining sample containers. Refer to Section 5.2.2 of this procedure.

11. Follow steps 4 and 5 listed under Section 5.3 of this procedure.

5.6 Subsurface Soil Sampling With a Split-Barrel Sampler (ASTM D1586-84)

Split-barrel (split-spoon) samplers consist of a heavy carbon steel or stainless steel sampling tube that can be split into two equal halves to reveal the soil sample (see Attachment A). A drive head is attached to the upper end of the tube and serves as a point of attachment for the drill rod. A removable tapered nosepiece/drive shoe attaches to the lower end of the tube and facilitates cutting. A basket-like sample retainer can be fitted to the lower end of the split tube to hold loose, dry soil samples in the tube when the sampler is removed from the drill hole. This split-barrel sampler is made to be attached to a drill rod and forced into the ground by means of a 140-lb. or larger casing driver.

Split-barrel samplers are used to collect soil samples from a wide variety of soil types and from depths greater than those attainable with other soil sampling equipment.

The following equipment is used for obtaining split-barrel samples:

- Drilling equipment (provided by subcontractor).
- Split-barrel samplers (O.D. 2 inches, I.D. 1-3/8 inches, either 20 inches or 26 inches long); Larger O.D. samplers are available if a larger volume of sample is needed.
- Drive weight assembly, 140-lb. weight, driving head and guide permitting free fall of 30 inches.
- Stainless steel mixing bowls.
- Equipment listed under Section 5.3 of this procedure.

The following steps shall be followed to obtain split-barrel samples:

1. Remove the drive head and nosepiece, and open the sampler to reveal the soil sample. Immediately scan the sample core with a real-time air monitoring instrument (e.g., FID, PID, etc.). Carefully separate the soil core, with a decontaminated stainless steel knife or trowel, at about 6-inch intervals while scanning the center of the core for elevated readings. Also scan stained soil, soil lenses, and anomalies (if present), and record readings.

2. Collect the volatile sample from the center of the core where elevated readings occurred. If no elevated readings where encountered the sample material should still be collected from the core's center (this area represents the least disturbed area with minimal atmospheric contact). Refer to Section 5.2.1 of this procedure.

3. Using the same trowel, remove remaining sample material from the split-barrel sampler (except for the small portion of disturbed soil usually found at the top of the core sample) and place the soil into a decontaminated stainless steel mixing bowl. Thoroughly homogenize the sample material prior to filling the remaining sample containers. Refer to Section 5.2.2 of this procedure.

4. Follow steps 4 and 5 listed under Section 5.3 of this procedure.

5.7 Subsurface Sol Sampling Using Direct Push Technology

Subsurface soil samples can be collected to depths of 40+ feet using direct push technology (DPT). DPT equipment, responsibilities, and procedures are described in SOP SA-2.5.

5.8 Excavation and Sampling of Test Pits and Trenches

5.8.1 Applicability

This subsection presents routine test pit or trench excavation techniques and specialized techniques that are applicable under certain conditions.

During the excavation of trenches or pits at hazardous waste sites, several health and safety concerns arise which control the method of excavation. No personnel shall enter any test pit or excavation except as a last resort, and then only under direct supervision of a Competent Person (as defined in 29 CFR 1929.650 of Subpart P - Excavations). Whenever possible, all required chemical and lithological samples should be collected using the excavator bucket or other remote sampling apparatus. If entrance is still required, all test pits or excavations must be stabilized by bracing the pit sides using specifically designed wooden or steel support structures. Personnel entering the excavation may be exposed to toxic or explosive gases and oxygen-deficient environments. Any entry may constitute a Confined Space and must be done in conformance with all applicable regulations. In these cases, substantial air monitoring is required before entry, and appropriate respiratory gear and protective clothing is mandatory. There must be at least two persons present at the immediate site before entry by one of the investigators. The reader shall refer to OSHA regulations 29 CFR 1926, 29 CFR 1910.120, 29 CFR 1910.134, AND 29 CFR 1910.146.

Excavations are generally not practical where a depth of more than about 15 feet is desired, and they are usually limited to a few feet below the water table. In some cases, a pumping system may be required to control water levels within the pit, providing that pumped water can be adequately stored or disposed. If data on soils at depths greater than 15 feet are required, the data are usually obtained through test borings instead of test pits.

In addition, hazardous wastes may be brought to the surface by excavation equipment. This material, whether removed from the site or returned to the subsurface, must be properly handled according to any and all applicable federal, state, and local regulations.

5.8.2 Test Pit and Trench Excavation

These procedures describe the methods for excavating and logging test pits and trenches excavated to determine subsurface soil and rock conditions. Test pit operations shall be logged and documented as described in SOP SA-6.3.

Test pits and trenches may be excavated by hand or by power equipment to permit detailed description of the nature and contamination of the in-situ materials. The size of the excavation will depend primarily on the following:

- The purpose and extent of the exploration.
- The space required for efficient excavation.
- The chemicals of concern.
- The economics and efficiency of available equipment.

Test pits normally have a cross section that is 4 to 10 feet square; test trenches are usually 3 to 6 feet wide and may be extended for any length required to reveal conditions along a specific line. The following table, which is based on equipment efficiencies, gives a rough guide for design consideration:

Equipment	Typical Widths, in Feet
Trenching machine	2
Backhoe	2-6
Track dozer	10
Track loader	10
Excavator	10
Scraper	20

The lateral limits of excavation of trenches and the position of test pits shall be carefully marked on area base maps. If precise positioning is required to indicate the location of highly hazardous waste materials, nearby utilities, or dangerous conditions, the limits of the excavation shall be surveyed. Also, if precise determination of the depth of buried materials is needed for design or environmental assessment purposes, the elevation of the ground surface at the test pit or trench location shall also be determined by survey. If the test pit/trench will not be surveyed immediately, it shall be backfilled and its position identified with stakes placed in the ground at the margin of the excavation for later surveying.

The construction of test pits and trenches shall be planned and designed in advance as much as possible. However, field conditions may necessitate revisions to the initial plans. The final depth and construction method shall be determined by the field geologist. The actual layout of each test pit, temporary staging area, and spoils pile will be predicated based on site conditions and wind direction at the time the test pit is made. Prior to excavation, the area can be surveyed by magnetometer or metal detector to identify the presence of underground utilities or drums.

As mentioned previously, no personnel shall enter any test pit or excavation except as a last resort, and then only under direct supervision of a Competent Person. If entrance is still required, Occupational Safety and Health Administration (OSHA) requirements must be met (e.g., walls must be braced with wooden or steel braces, ladders must be in the hole at all times, and a temporary guardrail must be placed along the surface of the hole before entry). It is emphasized that the project data needs should be structured such that required samples can be collected without requiring entrance into the excavation. For example, samples of leachate, groundwater, or sidewall soils can be taken with telescoping poles, etc.

Dewatering may be required to assure the stability of the side walls, to prevent the bottom of the pit from heaving, and to keep the excavation dry. This is an important consideration for excavations in cohesionless material below the groundwater table. Liquids removed as a result of dewatering operations must be handled as potentially contaminated materials. Procedures for the collection and disposal of such materials should be discussed in the site-specific project plans.

5.8.3 Sampling in Test Pits and Trenches

5.8.3.1 General

Test pits and trenches are usually logged as they are excavated. Records of each test pit/trench will be made as described in SOP SA-6.3. These records include plan and profile sketches of the test pit/trench showing materials encountered, their depth and distribution in the pit/trench, and sample locations. These records also include safety and sample screening information.

Entry of test pits by personnel is extremely dangerous, shall be avoided unless absolutely necessary, and can occur only after all applicable Health and Safety and OSHA requirements have been met.

The final depth and type of samples obtained from each test pit will be determined at the time the test pit is excavated. Sufficient samples are usually obtained and analyzed to quantify contaminant distribution as a function of depth for each test pit. Additional samples of each waste phase and any fluids encountered in each test pit may also be collected.

In some cases, samples of soil may be extracted from the test pit for reasons other than waste sampling and chemical analysis, for instance, to obtain geotechnical information. Such information would include soil types, stratigraphy, strength, etc., and could therefore entail the collection of disturbed (grab or bulk) or relatively undisturbed (hand-carved or pushed/driven) samples, which can be tested for geotechnical properties. The purposes of such explorations are very similar to those of shallow exploratory or test borings, but often test pits offer a faster, more cost-effective method of sampling than installing borings.

5.8.3.2 Sampling Equipment

The following equipment is needed for obtaining samples for chemical or geotechnical analysis from test pits and trenches:

- Backhoe or other excavating machinery.
- Shovels, picks and hand augers, stainless steel trowels.
- Sample container - bucket with locking lid for large samples; appropriate bottleware for chemical or geotechnical analysis samples.
- Polyethylene bags for enclosing sample containers; buckets.

- Remote sampler consisting of 10-foot sections of steel conduit (1-inch-diameter), hose clamps and right angle adapter for conduit (see Attachment B).

5.8.3.3 Sampling Methods

The methods discussed in this section refer to test pit sampling from grade level. If test pit entry is required, see Section 5.7.3.4.

- Excavate trench or pit in several depth increments. After each increment, the operator will wait while the sampler inspects the test pit from grade level to decide if conditions are appropriate for sampling. (Monitoring of volatiles by the SSO will also be used to evaluate the need for sampling.) Practical depth increments range from 2 to 4 feet.

- The backhoe operator, who will have the best view of the test pit, will immediately cease digging if:

- Any fluid phase or groundwater seepage is encountered in the test pit.

- Any drums, other potential waste containers, obstructions or utility lines are encountered.

- Distinct changes of material are encountered.

This action is necessary to permit proper sampling of the test pit and to prevent a breach of safety protocol. Depending upon the conditions encountered, it may be required to excavate more slowly and carefully with the backhoe.

For obtaining test pit samples from grade level, the following procedure shall be followed:

- Remove loose material to the greatest extent possible with backhoe.

- Secure walls of pit if necessary. (There is seldom any need to enter a pit or trench which would justify the expense of shoring the walls. All observations and samples should be taken from the ground surface.)

- Samples of the test pit material are to be obtained either directly from the backhoe bucket or from the material once it has been deposited on the ground. The sampler or Field Operations Leader directs the backhoe operator to remove material from the selected depth or location within the test pit/trench. The bucket is brought to the surface and moved away from the pit. The sampler and/or SSO then approaches the bucket and monitors its contents with a photoionization or flame ionization detector. The sample is collected from the center of the bucket or pile and placed in sample containers using a decontaminated stainless steel trowel or spatula.

- If a composite sample is desired, several depths or locations within the pit/trench are selected and a bucket is filled from each area. It is preferable to send individual sample bottles filled from each bucket to the laboratory for compositing under the more controlled laboratory conditions. However, if compositing in the field is required, each sample container shall be filled from materials that have been transferred into a mixing bucket and homogenized. Note that homogenization/compositing is not applicable for samples to be subjected to volatile organic analysis.

- Using the remote sampler shown in Attachment B, samples can be taken at the desired depth from the side wall or bottom of the pit. The face of the pit/trench shall first be scraped (using a long-handled shovel or hoe) to remove the smeared zone that has contacted the backhoe bucket. The sample shall then be collected directly into the sample jar, by scraping with the jar edge, eliminating the need to utilize samplers and minimizing the likelihood of cross-contamination. The sample jar is then capped, removed from the assembly, and packaged for shipment.

- Complete documentation as described in SOP SA-6.3.

5.8.3.4 In-Pit Sampling

Under rare conditions, personnel may be required to enter the test pit/trench. This is necessary only when soil conditions preclude obtaining suitable samples from the backhoe bucket (e.g., excessive mixing of soils or wastes within the test pit/trench) or when samples from relatively small discrete zones within the test pit are required. This approach may also be necessary to sample any seepage occurring at discrete levels or zones in the test pit that are not accessible with remote samplers.

In general, personnel shall sample and log pits and trenches from the ground surface, except as provided for by the following criteria:

- There is no practical alternative means of obtaining such data.

- The Site Safety Officer and Competent Person determines that such action can be accomplished without breaching site safety protocol. This determination will be based on actual monitoring of the pit/trench after it is dug (including, at a minimum, measurements of volatile organics, explosive gases and available oxygen).

- A Company-designated Competent Person determines that the pit/trench is stable or is made stable (by grading the sidewalls or using shoring) prior to entrance of any personnel. OSHA requirements must be strictly observed.

If these conditions are satisfied, one person will enter the pit/trench. On potentially hazardous waste sites, this individual will be dressed in safety gear as required by the conditions in the pit, usually Level B. He/she will be affixed to a safety rope and continuously monitored while in the pit.

A second individual will be fully dressed in protective clothing including a self-contained breathing device and on standby during all pit entry operations. The individual entering the pit will remain therein for as brief a period as practical, commensurate with performance of his/her work. After removing the smeared zone, samples shall be obtained with a decontaminated trowel or spoon. As an added precaution, it is advisable to keep the backhoe bucket in the test pit when personnel are working below grade. Such personnel can either stand in or near the bucket while performing sample operations. In the event of a cave-in they can either be lifted clear in the bucket, or at least climb up on the backhoe arm to reach safety.

5.8.3.5 Geotechnical Sampling

In addition to the equipment described in Section 5.7.3.2, the following equipment is needed for geotechnical sampling:

- Soil sampling equipment, similar to that used in shallow drilled boring (i.e., open tube samplers), which can be pushed or driven into the floor of the test pit.

- Suitable driving (i.e., a sledge hammer) or pushing (i.e., the backhoe bucket) equipment which is used to advance the sampler into the soil.

- Knives, spatulas, and other suitable devices for trimming hand-carved samples.

- Suitable containers (bags, jars, tubes, boxes, etc.), labels, wax, etc. for holding and safely transporting collected soil samples.

- Geotechnical equipment (pocket penetrometer, torvane, etc.) for field testing collected soil samples for classification and strength properties.

Disturbed grab or bulk geotechnical soil samples may be collected for most soils in the same manner as comparable soil samples for chemical analysis. These collected samples may be stored in jars or plastic-lined sacks (larger samples), which will preserve their moisture content. Smaller samples of this type are usually tested for their index properties to aid in soil identification and classification, while larger bulk samples are usually required to perform compaction tests.

Relatively undisturbed samples are usually extracted in cohesive soils using open tube samplers, and such samples are then tested in a geotechnical laboratory for their strength, permeability and/or compressibility. The techniques for extracting and preserving such samples are similar to those used in performing Shelby tube sampling in borings, except that the sampler is advanced by hand or backhoe, rather than by a drill rig. Also, the sampler may be extracted from the test pit by excavation around the sampler when it is difficult to pull it out of the ground. If this excavation requires entry of the test pit, the requirements described in Section 5.7.3.4 of this procedure must be followed. The open tube sampler shall be pushed or driven vertically into the floor or steps excavated in the test pit at the desired sampling elevations. Extracting tube samples horizontally from the walls of the test pit is not appropriate, because the sample will not have the correct orientation.

A sledge hammer or the backhoe may be used to drive or push the sampler or tube into the ground. Place a piece of wood over the top of the sampler or sampling tube to prevent damage during driving/pushing of the sample. Pushing the sampler with a constant thrust is always preferable to driving it with repeated blows, thus minimizing disturbance to the sample. If the sample cannot be extracted by rotating it at least two revolutions (to shear off the sample at the bottom), hand-excavate to remove the soil from around the sides of the sampler. If hand-excavation requires entry of the test pit, the requirements in Section 5.7.3.4 of this procedure must be followed. Prepare, label, pack and transport the sample in the required manner, as described in SOP SA-6.3.

5.8.4 Backfilling of Trenches and Test Pits

All test pits and excavations must be either backfilled, covered, or otherwise protected at the end of each day. No excavations shall remain open during non-working hours unless adequately covered or otherwise protected.

Before backfilling, the onsite crew shall photograph all significant features exposed by the test pit and trench and shall include in the photograph a scale to show dimensions. Photographs of test pits shall be marked to include site number, test pit number, depth, description of feature, and date of photograph. In addition, a geologic description of each photograph shall be entered in the site logbook. All photographs shall be indexed and maintained as part of the project file for future reference.

After inspection, backfill material shall be returned to the pit under the direction of the FOL.

If a low permeability layer is penetrated (resulting in groundwater flow from an upper contaminated flow zone into a lower uncontaminated flow zone), backfill material must represent original conditions or be impermeable. Backfill could consist of a soil-bentonite mix prepared in a proportion specified by the FOL (representing a permeability equal to or less than original conditions). Backfill can be covered by "clean" soil and graded to the original land contour. Revegetation of the disturbed area may also be required.

5.9 Records

The appropriate sample log sheet (see SOP SA-6.3; Field Documentation) must be completed by the site geologist/sampler. All soil sampling locations must be documented by tying in the location of two or more nearby permanent landmarks (building, telephone pole, fence, etc.) and shall be noted on the appropriate sample log sheet, site map, or field notebook. Surveying may also be necessary, depending on the project requirements.

Test pit logs (see SOP SA-6.3; Field Documentation) shall contain a sketch of pit conditions. In addition, at least one photograph with a scale for comparison shall be taken of each pit. Included in the photograph shall be a card showing the test pit number. Boreholes, test pits and trenches shall be logged by the field geologist in accordance with SOP GH-1.5.

Other data to be recorded in the field logbook include the following:

- Name and location of job.
- Date of boring and excavation.
- Approximate surface elevation.
- Total depth of boring and excavation.
- Dimensions of pit.
- Method of sample acquisition.
- Type and size of samples.
- Soil and rock descriptions.
- Photographs.
- Groundwater levels.
- Organic gas or methane levels.
- Other pertinent information, such as waste material encountered.

6.0 REFERENCES

American Society for Testing and Materials, 1987. ASTM Standards D1587-83 and D1586-84. ASTM Annual Book of Standards. ASTM. Philadelphia, Pennsylvania. Volume 4.08.

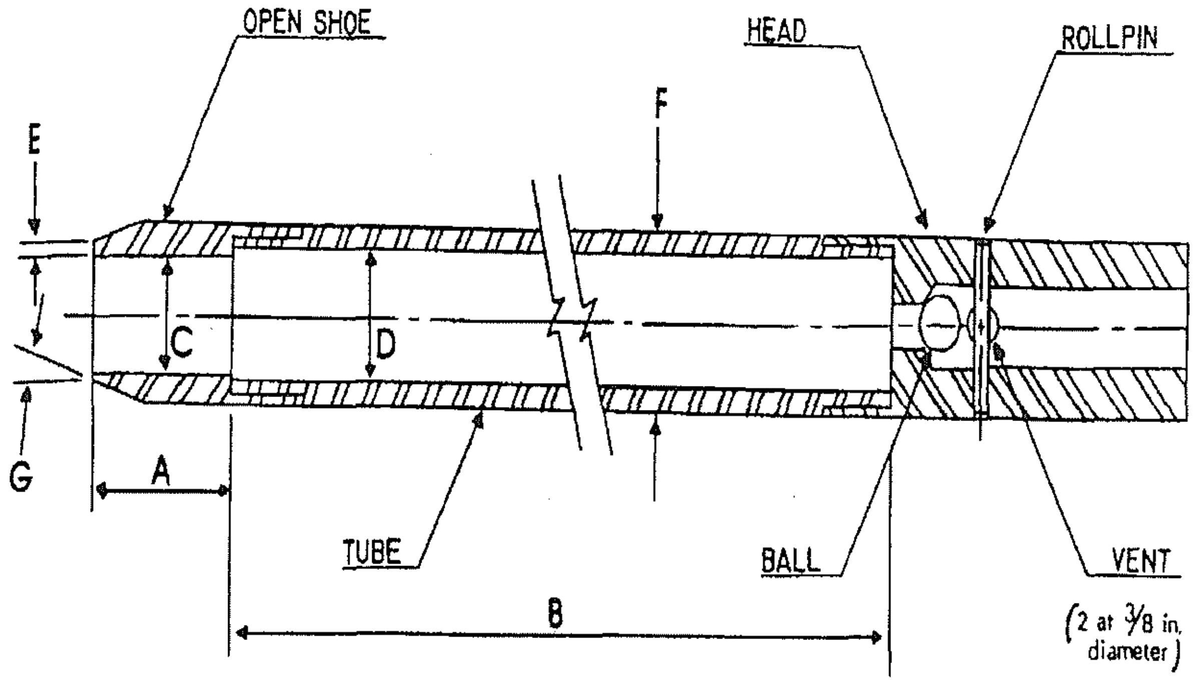
NUS Corporation, 1986. Hazardous Material Handling Training Manual.

NUS Corporation and CH2M Hill, August, 1987. Compendium of Field Operation Methods. Prepared for the U.S. EPA.

OSHA, Excavation, Trenching and Shoring 29 CFR 1926.650-653.

OSHA, Confined Space Entry 29 CFR 1910.146.

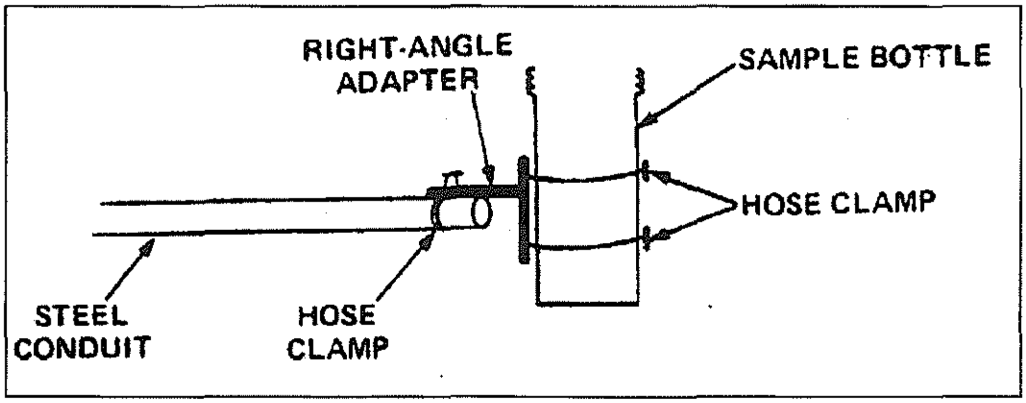
ATTACHMENT A
SPLIT-SPOON SAMPLER



A = 1.0 to 2.0 in. (25 to 50 mm)
B = 18.0 to 30.0 in. (0.457 to 0.762 m)
C = 1.375 ± 0.005 in. (34.93 ± 0.13 mm)
D = 1.50 ± 0.05 – 0.00 in. (38.1 ± 1.3 – 0.0 mm)
E = 0.10 ± 0.02 in. (2.54 ± 0.25 mm)
F = 2.00 ± 0.05 – 0.00 in. (50.8 ± 1.3 – 0.0 mm)
G = 16.0° to 23.0°

The 1½ in. (38 mm) inside diameter split barrel may be used with a 16-gage wall thickness split liner. The penetrating end of the drive shoe may be slightly rounded. Metal or plastic retainers may be used to retain soil samples.

ATTACHMENT B
REMOTE SAMPLE HOLDER FOR TEST PIT/TRENCH SAMPLING



TETRA TECH NUS, INC.	**STANDARD OPERATING PROCEDURES**	Number SA-2.5	Page 1 of 6
		Effective Date 09/03	Revision 3
		Applicability Tetra Tech NUS, Inc.	
		Prepared Earth Sciences Department	
Subject	DIRECT PUSH TECHNOLOGY (GEOPROBE®/HYDROPUNCH™)	Approved D. Senovich	

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1.0 PURPOSE

The purpose of this procedure is to provide general reference information on Direct Push Technology (DPT). DPT is designed to collect soil, groundwater, and soil gas samples without using conventional drilling techniques. The advantage of using DPT over conventional drilling includes the generation of little or no drill cuttings, sampling in locations with difficult accessibility, reduced overhead clearance requirements, no fluid introduction during probing, and typical lower costs per sample than with conventional techniques. Disadvantages include a maximum penetration depth of approximately 15 to 40 feet in dense soils (although it may be as much as 60 to 80 feet in certain types of geological environments), reduced capability of obtaining accurate water-level measurements, and the inability to install permanent groundwater monitoring wells. The methods and equipment described herein are for collection of surface and subsurface soil samples and groundwater samples. Soil gas sampling is discussed in SOP SA-2.4.

2.0 SCOPE

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

3.0 GLOSSARY

Direct Push Technology (DPT) - DPT refers to sampling tools and sensors that are driven directly into the ground without the use of conventional drilling equipment. DPT typically utilizes hydraulic pressure and/or percussion hammers to advance the sampling tools. A primary advantage of DPT over conventional drilling techniques is that DPT results in the generation of little or no investigation derived waste.

Geoprobe® - Geoprobe® is a manufacturer of a hydraulically-powered, percussion/probing machines utilizing DPT to collect subsurface environmental samples. Geoprobe® relies on a relatively small amount of static weight (vehicle) combined with percussion as the energy for advancement of a tool string. The Geoprobe® equipment can be mounted in a multitude of vehicles for access to all types of environmental sites.

HydroPunch™ - HydroPunch™ is a manufacturer of stainless steel and Teflon® sampling tools that are capable of collecting representative groundwater and/or soil samples without requiring the installation of a groundwater monitoring well or conventional soil boring. HydroPunch™ is an example of DPT sampling equipment.

Flame Ionization Detector (FID) - A portable instrument for the measurement of many combustible organic compounds and a few inorganic compounds in air at parts-per million levels. The basis for the detection is the ionization of gaseous species utilizing a flame as the energizing source.

Photo Ionization Detector (PID) - A portable instrument for the measurement of many combustible organic compounds and a few inorganic compounds in air at parts-per million levels. The basis for the detection is the ionization of gaseous species utilizing ultraviolet radiation as the energizing source.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for selecting and/or reviewing the appropriate DPT drilling procedure required to support the project objectives.

Field Operations Leader (FOL)- The FOL is primarily responsible for performing the DPT in accordance with the project-specific plan.

5.0 SOIL SAMPLING PROCEDURES

5.1 General

The common methodology for the investigation of the vadose zone is soil boring drilling and soil sampling. However, drilling soil borings can be very expensive. Generally the advantage of DPT for subsurface soil sampling is the reduced cost of disposal of drilling cuttings and shorter sampling times.

5.2 Sampling Equipment

Equipment needed for conducting DPT drilling for subsurface soil sampling includes, but is not limited to, the following:

- Geoprobe® Sampling Kit
- Cut-resistant gloves
- 4-foot x 1.5-inch diameter macrocore sampler
- Probe sampling adapters
- Roto-hammer with 1.5-inch bit
- Disposable acetate liners for soil macrocore sampler
- Cast aluminum or steel drive points
- Geoprobe® AT-660 Series Large Bore Soil Sampler, or equivalent
- Standard decontamination equipment and solutions

For health and safety equipment and procedures, follow the direction provided in the Safe Work Permit in Attachment 1, or the more detailed directions provided in the project's Health and Safety Plan.

5.3 DPT Sampling Methodology

There are several methods for the collection of soil samples using DPT drilling. The most common method is discussed in the following section. Variations of the following method may be conducted upon approval of the Project Manager in accordance with the project-specific plan.

- Macrocore samplers fitted with detachable aluminum or steel drive points are driven into the ground using hydraulic pressure. If there is concrete or pavement over a sampling location, a Roto-hammer is used to drill a minimum 1.5-inch diameter hole through the surface material. A Roto-hammer may also be used if very dense soils are encountered.

- The sampler is advanced continuously in 4-foot intervals or less if desired. No soil cuttings are generated because the soil which is not collected in the sampler is displaced within the formation.

- The sampler is retracted from the hole, and the 4-foot continuous sample is removed from the outer coring tube. The sample is contained within an inner acetate liner.

- Attach the metal trough from the Geoprobe® Sampling Kit firmly to the tail gate of a vehicle. If a vehicle with a tail gate is not available, secure the trough on another suitable surface.

- Place the acetate liner containing the soils in the trough.

- While wearing cut-resistant gloves (constructed of leather or other suitable material), cut the acetate liner through its entire length using the double-bladed knife that accompanies the Geoprobe® Sampling Kit. Then remove the strip of acetate from the trough to gain access to the collected soils. Do not attempt to cut the acetate liner while holding it in your hand.

- Field screen the sample with an FID or PID, and observe/examine the sample (according to SOP GH-1.3). If appropriate, transfer the sample to sample bottles for laboratory analysis. If additional volume is required, push an additional boring adjacent to the first and composite/mix the same interval. Field compositing is usually not acceptable for sample requiring volatile organics analysis.

- Once sampling has been completed, the hole is backfilled with bentonite chips or bentonite cement grout, depending upon project requirements. Asphalt or concrete patch is used to cap holes through paved or concrete areas. All holes should be finished smooth to existing grade.

- In the event the direct push van/truck cannot be driven to a remote location or a sampling location with difficult accessibility, sampling probes may be advanced and sampled manually or with air/electric operated equipment (e.g., jack hammer).

- Sampling equipment is decontaminated prior to collecting the next sample.

6.0 GROUNDWATER SAMPLING PROCEDURES

6.1 General

The most common methodology for the investigation of groundwater is the installation and sampling of permanent monitoring wells. If only groundwater screening is required, the installation and sampling of temporary well points may be performed. The advantage of temporary well point installation using DPT is reduced cost due to no or minimal disposal of drilling cuttings and well construction materials, and shorter installation/times sampling.

Two disadvantages of DPT drilling for well point installation are:

- In aquifers with low yields, well points may have to be sampled without purging or development.
- If volume requirements are high, this method can be time consuming for low yield aquifers.

6.2 Sampling Equipment

Equipment needed for temporary well installation and sampling using DPT includes, but is not limited, to the following:

- 2-foot x 1-inch diameter mill-slotted (0.005 to 0.02-inch) well point
- Connecting rods
- Roto-hammer with 1.5-inch bit
- Mechanical jack
- 1/4-inch OD polyethylene tubing
- 3/8-inch OD polyethylene tubing
- Peristaltic pump
- Standard decontamination equipment and solutions

6.3 DPT Temporary Well Point Installation and Sampling Methodology

There are several methods for the installation and sampling of temporary well points using DPT. The most common methodology is discussed below. Variations of the following method may be conducted upon approval of the Project Manager in accordance with the project specific plan.

- A 2-foot x 1-inch diameter mill-slotted (0.005 to 0.02-inch) well point attached to connecting rods is driven into the ground to the desired depth using a rotary electric hammer or other direct push drill rig. If there is concrete or pavement over a sampling location, a Roto-hammer or electric coring machine is used to drill a hole through the surface material.

- The well point will be allowed to equilibrate for at least 15 minutes, after which a measurement of the static water level will be taken. The initial measurement of the water level will be used to assess the amount of water which is present in the well point and to determine the amount of silt and sand infiltration that may have occurred.

- The well point will be developed using a peristaltic pump and polyethylene tubing to remove silt and sand which may have entered the well point. The well point is developed by inserting polyethylene tubing to the bottom of the well point and lifting and lowering the tubing slightly while the pump is operating. The pump will be operated at a maximum rate of approximately 2 liters per minute. After removal of sediment from the bottom of the well point, the well point will be vigorously pumped at maximum capacity until discharge water is visibly clear and no further sediments are being generated. Measurements of pH, specific conductance, temperature, and turbidity shall be recorded every 5 to 10 minutes during the purging process. After two consistent readings of pH, specific conductance, temperature and turbidity (±10 percent), the well may be sampled.

- A sample will be collected using the peristaltic pump set at the same or reduced speed as during well development. Samples (with the exception of the samples to be analyzed for volatile organic compounds, VOCs) will be collected directly from the pump discharge. Sample containers for VOCs will be filled by (first shutting off the pump) crimping the discharge end of the sample tubing when filled, removing the inlet end of the sample tubing from the well, suspending the inlet tubing above the vial, and allowing water to fill each vial by gravity flow.

- Once the groundwater sample has been collected, the connecting rods and well point will be removed from the hole with the direct push rig hydraulics. The hole will be backfilled with bentonite chips or bentonite cement grout, depending upon project requirements. Asphalt or concrete patch will be used to cap holes through paved or concrete areas. All holes will be finished smooth to existing grade.

- In the event the direct push van/truck cannot be driven to a remote location or sampling location with difficult accessibility, sampling probes may be advanced and sampled manually or with air/electric-operated equipment (e.g., jack hammer).

- Decontaminate the equipment before moving to the next location.

7.0 RECORDS

A record of all field procedures, tests, and observations must be recorded in the field logbook, boring logs, and sample log sheets, as needed. Entries should include all pertinent data regarding the investigation. The use of sketches and field landmarks will help to supplement the investigation and evaluation.

ATTACHMENT 1
SAFE WORK PERMIT FOR DPT OPERATIONS

Permit No. ______________ Date: ____________________ Time: From ____________ to ____________

SECTION I: General Job Scope

I. Work limited to the following (description, area, equipment used): **Monitoring well drilling and installation through direct push technology**

II. Required Monitoring Instruments: ______________________________

III. Field Crew: ______________________________

IV. On-site Inspection conducted ☐ Yes ☐ No Initials of Inspector ____________ TtNUS ____________

SECTION II: General Safety Requirements (To be filled in by permit issuer)

V. Protective equipment required

Level D ☒ Level B ☐
Level C ☐ Level A ☐
Detailed on Reverse

Respiratory equipment required

Full face APR	☐	Escape Pack	☐
Half face APR	☐	SCBA	☐
SKA-PAC SAR	☐	Bottle Trailer	☐
Skid Rig	☐	None	☒

Level D Minimum Requirements: Sleeved shirt and long pants, safety footwear, and work gloves. Safety glasses, hard hats, and hearing protection will be worn when working near or sampling in the vicinity of the DPT rig.

Modifications/Exceptions.

VI. Chemicals of Concern | Action Level(s) | Response Measures

VII. Additional Safety Equipment/Procedures

Hard-hat	☒ Yes ☐ No	Hearing Protection (Plugs/Muffs)	☒ Yes	☐ No
Safety Glasses	☒ Yes ☐ No	Safety belt/harness	☐ Yes	☒ No
Chemical/splash goggles	☐ Yes ☒ No	Radio	☐ Yes	☒ No
Splash Shield	☐ Yes ☒ No	Barricades	☒ Yes	☐ No
Splash suits/coveralls	☐ Yes ☐ No	Gloves (Type - ____________)	☐ Yes	☐ No
Steel toe Work shoes or boots	☒ Yes ☐ No	Work/warming regimen	☐ Yes	☐ No

Modifications/Exceptions: Reflective vests for high traffic areas.

VIII. Procedure review with permit acceptors

	Yes	NA		Yes	NA
Safety shower/eyewash (Location & Use)	☐	☒	Emergency alarms	☐	☐
Daily tail gate meetings	☒	☐	Evacuation routes	☐	☐
Contractor tools/equipment/PPE inspected	☐	☐	Assembly points	☐	☐

IX. Site Preparation

Utility Clearances obtained for areas of subsurface investigation	☐ Yes	☐ No
Physical hazards removed or blockaded	☐ Yes	☐ No
Site control boundaries demarcated/signage	☐ Yes	☐ No

X. Equipment Preparation

	Yes	NA
Equipment drained/depressurized	☐	☒
Equipment purged/cleaned	☐	☒
Isolation checklist completed	☐	☒
Electrical lockout required/field switch tested	☐	☒
Blinds/misalignments/blocks & bleeds in place	☐	☒
Hazardous materials on walls/behind liners considered	☐	☒

XI. Additional Permits required (Hot work, confined space entry) ☐ Yes ☐ No
If yes, complete permit required or contact Health Sciences, Pittsburgh Office

XII. Special instructions, precautions:

____

Permit Issued by: ______________________ Permit Accepted by: ______________________

TETRA TECH NUS, INC.	**STANDARD OPERATING PROCEDURES**	Number SA-6.1	Page 1 of 11
		Effective Date 02/04	Revision 3
		Applicability Tetra Tech NUS, Inc.	
		Prepared Earth Sciences Department	
Subject NON-RADIOLOGICAL SAMPLE HANDLING		Approved D. Senovich	

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SECTION **PAGE**

1.0 PURPOSE

The purpose of this Standard Operating Procedure (SOP) is to provide information on sample preservation, packaging, and shipping procedures to be used in handling environmental samples submitted for chemical constituent, biological, or geotechnical analysis. Sample chain-of-custody procedures and other aspects of field documentation are addressed in SOP SA-6.3. Sample identification is addressed in SOP CT-04.

2.0 SCOPE

This procedure describes the appropriate containers to be used for samples depending on the analyses to be performed, and the steps necessary to preserve the samples when shipped off site for chemical analysis.

3.0 GLOSSARY

Hazardous Material - A substance or material which has been determined by the Secretary of Transportation to be capable of posing an unreasonable risk to health, safety, and property when transported in commerce, and which has been so designated. Under 49 CFR, the term includes hazardous substances, hazardous wastes, marine pollutants, and elevated temperature materials, as well as materials designated as hazardous under the provisions of §172.101 and §172.102 and materials that meet the defining criteria for hazard classes and divisions in Part 173. With slight modifications, IATA has adopted DOT "hazardous materials" as IATA "Dangerous Goods."

Hazardous Waste - Any substance listed in 40 CFR, Subpart D (y261.30 et seq.), or otherwise characterized as ignitable, corrosive, reactive, or toxic (as defined by Toxicity Characteristic Leaching Procedure, TCLP, analysis) as specified under 40 CFR, Subpart C (y261.20 et seq.), that would be subject to manifest requirements specified in 40 CFR 262. Such substances are defined and regulated by EPA.

Marking - A descriptive name, identification number, instructions, cautions, weight, specification or UN marks, or combination thereof required on outer packaging of hazardous materials.

n.o.i - Not otherwise indicated (may be used interchangeably with n.o.s.).

n.o.s. - Not otherwise specified.

Packaging - A receptacle and any other components or materials necessary for compliance with the minimum packaging requirements of 49 CFR 174, including containers (other than freight containers or overpacks), portable tanks, cargo tanks, tank cars, and multi-unit tank-car tanks to perform a containment function in conformance with the minimum packaging requirements of 49 CFR 173.24(a) & (b).

Placard - Color-coded, pictorial sign which depicts the hazard class symbol and name and which is placed on the side of a vehicle transporting certain hazardous materials.

Common Preservatives:

- Hydrochloric Acid - HCl
- Sulfuric Acid - H_2SO_4
- Nitric Acid - HNO_3
- Sodium Hydroxide - $NaOH$

Other Preservatives

- Zinc Acetate
- Sodium Thiosulfate - $Na_2S_2O_3$

Normality (N) - Concentration of a solution expressed as equivalent per liter, an equivalent being the amount of a substance containing 1 gram-atom of replaceable hydrogen or its equivalent.

Reportable Quantity (RQ) - For the purposes of this SOP, means the quantity specified in column 3 of the Appendix to DOT 49 CFR §172.101 for any material identified in column 1 of the appendix. A spill greater than the amount specified must be reported to the National Response Center.

Sample - A sample is physical evidence collected from a facility or the environment, which is representative of conditions at the location and time of collection.

4.0 RESPONSIBILITIES

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

Field Samplers - Responsible for initiating the Chain-of-Custody Record (per SOP SA-6.3), implementing the packaging and shipping requirements, and maintaining custody of samples until they are relinquished to another custodian or to the shipper.

5.0 PROCEDURES

Sample identification, labeling, documentation, and chain-of-custody are addressed by SOP SA-6.3.

5.1 Sample Containers

Different types of chemicals react differently with sample containers made of various materials. For example, trace metals adsorb more strongly to glass than to plastic, whereas many organic chemicals may dissolve various types of plastic containers. Attachments A and B show proper containers (as well as other information) per 40 CFR 136. In general, the sample container shall allow approximately 5-10 percent air space ("ullage") to allow for expansion/vaporization if the sample warms during transport. However, for collection of volatile organic compounds, head space shall be omitted. The analytical laboratory will generally provide certified-clean containers for samples to be analyzed for chemical constituents. Shelby tubes or other sample containers are generally provided by the driller for samples requiring geotechnical analysis. Sufficient lead time shall be allowed for a delivery of sample container orders. Therefore, it is critical to use the correct container to maintain the integrity of the sample prior to analysis.

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

5.2 Sample Preservation

Many water and soil samples are unstable and therefore require preservation to prevent changes in either the concentration or the physical condition of the constituent(s) requiring analysis. Although complete and irreversible preservation of samples is not possible, preservation does retard the chemical and biological changes that inevitably take place after the sample is collected. Preservation techniques are usually limited to pH control, chemical addition(s), and refrigeration/ freezing (certain biological samples only).

5.2.1 Overview

The preservation techniques to be used for various analytes are listed in Attachments A and B. Reagents required for sample preservation will either be added to the sample containers by the laboratory prior to their shipment to the field or be added in the field (in a clean environment). Only high purity reagents shall be used for preservation. In general, aqueous samples of low-concentration organics (or soil samples of low- or medium-concentration organics) are cooled to 4°C. Medium-concentration aqueous samples, high-hazard organic samples, and some gas samples are typically not preserved. Low-concentration aqueous samples for metals are acidified with HNO_3, whereas medium-concentration and high-hazard aqueous metal samples are not preserved. Low- or medium-concentration soil samples for metals are cooled to 4°C, whereas high-hazard samples are not cooled.

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

The FOL is responsible for ensuring that an accurate Chemical Inventory is created and maintained for all hazardous chemicals brought to the work site (see Section 5 of the TtNUS Health and Safety Guidance Manual). Furthermore, the FOL must ensure that a corresponding Material Safety Data Sheet (MSDS) is collected for every substance entered on the site Chemical Inventory, and that all persons using/handling/ disposing of these substances review the appropriate MSDS for substances they will work with. The Chemical Inventory and the MSDSs must be maintained at each work site in a location and manner where they are readily-accessible to all personnel.

5.2.2 Preparation and Addition of Reagents

Addition of the following acids or bases may be specified for sample preservation; these reagents shall be analytical reagent (AR) grade or purer and shall be diluted to the required concentration with deionized water before field sampling commences. To avoid uncontrolled reactions, be sure to Add Acid to water (not vice versa). A dilutions guide is provided below.

Acid/Base	Dilution	Concentration	Estimated Amount Required for Preservation
Hydrochloric Acid (HCl)	1 part concentrated HCl: 1 part double-distilled, deionized water	6N	5-10 mL
Sulfuric Acid (H_2SO_4)	1 part concentrated H_2SO_4: 1 part double-distilled, deionized water	18N	2 - 5 mL
Nitric Acid (HNO_3)	Undiluted concentrated HNO_3	16N	2 - 5 mL
Sodium Hydroxide (NaOH)	400 grams solid NaOH dissolved in 870 mL double-distilled, deionized water; yields 1 liter of solution	10N	2 mL

The amounts required for preservation shown in the above table assumes proper preparation of the preservative and addition of the preservative to one liter of aqueous sample. This assumes that the sample is initially at pH 7, is poorly buffered, and does not contain particulate matter; as these conditions vary, more preservative may be required. Consequently, the final sample pH must be checked using narrow-range pH paper, as described in the generalized procedure detailed below:

- Pour off 5-10 mL of sample into a dedicated, clean container. Use some of this sample to check the initial sample pH using wide range (0-14) pH paper. Never dip the pH paper into the sample; always apply a drop of sample to the pH paper using a clean stirring rod or pipette.

- Add about one-half of the estimated preservative required to the original sample bottle. Cap and invert gently several times to mix. Check pH (as described above) using medium range pH paper (pH 0-6 or pH 7.5-14, as applicable).

- Cap sample bottle and seal securely.

Additional considerations are discussed below:

- To test if ascorbic acid must be used to remove oxidizing agents present in the sample before it can be properly preserved, place a drop of sample on KI-starch paper. A blue color indicates the need for ascorbic acid addition.

  If required, add a few crystals of ascorbic acid to the sample and retest with the KI-starch paper. Repeat until a drop of sample produces no color on the KI-starch paper. Then add an additional 0.6 grams of ascorbic acid per each liter of sample volume.

  Continue with proper base preservation of the sample as described above.

- Samples for sulfide analysis must be treated by the addition of 4 drops (0.2 mL) of 2N zinc acetate solution per 100 ml of sample.

  The 2N zinc acetate solution is made by dissolving 220 grams of zinc acetate in 870 mL of double-distilled, deionized water to make 1 liter of solution.

  The sample pH is then raised to 9 using the NaOH preservative.

- Sodium thiosulfate must be added to remove residual chlorine from a sample. To test the sample for residual chlorine use a field test kit specially made for this purpose.

  If residual chlorine is present, add 0.08 grams of sodium thiosulfate per liter of sample to remove the residual chlorine.

  Continue with proper acidification of the sample as described above.

For biological samples, 10% buffered formalin or isopropanol may also be required for preservation. Questions regarding preservation requirements should be resolved through communication with the laboratory before sampling begins.

5.3 Field Filtration

At times, field-filtration may be required to provide for the analysis of dissolved chemical constituents. Field-filtration must be performed prior to the preservation of samples as described above. General procedures for field filtration are described below:

- The sample shall be filtered through a non-metallic, 0.45-micron membrane filter, immediately after collection. The filtration system shall consist of dedicated filter canister, dedicated tubing, and a peristaltic pump with pressure or vacuum pumping squeeze action (since the sample is filtered by mechanical peristalsis, the sample travels only through the tubing).

- To perform filtration, thread the tubing through the peristaltic pump head. Attach the filter canister to the discharge end of the silicon tubing (note flow direction arrow); attach the aqueous sample container to the intake end of the silicon tubing. Turn the peristaltic pump on and perform filtration. Run approximately 100 ml of sample through the filter and discard prior to sample collection.

- Continue by preserving the filtrate (contained in the filter canister), as applicable and generally described above.

5.4 Sample Packaging and Shipping

Only employees who have successfully completed the TtNUS "Shipping Hazardous Materials" training course are authorized to package and ship hazardous substances. These trained individuals are responsible for performing shipping duties in accordance with this training.

Samples collected for shipment from a site shall be classified as either environmental or hazardous material samples. Samples from drums containing materials other than Investigative Derived Waste (IDW) and samples obtained from waste piles or bulk storage tanks are generally shipped as hazardous materials. A distinction must be made between the two types of samples in order to:

- Determine appropriate procedures for transportation of samples (if there is any doubt, a sample shall be considered hazardous and shipped accordingly.)

- Protect the health and safety of transport and laboratory personnel receiving the samples (special precautions are used by the shipper and at laboratories when hazardous materials are received.)

Detailed procedures for packaging environmental samples are outlined in the remainder of this section.

5.4.1 Environmental Samples

Environmental samples are packaged as follows:

- Place properly identified sample container, with lid securely fastened, in a plastic bag (e.g. Ziploc baggie), and seal the bag.

- Place sample in a cooler constructed of sturdy material which has been lined with a large, plastic bag (e.g. "garbage" bag). Drain plugs on coolers must be taped shut.

- Pack with enough cushioning materials such as bubble wrap (shoulders of bottles must be iced if required) to minimize the possibility of the container breaking.

- If cooling is required (see Attachments A and B), place ice around sample container shoulders, and on top of packing material (minimum of 8 pounds of ice for a medium-size cooler).

- Seal (i.e., tape or tie top in knot) large liner bag.

- The original (top, signed copy) of the COC form shall be placed inside a large Ziploc-type bag and taped inside the lid of the shipping cooler. If multiple coolers are sent but are included on one COC form, the COC form should be sent with the cooler containing the vials for VOC analysis. The COC form should then state how many coolers are included with that shipment.

- Close and seal outside of cooler as described in SOP SA-6.3. Signed custody seals must be used.

Coolers must be marked as containing "Environmental Samples." The appropriate side of the container must be marked "This End Up" and arrows placed appropriately. No DOT marking or labeling is required; there are no DOT restrictions on mode of transportation.

6.0 REFERENCES

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

International Air Transport Association (latest issue). Dangerous Goods Regulations, Montreal, Quebec, Canada.

U.S. Department of Transportation (latest issue). Hazardous Materials Regulations, 49 CFR 171-177.

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

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

ATTACHMENT A

GENERAL SAMPLE CONTAINER AND PRESERVATION REQUIREMENTS

Sample Type and Concentration		Container[1]	Sample Size	Preservation[2]	Holding Time[2]
WATER					
Organics (GC&GC/MS)	VOC Low	Borosilicate glass	2 x 40 mL	Cool to 4°C HCl to ≤ 2	14 days[9]
	Extractables (Low SVOCs and pesticide/PCBs)	Amber glass	2x2 L or 4x1 L	Cool to 4°C	7 days to extraction; 40 days after extraction
	Extractables (Medium SVOCs and pesticide/PCBs)	Amber glass	2x2 L or 4x1 L	None	7 days to extraction; 40 days after extraction
Inorganics	Metals Low	High-density polyethylene	1 L	HNO_3 to pH ≤2	6 months (Hg-28 days)
	Medium	Wide-mouth glass	16 oz.	None	6 months
	Cyanide Low	High-density polyethylene	1 L	NaOH to pH>12	14 days
	Cyanide Medium	Wide-mouth glass	16 oz.	None	14 days
Organic/ Inorganic	High Hazard	Wide-mouth glass	8 oz.	None	14 days
SOIL					
Organics (GC&GC/MS)	VOC	EnCore Sampler	(3) 5 g Samplers	Cool to 4°C	48 hours to lab preservation
	Extractables (Low SVOCs and pesticides/PCBs)	Wide-mouth glass	8 oz.	Cool to 4°C	14 days to extraction; 40 days after extraction
	Extractables (Medium SVOCs and pesticides/PCBs)	Wide-mouth glass	8 oz.	Cool to 4°C	14 days to extraction; 40 days after extraction
Inorganics	Low/Medium	Wide-mouth glass	8 oz.	Cool to 4°C	6 months (Hg - 28 days) Cyanide (14 days)
Organic/Inorganic	High Hazard	Wide-mouth glass	8 oz.	None	NA
Dioxin/Furan	All	Wide-mouth glass	4 oz.	None	35 days until extraction; 40 days after extraction
TCLP	All	Wide-mouth glass	8 oz.	None	7 days until preparation; analysis as per fraction
AIR					
Volatile Organics	Low/Medium	Charcoal tube -- 7 cm long, 6 mm OD, 4 mm ID	100 L air	Cool to 4°C	5 days recommended

1 All glass containers should have Teflon cap liners or septa.
2 See Attachment E. Preservation and maximum holding time allowances per 40 CFR 136.

ATTACHMENT B

ADDITIONAL REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES

Parameter Number/Name	Container(1)	Preservation(2)(3)	Maximum Holding Time(4)
INORGANIC TESTS:			
Acidity	P, G	Cool, 4°C	14 days
Alkalinity	P, G	Cool, 4°C	14 days
Ammonia - Nitrogen	P, G	Cool, 4°C; H_2SO_4 to pH 2	28 days
Biochemical Oxygen Demand (BOD)	P, G	Cool, 4°C	48 hours
Bromide	P, G	None required	28 days
Chemical Oxygen Demand (COD)	P, G	Cool, 4°C; H_2SO_4 to pH 2	28 days
Chloride	P, G	None required	28 days
Chlorine, Total Residual	P, G	None required	Analyze immediately
Color	P, G	Cool, 4°C	48 hours
Cyanide, Total and Amenable to Chlorination	P, G	Cool, 4°C; NaOH to pH 12; 0.6 g ascorbic acid(5)	14 days(6)
Fluoride	P	None required	28 days
Hardness	P, G	HNO_3 to pH 2; H_2SO_4 to pH 2	6 months
Total Kjeldahl and Organic Nitrogen	P, G	Cool, 4°C; H_2SO_4 to pH 2	28 days
Nitrate - Nitrogen	P, G	None required	48 hours
Nitrate-Nitrite - Nitrogen	P, G	Cool, 4°C; H_2SO_4 to pH 2	28 days
Nitrite - Nitrogen	P, G	Cool, 4°C	48 hours
Oil & Grease	G	Cool, 4°C; H_2SO_4 to pH 2	28 days
Total Organic Carbon (TOC)	P, G	Cool, 4°C; HCl or H_2SO_4 to pH 2	28 days
Orthophosphate	P, G	Filter immediately; Cool, 4°C	48 hours
Oxygen, Dissolved-Probe	G Bottle & top	None required	Analyze immediately
Oxygen, Dissolved-Winkler	G Bottle & top	Fix on site and store in dark	8 hours
Phenols	G	Cool, 4°C; H_2SO_4 to pH 2	28 days
Phosphorus, Total	P, G	Cool, 4°C; H_2SO_4 to pH 2	28 days
Residue, Total	P, G	Cool, 4°C	7 days
Residue, Filterable (TDS)	P, G	Cool, 4°C	7 days
Residue, Nonfilterable (TSS)	P, G	Cool, 4°C	7 days
Residue, Settleable	P, G	Cool, 4°C	48 hours
Residue, Volatile (Ash Content)	P, G	Cool, 4°C	7 days
Silica	P	Cool, 4°C	28 days
Specific Conductance	P, G	Cool, 4°C	28 days
Sulfate	P, G	Cool, 4°C	28 days

ATTACHMENT B
ADDITIONAL REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES
PAGE TWO

Parameter Number/Name	Container(1)	Preservation(2)(3)	Maximum Holding Time(4)
INORGANIC TESTS (Cont'd):			
Sulfide	P, G	Cool, 4°C; add zinc acetate plus sodium hydroxide to pH 9	7 days
Sulfite	P, G	None required	Analyze immediately
Turbidity	P, G	Cool, 4°C	48 hours
METALS:(7)			
Chromium VI (Hexachrome)	P, G	Cool, 4°C	24 hours
Mercury (Hg)	P, G	HNO_3 to pH 2	28 days
Metals, except Chromium VI and Mercury	P, G	HNO_3 to pH 2	6 months
ORGANIC TESTS:(8)			
Purgeable Halocarbons	G, Teflon-lined septum	Cool, 4°C; 0.008% $Na_2S_2O_3$(5)	14 days
Purgeable Aromatic Hydrocarbons	G, Teflon-lined septum	Cool, 4°C; 0.008% $Na_2S_2O_3$(5) HCl to pH 2 (9)	14 days
Acrolein and Acrylonitrile	G, Teflon-lined septum	Cool, 4°C; 0.008% $Na_2S_2O_3$(5) adjust pH to 4-5 (10)	14 days
Phenols(11)	G, Teflon-lined cap	Cool, 4°C; 0.008% $Na_2S_2O_3$(5)	7 days until extraction; 40 days after extraction
Benzidines(11),(12)	G, Teflon-lined cap	Cool, 4°C; 0.008% $Na_2S_2O_3$(5)	7 days until extraction(13)
Phthalate esters(11)	G, Teflon-lined cap	Cool, 4°C	7 days until extraction; 40 days after extraction
Nitrosamines(11),(14)	G, Teflon-lined cap	Cool, 4°C; store in dark; 0.008% $Na_2S_2O_3$(5)	7 days until extraction; 40 days after extraction
PCBs(11)	G, Teflon-lined cap	Cool, 4°C	7 days until extraction; 40 days after extraction
Nitroaromatics & Isophorone(11)	G, Teflon-lined cap	Cool, 4°C; 0.008% $Na_2S_2O_3$(5); store in dark	7 days until extraction; 40 days after extraction
Polynuclear Aromatic Hydrocarbons (PAHs)(11),(14)	G, Teflon-lined cap	Cool, 4°C; 0.008% $Na_2S_2O_3$(5); store in dark	7 days until extraction; 40 days after extraction
Haloethers(11)	G, Teflon-lined cap	Cool, 4°C; 0.008% $Na_2S_2O_3$(5)	7 days until extraction; 40 days after extraction
Dioxin/Furan (TCDD/TCDF)(11)	G, Teflon-lined cap	Cool, 4°C; 0.008% $Na_2S_2O_3$(5)	7 days until extraction; 40 days after extraction

ATTACHMENT B
ADDITIONAL REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES
PAGE THREE

(1) Polyethylene (P): generally 500 ml or Glass (G): generally 1L.
(2) Sample preservation should be performed immediately upon sample collection. For composite chemical samples each aliquot should be preserved at the time of collection. When use of an automated sampler makes it impossible to preserve each aliquot, then chemical samples may be preserved by maintaining at 4°C until compositing and sample splitting is completed.
(3) When any sample is to be shipped by common carrier or sent through the United States Mail, it must comply with the Department of Transportation Hazardous Materials Regulations (49 CFR Part 172).
(4) Samples should be analyzed as soon as possible after collection. The times listed are the maximum times that samples may be held before analysis and still be considered valid. Samples may be held for longer periods only if the permittee, or monitoring laboratory, has data on file to show that the specific types of samples under study are stable for the longer periods, and has received a variance from the Regional Administrator.
(5) Should only be used in the presence of residual chlorine.
(6) Maximum holding time is 24 hours when sulfide is present. Optionally, all samples may be tested with lead acetate paper before pH adjustments are made to determine if sulfide is present. If sulfide is present, it can be removed by the addition of cadmium nitrate powder until a negative spot test is obtained. The sample is filtered and then NaOH is added to pH 12.
(7) Samples should be filtered immediately on site before adding preservative for dissolved metals.
(8) Guidance applies to samples to be analyzed by GC, LC, or GC/MS for specific compounds.
(9) Sample receiving no pH adjustment must be analyzed within 7 days of sampling.
(10) The pH adjustment is not required if acrolein will not be measured. Samples for acrolein receiving no pH adjustment must be analyzed within 3 days of sampling.
(11) When the extractable analytes of concern fall within a single chemical category, the specified preservative and maximum holding times should be observed for optimum safeguard of sample integrity. When the analytes of concern fall within two or more chemical categories, the sample may be preserved by cooling to 4°C, reducing residual chlorine with 0.008% sodium thiosulfate, storing in the dark, and adjusting the pH to 6-9; samples preserved in this manner may be held for 7 days before extraction and for 40 days after extraction. Exceptions to this optional preservation and holding time procedure are noted in footnote 5 (re: the requirement for thiosulfate reduction of residual chlorine) and footnotes 12, 13 (re: the analysis of benzidine).
(12) If 1,2-diphenylthydrazine is likely to be present, adjust the pH of the sample to 4.0±0.2 to prevent rearrangement to benzidine.
(13) Extracts may be stored up to 7 days before analysis if storage is conducted under an inert (oxidant-free) atmosphere.
(14) For the analysis of diphenylnitrosamine, add 0.008% $Na_2S_2O_3$ and adjust pH to 7-10 with NaOH within 24 hours of sampling.
(15) The pH adjustment may be performed upon receipt at the laboratory and may be omitted if the samples are extracted within 72 hours of collection. For the analysis of aldrin, add 0.008% $Na_2S_2O_3$.

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		Prepared Earth Sciences Department	
Subject SOIL AND ROCK DRILLING METHODS		Approved D. Senovich	

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1.0 PURPOSE

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

2.0 SCOPE

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

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

3.0 GLOSSARY

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

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

4.0 RESPONSIBILITIES

Project Manager - In consultation with the project geologist, the Project Manager is responsible for evaluating the drilling requirements for the site and specifying drilling techniques that will be successful given the study objectives and the known or suspected geologic conditions at the site. The Project Manager also determines the disposal methods for products generated by drilling, such as drill cuttings and well development water, as well as any specialized supplies or logistical support required for the drilling operations.

Field Operations Leader (FOL) - The FOL is responsible for the overall supervision and scheduling of drilling activities, and is strongly supported by the project geologist.

Project Geologist - The project geologist is responsible for ensuring that standard and approved drilling procedures are followed. The geologist will generate a detailed boring log for each test hole. This log shall include a description of materials, samples, method of sampling, blow counts, and other pertinent drilling and testing information that may be obtained during drilling (see SOPs SA-6.3 and GH-1.5). Often this position for inspecting the drilling operations may be filled by other geotechnical personnel, such as soils and foundation engineers, civil engineers, etc.

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

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

The driller must report any major technical or analytical problems encountered in the field to the FOL within 24 hours of determination, and must provide advance written notification of any changes in field procedures, describing and justifying such changes. No such changes shall be made unless requested and authorized in writing by the FOL (with the concurrence of the Project Manager). Depending on the subcontract, the Project Manager may need to obtain written authorization from appropriate administrative personnel before approving any changes.

The drilling subcontractor is responsible for following decontamination procedures specified in the project plan documents. Upon completion of the work, the driller is responsible for demobilizing all equipment, cleaning up any materials deposited on site during drilling operations, and properly backfilling any open borings.

5.0 PROCEDURES

5.1 General

The purpose of drilling boreholes is:

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

All drilling and sampling equipment will be cleaned between samples and borings using appropriate decontamination procedures as outlined in SOP SA-7.1. Unless otherwise specified, it is generally advisable to drill borings at "clean" locations first, and at the most contaminated locations last, to reduce the risk of spreading contamination between locations. All borings must be logged by the site geologist as they proceed (see SOPs SA-6.3 and GH-1.5). Situations where logging would not be required would include installation of multiple well points within a small area, or a "second attempt" boring adjacent to a boring that could not be continued through resistant material. In the latter case, the boring log can be resumed 5 feet above the depth at which the initial boring was abandoned, although the site geologist should still confirm that the stratigraphy at the redrilled location conforms essentially with that encountered at the original location. If significant differences are seen, each hole should be logged separately.

5.2 Drilling Methods

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

5.2.1 Continuous-Flight Hollow-Stem Auger Drilling

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

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

Disadvantages and limitations of this method of drilling include:

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

Hollow-stem auger drilling is the preferred method of drilling. Most alternative methods require the introduction of water or mud downhole (air rotary is the exception) to maintain the open borehole. With these other methods, great care must be taken to ensure that the method does not interfere with the collection of a representative sample (which may be the prime objective of the borehole construction). With this in mind, the preferred order of choice of drilling method after hollow-stem augering (HSA) is:

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

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

The procedures for sampling soils through holes drilled by hollow-stem auger shall conform with the applicable ASTM Standards: D1587-83 and D1586-84. The guidelines established in SOP SA-1.3 shall also be followed. The hollow-stem auger may be advanced by any power-operated drilling machine having sufficient torque and ram range to rotate and force the auger to the desired depth. The machine must, however, be equipped with the accessory equipment needed to perform required sampling, or rock coring.

The hollow-stem auger may be used without the plug when boring for geotechnical examination or for well installation. However, when drilling below the water table, specially designed plugs which allow passage of formation water but not solid material shall be used (see Reference 1 of this guideline). This drilling configuration method also prevents blow back and plugging of the auger when the plug is removed for sampling.

Alternately, it may be necessary to keep the hollow stem full of water, at least to the level of the water table, to prevent blowback and plugging of the auger. If water is added to the hole, it must be sampled and analyzed to determine if it is free from contaminants prior to use. In addition, the amount of water introduced, the amount recovered upon attainment of depth, and the amount of water extracted during well development must be carefully logged in order to ensure that a representative sample of the formation water can be obtained. Well development should occur as soon after well completion as practicable (see SOP GH-2.8 for well development procedures). If gravelly or hard material is encountered which prevents advancing the auger to the desired depth, augering should be halted and either driven casing or hydraulic rotary methods should be attempted. If the depth to the bedrock/soil interface and bedrock lithology must be determined, then a 5-foot confirmatory core run should be conducted (see Section 5.2.9).

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

5.2.2 Continuous-Flight Solid-Stem Auger Drilling

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

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

5.2.3 Rotary Drilling

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

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

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

Disadvantages to using this method include:

- Formations must be logged from the cuttings that are blown to the surface and thus the depths of materials logged are approximate.

- Air blown into the formation during drilling may "bind" the formation and impede well development and natural groundwater flow.

- In-situ samples cannot be taken, unless the hole is cased.

- Casing must generally be used in unconsolidated materials.

- Air-rotary drill rigs are large and heavy.

- Large amounts of Investigation Derived Waste (IDW) may be generated which may require containerization, sampling, and off-site disposal.

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

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

Advantages to the fluid-rotary drilling method include:

- The ability to drill in many types of formations.

- Relatively quick and inexpensive.

- Split-barrel (split-spoon) or thin-wall (Shelby) tube samples can be obtained without removing drill rods if the appropriate size drill rods and bits (i.e., fish-tail or drag bit) are used.

- In some borings temporary casing may not be needed as the drilling fluids may keep the borehole open.

- Drill rigs are readily available in most areas.

Disadvantages to this method include:

- Formation logging is not as accurate as with hollow-stem auger method if split-barrel (split-spoon) samples are not taken (i.e., the depths of materials logged from cuttings delivered to the surface are approximate).

- Drilling fluids reduce permeability of the formation adjacent to the boring to some degree, and require more extensive well development than "dry" techniques (augering, air-rotary).

- No information on depth to water is obtainable while drilling.

- Fluids are needed for drilling, and there is some question about the effects of the drilling fluids on subsequent water samples obtained. For this reason as well, extensive well development may be required.

- In very porous materials (i.e., rubble fill, boulders, coarse gravel) drilling fluids may be continuously lost into the formation. This requires either constant replenishment of the drilling fluid, or the use of casing through this formation.

- Drill rigs are large and heavy, and must be supported with supplied water.

- Groundwater samples can be potentially diluted with drilling fluid.

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

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

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

5.2.4 Rotosonic Drilling

The Rotosonic drilling method employs a high frequency vibrational and low speed rotational motion coupled with down pressure to advance the cutting edge of a drill string. This produces a uniform borehole while providing a continuous, undisturbed core sample of both unconsolidated and most bedrock formations. Rotosonic drilling advances a 4-inch diameter to 12-inch diameter core barrel for sampling and can advance up to a 12-inch diameter outer casing for the construction of standard and telescoped monitoring wells. During drilling, the core barrel is advanced ahead of the outer barrel in increments as determined by the site geologist and depending upon type of material, degree of subsurface contamination and sampling objectives.

The outer casing can be advanced at the same time as the inner drill string and core barrel, or advanced down over the inner drill rods and core barrel, or after the core barrel has moved ahead to collect the undisturbed sample and has been pulled out of the borehole. The outer casing can be advanced dry in most cases, or can be advanced with water or air depending upon the formations being drilled, the depth and diameter of the hole, or requirements of the project.

Advantages of this method include:

- Sampling and well installation are faster as compared to other drilling methods.
- Continuous sampling, with larger sample volume as compared to split-spoon sampling.
- The ability to drill through difficult formations such as cobbles or boulders, hard till and bedrock.
- Reduction of IDW by an average of 70 to 80 percent.
- Well installations are quick and controlled by elimination of potential bridging of annular materials during well installation, due to the ability to vibrate the outer casing during removal.

Disadvantages include:

- The cost for Rotosonic drilling as compared to other methods are generally higher. However, the net result can be a significant savings considering reduced IDW and shortened project duration.
- Rotosonic drill rigs are large and need ample room to drill, however, Rotosonic units can be placed on the ground or placed on an ATV.
- There are a limited number of Rotosonic drilling contractors at the present time.

5.2.5 Reverse Circulation Rotary Drilling

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

Advantages of the latter method include:

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

Disadvantages include:

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

5.2.6 Drill-through Casing Driver

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

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

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

Some of the disadvantages include:

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

5.2.7 Cable Tool Drilling

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

When drilling through the unsaturated zone, some water must be added to the hole. The cuttings are suspended in the water and then bailed out periodically. Below the water table, after sufficient ground water enters the borehole to replace the water removed by bailing, no further water needs to be added. When soft caving formations are encountered, it is usually necessary to drive casing as the hole is advanced to prevent collapse of the hole. Often the drilling can be only a few feet below the bottom of the casing. Because the drill bit is lowered through the casing, the hole created by the bit is smaller than the casing. Therefore, the casing (with a sharp, hardened casing shoe on the bottom) must be driven into the hole (see Section 5.2.5 of this guideline).

Advantages of the cable-tool method include the following:

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

Disadvantages include:

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

5.2.8 Jet Drilling (Washing)

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

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

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

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

Disadvantages include the following:

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

5.2.9 Drilling with a Hand Auger

This method is applicable wherever the formation, total depth of sampling, and the site and groundwater conditions are such as to allow hand auger drilling. Hand augering can also be considered at locations where drill rig access is not possible. All hand auger borings will be performed according to ASTM D1452-80.

Samples should be taken continuously unless otherwise specified by the project plan documents. Any required sampling is performed by rotation, pressing, or driving in accordance with the standard or approved method governing use of the particular sampling tool. Typical equipment used for sampling and advancing shallow "hand auger" holes are Iwan samplers (which are rotated) or post hole diggers (which are operated like tongs). These techniques are slow but effective where larger pieces of equipment do not have access, and where very shallow holes are desired (less than 15 feet). Surficial soils must be composed of relatively soft and non-cemented formations to allow penetration by the auger.

5.2.10 Rock Drilling and Coring

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

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

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

Soft or decomposed rock should be sampled with a driven split-barrel whenever possible or cored with a Denison or Pitcher sampler.

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

Advantages of core drilling include:

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

Disadvantages include:

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

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

5.2.11 Drilling & Support Vehicles

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

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

- Totally portable drilling/sampling equipment, where all necessary components (tripods, samplers, hammers, catheads, etc.) may be hand carried to the borehole site. Drilling/sampling methods used with such equipment include:

    - Hand augers and lightweight motorized augers.
    - Retractable plug samplers--driven by hand (hammer).
    - Motorized cathead - a lightweight aluminum tripod with a small gas-engine cathead mounted on one leg, used to install small-diameter cased borings. This rig is sometimes called a "monkey on a stick."

- Skid-mounted drilling equipment containing a rotary drill or engine-driven cathead (to lift hammers and drill string), a pump, and a dismounted tripod. The skid is pushed, dragged, or winched (using the cathead drum) between boring locations.

- Small truck-mounted drilling equipment using a Jeep, stake body or other light truck (4 to 6 wheels), upon which are mounted the drill and/or a cathead, a pump, and a tripod or small drilling derrick. On some rigs, the drill and/or a cathead are driven by a power take-off from the truck, instead of by a separate engine.

- Track-mounted drilling equipment is similar to truck-mounted rigs, except that the vehicle used has wide bulldozer tracks for traversing soft ground. Sometimes a continuous-track "all terrain vehicle" is also modified for this purpose. Some types of tracked drill rigs are called "bombardier" or "weasel" rigs.

- Heavy truck-mounted drilling equipment is mounted on tandem or dual tandem trucks to transport the drill, derrick, winches, and pumps or compressors. The drill may be provided with a separate engine or may use a power take-off from the truck engine. Large augers, hydraulic rotary and reverse circulation rotary drilling equipment are usually mounted on such heavy duty trucks. For soft-ground sites, the drilling equipment is sometimes mounted on vehicles having low pressure, very wide diameter tires and capable of floating; these vehicles are called "swamp buggy" rigs.

- Marine drilling equipment is mounted on various floating equipment for drilling borings in lakes, estuaries and other bodies of water. The floating equipment varies, and is often manufactured or customized by the drilling subcontractor to suit specific drilling requirements. Typically, the range of flotation vehicles include:

  - Barrel-float rigs - a drill rig mounted on a timber platform buoyed by empty 55-gallon drums or similar flotation units.

  - Barge-mounted drill rigs.

  - Jack-up platforms - drilling equipment mounted on a floating platform having retractable legs to support the unit on the sea or lake bed when the platform is jacked up out of the water.

  - Drill ships - for deep ocean drilling.

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

5.2.12 Equipment Sizes

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

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

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

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

5.2.13 Estimated Drilling Progress

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

- The speed of the drilling method employed.

- Applicable site conditions (e.g., terrain, mobility between borings, difficult drilling conditions in bouldery soils, rubble fill or broken rock, etc.).

- Project-imposed restrictions (e.g., drilling while wearing personal protective equipment, decontamination of drilling equipment, etc.).

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

Drilling Method	Average Daily Progress (linear feet)
Hollow-stem augers	75'
Solid-stem augers	50'
Mud-Rotary Drilling	100' (cuttings samples)
Rotosonic Drilling	100'-160' (continuous core)
Reverse-Circulation Rotary	100' (cuttings samples)
Skid-Rig with driven casing	30'
Rotary with driven casing	50'
Cable Tool	30'
Hand Auger	Varies
Continuous Rock Coring	50'

5.3 Prevention of Cross-Contamination

A telescoping or multiple casing technique minimizes the potential for the migration of contaminated groundwater to lower strata below a confining layer. The telescoping technique consists of drilling to a confining layer utilizing a spun casing method with a diamond cutting or augering shoe (a method similar to the rock coring method described in Section 5.2.10, except that larger casing is used) or by using a driven-casing method (see Section 5.2.6 of this guideline) and installing a specified diameter steel well casing. The operation consists of three separate steps. Initially, a drilling casing (usually of 8-inch diameter) is installed followed by installation of the well casing (6-inch-diameter is common for 2-inch wells). This well casing is driven into the confining layer to ensure a tight seal at the bottom of the hole. The well casing is sealed at the bottom with a bentonite-cement slurry. The remaining depth of the boring is drilled utilizing a narrower diameter spun or driven casing technique within the outer well casing. A smaller diameter well casing with an appropriate length of slotted screen on the lower end, is installed to the surface.

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

5.4 Cleanout of Casing Prior to Sampling

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

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

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

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

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

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

5.5 Materials of Construction

The effects of monitoring well construction materials on specific chemical analytical parameters are described and/or referenced in SOP GH-2.8. However, there are several materials used during drilling, particularly drilling fluids and lubricants, which must be used with care to avoid compromising the representativeness of soil and ground water samples.

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

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

5.6 Subsurface Soil Samples

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

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

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

Surface protocols for various soil sampling techniques are discussed in SOP SA-1.3. Continuous-core soil sampling and rock coring are discussed below. The procedures described here are representative of a larger number of possible drilling and sampling techniques. The choice of techniques is based on a large number of variables such as cost, local geology, etc. The final choice of methods must be made with the assistance of drilling subcontractors familiar with the local geologic conditions. Alternative techniques must be based upon the underlying principles of quality assurance implicit in the following procedures.

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

5.7 Rock Sampling (Coring) (ASTM D2113-83)

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

Borehole diameter can be drilled to various sizes, depending on the information needed. Standard sizes of core barrels (showing core diameter) and casing are shown in Figure 1.

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

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

FIGURE 1

STANDARD SIZES OF CORE BARRELS AND CASING

Coring Bit Size	Nominal*		Set Size*	
	O.D.	I.D.	O.D.	I.D.
RWT	1 5/32	3/4	1.160	0.735
EWT	1 1/2	29/32	1.470	0.905
EX, EXL, EWG, EWM	1 1/2	13/16	1.470	0.845
AWT	1 7/8	1 9/32	1.875	1.281
AX, AXL, AWG, AWM	1 7/8	1 3/16	1.875	1.185
BWT	2 3/8	1 3/4	2.345	1.750
BX, BXL, BWG, BWM	2 3/8	1 5/8	2.345	1.655
NWT	3	2 5/16	2.965	2.313
NX, NXL, NWG, NWM	3	2 1/8	2.965	2.155
HWT	3 29/32	3 3/16	3.889	3.187
HWG	3 29/32	3	3.889	3.000
2 3/4 x 3 7/8	3 7/8	2 3/4	3.840	2.690
4 x 5 1/2	5 1/2	4	5.435	3.970
6 x 7 3/4	7 3/4	6	7.655	5.970
AX Wire line ___|___/	1 7/8	1	1.875	1.000
BX Wire line ___|___/	2 3/8	1 7/16	2.345	1.437
NX Wire line ___|___/	3	1 15/16	2.965	1.937

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

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

FIGURE 1
STANDARD SIZES OF CORE BARRELS AND CASING
PAGE TWO

Size Designations			Casing Coupling					Approximate Core Diameter	
Casing; Casing coupling; Casing bits; Core barrel bits	Rod; rod couplings	Casing O.D., Inches	O.D., Inches	I.D., Inches	Casing bit O.D., Inches	Core barrel bit O.D., Inches*	Drill rod O.D., Inches	Normal, Inches	Thinwall, Inches
RX	RW	1.437	1.437	1.188	1.485	1.160	1.094	—	0.735
EX	E	1.812	1.812	1.500	1.875	1.470	1.313	0.845	0.905
AX	A	2.250	2.250	1.906	2.345	1.875	1.625	1.185	1.281
BX	B	2.875	2.875	2.375	2.965	2.345	1.906	1.655	1.750
NX	N	3.500	3.500	3.000	3.615	2.965	2.375	2.155	2.313
HX	HW	4.500	4.500	3.938	4.625	3.890	3.500	3.000	3.187
RW	RW	1.437	Flush Joint	No Coupling	1.485	1.160	1.094	—	0.735
EW	EW	1.812			1.875	1.470	1.375	0.845	0.905
AW	AW	2.250			2.345	1.875	1.750	1.185	1.281
BW	BW	2.875			2.965	2.345	2.125	1.655	1.750
NW	NW	3.500			3.615	2.965	2.625	2.155	2.313
HW	HW	4.500			4.625	3.890	3.500	3.000	3.187
PW	—	5.500			5.650	—	—	—	—
SW	—	6.625			6.790	—	—	—	—
UW	—	7.625			7.800	—	—	—	—
ZW	—	8.625			8.810	—	—	—	—
—	AX __|__\	—	—	—	—	1.875	1.750	1.000	—
—	BX __|__\	—	—	—	—	2.345	2.250	1.437	—
—	NX __|__\	—	—	—	—	2.965	2.813	1.937	—

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

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

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

5.7.1 Diamond Core Drilling

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

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

- Firmly seat a casing into the bedrock or the hard material to prevent loose materials from entering the hole and to prevent the loss of drilling fluid return. Level the surface of the rock or hard material when necessary by the use of a fishtail or other bits. If the drill hole can be retained open without the casing and if cross-contamination of aquifers in the unconsolidated materials is unlikely, leveling may be omitted.

- Begin the core drilling using a double-tube swivel-core barrel of the desired size. After drilling no more than 10 feet (3 m), remove the core barrel from the hole and take out the core. If the core blocks the flow of the drilling fluid during drilling, remove the core barrel immediately. In soft materials, a large starting size may be specified for the coring tools; where local experience indicates satisfactory core recovery or where hard, sound materials are anticipated, a smaller size or the single-tube type may be specified and longer runs may be drilled. NX/NW size coring equipment is the most commonly used size.

- When soft materials are encountered that produce less than 50 percent recovery, stop the core drilling. If soil samples are desired, secure such samples in accordance with the procedures described in ASTM Method D 1586 (Split-barrel Sampling) or in Method D 1587 (Thin-Walled Tube Sampling); sample soils per SOP SA-1.3. Resume diamond core drilling when refusal materials are again encountered.

- Since rock structures and the occurrence of seams, fissures, cavities, and broken areas are among the most important items to be detected and described, take special care to obtain and record these features. If such broken zones or cavities prevent further advance of the boring, one of the following three steps shall be taken: (1) cement the hole; (2) ream and case; or (3) case and advance with the next smaller size core barrel, as conditions warrant.

- In soft, seamy, or otherwise unsound rock, where core recovery may be difficult, M-design core barrels may be used. In hard, sound rock where a high percentage of core recovery is anticipated, the single-tube core barrel may be employed.

5.7.2 Rock Sample Preparation and Documentation

Once the rock coring has been completed and the core recovered, the rock core shall be carefully removed from the barrel, placed in a core tray (previously labeled "top" and "bottom" to avoid confusion), classified, and measured for percentage of recovery as well as the rock quality designation (RQD). Each core shall be described, classified, and logged using a uniform system as presented in SOP GH-1.5. If moisture content will be determined or if it is desirable to prevent drying (e.g., to prevent shrinkage of clay formations) or oxidation of the core, the core shall be wrapped in plastic sleeves immediately after logging. Each plastic sleeve shall be labeled with indelible ink. The boring number, run number, and the footage represented in each sleeve shall be included, as well as designating the top and bottom of the core run.

After sampling, rock cores shall be placed in the sequence of recovery in well-constructed wooden boxes provided by the drilling contractor. Rock cores from two different borings shall not be placed in the same core box unless accepted by the Project Geologist. The core boxes shall be constructed to accommodate at least 20 linear feet of core in rows of approximately 5 feet each and shall be constructed with hinged tops secured with screws, and a latch (usually a hook and eye) to keep the top securely fastened down. Wood partitions shall be placed at the end of each core run and between rows.

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

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

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

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

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

6.0 REFERENCES

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ATTACHMENT A

DRILLING EQUIPMENT SIZES

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

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

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

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

TETRA TECH NUS, INC.	**STANDARD OPERATING PROCEDURES**	Number: GH-2.9	Page: 1 of 5
		Effective Date: 09/03	Revision: 2
		Applicability: Tetra Tech NUS, Inc.	
		Prepared: Earth Sciences Department	
Subject: WELL ABANDONMENT		Approved: D. Senovich	

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1.0 PURPOSE

Well abandonment is that procedure by which any monitoring well is permanently closed. Abandonment procedures are designed to prevent fluids from entering or migrating within the monitoring well. Therefore, an abandoned monitoring well must be sealed in such a manner that it can not act as a conduit for migration of contaminants from the ground surface to the water table or between aquifers.

It is important that the appropriate state or local agency be notified of monitoring well abandonment. The application of and adherence to this SOP must be tailored to applicable state, local, and Federal regulatory requirements.

2.0 SCOPE

The methods described in this procedure shall be used for all projects requiring well abandonment where specific state, local, or Federal regulations are unavailable. An abandoned well shall be filled and sealed so that it will not act as a pathway for the interchange of water between the surface and subsurface or present a hazard to the environment.

3.0 GLOSSARY

Well - Any constructed access point to an aquifer, confined or unconfined, including, but not limited to, test borings, hydropunch holes, monitoring points, and production wells.

Abandon - To permanently discontinue the use of a well. Any well shall require abandonment when it is no longer serving as a monitoring point or is in such a state of disrepair that continued use for the purpose of obtaining groundwater is impracticable, or when it has been permanently disconnected from any water supply system or irrigation system.

4.0 RESPONSIBILITIES

Project Manager - It shall be the responsibility of the Project Manager and/or Project Hydrogeologist to determine the applicability of well abandonment, based on the established scope and objective of the project and program-specific requirements. It shall be the responsibility of the Project Manager (or designee) to ensure that the procedures established for well abandonment are thoroughly specified and/or referenced in the relevant project planning documents. It shall be the responsibility of the Project Manager to ensure that the Field Operations Leader is familiar with the proper procedures for well abandonment and confirm the supervising project geologist or the subcontractor performing the well abandonment are qualified to perform such activities.

Field Operations Leader (FOL) - It shall be the responsibility of the Field Operations Leader to ensure that all field technicians and/or drilling personnel are thoroughly familiar with this Standard Operating Procedure. It shall be the responsibility of the FOL to ensure that the procedures identified in this SOP are used during well abandonment.

5.0 PROCEDURES

5.1 General

Well abandonment is warranted when the project team has reason to believe, on the basis of local conditions, that the well is causing or is a potential source of pollution to an aquifer; is a production well that is producing water that is polluted; or does not have a certificate of potability, if required. Wells may also be abandoned once their designed purposes have been fulfilled and are determined to no longer be of use.

Well abandonment is conducted to eliminate physical hazards, prevent groundwater contamination, prevent intermixing of aquifer waters, and conserve aquifer yield and hydrostatic head.

Please note Federal, state, and local regulations concerning this activity may vary. Therefore, applicable regulatory requirements should be reviewed to determine the need for Licensed/Certified Well Drillers to complete/oversight this activity.

5.2 Material for Sealing

Acceptable sealing materials include concrete, portland cement grout, sodium-base bentonite clay, or combinations of these materials. These materials are defined as follows:

- Concrete may be used for filling the upper part of a well or water bearing formation, or plugging short sections of casing and filling large diameter wells.
- Portland cement grout is superior for sealing small openings, penetrating any annular space outside the casing, and for filling voids in the surrounding formation. Portland cement grout shall be composed of one bag of Type I cement per 6 to 8 gallons of water. Two parts sand to one part cement may be added.
- Bentonite clay, when applied as a heavy mud-laden fluid under pressure, has most of the advantages of cement grout, but under some conditions may be carried away into the surrounding formation. A bentonite clay mixture shall be composed of not less than 2 pounds of clay per gallon of water. Bentonite clay may not be used where it will come in contact with water of a pH below 5.0 or total dissolved solids (TDS) content greater than 1,000 mg/L or both. Bentonite may also be added to cement grout to add flexibility.

Fill materials include clay, silt, sand, gravel, crushed stone, or a mixtures of these materials may be used as a filler in sealing a well when used in conjunction with the sealing materials described above. Organic material may not be used and fill material may be required to be disinfected or certified clean prior to use. Spent drilling muds or drill cuttings are not to be used to seal a well.

5.3 Procedures for Sealing Wells

5.3.1 Preliminary Considerations

Several factors should be considered to determine the appropriate well abandonment method. These factors include:

- Conditions of the well.
- Details of well construction, including casing material, diameter of casing, depth of well, and well plumbness.
- Obstructions within the well that may interfere with filling or sealing.
- Hydrogeologic setting.
- Level of contamination and the zone or zones where it occurs.
- Regulatory requirements.

Degraded wells may not permit casing removal by pulling. Also, the casing material may dictate whether a casing can be removed intact. Stainless steel will have a higher tensile strength than PVC and may hold together while pulling the casing; PVC well casing may break under pulling and may need to be overdrilled to remove it. The depth of the well and well plumbness may limit casing removal depending on whether a casing is pulled or overdrilled. In some cases, casings can be left in-place if they are properly filled with appropriate backfill.

The formation lithology influences the selection of casing removal. Unconsolidated materials can be drilled with hollow-stem augering techniques whereas consolidated materials cannot. Unconsolidated materials may also cave-in during well casing removal.

5.3.2 Filling and Sealing Procedures

Drilled wells (all wells not dug) shall be filled with sealing material or a combination of sealing material and fill material.

In some cases, well casing removal is necessary for well abandonment. If the borehole is unstable and may cave-in, sealing material will be emplaced simultaneously during casing removal. If the well is not grouted, casing may be pulled with hydraulic jacks or a drilling rig. It may also be pulled by sandlocking. Sandlocking consists of lowering a pipe wrapped with burlap approximately 2/3 of the well depth and filling the burlap wrap with sand. The pipe is slowly lifted and locks the sand, pulling the casing. Well casings can also be removed by overdrilling. Wells can be overdrilled with larger diameter hollow steam or solid stem augers or direct rotary techniques, using air or mud. Augers used for overdrilling should be at least 2 inches larger in diameter than the diameter of the well casing.

If well casing is in poor condition or is grouted in place, the casing may be ripped or perforated and filled and pressure grouted in place.

Abandoned wells shall be filled with the appropriate filling and sealing material placed from the bottom of the well upward. When Portland cement grout or concrete is used, it shall be placed in continuous operation using a tremie pipe. Sealing material shall be placed in the interval or intervals to be sealed by methods that prevent free fall, dilution, and/or separation of aggregates from cementing material.

A well constructed in unconsolidated material in an unconfined groundwater zone shall be filled and sealed by placing fill material in the well to the level of the water table, and filling the remainder of the well with sealing material. If the water table is at a depth greater than 40 feet, a minimum of 40 feet of sealing material shall be required.

A well which penetrates several aquifers or formations shall be filled and sealed in such a way as to prevent the vertical movement of water from one aquifer or formation to another. If the casing has been removed, sealing material shall be placed opposite the confining formations and from the surface down to the first confining formation. Sand and other suitable fill material may be placed opposite the producing aquifer. Ideally, the entire well can be filled with sealing material. If the casing has not been removed, the entire well shall be fill with sealing material.

A well penetrating creviced or cavernous rock shall be filled using coarse fill material opposite the cavernous or creviced rock portions of the well. Sealing material shall extend from the top of the unfractured rock portion of the well or base of the casing, whichever is deeper, to the surface. The minimum depth of sealing material may not be less than 10 feet.

In the case where wells penetrate specific aquifers where conditions necessitate the sealing of specific aquifers or formations, the annular space in the area of the specific aquifer or formation shall be sealed during the abandonment of the well.

A dug well exceeding 24 inches in diameter shall be filled and sealed by placing fill material (excluding clay or silt) in the well to a level approximately 5 feet below the land surface, and placing a 3 foot plug of sealing material above the fill. The remainder of the well shall be back filled with soil material.

6.0 REFERENCES

Maryland Department of the Environment (MDE Regulations); Title 26, Subtitle 04; Regulation of Water Supply, Sewage Disposal, and Solid Waste; Chapter 4--Well Construction.

U.S. EPA, February 1990. Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells.

TETRA TECH NUS, INC.	**STANDARD OPERATING PROCEDURES**	Number SA-7.1	Page 1 of 8
		Effective Date 09/03	Revision 3
		Applicability Tetra Tech NUS, Inc.	
		Prepared Earth Sciences Department	
Subject DECONTAMINATION OF FIELD EQUIPMENT		Approved D. Senovich	

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1.0 PURPOSE

Decontamination is the process of removing and/or neutralizing site contaminants that have contacted and/or accumulated on equipment. The objective/purpose of this SOP is intended to protect site personnel, general public, and the sample integrity through the prevention of cross contamination onto unaffected persons or areas. It is further intended through this procedure to provide guidelines regarding the appropriate procedures to be followed when decontaminating drilling equipment, monitoring well materials, chemical sampling equipment and field analytical equipment.

2.0 SCOPE

This procedure applies to all equipment including drilling equipment, heavy equipment, monitoring well materials, as well as chemical sampling and field analytical equipment decontamination that may be used to provide access/acquire environmental samples. Where technologically and economically feasible, single use sealed disposable equipment will be employed to minimize the potential for cross contamination. This procedure also provides general reference information on the control of contaminated materials.

3.0 GLOSSARY

Acid - For decontamination of equipment when sampling for trace levels of inorganics, a 10% solution of nitric acid in deionized water should be used. Due to the leaching ability of nitric acid, it should not be used on stainless steel.

Alconox/Liquinox - A brand of phosphate-free laboratory-grade detergent.

Decontamination Solution - Is a solution selected/identified within the Health and Safety Plan or Project-Specific Quality Assurance Plan. The solution is selected and employed as directed by the project chemist/health and safety professional.

Deionized Water (DI) - Deionized water is tap water that has been treated by passing through a standard deionizing resin column. This water may also pass through additional filtering media to attain various levels of analyte-free status. The DI water should meet CAP and NCCLS specifications for reagent grade, Type I water.

Potable Water - Tap water used from any municipal water treatment system. Use of an untreated potable water supply is not an acceptable substitute for tap water.

Pressure Washing - Employs high pressure pumps and nozzle configuration to create a high pressure spray of potable water. High pressure spray is employed to remove solids.

Solvent - The solvent of choice is pesticide-grade Isopropanol. Use of other solvents (methanol, acetone, pesticide-grade hexane, or petroleum ether) may be required for particular projects or for a particular purpose (e.g. for the removal of concentrated waste) and must be justified in the project planning documents. As an example, it may be necessary to use hexane when analyzing for trace levels of pesticides, PCBs, or fuels. In addition, because many of these solvents are not miscible in water, the equipment should be air dried prior to use. Solvents should not be used on PVC equipment or well construction materials.

Steam Pressure Washing - This method employs a high pressure spray of heated potable water. This method through the application of heat provides for the removal of various organic/inorganic compounds.

4.0 RESPONSIBILITIES

Project Manager - Responsible for ensuring that all field activities are conducted in accordance with approved project plan(s) requirements.

Field Operations Leader (FOL) - Responsible for the onsite verification that all field activities are performed in compliance with approved Standards Operating Procedures or as otherwise dictated by the approved project plan(s).

Site Health and Safety Officer (SHSO) - The SHSO exercises shared responsibility with the FOL concerning decontamination effectiveness. All equipment arriving on-site (as part of the equipment inspection), leaving the site, moving between locations are required to go through a decontamination evaluation. This is accomplished through visual examination and/or instrument screening to determine the effectiveness of the decontamination process. Failure to meet these objectives are sufficient to restrict equipment from entering the site/exiting the site/ or moving to a new location on the site until the objectives are successfully completed.

5.0 PROCEDURES

The process of decontamination is accomplished through the removal of contaminants, neutralization of contaminants, or the isolation of contaminants. In order to accomplish this activity a level of preparation is required. This includes site preparation, equipment selection, and evaluation of the process. Site contaminant types, concentrations, media types, are primary drivers in the selection of the types of decontamination as well as where it will be conducted. For purposes of this SOP discussion will be provided concerning general environmental investigation procedures.

The decontamination processes are typically employed at:

- Temporary Decontamination Pads/Facilities
- Sample Locations
- Centralized Decontamination Pad/Facilities
- Combination of some or all of the above

The following discussion represents recommended site preparation in support of the decontamination process.

5.1 Decontamination Design/Constructions Considerations

5.1.1 Temporary Decontamination Pads

Temporary decontamination pads are constructed at satellite locations in support of temporary work sites. These structures are generally constructed to support the decontamination of heavy equipment such as drill rigs and earth moving equipment but can be employed for smaller articles.

The purpose of the decontamination pad is to contain wash waters and potentially contaminated soils generated during decontamination procedures. Therefore, construction of these pads should take into account the following considerations

- Site Location – The site selected should be within a reasonable distance from the work site but should avoid:

  - Pedestrian/Vehicle thoroughfares
  - Areas where control/custody cannot be maintained
  - Areas where a potential releases may be compounded through access to storm water transport systems, streams or other potentially sensitive areas.
  - Areas potentially contaminated.

- Pad – The pad should be constructed to provide the following characteristics

  - Size – The size of the pad should be sufficient to accept the equipment to be decontaminated as well as permitting free movement around the equipment by the personnel conducting the decontamination.

  - Slope – An adequate slope will be constructed to permit the collection of the water and potentially contaminated soils within a trough or sump constructed at one end. The collection point for wash waters should be of adequate distance that the decontamination workers do not have to walk through the wash waters while completing their tasks.

  - Sidewalls – The sidewalls should be a minimum of 6-inches in height to provide adequate containment for wash waters and soils. If splash represents a potential problem, splash guards should be constructed to control overspray. Sidewalls maybe constructed of wood, inflatables, sand bags, etc. to permit containment.

  - Liner – Depending on the types of equipment and the decontamination method the liner should be of sufficient thickness to provide a puncture resistant barrier between the decontamination operation and the unprotected environment. Care should be taken to examine the surface area prior to placing the liner to remove sharp articles (sticks, stones, debris) that could puncture the liner. Liners are intended to form an impermeable barrier. The thickness may vary from a minimum recommended thickness of 10 mil to 30 mil. Achieving the desired thickness maybe achieved through layering lighter constructed materials. It should be noted that various materials (rubber, polyethylene sheeting) become slippery when wet. To minimize this potential hazard associated with a sloped liner a light coating of sand maybe applied to provide traction as necessary.

  - Wash/drying Racks – Auger flights, drill/drive rods require racks positioned off of the ground to permit these articles to be washed, drained, and dried while secured from falling during this process. A minimum ground clearance of 2-feet is recommended.

  - Maintenance – The work area should be periodically cleared of standing water, soils, and debris. This action will aid in eliminating slip, trip, and fall hazards. In addition, these articles will reduce potential backsplash and cross contamination. Hoses should be gathered when not in use to eliminate potential tripping hazards.

5.1.2 Decontamination Activities at Drill Rigs/DPT Units

During subsurface sampling activities including drilling and direct push activities decontamination of drive rods, Macro Core Samplers, split spoons, etc. are typically conducted at an area adjacent to the operation. Decontamination is generally accomplished using a soap/water wash and rinse utilizing buckets and brushes. This area requires sufficient preparation to accomplish the decontamination objectives.

Buckets shall be placed within mortar tubs or similar secondary containment tubs to prevent splash and spills from reaching unprotected media. Drying racks will be employed as directed for temporary pads to permit parts to dry and be evaluated prior to use/re-use.

5.1.3 Decontamination Activities at Remote Sample Locations

When sampling at remote locations sampling devices such as trowels, pumps/tubing should be evacuated of potentially contaminated media to the extent possible. This equipment should be wrapped in plastic for transport to the temporary/centralized decontamination location for final cleaning and disposition.

5.2 <u>Equipment Decontamination Procedures</u>

The following represents procedures to be employed for the decontamination of equipment that may have contacted and/or accumulated contamination through site investigation activities.

5.2.1 Monitoring Well Sampling Equipment

5.2.1.1 <u>Groundwater sampling pumps – This includes pumps inserted into the monitoring well such as Bladder pumps, Whale pumps, Redi-Flo, reusable bailers, etc.</u>

1) Evacuate to the extent possible, any purge water within the pump.

2) Scrub using soap and water and/or steam clean the outside of the pump and tubing, where applicable.

3) Insert the pump and tubing into a clean container of soapy water. Pump a sufficient amount of soapy water through the pump to flush any residual purge water. Once flushed, circulate soapy water through the pump to ensure the internal components are thoroughly flushed.

4) Remove the pump and tubing from the container, rinse external components using tap water. Insert the pump and tubing into a clean container of tap water. Pump a sufficient amount of tap water through the pump to evacuate all of the soapy water (until clear).

5) Rinse equipment with pesticide grade isopropanol

6) Repeat item #4 using deionized water through the hose to flush out the tap water and solvent residue as applicable*.

7) Drain residual deionized water to the extent possible, allow components to air dry.

8) Wrap pump in aluminum foil or a clear clean plastic bag for storage.

5.2.1.2 <u>Electronic Water Level Indicators/Sounders/Tapes</u>

During water level measurements, rinsing with the extracted tape and probe with deionized water and wiping the surface of the extracted tape is acceptable. However, periodic full decontamination should be conducted as indicated below.

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* - The solvent should be employed when samples contain oil, grease, PAHs, PCBs, and other hard to remove materials. If these are not of primary concern, the solvent step may be omitted. In addition, do not rinse PE, PVC, and associated tubing with solvents.

1) Wash with soap and water
2) Rinse with tap water
3) Rinse with deionized water

Note: In situations where oil, grease, free product, other hard to remove materials are encountered probes and exposed tapes should be washed in hot soapy water.

5.2.1.3 Miscellaneous Equipment

Miscellaneous equipment including analytical equipment (water quality testing equipment) should be cleaned per manufacturer's instructions. This generally includes wiping down the sensor housing and rinsing with tap and deionized water.

Coolers/Shipping Containers employed to ship samples are received from the lab in a variety of conditions from marginal to extremely poor. Coolers should be evaluated prior to use for

- Structural integrity – Coolers missing handles or having breaks within the outer housing should be removed and not used. Notify the laboratory that the risk of shipping samples will not be attempted and request a replacement unit.
- Cleanliness – As per protocol only volatile organic samples are accompanied by a trip blank. If a cooler's cleanliness is in question (visibly dirty/stained) or associated with noticeable odors it should be decontaminated prior to use.

  1) Wash with soap and water
  2) Rinse with tap water
  3) Dry

If these measures fail to clean the cooler to an acceptable level, remove the unit from use as a shipping container and notify the laboratory to provide a replacement unit.

5.2.2 Down-Hole Drilling Equipment

This includes any portion of the drill rig that is over the borehole including auger flights, drill stems, rods, and associated tooling that would extend over the borehole. This procedure is to be employed prior to initiating the drilling/sampling activity, then between locations.

1) Remove all soils to the extent possible using shovels, scrapers, etc. to remove loose soils.
2) Through a combination of scrubbing using soap and water and/or steam cleaning remove visible dirt/soils.
3) Rinse with tap water.
4) Rinse equipment with pesticide grade isopropanol
5) To the extent possible allow components to air dry.
6) Wrap or cover equipment in clear plastic until it is time to be used.

5.2.3 Soil/Sediment Sampling Equipment

This consists of soil sampling equipment including but not limited to hand augers, stainless steel trowels/spoons, bowls, dredges, scoops, split spoons, Macro Core samplers, etc.

1) Remove all soils to the extent possible.

2) Through a combination of scrubbing using soap and water and/or steam cleaning remove visible dirt/soils.

3) Rinse with tap water.

4) Rinse equipment with pesticide grade isopropanol

5) Rinse with deionized water

6) To the extent possible allow components to air dry.

7) If the device is to be used immediately, screen with a PID/FID to insure all solvents (if they were used) and trace contaminants have been adequately removed.

8) Once these devices have been dried wrap in aluminum foil for storage until it is time to be used.

5.3 <u>Contact Waste/Materials</u>

During the course of field investigations disposable/single use equipment becomes contaminated. These items include tubing, trowels, PPE (gloves, overboots, splash suits, etc.) broken sample containers.

With the exception of the broken glass, single use articles should be cleaned (washed and rinsed) of visible materials and disposed of as normal refuse. The exception to this rule is that extremely soiled materials that cannot be cleaned should be containerized for disposal in accordance with applicable federal state and local regulations.

5.3.1 Decontamination Solutions

All waste decontamination solutions and rinses must be assumed to contain the hazardous chemicals associated with the site unless there are analytical or other data to the contrary. The waste solution volumes could vary from a few gallons to several hundred gallons in cases where large equipment required cleaning.

Containerized waste rinse solutions are best stored in 55-gallon drums (or equivalent containers) that can be sealed until ultimate disposal at an approved facility. These containers must be appropriately labeled.

5.4 <u>Decontamination Evaluation</u>

Determining the effectiveness of the decontamination process will be accomplished in the following manner

- Visual Evaluation – A visual evaluation will be conducted to insure the removal of particulate matter. This will be done to insure that the washing/rinsing process is working as intended.

- Instrument Screening – A PID and/or an FID should be used to evaluate the presence of the contaminants or solvents used in the cleaning process. The air intake of the instrument should be passed over the article to be evaluated. A positive detection requires a repeat the decontamination process. It should be noted that the instrument scan is only viable if the contaminants are detectable within the instruments capabilities.

- Rinsate Blanks – It is recommended that Rinsate samples be collected to

  - Evaluate the decontamination procedure representing different equipment applications (pumps versus drilling equipment) and different decontamination applications.

  - Single use disposable equipment – The number of samples should represent different types of equipment as well as different Lot Numbers of single use articles.

The collection and the frequency of collection of rinsate samples are as follows:

- Per decontamination method
- Per disposable article/Batch number of disposable articles

It is recommended that an initial rinsate sample be collected early in the project to ensure that the decontamination process is functioning properly and in an effort to avoid using a contaminated batch of single use articles. It is recommended that a follow up sample be collected during the execution of the project to insure those conditions do not change. Lastly, rinsate samples collection may be driven by types of and/or contaminant levels. Hard to remove contaminants, oils/greases, some PAHs/PCBs, etc. may also support the collection of additional rinsates due to the obvious challenges to the decontamination process. This is a field consideration to be determined by the FOL.

APPENDIX C

FIELD DOCUMENTATION FORMS

TETRA TECH NUS, INC.

PHOTOIONIZATION DETECTOR FIELD CALIBRATION LOG

Serial No.: ____________________ Model No.: ____________________ Decal No.: ____________________

Site Name/Location: ______________________________ Tetra Tech NUS Charge No.: ____________________

CALIBRATION DATE	STANDARD GAS-ISOBUTYLENE	CALIBRATION READING Isobutylene Equiv. (ppm)	CALIBRATION CHECK Isobutylene Equiv. (ppm)	SIGNATURE	COMMENTS
	Lot # ________ Conc. = ________ ppm				
	Lot # ________ Conc. = ________ ppm				
	Lot # ________ Conc. = ________ ppm				
	Lot # ________ Conc. = ________ ppm				
	Lot # ________ Conc. = ________ ppm				
	Lot # ________ Conc. = ________ ppm				
	Lot # ________ Conc. = ________ ppm				
	Lot # ________ Conc. = ________ ppm				
	Lot # ________ Conc. = ________ ppm				

TtNUS Form 0006

TETRA TECH NUS, INC.

SAMPLE LOG SHEET - SOLID PHASE

Site Name: ______________________ Tetra Tech NUS Charge No. ______________________
Sample ID: ______________________ QC Information: ______________________(if applicable)

Sample Method: ______________________
Depth Sampled: ______________feet
Sample Date & Time: ____/_____/_____ __________hours Dup_____hours
Sampler(s): ______________________

Data Recorded By: ______________________
Signature

PID/OVA Monitor Reading: ______________________ ppm

TYPE OF SAMPLE: (Check all that apply)

_____ Soil
_____ Sediment
_____ Lagoon/Pond
_____ Grab
_____ Trip Blank*
_____ Rinsate Blank*
_____ Field Duplicate collected
_____ Other (Specify): __________

Description: (Sand, Clay, Muck, Peat, Dry, Moist, Wet, Etc.)

SAMPLE DATA/REMARKS: ______________________

ANALYSIS	BOTTLE LOT No.

NOTES/SKETCH:

TtNUS Form 0005

BORING LOG FOR: ______
PROJECT NO.: ______
LOGGED BY: ______
DRILLED BY (Company/Driller): ______
GRD. SURFACE ELEVATION: ______

TRANSCRIBED BY: ______
ELEVATION FROM: ______

BORING NO.: ______
START DATE: ______
COMPLETION: DATE: ______
MON. WELL NO.: ______
CHECKED BY: ______

DEPTH (FEET)	BLOWS PER 6"	SAMP REC. / SAMP LENG.	SAMPLING TIME & SAMPLE NO. (QA/QC STATUS)	DEPTH MAT'L CHG./ WELL PROF'L	SOIL DENSITY/ CONSIS. or ROCK HARD.	CLR	MATERIAL CLASSIFICATION	USCS or ROCK BRKN	REMARKS (moisture condition; odors; geological classification; rock weathering; etc.)	FIELD SCREENING DATA *METHOD* = [FID, (PPM)]

TYPE OF DRILLING RIG: ______
METHOD OF ADVANCING BORING: ______
METHOD OF SOIL SAMPLING: ______
METHOD OF ROCK CORING: ______
GROUNDWATER LEVELS: ______
OTHER OBSERVATIONS: ______

BORING NO.:

Tetra Tech NUS, Inc.

PAGE: OF

Ttnus Form 0018

TETRA TECH NUS, INC.

SAMPLE LOG SHEET - LIQUID PHASE

Site Name: ______________________ Tetra Tech NUS Charge No. ______________________
Sample ID: ______________________ QC Information: ______________________ (if applicable)

Sample Method/Device: ______________________
Depth Sampled: ________ feet Total Depth ________ feet (SW Only)
Sample Date & Time: ___/___/___ ____________ hours
Sampler(s): ______________________

____

Recorded By: ______________________
Signature

TYPE OF SAMPLE: (Check all that apply)

_____ Groundwater
_____ Surface Water
_____ Residential Supply
_____ Grab
_____ Composite
_____ Trip Blank*
_____ Rinsate Blank*
_____ Field Duplicate Collected
_____ Other (Specify): ______________________

* include sample source & lot No.

WELL PURGE DATA:

Micro Tip/OVA Monitor Reading: ppm

Well Depth	feet	Purge Start	hrs
Inside Diameter	Inches	Purge Stop Time	hrs
Water Level	feet	Total Gallons Purged	
Well Volume	gal.	Purge Method	

Color: ____________ Turbidity: CLR/SL CLDY/CLDY/OPAQ

Sampling/Purge Data:

Vol. #	Temp °C	pH	Spec. Cond.	DO
0	____	____	____	____
1	____	____	____	____
3	____	____	____	____
4	____	____	____	____

ANALYSIS	BOTTLE LOT NO.	TRAFFIC REPORT NO.		COMMENTS
		ORGANIC	INORGANIC	

TtNUS Form 0004

TETRA TECH NUS, INC.

FIELD MODIFICATION RECORD

Site Name: ______________________________ Location: ____________________

Project Number: ___________________________ Task Assignment: ______________

To: ____________________ Location: __________________ Date: ___________

Description: ____

Reason for Change: ____

Recommended Action: ____

Field Operations Leader (Signature): __________________________ Date: __________

Disposition/Action: ____

Project Manager (Signature): ______________________________ Date: __________

Distribution:

Program Manager:	____________	Others as Required:
Project Manager:	____________	____________
Quality Assurance Officer:	____________	____________
Field Operations Leader:	____________	____________
Project File:	____________	____________