MULTI-SITE FIELD SAMPLING PLAN
FORMER MANUFACTURED GAS PLANT SITES

Prepared for:

Wisconsin Public Service Corporation, Peoples Gas Light and Coke Company, North Shore Gas Company

Managed By:

Integrys Business Support, LLC
130 East Randolph Drive
Chicago, Illinois 60601

Integrys Business Support, LLC
700 North Adams Street
Green Bay, Wisconsin 54307

Prepared For Use By:

The Consultant/Contractor

Revision 4
September 8, 2008

TABLE OF CONTENTS

FIGURES

TABLES

APPENDICES

ACRONYMS

Acronyms used in this Multi-Site Field Sampling Plan.

°C	Degrees Celsius
°F	Degrees Fahrenheit
μm	Micrometer / Micron
μmhos/cm	Micromhos Per Centimeter
ASTM	ASTM International (fka American Society for Testing and Materials)
AVS SEM	Acid Volatile Sulfides-Simultaneously Extracted Metals
BERA	Baseline Ecological Risk Assessment
bgs	Below Ground Surface
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
CA	Cost Analysis
cm	Centimeter
COC	Chain-of-Custody
COPC	Chemicals of Potential Concern
CPT	Cone Penetrometer Technology
CSM	Conceptual Site Model
DET	Diffusion Equilibration in Thin Films
DNAPL	Dense Non-Aqueous Phase Liquid
DQO	Data Quality Objective
DPT	Direct Push Technologies
EE	Engineering Evaluation
ESB	Equilibrium Partitioning Sediment Benchmark
eV	Electron Volt
EZ	Exclusion Zone
FAM	Field Analytical Method
FEMA	Federal Emergency Management Agency
FOP	Field Operating Procedures
FSP	Field Sampling Plan
GPS	Global Positioning System
GW/SW	Groundwater / Surface Water Interface
HSA	Hollow Stem Augers
HAZWOPER	Hazardous Waste Operations and Emergency Response
HASP	Health and Safety Plan
HDPE	High-Density Polyethylene
ID	Inside Diameter

ACRONYMS (CONT'D)

IDW	Investigative Derived Wastes
Illinois EPA	Illinois Environmental Protection Agency
ITRC	Interstate Technology and Regulatory Council
LDPE	Low-Density Polyethylene
LIF	Laser Induced Fluorescence
LNAPL	Light Non-Aqueous Phase Liquid
m	Meter
MGP	Manufactured Gas Plant
mg/L	Milligrams per Liter
MIP	Membrane Interface Probe
mL	Milliliter
mL/min	Milliliters Per Minute
MS/MSD	Matrix Spike/Matrix Spike Duplicate
mV	Millivolts
NAPL	Non-Aqueous Phase Liquid
NAVD88	North American Vertical Datum of 1988
NTU	Nephelometric Turbidity Unit
OD	Outside Diameter
ORP	Oxidation / Reduction Potential
OSHA	Occupational Safety and Health Administration
OWSER	Office of Solid Waste and Emergency Response
PAHs	Polynuclear aromatic hydrocarbons
PCB	Polychlorinated Biphenyl
PDB	Polyethylene Diffusion Bag
PID	Photoionization Detector
POTW	Publicly-Owned Treatment Works
PPE	Personal Protective Equipment
ppm	Parts Per Million
PQLs	Project Quantitation Limits
PVC	Polyvinyl Chloride
PVD	Passive-Vapor-Diffusion
PVOC	Petroleum Volatile Organic Compound
QA	Quality Assurance
QA/QC	Quality Assurance/Quality Control

ACRONYMS (CONT'D)

QAM	Quality Assurance Manual
QAPP	Quality Assurance Project Plan
QC	Quality Control
RAF	Risk Assessment Framework
RBP	Rapid Bioassessment Protocols
RI/FS	Remedial Investigations and Feasibility Studies
ROST	Rapid Optical Screening Tool
Settlement Agreement	Settlement Agreement and Administrative Order on Consent
SI	Site Investigation
SIM	Selected Ion Monitoring
SLERA	Screening Level Ecological Risk Assessment
SOP	Standard Operating Procedure
SSA	Solid Stem Auger
SOW	Statement of Work
SPE	Solid-Phase Extraction
SPP	Systematic Planning Process
SSWP	Site-Specific Work Plan
TarGOST	Tar-specific Green Optical Screening Tool
TOC	Total Organic Carbon
μS/cm	Microsiemens per centimeter
USCS	United Soil Classification System
USDOE	United States Department of Energy
USGS	United States Geological Survey
USEPA	United States Environmental Protection Agency
UVOST	Ultra-Violet Optical Screening Tool
VOA	Volatile Organic Analyte
VOC	Volatile Organic Compounds
WDNR	Wisconsin Department of Natural Resources

1 INTRODUCTION

1.1 Background

This Multi-Site Field Sampling Plan (FSP) was prepared in accordance with the respective Statement of Work (SOW) attached to the Settlement Agreement and Administrative Order on Consent (Settlement Agreement) between the United States Environmental Protection Agency (USEPA) and Wisconsin Public Service Corporation (WPSC) effective May 5, 2006; The Peoples Gas Light and Coke Company (PGL) effective June 5, 2007; and North Shore Gas Company (NSG) effective July 23, 2007. The Multi-Site FSP addresses former manufactured gas plants (MGPs) operated by WPSC, PGL and NSG, collectively the Company. Integrys Business Support, LLC (IBS) is managing the work in the Settlement Agreement on behalf of the Company.

Manufactured gas was utilized for residential and industrial lighting, heating, and other uses from the early 1800s through the mid 1900s, before electricity and/or natural gas were commercially available. Gas was produced by various means, including coal carbonization (also known as coal gasification), carburetted water gas, and oil gas. Coal carbonization was the simplest process wherein coal was heated in an airtight chamber called a retort to approximately 2,200 degrees Fahrenheit (°F), causing the coal to decompose into gas, tar and residual coke. When steam was added to the coke and coal in the retort, water gas was produced. The addition of oil to the process resulted in a gas with a higher thermal content, called carburetted water gas. Production of gas using heavy oils such as naphtha as feedstock without coal (popular in areas with more oil than coal, such as the west coast) resulted in yet another type of gas called oil gas.

Regardless of the method of gas production, the gas produced then had to be cooled and purified before distribution to consumers. The gas was first passed through a series of condensers, tar baths, water baths, and washers to remove ammoniacal liquors and tars. The gas was then passed through a purifier to remove impurities such as sulfur, carbon dioxide, cyanide, and ammonia. Dry purifiers used trays and sieves containing lime or hydrated iron oxide mixed with wood chips. The gas was then stored in large holders on the MGP property prior to distribution for lighting and heating.

The MGP manufacturing processes resulted in the production of various byproducts, some valuable and some simply waste. Coke could be reused in the retort ovens and coal tar was often burned on the MGP property for energy recovery, sold off-site and beneficially reused for roofing, wood treatment, and road paving. Purifier box wastes however, were often dispersed throughout the MGP property. Releases of these byproducts on MGP properties were later discovered to have potential for impacting soil and groundwater with petroleum hydrocarbons, polynuclear aromatic hydrocarbons (PAHs), cyanide, and other compounds.

When natural gas became widely available with the advent of interstate pipelines in the 1940s and 1950s, MGPs became obsolete and plants were dismantled or simply razed. Because little or no documentation often exists concerning how these facilities were decommissioned, the assessment of former MGPs requires investigators to reconstruct historical MGP operational data. Experience evolving since the mid-1980s has shown that soil and groundwater are often impacted at many MGP properties and some, located adjacent to surface water bodies, may include sediment impacts.

1.2 Sampling Objectives

The overall goal of the Remedial Investigation and Feasibility Study or Engineering Evaluation and Cost Analysis (Study) process is to collect sufficient data to characterize the nature and extent of impacts and risks at each of the sites and provide a feasibility study for a range of potential remedial options leading to the selection of a proposed remedial action at each site. The Company sites encompassed within this FSP exhibit two areas affected by MGP residuals to varying degrees: 1) the former MGP properties where manufactured gas operations occurred and adjacent properties, and 2) adjacent surface water bodies. Previously obtained site investigation (SI) data will be supplemented, as appropriate, with additional investigations necessary to evaluate potential exposure pathways, if any, and to characterize the nature and extent of contamination, evaluate potential remedial alternatives protective of human health and the environment.

This FSP is intended to ensure that sample collection and analytical activities are conducted in accordance with acceptable protocols that meet Data Quality Objectives (DQOs) as established in the Multi-Site Quality Assurance Project Plan (QAPP). The information presented in this FSP and in the QAPP will enable field personnel to collect field samples and measurements in a manner that meet the project DQOs.

Accordingly, the intent of this FSP is not to detail specific sampling locations and investigative methods to be employed at each of the Company MGP sites. Rather, the FSP identifies the probable range of investigative approaches likely to be employed along with appropriate procedures and protocols that will form the basis for developing and implementing Site-Specific Work Plans (SSWPs).

1.3 Site-Specific Work Plans

1.3.1 Technical Approach

The SSWPs will follow the Triad approach, to identify and manage decision uncertainties in relation to the Generalized Conceptual Site Model (CSM). The Generalized CSM will be refined and included as part of the SSWP on a site-by-site basis to provide the framework for a concise statement of project goals. Site project goals will be used to develop a field-decision framework for SSWPs, which will identify an approach to determine sample locations, types, frequencies, collection methods, and field analysis. The CSM will be updated as data are generated. SSWPs or site-specific RI Reports will present these data in cross-sections or other visualizations, as appropriate, to evaluate potentially complete pathways.

Innovative sampling tools may be employed, as appropriate, to obtain quality data in an expedited manner consistent with *'A Resource for MGP Site Characterization and Remediation'* (OSWER Publ. EPA 542-R-99-005). The Generalized CSM will be updated and included as part of the SSWP as field data are evaluated. Real-time data generation and interpretation will be used in a flexible field-decision framework to modify field activities based on changes in site-specific conditions. The SSWPs will detail the decision-process and site knowledge that will be utilized on a real-time basis to determine sample type, location, frequency, and analytes. A generic decision tree diagram is provided as Figure 1. Field staff must maintain close communication with project oversight team members during implementation of the dynamic SSWPs.

Table 1 provides an example Sampling and Analysis Summary that will be detailed in SSWPs with figures depicting previous and proposed initial sampling locations, as appropriate. The following sections summarize other key elements of dynamic SSWPs.

1.3.2 Project Personnel

1.3.2.1 Project Team

The SSWPs will identify key project staff responsible for project planning, data and decision quality, and final work products, consistent with the QAPP. Personnel qualifications will be provided in SSWPs, when applicable. If individuals are not identified in a SSWP, general qualifications for the team member position will be detailed. Team members will meet suggested experience and qualification levels identified by USEPA (2003 OWSER No. 9200.1-40, 540/R-03/002). A generic team member diagram is included as Figure 2 Generic Communication Strategy Diagram.

1.3.2.2 Subcontractors

When practical, SSWPs will identify specific subcontractors and will provide subcontractor qualification information. If a specific subcontractor is not identified in a SSWP, the SSWP will identify the required qualifications for each type of subcontracted activity. SSWPs will include subcontractors within the Communication Strategy and Decision-Making Process.

1.3.3 Communication Strategy

SSWPs will provide a site-specific communication strategy, which will identify project communication flow, frequency, and documentation requirements between potentially responsible parties/responsible parties, regulators, project managers, field personnel, contractors, and others as identified on a site-specific basis. Key Decision-Making Process team members will be identified by name and methods of contact. The communication strategy will be provided in a manner that visually depicts communication hierarchy and required reporting periods.

1.3.4 Decision-Making Processes

The Decision-Making Process will identify decision steps that will be based on field data, require regulatory agency discussion for implementation, and project management approval. The process will identify key steps and decision points at which point field team(s) will adjust the track of investigation as appropriate based on field conditions and the established hierarchy for decision-making and management responsibilities.

Decision steps identified will include authorization hierarchy for steps such as:

- Criteria for sample location, type, analysis, etc.;
- Criteria to conclude a phase or type of sampling;
- Criteria for location and construction of groundwater monitoring wells;
- Cessation of sampling for reasons other than achieving SSWP goals; and
- Changes in sampling and/or analytical method(s).

1.3.5 Data Exchange

SSWPs will identify data required for decision-making, establish formats, and schedule for the exchange of data. Data requirements will include data types, schedule, and format.

2 SAMPLE LOCATIONS

Several of the Company facilities and adjacent surface waters have been the subject of multiple phases of investigations for MGP residuals. In some cases, contaminant sources present in soil have been remediated. These previous SI activities have focused on:

- Evaluation of historic MGP operations and property development through time;
- Locations of historic MGP structures, process areas, subsurface piping and/or utilities;
- Evaluation of the extent of MGP residuals in soil; and
- Evaluation of the extent of affected groundwater plumes.

Site-specific Completion Reports will be submitted to USEPA for review and approval. The Completion Reports will summarize the results of previously performed SI activities and will be used to identify areas and/or media of each Site that may require additional Study activities. Previously obtained SI data will be evaluated for usability in the SSWPs and used to direct locations of further Study sampling, as appropriate, of all applicable media. Supplemental sample locations will be evaluated based on the needs and data gaps identified in the Site-specific CSM and risk assessments. The data needs of the risk assessments will consider current land use as well as a reasonable range of future land uses that also consider the site's location, history, neighboring land use and community input. Elements used to identify and develop the Site-specific CSM and risk assessments are discussed in the Generalized CSM.

Samples will be collected as necessary and at an appropriate frequency to support the Site-specific CSM and risk assessments in relation to the nature, magnitude, and extent of MGP-related impacts. Sample media will be identified in SSWPs and may include:

- Surface soil (0 to 2 feet below ground surface (bgs) or as determined in SSWPs) and subsurface soil (vadose zone material below surface soil);
- Surface Water;
- Groundwater;

- Sediment; and
- Air.

Samples may also be collected for waste characterization as well as physical and/or engineering parameters that may be necessary to screen remedial options for the Study.

3 FIELD MOBILIZATION AND SITE ACCESS

Prior to initiating field activities, the Study Leader will review the Site-specific project goals, objectives and scope with the Field Sampling Team. The Field Sampling Team will review the HASP, SSWP, and contractor's/consultant's field SOPs. If necessary, field activity area(s) reconnaissance may be performed to familiarize field staff with field conditions, identify access points, and locate proposed initial sampling points.

3.1 Site Access

Controlling field activity area access is of utmost importance to protect the public from exposure to contaminants and physical hazards at the Site during field investigation activities. All visitors must check in with the Field Manager before being allowed into the field activity area. Visitor information (e.g., affiliation, reason for visit, etc.) will be documented in the field notebook. Unauthorized visitors will not be allowed in field activity areas. Personnel entering the field activity area will review the HASP and the Site-specific elements included in the SSWP.

Visitors will not be allowed to enter work area exclusion zones without permission from the Project Manager. The work area exclusion zone will be secured with either traffic cones/barriers, and/or caution tape. Test pits that may be excavated during field activities will be backfilled before the end of the day to eliminate physical hazards as well as the possibility of exposure to contaminants when work is not taking place.

3.2 Mobilization Activities

The IBS Project Coordinator will notify USEPA no less than 15 business days prior to beginning field activities. Mobilization activities may include:

- Prepare a Site contact list, including the names of field team personnel and subcontractors, affiliation, and contact numbers for distribution to all field team members and the Study Leader;

- Receive permission to access privately and/or publicly owned properties, if required, to perform off-property investigations. Where feasible, off-property access will be coordinated within schedule constraints, such as limiting activities during school hours, peak business hours, etc.;
- Clear underground utilities. If utilities are identified, a Site meeting may be arranged with utility representatives and/or initial sampling locations may be adjusted (SOP SAS-005-01);
- Evaluate access for accessibility to sampling locations with proposed equipment;
- Coordinate subcontractors which may include drillers, laboratories, surveyors, etc. and review scope of work, schedule, and discuss special equipment needs;
- Acquire proper personal protective equipment (PPE);
- Review analytical requirements, request appropriate sampling containers from the analytical, toxicity, and/or geotechnical laboratories, and discuss delivery/pickup of coolers/packages, including weekend deliveries;
- Secure and verify working conditions of field instruments in accordance with their respective SOPs;
- Load appropriate equipment and supplies to perform the field activities in accordance with procedures outlined in SOP SAS-02-01;
- Coordinate the management/disposal of investigative waste;
- Prepare equipment staging areas, if necessary; and
- Locate survey information or identifying the need to survey previous and/or proposed initial sampling locations. Surveys, if necessary, will be performed using the coordinate system specified in the SSWP.

3.3 Site Safety

Field activities will be conducted in accordance with the Multi-Site HASP and Site-Specific HASP elements.

3.4 Demobilization Activities

USEPA will be notified of completion of field activities in writing. Demobilization activities may include:

- Disposal of investigation derived waste (IDW) (Section 9);
- Additional Site survey tasks, if appropriate (SOP SAS-02-02);
- Site restoration, if appropriate; and
- Data management activities (SOP SAS-01-02).

4 DATA COLLECTION PROCEDURES

4.1 Field Standard Operating Procedures

SOPs are included as Appendix A. These SOPs will be referenced in the development of SSWPs for each of the Company's former MGP Sites.

4.2 Soil Sampling

This section describes soil sampling collection methods and requirements. Soil sampling and field screening methods may be evaluated and chosen to maximize the effectiveness of site characterization and limit heterogeneity uncertainties in the CSM. Sampling option speed, cost, accessibilities, and associated field analytical method (FAM) will also be evaluated during sampling technique selection. General soil sample options and characteristic comparisons are presented on Tables 2 and 3.

A qualified geologist or engineer will classify soils utilizing the United Soil Classification System (USCS) in accordance with ASTM International (ASTM) Standard Procedure ASTM D2488 and will record soil sampling data, field conditions, sampling depths and other sampling details in accordance with QAPP Section 1.7, SOP SAS-05-02 and the SSWP.

4.2.1 Data Uses

Soil data may be collected to support screening level ecological risk assessment and baseline ecological risk assessment, human health risk assessment (consistent with the CSM), delineation of the extent and magnitude of contamination (laterally and vertically), evaluation of remedial alternatives, potential to affect groundwater, and waste characterization.

Surface soil data will be collected from 0 to 2 feet bgs (or as otherwise defined in SSWPs) and will be used to support the human health incidental ingestion, dermal and inhalation exposure routes, if applicable for each human health receptor. In addition, surface soil samples will be used in the ecological risk assessment, if required to evaluate potential risk in the upland portions of the Sites to terrestrial small mammals.

Sub-surface soil data will be collected from 2 feet bgs to generally 6 feet bgs (or as otherwise defined in the SSWPs) to facilitate installation of sub-surface utilities and will be used to support the human health dermal and inhalation exposure routes for the construction worker human health receptor. Deeper sub-surface soil samples may be collected to evaluate the vertical extent of MGP residuals or evaluate remedial alternatives.

4.2.2 Surface Soil Samples

Surface soil samples may be collected from soil borings, soil probes, test pits, hand augers, hand tools (shovel, trowel, spatulas, etc.), or similar apparatus (SOPs SAS-06-01, SAS-06-02, and SAS-05-06). Surface soil samples may be collected as a composite sample, consisting of an appropriate number of sub-samples or increments over an appropriate area (as determined on a site-specific basis) or as discrete samples when collected from soil boring locations. Samples collected for volatile organic compound (VOC) analysis will be discrete samples. The use of composite versus discrete samples will be identified in the SSWP. If gravel or cobbles are encountered at the surface, the sample will be collected from soil just below the gravel/cobbles. If the surface is vegetated, the surface soil sample will be collected just below the root zone.

Field photoionization detector (PID) screening for VOCs may be conducted on soil samples in accordance with the SSWP and field SOPs. Samples may be screened with a hand held PID equipped with a 10.6 or 11.7 eV lamp. The field analysis data and other visual observations of affected soil, as described in SOP-SAS-05-02, may be used to select soil samples for field or fix-laboratory analysis.

4.2.3 Sub-Surface Soil Samples

Sub-surface soil samples may be collected from soil borings, soil probes, test pits, hand augers, hand tools (shovel, trowel, spatulas, etc.), or similar apparatus (SOPs SAS-06-01, SAS-06-02, and SAS-05-06).

Sub-surface soil samples will generally be collected as discrete samples, typically over a 6-inch interval or as determined based on observed soil horizons or indications of MGP residuals.

Field PID screening for VOCs may be conducted on soil samples in accordance with the SSWPs and field SOPs. Samples may be screened with a hand held PID equipped with a 10.6 or 11.7 eV lamp. The field analysis data and other visual observations of affected soil, as described in SOP-SAS-05-02, may be used to select soil samples for field or fix-laboratory analysis.

4.2.4 Test Pits

When access permits, test pit excavation may be the primary means to locate and evaluate shallow (less than 15 feet bgs) MGP structures, activity areas, and the nature and magnitude of residuals. Test pit excavations will be field logged in accordance with the SSWP and SOP SAS-05-06.

Excavations may be performed with a backhoe or hand shovel. Decontamination of equipment shall occur after an excavation is completed or daily following the procedures described in SOP SAS-04-04.

Analytical samples generally will not be collected within test pits excavated to evaluate utility corridors, structures, etc. Test pits excavated for other purposes may be selected for analytical sampling, as determined in the SSWPs, considering the DQOs. SSWPs will detail the sampling requirements on a site-by-site basis. Soil samples may be collected from test pits using hand tools (spoons, trowels, and/or shovels), clean spatulas, and sample containers as described in SOP SAS-05-06.

Soil samples may be collected from the walls or based of the test pit. Sampling directly from the excavator bucket is not preferred. However, soil samples may be collected directly from the excavator bucket after removal from the excavation or from the soil stockpile if the test pit depth is deeper than can be safely accessed, unstable side walls, or would otherwise require a confined space permit. If sampling from an excavator bucket is required, soil samples will be collected from the center of the bucket as soon as the bucket has been brought to the surface to minimize volatilization. Procedures for soil sample collection are described in SOPs SAS-05-06, SAS-06-01, and SAS-06-02.

In general, field crews shall never enter an excavation without proper safety precautions and shoring. After test pit excavation, logging and sampling are completed, test pits will be backfilled in accordance with SOP SAS-05-07 or as specified in the SSWP.

4.2.5 Soil Borings

Soil borings may be advanced by multiple drilling techniques as detailed in SOP SAS-05-02 and/or the SSWPs and include:

- Direct push technology (DPT);
- Hollow-stem auger (HSA);
- Solid-stem auger (SSA);
- Continuous coring;
- Sonic Drilling;
- Air Rotary Drilling; and
- Mud Rotary Drilling.

In general, HSA, SSA, sonic, and rotary drilling methods yield low sample collection rates and increased costs over DPT. The SSWPs will provide the rationale for selecting a specific method. These drilling methods may be utilized, as specified in SSWPs, for construction of monitoring wells that require well diameters of 2-inches or greater or for testing that requires large sample volume, such as bench-scale testing for various remedial alternatives. These drilling techniques may also significantly increase investigative waste volume and may be utilized primarily when DPT sampling is not feasible due to access, refusal, and/or sampling depth.

Soil samples will generally be collected in 2-foot increments on a continual or 5-foot sampling basis, with the exception of sonic drilling and continuous coring, which yields a continuous soil core. Samples will be logged by a field engineer, geologist, or qualified geotechnical/geophysical equipment operator as specified in SSWPs.

4.2.6 Subsurface Probes

A variety of probing devices are available that may provide semi-qualitative subsurface data that are briefly described below. SOPs will be developed, as needed, in the event these technologies are deemed appropriate and suitable for the SSWPs.

4.2.6.1 Conductivity Probe

The conductivity probe is a geophysical tool that is deployed with DPT probes. For cone penetrometer technology (CPT) probes, the conductivity probe is typically placed above the standard penetrometer tip. Conductivity probes are also available as single drive tips. The probe measures resistivity in adjacent soil with probe depth, producing a continuous conductivity log. Conductivity variations are related to stratigraphic changes, yielding detailed lithologic logs for expedited field characterization.

4.2.6.2 Cone Penetrometer

CPT is commonly used in geotechnical activities to evaluate various physical properties of the soil in the subsurface. CPT sampling depth is generally increased with the weight of the CPT vehicle, which in turn limits the accessibility of CPT equipment. As a CPT probe is advanced through the subsurface at a predetermined rate, the probe cone measures tip resistance and the probe side (sleeve) measures soil friction. Probe data may be correlated to specific Site stratigraphy, if resistance and friction are directly compared to analytical soil data. CPT technology is capable of obtaining discrete soil cores and water samples.

CPT probes may provide pore pressure data with a pressure transducer located within the probe, which is connected to a ceramic screen that is generally mounted above the cone. Pore pressures may be used to evaluate soil hydraulic conductivity and soil type.

Drawbacks: The CPT does not directly measure soil types or chemical species. In addition, if the intention is to use the stratigraphy capability, it needs to be calibrated against one or more conventionally logged boreholes (drilled or direct push continuous soil sampling). However, a CPT rig can be fitted with direct push continuous coring capabilities so only one piece of equipment is required to conduct a survey. CPT cannot be used in hilly areas.

4.2.6.3 Laser Induced Fluorescence

Induced fluorescence provides qualitative in-situ data that measures the fluorescent response of a chemical to an ultraviolet light source (lasers and mercury vapor lamps). The laser induced fluorescence (LIF) probe is typically developed on a CPT rig for detection of contaminants that fluoresce, consisting primarily of PAHs among the MGP contaminants of potential concern (COPC). Several natural minerals (e.g., calcite) fluoresce also. Therefore, background levels must be checked to ensure probe calibration.

LIF probes typically read and analyze one sample interval per second with a typical advancement of a CPT probe yielding a reading for every 0.2 feet.

An approximate correlation between LIF data and analytical contaminant levels may be created if soil cores are collected and quantitatively analyzed (field or fixed-laboratory) adjacent to CPT data areas that indicated probable contaminants. Potential bias and interferences associated with the LIF probe include:

- Increasing concentration are not always read by the LIF probe as linear changes; and
- The LIF probe is sensitive to soil lithology changes (grain size, mineralogy, moisture, and surface area).

LIF probe response to coal tar is relatively weak (USEPA 2004 EPA 542-R-04-017) as the probe does not readily read heavier end aromatics. Therefore, the probe is typically calibrated to multiple components to ensure the coal tar is not missed. LIF improvements continually evolve and prospective vendors may be consulted, as appropriate, to evaluate potential applications.

4.2.6.4 In-Situ Camera

In-situ camera probes (GeoVIS®, videocone, etc.) produce visual images of subsurface soils. The images are collected as the probe is advanced and encoded with depth and time readings. GeoVIS images approximately a 2 by 3 mm area with a resolution as small as 10 µm, frequently showing visual evidence of non aqueous phase liquids (NAPLs), other than clear liquids. Camera and LIF probe may be deployed in the same borehole; however, probe speeds are typically different, occasionally preventing dual deployment. Prospective vendors may be consulted, as appropriate, to evaluate the use of multiple probes.

4.2.6.5 Membrane Interface Probe

The membrane interface probe (MIP), developed by Geoprobe®, measures total VOCs in soil, which is useful in site characterization in conjunction with probes and analytical data that provide specific contaminant concentrations. The probe is a semi-permeable membrane impregnated into a stainless steel screen. The screen is placed in direct contact with the soil sample interval and the membrane is heated to between 100 and 120 degrees Celsius (°C). Potential contaminants in soil migrate across the membrane, and are transported to the surface with a carrier gas (typically nitrogen or helium). FAMs typically utilized to analyze the MIP gas include PIDs, flame ionization detectors, electron capture detectors, and ion-trap mass spectrometers. The presence of NAPL may require dilution of the gas stream, reducing the number of samples analyzed per day.

4.2.7 Borehole Abandonment

All boreholes will be abandoned and documented in accordance with ASTM standard procedures, the SSWP, state specific regulations (if applicable), and SOP SAS-05-05. Boreholes will be completely filled with bentonite granules, bentonite chips, bentonite slurry, etc. Sealing material will be placed via gravity with the exception of grout, which will be placed from the base of the borehole with a tremie pipe. Sealing material will be placed in the borehole in a manner that detects and prevents bridging and displaces the borehole water column, if present. Borehole bentonite granules and chips will be hydrated in lifts if the borehole is dry or does not contain sufficient borehole water. Abandonment documentation will be provided to USEPA in subsequent reports.

Particular attention will be given to boreholes that penetrate confining units or extend through NAPL, particularly if they penetrate a lower confining unit. Abandonment of these boreholes may require over-drilling and additional options (e.g. grout injection) for sealing material explored to ensure a preferential migration pathway is not created at the borehole migration. Borings in which NAPL is observed may be abandoned and relocated, depending on site-specific DQOs, to minimize potential NAPL migration.

4.3 Geophysical Methods

4.3.1 Overview

Geophysical data collection provides quantitative and qualitative data on physical properties of the subsurface materials, such as conductivity/resistivity, and density, etc. Geophysical data may be collected and evaluated as surface surveys, surface to borehole, borehole-to-borehole, single borehole, and water-born methods. For many surface and some soil borehole survey methods, interpretation requires the geophysical data be calibrated with nearby physical data to accurately describe subsurface characteristics. Data may be presented as graphs, plan view contour maps, 2-dimensional cross-sections, or in some cases, three-dimensional imaging software.

Geophysical data resolution and accuracy depends on the degree of interpolation between measured points, depth (resolution generally decreases with depth), and the degree of physical property contrast between geologic structure(s) and targets in the subsurface. These characteristics will be integrated into geophysical field method evaluation. Geophysical data may be used to begin data gathering or enhance existing data on:

- Geologic lithology, thicknesses, and bedrock surface elevations;
- Aquifer characterization (depth to water table, water quality, fracture mapping);
- Dense non-aqueous-phase liquid (DNAPL) mass location(s) when the mass is substantial enough to cause a resolvable change in physical characteristics of the host matrix;
- Buried structure location and depth;
- Bathymetry;
- Sediment thickness; and
- Sediment surface structures and morphology.

Resources for evaluation of geophysical methods are summarized on Tables 4 and 5. Site-specific objectives and requirements will be considered in selecting geophysical methods. On a site-specific basis, select geophysics contractors may be requested to demonstrate applicability of these methods prior to final selection.

4.3.2 Upland Applications

In general, geophysical techniques may be used to assist in field characterization in areas other than water bodies (Upland Areas). Geophysical techniques may include a natural gamma survey and an induction log electro magnetic survey. The appropriate borehole application methods will be identified in the SSWPs.

4.3.3 Sediment Applications

Prior to collection of sediment samples, surface water body bathymetry and the location of soft sediment deposits may be evaluated through hydrographic surveys, including multi-beam sonar (bathymetry), sub-bottom profiling (sediment thickness), and side scan sonar. The bathymetric survey will map the sediment bed elevation, while the side scan sonar survey will identify sediment surface morphology and the location of potential submerged obstructions. In addition, the sub-bottom profiling survey may help identify areas with accumulation of soft sediment. Sediment stratigraphy and thickness may be confirmed through sediment poling during sediment sampling. The bathymetric survey may be performed prior to the side scan and sub-bottom surveys as the bathymetry data may be used to select the orientation of side scan sonar transects. The surveys will be performed in accordance with the subcontractor's technical field operating procedures (FOPs), to be included in SSWPs.

The results from the hydrographic surveys will provide an assessment of the extent and thickness of soft sediment that may be used in evaluating remedial options. Data collected during these activities may be used to identify appropriate locations to collect sediment samples. For river sediment sampling, bathymetry data may be utilized with stream flow measurements to calculate flow velocities and discharge. Flood information available from Federal Emergency Management Agency (FEMA) may be used to assess flood flow frequency, volume, and discharge velocities for evaluation of potential scour in river channels, if applicable.

Geophysical survey quality assurance / quality control (QA/QC) requirements to achieve CSM goals will be presented in SSWPs.

4.3.4 Base Mapping and Survey Control

Topographic and bathymetric surveys may be utilized to develop base maps to provide accurate data essential for the CSM and in support of final engineering design. Survey data and locations will be in latitude/longitude (degrees, minutes, and seconds), state-specific plane coordinate system, or by other means specified in the SSWP for horizontal control. Vertical control will be referenced to the system or method specified in the SSWP. Base maps may be used for the following:

- Depiction of utility data, derived from outside sources, on an area wide basis;
- Depiction of public and private shoreline features that will be incorporated into the CSM and utilized for evaluation of potential remedial work (docks, bulkheads, etc.);
- Sediment elevation depiction;
- Plotting proposed sediment sample location(s) on an x-y-z coordinate system;
- Current distribution and volume estimates of soft sediment;
- Construction base map for remedial action infrastructure and facilities (docks, slurry piping, dewatering plant, wastewater treatment plant, etc.); and
- Establishing a construction grid system upon which engineering calculations will be based.

4.4 Groundwater Sampling

4.4.1 Overview

This section describes the groundwater sampling collection methods and requirements. Groundwater sampling may be completed to delineate the extent (both laterally and vertically) of MGP affected areas and support risk evaluations (consistent with the CSM). Applicable DQOs from the QAPP will be identified and considered when groundwater sampling is required, so that the methodology selected and resulting data will satisfy the DQOs. This may be especially significant when the existing monitoring network requires additional points to assess the extent of groundwater impacts

Installation of the groundwater sampling points (whether a temporary or permanent device/well), as well as the particular sampling technique(s) may be evaluated and chosen to maximize field characterization and limit heterogeneity uncertainties in the CSM (SOP SAS-05-03). Sampling option speed, cost, accessibilities, and associated FAM will also be evaluated during sampling technique selection. General groundwater sample options and characteristic comparisons are presented on Table 2 and 3. Sampling activity details will be recorded in field logbooks and sampling sheets as described in the QAPP - Section 1.7, the SSWP, and SOPs SAS-08-02, SAS-08-03

4.4.2 Data Uses

Groundwater monitoring shall be performed at each Site at the frequency specified in the SSWP. Sites in which an upland remedial action has been completed will be evaluated for post-remediation trends in MGP residual concentrations and/or to evaluate whether conditions may be favorable to remedial alternatives and trend analysis. Sites in which an upland remedial action has not been implemented will be monitored to establish a pre-remediation baseline.

Groundwater samples will be collected as grab samples or from temporary monitoring wells during Study activities and from permanent groundwater monitoring wells during Study activities and post-remediation monitoring. Monitoring wells are constructed to characterize the nature and extent (vertically and laterally) of MGP residuals, evaluate groundwater flow direction and use, evaluate hydraulic conductivity and vertical gradients, and compile data for use in groundwater modeling.

Groundwater sampling data will be recorded on field notes and forms, which will include Sample Control Logs, Daily or Weekly Field Logs, chain of custody (COC) Sheets, and Groundwater Monitoring Field Forms.

4.4.3 Water Level Elevation Readings

Groundwater elevation readings will be collected prior to well or borehole purge activities. Permanent equipment will be stored within the water column, if possible, in a manner that allows water levels to be measured without removing dedicated equipment. If permanent equipment cannot be feasibly stored within the water column, the equipment will be tied above the anticipated stabilized water elevations. The equipment may be removed prior to collecting elevation data without disturbance of the water column or may remain in place during water level measurements. Groundwater elevation readings will be collected to the hundredth of a foot in accordance with the SSWP and SOP SAS-08-01 and will be recorded on in the field logbook and/or on the appropriate field form.

In general, depth to water level measurements will not collected with standard water level probes from monitoring wells with tar. Water levels in these wells may be approximate to the tenth of an inch with a weighted standard measuring tape. Groundwater elevations from up-, side-, and downgradient from wells with tar and l all other site wells may be sufficient for groundwater flow interpretation. Alternatively, water levels and NAPL (LNAPL and DNAPL) measurements may be collected as described in SAS-08-01.

4.4.4 Groundwater Grab Samples

Numerous grab groundwater sampling techniques for use with DPT and borehole drilling techniques are commercially available. A number of available systems are summarized below; the spectrum of sampling options is too wide to detail entirely below and continually evolves. Commercially available sampling techniques will be evaluated during planning phases and detailed in SSWPs.

4.4.4.1 HydroPunch® Small Diameter Telescoping Screen

A small diameter-telescoping screen used to take depth discrete groundwater samples, commercially available as HydroPunch®, among others. The screen may be deployed using DPT (including CPT) or HSA rigs. A stainless steel tip and rod are driven to a desired sampling. A stainless-steel sampling screen is exposed when the probe sleeve is retracted slightly. Groundwater enters the inter probe casing and a groundwater sample is collected with a small-diameter bailer, peristaltic pump, or small diameter bladder pump.

The HydroPunch® II may be equipped with an internal double ball valve sample device. As water enters the probe and sample device, hydrostatic pressure moves the bottom ball valve up and groundwater fills the sample container (typically 1-liter volume). As the probe is withdrawn with the filled sample container, the top valve prevents water from entering the chamber, and the bottom valve prevents water from exiting the container. To function, the top of the sample chamber must be below the surface of the water table during sampling activities.

4.4.4.2 Geoprobe® Groundwater Sampling Systems

Geoprobe® offers three main systems to collect groundwater samples, Screen Point Groundwater Sampling Systems, Groundwater Profiler, and the MIP.

4.4.4.3 Screen Point 15/Groundwater Sampling System

The Screen Point Sampling systems are utilized for collection of groundwater samples within unlithified materials from just below ground surface to 100-feet bgs under applicable lithology conditions.

DPT advances a stain-less steel rod with a protected stainless steel or PVC screen used to collect discrete interval groundwater samples from the probe interior with a bailer, bladder pump, etc. Screen length may vary from a few inches to 41-inches. A grout plug, present at the base of the screen, enabling bottom-up bentonite grout placement for borehole abandonment as sampling equipment is removed. Disposable screens designed to be left in the borehole are available to reduce decontamination and disposal costs.

4.4.4.4 Groundwater Profiler

The Geoprobe® Groundwater Profiler enables groundwater vertical profiling, particularly in sand and gravel aquifers. Geophysical logs or soil sampling should be completed prior to use to evaluate borehole lithology to minimize clogging of the sample screen with fine-grained materials.

Groundwater samples are collected from discrete intervals with 6- to 12-inch long, 0.004-inch slotted screens, as the DPT probe is advance. Probe removal is not required between sample intervals, and development of the screen interval may be performed prior to sample collection to reduce turbidity. The probe may also be utilized for hydraulic conductivity testing at each sample interval.

4.4.4.5 Membrane Interface Probe (MIP)

The MIP is a semi-quantitative field analytical probe that measures total VOCs in groundwater with a semi-permeable membrane of a thin film polymer impregnated into a stainless steel screen for support. The membrane is heated to approximately 100 to 120 °C to accelerate diffusion of possible contaminate through the membrane, which are transported to the surface with a carrier gas (typically nitrogen or helium). Travel time from the membrane interface to the detector(s) is approximately 30 to 45 seconds (depending on the length of the sample line and flow rate).

FAMs typically utilized to analyze the MIP gas include photoionization detectors, flame ionization detectors, electron capture detectors, and ion-trap mass spectrometers. The presence of NAPL may require dilution of the gas stream, reducing the number of samples analyzed per day.

4.4.4.6 Drive-Point Profiler®

The Solinst® Drive-Point Profiler® is designed to collect samples from multiple discrete groundwater samples in a single DPT drilling location. The profiler is a modified version of the Waterloo Profiler® and consists of a 1.75-inch stainless steel probe with one row of screened inlet holes that are connected to a stainless steel, low-density polyethylene (LDPE), or Teflon® sampling tube that is attached to a surface pump (e.g., peristaltic pump). VOC samples are collected in-line through a Solinst VOA Bottle Filler, which is placed before the peristaltic pump heads to minimize loss of volatiles. The profiler collects samples and seals boreholes in a similar manner to the Geoprobe® systems described above.

4.4.4.7 BAT® GMS Sampling

The BAT® Groundwater Monitoring System (BAT) utilized with DPT offers temporary or permanent interconnection between BAT Piezometers for pore pressure and groundwater level measurement and vertical profiling, BAT Groundwater Sampler for discrete groundwater samples, collection of discrete soil gas samples, and BAT Permeameter for in-situ soil permeability measurement. Multiple discrete groundwater samples may be collected during a single DPT push and sampling does not require pumps. However, the probe does not provide direct or indirect stratigraphy interpretation and sampling time requirements may be excessive, if large sample volume is required.

The top of the probe sample housing is sealed with a flexible septum. The stainless steel tip is used to drive the probe to a desired sampling depth. At the designated sampling depth, the body of the probe is retracted to expose a stainless steel screen through which groundwater enters. The interior of the probe contains a sample vial (35 to 500 ml) with a septum cap. A double-ended needle, lowered through the push rod, penetrates the probe housing septum and the vial septum, permitting water to enter the sample vial. When the vial is full, the needle is removed and the vial is retrieved for storage or analysis.

The BAT® groundwater sample collection system also offers a probe tip constructed of porous high-density polyethylene (HDPE), which enables water to enter the probe when placed under a vacuum. The HDPE filter tip has the advantage of low turbidity over the standard stainless screen sampling system.

4.4.5 Monitoring Wells

4.4.5.1 Well Placement

Monitoring well networks may be constructed to evaluate:

- Groundwater flow (horizontally and vertically);
- Upgradient groundwater quality (on- and/or off-Site);
- Magnitude of MGP-related constituent concentrations in areas of release;
- Extent of MGP-related constituent concentrations down and side-gradient of release areas to define the extent of concentrations that exceed regulatory standards;
- Vertical extent of MGP-related constituent concentrations that exceed regulatory standards;
- Characterization of the nature and extent of NAPL (LNAPL or DNAPL); and
- Aquifer characteristics (e.g., hydraulic conductivity).

Evaluation for monitoring well network construction will also include evaluation of municipal, residential, and industrial wells within at least ¼-mile of the extent of constituent concentrations that exceed regulatory standards.

4.4.5.2 Well Screen Placement

Nested monitoring wells constructed to evaluate vertical extent and vertical flow may be constructed within 5-feet of each other horizontally. Nested monitoring wells in the same borehole may be considered on a site-specific basis if nested well locations are limited by underground utilities, access issues, or other site-specific conditions. If field conditions do not permit a 5-foot or less separation, the well separation will be expanded to 10-feet and field conditions requiring the expanded separation will be documented. Wells will not be considered nested if there are more than 10-feet separating them horizontally. To maintain well integrity, nested well construction within the same borehole will be performed only when justified by site-specific conditions, as discussed in SSWPs.

Water table monitoring well screens may be constructed in 5-, 10-, or 15-foot sections, dependent on field conditions. Typical water table monitoring well screens will be 10 feet in length. Site conditions that may require alternate screen lengths include: 1) a shorter well screens (5 feet) may be chosen to avoid penetration of a confining unit; 2) a longer well screen (15 feet) may be chosen when significant fluctuations are anticipate (e.g., adjacent to a dam). Piezometer screens will not exceed 5-feet in length.

Vertical placement of nested well screens will have a minimum 10-foot separation between the top and bottom of each filter pack, to reduce overlap between monitoring elevations. Variations due to field conditions (e.g., borehole refusal) will be documented.

4.4.5.3 Temporary Monitoring Wells

Temporary monitoring wells will generally not be used. Temporary monitoring well construction will be provided in SSWPs, if appropriate.

4.4.5.4 Small-Diameter Prepacked Monitoring Wells

Permanent small diameter prepacked monitoring wells may be constructed in DPT boreholes in accordance with ASTM D6725, Standard Practice for Direct Push Installation of Prepacked Screen Monitoring Wells in Unconsolidated Aquifers. SSWPs will provide specification data for the chosen manufacture(s) of prepacked monitoring wells. Material specifications for two manufactures with products that meet or exceed ASTM procedures (GeoInsight® (http://www.geoinsightonline.com/) and

Geoprobe® (http://www.geoprobe.com/index.htm)) were utilized for generalized discussion within this FSP.

The prepacked screens consist of a slotted schedule 40 and 80 PVC well screen pipe wrapped in stainless steel mesh. Sand is packed between the slotted PVC and the stainless steel mesh and screens typically are available in 1.4- and 2.5-inch outside diameter (OD) sizes. The well assembly is lowered to the base of the DPT probe rod string with threaded PVC riser pipe. The probe rod string is retracted above the well screen. Some systems are constructed with prepacked expanding annular space seal material. Systems that are not manufactured with a prepacked annular space seal are sealed with a filter pack seal (fine sand), placed directly above the well screen, preventing annual space seal grout from entering the screen. Granular bentonite or bentonite slurry is then placed above the fine sand as an annular space seal and surface seal. Small-diameter surface protection (stick-up and flush-mount) and well caps will be installed as well protection.

Small-diameter prepacked monitoring wells offer the following benefits over standard 2-inch diameter (or larger) monitoring well construction:

- Rapid and consistent well construction and installation;
- Minimal soil and water investigative waste generated for reduced disposal costs;
- Well seal and grouting meet USEPA and ASTM D5092 procedures;
- Minimal disturbance of natural formation;
- Ultra-fine sand filter packs are available that could not be consistently installed with traditional well construction techniques. The fine sand filter pack lowers turbidity and retards or eliminates well siltation in fine-grained material lithology; and
- Reduced development and sampling time requirements.

4.4.5.5 Large-Diameter Monitoring Wells

4.4.5.5.1 Well Borehole

Boreholes utilized for the construction of permanent large-diameter monitoring wells (2-inch OD or greater) will be drilled with 4-¼-inch inside diameter (ID) or larger HSAs or 6-inch ID or larger air or mud rotary or sonic borehole in accordance with SOP SAS-05-03. Drilling method(s) will be identified in Site-Specific Work Plans or FSPs. Continuous or five-foot interval soil samples may be collected with a 2-foot split-spoon sampler from ground surface to the base of each borehole in accordance with ASTM D4700 and D1586, with the exception of sonic boreholes, which yield a continuous core. Soil samples will be field identified utilizing USCS in accordance with ASTM D2488 and recorded on soil boring log information forms. Field visual and olfactory observations will also be noted on the boring logs.

4.4.5.5.2 Large-Diameter Monitoring Well Construction

Wells will be constructed in accordance with ASTM D5092, the SSWP, and SOP SAS-05-03 and will typically consist of a 2-inch OD PVC riser with a 0.01-inch factory constructed well screen. Water table monitoring wells will typically be constructed with a 10-foot well screen and piezometers with a 5-foot well screen or as determined on a site-specific basis.

Typically, filter-pack sand will be extended from 0.5-feet below the screen base to 2-feet above the screen top. A fine sand filter-pack seal will then be placed to 2-feet above the filter-pack sand. The annular space will be sealed with chipped bentonite, granular bentonite (shallow wells only), or bentonite grout. If grout is used, an additional filter-pack seal consisting of 2-feet of bentonite pellets will be placed above the fine sand filter-pack seal before placement of the grout. The well surface seal will consist of 5-feet of chipped bentonite with the well casing and a locking protective cover extending at least 2-feet above the final surface grade. If a flush-mount well protective cover is utilized, the well PVC will be terminated approximately 2- to 6-inches bgs and covered with a watertight cap. The protective cover will be one-foot aluminum or iron cover set in a concrete pad that extends at least 2-feet in diameter around the protective cover, which will be slightly raised in the center and sloped to the sides to allow positive drainage, away from the well. One to two inches of fine-grained sand may be placed at the base of the flush-mounted protective cover to facilitate drainage or weep holes may be drilled into the protective cover. A locking expandable well cap will be placed on the top of the well casing to prevent surface water infiltration into the water column. Monitoring well construction forms will be completed and submitted with the subsequent reporting phase.

4.4.6 Monitoring Well Development

Monitoring wells will be developed and details will be recorded in general accordance with USEPA Monitoring Well Development Guidelines for Superfund Project Managers (1992), ASTM D5521, the SSWP, and SOP SAS-05-04 requirements (i.e., in field notes and on the monitoring well development forms). Wells will be developed using decontaminated or dedicated sampling equipment to reduce the possibility of cross contamination. The primary method for well development is a pump. Bailers may be used for development for low yielding wells or wells with a significant amount of sediment (approximately 10% in the well screen) to remove excess sediment. Purge water collected during well development will be treated by a mobile remediation system prior to discharge to a sanitary sewer or containerized as per the SSWP.

In general, monitoring wells that cannot be purged dry will be developed by alternating surging and purging the water column for at least 30-minutes and approximately 10 well volumes have been removed. If the drilling methods introduce water to the aquifer, three times the volume of water lost during drilling will be purged from the well prior to well development. Purge water volume may be reduced by completing development activity when purge water has no visible turbidity and field measurements have stabilized for specific conductance, pH, temperature, dissolved oxygen, ORP, and turbidity. Field measured parameters will be measured using a flow-through cell, if a pump is used for sampling. If bailers are used for sampling, representative purge water will be transferred to a disposable plastic cup or stainless steel cup and the water quality probe will be inserted or a down-hole meter will be used to measure field parameters. Stabilization is achieved when three consecutive readings spaced approximately 2 to 10 minutes, or 0.5 well volumes or more apart, are within the following ranges for the following indicator parameters:

Field Parameter	Stabilization Criterion[1]
Specific Conductance	± 3% (µS/cm @ 25°C)
pH	±0.1 pH units
Temperature	±0.1 ºC
Dissolved Oxygen	±0.3 mg/L
Eh or ORP	± 10 mV
Turbidity	<10 NTUs or ± 10% when turbidity is greater than 10 NTUs and/or visually clear water

Surging activity will not be performed on monitoring wells that can be purged dry. The primary focus for development of monitoring wells constructed in fine-grained material is to limit the agitation of the water column, as this may form a "skin" around the exterior surface of the well, by which fine-grained sediment accumulates at the screen inlets and consolidates to form a low conductivity barrier. Additionally, the water column should be kept fairly stable during development, to ensure air is not introduced into the adjacent aquifer material.

Low hydraulic conductivity wells will generally be developed utilizing low-purge rate techniques with peristaltic/bladder pumps or dedicated/disposable bailers (if pumps are not feasible). Purging will alternate between pumping or bailing and a rest period, allowing the well to recover to within 90% of the pre-development standing water volume. Development will continue until the purge water is no longer turbid, with a minimum of two and a maximum of five purge periods.

[1] 2002, USEPA, Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers; EPA 542-S-02-001, May.

Monitoring well development data will be recorded in field logbooks and/or on the appropriated field form in accordance with the SSWP and SOP SAS-05-04. Monitoring well development forms are included in Appendix B.

4.4.7 Monitoring Well Groundwater Sampling

Water level data will be collected from monitoring wells prior to sampling activities, as described in Section 4.4.3. Samples may be collected with low-flow sampling techniques in accordance with USEPA and ASTM guidelines or with dedicated bailers, based on site-specific conditions, as specified in SSWPs in accordance with SOPs SAS-08-01, SAS-08-02, and SAS-08-03. Water level measurements and well sampling will generally be conducted from least to most contaminated wells to limit the possibility of cross-contamination. Well integrity will be evaluated in accordance with SOP SAS-08-05 prior to collection of field data. Compromised monitoring wells may not be sampled and the scope deviation will be immediately discussed with the project manager for further well evaluation and repair or abandonment.

4.4.7.1 Purging

Wells will be purged with dedicated or decontaminated bailers or pumps. Bailers will be used if samples cannot be collected with a pump due to low yielding wells. Field measurements for specific conductance, pH, temperature, ORP, dissolved oxygen, and turbidity will be taken at the time of sample collection. Field measured parameters will be measured using a flow-through cell, if a pump is used for sampling. If bailers are used for sampling, representative purge water will be transferred to a container and the water quality probe will be inserted or a down-hole meter will be used to measure field parameters. The procedures for measuring groundwater field parameters, operating the equipment and a comprehensive list of sampling equipment needed to collect groundwater samples is provided in the SSWP and SOPs SAS-08-02 and SAS-08-03. Purging for low-flow sampling wells may be conducted as described below for low-flow sampling wells. Wells purged with bailers will be purged in accordance with USEPA requirements and ASTM recommendations and will generally follow the procedures listed below. Purge techniques will be chosen SSWPs.

- Volume Purge: Field readings, summarized below, will be collected prior to and following well purging activities. At least 4-well volumes will be removed from the well casing in a manner that limits agitation of the water column with bailers or pumps. Field readings will be recorded in field logbooks and/or on the appropriate field form. Purge volumes may be established on a site-specific basis when monitored natural attenuation parameters are not required and sufficient data exists to determine an appropriate purge volume.

- Stabilization Purge: Field measured parameters, listed below, will be monitored during purge activity. Stabilized parameters indicate the completion of the purging phase. At least three consecutive readings spaced approximately 2 minutes, or 0.5 well volumes or more apart, are within the following ranges for the following indicator parameters:

Field Parameter	Stabilization Criterion[1]
Specific Conductance	± 3% µS/cm @ 25°C
pH	±0.1 pH units
Temperature	±0.1 ºC
Dissolved Oxygen	±0.3 mg/L
Eh or ORP	± 10 mV
Turbidity	<10 NTUs or ± 10% when turbidity is greater than 10 NTUs and/or visually clear water

4.4.7.2 Sample Collection

Samples will be placed in appropriate laboratory supplied containers and preserved in accordance with the example analytical requirements for methods listed in Table 1. Samples will be collected in order of analyte stability, as summarized below.

- VOCs/PVOCs;
- PAHs;

[1] 2002, USEPA, Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers, EPA 542-S-02-001, May.

- Non-filtered, non-preserved samples (total metals, sulfate, PCBs, etc.);
- Non-filtered, preserved samples (phenols, nitrogen, phosphorous, cyanide, TOC, total metals, etc.);
- Filtered, non-preserved;
- Filtered, preserved immediately (dissolved metals); and
- Miscellaneous parameters.

QC samples will be collected consecutively to ensure appropriate duplicate sample collection. An example of bottle filling order is summarized below.

- Well A - VOC containers filled;
- Well A Duplicate Sample - VOC containers filled;
- Well A - PAH container filled;
- Well A Duplicate Sample - PAH container filled;
- Well A - Cyanide container filled; and
- Well A Duplicate Sample - Cyanide container filled.

Groundwater samples will be placed in appropriate laboratory supplied containers and preserved in accordance with the analytical requirements summarized in Table 1. Procedures for collecting groundwater samples are described in the SSWP and SOPs SAS-08-02 and SAS-08-03. Samples submitted for dissolved analytes will be field filtered prior to placement in containers. Procedures for field filtering are described in the SSWP and SOPs SAS-08-02.

4.4.7.2.1 Bailer Sampling

Bailers may be used to collect samples in low yielding wells. Bailers, dedicated or disposable, will be raised and lowered in a manner that limits agitation of the water column. Bailers will not be allowed to touch the base of the well to limit suspension of fine particles. Sampling equipment, including bailer rope, will not be allowed to touch the ground surface. Water will be decanted from the bailer and into sample containers with a bottom-emptying device to limit sample volatilization.

4.4.7.2.2 Low-Flow Sampling

Low flow sampling is synonymous with low-stress sampling; this should be kept in mind by persons conducting low-flow sampling. The purpose of low-flow sampling is to collect a representative formation sample. This is accomplished through use of low discharge pump rates equilibrated with groundwater infiltration into the well, usually between 100 and 500 mL/min. Higher rates are possible in highly permeable formations. Low flow conditions have not been reached until the following conditions have been met:

- The water level within the well has stabilized during pumping;
- The water being removed is within the screen interval; and
- The measurements of water quality indicators have stabilized.

Refer to SOP SAS-08-02 to determine if low flow sampling is the appropriate method of sample collection for a specific well.

The following equipment is required to perform low-flow sampling:

- Pump capable of withdrawal at a constant rate between 100 and 500 mL/min that can meet the designed lift requirements (e.g., peristaltic pump and/or bladder pump). Peristaltic pumps may be used when the well depth is less than or equal to fifteen feet, in zones of high contamination, or as approved in a SSWP. The sampling method may be modified to demonstrate attainment of cleanup goals in the future;
- In-line flow cell equipped with a multiprobe such as the QED-MP20;
- All necessary tubing required to reach the screened interval of the well and connect the pump to the flow cell;
- A flow meter or other type of water measuring device to accurately measure and monitor the discharge from the pumping well;
- Electric water level indicator(s) capable of measurement to the hundredth of a foot;
- A 5-gallon pail to collect purge water; and
- Low flow sampling field forms (Appendix B), pens, and field book.

Prior to sample collection, any equipment that comes into contact with the water should be decontaminated in accordance with the SSWP and SOP SAS-04-04. The cleaned equipment should not come into contact with the ground or any other surface that may impart contaminants. The sampling tube is lowered to an elevation near the center of the screen, a minimum of 1-foot above the well sump to the extent practical. Subsequent sampling should be performed at approximately the same elevation. The pumping rate will be determined by field staff based on:

- Start the pump at 100 mL/min or the lowest rate possible;
- Monitor drawdown, which must not exceed 0.1 meters or 0.3 feet (SOP SAS-08-02);
- Slowly increase the pumping rate and monitor drawdown;
- If drawdown is rapid decrease the pumping rate;
- If drawdown continues at the lowest pumping rate, cease pumping and evaluate the use of bailer sampling or diffusion samplers with the project manager; and
- If there is no drawdown, the pumping rate may be increased slowly until drawdown occurs and stabilizes.

During drawdown and through sample collection, water quality is continually monitored and recorded by a water quality probe in a flow-through cell (e.g., QED MP-20). Measurements will be recorded at a rate equivalent to the time required to fill the flow-through cell volume. Therefore, if the volume of the flow through cell is 500 mL/min and the pumping rate is 250 mL/min; one reading should be taken every 2 minutes. Stabilization is achieved when three consecutive readings have fallen within the rages of the parameters in the table below.

Field Parameter	Stabilization Criterion[1]
Specific Conductance	± 3% µS/cm @ 25°C

[1] 2002, USEPA, Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers, EPA 542-S-02-001, May.

Field Parameter	Stabilization Criterion[1]
pH	±0.1 pH units
Temperature	±0.1 ºC
Dissolved Oxygen	±0.3 mg/L
Eh or ORP	± 10 mV
Turbidity	$\leq$10 NTUs or ± 10% when turbidity is greater than 10 NTUs and/or visually clear water

Prior to sample collection, the flow-through cell will be disconnected and laboratory containers will be filled from the system tubing. The flow rate will not be adjusted following parameter stabilization or during sample collection.

4.4.7.2.3 Diffusion Sampling

Diffusion samplers and related sampling technologies will not typically be utilized for sample collection. Diffusion sampling will be considered for monitoring wells with extremely low hydraulic conductivity that cannot readily be purged without removing the entire water column and/or requires multiple field visits for purging and sample collection.

The diffusion sampler is considered a passive sampling device and consists of a semi-permeable polyethylene diffusion bag (PDB), a stainless-steel hanger, and a stainless-steel weight. The PDB is filled with deionized water, lowered into the well, and left in place adjacent to the well screen. Potential contaminants in the groundwater diffuse into the sampler until the concentration gradient equilibrates between the formation and PDB water. The sampler is retrieved and the PDB contents are considered the well sample. Additional diffusion sampling information will be provided in SSWPs if the sampling technique is proposed.

4.4.8 Potable Wells

As part of the CSM development, potable well construction information will be obtained, if it exists. Water levels will generally not be collected from potable wells. If water levels are collected from potable wells, sampling equipment must be decontaminated and disinfected prior to data collection SOP SAS-04-04). Disinfection procedures will be included in SSWPs if potable well water readings will be collected. Sampling of large water supply wells (e.g., public water utilities) is not generally conducted and specifics for these types of sample collection will be included in SSWPs.

Small water supply well samples will be collected from the tap that is closest to the well pump as practical (SOP SAS-08-06). Preferably, the faucet should be in the water supply line after the wellhead and before pressure tanks, water heaters, water softeners, iron filters, etc. Aerators and filters will be removed from the tap prior to sampling. Water will be discharged at the faucet or a nearby sink for at least two minutes after the pump is activated. The time period after pump activation should allow for at least one full pump cycle and to ensure formation water is sampled. Field data (e.g., sampling locations, discharge volume, and time) will be recorded in field logbooks.

If a sample is collected from a faucet after the pressure tank or other appliances, the water discharged prior to sample collection should be two to three times the volume of water in each appliance. Sample collection variations will be recorded in field logbooks.

4.4.9 Aquifer Characterization

Aquifer characterization will include collection of grain-size distribution samples, hydraulic conductivity testing, constant-rate pumping tests, etc. Aquifer characteristic measured by or estimated from these tests include transmissivity (T), hydraulic conductivity (K), specific yield (Sy) for unconfined aquifers, storage coefficient (S) for confined aquifers, effective porosity, flow velocity, etc. Formations of high hydraulic conductivity represent areas of greater groundwater flow; therefore, zones of potential preferred contaminant migration. Further, anisotropy within strata or formations affects the magnitude and direction of groundwater flow. Thus, information on aquifer characterization is necessary to evaluate preferential flow paths and groundwater velocity.

Hydrogeologic assessments should contain data on the hydraulic conductivities of significant formations as measured in monitoring wells. It may be beneficial to use numerical or laboratory methods to augment results of field tests. However, field methods provide the best definition of the horizontal hydraulic conductivity in most cases. Field methods differ from laboratory methods which measure vertical hydraulic conductivity, typically in Shelby tube samples.

Varieties of procedures are available for evaluating hydraulic conductivity in the field. ASTM D4043 Standard Guide for Selection of Aquifer Test Method in Determining Hydraulic Properties by Well Techniques will be consulted in selecting an appropriate test method. Field methods for collecting hydraulic conductivity data are described in a number of ASTM standard practices and detailed in (SOP SAS-08-04). Additional methods, such as high density samplers and direct sensing tools, will be evaluated on a site site-specific basis, as appropriate, and included in SSWPs as applicable.

4.4.9.1 Single Well Tests

Hydraulic conductivity can be determined in the field using a variety of test methods, each addressing specific conditions, and/or data collection objectives. These methods are commonly referred to as bail down or slug tests and are performed by removing a slug (known volume) of water from a well and observing the recovery of the water surface to its original level. Similar results can be achieved by removing a cylindrical "slug" of inert solid material, pressurizing the well casing, depressing the water level, and suddenly releasing the pressure to simulate removal of water from the well. Hydraulic conductivity can be determined in monitoring wells with well screens below the water table using the falling head test. The falling head tests are performed by adding a known volume of water or inserting a cylindrical "slug" of inert solid into the well and observing the recovery of the water surface to its original level.

Observation wells in which the well screen intersects the water table (e.g., water table wells) will be tested only by methods involving the use of a solid slug or removal of water from the well in order to minimize the potential for well screen filter pack interference. Addition of water to a monitor well is appropriate only to piezometer installation. However, the addition of water to any monitoring well shall be avoided whenever possible, since the addition may affect water quality in sampling events. In cases where addition of water to a well is unavoidable, it should be of documentable known quality and 3 times the volume of water added should be removed upon completion of the test.

It is important that bail-down or falling head tests be of sufficient duration to provide representative measures of hydraulic conductivity. Data from the tests shall be analyzed entered into a computerized format such as Aqtesolv® or equivalent software. The appropriate method (e.g., Bouwer and Rice [1976], etc.) to analyze single well tests is dependent on the characteristics of the response (i.e., oscillatory, etc.) observed.

4.4.9.2 Pneumatic Slug Test Kit

Geoprobe® offers the pneumatic slug test kit for use with small-diameter monitoring wells. Pneumatic slug testing includes sealing the wellhead and applying air pressure to displace (lower) the water column until the pressure exerted by the water and air are equal, at the point the water level stabilizes. A release valve is then quickly opened, instantaneously releasing the air pressure. The water level recovers, providing a rising head slug test. A pressure transducer and data logger are utilized to record the changes in water level and time.

4.4.9.3 Multiple Well Tests

Multiple well tests, more commonly referred to as pumping tests, are performed by pumping water from one well and observing the resulting drawdown in nearby wells. Tests conducted with wells screened in the same water-bearing formation provide hydraulic conductivity data. Tests conducted with wells screened in different water-bearing zones furnish information concerning hydraulic communication between units. Multiple well tests for hydraulic conductivity are advantageous because they characterize a greater proportion of the subsurface and thus provide a greater amount of detail. Multiple well tests are subject to similar constraints to those listed above for single well tests. Some additional problems that should have been considered in conducting a multiple well test include: (1) storage of potentially contaminated water pumped from the well system, and (2) potential effects of groundwater pumping on existing waste plumes. The geologic constraints should be considered to interpret the pumping test results. Incorrect assumptions regarding geology may translate into incorrect estimations of hydraulic conductivity.

4.4.9.4 Controlled Pumping Tests

The most representative method for determining aquifer characteristics is by controlled aquifer pumping tests, because these tests stress a much larger volume of the formation than slug tests and laboratory tests. Pumping tests require a higher level of effort and expense and are not always required to achieve CSM goals. As an example, slug tests may be acceptable for hydrogeologic characterization, whereas pumping tests may be performed to support remedial design or modeling.

These are standard (i.e., typically applicable) operating procedures which may be varied or changed as required dependent on field conditions, equipment limitations, or limitations imposed by the procedure. In all instances, the ultimate procedures employed should be documented and associated with the final report. Detailed information for controlled pumping tests will be provided with appropriate SSWPs.

4.4.10 Monitoring Well Abandonment

Monitoring wells will be abandoned in accordance with the SSWP and SOP SAS-05-05. The well casing will be completely filled with bentonite chips, grout, or granules. If the well casing is removed during abandonment, the bentonite seal will be placed as the casing is removed. The well protective cover and surface seal material will then be removed and the well casing cut off at least 30 inches bgs. The annular space shall be filled with bentonite chips, grout, or granules to at least 30 inches bgs unless land use requires a design modification to use ,native material (gravel, soil, etc.) or material in adjacent areas (asphalt, concrete, etc.) to bring the former well location to grade. These modifications will be addressed in the SSWP. Monitoring well abandonment will be documented in accordance with the SSWP and SOP SAS-01-01. The appropriate state, and/or local borehole abandonment form(s) must also be completed to document abandonment activities.

4.5 Groundwater / Surface Water Dynamic Evaluation

This section summarizes data collection methods for evaluation the groundwater / surface water interface (GW/SW) at Sites with upland and water body areas. These methods are intended to evaluate the migration of contaminants into groundwater from contaminated sediments (losing stream) and/or surface water or into sediment from contaminated groundwater (gaining stream) or surface water. GW/SW evaluations will be conducted to support risk evaluation (consistent with the CSM and RAF or SSWP) and delineation of extent as part of the remedial investigation. Applicable DQOs from the QAPP and SOPs SAS-04-01 and SAS-04-02 will be identified and considered for interface assessment and sampling, as applicable, to ensure satisfactory SSWP sampling methodologies. This may be especially significant when the extent of upland and/or sediment contamination is present at or near the interface. SSWPs will identify specific sampling methods for evaluation of the GW/SW based on data objectives and hydrology/geology characteristics.

4.5.1 Direct Pore Water Sampling

Direct pore water samples may be collected from the GW/SW interface for geochemical characteristics as well as contaminant concentrations. The field of collecting pore water samples is currently expanding quickly due to regulatory and private industry research in evaluating the GW/SW interface. Collection of field data for evaluation of the GW/SW interface can be performed with a variety of devices:

- Small-Diameter Piezometers

  Small-diameter nested temporary and/or permanent piezometers are clustered to provide hydraulic head differential and pore water samples for COPC concentration analysis (ITRC 2004). Piezometers are generally restricted to use in shallow water with relatively weak currents to the long-term integrity of the sample device. Pore water samples are collected from the piezometers with peristaltic, centrifugal, or bladder pumps. The primary advantages of piezometers are that they can be installed to depths of several feet by hand, and, if protected, they potentially allow repeated samples over time from a particular location and depth interval.

- Syringe Sampling

  Plastic and metal syringes, pushed into sediment, can be used to take collect pore water samples. Collection volumes are dependent on the syringe barrel volume and sample depth is dependent on needle length the bore ID. Pore water samples are obtained by pushing the needle to the desired depth and retracting the plunger. Syringes may not be effective in compacted sediments or gravels and can become plugged in very fine sediments (ITRC 2004). They are also depth limited.

- BAT Sampler

  The BAT system, as described in Section 4.4.4.7, may be deployed in sediments for collecting profile samples, which may be used to evaluate the GW/SW interface. The BAT system mat is driven by machine, or by hand if in soft sediments.

- Pushpoint Pore Water Tool

A pushpoint sampler is a needle-like, small-diameter tube with a "T" handle, which is pushed into sediment. Water and sediment are prevented from entering the tube during placement by a solid rod that is inserted into the tube. The rod is pulled upward once the sampler has been driven to the desired sample depth. Maximum sample depth is 6-feet, and this device has been proven effective for sampling porewater from submerged sediments. Peristaltic pumps or syringes are utilized to collect water samples from the sampler (MHE 2001 and ITRC 2007).

- Seepage Meters

  There is a significant body of work in the literature describing seepage meters. While originally designed as an inexpensive approach to measure the flux of groundwater seepage into or out of a water body, high-tech versions are now available for porewater sampling. The advantages of these devices are their ability to measure groundwater flux and obtain pore water samples in deep water.

4.5.2 Indirect Pore Water Samplers

Indirect samplers provide sample analysis of contaminants through diffusion and dialysis. The sampler is buried in the sediment, or is placed in a tube inserted in the sediment, and retrieved days, weeks, or months later, depending on the time needed to achieve equilibrium (USEPA, 2001). These samplers are the focus of ongoing research to determine their compatibility with different chemical constituents and substrates. A list of devices is provided below, and a summary can be obtained at http://clu-in.org/programs/21m2/sediment/.

- Diffusion Sampler
- Dialysis Sampler
- Peeper Sampler
- Diffusion Equilibration in Thin Films
- Vapor Diffusion Samplers
- Semi-permeable Membrane Samplers

4.5.3 Pore Water Sampling Summary

The pushpoint porewater sampler offers significant advantages over the other approaches in that it is a proven technology, can be used to measure hydraulic head in the sediment, can be used to collect as large of a porewater sample as the sediment can yield, is minimally invasive, can be used under water, and is economical. Its limitations are that it is limited to depths of 6-feet, is difficult to use in deep water, and it may be difficult to push or extract water in tight, low-permeability clays. However, other sampling devices described here can be used in these situations.

4.6 Surface Water Monitoring

4.6.1 Surface Water Sampling

The former MGP properties are adjacent to rivers in which MGP residuals have been detected in either sediments and/or surface water, based on sampling that has been conducted in previous studies. River water samples may be collected for analysis of chemical parameters to evaluate their magnitude as well as the mass of COPCs discharged from the river. Surface water sampling requirements will be identified in the SSWPs.

In general, site, upstream, and downstream sample results are compared to evaluate whether concentrations of COPCs increase as water flows through the Site. Sample locations relative to flow will be identified in SSWPs. An example of the analytical methods, detection limits, required sample volumes, holding times, and preservatives for each of these parameters are summarized on Table 1.

Surface water sampling will follow procedures outlined in the SSWP and SOP SAS-09-01. Water samples will be collected using a discrete depth sampler such as a Kemmerer or Van Dorn-type sample bottle or using a pump. Sample depths will be established in the SSWP (e.g., mid-water or 0.2 and 0.8 times the total depth) depending on site-specific conditions (e.g., total water depth) and DQOs. At the time of sample collection field measurements of temperature, conductivity, pH, ORP, and dissolved oxygen will also be made at all locations.

4.6.1.1 Ecological Risk Assessment Samples

Surface water samples may be collected on a transect extending from the shoreline to the opposite shoreline or beyond the area of impacted sediment under base flow conditions, to the extent practical. Reference transects may also be sampled. Samples may be collected under various river flow conditions, including high-energy events that may result in sediment re-suspension. Collected samples may be split with one fraction filtered (0.45 µm filter) in the field. Both the filtered (if collected) and unfiltered fractions will may be analyzed for COPCs determined by the SSWP. Samples will be filtered in accordance with procedures for groundwater sample filtration described in SOP SAS-08-02.

4.6.1.2 Human Health Risk Assessment Samples

Surface water samples may be collected along the shoreline adjacent to the former MGP property or on a transect extending from the shoreline to the opposite shoreline, and at reference locations in water two to three feet deep under base flow conditions, to the extent practical. Samples may be collected under various river flow conditions. Unfiltered samples will be analyzed for COPCs determined by the SSWP.

4.6.2 River Hydrology

Measurements of river discharge will be obtained from river gauging data available through the US Geological Survey and/or the appropriate state-specific agency. These data generally include information on base, average and flood flow discharges that may be used to assess COPC mass movement. These data may also be used to evaluate conditions where sediments become re-suspended and for related engineering parameters for remedial alternative analysis. SOP SAS-09-02 describes procedures for measuring streamflow, at sites where a gaging station is not located nearby. Other pertinent information will be as described in the SSWP.

4.7 Sediment Sampling

4.7.1 Overview

This section describes sediment sample requirements and collection methods. Sediment sampling will be conducted to support a risk evaluation (consistent with the CSM) and identify areas to be considered in the Study Applicable DQOs from the QAPP and SOPs SAS-04-01 and SAS-04-02 will be identified and considered for sediment sampling requirements on a site-specific basis to ensure chosen sampling methodologies satisfy DQOs. This is especially significant when the extent of sediment contamination is to be defined.

Sediment sampling techniques will be chosen and details discussed within the framework of each SSWP. Factors considered for selecting sediment-sampling techniques include existing data (e.g., distribution of known contaminants, sediment thicknesses, sediment type, water depth, and access) and specifications for risk evaluation. Sampling option speed, cost, and accessibilities will also be evaluated during sampling technique selection. Sampling activity details will be recorded in field logbooks and boring logs as described in the QAPP Section 1.7, the SSWPs, and SOPs SAS-01-01, SAS-07-02, and SAS-07-03.

4.7.2 Sediment Sampling Locations

The results of all previous sediment sampling will be used to focus initial Study sampling activities, including candidate stations to be sampled. Initial locations will be chosen prior to mobilizing the Study sampling effort. It is the intent of the dynamic sampling approach to allow for incorporating real-time information to drive flexibility with sample numbers and locations. Site-specific sampling locations will be detailed in the SSWP.

In general, sediment samples will be collected as discrete samples (for field or fixed-laboratory analysis). Some of these discrete samples will be composited if a large sample volume is needed (e.g., sediment toxicity testing). Specificity on discrete and composite sample analysis procedures and determination will be provided in SSWPs. Required sample volumes will be detailed in the SSWP. Samples that will be analyzed by a fixed-based laboratory will be shipped under COCs in accordance with the SSWP and SOPs SAS-03-01 and SAS-03-02. Sampling apparatus will be decontaminated in accordance with the SSWP and SOP SAS-04-04.

4.7.3 Sediment Data Uses

Sediment data will be collected to support screening level ecological risk assessment and baseline ecological risk assessment, human health risk assessment, delineation of the extent of contamination, sediment stability, and waste characterization. The sediment sampling approach will be presented in the SSWPs. Sediment sample analysis will also be identified in the SSWPs and may include PAHs (alkylated and parent), PVOCs, phenols, metals, cyanide, total organic carbon, black carbon content, percent solids, and grain-size distribution.

4.7.3.1 Screening Level Ecological Risk Assessment (SLERA) and Baseline Ecological Risk Assessment (BERA)

The RAF or SSWP describes the approach to assessing ecological risk. Sediment samples collected to assess the exposure to ecological receptors are typically limited to the surficial six inches of sediment (the biologically active zone). Sample locations will also be identified in the SSWPs.

4.7.3.2 Bioavailability Samples

Sediment samples may be analyzed for soot-phase black carbon (soot) in a fixed laboratory for use in bioavailability assessments as described in the RAF or SSWP. Microscopic inspection of the larger particle sizes to evaluate the amount of coal particles or coal dust in the sample may also performed. Special handling techniques are not required for samples to be analyzed for soot carbon.

The determination of soot is based upon the method of Accardi-Dey and Gschwend (2003). Microscopic inspection of samples using reflected light organic petrology methods (Stach 1982) also will be conducted and reflectance of organic particles (soot, lampblack, and coal) will be quantitatively measured for source identification purposes.

While analyses for total metals can be collected throughout the sediment column, samples for acid volatile sulfides-simultaneously extracted metals (AVS-SEM) analysis will be collected from the upper 2.0 cm of sediment, in accordance with USEPA recommendations (USEPA 2005). Further, USEPA recommends that AVS-SEM samples be collected between November and May, when formation of AVS compounds is generally lowest due to specific environmental conditions that occur during this portion of the year (USEPA, 2005). These samples will be collected using grab or coring methods to limit oxidation during sample retrieval. Coring is the preferred sample collection method because there is generally less disturbance of the sediment, various horizons of the sediment may be collected and analyzed, and the sample can be retrieved with less possibility of oxidation, especially if PVC liners are used.

4.7.3.3 Benthic Community Investigation

A benthic community investigation may be performed as discussed in the SSWPs. Benthic community samples of the surface sediments (0 to 6 inches) will be collected from the sample locations to be discussed in the SSWP and refined based on analytical results. Benthic community samples may be collected concurrently with other samples or during a separate sampling event after comparison of chemical results to screening values. Benthic community sampling and laboratory analysis procedures will be described in detail in SSWPs. As described in the SSWP, the quality of the aquatic environment will be evaluated using methods adopted from USEPA's Rapid Bioassessment Protocol (RBP) (USEPA, 1999). The benthic community investigation design will consider the following factors:

- Substrate type;
- Water velocity;
- Water depth; and
- Analytical results and distribution of COPCs.

The results from the sites will be qualitatively compared to the results from the areas ambient conditions. Establishing the locations of ambient conditions is discussed in the RAF or SSWP and will also be discussed in the SSWP to include site-specific conditions. The following benthic community structure attributes may be evaluated:

- Total taxa richness;
- Total chironomid richness;
- Total density;
- Chironomid density;
- Oligochaete density; and
- Relative species abundance.

4.7.3.4 Sediment Toxicity Testing

A 28-day Hyalella azteca toxicity test may be conducted as part of the modified SLERA approach discussed in the RAF or SSWPs. Each set of whole sediment toxicity tests will be conducted with uncontaminated control sediment and a minimum of 8 replicates of each sediment sample with a survival and growth endpoint. The procedure is described in EPA/600/R-99/064 Methods for Measuring the

Toxicity and Bioaccumulation of Sediment-Associated Contaminants with Freshwater Invertebrates, Second Edition; Method 100.4.

4.7.3.5 Human Health Risk Assessment

Sediment samples will be collected for a human health risk assessment. Soft sediment samples will be collected adjacent to and slightly downstream of the former MGP property, generally within the areas previously investigated and in areas where there is a higher probability of direct contact to MGP residuals in the sediments due to recreational activities (e.g., wading, swimming, fishing, etc). The absolute elevation, depth to the top of soft sediment, and the thickness of soft sediment will be recorded on field logs in accordance with the SSWP and SOP SAS-07-01. Human health risk assessment sediment location selection criteria will be identified in SSWP. Samples will be collected with devices and processed as described in Section 4.7.7 below. Sediment samples may be analyzed in a field or fixed-based laboratory. The samples will be sent to a fixed-base laboratory under COC procedures and may be analyzed for the COPCs identified in the CSM and RAF or SSWP.

4.7.4 Delineation Sediment Sampling

Sediment coring will be conducted to further characterize sediment concentrations and the nature of soft sediment. The soft sediment samples will be collected using a coring device and processed as described in the SSWP and SOP SAS-07-03. Each soft sediment sample will be analyzed in a field or fixed-based laboratory to further characterize sediment concentrations of the COPCs identified in the SSWP. The number of samples to be collected to meet the DQOs will be discussed in SSWPs. Cores which exhibit visible evidence of tar or significant sheen in all intervals may not be analyzed because these visual observations may be used to establish areas for which remedial alternatives will be developed. Cores without visual evidence of tar or significant sheen will be analyzed for COPCs (identified in the CSM and RAF or SSWP) to characterize concentrations in sediment. The analytical data packages will be fully validated by a person independent of the laboratory producing the data.

4.7.5 Sediment Stability and Contaminant Fate and Transport

The remedial investigations will include an appropriate assessment of sediment stability and contaminant fate and transport. The goal is to determine the likelihood that buried contaminants will stay buried or be exposed due to both natural and man-made (anthropogenic) forces. This will be an important factor in the feasibility study for appropriate remedies such as monitored natural recovery, removal by excavation or dredging, or in-situ containment by capping.

The former MGP Sites are considered relatively “small” in scale and “simple” in complexity, versus “large” and “complex” sediment sites. Therefore, appropriate empirical methods in lieu of computer models are planned to be used to assess the extent of past sediment and contaminant movement. A list of key empirical methods is provided in Table 6 (USEPA 2005). The SSWPs will describe the methods to be used on a Site-specific basis.

4.7.6 Geotechnical and Waste Characterization Sampling

At approximately 20 percent of the core locations for delineation, a co-located core may be collected for testing of geotechnical parameters for use in the Study. These parameters include Atterberg limits, grain size, specific gravity, organic content by loss-on-ignition, and moisture content. Field measurements to estimate shear strength may be collected using a pocket penetrometer and a torvane (using a large vane for soft soils). Geotechnical samples may be discrete intervals, or composite samples, depending on the conditions observed.

A composite sample will also be prepared for waste characterization by collecting and combining the entire co-located core from 3 different locations in the project area. The number of cores/locations required may be adjusted based on site-specific field encountered conditions. These locations will be chosen to represent the impacted site area(s) as required by the SSWP for use in the FS. The cores will be composited as described in SOP SAS-06-01. The composite sample will be sent to a fixed-base laboratory following COC procedures. The sample will be analyzed for typical disposal parameters (e.g., reactivity, corrosivity, etc.) to identify potential disposal options and manage investigative waste.

Disposal and/or dredging of river sediments may be regulated by local, state, and federal agencies (refer to Section 9.1). Research will be conducted on a site-specific basis to determine which regulations and appropriate permits apply. Research may include, but not be limited to, contacting local zoning offices, evaluating state regulations, and contacting the US Army Corps of Engineers for permit requirements.

4.7.7 Sediment Collection Devices and Methods

This section describes sediment collection devices used to collect sediments of different thicknesses. Sample processing steps are also included. All details regarding sample collection will be recorded in the field logbook. Procedures for sediment sampling are described in the SSWP and SOP SAS-07-03. Analyses required for preliminary sediment samples will be provided in SSWPs.

4.7.7.1 Surficial Sediment Collection and Processing

A Ponar™ grab sampler (or equivalent) will be used to collect surficial sediment samples (defined as the 0 to 6 inch interval of sediments). The depth to the top of soft sediment and the thickness of soft sediment measured by poling techniques will be recorded prior to using the Ponar™ grab sampler.

The Ponar™ grab is a self-closing sampler which uses a spring loaded "pinch-pin" that releases when the lowering line becomes slack. The grab sampler can be used for taking samples from hard bottoms (sand, clay) as well as soft sediment deposits. This type of sampler is used for collecting surficial (top six inches) sediment samples which can be used for delineating extent of contamination in surficial sediment, assessing benthic community structure, and for collecting larger sample volumes that are needed for toxicity testing.

The grab sampler will be manually lowered into the water to the top of sediment at which time the sample device will shut and the sampler will be manually raised to the boat deck. The sample will be analyzed for the presence of volatile organic vapors with a PID, inspected for acceptance criteria (e.g., grab sampler penetrated at least four-inches, was not overfilled, and was completely closed when brought to the surface), standing water will be removed, and the sediment will be described according to ASTM D2488, as referenced in SAS-07-02. Visual observations of affected sediment will be recorded using the descriptions from SAS-05-02, Attachment E. The sediment will be removed from the grab sampler. If VOCs/PVOCs are to be analyzed a discrete sample will be collected. The remaining sample will be homogenized in a stainless steel bowl using a stainless steel spoon. Sufficient sediment volume will be collected (as described in the QAPP) and mixed in the bowl to allow for chemical analysis (mobile laboratory and fixed-base laboratory, in select samples), physical analysis, and sediment toxicity testing. The grab sampler will then be decontaminated following SOP SAS-04-04. Horizontal control will utilize global positioning system (GPS) and the boat will be properly anchored to maintain position. Complete procedures for the collection of sediment samples using a grab sampler are outlined in the SSWP and SOP SAS-07-03. Sediment will be classified consistent with SOP SAS-07-02.

4.7.7.2 Coring Devices

Two types of coring devices may be used to collect core samples. A hand or push corer may be used to collect short cores (e.g., 0 to 2 feet bgs) and a Vibracore™ sampler may be used to collect core samples from the SSWP identified sediment column depth(s).

4.7.7.3 Hand or Push Core Sampling and Processing

For sediment samples up to four feet below the sediment/surface water interface, an Ogeechee™ open barrel corer or other drive-push sampler will be manually pushed or driven to collect undisturbed sediment samples in water depths ranging from 0.5 to 10 m.

The corer is deployed from the sampling vessel by hand and is manned by two crewmembers: one field personnel handles the deployment and retrieval of the core, while the other field personnel operates the vessel and records the sampling information. Following retrieval of the corer, the sample will be extruded from the core sleeve, analyzed for the presence of volatile organic vapors with a PID, and the sediment will be described in accordance with ASTM D2488. Non-representative material (e.g., stones, wood chips) will be removed from the sample at the discretion of the field sampler and will be documented in the field log. Sufficient sediment volume will be collected (as described in the QAPP) and mixed in the bowl to allow for chemical analysis which may include the COPCs identified in the CSM and SSWP. Procedures for the collection of sediment samples using a core sampler are outlined in the SSWP and SOP SAS-07-03.

4.7.7.4 Vibracore Sampling and Processing

A Vibracore sampler or equivalent may be used to sample sediments to refusal (e.g., top of consolidated sediment). The Vibracore sampler is electrically powered to advance a core tube up to 20 feet into soft sediment. Previously obtained data has shown that core recoveries are as low as 60 percent; however, technology for collecting core samples has advanced to the point where 90 percent recovery is common for most sample types. To prevent precluding any emergent technologies, a performance-based specification will be written in the request for proposal to potential sampling subcontractors. The specifications that will be required include:

- Ability to attain and maintain station position: use of spuds is preferred over anchoring;
- Station location: less than 3 feet (approximately 1 m) (x, y) using GPS in latitude/longitude degrees, minutes, and seconds;
- Depth measurement with water level correction: less than 0.1 feet (approximately 3 cm) (z) referenced to vertical control system specified in the SSWP; water elevation to be surveyed at least once per day (e.g., mid-day) for determining core sample elevation;
- Coring equipment: Vibracore or equivalent;
- Recovery/penetration: greater than 80 percent (this is a goal, not a minimum requirement);
- Ability to document rate of penetration; and
- Ability to collect core samples down to the native clay layer (potentially 5 to 20 feet).

As cores are brought to the surface, the sediment will be analyzed for the presence of volatile organic vapors with a PID and described in accordance with the ASTM D2488. Each core will be subdivided into 1-foot intervals. The bottom interval will be combined with the interval above it if it is less than 6 inches long. If greater than 6 inches, the bottom interval will be its own sample. Each 1-foot interval will be homogenized in a stainless steel bowl using a stainless steel spoon. Non-representative material (e.g., stones, wood chips) will be removed from the sample at the discretion of the field sampler and will be documented in the field log. Sufficient sediment volume will be collected (as described in the QAPP) and mixed in the bowl to allow for chemical analysis which may include the COPCs identified in the CSM and SSWP. Complete procedures for the collection of sediment samples using a Vibracore are described in SSWP and SOP SAS-07-03.

4.7.7.5 Support Sediment Sampling Equipment

In addition to the sediment sampling devices additional equipment needed to collect sediment samples including a boat, GPS unit, sample containers, and appropriate PPE as required by the HASP. The SSWP and SOP SAS-07-03 provide a comprehensive list of sampling equipment.

4.7.8 In-Situ Field Screening Methods

A variety of probing devices are available that provide real-time qualitative to semi-qualitative subsurface data. The in-situ field screening methods are rapidly developing and changing; therefore, SSWPs will evaluate the current state of the practice for in-situ field screening on a Site-specific basis. SOPs will be developed, as needed, in the event these technologies are deemed appropriate and suitable for the SSWPs. Several screening methods will be evaluated for use in sediment screening on a Site-specific basis and these are described below:

4.7.8.1 LIF Screening Methods

LIF probes that will be evaluated include the Rapid Optical Screening Tool (ROST™) and the Tar-specific Green Optical Screening Tool (TarGOST®), which is a specialized version of the UltraViolet Optical Screening Tool (UVOST™). These tools are operated in the field by the vendor to identify the presence or absence of tars. Examples of current industry field operating standards are provided as Appendix C. If selected, the vendors SOP will be provided in the SSWP or prior to initiating field activities.

TarGOST® detection limits are currently less than or equal to 500 ppm, when calibrated to site-specific conditions, which will be useful in locating and delineating the presence of tar in sediment. ROST™ detection limits vary from 50 to 1,000 ppm, depending on sample matrix and contaminant characteristics. Potential limitations of LIF probes include interference induced by naturally occurring organic matter and probe difficulties with advancing through hard surfaces. These potential limitations will be evaluated on a Site-specific basis.

LIF precision is estimated by evaluating multiple calibration samples, analyzed before and after each push. LIF accuracy is evaluated qualitatively by assessing the agreement between LIF probe detection and non-detection and corresponding laboratory confirmation samples. The false negative rate for the ROST probe ranges from 3.3 to 10 percent, depending on the confirmatory method used[1].

4.7.8.2 DART Method

In sediment areas where LIF probe deployment is not technically or economically feasible, the DART system[2] may be evaluated to screen sediments for PAHs. The DART sampler is a continuous rod coated with a solid-phase extraction (SPE) media that sorb PAH constituents. Rods are manually deployed, with typical depths achieved ranging from 1 to 20 feet. PAHs sorb to the rod from sediment particles, pore water, or NAPL in sediment pores. The rods are typically deployed for 24 hours (may be longer) to allow sufficient time for the concentration gradient between PAHs in the sediment matrix and pores and the SPE to equilibrate. Following equilibration, the rods are removed and shipped for laboratory analysis by LIF.

4.7.9 Sediment Poling

Poling is used to determine soft sediment thickness. Data collected from poling is used to supplement and field verify hydrographic surveys results, and to collect additional data for specific sampling locations. The pole is a 2-inch diameter, aluminum pole and consists of several six-foot long aluminum sections that can be placed together to the appropriate length, and is marked in one-foot increments which in turn are subdivided into one-inch increments. The pole is deployed by hand from the sampling vessel manned by two crewmembers; one field personnel handles the deployment and retrieval of the pole, while the other field personnel operates the vessel and records the sampling information.

---

[1] USEPA, November 22, 2006, Technology Innovation Program Website, *Laser-Induced Fluorescence Web Page*, http://www.clu-in.org/char/technologies/lif.cfm.

[2] Dakota Technologies, February 2007, http://www.dakotatechnologies.com/?content=templates/news_detail.tpl&id=97.

Essentially, the pole is slowly lowered into the water column until there is slight resistance, at which point the pole is read to the nearest inch mark and the result recorded in accordance with the SSWP and Field SOP(s). This is the depth to sediment from the water surface. The pole is the pushed until refusal occurs, at which point the pole is read again to the nearest inch mark and the reading recorded in the field logbook and/or on the appropriate field form. That is the depth to refusal measurement. The pole is then slowly retrieved from the sediment. All observations (potential sediment type encountered, olfactory evidence of contamination) will be recorded. Horizontal control will utilize GPS and the boat will be properly anchored to maintain position. Sediment poling will follow the procedures outlined in the SSWP and SOP SAS-07-01.

4.8 Soil Vapor Assessment

4.8.1 Overview

This section describes the soil vapor sampling collection method. Soil vapor sampling may be completed to support risk evaluations (consistent with the CSM and RAF or SSWP). Soil vapor sampling locations may be selected based both existing and planned building locations, if necessary, to evaluate possible vapor migration pathways. Applicable DQOs from the QAPP will be identified and considered when soil vapor sampling is required, so that the resulting data will satisfy the DQOs. SSWPs will be developed with inclusions of emerging regulatory and industry accepted procedures, including USEPA (draft vapor intrusion guidance (USEPA 2002)), Interstate Technology & Regulatory Council (ITRC) guidance on assessment of the vapor intrusion pathway (ITRC 2007), and pending ASTM guidance on vapor intrusion assessment. If necessary, sites will be screened for potential vapor assessment requirements utilizing groundwater and soil concentration data in accordance with USEPA and ITRC guidelines.

4.8.2 Data Uses

Soil vapor samples may be collected to evaluate vapor migration pathways and entry routes in the vicinity of the former MGP facilities, if applicable to assess Human Health Risk. Air sample collection will include the installation of small-diameter vapor monitoring wells and subsequent soil vapor air sample collection. Soil vapor investigations will be conducted in accordance with the SSWP, SOPs SAS-11-01 and SAS-11-02 and the OSWER 2002 *Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance)*.

4.8.3 Soil Vapor Methodology and Analysis

Soil vapor samples will be collected from small-diameter soil vapor wells installed in the upper 10-feet of subsurface material, or shallower. Site-specific DQOs will be considered when evaluating the appropriate sample depth, as presented in SSWPs. These samples will provide data used to evaluate potential vapor migration. Vapor monitoring wells will be installed with DPT. Soil vapor monitoring wells will be constructed in the same manner as small-diameter groundwater monitoring wells described in Section 4.4.5.4.

Soil vapor samples will be analyzed for VOCs by USEPA Method TO15A. Samples will be collected in evacuated summa canisters provided by the laboratory, and shipped via overnight courier to the laboratory. Grab samples will be collected from the vapor wells, the canisters will be filled in less than one minute. Air samples will be collected in accordance with SOPs included in SSWPs. A minimum of two rounds of soil vapor samples will be collected prior to analysis of the soil vapor analytical results, so that the presence or absence of vapors can be confirmed.

Additional procedures related soil vapor sampling and measurement procedures will be addressed in the SSWP, if relevant and are presented in SOPs SAS-11-03, SAS-11-04, SAS-11-05, and SAS-11-06, which all pertain to monitoring and measuring soil vapor extraction (SVE) system effectiveness and field screening for fixed gases and soil vapor concentrations.

4.9 Field Documentation

4.9.1.1 Field Data Recording

Field activities will be documented in accordance with the SSWP, QAPP Section 1.7, and SOP SAS-01-01. Data generated in the field will be reduced and validated in the field, as appropriate, and before reporting as described in QAPP Section 4. SSWPs will provide data flow charts detailing Site-specific document review, document control, data visualization, data flow management charts and communication lines and time frames to implement the dynamic work plan. A Generic Sample Data Management Flow Diagram is presented as Figure 4.

4.9.1.2 Data Tracking, Storage, and Retrieval

Field data forms and sheets will be tracked and stored electronically in the project file and retrieved as described in the SSWP and SOP SAS-01-02.

4.9.1.3 Final Evidence Files

All final data, field notes, and other pertinent documents produced or delivered will be tracked and stored as required by the SOP SAS-01-02.

5 SAMPLE HANDLING

Sampling handling and chain of custody requirements are described the SSWP and SOPs SAS-03-01 and SAS-03-02. Laboratory custody, handling, and tracking procedures are discussed in the QAPP Section 2.

5.1.1 Sample Identification

Laboratory and field analytical samples will be assigned a unique sample number in accordance with the SSWP, SOP SAS-03-01, and as described in the QAPP Section 2.3.

5.1.2 Sample Container, Volume, Preservation and Holding Times

Sampled media (soil, water, sediment, air, and waste) will be containerized, preserved, and stored in accordance with the SSWP and SOP SAS-03-01. An example of general sample containers, volumes, preservatives, and holding times for soil, water, and sediment samples are summarized on Table 1. Prior to initiating Study activities, the analytical laboratories will verify sample container, volume, preservation, and holding times.

5.1.3 Field Sampling Quality Control

Field quality control samples will be collected as described in QAPP Section 2.5, the SSWPs, and SOP SAS-04-03.

5.1.4 Sample Custody

Chain of custody procedures will be conducted in accordance with the SSWP and SOP SAS-03-02 and as described in QAPP Section 2.3.2.

5.1.5 Sample Shipping

Transportation and shipping requirements are detailed in the SSWP, SOP SAS-03-01, and QAPP Section 2.3.

6 SAMPLE ANALYSIS

6.1.1 Previous Sampling and Analysis

The COPCs presented in the Generalized CSM are based on the results of previous sampling and analysis activities at the Sites. A summary of previous analytical methods utilized for soil, sediment, water, and air is provided as Table 7.

In general, soil and groundwater samples were collected from several former MGP properties between the late 1980s and the present. Soil samples were previously collected as discrete samples from test pits, remedial excavations, soil borings, and surface soil grabs. On occasion, soil samples were composited for physical and/or chemical tests needed for remedial option analysis. Groundwater samples were previously collected with standard dedicated bailers for each well. Bailers have been removed from monitoring wells that are currently sampled utilizing low-flow sampling techniques. A few HydroPunch® and borehole grab samples were collected and analyzed for benzene, toluene, ethylbenzene, and total xylenes (BTEX), PAH, and occasionally cyanide.

As summarized on Table 7, initial soil and groundwater samples were typically analyzed for VOCs/PVOCs, base/neutrals or PAHs, metals, cyanide, and various inorganics parameters (e.g., ammonia, nitrogen, and sulfate). Constituents that were not detected after repeated sampling rounds were not carried forward in subsequent sampling events. The need to analyze for additional constituents, beyond the COPCs provided in the Generalized CSM, will be evaluated on a site-by-site basis as part of developing the SSWPs.

6.1.2 Chemical Analysis

COPCs are discussed in the Generalized CSM Section 4.1 and include:

- PVOCs;
- (parent and alkylated) PAHs;
- Select phenols;
- Cyanide compounds; and

- Metals.

Additional COPCs may be evaluated on a site-by-site basis. Geochemical analysis may be performed to assess the remedial alternative and trend analysis. These parameters may include:

- Alkalinity;
- Chloride;
- Total Dissolved Solids;
- Total Organic Carbon;
- Nitrate; and
- Sulfate.

Analytical parameters and Project Quantitation Limits (PQLs) for media of concern are summarized on Tables 8 and 9. SSWPs will present site-specific PQLs, as appropriate. Analytical methods will be selected based on data needs, quality objectives, regulatory requirements and acceptance, cost, optimization of real-time decision-making and Site-specific conditions. A site-specific Sampling and Analysis Plan Summary will be provided within the SSWP. An example is provided in Table 1.

6.1.3 Field Based Analytical Method Selection Criteria

FAMs will be initially screened for evaluation in accordance with the QAPP and Laboratory Quality Assurance Manuals (QAM). FAMs will be identified with field sampling techniques to ensure representative samples of known quality are collected to achieve project goals. A Generic Method Selection Process is presented as Figure 3. Utilizing project goals and field conditions, and how the technology or strategy performs, field analytical methods will be evaluated for selection based on the following:

- Sensitivity (detection and quantitation limits);
- Selectivity (detection or quantification of single or class analytes);
- Dynamic Range (detection range without dilution);

- Analytical Turn Around Time;
- Precision and Accuracy (method bias may be manageable within project goals);
- Indirect Measurement;
- Field Condition Constraints (accessibility, size, utility requirements), and
- Analysis Derived Waste (safety, cost, and disposal issues).

These selection criteria will be used to determine if the selected method(s) are capable of quantifying analytes in a timely and cost-efficient manner. SSWP will detail the sensitivity, selectivity, dynamic range, and how well the technology or strategy performs for selected field methods to support project decisions. SSWP will also detail QA/QC procedures, samples, and schedule, in accordance with the QAPP and QAM, which will be utilized to ensure the quality of field generated data. FAMs that may be used, but are not limited to the options listed below.

- LIF;
- MIP;
- Ion-Specific Electrode (conventional and In-Situ; SW-846 9200);
- X-ray Fluorescence (SW-846 6200);
- Immunoassay (SW-846 4000);
- Colorimetric (SW-846 8500 and 9000);
- Gas Chromatograph (SW-846 8000);
- Mass Spectrometer (SW-846 8265); and
- Electrochemical Methods (SW-846 7472 and 9078).

Indirect FAMs that may be used, but are not limited to, the options listed below.

- CPT;
- GeoVIS®; and
- Fiber-Optic Sensors.

SOPs for these field analytical methods will be developed as they may be incorporated into sampling and analysis strategies on a Site-specific basis.

6.1.4 Geotechnical Testing

Samples will be collected in accordance with SSWP requirements and may be tested for grain size distribution, moisture content, specific capacity, strength, hydraulic conductivity testing, aquifer pump test, etc. General precision and field units are presented on Tables 8 and 9. Site-specific tests and associated precision and measurement requirements will be presented in SSWPs.

7 FIELD SURVEYING

7.1.1 Overview

Base maps exist or shall be prepared for each of the former MGP properties covered by this FSP. In general, features included on the survey include property boundaries and topographic survey, staff gauge locations, soil sampling locations, sediment-sampling locations, and existing and abandoned groundwater monitoring well locations. If appropriate, field surveying will be performed as necessary to update the project mapping. Field surveying will be used to locate sampling locations, assess the lateral and vertical extent of affected areas, and evaluate the interaction of surface water and groundwater.

7.1.2 Horizontal and Vertical Control

The location of sample points will be determined with horizontal control as described in the SSWP and SOP SAS-03-03. Elevation measurements will be based on the system specified in the SSWP and SOP SAS-02-02. This coordinate system will be used for establishing horizontal and vertical control to sampling data. On a site-specific basis, additional survey control may be utilized and SOPs will be provided in SSWPs.

7.1.3 Data Acquisition

A minimum of two control points will be established at the Site upon which the SSWP-specific coordinates and elevation are set. These points will be established in a permanent location where they will not be disturbed.

Measured elevations will be tied to existing site control points, which will be referenced to elevations and horizontal locations using the vertical and horizontal controls specified in the SSWP. Horizontal orientation locations will be accurate to ±0.1 feet and vertical orientation elevations accurate to ±0.01 feet.

7.1.4 Previously Obtained Survey Data

A number of the MGP Sites have previously obtained sample locations that were surveyed based on an arbitrary coordinate system. The coordinate data associated with these previously obtained samples will be converted to agree with the coordinate system established for each individual Site in the SSWP.

8 DECONTAMINATION

8.1 Overview

Decontamination procedures will be performed to remove chemical constituents from sampling equipment used during Study activities. Proper decontamination procedures prevent chemical constituents from being transferred between sampling location and being transported out of controlled areas.

Decontamination procedures for Field Team Members are addressed in Section 9 of the HASP. Field Team Members will follow applicable safety procedures while performing equipment decontamination including, wearing safety glass and boots, and refraining from eating, smoking, or chewing gum.

8.2 Decontamination of Personnel

A decontamination area for sample preparation equipment will be established within or near the boundary of the Exclusion Zone (EZ). The EZ is defined as the area where contamination is either known or likely to be present, or because of activity, will potentially harm personnel. Entry into the EZ requires the use of personal protective equipment.

A personnel decontamination station will be established outside and adjacent to the EZ. All personnel will remove excess dirt from boots and clothing prior to leaving the decontamination area. If necessary, boots will be decontaminated similarly to sampling tools (Alconox and rinse water). All personnel will wash their hands prior to leaving the decontamination stations. Personal protective equipment will be left in the field activity area(s) during breaks after performing decontamination procedures.

Certain parts of respirators, such as the harness assembly and cloth components are difficult to decontaminate. If grossly contaminated, they will be discarded. Rubber components can be soaked in soap and water and scrubbed with a brush. Individual owners of respirators are responsible for decontaminating and maintaining their own respirators.

8.3 Decontamination of Equipment

Cleaning and decontamination of all equipment shall occur at a designated field activity area, downgradient, and downwind from the clean equipment drying and storage areas. The cleaning and decontamination area will consist of a decontamination pad constructed out of wood and lined with plastic to contain the waste/rinse water until it is containerized and handled as investigative waste. Decontamination procedures will be performed and documented in accordance with the SSWP and SOP SAS-04-04.

8.3.1 Sampling Equipment

Sampling equipment requires special cleaning. Decontamination of all sampling equipment will be performed in accordance with the following procedure:

- Wash the equipment with a solution of Alconox and potable water. Additionally, circulate the solution through non-dedicated equipment, such as submersible pumps; and
- Triple rinse the equipment with distilled water, allow to air dry.

8.3.2 Tools

Tools used during sample preparation (e.g., mixing bowls, hand augers, split spoons, and spatulas) will be decontaminated in accordance with the following procedure:

- Remove all soil by scrubbing with a mixture of Alconox and potable water;
- Rinse with potable water; and
- Triple rinse with distilled water.

8.3.3 Heavy Equipment and Vehicles

Drill rigs and other heavy equipment are difficult to decontaminate. Generally, they are steam cleaned with water under high pressure and/or accessible parts are scrubbed with detergent/water solution under pressure, if possible. Particular care must be given to those components in direct contact with contaminants, such as tires, augers, or buckets. Before leaving field activity areas, all heavy equipment and vehicles will be inspected by the Field Leader to confirm the decontamination effort.

8.3.4 Cleaning and Decontamination of Equipment/Sample Containers

8.3.4.1 Equipment Decontamination

As described in the QAPP Section 2.2.2, equipment decontamination procedures will be kept to a minimum through the use of either dedicated or disposable sampling equipment. However, some sampling equipment will require decontamination, and these include equipment made of glass, metals, Teflon™, and other plastic materials. Equipment decontamination procedures are described in the SSWP and SOP SAS-04-04.

8.3.4.2 Sample Container Decontamination

Sample container decontamination is not anticipated to be required, as the analytical laboratory will provide all containers for samples to be submitted for laboratory analysis. As described in the QAPP Section 2.2.2, sample containers will not be used if the container integrity is compromised in any manner.

9 MANAGEMENT OF INVESTIGATIVE DERIVED WASTES

IDW will be generated during the Study sampling activities. The methodology for the management, storage, and disposal of the wastes is described below. Each investigative waste stream will require specific handling, storage, and disposal procedures to ensure that potential adverse environmental impacts associated with the waste do not occur, and that all wastes are characterized ,transported, and disposed in accordance with the provisions set forth in the Off-Site Rule, Code of Federal of Regulations (40 CFR 300.400).

9.1 Investigative Waste Sources

Sources of investigative derived waste likely to be generated at the Sites include the following:

- Soil and/or sediment generated during the sampling and installation of test pits, soil borings, and monitoring wells;
- Groundwater IDW generated during monitoring well development, purging, and sampling activities;
- Decontamination wastes generated during decontamination of field equipment, sampling equipment, and personal protective equipment; and
- Personal protective equipment associated with worker health and safety.

9.2 Soil and/or Sediment

Soil and/or sediment generated during the advancement of drilling and similar activities (augers, hydraulic push, sonic) will be handled as a waste product. Drill cuttings will be accumulated at the drilling location in a manner that prevents erosion or direct contact exposure (e.g., 55-gallon drums, landfill roll-off boxes, tarped and bermed stockpiles, etc.). Drilling mud, if generated, will be solidified and classified as drill cuttings. Waste soil is occasional generated during test pit sampling that cannot be replaced in the test pit. This soil and/or sediment will be disposed off-Site on a Site-specific basis based on field use and activity phase and in accordance with USEPA's Off-Site Rule (40 CFR 300.440).

Each container or stockpile will be labeled with the information necessary to identify source area(s) and dates of accumulation. Soil and/or sediment will be temporarily stored while waste characterization analysis is completed. Waste characterization will be performed and a waste profile will be established for these materials unless the waste is covered under an existing profile. Soils and/or sediment will be disposed of as a special solid waste at facilities previously used and/or approved by the Company and USEPA. In these cases, off-site disposal will be coordinated prior to or as soon as practical following the completion of field activities.

Soils and/or sediment generated that are different (either physically or contaminant source area) from historic drilling wastes may need to be profiled separately. A composite sample will be collected from the drums of drilling spoil and submitted for laboratory analysis. The permitted disposal facility will determine what analyses are required to complete the waste profile. Following waste characterization profile acceptance by a disposal facility, the soil and/or sediment will be transported by a certified waste hauler for off-site disposal.

9.3 Well Development and Purge Water

Purge water generated from well development and groundwater sample collection activities will be managed as a waste. The procedures for handling development/purge water will require the collection of this water at the monitoring well location in a bulk storage container. The bulk storage container should be inspected prior to use to assure it will not leak.

Development/purge water will then be treated in field activity area(s) through a portable granular activated carbon canister prior to discharge to a publicly owned treatment works (POTW) sanitary sewer system, or disposed of off-site in accordance with federal, state, and local regulations and the SSWP. Development/purge water containing NAPL will be filtered through a strainer and PIG® Oil-Only Pad. The strainer and pad will be placed in a sealed 55-gallon drum and co-disposed with soil in bulk containers as solid waste.

9.4 Decontamination Wastes

Wastes associated with the decontamination of field equipment will consist primarily of liquids, with minor amounts of solids. The wastes will be generated by the cleaning of:

- Soil boring and sampling equipment (e.g., drill rig/backhoe);
- Monitoring well development equipment; and
- Personnel exiting the exclusion zone around each sampling location.

Following generation, decontamination water will be placed in a bulk storage container. The decontamination water should be decanted during transfer to the bulk storage container as to minimize the amount of solids transferred. Solids present after decanting will be placed in drums and treated as soil investigative waste. Disposal of decanted decontamination water will be the same as for the disposal of development/purge water.

9.5 Personal Protective Equipment

Waste personal PPE generated during the field activities will be placed in a sealed 55-gallon drum and co-disposed with soil in bulk containers. Waste PPE that is free of NAPL will be stored in plastic garbage bags and disposed of in a dumpster with general refuse, unless otherwise specified in the SSWP.

10 REFERENCES

Accardi-Dey, A, and P.M. Gschwend. 2003. *Reinterpreting literature sorption data considering both partitioning into organic carbon and Adsorption on to Black Carbon*. Environmental Science and Technology, v 37:1, p 99-106.

ASTM International. 1999. D1586-99 Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils. ASTM Book of Standards Volume 4.08.

ASTM International. 2002a. D421-85(2002) Standard Practice for Dry Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants. ASTM Book of Standards Volume 4.08.

ASTM International. 2002b. D422-63(2002)e1 Standard Test Method for Particle-Size Analysis of Soils. ASTM Book of Standards Volume 4.08.

ASTM International. 2002c. D1557-02e1 Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3(2,700 kN-m/m^3)). ASTM Book of Standards Volume 4.08.

ASTM International. 2003. D5084-03 Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter. ASTM Book of Standards Volume 4.08.

ASTM International. 2004a. D422 D3080-04 Standard Test Method for Direct Shear Test of Soils Under Consolidated Drained Conditions. ASTM Book of Standards Volume 4.08.

ASTM International. 2004b. D4043-96(2004) Standard Guide for Selection of Aquifer Test Method in Determining Hydraulic Properties by Well Techniques. ASTM Book of Standards Volume 4.08.

ASTM International. 2004c. D6725-04 Standard Practice for Direct Push Installation of Prepacked Screen Monitoring Wells in Unconsolidated Aquifers. ASTM Book of Standards Volume 4.08.

ASTM International. 2004d. D5092-04e1 Standard Practice for Design and Installation of Ground Water Monitoring Wells. ASTM Book of Standards Volume 4.08.

ASTM International. 2005a. D2216-05 Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass. ASTM Book of Standards Volume 4.08.

ASTM International. 2005b. D4318-05 Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils. ASTM Book of Standards Volume 4.08.

ASTM International. 2005c. D5521-05 Standard Guide for Development of Ground-Water Monitoring Wells in Granular Aquifers. ASTM Book of Standards Volume 4.08.

ASTM International. 2006a. D2488-06 Standard Practice for Description and Identification of Soils (Visual-Manual Procedure). ASTM Book of Standards Volume 4.08.

ASTM International. 2006b. D4700-91(2006) Standard Guide for Soil Sampling from the Vadose Zone. ASTM Book of Standards Volume 4.08.

Code of Federal Regulations, Title 40 Volume 25, Title 40 – Protection of Environment, Chapter I Environmental Protection Agency, Part 300 – National Oil and Hazardous Substances Pollution Contingency Plan, Subpart E – Hazardous Substance Response, Section 300.400, Procedures for Planning and Implementing Off-Site Response Actions, Revised July 1, 2003.

Crumbing, D., J. Hayworth, B. Call, W. Davis, R. Howe, D. Miller and R Johnson, 2004, The Maturing Triad approach: Avoiding Misconceptions; Remediation, Autumn 2004, pp. 81-96.

GeoInsight®, 2006, GeoInsight Web Pages, http://www.geoinsightonline.com/.

Geoprobe®, 2006, Geoprobe Web Pages, http://www.geoprobe.com/index.htm.

ITRC, 2004. Sampling for Contaminants in Sediments and Sediment Pore Water. http://clu-in.org/programs/21m2/sediment/.

ITRC. 2007a. Vapor Intrusion Pathway: A Practical Guideline (VI-1). ITRC, Washington DC, January 2007.

ITRC. 2007b. Vapor Intrusion Pathway: Investigative Approaches for Typical Scenarios, A Supplement to *Vapor Intrusion Pathway: A Practical Guideline* (VI-1A). ITRC, Washington DC, January 2007.

ITRC, 2007c, Integrated Pore-Water and Geophysical Investigations Streamline Characterization of Ground-Water Discharges to Surface Water, http://cluin.org/products/newsltrs/tnandt/view.cfm?issue=0307.cfm#4

Integrys Business Support, 2007a, Multi-Site Conceptual Site Model, Former Manufactured Gas Plant Sites, Rev 0, August 2007.

Integrys Business Support, 2007b, Multi-Site Risk Assessment Framework, Former Manufactured Gas Plant Sites, Rev 0, August 2007.

Integrys Business Support, 2007c, Multi-Site Health and Safety Plan, Former Manufactured Gas Plant Sites, Rev 0, August 2007.

Integrys Business Support, 2007d, Multi-Site Quality Assurance Project Plan, Former Manufactured Gas Plant Sites, Rev 2, September 2007.

MacDonald, D.D., C.G., Ingersoll, and T.A. Berger, 2000, Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems, Archives of Environmental Contamination and Toxicology 39: 20-31.

MHE Products, 2001, PushPoint Sampler Operators Manual and Applications Guide, Ver. 2.00 (Models: PP27, PP14, PPX36, PPX72).

Stach, E. 1982. Stach's Textbook of Coal Petrology, third revised and enlarged edition. Gebr Borntraeger Verlagsbuchhandlung, Science Publishers.

USDOE, 2002, *Adaptive Sampling and Analysis Program (ASAP)*, Environmental Assessment Division (EAD), http://www.ead.anl.gov/project/dsp_topicdetail.cfm?topicid=23.

USEPA, 1987, A Compendium of Superfund Field Operation Methods, Office of Emergency and Remedial Response, EPA/540/P-87/001, December 1987.

USEPA, 1988, Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Office of Solid Waste and Emergency Response, EPA/540/G-89/004, October 1988.

USEPA, April 1992, Monitoring Well Development Guidelines for Superfund Project Managers, Office of Solid Waste and Emergency Response.

USEPA, 1992, Guide to Management of Investigative- Derived Waste (IDW). Office of Solid Waste and Emergency Response. Publication 9345.3-03FS, January 1992.

USEPA. 1996. Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, Method 8270C - Semivolatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS). USEPA SW-846. December 1996.

USEPA, 1997a, Ecological Risk Assessment Guidance for Superfund (ERAGS): Process for Designing and Conducting Ecological Risk Assessments, Interim Final, EPA/540/R 97/006, Environmental Response Team, Edison, NJ, 1997.

USEPA, 1997b, Field Analytical and Site Characterization Technologies Summary of Applications, EPA-542-R-97-011, Office of Solid Waste and Emergency Response, Washington, DC, November 1997.

USEPA, 1998, Guidelines for Ecological Risk Assessment, EPA/630/R-95/002F, Risk Assessment Forum, Washington, D.C., 1998.

USEPA, 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002.

USEPA. 2000a. Methods for Measuring the Toxicity and Bioaccumulation of Sediment-associated Contaminants with Freshwater Invertebrates, 2nd edition. EPA 600/R-99-0\4, March 2000. http://www.ehso.com/ehso3.php?URL=http%3A%2F%2Fwww.epa.gov/ost/cs/freshfact.html.

USEPA, 2000b Innovations In Site Characterization Case Study: Site Cleanup Of The Wenatchee Tree Fruit Test Plot Site Using A Dynamic Work Plan, EPA 542-R-00-009, Washington, DC, August 2000.

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual, USEPA Region IV, November 2001.

USEPA, 2002a, Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance), OSWER, EPA 530-D-02-004.

USEPA, 2002b, On-line field analytical technologies encyclopedia (FATE), http://fate.clu-in.org/.

USEPA, 2002c, Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers, OSWER, EPA 542-S-02-001.

USEPA, 2003a, Improving Decision Quality: Making the Case for Adopting Next-Generation Site Characterization Practices, Wiley Periodicals, Inc.

USEPA, 2003b, Procedure for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: PAH Mixtures, EPA-600-R-02-013, Office of Research and Development, Washington, D.C., 2003.

USEPA, 2003c, Using Dynamic Field Activities for On-Site Decision Making: A Guide for Project Managers, EPA/540/R-03/002, OSWER No. 9200.1-40, -600-R-02-013, Office of Solid Waste and Emergency Response, Washington, D.C., May 2003.

USEPA, 2004a, *A Site Characterization Technologies for DNAPL Investigations,* USEPA 542-R-04-017.

USEPA, 2004b, Improving Sampling, Analysis, and Data Management for Site Investigation and Cleanup, Office of Solid Waste, EPA-542-F-04-001a, www.epa.gov/tio, www.cluin.org, April 2004,

USEPA, 2004c, Site Characterization Technologies for DNAPL Investigations, Office of Solid Waste, EPA 542-R-04-017 Emergency Response (5102G), http://www.epa.gov/tio, September 2004.

USEPA, 2005. Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: Metal Mixtures (Cadmium, Copper, Lead, Nickel, Silver, and Zinc), EPA/600/R-02/011, Office of Research and Development, Washington, D.C., January 2005.

USEPA, 2006, Settlement Agreement for Remedial Investigations and Feasibility Studies, WPSC MGP Sites, Wisconsin, USEPA Region 5, CERCLA Docket No. V-W-'06-C-847, April 27, 2006, effective date May 5, 2006.

USEPA, 2007, *Settlement Agreement and Administrative Order on Consent for the conduct of Engineering Evaluations and Cost Analysis*. , The Peoples Gas Light and Coke Company and U.S. EPA Region 5, CERCLA Docket No.V-W-07-C-869, dated June 5, 2007.

USEPA, 2007, *Settlement Agreement and Administrative Order on Consent for the conduct of Remedial Investigations and Feasibility Studies*. North Shore Gas Company and U.S. EPA Region 5, CERCLA Docket No. V-W-07-C-877, dated July 23, 2007.

USGS, 2002, Guidance on the Use of Passive-Vapor-Diffusion Samplers to Detect Volatile Organic Compounds in Ground-Water-Discharge Areas, and Example Applications in New England: U.S. Geological Survey Water-Resources Investigations Report 02-4186, 79 p. Church, P.E., Vroblesky, D.A., Lyford, F.P., and Willey, R.E.,

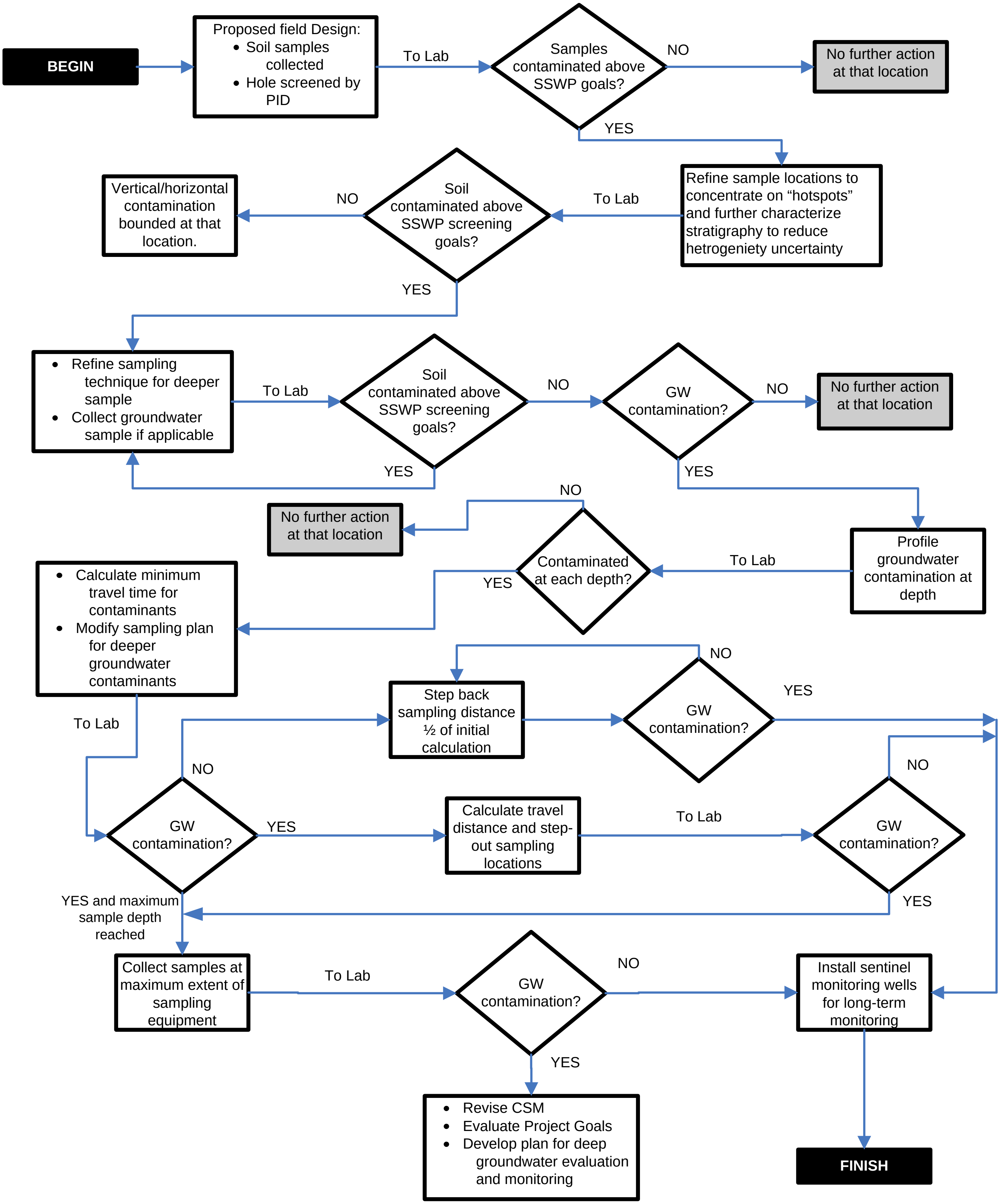
Water-Resources Investigations Report 02-4186. Peter E. Church, Don A. Vroblesky, Forest P. Lyford, and Richard E. Willey.

WDNR, 1992, *Campmarina, The Former Coal Gas Facility Operated by Wisconsin Public Service Corporation and Owned By the City of Sheboygan located in Sheboygan, WI*, Section 144.442, Wisconsin Statutes, Contract Number SF-91-04, April 6, 1992.

WDNR. 2003. Guidance for Applying the Sediment Sampling and Analysis Requirements of Chapter NR 347, Wisconsin Administrative Code. PUB-WT-778. December 2003.

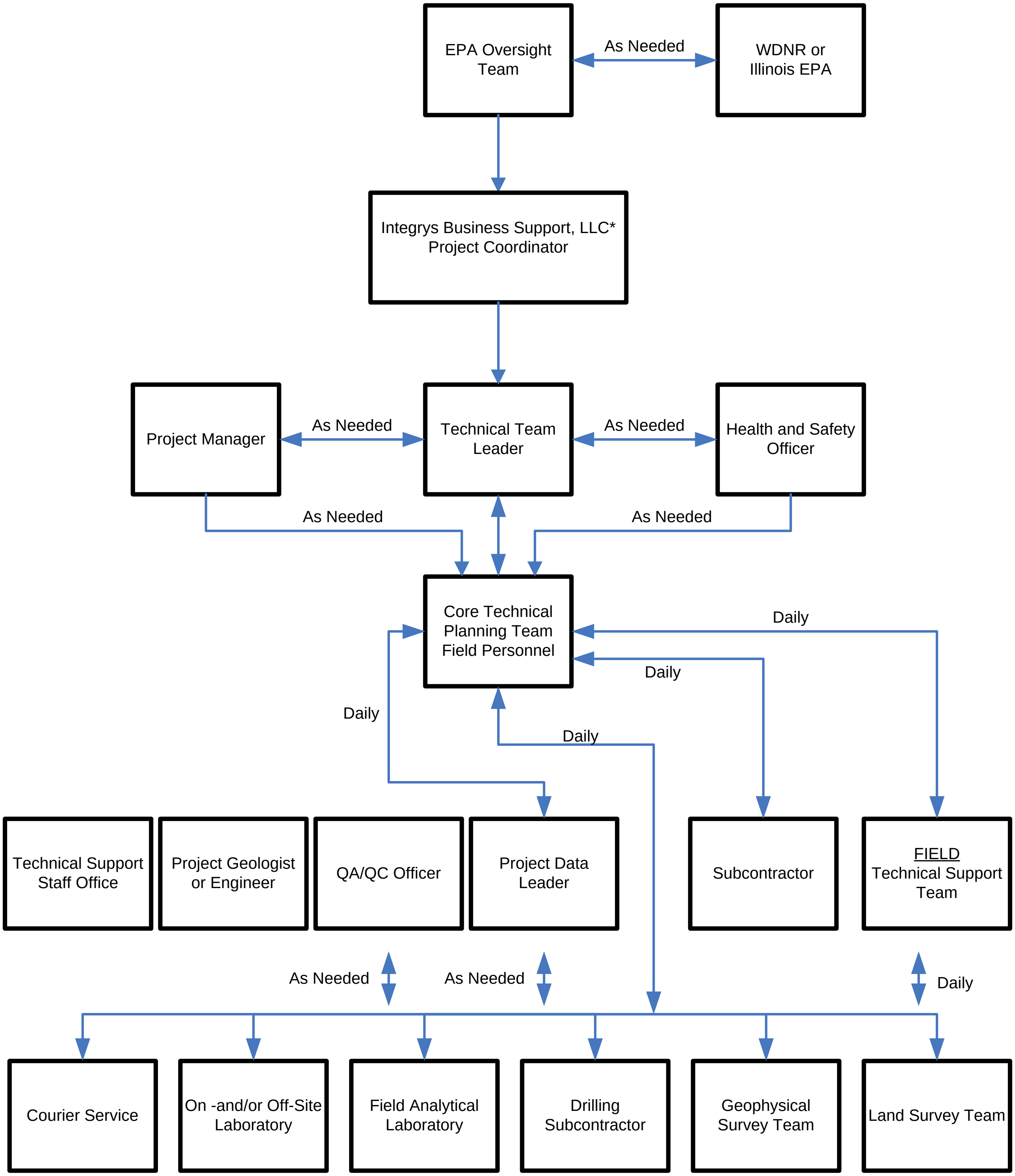
FIGURES

FIGURE 1 GENERIC REMEDIAL INVESTIGATION / ENGINEERING EVALUATION FIELD DATA DECISION TREE



Source: USEPA, 2003, Using Dynamic Field Activities for On-Site Decision Making, OSWER 9200.1-40

FIGURE 2 GENERIC TECHNICAL TEAM STRATEGY

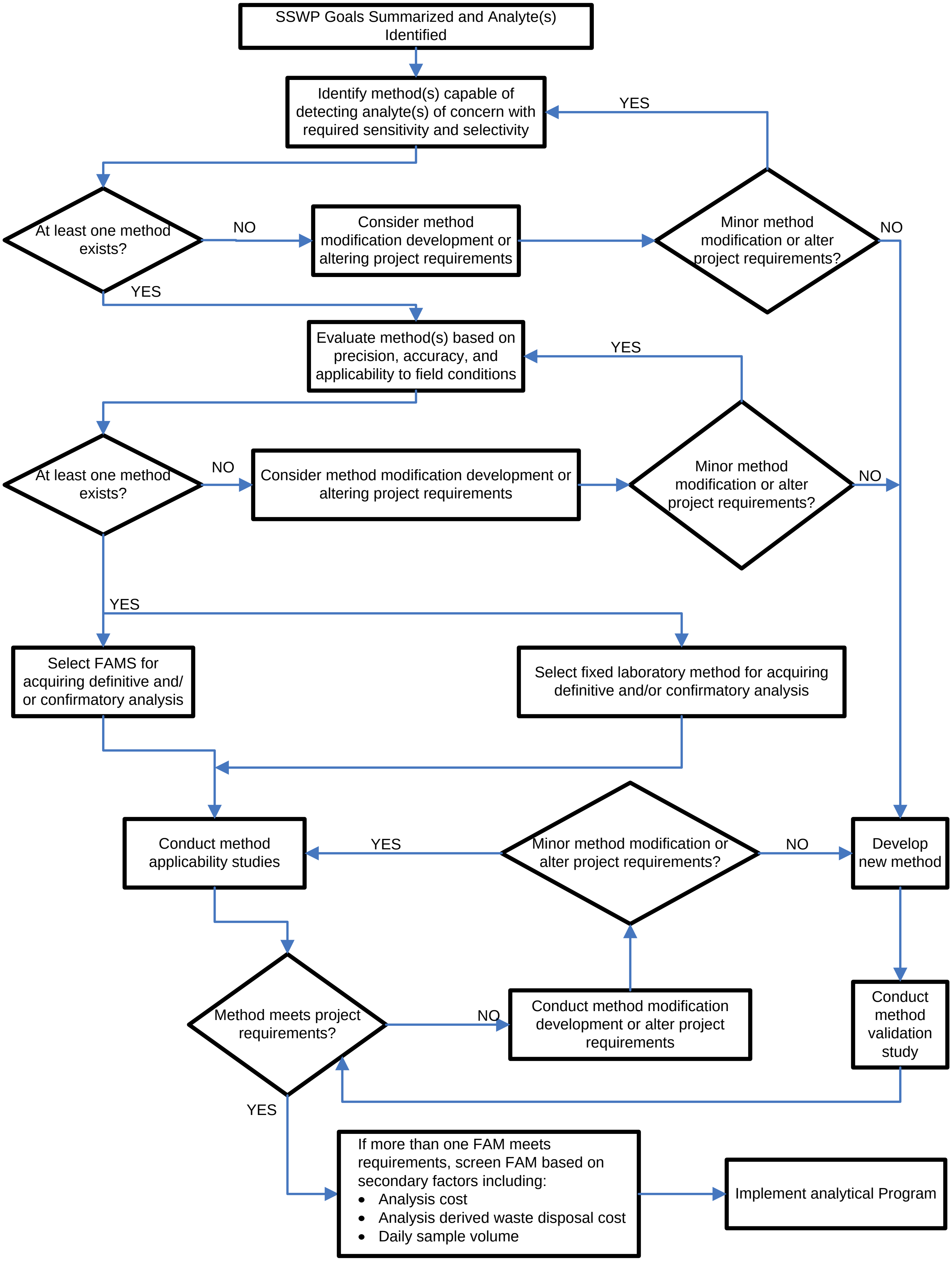


Source: USEPA, 2003, Using Dynamic Field Activities for On-Site Decision Making, OSWER 9200.1-40

NOTE

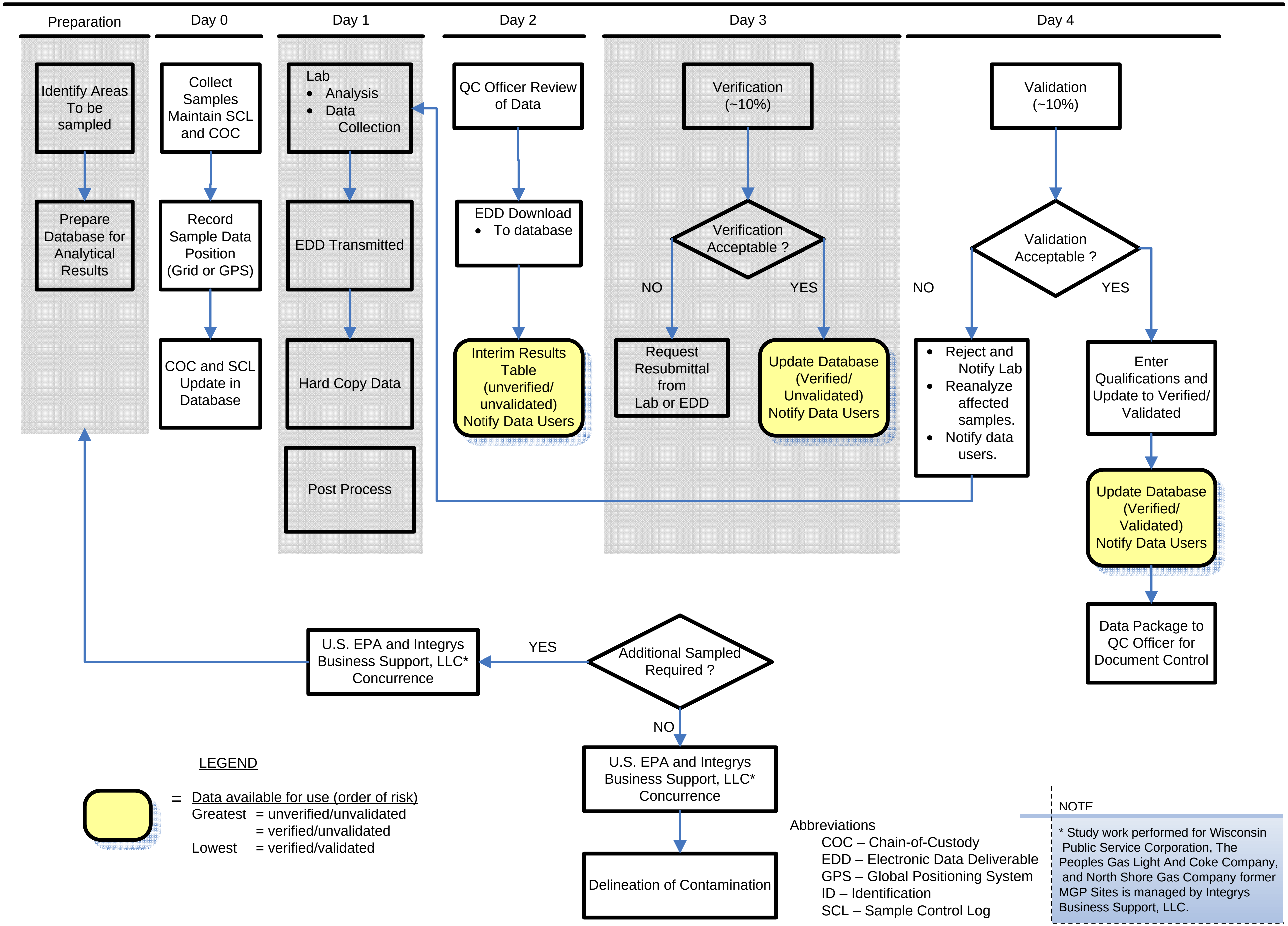
* Study work performed for Wisconsin Public Service Corporation, The Peoples Gas Light And Coke Company, and North Shore Gas Company former MGP Sites is managed by Integrys Business Support, LLC.

FIGURE 3 GENERIC METHOD SELECTION PROCESS OVERVIEW



Source: USEPA, 2003, Using Dynamic Field Activities for On-Site Decision Making, OSWER 9200.1-40

FIGURE 4 GENERIC SAMPLING DATA MANAGEMENT FLOW DIAGRAM



Source: USEPA, 2003, Using Dynamic Field Activities for On-Site Decision Making, OSWER 9200.1-40

TABLES

Table 1. Multi-Site Field Sampling Plan Summary

Integrys Business Support, LLC
Former MGP Sites
USEPA Region 5
CERCLA Docket Nos. V-W-'06-C-847, V-W-'07-C-869, and V-W-'07-C-877

Sample Type/Location[1]	Matrix	Parameter [2]	Method	Sample Quantity [3]	Field Duplicates [4]	Equipment Blanks [5]	MS/MSD[6]	TOTAL	Container Type	Minimum Volume	Preservation	Holding Time from Sample Date
Surface Soil for human health and terrestrial ecological risk assessments (0 to 2 feet bgs)	soil	PVOCs	SW846 8260B						glass	2 oz.	methanol, Cool to 4° ≥ 2°C	7/28 days
		PAHs	SW846 8270C GC/MS SIM						amber glass	2 liters	Cool to 4° ≥ 2°C	14 days
		Phenols	SW846 9066						amber glass	250 ml	Cool to 4° ≥ 2°C	28 days
		Cyanide	SW846 9012A						plastic	125 ml	Cool to 4° ≥ 2°C	14 days
		MGP Metals[7]	SW846 6020A SW846 7470A						plastic	600 ml	HNO_3 to pH<2 Cool to 4° ≥ 2°C	6 months
Sub-surface Soil for human health risk assessments (2 feet bgs to water table)	soil	PVOCs	SW846 8260B						glass	2 oz.	methanol, Cool to 4° ≥ 2°C	7/28 days
		PAHs	SW846 8270C GC/MS SIM						amber glass	2 liters	Cool to 4° ≥ 2°C	14 days
		Phenols	SW846 9066						amber glass	250 ml	Cool to 4° ≥ 2°C	28 days
		Cyanide	SW846 9012A						plastic	125 ml	Cool to 4° ≥ 2°C	14 days
		MGP Metals[7]	SW846 6020A, 7470A						plastic	600 ml	HNO_3 to pH<2 Cool to 4° ≥ 2°C	6 months
Groundwater for human health risk assessments	water	PVOCs	SW846 8260B						glass vial	2-40 ml	HCl to pH<2, Zero Headspace, Cool to 4° ≥ 2°C	14 days
		PAHs	SW846 8270C GC/MS SIM						amber glass	2 liters	Cool to 4° ≥ 2°C	14 days
		Phenols	SW846 9066						amber glass	1 liters	H_2SO_4 to pH<2 Cool to 4° ≥ 2°C	28 days
		Cyanide, total	SW846 9012A						plastic	500 ml	NaOH ≥ 12 Cool to 4° ≥ 2°C	14 days
		Cyanide, available	USEPA OIA 1677						amber glass	250 ml	NaOH ≥ 12 Cool to 4° ≥ 2°C $PbCO_3$ & filter if S^{-2} present $C_6H_8O_6$ if Cl, OCl^-, SO_3^{-2} present $C_2H_8N_2$ if soluble O=CH^- present	14 days
		MGP Metals[7]	SW846 6020A, 7470A						plastic	600 ml	HNO_3 to pH<2 Cool to 4° ≥ 2°C	6 months
		Temperature	field instruments						field measured	n/a	n/a	immediate field measurement
		pH	field instruments						field measured	n/a	n/a	immediate field measurement
		Specific Conductivity	field instruments						field measured	n/a	n/a	immediate field measurement
		Oxidation-Reduction Potential	field instruments						field measured	n/a	n/a	immediate field measurement
		DO	field instruments						field measured	n/a	n/a	immediate field measurement
		Turbidity	field instruments						field measured	n/a	n/a	immediate field measurement

Table 1. Multi-Site Field Sampling Plan Summary

Integrys Business Support, LLC
Former MGP Sites
USEPA Region 5
CERCLA Docket Nos. V-W-'06-C-847, V-W-'07-C-869, and V-W-'07-C-877

Sample Type/Location[1]	Matrix	Parameter [2]	Method	Sample Quantity [3]	Field Duplicates [4]	Equipment Blanks [5]	MS/MSD[6]	TOTAL	Container Type	Minimum Volume	Preservation	Holding Time from Sample Date
Groundwater for trend analysis	water	PVOCs	SW846 8260B						glass vial	2-40 ml	HCl to pH<2, Zero Headspace, Cool to 4° ≥ 2°C	14 days
		PAHs	SW846 8270C GC/MS SIM						amber glass	2 liters	Cool to 4° ≥ 2°C	14 days
		Phenols	SW846 9066						amber glass	1 liters	H_2SO_4 to pH<2 Cool to 4° ≥ 2°C	28 days
		Cyanide, total	SW846 9012A						plastic	500 ml	NaOH ≥ 12 Cool to 4° ≥ 2°C	14 days
		Cyanide, available	USEPA OIA 1677						amber glass	250 ml	NaOH ≥ 12 Cool to 4° ≥ 2°C $PbCO_3$ & filter if S^{-2} present $C_6H_8O_6$ if Cl, OCl^-, SO_3^{-2} present $C_2H_8N_2$ if soluble $O{=}CH^-$ present	14 days
		MGP Metals[7]	SW846 6020A SW846 7470A						plastic	600 ml	HNO_3 to pH<2 Cool to 4° ≥ 2°C	6 months
		Alk (bi-carb)	USEPA 310.2						plastic	100 ml	Cool to 4° ≥ 2°C	14 days
		Alk (carb)	USEPA 310.2						plastic	100 ml	Cool to 4° ≥ 2°C	14 days
		Ammonia	USEPA 350.1						plastic	500 ml	H_2SO_4 to pH<2 Cool to 4° ≥ 2°C	28 days
		Chloride	USEPA 300.0, 325.1						plastic	50 ml	Cool to 4° ≥ 2°C	28 days
		Total Hardness	SW846 6010						plastic	100 ml	H_2SO_4 to pH<2 Cool to 4° ≥ 2°C	6 months
		Nitrate	USEPA 353.2, 300.0, 9056						plastic	100 ml	H_2SO_4 to pH<2 Cool to 4° ≥ 2°C	48 hours
		Sulfate	USEPA 300.0, 9056						plastic	50 ml	Cool to 4° ≥ 2°C	28 days
		Sulfide	USEPA 9030						plastic	500 ml	NaOH, 20 drops zinc acetate to pH>9, Cool to 4° ≥ 2°C	7 days
		Ferrous Iron	SW846 6020A						plastic	8 oz.	Cool to 4° ≥ 2°C	upon receipt
		TDS	USEPA 160.1						plastic	100 ml	Cool to 4° ≥ 2°C	7 days
		TKN	USEPA 351.1						plastic	500 ml	H_2SO_4 to pH<2 Cool to 4° ≥ 2°C	28 days
		TSS	USEPA 160.2						plastic	100 ml	Cool to 4° ≥ 2°C	7 days
		TOC	USEPA 415.1, 9060						plastic	(3) 40 ml	H_2SO_4 to pH<2 Cool to 4° ≥ 2°C	28 days
		Temperature	field instruments						field measured	n/a	n/a	immediate field measurement
		pH	field instruments						field measured	n/a	n/a	immediate field measurement
		Specific Conductivity	field instruments						field measured	n/a	n/a	immediate field measurement
		Oxidation-Reduction Potential	field instruments						field measured	n/a	n/a	immediate field measurement
		DO	field instruments						field measured	n/a	n/a	immediate field measurement
		Turbidity	field instruments						field measured	n/a	n/a	immediate field measurement

Table 1. Multi-Site Field Sampling Plan Summary
Integrys Business Support, LLC
Former MGP Sites
USEPA Region 5
CERCLA Docket Nos. V-W-'06-C-847, V-W-'07-C-869, and V-W-'07-C-877

Sample Type/Location[1]	Matrix	Parameter [2]	Method	Sample Quantity [3]	Field Duplicates [4]	Equipment Blanks [5]	MS/MSD[6]	TOTAL	Container Type	Minimum Volume	Preservation	Holding Time from Sample Date
Surface water for human health and ecological risk assessments	water	PVOCs	SW846 8260B						glass vial	2-40 ml	HCl to pH<2, Zero Headspace, Cool to 4° ≥ 2°C	14 days
		PAHs	SW846 8270C GC/MS SIM						amber glass	2 liters	Cool to 4° ≥ 2°C	14 days
		Phenols	SW846 9066						amber glass	1 liters	H_2SO_4 to pH<2 Cool to 4° ≥ 2°C	28 days
		Cyanide, total	SW846 9012A						plastic	500 ml	NaOH ≥ 12 Cool to 4° ≥ 2°C	14 days
		Cyanide, available	USEPA OIA 1677						amber glass	250 ml	NaOH ≥ 12 Cool to 4° ≥ 2°C $PbCO_3$ & filter if S^{-2} present $C_6H_8O_6$ if Cl, OCl^-, SO_3^{-2} present $C_2H_8N_2$ if soluble $O{=}CH^-$ present	14 days
		MGP Metals[7]	SW846 6020A SW846 7470A						plastic	600 ml	HNO_3 to pH<2 Cool to 4° ≥ 2°C	6 months
		Percent Solids	160						glass	4 oz	Cool to 4° ≥ 2°C, dark	28 days
		TOC	USEPA 415.1, 415.2						plastic	100 g	Cool to 4° ≥ 2°C, dark	28 days
		Temperature	field instruments						field measured	n/a	n/a	immediate field measurement
		pH	field instruments						field measured	n/a	n/a	immediate field measurement
		Specific Conductivity	field instruments						field measured	n/a	n/a	immediate field measurement
		Oxidation-Reduction Potential	field instruments						field measured	n/a	n/a	immediate field measurement
		DO	field instruments						field measured	n/a	n/a	immediate field measurement
		Turbidity	field instruments						field measured	n/a	n/a	immediate field measurement
Groundwater and Surface Water Waste Characterization *Parameters vary on a site-specific basis*	Water	PVOCs	SW846 8260B						glass vial	2-40 ml	HCl to pH<2, Zero Headspace, Cool to 4° ≥ 2°C	14 days
		PAHs	SW846 8270C GC/MS SIM						amber glass	2 liters	Cool to 4° ≥ 2°C	14 days
		Cyanide, total	SW846 9012A						plastic	500 ml	NaOH ≥ 12 Cool to 4° ≥ 2°C	14 days
		MGP Metals[7]	SW846 6020A, 7470A						plastic	600 ml	HNO_3 to pH<2 Cool to 4° ≥ 2°C	6 months
		Percent Solids	160						glass	4 oz	Cool to 4° ≥ 2°C, dark	28 days
		TSS	USEPA 160.2						plastic	100 ml	Cool to 4° ≥ 2°C	7 days

Table 1. Multi-Site Field Sampling Plan Summary

Integrys Business Support, LLC
Former MGP Sites
USEPA Region 5
CERCLA Docket Nos. V-W-'06-C-847, V-W-'07-C-869, and V-W-'07-C-877

Sample Type/Location[1]	Matrix	Parameter [2]	Method	Sample Quantity [3]	Field Duplicates [4]	Equipment Blanks [5]	MS/MSD[6]	TOTAL	Container Type	Minimum Volume	Preservation	Holding Time from Sample Date
Groundwater and Surface Water Waste Characterization continued…	Water	TOC	USEPA 415.1, 9060						plastic	(3) 40 ml	H_2SO_4 to pH<2 Cool to 4° ≥ 2°C	28 days
		Temperature	field instruments						field measured	n/a	n/a	immediate field measurement
		pH	field instruments						field measured	n/a	n/a	immediate field measurement
		Specific Conductivity	field instruments						field measured	n/a	n/a	immediate field measurement
		Oxidation-Reduction Potential	field instruments						field measured	n/a	n/a	immediate field measurement
		DO	field instruments						field measured	n/a	n/a	immediate field measurement
		Turbidity	field instruments						field measured	n/a	n/a	immediate field measurement
Sediment for ecological risk assessments (typically 0 to 6 inches below mudline)	sediment	PVOCs	SW846 8260B						glass	2 oz.	methanol, Cool to 4° ≥ 2°C	7/28 days
		34 PAHs[8]	SW846 8270C GC/MS SIM						amber glass	4 oz.	Cool to 4° ≥ 2°C	14/40 days
		Cyanide	SW846 9012A						plastic	125 ml	Cool to 4° ≥ 2°C	14 days
		MGP Metals[7]	SW846 6020A SW846 7470A						glass	16 oz	Cool to 4° ≥ 2°C	6 months
		Phenols	SW846 9066						amber glass	250 ml	Cool to 4° ≥ 2°C	28 days
		"Soot" Carbon[9]	Gusstaffson et al.						Plastic	500 g	Cool to 4° ≥ 2°C, dark	28 days
		Percent Solids	160						glass	4 oz	Cool to 4° ≥ 2°C, dark	28 days
		TOC	USEPA 415.1						plastic	100 g	Cool to 4° ≥ 2°C, dark	28 days
		Description	ASTM D 2488						field measured	n/a	n/a	immediate field measurement
		Biological Testing[10]	Method 100.4						Plastic	2L	Cool to 4° ≥ 2°C, dark	
Sediment for Human Health Risk Assessment (typically 0 to 2 feet below mudline)	sediment	PVOCs	SW846 8260B						glass	2 oz.	methanol, Cool to 4° ≥ 2°C	7/28 days
		PAHs	SW846 8270C GC/MS SIM						amber glass	4 oz.	Cool to 4° ≥ 2°C	14/40 days
		Cyanide	SW846 9012A						plastic	125 ml	Cool to 4° ≥ 2°C	14 days
		MGP Metals[7]	SW846 6020A SW846 7470A						glass	16 oz	Cool to 4° ≥ 2°C	6 months
		Phenols	SW846 9066						amber glass	250 ml	Cool to 4° ≥ 2°C	28 days
		Percent Solids	160						glass	4 oz	Cool to 4° ≥ 2°C, dark	28 days
		TOC	USEPA 415.1						plastic	100 g	Cool to 4° ≥ 2°C, dark	28 days
		Description	ASTM D 2488						field measured	n/a	n/a	immediate field measurement

Table 1. Multi-Site Field Sampling Plan Summary
Integrys Business Support, LLC
Former MGP Sites
USEPA Region 5
CERCLA Docket Nos. V-W-'06-C-847, V-W-'07-C-869, and V-W-'07-C-877

Sample Type/Location[1]	Matrix	Parameter [2]	Method	Sample Quantity [3]	Field Duplicates [4]	Equipment Blanks [5]	MS/MSD[6]	TOTAL	Container Type	Minimum Volume	Preservation	Holding Time from Sample Date
Soil and Sediment Remedial Alternatives and Waste Characterization (depth varies)	soil	COPC[11]	various						plastic	5 gal.	various	various
		Protocol B	various						glass	26 oz.	VOCs, methanol, cool to 4°C, dark; Others cool to 4°C, dark	varies
		Specific Gravity	ASTM D 854						glass	8 oz.	n/a	6 months
		Grain Size Distribution	ASTM D 421, D 422						plastic	5 gal.	n/a	6 months
		Atterberg Limits	ASTM D 4318						glass or plastic	8 oz.	n/a	6 months
		TOC	USEPA 415.1						glass	125 ml	Cool to 4° ≥ 2°C, dark	28 days
		Modified Proctor	ASTM D 1557						glass or plastic	8 oz.	n/a	6 months
		Shear Strength	Pocket Penetrometer or Torvane						field measured	n/a	n/a	immediate field measurement
		Moisture Content	ASTM D 2216						plastic	8 oz.	Cool to 4° ≥ 2°C, dark	7 days

References:
(1) Test Methods for Evaluating Solid Wastes, USEPA SW-846, revised 1991.
(2) Code of Federal Regulations Chapter 40 Part 136.

Notes:
1. Sample locations will be provided in Site-Specific Work Plans.
2. Parameter list includes anticipated constituents of concern as identified in the Generalized Conceptual Site Model and Multi-Site Risk Assessment Framework. Constituents to be analyzed will be identified in Site-Specific Work Plans. The table provided herein is provided as an example parameter list.
EPA-approved methods published in References 1 and 2 above may be used. The list of analytes, laboratory method and the method detection limit for each parameter are included in Tables 2 through 5 of the QAPP for each matrix.
3. Sample media and quantities to be determined in Site-Specific Work Plans.
4. Field duplicates collection frequency - one per group of ten or fewer investigative water samples and one per group of twenty or fewer investigative soil samples.
5. Equipment blanks will be collected at a frequency of one per sampling day with non-dedicated sampling equipment.
6. Matrix Spike/Matrix Spike Duplicate (MS/MSD) sample frequency - one per group of 20 or fewer investigative water samples. Laboratory requirements will determined additional volume.
7. MGP Metals as determined in the Generalized Conceptual Site Model and Multi-Site Risk Assessment Framework.
8. May include a list of 34 PAHs, including parent and alkylated parameters as provided in USEPA Guidance Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: PAH Mixtures, 2002 by SW-846 Method 8270C with gas chromatograph/mass spectrometry in selected ion mode of operation.
9. "Soot" Carbon is the remaining carbon after muffle furnace drying and acid treatment of sediments to remove other forms of carbon. Used to estimate the bioavailable concentration of PAHs in sediment from the "freely-dissolved" chemical in the interstitial water based on USEPA Bioavailability Procedure, 2000, Gustafsson, et al. 1997, and Accardi-Day and Gschwend, 2003.
10. The *Hyallella* (amphipod) 28-day test may be used to evaluate the toxicity of whole sediments. This test will be performed to a 28-day survival and growth endpoint modified from USEPA Methods for Measuring the Toxicity and Bioaccumulation of Sediment-Associated Contaminants with Freshwater Invertebrates, Second Edition, Method 100.4 (EPA/600/R-99/064).
11. Constituents of Potential Concern vary on a site-by-site basis.

Acronyms:
Alk (bi-carb) = Bi-carbonate alkalinity
Alk (carb) = Carbonate alkalinity
BTEX = Benzene, Toluene, Ethylbenzene, Xylenes
DO = Dissolved Oxygen (field measured)
DOC = Dissolved Organic Carbon
MS/MSD = Matrix Spike/Matrix Spike Duplicate
PAHs = Polynuclear Aromatic Hydrocarbons
TOC = Total Organic Carbon
TSS = Total Suspended Solids
VOC = Volatile Organic Compounds

Geotechnical Parameter Methods:
Atterberg Limit = ASTM D 4318
TOC = Walkey Black Method
Grain size Distribution = ASTM D 421, D 422
Shear Strength = ASTM D 3080
Modified Proctor = ASTM D 1557
Recompacted Permeability = ASTM D 5084
Moisture Content = ASTM D 2216

Table 2. Field Sampling Option Summary
Integrys Business Support, LLC
Former MGP Sites
USEPA Region 5
CERCLA Docket Nos. V-W-'06-C-847, V-W-'07-C-869, and V-W-'07-C-877

	FIELD SAMPLING AND ANALYSIS MATRIX: FIELD SAMPLING AND COLLECTION TECHNIQUES								
	Soil Impact	GW Impact	Surface Water Impact	Air Impact	Depth (feet)	Production Rate (Time)	Derived Waste Volume	Technology Status	Relative Cost Per Sample
ACCESS TOOLS									
Non-Lithified Material									
Hollow-Stem Auger	Min	Mod	na	Max	≤ 100	Short	Large	Routinely used	$$
Mud Rotary	Mod	Max	na	Max	≥ 100	Short	Large	Routinely used	$$
Directional Drilling	Mod	Mod	na	Max	≤ 100	Short	Large	Routinely used	$$$
Solid Flight and Bucket Augers	Min	Max	na	Max	≤ 100	Short	Large	Routinely used	$$
Jetting Methods	Max	Max	na	Max	≤ 100	Quick	Large	Routinely used	$
Sonic Drilling	Min	Mod	na	Max	≥ 100	Quick	Small	Moderate field experience	$$$
Lithified Material									
Direct Air Rotary with Rotary Bit / Downhole Hammer	Min	Mod	na	Max	≥ 100	Short	Large	Routinely used	$$
Cable Tool	Min	Mod	na	Max	≥ 100	Extended	Medium	Routinely used	$$
Rotary Diamond Drilling	Min	Mod	na	Max	≥ 100	Extended	Large	Routinely used	$$$
Direct Push Technology									
Cone Penetrometer	Min	Min	na	Min	≤ 100	Quick	Small	Routinely used	$$
Direct Push Sampler	Min	Mod	na	Mod	≤ 100	Quick	Small	Moderate field experience	$
Sampling Installations for Portable Samplers									
Driven Wells	na	Min	na	Mod	≤ 100	Quick	Small	Routinely used	$
Single Riser / Limited Interval Wells	na	Min	na	Mod	≤ 100	Quick	Large	Routinely used	$$
Nested Wells / Single Borehole	na	Min	na	Mod	≤ 100	Extended	Large	Moderate field experience	$$
Sampling Installations for Portable Samplers - continued									
Nested Wells / Multiple Boreholes	na	Min	na	Mod	≤ 100	Extended	Large	Moderate field experience	$$
Portable In-Situ Ground Water Samplers / Sensors									
Direct Drive Samplers	na	Min	Min	Mod	≤ 100	Short	Small	Moderate field experience	$
Passive Multilayer Samplers	na	Min	na	Min	≤ 100	Short	Small	Moderate field experience	$
Fixed In-Situ Samplers									
Multilevel Capsule Samplers	na	Min	na	Mod	≤ 100	Short	Medium	Moderate field experience	$$
Multiple-Port Casings	na	Min	na	Mod	≤ 100	Short	Medium	Moderate field experience	$
Passive Multilayer Samplers	na	Min	na	Min	≤ 100	Short	Small	Moderate field experience	$

Table 2. Field Sampling Option Summary
Integrys Business Support, LLC
Former MGP Sites
USEPA Region 5
CERCLA Docket Nos. V-W-'06-C-847, V-W-'07-C-869, and V-W-'07-C-877

	FIELD SAMPLING AND ANALYSIS MATRIX: FIELD SAMPLING AND COLLECTION TECHNIQUES								
	Soil Impact	GW Impact	Surface Water Impact	Air Impact	Depth (feet)	Production Rate (Time)	Derived Waste Volume	Technology Status	Relative Cost Per Sample
Destructive Sampling Methods									
Coring and Extraction	na	Min	na	Mod	≤ 100	Short	Medium	Moderate field experience	$
Temporary Installations	na	Min	na	Mod	≤ 100	Short	Medium	Routinely used	$
COLLECTION TOOLS									
Hand-Held Methods									
Scoops, Spoons, and Shovels	Min	na	na	na	≤ 25	Quick	Small	Routinely used	$
Augers	Min	Max	na	Max	≤ 25	Quick	Small	Routinely used	$
Tubes	Min	na	na	na	≤ 25	Quick	Small	Routinely used	$
Power-Driven Soil Samplers									
Split and Solid Barrel	Min	na	na	na	≤ 25	Quick	Small	Routinely used	$
Rotating Core	Min	na	na	na	≤ 25	Short	Medium	Moderate field experience	$$
Thin-Wall Open Tube	Min	na	na	na	≤ 25	Quick	Small	Routinely used	$$
Thin-Wall Piston / Specialized Thin Wall	Min	na	na	na	≤ 25	Quick	Small	Routinely used	$$
Portable Positive Displacement									
Bladder Pump	na	Min	Min	na	≥ 100	Quick	Medium	Routinely used	$$
Gear Pump	na	Min	Min	na	≤ 100	Short	Medium	Limited field experience	$$
Submersible Helical Rotor Pump	na	Min	Min	na	≤ 100	Short	Medium	Limited field experience	$$$
Gas-Driven Displacement Pumps	na	Min	Min	na	≤ 100	Short	Medium	Routinely used	$
Gas-Driven Piston Pumps	na	Min	Min	na	≥ 100	Short	Medium	Moderate field experience	$$$
Other Portable Ground Water Sampling Pumps									
Suction-Lift Pumps (peristaltic)	na	Min	Min	na	≤ 25	Short	Medium	Routinely used	$
Submersible Centrifugal Pump	na	Min	Min	na	≥ 100	Short	Medium	Routinely used	$$$
Other Portable Ground Water Sampling Pumps - continued									
Inertial-Lift Pumps	na	Min	Min	na	≤ 100	Short	Medium	Moderate field experience	$
Portable Grab Samplers									
Bailer	na	Min	Min	na	≥ 100	Short	Large	Routinely used	$
Pneumatic Depth-Specific Samplers	na	Min	Min	na	≥ 100	Short	Small	Moderate field experience	$$
Mechanical depth-Specific Samplers	na	Min	Min	na	≥ 100	Short	Large	Routinely used	$

Table 2. Field Sampling Option Summary
Integrys Business Support, LLC
Former MGP Sites
USEPA Region 5
CERCLA Docket Nos. V-W-'06-C-847, V-W-'07-C-869, and V-W-'07-C-877

	FIELD SAMPLING AND ANALYSIS MATRIX: FIELD SAMPLING AND COLLECTION TECHNIQUES								
	Soil Impact	**GW Impact**	**Surface Water Impact**	**Air Impact**	**Depth (feet)**	**Production Rate (Time)**	**Derived Waste Volume**	**Technology Status**	**Relative Cost Per Sample**
Extractive Collection Methods									
Soil Water Extraction	Min	Max	Max	na	≤ 100	Extended	Small	Moderate field experience	$$
Sorbent Devices	na	Min	Min	Min	na	Short	Small	Routinely used	$
Biological Indicators	Min	Min	Min	Min	na	Extended	Medium	Moderate field experience	$$
Gas / Air Collection Methods									
Soil Gas Sampling (static)	na	na	na	Min	≤ 25	Short	Small	Routinely used	$
Soil Gas Probes	na	na	na	Min	≤ 100	Quick	Small	Routinely used	$
Air Sampling Devices	na	na	na	Min	na	Short	Small	Routinely used	na
EXTRACTION METHODS									
Solvent Extraction	Min	Mod	Mod	na	na	Short	Large	Moderate field experience	$$
Thermal Digestion	Min	Min	Min	na	na	Quick	Medium	Moderate field experience	$$
Thermal Extraction / Desorption	Min	Min	Min	na	na	Quick	Medium	Moderate field experience	$$
Purge and Trap	Min	Min	Min	na	na	Quick	Medium	Routinely used	$$
Headspace	Mod	Mod	Mod	Min	na	Quick	Medium	Routinely used	$
Supercritical Fluid Extraction	Min	Mod	Mod	na	na	Quick	Medium	Limited field experience	$$$
Membrane Extraction	na	Min	Min	Min	na	Quick	Small	Limited field experience	$$
Sorbent Extraction	na	Min	Min	Min	na	Quick	Small	Moderate field experience	$

Note: Ratings are based on USEPA screening opinions for dynamic field sampling goals (http://www.frtr.gov/site/).
$: Least Expensive
$$: Mid-range Expensive
$$$: Most Expensive
Min : Minimum
Mod : Moderate
Max : Maximum
na : Not Applicable

Table Source :
Federal Remediation Technologies Roundtable, 2006, Technology Screening Web Site, http://www.frtr.gov/site/

Table 3. Field Analysis Option Summary
Integrys Business Support, LLC
Former MGP Sites
USEPA Region 5
CERCLA Docket Nos. V-W-'06-C-847, V-W-'07-C-869, and V-W-'07-C-877

	Sample Media			Performance Ratings									
	Soil / Sediment	Water	Air	Selectivity	Susceptibility to Interference	Detection Limits	Turn Around Time Per Sample	Screen / Identify	Characterize / Quantify	Cleanup Performance	Long-Term Monitoring	Quantitative Data Capabilities	Relative Cost per Analysis
VOCs, SVOCs, and Pesticides													
In-Situ Analysis													
Solid / Porous Fiber Optic	E	B	A	I	Low	Midrange	Minutes	B	A	B	A	yes	$
Laser Induced Fluorescence	A	B	na	I	Medium	Midrange	Minutes	B	A	B	A	yes	$
Ex-Situ Analysis													
Photoionization Detector	E	E	B	I	High	Midrange	Minutes	B	S	B	S	yes	$
Flame-Ionization Detector	E	E	B	I	High	Low	Minutes	B	S	B	S	yes	$
Explosimeter	E	E	B	P	High	Midrange	Minutes	B	S	B	S	yes	$
Gas chromatography (GC) plus detector	E	E	B	D	Low	Low	Hours	B	B	B	B	yes	$$
Catalytic Surface Oxidation	E	E	B	I	Medium	Midrange	Minutes	B	A	B	B	yes	$
Detector Tubes	E	E	B	I	Medium	Midrange	Minutes	B	S	B	S	yes	$
Mass Spectrometry (MS)	E	E	B	D	Medium	Midrange	Hours	A	B	B	A	yes*	$$$
GC / MS	E	E	B	D	Low	Low	>1 day	B	B	B	A	yes	$$$
GC/Ion Trap MS	E	E	B	D	Low	Low	Hours	A	B	B	A	yes*	$$$
Ion Trap MS	E	E	B	D	Medium	Low	Hours	B	B	B	B	yes	$$$
Ion Mobility Spectrometer	E	E	B	D	Medium	Low	Minutes	B	A	B	A	yes	$$
Ultraviolet (UV) Fluorescence	A	B	A	P	Medium	Low	Hours	B	A	B	B	yes	$$
Synchronous Luminescence/Fluorescence	E	B	A	I	Medium	Low	Hours	B	A	B	B	yes	$$
UV-Visible Spectrophotometry	E	B	A	P	High	Low	Minutes	B	A	B	B	yes	$$
Infrared Spectroscopy	E	E	B	I	High	Midrange	Minutes	B	A	B	B	yes	$$
Fourier Transform Infrared (FTIR) Spectroscopy	E	E	B	D	Medium	Low	Minutes	B	A	B	B	yes	$$
Scattering / Absorption LIDAR	E	E	B	P	High	High	Minutes	B	A	B	B	yes	$$

Table 3. Field Analysis Option Summary
Integrys Business Support, LLC
Former MGP Sites
USEPA Region 5
CERCLA Docket Nos. V-W-'06-C-847, V-W-'07-C-869, and V-W-'07-C-877

	Sample Media			Performance Ratings									
	Soil / Sediment	Water	Air	Selectivity	Susceptibility to Interference	Detection Limits	Turn Around Time Per Sample	Screen / Identify	Characterize / Quantify	Cleanup Performance	Long-Term Monitoring	Quantitative Data Capabilities	Relative Cost per Analysis
VOCs, SVOCs, and Pesticides Ex-Situ Analysis - continued													
Raman Spectroscopy/Surface Enhanced Raman Scattering (SERS)	E	B	E	P	High	Low	Minutes	B	A	B	B	yes	$$
Near IR Reflectance/Transmittance Spectroscopy	B	na	na	P	High	High	Minutes	B	A	B	B	yes	$$
Immunoassay Colorimetric Kits	B	B	na	I	Medium	Midrange	Minutes	B	A	B	A	yes	$
Amperometric and Galvanic Cell Sensor	E	na	B	D	Medium	Low	Minutes	B	A	B	B	yes	$
Semiconductor Sensors	E	B	B	I	Medium	Low	Minutes	B	A	B	B	yes	$
Piezoelectric Sensors	E	E	B	D	High	Low	Minutes	B	A	B	B	yes	$
Field Bioassessment	B	B	B	P	High	na	>1 day	B	B	S	A	yes	$$$
Toxicity Tests	B	B	B	P	High	na	Hours	B	B	S	B	yes	$
Room-Temperature Phosphorimetry	A	B	A	D	High	Low	Hours	B	A	B	B	yes	$$
Chemical Colorimetric Kits	A	B	na	I	Medium	Midrange	Minutes	B	A	B	B	yes	$
Free Product Sensors	na	B	na	P	Low	High	Minutes	B	B	B	B	yes	$
Ground Penetration Radar	A	S	na	P	High	High	>1 day	A	B	A	A	yes*	$$
Thin-Layer Chromatography	E	B	na	I	Medium	Low	Hours	B	B	B	B	yes	$$$
METALS													
Ex-Situ Analysis													
Atomic Absorption (AA) Spectroscopy	E	E	B	D	Low	Low	>1 day	S	B	S	A	no	$$$
Inductively-Coupled Plasma-Atomic Emission Spectroscopy (ICP-AES)	E	E	B	D	Low	Low	Hours	S	B	S	A	no	$$$
X-Ray Fluorescence	B	B	E	D	Low	Midrange	Minutes	B	A	B	A	yes	$
Chemical Colorimetric Kits	A	B	na	D	Medium	Midrange	Hours	B	A	B	B	yes	$

Table 3. Field Analysis Option Summary
Integrys Business Support, LLC
Former MGP Sites
USEPA Region 5
CERCLA Docket Nos. V-W-'06-C-847, V-W-'07-C-869, and V-W-'07-C-877

	Sample Media			Performance Ratings									
	Soil / Sediment	Water	Air	Selectivity	Susceptibility to Interference	Detection Limits	Turn Around Time Per Sample	Screen / Identify	Characterize / Quantify	Cleanup Performance	Long-Term Monitoring	Quantitative Data Capabilities	Relative Cost per Analysis
Titrimetry Kits	A	B	na	D	Medium	Midrange	Hours	B	A	B	B	yes	$
Metals Ex-Situ Analysis - continued													
Immunoassay Colorimetric Kits	B	B	na	I	Medium	Low	Minutes	B	A	B	B	yes	$
Anodic Stripping Voltammetry	E	B	na	D	Medium	Low	Minutes	A	B	B	A	yes*	$$
Fluorescence Spectrophotometry	E	E	B	D	Medium	Low	Minutes	B	B	B	B	yes	$$
Amperometric and Galvanic Cell Sensor	E	B	na	D	Medium	Midrange	Minutes	B	A	B	B	yes	$
Field Bioassessment	B	B	B	P	High	na	>1 day	B	B	S	A	yes	$$$
Toxicity Tests	B	B	B	P	High	na	Hours	B	B	S	B	yes	$
Ion Chromatography	E	B	na	I	Medium	Low	Minutes	B	B	B	B	yes	$$

Note: Ratings are based on USEPA screening opinions for dynamic field sampling goals (http://www.frtr.gov/site/).

B : Better
E : Requires selection of extraction procedure
A : Adequate
S : Serviceable
na : Not Applicable
*** :** with additional effort
I : Measures the contaminant indirectly
D : Measures the specific contaminant directly
P : Measures a part of the compound

Low : 100-1000 ppb (soil); 1-50 ppb (water)
Midrange : 10-100ppm (soil); 0.5-10ppm (water)
High : 500+ ppm (soil); 100+ ppm (water)
$: Least Expensive
$$: Mid-range Expense
$$$: Most Expensive

Table Source : Federal Remediation Technologies Roundtable, 2006, Technology Screening Web Site, http://www.frtr.gov/site/

Table 4. Surface Geophysical Methods Summary
Integrys Business Support, LLC
Former MGP Sites
USEPA Region 5
CERCLA Docket Nos. V-W-'06-C-847, V-W-'07-C-869, and V-W-'07-C-877

Applications	Geophysical Options
Assessing Natural Geologic And Hydrogeologic Conditions	
Depth and Thickness of Soil and Rock Layers	Radar / Gravity / EM Time / Resistivity / Refraction / Reflection
Mapping Lateral Variations in Soil and Rock	
Larger regional structural features (major synclines and faults)	Radar / Gravity / EM Time / Resistivity / Refraction / Reflection / Magnetic / Thermal
Smaller local features (permeable zones, joints, faults, karst, cavities and subsidence, synclines, grabbens, buried channels)	Radar / Gravity / EM Time / VLF / Resistivity / SP / Refraction / Reflection / Magnetic / Metal Detector / Gravity / Thermal / Radiation
Depth of Water Table	Radar / Gravity / EM Time / Resistivity / Refraction / Reflection
Locating And Mapping Contaminant Plumes And Spills	
Assessing Natural Geologic And Hydrogeologic Conditions Delineate Pathways And Trap	Radar / Gravity / EM Time / VLF / Resistivity / SP / Refraction / Reflection / Magnetic / Gravity / Thermal / Radiation
Inorganics (electrically conductive, i.e. landfill, leachate, salt water intrusion, acids)	
Mapping horizontal extent	Radar / Gravity / Resistivity
Defining vertical extent	Radar / Gravity / EM Time / Resistivity
Organics	
Floaters	Radar / Gravity / Resistivity
Mixers (do not detect with geophysics)	Radar
Sinkers (DNAPLS; limited detection with geophysics)	Radar
Locating And Mapping Fill, Buried Wastes, Drums, Or Other Underground Structures And Utilities	
Buried Bulk Wastes - without metal	Radar / Gravity / Resistivity / Reflection
Buried Bulk Wastes - with metal	Radar / Gravity / Resistivity / Refraction / Magnetic / Metal Detector
Depth of Buried Trenches and Landfills	Radar / EM Time / Resistivity / Refraction / Magnetic / Thermal
Detection of 55-gallon Steel Drums	Radar / Gravity / Magnetic / Metal Detector
Buried Pipes and Tanks	Radar / Gravity / Magnetic / Metal Detector
Mapping of Utility Trenches (as potential pathways of contaminant migration)	Radar / Gravity / Magnetic / Metal Detector / Thermal
Location Of Abandoned Wells With Steel Casings	Magnetic / Thermal

Table 4. Surface Geophysical Methods Summary
Integrys Business Support, LLC
Former MGP Sites
USEPA Region 5
CERCLA Docket Nos. V-W-'06-C-847, V-W-'07-C-869, and V-W-'07-C-877

Applications	Geophysical Options
Evaluation Of Man-Made Soil, Rock Or Concrete Structures	
Earthen Dams	Radar / Gravity / EM Time / Resistivity / Refraction / Thermal
Concrete / Rebar	Radar / Thermal
Roads and Runways	Radar / Thermal
Concrete Dams, Tunnels, and Foundations	Radar / Thermal
Seepage	
Pipe, Joint Failure (resulting in soil piping and surface subsidence)	Radar / Gravity / Thermal
Mine Induced Subsidence	Radar / Gravity / Resistivity / Thermal
Locating and Mapping of Abandoned Mines, Tunnels, etc.	Radar / Gravity / EM Time / Resistivity / Refraction / Reflection / Gravity / Radiation

Radar : Ground Penetrating Radar
EM Freq. : Frequency Domain Electromagnetics (EM)
EM Time : Time Domain Electromagnetics
VLF : Very Low Frequency
SP : Spontaneous Potential
Refraction : Seismic Refraction
Reflection : Seismic Reflection

Note: Source - Technos, Inc., 1992, *Technotes Vol. 1 - Surface Geophysics* .

Table 5. Borehole Geophysical Methods Summary
Integrys Business Support, LLC
Former MGP Sites
USEPA Region 5
CERCLA Docket Nos. V-W-'06-C-847, V-W-'07-C-869, and V-W-'07-C-877

Log	Parameter Measured Or Calculated	Applications
Borehole Nuclear Logs		
Gamma	Total count rate of natural gamma radiation	Identification of soil and rock lithology, stratigraphic correlation, and relative porosity of soil and rock based upon clay content.
Gamma Spectrometry	Identification and quantitative analysis of the radioisotopes that contribute to the total count rate	Identification of soil and rock lithology, characterize mineralogy based upon radio isotopes, identify natural and artificial radio isotopes migrating in ground water for tracers.
Gamma-Gamma (Density)	Relative density or true density if calibrated	Bulk density determinations, also used as a cement bond log in monitoring wells
Neutron (Moisture/Porosity)	Moisture/fluid content of soil and rock	Provides moisture content above the water table, porosity below the water table.
Borehole Electrical / Electromagnetic Logs		
Induction	Bulk electrical conductivity of soil, rock, and pore fluids and magnetic susceptibility	Identification of soil and rock lithology, stratigraphic correlation. Indicate clay content based upon conductivity. Estimate porosity based upon fluid content.
Resistivity	Electrical resistivity of soil, rock and pore fluids	Measure of contaminants presence based upon fluid conductivity.
Single Point Resistance	Electrical resistance of soil, rock and pore fluids	Measure of contaminants present in a soil and rock (based upon fluid conductivity Identification of soil and rock lithology, stratigraphic correlation. Fracture detection in rock.
Spontaneous Potential (SP)	Voltage. Responds to electrochemical effects of differences in borehole fluids and oxygen reduction of minerals also due to streaming potential due to movement of pore fluids	Identification of soil and rock lithology, stratigraphic correlation. Flow and fracture detection in rock.
Dipmeter	Resistivity of formation	Determine dip of strata.
Radar (Min. OD 2-6 in.)	Travel time of the electromagnetic wave (Distance is calculated)	Identification of anomalous conditions, far a field from the borehole, such as fractures, cavities, tunnels and mines. Flow path analysis. using the saline trace method. Can also be used hole to hole.
Metal Detector	Responds to ferrous or non-ferrous metal	Location of drilling hazards, rebar in concrete or other well problems.

Table 5. Borehole Geophysical Methods Summary
Integrys Business Support, LLC
Former MGP Sites
USEPA Region 5
CERCLA Docket Nos. V-W-'06-C-847, V-W-'07-C-869, and V-W-'07-C-877

Log	Parameter Measured Or Calculated	Applications
Borehole Fluid Logs		
Conductivity	Electrical conductivity of borehole fluids	Provides a measure of borehole fluid, specific conductance (or total dissolved solids). Assess movement of water into or out of borehole locating permeable or fracture zones. Determine salt water interface.
Flow Meter (Movement)	Movement of fluid within the borehole	Locating permeable or fracture zones by movement of water into or out of borehole. Provides a means to estimate or calculate hydraulic conductivity.
Flow (Tracers)	Detection of tracers within the borehole fluid	Measures flow into and out of borehole. Used with pump tests locating permeable or fracture zones. Provides means to estimate or calculate hydraulic conductivity. Can be used to assess leaks in casing.
Temperature	Temperature of borehole fluid	Locating permeable or fracture zones by movement of water into or out of borehole. Also used for temperature correction to other logs and measurements.
In-Situ Chemical Sensors (Min. OD 2-6 in.)	Selected chemical parameters of the borehole fluid	Movement of temperature, conductivity, pH, oxygen, Eh, specific ion electrodes, tracers.
Borehole Mechanical Logs		
Caliper	Diameter of borehole or casing	Measure borehole or casing diameter for corrections to other logs, and location of large fractures and cavities.
Deviation	Inclination and direction of borehole (deviation from vertical	Correction to televiewer and other logs as well as borehole to borehole measurements.
Borehole Acoustic / Sonic / Seismic Logs		
Acoustic Televiewer (OD Min 3-in, Max 16-in)	Acoustic reflections from borehole wall	Provides a high frequency acoustic image of borehole wall to define strike, dip and aperture of fractures.
Sonic or Full Wave Sonic (Acoustic velocity)	Travel time and magnitude of seismic signal in soil and rock	Soil and rock porosity, lithology, fracture detection, compressive strength related to velocity, elastic moduli determination. Assessment of cement bond.
Vertical Seismic Profiling (VSP) (Min 2- to 3-in OD)	Seismic travel time in soil and rock	Provides vertical seismic velocities from the surface to the maximum depth of the borehole. Data is used to model and interpret seismic refraction and reflection data and can also be used for engineering purposes.
Scanning Sonar (Min 3-in OD)	Travel time of acoustic signal (distance is calculated)	Size and shape determination of large cavities in water-filled boreholes.

Table 5. Borehole Geophysical Methods Summary
Integrys Business Support, LLC
Former MGP Sites
USEPA Region 5
CERCLA Docket Nos. V-W-'06-C-847, V-W-'07-C-869, and V-W-'07-C-877

Log	Parameter Measured Or Calculated	Applications
Visual Logs		
Television	Visual image of borehole or casing	Identification of lithology. Location of fractures and cavities. Inspection of piezometers, wells, or structure.
Remote Operated Vehicle (ROV) (Min 6-in OD)	Visual image of well, pipe, tunnel or cavity	Used for video inspection of large diameter boreholes, wells and pipes, tunnels or cavities. Can be adapted to certain sampling and other work tasks within larger areas or cavities.
Other Logs		
Magnetometer	Magnetic susceptibility responds to presence of ferrous metals	Exploration for ferrous minerals. Location of steel casing, drilling hazards, or other well problems.
Gravity (Min 5-in OD)	Changes in density of soil and rock	Provide far-field measurements of changes in soil or rock density indicating material type. Data used for structural geologic evaluation, estimating change in porosity, and fracture or cavity detection.

Min. : Minimum
Max. : Maximum
OD : Outside diameter of borehole
in. : inch
Note: Source - Technos, Inc., 1992, Technotes Vol. 2 - Borehole Geophysics.

Table 6. Key Empirical Methods to Evaluate Sediment and Contaminant Movement (USEPA OSWER)
Integrys Business Support, LLC
Former MGP Sites
USEPA Region 5
CERCLA Docket Nos. V-W-'06-C-847, V-W-'07-C-869, and V-W-'07-C-877

Highlight 2-10: Key Empirical Methods to Evaluate Sediment and Contaminant Movement
Bathymetry (evaluates net change in sediment surface elevations)
•Single point/local area devices
•Transects/cross-sections (with known vertical and horizontal accuracy)
•Longitudinal river profiles along the thalweg (i.e., location of deepest depth)
•Acoustic surveys (with known vertical and horizontal accuracy)
•Comparison to dredging records, aerial photos, overall geomorphology
Contaminant data (from continuous cores, surface sediment, and water column):
•Time-series observations (event scale and long-term seasonal, annual, decade-scale)
•Comparison of core pattern or changing pattern in surface sediment, with pollutant loading history
•Comparison of concentration patterns during and after high energy events
Sediment data (e.g., from continuous cores or surface samples):
•Patterns of grain-size distribution (McLaren and Bowles 1985, McLaren et al. 1993, Pascoe et al. 2002)
•In-situ or ex-situ erosion measurement devices [e.g., SEDFLUME (Jepsen et al. 1997, McNeil et al. 1996), PES (Tsai and Lick 1986), Sea Carousel (Maa et al. 1993), or Inverted Flume (Ravens and Gschwend 1999)]
•Sediment water interface camera
Geochronology (evaluates continuity of sedimentation and age of sediment with depth in cores):
•^{137}Cs, lignin, stable Pb (longer-lived species to evaluate burial rate and age progression with depth)
•^{210}Pb, 7Be, 234Th (shorter-lived species to evaluate depth of mixing zone)
•X-radiography, color density analysis
Geomorphological studies:
•Land and water body geometry and bathymetry; physical processes
•Human modifications
Sediment-contaminant mass balance studies, especially during high energy events:
•Upstream and tributary loadings (grain size distributions and rating curves)
•Tidal cycle sampling (in marine estuaries and coastal seas)
•Sampling during the rising limb of a rain-event generated runoff hydrograph (frequently greatest erosion)
Dissolved contaminant movement:
•Seepage meters at sediment surface
•Gradients near water body

Table Source: USEPA OSWER, 2005, Contaminated Sediment Remediation Guidance for Hazardous Waste Sites, EPA 540/R-05/012; December 2005

Table 7. Summary of Previously Obtained Analytical Methods Utilized for Soil, Sediment, Water, and Air
Integrys Business Support, LLC
Former MGP Sites
USEPA Region 5
CERCLA Docket Nos. V-W-'06-C-847, V-W-'07-C-869, and V-W-'07-C-877

SOIL			
VOC (USEPA 8020)	PAHs (USEPA 8310)	Metals	Base-Neutral Fraction
BTEX (USEPA 8020)	Acenapthalene	Arsenic (SM 7060)	Hexachloroethane
Diesel Range Organics	Anthracene	Antimony (SM 6010)	Hexachlorobutadiene
pH (SM 150.1)	Benzo	Barium (SM 6010)	1,2,4-Trichlorobenzene
TOC (SM 451.1)	Benz(a)anthracene	Beryllium (SM 6010)	Hexachlorocyclopentadiene
COD (SM 410.1+2)	Benzo(a)pyrene	Cadmium (SM 6010)	Nitrobenzene
Oil and Grease (SM 503A)	Benzo(b)fluoranthene	Copper (SM 6010)	2-Chloronaphtalene
Chloride (SM 300.0)	Benzo(k)fluoranthene	Lead (SM 3020/7421)	Acenaphthene
Phenol, total (USEPA 420.1)	Chrysene	Mercury (SM 7470)	Isophorone
Cyanide, total and amenable (USEPA 9010)	Dibenz(a,h)anthracene	Nickel (SM 6010)	Fluorene
	Fluoranthene	Selenium (SM 7740)	2,4-Dinitrotoluene
Cyanide, dissociable(412-H)	Fluorene	Silver (SM 7760)	1,2-Diphenylhydrazine
Nitrate (SM 353.2)	Indeno(1,2,3)pyrene	Thallium (SM 6010)	2,6-Dinitrotoluene
Phosphate (SM 365.2)	Naphthalene	Zinc (SM 6010)	N-Nitrosodiphenylamine
	Phenanthrene		Hexachlorobenzene
	Pyrene		4-Bromophenyl Phenyl Ether
			4-Chlorophenyl Phenyl Ether
			Anthracene
			Phenanthrene
			Dimethyl Phthalate
			Bis-(2-chloroethyl) ether
			Di-n-butyl phthalate
			Diethyl Phthalate
			Butyl Benzyl Phthalate
			Benzidine
			Pyrene
			Fluoranthene
			Chrysene

AIR
BTEX (NIOSH 1501)
PAHs (NIOSH 5506-Mod.)
Cyanide, total
Total Suspended Particulate
Lead

WATER		
BTEX (USEPA 8020)	PAH (USEPA 8270 / 8310)	Metals
VOC (USEPA 8020)	Acenapthalene	Arsenic (SM 7060)
Diesel Range Organics	Anthracene	Antimony (SM 6010)
Phenol, total (USEPA 420.1)	Benzo	Barium (SM 6010)
Chloride (SM 325.3)	Benz(a)anthracene	Beryllium (SM 6010)
COD	Benzo(a)pyrene	Cadmium (SM 6010)
TOC	Benzo(b)fluoranthene	Copper (SM 6010)
Nitrogen	Benzo(k)fluoranthene	Lead (SM 3020/7421)
Phosphate (SM 365.2)	Chrysene	Mercury (SM 7470)
Ammonia (350.1)	Dibenz(a,h)anthracene	Nickel (SM 6010)
Nitrate (353.2)	Fluoranthene	Selenium (SM 7740)
Sulfides (376.1)	Fluorene	Silver (SM 7760)
Thiocyanates (412 L)	Indeno(1,2,3)pyrene	Thallium (SM 6010)
Sulfate (SM 375.2)	Naphthalene	Zinc (SM 6010)
Cyanide, dissociable(412-H)	Phenanthrene	
Cyanide, total (USEPA 9010 & SM 335.2)	Pyrene	
Cyanide, amenable (USEPA 9010 & SM 335.1)		

Table 8. Project Goals For Precision, Accuracy, and Completion of Field Measurements
Integrys Business Support, LLC
Former MGP Sites
USEPA Region 5
CERCLA Docket Nos. V-W-'06-C-847, V-W-'07-C-869, and V-W-'07-C-877

	Precision Goal	**Accuracy Goal**	**Completion Goal**
Temperature (°C) [1]	± 0.1°C	± 0.4°C	90%
pH (units)	± 0.1 unit	± 0.1 unit	90%
Specific Conductance (µS/cm @ 25°C) [2]	± 100 µS/cm @ 25°C	± 100 µS/cm @ 25°C	90%
Actual Conductivity (µS/cm) [2]	± 100 µS/cm	± 100 µS/cm	90%
Turbidity (NTU)	± 0.05 NTU	± 0.05 NTU	90%
Eh (mV)	± 1.0 mV	± 1.0 mV	90%
Dissolved Oxygen (mg/L)	± 0.3 mg/L	± 0.3 mg/L	90%
Water level (feet)	± 0.01 foot	± 0.01 foot	90%

Notes:
1. °C = degrees Centigrade
2. µS/cm = microsiemens per centimeter

Table 9. Data Measurement Units for Field and Laboratory Measurements
Integrys Business Support, LLC
Former MGP Sites
USEPA Region 5
CERCLA Docket Nos. V-W-'06-C-847, V-W-'07-C-869, and V-W-'07-C-877

Parameter	Units
Atterberg Limits	percent (%)
Actual Conductivity	siemens per centimeter (S/cm)
Concentration of chemical in soil/sediment matrix	micrograms per kilogram (µg/kg) organic milligrams per kilogram (mg/kg) inorganic
Concentration of chemical in water matrix	micrograms per liter (µg/l) organic milligrams per liter (mg/l) inorganic
Dissolved Oxygen	milligrams per liter (mg/L)
Grain Size Distribution	percent (%)
Moisture Content	percent (%)
Organic Content by Loss-on-Ignition	percent (%)
pH	pH units
Specific Conductance	siemens per centimeter @ 25°C (S/cm @ 25°C)
Specific Gravity	(dimensionless)
Strength	pounds per foot inch (psf)
Temperature	degrees Celsius (°C)
Total Organic Carbon (TOC)	milligrams per kilogram (mg/kg)
Turbidity	Nephelometric Turbidity Unit (NTU)

APPENDIX A

CONSULTANT STANDARD OPERATING PROCEDURES

INTEGRYS BUSINESS SUPPORT, LLC

SOP Name:	Table of Contents
SOP Number:	SAS-TOC
Revision:	4
Effective Date:	08/27/2008
Page:	1 of 2

Author:	T. Gilles	Q2R & Approval By:	C. Barry	Q3R & Approval By:	M. Kelley

STANDARD OPERATING PROCEDURE
TABLE OF CONTENTS

SOP SERIES SAS-01
FILE AND DATA MANAGEMENT

Author:	C. Barry	Q2R & Approval By:	J. Gonzalez	Q3R & Approval By:	M. Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-01-01

FIELD ACTIVITY DOCUMENTATION
Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes procedures for documenting field activities and guidance on types and specificity of data to be recorded. Procedures are included for documentation on field logbooks, field forms, and/or field electronic data recorders. This standard is also applicable to photographic documentation collected to support field observations of site conditions and field data entries.

2.0 EQUIPMENT AND MATERIALS

- Field logbooks;
- Field forms;
- Camera and/or camcorder; and
- Waterproof pens with non-erasable ink.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 FORMAT

4.1 FIELD LOGBOOK

Field logbooks shall be bound books that are permanently assigned to a specific project. The cover of each logbook will provide the following identifying information:

- Name of project/site;
- Project number; and
- Book number.

The consultant's contact person(s), address and phone number should be recorded on the inside cover of the field logbook. Only field logbooks with pre-numbered pages shall be used and no pages shall be removed from the logbook.

4.2 Field Forms

Field recording forms are also used for data collection in a variety of activities. The forms include logs for boreholes, well construction, well sampling, etc. It is not necessary to duplicate information recorded on field forms into the field logbooks.

5.0 ENTRIES

5.1 Daily Entries

At the beginning of each daily entry, the following information is recorded:

- Date;
- Time of arrival at the site;
- Weather conditions;
- Physical/environmental conditions at the field site;
- Field personnel present and their responsibilities;
- Level of personal protection if other than Level D; and
- Signature of the person making the entry.

For investigation activities, the entry for each day will contain a complete record of the day's activities including, but not limited to, the following information, unless the data is recorded on field forms.

- Names and titles of site visitors;
- Information concerning sampling changes, scheduling modifications and change orders.
- Location, description and log of photographs of sampling points;
- Description of reference points for maps and photographs of sampling site;
- Field observations;
- Field measurements;
- Equipment calibration and maintenance;
- Sample identification numbers;
- Name of laboratory and overnight delivery service provider or name of laboratory courier and time of sample pick-up;
- Sample documentation, such as chain-of-custody form numbers and shipment air bill numbers;
- Decontamination procedures used;
- Documentation for investigation-derived wastes, such as contents and approximate waste volume in each drum, and number of drums generated;
- Time of departure from the site; and
- Signature of person responsible for observations and date.

Field logbooks are also used as a daily record for remediation activities. General entries similar to the ones listed above are used in remediation activity logbooks. In addition, daily entries regarding excavation activities, waste disposal quantities and methods of transport, system performance data from any remediation systems (e.g. soil vapor extraction systems, recovery well systems, etc.), system or equipment calibration or maintenance performed, and any other pertinent information regarding daily activities.

All logbook entries shall be printed legibly using a pen with waterproof, non-erasable ink. Any lines or pages inadvertently left blank will have a single line drawn through them with the logging person’s initials and date written on the line.

When a field log form is used to record field data, all form fields will be completed in full on a daily basis. If a specific data entry area is not applicable, it will be clearly marked as such with the use of "NA" or a dashed line drawn through it. A single line will be drawn through any unused data entry areas on the form with the field person's signature on the line.

5.2 Entry Changes

Entry changes should be avoided by carefully entering data in the logbook. If a change is required, it should be made by drawing a single line through the original entry such that the original entry is not obscured and entering the correct information next to the original entry. The change in entry will be initialed and dated by the logger. Only the person making the entry may change it.

If there is a change in the person recording field notes during a particular day, that person shall be identified in the logbook prior to making entries. The new logger shall sign and date the logbook at the beginning and end of his entry.

6.0 FORM AND LOGBOOK MANAGEMENT

Site-specific field logbooks and forms will be kept in the in-office project file when not in use. If forms or logbooks are used in the field for an extended period of time, copies of used pages will be made, delivered to the office, and filed in the project file on a periodic basis.

7.0 PHOTOGRAPHIC AND VIDEO RECORDS

7.1 Photographic Record

Photographs shall be taken in the field on a daily basis to document field activities. Field log entries for each photograph may include:

- Photographer’s name;
- Project name and project number;
- Roll and frame number, or digital photograph number;
- Date and time;
- Description of photograph including sampling point, sample name, depth and other relevant identifying information, such as direction faced (e.g. “looking south”) and relationship of photograph to site features.

Photograph prints and negatives will be stored in the project file. Digital photographs will be stored in the electronic project file. If digital photographs are downloaded from the camera in the field, they will be transferred to the in-office electronic file on a regular basis. Photographic prints or paper copies of digital images will be identified with recorded field book entry information.

7.2 Video

Video site recordings will be logged in the field logbook with the following information:

- Recorder's name;
- Project name and project number;
- Date and time;
- Description of subject of video including identification of any persons appearing in video.

If video does not have accompanying audio, record a placard of the site name, date and time and subject of video at the beginning of the video. If the video recorder has an audio recording feature, a narration of the video identifying information may be used. The video tape or digital video disk (DVD) will be labeled with the project name, project number, date, location, and subject). The original, unaltered tape shall be placed in the official files.

8.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, D0420-98R03 Guide to Site Characterization for Engineering Design and Construction Purposes.

ASTM International, D4840-99R04 Guide for Sample Chain-of-Custody Procedures.

ASTM International, D5434-03 Guide for Field Logging of Subsurface Explorations of Soil and Rock.

ASTM International, D6089-97R03E01 Guide for Documenting a Ground-Water Sampling Event.

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia, www.epa.gov/region4/sesd/eisopqam/eisopqam.html.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

Author:	**T. Gilles**	**Q2R & Approval By:**	**C. Barry**	**Q3R & Approval By:**	**M. Kelley**

STANDARD OPERATING PROCEDURE
NO. SAS-01-02

PROJECT FILE MANAGEMENT
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines to assure the integrity and preservation of electronic files within the Network. It also describes the manner in which electronic files are to be identified and handled in the routine entry of data, reports, proposals, etc. onto computer hard drives and tapes.

2.0 EQUIPMENT AND MATERIALS

- Project files including, but not limited to, documents, data, photographs, correspondence and maps.
- Appropriate paper document storage supplies, furniture and facilities.
- Permanent electronic file storage equipment (computer hard drives and random access memory computer disks [CD-ROMs]).

3.0 FILE SECURITY

Adequate security will be maintained for both paper and electronic files relating to each project in accordance with its corporate document security policies.

4.0 PAPER FILES

4.1 ACTIVE PROJECTS

Paper files containing documents relating to an active project will be maintained at the consultant's office. All paper files will be sorted according to type and filed in accordance with the consultant's internal project-specific paper filing system. Paper documents from field activities will be brought from the field to the consultant's office for filing on a regular basis. All paper documents will be maintained in the active project files until final closure of the project.

4.2 CLOSED PROJECTS

Upon final closure of the project, all paper files containing documents relating to the project will be permanently archived in accordance with the consultant's internal file retention policies and client-specified file retention or archiving requirements. Discuss these procedures with the Project Manager.

5.0 ELECTRONIC FILES

5.1 ACTIVE PROJECTS

Electronic files containing documents relating to active project will be maintained at the consultant's office. All electronic files will be sorted according to type and filed in accordance with the consultant's internal electronic project filing system. Data saved electronically to field computers will be transferred to the consultant's in-office computer network on a regular basis via CD-ROMs or as attachments to electronic mail (email) transmissions. All electronic documents will be maintained in the active project files until final closure of the project.

5.2 CLOSED PROJECTS

Upon final closure of the project, all electronic files containing documents relating to the project will be permanently archived in accordance with the consultant's internal file retention policies and client-specified file retention or archiving requirements.

5.0 REFERENCES AND ADDITIONAL RESOURCES

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

SOP SERIES SAS-02
FIELD MEASUREMENTS - GENERAL

Author:	T. Gilles	Q2R & Approval By:	J. Gonzalez	Q3R & Approval By:	M. Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-02-01

EQUIPMENT CALIBRATION, OPERATION, AND MAINTENANCE
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for controls, calibration, and maintenance of measurement and testing equipment to be used for obtaining samples for chemical analyses, for measuring field parameters, and for testing various parameter/characteristics. The purpose of this SOP is to ensure the validity of field measurement data generated during field activities as required in the Work Plan or as otherwise specified.

2.0 EQUIPMENT AND MATERIALS

- Measurement and testing equipment ;
- Equipment/instrumentation-specific operation manuals;
- Equipment/instrumentation-specific cases, battery chargers, and attachments; and
- Calibration standards (e.g. standard gas(es), calibration fluids, pH standards, etc.).

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 EXECUTION

4.1 General

Field measurements are used to verify sampling procedures, assist in sample selection, and evaluate field conditions. A variety of equipment/instrumentation may be utilized to obtain the field measurements required to satisfy and document project goals outlined in Work Plans or otherwise specified. Therefore, instrument operators must be thoroughly familiar with the operation of measuring instruments. Users will complete the appropriate training and be certified, if required, before using the instrument in the field.

All equipment/instrumentation will be uniquely and permanently identified (model/serial number, equipment inventory number, etc.). Manufacturer's guides/operation manuals will be kept with the instrument or a designated area on the Site, as appropriate. The Site Manager or designee will obtain, identify, and control all equipment/instrumentation to be used during the project.

4.2 Calibration

Measuring equipment/instrumentation must be calibrated before initial use as recommended in the manufacturer's guide/operation manual. Equipment/instrumentation shall be re-calibrated following 1) the manufacturer's recommended calibration frequency, 2) long periods between uses, 3) readings observed above or below the range of the instrument, and/or 4) signs or evidence of equipment malfunction. Daily calibration and re-calibration activities will be recorded in the field logbook and/or on the appropriate field form and will include the following information:

- Date and time of calibration or re-calibration;
- Equipment/instrumentation manufacturer, make, and model;
- Equipment/instrumentation serial or unique inventory number;
- Method of calibration (may reference procedures outlined in the guide/instrument manual);
- Calibration standard(s) used; and
- Deviations, if any, from the manufacturer's recommended procedure(s) or calibration frequency.

4.3 Operation

Manufacturer's instructions will be followed for correct method(s) of operation. Equipment malfunctions and deviations, if any, from the manufacturer's recommended method(s) of operation will be documented in the field logbook and/or on the appropriate field form. Readings obtained from each instrument shall be recorded in the field logbook or on the appropriate field form.

4.4 Maintenance

Equipment/instrumentation will be maintained in accordance with the manufacturer's recommendations. Equipment/instrumentation that malfunctions or is scheduled for routine maintenance will be clearly labeled to prevent its continued use until repairs/maintenance is completed. The Site Manager or her/his designee will be responsible for ensuring that malfunctioning equipment is identified, marked for repair, repaired either in-house or by an outside company in accordance with manufacturer guidelines, checked following repair, and returned to service. The Site Manager or her/his designee will maintain an equipment log, which contains the following:

- Equipment/instrumentation manufacturer, make, and model;
- Equipment/instrumentation serial or unique inventory number;
- Recommended calibration frequency;
- Recommended maintenance frequency, as appropriate;
- Status (in service, not in use, or out of service for repair/maintenance);
- Dates of status changes (e.g. date returned to service); and
- Inspection and maintenance/repair dates.

5.0 REFERENCE

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001

Author: T. Gilles | Q2R & Approval By: J. Gonzalez | Q3R & Approval By: M. Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-02-02

SURVEYING
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for surveying activities that will be performed by the consultant. Timeframes or budgets may not always allow for surveying by licensed surveying professionals. The consultant may need to obtain information in a timely and cost effective manner that will aid in project decisions (e.g. groundwater flow direction, hydraulic gradient, etc.). In these cases, the consultant will perform basic surveying to obtain this information. The purpose of this SOP is to outline general procedures to obtain reliable surveying data in support of project goals and decisions as required in the Work Plan or as otherwise specified.

2.0 EQUIPMENT AND MATERIALS

- Topcon Auto Level or equivalent;
- Tripod;
- Plumb line;
- Graduated surveying stick; and
- Field logbook and/or appropriate field form.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 EXECUTION

4.1 General

Survey equipment shall be inspected prior to commence of surveying activities to ensure that all components are present and functional. Graduations on the surveying stick should be well marked. Equipment not in satisfactory condition should be removed from service and repaired or replaced, as appropriate.

Operators must be thoroughly familiar with the operation of surveying equipment. Operators should complete the appropriate training and be certified, if required, before using the equipment in the field.

4.2 Benchmark Selection

A fixed, permanent reference point is critical for tying in surveying results to known site features and reproducing surveying results in the field. The benchmark should be a unique location, preferable one that would appear on a plat of survey, that is not likely have its elevation affected by field or outside activities (e.g. flange bolt on a fire hydrant, base of a property boundary stake, corner of a loading dock, etc.). The benchmark shall be documented and clearly described in the field logbook and/or on the appropriate field form. The location of the benchmark should also be measured relative to a minimum of two other permanent site features. These measurements should also be recorded in the field logbook and/or on the appropriate field form. Typically, a licensed surveyor will establish the benchmark which will be used on the site. If the benchmark cannot be established by a licensed surveyor, make sure the Project Manager is informed.

4.3 General Procedures

Surveying will be conducted following the procedures outlined below:

1. Make a table in the field logbook or utilized the appropriate field form to record the following information:
    a. Benchmark;
    b. Assigned benchmark elevation;

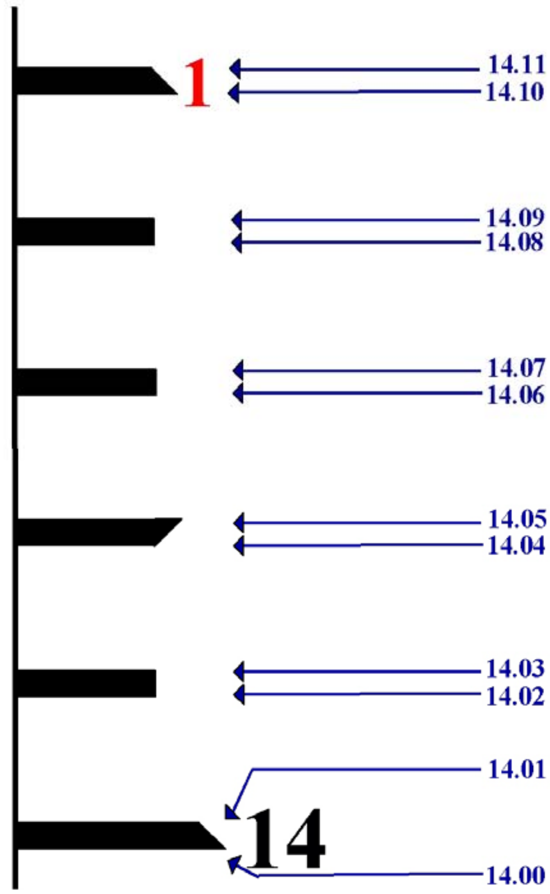
   c. Instrument Height(s);
   d. Temporary Benchmark(s);
   e. Survey points (e.g. monitoring well top of casing, ground surface, etc.); and
   f. Surveying stick graduation.

2. Locate a benchmark (BM).
3. Describe the BM in the field logbook and/or on the appropriate field form. The description must be detailed enough to allow a person unfamiliar with the Site to locate the BM.
4. Measure the location of the BM from at least two other permanent site features and record the measurements in the field logbook and/or on the appropriate field form.
5. Choose a location for the tripod that is in view of the benchmark and as many surveying points as possible.
6. Set up the tripod and attach the plumb line.
7. Adjust the tripod legs until the plumb line hangs at a 90-degree angle from the top plate of the tripod.
8. Place the Topcon Auto Level (or equivalent) on the tripod.
9. Adjust the auto level legs until the Topcon Auto Level is level as indicated by the leveling bubble (Note: The bubble should be centered in the circle).
10. Verify the auto level is level by rotating the auto level 90, 180, and 270-degrees. The bubble should be centered in the circle at all three positions. If the bubble is not centered in the circle, repeat Steps 7 through 10.
11. The surveying assistant will stand the surveying stick on the benchmark.
12. The operator should view the surveying stick through the Topcon Auto Level (or equivalent), read and record the surveying stick graduation that intercepts the center crosshairs of the auto level electronically or in the field logbook and/or on the appropriate field form as the back sight measurement.
13. The operator shall record Instrument Height #1 (IH_1), which is obtained by adding the surveying stick graduation to the arbitrary benchmark elevation (usually 100.00 feet), in the field logbook and/or on the appropriate field form.
14. The surveying assistant will stand the surveying stick on a surveying point.

15. The operator should view the surveying stick through the Topcon Auto Level (or equivalent), read and record the surveying stick graduation that intercepts the center crosshairs of the auto level in the field logbook and/or on the appropriate field form as the front sight measurement.
16. The operator shall record Survey Point #1 (SP_1) elevation, which is obtained by subtracting the surveying stick graduation from IH_1, electronically or in the field logbook and/or on the appropriate field form.
17. Repeat Steps 14 through 16 until all survey points or all survey points visible from the first instrument location have been measured.
18. Locate a Temporary Benchmark (TBM_1).
19. The surveying assistant will stand the surveying stick on TBM_1.
20. The operator should view the surveying stick through the Topcon Auto Level (or equivalent), read and record the surveying stick graduation that intercepts the center crosshairs of the auto level in the field logbook and/or on the surveying data form as the front sight measurement.
21. The operator shall record TBM_1 elevation, which is obtained by subtracting the surveying stick graduation from IH_1, electronically or in the field logbook and/or on the appropriate field form.
22. The operator shall relocate the instrument and repeats Steps 6 through 10. Note: During this time the surveying assistant should not remove the surveying stick from the top of TBM_1.
23. Once the instrument has been relocated and leveled, the operator should view the surveying stick through the Topcon Auto Level (or equivalent), read and record the surveying stick graduation that intercepts the center crosshairs of the auto level in the field logbook and/or on the surveying data form as the back sight measurement.
24. The operator shall record Instrument Height #2 (IH_2), which is obtained by adding the surveying stick graduation to the TBM_1 elevation determined in Step 21, electronically or in the field logbook and/or on the appropriate field form.
25. If all surveying points have been measured, skip to Step 36. If all surveying points have not been measured, proceed to step 26.
26. Repeat Steps 14 through 16 until all survey points or all survey points visible from the instrument location have been measured.
27. Locate another Temporary Benchmark ($TBM_{\#}$).
28. The surveying assistant will stand the surveying stick on $TBM_{\#}$.

29. The operator should view the surveying stick through the Topcon Auto Level (or equivalent), read and record the surveying stick graduation that intercepts the center crosshairs of the auto level in the field logbook and/or on the surveying data form as the front sight measurement.
30. The operator shall record $TBM_{\#}$ elevation, which is obtained by subtracting the surveying stick graduation from $IH_{\#}$, electronically or in the field logbook and/or on the appropriate field form.
31. The operator shall relocate the instrument and repeats Steps 6 through 10. Note: During this time the surveying assistant should not remove the surveying stick from the top of $TBM_{\#}$.
32. Once the instrument has been relocated and leveled, the operator should view the surveying stick through the Topcon Auto Level (or equivalent), read and record the surveying stick graduation that intercepts the center crosshairs of the auto level electronically or in the field logbook and/or on the appropriate field form as the back sight measurement.
33. The operator shall record Instrument Height # ($IH_{\#}$), which is obtained by adding the surveying stick graduation to the $TBM_{\#}$ elevation determined in Step 30, electronically or in the field logbook and/or on the appropriate field form.
34. Repeat Steps 14 through 16 until all survey points or all survey points visible from the instrument location have been measured.
35. If all surveying points have been measured, skip to Step 36. If all surveying points have not been measured, proceed to step 27.
36. The surveying assistant will stand the surveying stick on the benchmark.
37. The operator should view the surveying stick through the Topcon Auto Level (or equivalent), read and record the surveying stick graduation that intercepts the center crosshairs of the auto level in the field logbook and/or on the surveying data form as the front sight measurement.
38. The operator record BM elevation, which is obtained by subtracting the surveying stick graduation from $IH_{\#}$, electronically or in the field logbook and/or on the appropriate field form.
39. If the BM elevation is within 02/100 of an inch ($\pm$0.02) of the initial or assigned BM elevation, the surveying has been completed successfully. If the BM elevation is not within 02/100 of an inch ($\pm$ 0.02) of the initial or assigned BM elevation, an error was made or the tripod and/or auto level were bumped during surveying. In this case, the surveying activities were not completed successfully and must be repeated.

4.4 Reading the Surveying Stick



5.0 REFERENCE

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001

SOP SERIES SAS-03
SAMPLE COLLECTION - GENERAL

STANDARD OPERATING PROCEDURE
NO. SAS-03-01

SAMPLE IDENTIFICATION, LABELING, DOCUMENTATION AND PACKING FOR TRANSPORT
Revision 2

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes procedures for identifying, logging, packing, preserving and transporting environmental samples for chemical or physical analysis.

2.0 EQUIPMENT AND MATERIALS

- Sample containers;
- Sample labels;
- Field logbook;
- Pens with waterproof, non-erasable ink;
- Chain-of-custody (COC) forms;
- Custody seals
- Clear plastic sealing tape;
- Coolers for transporting samples to the laboratory;
- Ice (if required)
- Gallon-size sealable plastic bags; and
- Air bills or similar transportation provider forms.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 SAMPLE IDENTIFICATION

A unique 9-digit identification code will be assigned to each sample retained for analysis on all United States Environmental Protection Agency (USEPA) sites and on a site-specific basis as determined by the project manager. This code will be formatted as a number series with the sample month (2-digit), date (2-digit), year (2-digit) and consecutive sample number (3-digit).

Example: The first sample for a particular phase of an investigation collected on May 18, 2004 would be identified as 051804001, as detailed below.

05	**18**	**04**	**001**
Month	**Date**	**Year**	**Consecutive Sample Number**

Consecutive sample numbers will indicate the individual sample sequence in the total set of samples collected during that phase of investigation.

Duplicate samples will be assigned a unique 9-digit identification code. Samples selected for matrix spike/matrix spike duplicates (MS/MSD) will include "MS/MSD" at the end of the unique 9-digit identification code. The unique 9-digit identification code is compatible with USEPA electronic data submittal requirements. Sample identification numbers will be used on sample labels, COC forms and other applicable sampling activity documentation.

Sample media codes will be noted on field notes and logs using the following media codes:

Sample numbering will consist of up to three components: a three-character alpha Site identification code; a four- to five-character alpha numeric sample type code; and the sample depth below ground surface (bgs, if soil) or the sample depth below top of mudline (sediment). Groundwater samples will typically not include sample depth bgs unless there are multiple intervals sampled in one open borehole. An example of a completely numbered sample, with each component identified follows.

Example: AES-SP01-(0-0.5)

Where: AES – Any Environmental Site
SP01 – Soil probe location number 1
(0-0.5) – soil sample collected 0-0.5 feet bgs

The site identification code (e.g. AES in the sample above) will remain the same for all samples collected at the Site.

The sample type code (SP01) will vary depending on sample type and location. The following are typical alpha codes to be used in the alphanumeric sample type code for samples:

- AS – air sparging sample;
- CF – confirmation soil sample;
- GP – gas probe sample;
- MW – groundwater monitoring well (if deep and shallow wells are sampled for the same location, this type code is modified to DMW (deep well) and SMW (shallow well);
- PZ – piezometer sample;
- RW – recovery well sample;
- SB – soil boring sample;
- SD – sediment sample;
- SP – soil probe sample;
- SS – surface soil sample;
- SR – source material (used if source material is known to exist);

- SV – soil vapor probe sample;
- SW – surface water sample;
- TP – test pit sample; and
- VE – vapor extraction sample.
- WC – waste characterization (may be preceded by S for solid waste or L for liquid waste).

If additional sampling type codes are required, they will be specified in the site-specific work plan.

When completing soil borings and probes, if a water sample is collected from an open boring or probe location a "w" will be attached to the end of the alpha-numeric sample type code (e.g., SB01W). The numerical portion of the sample type code will indicate the sample location (i.e., boring location 01, 02, 03, etc.).

5.0 SAMPLE LABELING

The following information will be included on each sample label: site name/client, sample number, name of sampler, sample collection date and time, depth of sample (if applicable), analyses or tests requested and preservations added. Information known before field activities (site name, analyses requested, etc.) can be preprinted on sample labels. Duplicate sample labels can be prepared when various sample aliquots must be submitted separately for individual analyses.

6.0 SAMPLE DOCUMENTATION

The following itemized list will be used as a general reference for completion of sample documentation:

- Record all pertinent sample activity in the field logbook in accordance with SOP SAS-01-01, Field Documentation and Reporting.
- Make or obtain a list of samples to be packaged and shipped that day.
- Determine number of coolers required to accommodate the day's shipment based on number of samples to be shipped, number of containers per sample and number of sample containers that will fit in each cooler.
- If samples are shipped by Federal Express or other express shipping service, complete an air bill.

- Assign chain-of-custody form to each cooler and determine which sample containers will be shipped in each cooler. (Note: More than one chain-of-custody form may be needed to accommodate number of samples to be shipped in one cooler).
- Determine which samples will be shipped under each chain-of-custody form. Each day that samples are shipped, record chain-of-custody form numbers, and air bill numbers (if used) in field logbook. Cross-reference air bill and chain-of-custody numbers.
- Complete COC forms in accordance with SOP SAS-03-02, Chain of Custody.
- Assign custody seals to each cooler and temporarily clip seals to each chain-of-custody form.
- Group paperwork associated with each cooler with a separate clip.
- Obtain necessary field team members' full signatures or initials on appropriate paperwork.

7.0 SAMPLE PACKING FOR TRANSPORT

The steps outlined below will be followed to pack the sample containers into coolers for shipment.

1. Each glass sample container will be wrapped with protective packing material.
2. Packing material will be placed in the bottom of each cooler for cushioning.
3. Sample containers will be placed inside each cooler, taking care not to overfill the cooler.
4. Ice will be double bagged sealable plastic bags and added to the cooler on top of the samples. Sample containers will be packed so that they are not in direct contact with ice. The remaining empty space in each cooler will be filled with packing material.
5. Packing material will be placed over the top of the bagged ice.
6. The chain-of-custody records will be signed, and the date and time at which the coolers are sealed for transport by a shipping company, or relinquished to a delivery service or the laboratory sample receiving department will be indicated.
7. Copies of chain-of-custody records will be separated. The original signature copies will be sealed in a large, sealable, plastic bag and taped to the inside lid of a cooler. A copy of each COC will be retained by the Site Manager.
8. If any cooler has a drain, the drain will be taped shut.
9. The lid to each cooler will be closed and latched. Custody seals will be affixed to each cooler between the lid and the body of the cooler. One custody seal will be placed on the front of the cooler, and one will

be placed on the back. Custody seals will be covered with clear plastic tape. An example of a custody seal is located in SOP SAS-03-02, Chain-of-Custody.

10. The cooler will be closed and taped shut on both ends with several revolutions of tape. Also, tape will be wrapped several times around the cooler body and the cooler lid to firmly secure the cooler lid and body together.
11. Samples will be packed and transported to the analytical laboratory within one day of collection.

8.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, D3694-96(2004) Standard Practices for Preparation of Sample Containers and for Preservation of Organic Constituents

ASTM International, D4220-95R00 Practices for Preserving and Transporting Soil Samples

ASTM International, D4840-99(2004) Standard Guide for Sampling Chain-of-Custody Procedures.

ASTM International, D6911-03 Guide for Packaging and Shipping Environmental Samples for Laboratory Analysis

International Air Transport Association (IATA), 2005, Dangerous Goods Regulations.
USEPA, 1981, *Final Regulation Package for Compliance with DOT Regulations in the Shipment of Environmental Laboratory Samples*, Memo from David Weitzman, Work Group Chairman, Office of Occupational Health and Safety (PM-273), April 13, 1981.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/60/B-07/001.

Author:	M. Skyer	Q2R & Approval By:	J. Gonzalez	Q3R & Approval By:	M. Kelley

STANDARD OPERATING PROCEDURE NO. SAS-03-02

CHAIN OF CUSTODY Revision 0

1.0 PURPOSE

This Standard Operating Procedure describes procedures for preparation and use of the chain of custody (COC) form that accompanies field-collected soil, sediment, water, air or geotechnical samples. Procedures are also provided for preparation and use of custody seals for securing openings of sample containers during transport of samples to the analytical laboratory. COC forms and custody seals are used to provide documentation of sample integrity from the time of collection to time of sample receipt and acceptance by the analyzing laboratory or testing laboratory.

2.0 EQUIPMENT AND MATERIALS

- COC forms;
- Custody seals;
- Gallon-size plastic sealable bags; and
- Clear plastic packing tape.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 METHODS/PROCEDURES

4.1 Chain of Custody Form Items to Complete

Attachment A presents an example COC form. The following general information must be completed on the COC form:

- Laboratory name, address, telephone number;
- Document control number;
- Site manager name on Attention line;
- Project number;
- Site name;
- Complete field sample identification number;
- Sample collection date for soil, sediment and water samples or sample start and collection dates for ambient air monitoring samples;
- Time of sample collection for soil, sediment and water samples or sample start and collection times for air monitoring samples;
- Sample matrix (i.e. liquid, solid, or gas);
- Number of containers;
- Analysis or testing method requested;
- End pressure, Summa can identification number, and flow controller serial number for air monitoring BTEX samples and filter identification number for air monitoring PM10 samples.
- Sample preservatives used (other than ice) in Remarks column;
- Turn-around time requested (specify if turn-around time is business or calendar days) in Special Instructions box;
- Signature of person(s) conducting sampling;
- Strike line with samplers initials and the date samples are relinquished in order to complete unused portion of COC form;
- Signature of person relinquishing the sample custody (person relinquishing custody must be a sampler to ensure chain of custody is maintained);
- Signature of person transporting samples to the lab if other than sampler/relinquisher or third-party carrier;

- **DO NOT** write "FedEx" or other third-party carrier's name in the Relinquished To box. The air bill and carrier's established custody documentation procedure is used to verify custody during transportation.
- Date and time samples are relinquished;
- Custody seal identification numbers; and
- Freight bill identification number in Special Instructions box or at bottom of Remarks column (if third party shipper is used to transport).

4.2 Chain of Custody Form and Procedures

- If a sampling event requires the use of more than one shipping container (cooler for soil/sediment/water samples or box for certain air monitoring samples or soil samples for geotechnical testing) a separate COC form must be completed for each shipping container. For each container, the associated COC form must list only the samples contained in that container.
- When it is known that numerous chains of custody will be required for a project or for a single sampling event, it is acceptable to pre-type the laboratory name, address, telephone number, project number, site name, 3-letter project name abbreviation in Document Control Number area, and site manager name. These are the only information fields that may be pre-typed.
- Each COC should contain a unique document control number in the format: 3-letter project name abbreviation – identification number – 4 digit year, e.g. AES-001-2006, AES-002-2006 and so on. For each project COC identification numbers should be assigned sequentially beginning with 001 for each calendar year. (Exception: for remediation ambient air monitoring projects that span two or more calendar years, continue sequential numbering throughout the project.)
- The COC form must be completed in ink.
- Corrections must be made by drawing a single line through the data that is in error and initialing and dating at the end of the line. The use of correction fluid or tape is not allowed. Do not write over text or numbers to correct. If multiple corrections are needed, copy correct information to a new COC and destroy copy with errors.
- If the number of samples included in the shipping container is less than the number of data entry lines on the COC, draw a single diagonal line running from left down to the lower right hand corner of the field sample data area. The sampler's initials and date must appear along the line.

- Seal the completed COC form in a plastic storage bag. For cooler shipping containers, tape the bag to the inside of the cooler lid prior to sealing the cooler. For box shipping containers, insert the bagged COC form into the box prior to sealing the box.
- If samples are to be shipped by a third party carrier (e.g. Federal Express) the third party carrier does not need to sign the chain of custody. The COC form may be sealed inside the container prior to shipping. If samples are to be hand-delivered to a laboratory by someone other than the sampler/relinquisher (e.g., site construction manager or laboratory courier), the sampler/relinquisher must transfer custody by having the carrier sign in the "Received By" section of the COC form and enter the date and time of transfer. Then seal the COC form inside the container.

4.3 Custody Seal Procedures

A sample custody seal is a strip of adhesive paper used to detect unauthorized tampering with samples prior to receipt by the laboratory. Attachment A presents an example of a completed custody seal. Custody seals are pre-numbered and should be used instead of laboratory custody seals whenever possible.

- A minimum of two custody seals are used per shipping container, one on each long side of the cooler or across each opening of a box. For coolers, one of the custody seals must be placed from the lid to the side of the cooler such that it would be necessary to break the seal in order to open the shipping container. Cover each custody seal with a single piece of clear packing tape wrap it around the perimeter of the cooler. For boxes, place a custody seal across each opening of the box (top and bottom) and cover with a piece of packing tape, making sure tape is secured in such a way that it cannot easily be removed.
- The relinquisher must sign and date each custody seal in ink and include the site identification abbreviation in the custody seal number area.
- Each custody seal has a pre-printed unique six-digit identification number. This number along with the site identification abbreviation must be transferred exactly to the Custody Seal Number box on the COC. The identification number of all custody seals used in conjunction with the COC must be listed on the COC. If a custody seal other than the pre-numbered one, a unique identification number must be printed on the seal and transferred exactly to the Custody Seal Number box on the COC.

5.0 DATA MANAGEMENT AND RECORDS MANAGEMENT

A copy of the COC forms and freight bills used in the above procedure will be transferred to the Project Manager and maintained in the project-specific file as part of the official chain of custody record.

6.0 QUALITY CONTROL AND QUALITY ASSURANCE

- Each COC will be checked for accuracy and completeness (i.e. sample list complete, sample data entered correctly etc.) by another member of the field sampling team before samples are relinquished for transport. In the event the sampler is the sole person on-site, the COC will be checked for accuracy and completeness within 24 hours of the sampling event by a member of the project team.
- Review of the COC forms and freight bills used in the above procedure will be conducted during evaluations of sampling procedures by personnel. The COC forms will also be reviewed as part of the data validation process when the laboratory returns the completed COCs following receipt and analysis of samples.

7.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM, International, 1999, D 4840-99 (2004) Standard Guide for Sample Chain-of-Custody Procedures.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

ATTACHMENT A
EXAMPLE CHAIN-OF-CUSTODY AND CUSTODY SEAL FORMS

Request for Chemical Analysis and Chain of Custody Record

Send Results to:	Laboratory:	Document Control No.:
	Address:	Lab. Reference No. or Episode N
Attention:	City/State/ZIP:	
	Telephone:	

Project Number:	Sample Type	
Site Name:		Matrix

Sample Number			Sample Event		Sample Depth (in feet)		Sample Collected		Liquid	Solid	Gas	Number of Containers	Parameter/Method Code						Remarks
Group or SWMU Name	Sample Point	Sample Designator	Round	Year	From	To	Date	Time											

Sampler *(Print Name)*:	Sampler *(signature)*:	Custody Seal Number	Special Instructions

Relinquished By *(signature)*: 1.	Date/Time	Received By *(signature)*: 1.	Date/Time	Ice Present in Container: Yes ☐ No ☐	Temperature Upon Receipt:
Relinquished By (signature): 2.	Date/Time	Received By (signature): 2.	Date/Time	Laboratory Comments:	

Signature ______________________________

Date ______________ # ________ -112504

Author:	M. Skyer	Q2R & Approval By:	A. Bazan	Q3R & Approval By:	M Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-03-03

SAMPLE LOCATION IDENTIFICATION AND CONTROL
Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for the identification of sample locations and field measurements of topographic features, water levels, geophysical parameters, and physical dimensions frequently required during groundwater, hazardous waste, and related field investigation activities. The scope of such measurements depends on the purpose of the field investigation. Samples collected from each sampling location will have a unique sample identified in accordance with ENV-03-01.

All sampling locations shall be uniquely identified and depicted on an accurate drawing or a topographic or other site map, or be referenced in such a manner that their location(s) are established and reproducible. A sample location must be identified by a coordinate system or other appropriate procedures which would enable an independent investigator, to collect samples from reproducible locations. Repetitive sampling might be performed, for example, to monitor the progress of a remedial program, to check for suspected erroneous results from an initial sampling, or to check the reproducibility of results.

2.0 EQUIPMENT AND MATERIALS

- Site map;
- Surveying equipment;
- Measuring tape;
- Field notebooks/logs; and
- GPS unit.

3.0 SAMPLE LOCATION IDENTIFICATION

Locations for collection of samples are assigned alphanumeric codes which are used to coordinate laboratory data tracking and graphic depiction of sample locations on drawings and figures. Samples collected from each sampling location will have a unique sample identified in accordance with ENV-03-01. Each sample location is issued a unique numeric code that corresponds to a specific map location on a plan view of a site and vicinity. An alpha-code (letter) is used to describe the type of sampling activity performed at the specific numeric location. The following alpha codes will be used:

Air	AS	Air Sparging Point
	GP	Gas Probe
	GM	Gas Monitoring Well
	SV	Soil Vapor Probe
	VE	Soil Vapor Extraction Well
Material	AC	Asbestos Containing Material
	LS	Lead Wipe Sample
Sediment	SD	Sediment
Soil	SB	Soil Boring
	SS	Surface Soil
	TP	Test Pit
	EB	Excavation Base
	EW	Excavation Well
Water	MW	Groundwater Monitoring Well
	PZ	Piezometer
	PW	Potable Water Well
	RW	Recovery Well
	TW	Temporary Monitoring Well
	SW	Surface Water
	SG	Surface Water Staff Gauge

A typical series of alpha numeric codes for a site might include test pit locations TP01 through TP12; borings SB01, SB02, SB03; monitoring wells MW01, MW02, MW03, etc.

Each sample location will have only one alphanumeric code. A borehole drilled for the purpose of installing a monitoring well will be identified as MW01. There should not be a location SB01 for soil sample location identification and MW01 for groundwater sample location identification.

Note that soil borings performed for the purpose of collecting a groundwater grab sample (e.g. through screened auger, open borehole, Geoprobe®, Hydro-Punch®, etc.) are identified as soil borings, not monitoring wells. These types of sampling locations may be further identified on site figures with a clarifying suffix (GW), such as SB01(GW). The site map legend will explain the meaning of all symbols used to identify sampling points.

If previous work has been performed at a site, the alphanumeric code should continue with previous successive numbers. If there is any potential for conflict with existing sample number identifiers, the proposed sample number should begin with series 101, 1001, or other appropriate system. Dashes should be eliminated from sample number identifiers, such as SB101 should be used instead of SB-101.

4.0 SURVEYED LOCATIONS

Survey control should be performed following monitoring well and borehole installations by a surveyor licensed in the state of the project site. Vertical elevations to the top of each new well casing will be established within ± 0.01 foot. Ground surface elevations at each well and borehole location should be established within ± 0.01 foot. Elevations should be referenced to the North American Vertical Datum of 1988 (NAVD 88). Alternative systems may be used on a project-specific basis, with appropriate reference documentation in the master project file and final reports.

Lateral locations based on an established grid system will be determined for each sampling location. Lateral locations should be calculated to within ± 1-foot. The site map should include at minimum sampling locations, structure boundaries, property boundaries, nearby surface water, site grid system origin according to either a state plane coordinate system or latitude and longitude, bar scale, and a north arrow. Specific state reporting and mapping requirements should be checked prior to final plan development.

In conducting vertical surveys, the following procedures should be used or should be referenced in subcontractor service agreements with licensed surveyor:

- When practical, level circuits will close on a bench mark other than starting bench mark;
- Readings should be recorded to the closest 0.01 foot using a calibrated rod;
- Foresight and backsight distances should be reasonably balanced;
- Rod levels should be used;
- No side shot should be used; and
- Benchmarks should be traceable to USGS benchmarks.

Field staff and contractors will record all field data collected during survey activities in accordance with SOP SAS-01-01 for incorporation into site data reports, maps, tables, etc.

5.0 TRIANGULATION

Triangulation shall be used if a registered surveyor is not contracted. This method encompasses distance measurement from sampling points relative to two and sometimes three known points. Distance measurements should be accurate to within ±1 foot allowing for sag in the measuring tape and other inaccuracies. Measuring to two known points is typically adequate for rough measurements made with a pocket transit and 100-foot tape; however, measuring to three known points reduces potential error. Distance measurements should be made relative to distinctive features having a probable life span in excess of 10 years. Examples include the following:

- Power pole located on north side of plant entrance #1 driveway;
- SE corner of plant building 2 located at 111 Survey Circle; or
- NW corner of retaining wall running north-south along Bass Creek.

Unacceptable triangulation points include fence posts, trees, temporary stakes or markers etc., unless these features are to be located within 15 days by survey.

When locating sampling points, decide which site features will be important to illustrate on a site map in the report. If appropriate, also locate areas of known or suspected spills and manholes which may represent migration pathways. Establish relative locations of these and other pertinent site features by triangulation.

The client should be consulted regarding the existence of plant drawings or other surveyed maps which accurately show the relative location of major site features. The field notebook should record information describing the drawing (e.g., who it was prepared by, date, drawing number, etc.) and describe the points on the drawing being used for triangulation purposes.

If only one site feature is convenient for triangulation, the remaining two reference points can be established by running a line toward a more distant site feature, which can be easily located later, and the recorded distance from a defined point along that line.

6.0 GLOBAL POSITIONING SYSTEM (GPS)

Global Positioning System (GPS) is an appropriate method to determine the location of site investigation features in limited circumstances, and is solely at the discretion of the project manager.

There are significant accuracy limitations with GPS which limits the effectiveness of this technology in the role of sample location. For sites where accuracy less than ± 10 feet is acceptable, or surveying is impractical, GPS is a suitable sample location method. GPS is not suitable for sites requiring a higher degree of accuracy. However, the recording of GPS coordinates is encouraged for all sites where monitoring wells or other permanent features may be obscured by snow, vegetation, or other obstructions. In such cases, GPS may assist in locating the monitoring well, etc. despite the accuracy limitations.

7.0 REFERENCES

ASTM International, 2002, D5906-02 Guide for Measuring Horizontal Positioning During Measurements of Surface Water Depths.

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia, www.epa.gov/region4/sesd/eisopqam/eisopqam.html.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/60/B-07/001.

Zilkoski, David B., J.H. Richards, and G.M. Young , 1992, Results of the General Adjustment of the North American Vertical Datum of 1988, American Congress on Surveying and Mapping, Surveying and Land Information Systems, Vol. 52, No. 3, 1992, pp.133-149.

SOP SERIES SAS-04
SAMPLING QUALITY CONTROL

Authors:	M. Skyer / T. Gilles	Q2R & Approval By:	C. Barry	Q3R & Approval By:	M. Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-04-01

DATA QUALITY GENERAL CONSIDERATIONS
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes general guidelines that are to be used in conjunction with the USEPA mandatory data quality objectives (DQO) process. Guidelines are intended to assist with planning and conducting quality sampling operations in the field.

2.0 EQUIPMENT AND MATERIALS

Equipment and materials will vary based on the type of data and method of data collection. In general, the following equipment and materials shall be utilized to assist with the collection and recording of quality data:

- Site map(s);
- Field logbook and/or appropriate field forms;
- Method-specific, laboratory-provide containers for the collection of samples for chemical analysis;
- Chain of custody (COC) forms;
- Measuring tape(s), Global Position System (GPS), or other equipment necessary to document sample location; and
- Camera.

3.0 HEALTH AND SAFETY WARNING

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 SAMPLING CONSIDERATIONS

There are two categories of sampling collection activities. The categories include 1) collection of screening data with definitive confirmation and 2) collection of definitive data. The decision making process in each category incorporates a wide range of analytical methods and provides quality analytical data.

Screening data provides a quick, preliminary assessment of site contamination that involves rapid, non-rigorous methods of sample preparation and less precise analytical methodologies. Preliminary assessments of types and levels of contaminants can be made quickly which allows for the greatest amount of data with the least expenditure of time and money. Screening data generally produces data that can be identified and quantified, but may not be relatively precise. A minimum of 10 percent of the screening data must be confirmed using definitive data. Without sufficient confirmation data, screening data will not be recognized as quality data.

Data that is generated by stringent analytical methods (e.g. approved USEPA methods) is defined as definitive data. Whether generated on or off-site, the quality assurance/quality control (QA/QC) protocol of the analytical methods must be achieved. Analytical and total measurement of error must be calculated for the data to be considered definitive. Definitive data is generally analyte-specific and can be confirmed by subsequent analysis (e.g. duplicate, matrix spike/matrix spike duplicate, etc.). Printed or electronic data, spectra, and chromatographs are typically provided as backup information.

Several factors must be considered prior to data collection to ensure the data obtained meets the DQOs and is appropriately addressed and incorporated into procedures outlined the Site-Specific Work and/or Field Sampling Plan (FSP) or otherwise specified in activity- or task-specific SOPs:

- Representative Sampling Sites – Selection of representative sampling sites is dependent on the type of investigation undertaken.

- Analytical Methods/Parameters – The analytical methods/parameters shall be dictated by the constituents of potential concern (COPCs), sample media, potential range of chemical concentrations, site conditions, and field investigator's knowledge.
- Sample Collection Method – The sample collection method to be used shall be dictated by the investigation, analytical methods/parameters, and category of data desired (screening data with definitive confirmation or definitive data).
- Sampling Equipment – The sampling equipment shall be dictated by the investigation, category of data desired (screening data with definitive confirmation or definitive data), analytical method, sampling method, and the potential for the equipment materials to affect analytical results (e.g. cross-contamination potential, sorption potential, etc.).

5.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, 2000, D6568 Standard Guide for Planning, Carrying Out, and Reporting Traceable chemical Analyses of Water Samples.

ASTM International, 2004, D7069-04 Guide for Field Quality Assurance in a Ground-water Sampling Event.

USEPA. 1994a. Evaluation of Sampling and Field-Filtration Methods for the Analysis of Trace Metals in Ground Water s. September 1994, EPA/600/SR-94/119.

USEPA, 1995. Method 1669: Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria levels. April 1995, EPA/621/R-95/114.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

Authors:	**M. Skyer / T. Gilles**	**Q2R & Approval By:**	**C. Barry**	**Q3R & Approval By:**	**M Kelley**

STANDARD OPERATING PROCEDURE
NO. SAS-04-02

DATA QUALITY OBJECTIVES
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for determining Data Quality Objectives (DQOs). The USEPA has established a mandatory DQO process for sites to ensure that all data is scientifically valid. The DQO process also establishes protocols to support decision making which includes defining the type, number, and quality of the environmental data to be collected.

2.0 DATA QUALITY OBJECTIVES PROCESS

The DQO process is a series of seven steps that facilitate the planning of environmental data collection activities. DQOs are qualitative and quantitative statements developed from the DQO process. The DQO process helps investigators ensure that data collected are of the right type, quantity, and quality needed to support environmental decisions.

The following are the seven steps of the DQO process (USEPA 2006):

1. State the problem.
2. Identify the goal of the study.
3. Identify information inputs.
4. Define the boundaries of the study.
5. Develop the analytic approach.
6. Specify performance or acceptance criteria.
7. Develop the plan for obtaining data.

This DQO process shall define qualitative and quantitative criteria for determining when, where, and how many samples (measurements) to collect for a desired level of confidence. The DQO process shall be employed during the planning stages of any field investigation activities that include analytical data collection. This information along with sampling procedures, analytical procedures, and appropriate quality assurance/quality control (QA/QC) procedures shall be documented in the Quality Assurance Project Plan (QAPP), Field Sampling Plan and SOPs, and/or Site-Specific Work Plan(s).

3.0 DATA QUALITY OBJECTIVE (DQO) LEVELS

Data collected and analyzed from a field investigation is categorized by five DQO levels. Each of these levels is determined by the types of technology and documentation used, and the analytical degree of sophistication. These DQO levels are numbered I through V, with Level I being the lowest quality data and Level V the highest. These DQO levels will be used when determining the appropriate data collection methods for achieving the goals of the field investigation.

3.1 DQO Level I

DQO Level I data typically are field screening data collected in real-time using portable instruments, e.g. photoionization detector (PID). This DQO level is normally used to aid in sample point selection and to differentiate highly impacted samples from low-level impacts. Level I analyses are used for qualitative data collection only, and results cannot be considered quantitative. Instrument calibration provides the quality control component for Level I data.

3.2 DQO Level II

DQO Level II data is typically characterized by field analysis of samples using portable instruments that can be used on-site, e.g. portable gas chromatograph (GC) instrument. This level is considered semi-quantitative due to lack of supporting QA/QC documentation. Instrument calibration provides the quality control component for Level II data.

3.3 DQO Level III

DQO Level III data is data generated in an analytical laboratory using USEPA and other recognized standard methods with rigorous QA/QC protocols. The analytical laboratory can be either an on-site mobile laboratory or a remote laboratory. Level III data is considered quantitative; it provides identification and quantification of chemicals in environmental samples. This data may be used for evaluating compliance of sample results relative to environmental standards, in risk assessment studies, and may be compared to results of other samples collected at a similar DQO level.

3.4 DQO Level IV

DQO Level IV data is the same as DQO Level III with the addition of rigorous documentation including raw data from the analytical laboratory instruments. Level IV analytical data is quantitative and defensible. Superfund investigations normally require DQO Level IV for data used in conducting formal human health risk assessment studies. Standard USEPA-designated field procedures are required on all investigations requiring DQO Level IV quality data. Any deviations from these methods shall be documented in the field logbook and/or on the appropriate field form, or in the approved Site-Specific Work and/or Sampling Plan. Field personnel involved in data collection shall be aware that such deviations in the fieldwork may reduce the DQO level of the data, with a subsequent reduction in data usability.

3.5 DQO Level V

DQO Level V data include deviations from the standard suites of parameters normally analyzed under the USEPA protocols. DQO Level V procedures are by definition non-standard and, therefore, they are not discussed in detail. DQO Level V procedures generally require pre-approval before use and shall be addressed in Site-Specific Work and/or FSP(s), as appropriate.

4.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, D7069-04 Guide for Field Quality Assurance in a Ground-water Sampling Event.

USEPA, 1990, Quality Assurance/Quality Control Guidance for Removal Activities, Sampling QA/QC Plan and Data Validation Procedures, Interim Final, EPA/540/G-90/004.

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia.

USEPA, 2002a, Quality Management Plan for the Superfund Division, Region 5, Chicago, Illinois.

USEPA, 2002b, Guidance for Quality Assurance Project Plans, EPA QA/G-5, EPA/240/R-02/009.

USEPA, 2006, Guidance on Systematic Planning Using the Data Quality Objectives Process, EPA QA/G-4, EPA/240/B-06/001.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

Authors:	**M. Skyer / T. Gilles**	**Q2R & Approval By:**	**A. Bazan**	**Q3R & Approval By:**	**M. Kelley**

STANDARD OPERATING PROCEDURE NO. SAS-04-03

QUALITY CONTROL SAMPLES Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for the collection of quality control (QC) samples. QC samples are utilized to evaluate field and laboratory quality control procedures and the precision, accuracy, representativeness and comparability of data obtained during investigative activities.

2.0 EQUIPMENT AND MATERIALS

Equipment and materials for the collection and analysis for quality control samples shall be identical to those used for the collection and analysis of the sample of similar media and collection method.

3.0 HEALTH AND SAFETY WARNING

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 QUALITY CONTROL SAMPLES

QC samples include field duplicate samples, matrix spike (MS) and matrix spike duplicate (MSD) samples, trip blanks, and field/equipment blanks.

4.1 Field Duplicate Samples

Duplicate samples are collected from various media to evaluate the representativeness and comparability of data obtained during investigative activities. These samples shall be collected at the same time, using the same procedures, the same equipment, and in the same types of containers as the original sample. They shall also be preserved in the same manner and submitted for the same analyses as the requested analytes. The minimum/required frequency of duplicate sample collection for each sample media shall be specified in the Quality Assurance Project Plan (QAPP), Field Sampling Plan (FSP), and/or Site-Specific Work and/or Sampling Plan(s). If the frequency of collection is in conflict between the above mentioned documents, the Site-Specific Work shall take precedence. The evaluation of these samples is described in the QAPP.

4.2 Matrix Spike and Matrix Spike Duplicate Samples

MS/MSD samples are collected from various media to evaluate the precision and accuracy of laboratory procedures. As with field duplicate samples, MS/MSD samples shall be collected at the same time, using the same procedures, the same equipment, and in the same types of containers as the original sample. They shall also be preserved in the same manner and submitted for the same analyses as the requested analytes. The minimum/required frequency of MS/MSD sample collection for each sample media shall be specified in the QAPP, FSP, and/or Site-Specific Work and/or Sampling Plan(s). If the frequency of collection is in conflict between the above mentioned documents, the Site-Specific Work shall take precedence. The evaluation of these samples is described in the (QAPP).

4.3 Trip Blanks

Trip blanks are used as control or external quality assurance/quality control (QA/QC) samples to detect contamination that may be introduced in the field, in transit to or from the sampling site, or in bottle preparation, sample log-in, or sample storage sites within the laboratory. Trip blanks will also reflect contamination that may occur during the analytical process. Trip blanks are samples of reagent free water, properly preserved, which are prepared in a controlled environment prior to field mobilization. These samples are prepared by the analytical laboratory. The trip blanks are kept with the laboratory provided containers through the sampling process and returned to the laboratory with the other aqueous samples for VOC analysis. Trip blanks must be used for samples intended for VOC analysis and are preserved and analyzed for

VOCs only. One trip blank will accompany each cooler containing aqueous samples for VOC analysis or as specified in the QAPP, FSP, and/or Site-Specific Work and/or Sampling Plan(s). If the frequency of collection is in conflict between the above mentioned documents, the Site-Specific Work shall take precedence. The evaluation of these samples is described in the QAPP.

4.4 Field/Equipment Blanks

Field/equipment blanks are used to determine 1) if non-disposable equipment decontamination procedures are being carried out properly and there is no "carryover" from one sample to another and 2) ensure that disposable equipment is free of measurable concentrations of constituents of potential concern. Field/equipment blank shall be collected by pouring distilled or ultrapure/DI water onto or into the sampling equipment and direct filling the appropriate sample containers with the DI water from the sampling equipment. Field blank will be handled and treated in the same manner as all samples collected unless noted otherwise below. Field/equipment blanks are always collected after sampling equipment has been decontaminated and may be performed prior to collecting the first sample, after collecting highly impacted samples, and/or at the conclusion of sampling. The minimum/required frequency of field/equipment blanks for each sample media shall be specified in the QAPP, FSP, and/or Site-Specific Work and/or Sampling Plan(s). If the frequency of collection is in conflict between the above-mentioned documents, the Site-Specific Work shall take precedence. The evaluation of these samples is described in the QAPP.

5.0 REFERENCES AND ADDITIONAL RESOURCES

USEPA, 1990, Quality Assurance/Quality Control Guidance for Removal Activities, Sampling QA/QC Plan and Data Validation Procedures, Interim Final, EPA/540/G-90/004.

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia.

USEPA, 2002a, Quality Management Plan for the Superfund Division, Region 5, Chicago, Illinois.

USEPA, 2002b, Guidance for Quality Assurance Project Plans, EPA QA/G-5/ EPA/240/R-02/009.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

Author:	M. Skyer	Q2R & Approval By:	T. Gilles	Q3R & Approval By:	M. Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-04-04

EQUIPMENT DECONTAMINATION
Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for decontamination of equipment prior to its 1) initial use onsite 2) reuse at another sampling interval or location, and 3) demobilization from Site as specified in the Site-Specific Work Plan or as otherwise specified. Personnel decontamination is described in the site-specific Health and Safety Plan (HASP).

2.0 EQUIPMENT AND MATERIALS

Decontamination equipment and materials may vary based on the size or type of equipment, but generally include the following:

- Decontamination detergents (e.g. Alconox);
- Tap water;
- Deionized, distilled and organic-free water;
- Acid solution (optional);
- Approved cleaning solvent (e.g. isopropanol, hexane, Stoddard) (optional and/or site-specific);
- Metal scrapers;
- Brushes;
- Buckets;
- Steam cleaner or high-pressure, hot water washer;
- Racks, normally metal (not wood) to hold miscellaneous equipment;
- Buckets, 55-gallon drums, or other approved storage containers;
- Plastic sheeting;
- Utility pump (optional);
- Paper towels;
- Personal protective equipment; and

- Logbook and/or appropriate field form.

3.0 HEALTH AND SAFETY WARNINGS

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific HASP based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 EXECUTION

4.1 General Requirements

All expected types and levels of contamination shall be discussed during field activity planning and a decontamination plan sufficiently scoped within the Site-Specific Work Plan. Until proven otherwise, all personnel and equipment exiting the area of potential contamination/work zone will be assumed to be contaminated. Personnel involved in decontamination efforts shall be equipped with the same personal protective equipment as those conducting the field activity until a lower level of risk can be confirmed.

Decontamination procedures may be subject to federal, state, local, and/or the client's regulations. All regulatory requirements shall be satisfied, but the procedures adopted shall be no less rigorous than those presented in this SOP.

Climatic conditions anticipated during decontamination activities may impact the implementation of the procedures describe in this SOP. Special facilities or equipment may be needed to compensate for weather conditions (e.g. temporary, heated structures for winter work). In addition, it may be necessary to establish special work conditions during periods of high heat or cold stress.

4.2 Preparation

4.2.1 Site Selection

The equipment decontamination facility or area shall be located in an area where contaminants can be controlled and at the boundary of a "clean zone" or "cold zone". The location shall also be selected to prevent equipment from being exposed to additional or other contamination. When Site layout and size allow, a formal "contamination reduction zone" or "warm zone" shall be established in which decontamination efforts will be conducted. This area shall be conspicuously marked as "off-limits" to all personnel not involved with the decontamination process.

The equipment decontamination facility or area shall also be located where decontamination fluids and materials can be contained and easily discarded or discharged into controlled areas of waste. This facility or area shall have adequate space for the storage of unused and used storage containers, until such time as they can be relocated or disposed of.

4.2.2 Decontamination Pad

Some Site may have an existing decontamination pad. If a decontamination pad has been previously constructed, it shall be evaluated for logistics capabilities, such as water supply, electrical power, by-product handling capabilities, and cleanliness. An existing decontamination pad shall be used or modified to the extent practical. If a decontamination pad is not present or the existing pad cannot be used or modified for use, a pad consisting of a sturdy base, lined with plastic sheeting of high-density polyethylene with four raised sides and a sump for collection of fluids will be constructed unless otherwise specified by the Site-Specific Work Plan. Some field activities, which consist of hand sampling or other small equipment, may not require a decontamination pad. In these cases, buckets, small wash tubs, or small pools may be sufficient for equipment decontamination.

4.2.3 Water Supply

Large volumes of water, often exceeding 1,000 gallons per day, may be required for decontamination activities, especially for drill rigs and other large equipment. The water used for decontamination must be clean, potable water. In most cases, municipal water supplies are adequate. Private potable water supplies shall be evaluated on a case-by-case basis prior to use.

4.2.4 Cleaning Equipment and Supplies

A portable steam cleaner or high-pressure hot water washer is normally required to clean contaminated heavy machinery (e.g. drill rig, backhoe, etc.) as well as materials and associated tools. Most steam cleaners and washers are commercially available for both portable generators or supplied AC power. Site logistical considerations may dictate the type of equipment required. Typical steam cleaners/washers operated on relatively low water consumption rates (2 to 6 gallons per minute) and can be used in conjunction with other cleaning fluids mixed with the water. High-pressure steam is preferred to high-pressure water because of steam's ability to volatilize organics and to remove oil and grease from equipment. Since units tend to malfunction easily and are susceptible to frequent maintenance and repair (especially under frequent use and freezing conditions), a second or back-up unit should be available onsite or arranged for with a nearby vendor to the extent practical, for longer duration field activities.

Garden sprayers may be used for final rinsing or cleaning. However, these sprayers shall be limited to use with small hand tools and sampling equipment. Since these sprayers tend to malfunction or break down easily, a second or backup sprayer shall be maintained onsite.

Metal scrapers and brushes shall be used to physically remove heavy mud, dust, etc. from equipment prior to and during the equipment rinses. Scrapers and brushes are relatively inexpensive and shall be replaced as necessary to support cleaning activities.

Decontamination solutions may consist of the following:

- Laboratory detergent shall be a standard brand of laboratory detergent such as Alconox® or Liquinox®;
- Nitric acid solution (10 percent) will be made from reagent-grade nitric acid and deionized water;
- Cleaning solvent;
- Potable water;
- Deionized water;
- Distilled water; and
- Organic-free water.

The use of cleaning solvents shall be carefully considered prior to use with respect to safety, handling and disposal, and potential impact to analytical results and the environment.

Potable, deionized, distilled, and organic-free water should contain no heavy metals or other inorganic compounds (i.e., at or above analytical detection limits) as defined by a standard Inductively Coupled Argon Plasma Spectrophotometer (ICP) scan and no pesticides, herbicides, extractable organic compounds, and less than 5 µg/l of purgeable organic compounds as measured by a low-level GC/MS scan. The level of QA/QC required during the project to verify and document the purity of the water and the number of rinsate blanks required to verify and document the effectiveness of decontamination procedures shall be based on data quality and project objectives as specified by the Site-Specific Work and/or Quality Assurance Project Plan (QAPP). The use of non-potable or untreated potable water supply for decontamination is not acceptable.

4.3 Equipment and Vehicle Decontamination Procedures

4.3.1 General Procedures

The following procedures are presented as general guidelines and shall be followed unless otherwise required by the Site-Specific Work Plan or otherwise specified:

1. Physical removal of particles;
2. Steam or water wash with potable water to remove particles;
3. Rinse critical pieces of equipment with an approved cleaning solvent or nitric acid solution (optional and/or site-specific);

4. Steam or water wash with a mixture of detergent and potable water;
5. Steam or water rinse with potable water; and
6. Air dry.

4.3.2 Special Case – Drilling Equipment

During decontamination of drilling equipment and accessories, clean auger flights, drill rods, and drill bits as well as all couplings and threads. Generally, decontamination can be limited to the back portion of the drill rig, drill rig tires, drill rig mast, and parts that come in direct contact with samples or casings or drilling equipment placed into or over the borehole.

Some items of drilling equipment cannot typically be decontaminated. These items include wood materials (e.g. planks), porous hoses, engine filters, etc. These items shall not be removed from site until ready to dispose of in an appropriate manner.

Other drilling equipment that requires extensive decontamination is water or grout pumps. Circulating and flushing with a potable water and detergent solution followed by potable may be sufficient to clean them. However, if high or unknown contaminant concentrations or visible product is known to exist, then disassembly and thorough cleaning of internal parts shall be required before removal of the equipment from the Site.

4.4 Sampling Equipment Decontamination Procedures

4.4.1 General Procedures

Sampling equipment shall be decontaminated prior to its 1) initial use onsite 2) reuse at another sampling interval or location, and 3) demobilization from Site using the following procedure as general guidelines unless otherwise required by the Site-Specific Work Plan or otherwise specified:

1. Physical removal of particles;
2. Rinse with an approved cleaning solvent or nitric acid solution (optional and/or site-specific);
3. Wash and scrub with a detergent and potable water solution;
4. Rinse with potable water;

5. Rinse with high-grade water (deionized, distilled, or organic-free);
6. Air dry; and
7. Wrap in aluminum foil, shiny side out, for transport.

4.4.2 Special Cases

Steel tapes, water and interface probes, transducers, and thermometers, shall be cleaned with a detergent solution and rinsed with high-grade water. Water quality meters shall be rinsed with high-grade water.

Pumps with internal components that contact a water sample (e.g., bladder pump) shall be deconned by pumping a detergent solution (minimum two gallons) followed by potable water rinse (minimum two gallons) and a high-grade water rinse (minimum two gallons). If field conditions (e.g., the presence of product) indicate circulating and flushing a pump with a detergent solution followed by potable water is not an adequate field decontamination procedure, the pump shall be disassembled and internal parts thoroughly cleaned with a detergent solution followed by potable water rinse and a high-grade water rinse.

4.5 Well Material Decontamination Procedures

Well construction materials, including end cap, screen, and riser pipe, whether polyvinyl chloride (PVC), stainless steel, or other material shall be cleaned with a steam cleaner or high-pressure hot water washer before it is installed in the borehole. Well construction materials shall be handled while wearing latex, nitrile, or equivalent gloves.

4.6 Equipment Segregating and Labeling

Decontaminated equipment shall be stored separating from contaminated equipment in a manner that prevents the recontamination of “clean” equipment. Equipment that is cleaned utilizing these procedures shall receive a final decontamination process at the completion of field activities and will be tagged, labeled, or marked with the date that the equipment was cleaned.

4.7 Disposal Practices

4.7.1 General Disposal Requirements

Disposal practices shall be in accordance with the procedures specified in the Site-Specific Work Plan. Decontamination derived waste shall be contained, consolidated, and disposed shall be conducted to prevent the spread of contaminants offsite or to "clean" locations onsite and in a manner consistent with the acceptable disposal practices for the type and concentration of wastes that may be contained in the decontamination derived waste. Contaminated equipment or solutions shall not be discarded in any manner that may lead to the contamination of the environment by the migration of hazardous constituents from the Site by air, surface, or subsurface transport mechanisms.

4.7.2 Onsite Storage, Treatment, and Disposal

On controlled, secured facilities, most decontamination derived waste shall remain onsite pending waste characterization and disposal. The decontamination derived waste shall be labeled and stored in a manner that does not pose a threat to contamination of personnel or areas to be sampled or a threat of release to the environment. Liquids and solids shall be containerized separately in approved storage containers. Each storage container shall be labeled with the following:

- Contents (e.g. decontamination fluids);
- Incompatibilities (if applicable);
- Accumulation date; and
- Contact person and phone number.

In some cases, an onsite treatment system is available for certain types of decontamination derived waste. Treatment of decontaminated derived wastes shall be performed in accordance with any applicable permit requirements and federal, state, and local laws and regulations.

In some cases, certain materials that are not contaminated or contain very low levels of contamination may be disposed of onsite. Such materials may include may include drill cuttings, wash water, drilling fluids, and water removed during the purging or sampling of wells. The low level of contamination (concentrations below applicable cleanup objectives) shall be confirmed prior to onsite disposal. Onsite disposal shall comply with federal, state, and local laws and regulations.

4.7.3 Offsite Disposal

In most cases, decontamination derived waste cannot be disposed of or treated onsite. Decontaminated derived waste shall be properly characterized prior to shipment to a licensed and approved treatment, storage, and disposal facility. Decontamination fluids discharged to sanitary and/or storm sewers shall be properly permitted prior to discharge. Offsite disposal shall comply with federal, state, and local laws and regulations.

5.0 DOCUMENTATION

Decontamination activities, including deviations for general procedures, shall be recorded in the field logbook and/or on the appropriate field form as specified in SOP ENV-01-01 or as required by the Site-Specific Work.

6.0 REFERENCES

ASTM International, D5088-02 Practices for Decontamination of Field Equipment Used at Waste Sites.

USEPA, Region IV, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), Enforcement and Investigations Branch, SESD, Athens, Georgia.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/60/B-07/001.

SOP SERIES SAS-05
SUBSURFACE INVESTIGATION METHODS

STANDARD OPERATING PROCEDURE
NO. SAS-05-01

SUBSURFACE EXPLORATION CLEARANCE
Revision 0

1.0 PURPOSE

The purpose of this standard operating procedure (SOP) is to ensure intrusive site activities are conducted with the knowledge and approval of property owners, utility providers, and governmental agencies, as appropriate, in a manner that minimizes potential exposure to subsurface hazards and damage to subsurface utilities. Clearance of intrusive activity areas must be obtained from appropriate authorities and site operators. This clearance comes in the form of 1) permission to enter a property, 2) ensuring subsurface conditions will not be encountered that endanger the safety of site personnel, subcontractors, and authorized visitors, and 3) demarcation of subsurface utilities/structures.

2.0 HEALTH AND SAFETY WARNING

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

3.0 SITE ACCESS AND ENTRY

Access to properties subject to activities conducted under the contracted scope of services/work order is the responsibility of the client as set forth in the environmental engineering and consulting services agreement. The client will give reasonable access to client-owned properties for performance of services. If the client does not own or operate the property, it will secure an access agreement or other authorization for consultant access to the site that will address the terms of access as well as any access restrictions.

Site entrance procedures are as follows:

- The client will be advised of the date and time of site entrance and the purpose of the entrance.
- In addition, if the site is not owned by the client, the owner of the property will be advised of the date and time of site entrance and the purpose of the entrance.
- Entrance to the site shall be through the main gate or other entrance specified by the client or owner.
- If a site contact is present at the site, the consultant will introduce herself/himself and provide the site contact with a business card. The consultant shall also identify other personnel who are or will be on-site and explain their functions.
- The consultant will complete any general sign-in procedures required for site entrance, unless otherwise instructed by the client or property owner.
- If a liability waiver is presented that is not pre-agreed to by the consulting company and the client or owner, the consultant will call her/his Project Manager for instructions.
- If entry is refused, the consultant will leave the site entrance and call her/his Project Manager for instructions.
- The time of site entrance, or refusal of entrance will be included in the field logbook entry for the day.

4.0 SITE CLEARANCE

Site clearance is required prior to commencement of any investigation or remediation activities. Three categories of site clearance are required:

1. Property boundary identification,
2. Utility clearance, and
3. Clearance of any on-site subsurface obstructions, hazards or protected structures identified by the client or property owner.

4.1 Property Boundary Identification

The first step in site clearance is to demarcate the property boundaries. A client- or property owner-provided plat of survey will be used if available. If no current plat of survey is available, the client or property owner may be asked to have a licensed surveyor conduct a survey and mark the property boundaries or the consultant may hire a surveyor to conduct the survey on behalf of the client. All property boundaries should be fully known and marked prior to commencement of any site investigation activities. If an investigation location appears to be outside of the property boundaries that encompass the area to which access has been granted, the Project Manager shall be consulted prior to commencement of any activity at that location.

4.2 Utility Clearance

Written clearance of all underground utilities (private, commercial, and public) must be obtained prior to commencing intrusive site activities (e.g. soil borings, GeoProbe advancement, test pit or trench excavation). Utility clearance is vital for safe operations and provides notification to utility companies of intrusive work being conducted in the vicinity of underground lines and structures. The utility clearance process is initiated by calling a state- or city-specific one-call utility clearance hotline. One-call center information may be obtained by calling "811" or visiting http://www.call811.com/state-specific.aspx. Generally, utility clearance must be requested at least 48 hours in advance of the commencement of intrusive activities. In some states, including Illinois, utility clearance is the responsibility of the contractor performing the intrusive work (e.g. drilling subcontractor or excavation company) rather than the contracting environmental consultant.

Assemble the following information to make the call or provide this information to the subcontractor:

- Name, address and phone number of person making request;
- Type and extent (size of excavation) of work being performed;
- Start date and time of excavation;
- Address, including street, number, city, and county (township range, section and quarter section information may also be required);
- Nearest crossroad; and
- General legal description, if available.

The following table lists the one-call-center contact information for the Midwest.

	One Call System Name	Non-Emergency	Emergency	Website
Illinois (except City of Chicago)	J.U.L.I.E. Joint Utility Locating Information for Excavators	(800) 892-0123	- - -	http://www.illinois1call.com
City of Chicago	DIGGER	(312) 744-7000	- - -	http://www.cityofchicago.org
Indiana	I.U.P.P.S. Indiana Underground Plant Protection Service	(800) 382-5544	- - -	http://www.iupps.org
Iowa	Iowa One Call	(800) 292-8989	(800) 292-8989	http://www.iowaonecall.com
Kansas	Kansas One Call	(800) 344-7233	- - -	http://kansasonecall.com
Michigan	MISS DIG System Inc.	(800) 482-7171	- - -	http://www.missdig.org/MissDig/
Missouri	Missouri One Call System	(800) 344-7483	- - -	http://www.mo1call.com
Wisconsin	DIGGER	(800) 242-8511	(800) 500-9592	http://www.diggershotline.com

Utility location agencies may only mark-out utilities on public right-of-ways adjacent to the property under investigation and sewer and water departments may not be included in the locating services provided by the one-call centers. Request additional information from any utility companies or public utilities departments not included in the one-call locating services. It may be advisable at some properties to hire a private utility locating contractor to do additional on-site clearance prior to commencement of intrusive activities. Consult with the Project Manager about conducting additional locating activities if the information provided by the one-call center is not complete with respect to what is known about possible underground utilities at the site.

Do not proceed with any intrusive activities until all utility clearances and mark-outs have been performed by the locating services or participating utility companies. Do not proceed without verification from the subcontractor that the utility clearance has been performed if it was the subcontractor’s responsibility to request the utility locating service. Prior to start of intrusive activities, walk the site and surrounding public right-of-way with the subcontractor locating any utility markers and discuss procedures for avoiding marked utilities during the site investigation. If at any time, a potential hazard exists at a proposed investigation location that cannot be resolved with available information and utility location markings, contact the Project Manager for instructions.

4.3 On-Site Subsurface Obstructions, Hazards and Protected Structures Clearance

The property owner (client or third party) or a designated representative shall also be contacted prior to commencement of any intrusive activities to obtain additional information regarding on-site subsurface obstructions, hazards or protected structures and clearance to conduct the activities in pre-determined locations on the site. If possible, as part of the investigation planning activities, obtain architectural or engineering drawings of the site that include building layouts and locations of subsurface utilities and structures. Schedule an on-site meeting prior to commencement of activities to review locations of proposed locations for intrusive activities. Request that the owner or his authorized representative mark or flag the locations of any known subsurface obstruction, hazard or structure that must not be damaged. In some cases, it may be appropriate to make a site visit prior to the on-site review meeting to mark out proposed subsurface investigation locations for approval by the owner or his representative. During the review meeting, if verbal approval is given to proceed, make an entry in the field logbook including the date, time and person granting approval along with details of the approval given. Record any refusals of permission to perform intrusive activities in the same manner. Include detailed information regarding the reason for the refusal in the field logbook.

If permission for any proposed intrusive activities is refused by the property owner or his representative, inform the Project Manager. If the investigation location approval meeting is performed on a day scheduled for investigation activity, and any locations are not authorized by the owner or his representative, contact the site manager immediately for instructions. Do not proceed with any intrusive activity in the non-authorized locations unless subsequent approval is forthcoming, and do so only upon receiving approval to proceed from the owner/representative and the site Project Manager. Make a detailed record of the refusal and subsequent resolution in the field logbook.

On vacant or undeveloped sites, or sites located in remote areas, on-site client/owner approval of investigation areas may not be practical. In such situations, prior approval of investigation areas may be obtained from the client or owner by means of a site investigation map that includes investigation locations (boreholes, test pit or trench locations, monitoring wells, etc.). Site features, boundary lines, and any known subsurface utilities or structures shall also be included on the site investigation map to provide the reviewer with adequate information to determine if any subsurface hazards exist in the vicinity of any of the proposed intrusive activities.

5.0 REFERENCES

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001

USEPA, Region IV, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), Enforcement and Investigations Branch, SESD, Athens, Georgia

Author:	T. Gilles	Q2R & Approval By:	C. Barry	Q3R & Approval By:	M. Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-05-02

FIELD LOGGING AND CLASSIFICATION OF SOIL AND ROCKS
Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for logging and classifying soil samples and rock cores during subsurface explorations as described in the Site-Specific Work Plan, or as otherwise specified, for the purposes of characterizing subsurface geologic conditions at a Site.

2.0 EQUIPMENT AND MATERIALS

General:

- Ruler or tape measure in 0.01-foot increments;
- Field logbook and field boring log forms;
- Pen(s) with waterproof, non-erasable ink;
- Camera;
- 5-gallon bucket and wire or nylon brushes, decontamination water, laboratory grade detergent (Alconox or similar), and paper towels;
- Aluminum foil or roll-plastic; and
- Personnel protective equipment, as appropriate, including nitrile gloves for handling impacted soil samples.

Soil Logging:

- Large sharp stainless-steel knife;
- Slim stainless-steel spatula or carpenter's 5-in-1 tool;
- Color chart;
- Comparative charts; and
- Pocket penetrometer.

Rock Coring and Logging:

- Core box(es);
- Hand lens; and
- Comparative charts.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 GENERAL PROCEDURES

Geologic logging and material classification shall be conducted only by a trained logging technician (e.g. geologist, hydrogeologist, engineer, or environmental scientist). Field data and observations associated with field logging and material classification shall be documented during logging and for all drilling and sampling activities in accordance with SOP ENV-01-01, Field Documentation and Reporting, if not otherwise specified in this SOP. All field drilling activities should be recorded in a field logbook and/or on a field boring log form. In addition, tools and equipment used while logging boreholes shall be decontaminated between boring/probe locations and prior to each sampling event in accordance with the Quality Assurance Project Plan (QAPP).

5.0 LOGGING AND DOCUMENTATION PROCEDURES

The logging technician shall record all pertinent drilling information in the field logbook and/or on the field boring log form (Attachment A). At a minimum, the following technical information with respect to pre-sampling, drilling operations and observations, and sample recovery loss shall be recorded, if applicable:

- Project name and number;
- Location (well or boring/probe number) or other sample station identification, including a rough sketch;
- Name of the logging technician overseeing the drilling operations;
- Drill rig manufacturer and model;
- Drilling company name and city and state of origin;
- Driller and assistant(s) names;
- Drilling method(s) and fluids used to drill the borehole;
- Drilling fluid manufacturer;
- Drilling fluid gain or loss;
- Depth of drilling fluid loss;
- Water source (e.g. fire hydrant, faucet, municipality, etc.);
- Borehole diameter;
- Borehole start time and date;
- Borehole completion time and date;
- Sample type (e.g. split spoon, macrocore, etc.);
- Hammer weight/drop and blow counts;
- Sample recovery/loss and explanation of loss, if known;
- Drilling rates when applicable to lithology classification;
- Description of soil and/or rock classification and lithology;
- Lithologic changes and boundaries;
- Depth to water (first encountered [during drilling] and stabilized [upon completion of drilling]);
- Total borehole depth;
- Evidence of impact (e.g. staining, odors, free-phase product, etc.);
- Well materials, construction, and placement information (e.g. casing type and diameter, screen type and diameter, etc.);
- Sample identifications and depths for chemical and geotechnical samples;
- A description of any tests conducted in the borehole; and
- Problems with the drill rig or drilling process.

When rock coring is performed, the following information shall also be recorded:

- Top and bottom of cored interval;
- Core length;
- Coring rate in minutes per foot;
- Core breakage due to discontinuities (e.g. natural fractures versus coring-induced breaks);
- Total core breakage; and
- Number of breaks per foot.

6.0 SOIL SAMPLE CLASSIFICATION AND DESCRIPTIONS

6.1 Description of Hierarchy

The required order of terms is as follows:

1. Depth measured in tenths of a foot;
2. Soil color;
3. Major soil type (e.g. CLAY). This descriptor can include the secondary soil constituent as a modifier (e.g. silty CLAY);
4. Unified Soils Classification System (USCS) Group Symbol in parentheses (e.g. ML);
5. Evidence of environmental impacts, if encountered (e.g. free-phase product, staining, sheen, etc.);
6. Other soil components of the sample listed with the appropriate percent descriptor (i.e. “with”, “some” or “trace.”);
7. Consistency, relative density or degree of cementation;
8. Moisture and plasticity, if relevant; and
9. Miscellaneous (e.g. condition of sample, deposition, fractures, seams, bedding dip, bedding features, fossils, oxidation, drilling rate data when applicable for sample classification, etc.).

6.2 Color

The color descriptions will be consistent with the Munsell Soil Color Chart, Geological Society of America (GSA) Rock Color Chart, or as required by the Work Plan or otherwise specified. Write the Munsell color name with the Munsell color identification number in parenthesis following the color name. The major color is listed first with any accessory color(s) thereafter (e.g. clay, yellowish gray (5Y 7/2) with pale green (5G 7/2) mottles). If descriptors are used for other soil components, the color designation follows each descriptor.

6.3 Soil Types

Soil descriptions and classification shall be conducted in accordance with the USCS (ASTM D2488-06). The order and presentation of the primary textural classification terms is as follows:

1. Major soil type (e.g. CLAY). This descriptor can include the secondary soil constituent as a modifier (gravelly, sandy, silty, or clayey). Nouns are unabbreviated (e.g. CLAY); “TOPSOIL” is an adequate single term for the naturally occurring organic soil found at the ground surface. In urban areas, “FILL” is used to denote previously disturbed soil, followed by a description of the major and minor soil components (e.g. “FILL, silty clay with some fine sand”). USCS Group Symbol follows the major soil component in parentheses.
2. Other soil components of the sample are listed in descending order of percentage using adjectives “with”, “some” and “trace.”
3. Using the Wentworth Scale in Attachment E, add size, sorting or angularity modifiers to granular material descriptions as appropriate.

6.4 Consistency and Relative Density

The relative density of cohesionless soils and the consistency of cohesive soils should be included in visual classifications. Attachments B and C can be used in describing the consistency of cohesive soils and the relative density of cohesionless soils, respectively.

A pocket penetrometer will be used to measure consistency of cohesive soils with the result recorded on the field boring log form. Attachment B includes information for determining soil consistency from penetrometer measurements.

6.4 Moisture Content

Moisture Content – Criteria for describing moisture content of soils are described in Attachment D.

6.5 Miscellaneous Descriptions

1. Structure – Some soils possess structural features (e.g. fissures, slickensides, or lenses) that if present, should be described.
2. Accessories or Inclusions – Elements such as rock fragments, fine roots, or nodules are included in the soil description following all other modifiers for the major components of the soil matrix. Any mineralogical or other significant components should be described, as well as man-made or apparently foreign constituents that indicate the presence and possible source of fill material.
3. Environmental Impacts – If monitoring instruments or visual observations indicate the potential presence of environmental impacts, it will be noted in detail. Additional information for describing specific types of impacts may be found in the Work Plan.

To provide consistency in logging soils, tables with additional guidelines for soil description are included in Attachment E.

7.0 ROCK CLASSIFICATION

7.1 Lithology and Texture

The logging technician should describe the lithology of the rock and its mineral composition. The geological name, such as granite, basalt, or sandstone, usually describes the rock's origin. The stratigraphic unit should be identified and assigned the local geological name, if appropriate. Stratigraphic age or period should be identified, if possible. Modifiers will be included to describe the rock texture, including grain size, sorting, packing, cementation, etc. (e.g. interlocking, cemented, or laminated-foliated).

7.2 Color

The color descriptions will be consistent with the Munsell Soil Color Chart, Geological Society of America (GSA) Rock Color Chart, or as required by the Work Plan or otherwise specified. Write the Munsell color name with the Munsell color identification number in parenthesis following the color name. The major color is listed first with any accessory colors thereafter. If secondary or tertiary descriptors are used, the color designation follows each descriptor.

7.3 Hardness

Terms used to describe hardness are described below. One common method to determine hardness is the Mohs Scale of Hardness, which is defined as follows:

Descriptive Term	Defining Characteristics
Very Hard	• Cannot be scratched with a knife. • Does not leave a groove on the rock surface when scratched.
Hard	• Difficult to scratch with a knife. • Leaves a faint groove with sharp edges.
Medium	• Can be scratched with a knife. • Leaves a well-defined groove with sharp edges.
Soft	• Easily scratched with a knife. • Leaves a deep groove with broken edges.
Very Soft	• Can be scratched with a fingernail.

7.4 Weathering

Terms used to describe weathering are described below (ASTM D 5434-03):

Descriptive Term	Defining Characteristics
Fresh	• Rock is unstained. • May be fractured, but discontinuities are not stained.
Slightly	• Rock is unstained. • Discontinuities show some staining on the surface, but discoloration does not penetrate rock mass.
Moderate	• Discontinuous surfaces are stained. • Discoloration may extend into rock mass along discontinuous surfaces.
High	• Individual rock fragments are thoroughly stained and can be crushed with pressure of a hammer. • Discontinuous surfaces are thoroughly stained and may crumble.
Severe	• Rock appears to consist of gravel-sized fragments in “soil” matrix. • Individual fragments are thoroughly discolored and can be broken with fingers.

7.5 Rock Matrix Descriptions

Grain size is a term that describes the fabric of the rock matrix. It is usually described as fine-grained, medium-grained or coarse-grained. The modified Wentworth scale should be used or as required by the Work Plan or otherwise specified.

A description of bedding (after Ingram, 1954) or fracture joint spacing should be provided according to the following:

Spacing	Bedding	Joints/Fractures
< 1 inch	Very thin	Very close
1 – 4 inches	Thin	Close
4 inches to 1 foot	Medium	Moderately close
1 foot to 4.5 feet	Thick	Wide
> 4.5 feet	Very Thick	Very Wide

Discontinuity descriptors are terms that describe number, depth, and type of natural discontinuities. They also describe density, orientation, staining, planarity, alteration, joint or fractural fillings and structural features.

8.0 ROCK CORE HANDLING

The following guidelines shall be followed for rock core handling:

1. Core samples must be placed into core boxes in the sequence of recovery, with the top of the core in the upper left corner of the box.
2. At the bottom of each core run, spacer blocks must be placed to separate the runs. The spacer should be indelibly labeled with the drilling depth to the bottom of the core run regardless of how much core was actually recovered from the run.
3. Spacer blocks should be placed in the core box and labeled appropriately to indicate zones of core loss, if known. Where core samples are removed for laboratory testing, blocks equal to the core length removed should be placed in the box. Note: If wooden core boxes are used, spacer blocks should be nailed securely in place.

4. The core boxes for each boring should be consecutively numbered from the top of the boring to the bottom.
5. The core boxes containing recovered rock cores should be photographed. One core box should be photographed at a time with the box lid framed in the picture to include information printed on the inside of the lid. Be sure to include a legible scale in the picture. Photographs are taken in the field most easily and efficiently with natural light and while the core is fresh.
6. When transporting a boxed core, the box should be moved only if the lid is closed and secured with tape or nails.

9.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, 2007, D653-07b Terminology Relating to Soil, Rock, and Contained Fluids.

ASTM International, 1999, D1586-99 Standard Method for Penetration Test and Split-Barrel Sampling of Soils.

ASTM International, 2006, D2488-06 Practice for Description and Identification of Soils (Visual-Manual Procedure).

ASTM International, 2001, D4083-89R01E01 Practice for Description of Frozen Soils (Visual-Manual Procedure).

ASTM International, 2007, D4543-07 Practice for Preparing Rock Core Specimens and Determining Dimensional and Shape Tolerances.

ASTM International, 2002, D5079-02 (2006) Practice for Preserving and Transporting Rock Core Samples.

ASTM International, 2003, D5434-03 Guide for Field Logging of Subsurface Explorations of Soil and Rock.

ASTM International, 2000, D5715-00 (2006) Test Methods for Estimating the Degree of Humification of Peat and Other Organic Soils (Visual/Manual Method).

ASTM International, 2004, D6236-98 (2004) Guide for Coring and Logging Cement- or Lime-Stabilized Soil.

ASTM International, 2004, D7099-04 Terminology Relating to Frozen Soil and Rock.

Johnson, R.B., and J.V. DeGraff, 1988, Principles of Engineering Geology, John Wiley and Sons, New York.

U.S. Army Corps of Engineers, 2001, Engineering Manual EM1110-1-1804 - Engineering and Design - Geotechnical Investigations, January 1.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

Wentworth, C.R., 1922, A scale of grade and class terms for clastic sediments, Journal of Geology, 30: 377-392.

ATTACHMENT A
DRILLING LOG

Drilling Log

	Project Name		Project No.	Boring/Monitoring Well Number
	Site-Specific Coordinates		Ground Elevation	Page 1 of 1
	Total Depth (feet)	Hole Size (inches)	Driller (s)	
Drilling Rig			Drilling Company	
Date / To	Logged By:		Reviewed by:	Approved by:

Elevation (feet)	Depth (feet)	Description	Graphic Log	SAMPLING						PID Reading (PPM)	Remarks
				Sample Type	Sample Interval	Blow Counts per 0.5'	N Value	Sample Recovery/Length (feet)	Penetro-meter (TSF)		▽ Depth to water while drilling; ▼ Depth to water after drilling
	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	10										
	11										
	12										
	13										

ENVIRONMENTAL LOG COPY OF OSI 2003.GPJ BURNS_MO.GDT 8/30/07

ATTACHMENT B
CONSISTENCY OF COHESIVE SOILS

CONSISTENCY OF COHESIVE SOILS

Consistency	Rule-of-Thumb	Blows Per Foot[1] (N value)[2]	Penetrometer (tons/ft^2)
Very Soft	Core (height = twice diameter) sags under own weight	0 – 1	0.0-0.25
Soft	Can be easily pinched in two between thumb and forefinger	2 – 4	0.26-0.49
Firm (Medium Stiff)	Can be imprinted easily with fingers	5 – 8	0.5-0.99
Stiff	Can be imprinted with considerable pressure from fingers	9 – 15	1.0-1.99
Very Stiff	Barely can be imprinted by pressure from fingers	16 – 30	2.0-3.99
Hard	Cannot be imprinted by fingers	> 30	4.0+

Notes:

1) Blows as measure with a 2-inch outer diameter (OD), 1 3/8-inch inner diameter (ID) sampler driven 1 foot by a 140-pound hammer falling 30 inches. See Standard Methods for Penetration Test and Split-Barrel Sampling of Soils, ASTM D1586-99.
2) N value is the sum of the blows from 6 inches to 12 inches and from 12 inches to 18 inches in the 2-foot sample.

ATTACHMENT C
RELATIVE DENSITY OF COHESIONLESS SOILS

RELATIVE DENSITY OF COHESIONLESS SOILS

Consistency	Rule-of-Thumb	Blows Per Foot (N value)[2]
Very Loose	Easily penetrated with a ½-inch diameter steel rod pushed by hand	0 - 4
Loose	Easily penetrated with a ½-inch diameter steel rod pushed by hand	4 - 10
Medium Dense	Easily penetrated with a ½-inch diameter steel rod driven with a 5-pound hammer	11 - 30
Dense	Penetrated a foot with a ½-inch diameter steel rod driven with a 5-pound hammer	31 - 50
Very Dense	Penetrated only a few inches with a ½-inch diameter steel rod driven with a 5-pound hammer	> 50

Notes:
1) Blows as measure with a 2-inch outer diameter (OD), 1 3/8-inch inner diameter (ID) sampler driven 1 foot by a 140-pound hammer falling 30 inches. See Standard Methods for Penetration Test and Split-Barrel Sampling of Soils, ASTM D1586-99.
2) N value is the sum of the blows from 6 inches to 12 inches and from 12 inches to 18 inches in the 2-foot sample.

ATTACHMENT D
CRITERIA FOR ESTIMATING MOISTURE CONTENT OF SOILS

CRITERIA FOR ESTIMATING MOSITURE CONTENT OF SOILS

Adapted from USACE EM 1110-1-1804 and ASTM D 2488-06

Term	Description of Relative Moisture
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp, no visible water
Wet	Fine grained: well above optimum water content Coarse grained: visible free water
Saturated	Water is dripping from sample, usually encountered below water table

ATTACHMENT E
STANDARD SOIL DESCRIPTORS

STANDARD SOIL DESCRIPTORS

Grain Size Terminology		
Soil Type		**Diameter**
Boulders		12-inches or greater
Cobbles		3- to 12 inches
Gravel	Coarse	0.75-inch to 3 inches
	Fine	0.19-inch to 0.75-inch
Sand	Very Coarse	1 mm to 2 mm
	Coarse	0.5 mm to 1 mm
	Medium	0.25 mm to 0.5 mm
	Fine	0.06 mm to 0.25 mm
Silt		0.004 mm to 0.06 mm
Clay		Less than 0.004 mm

Notes:
1) mm = millimeter
2) Based on Wentworth Grain Size Scale for Sediment (Wentworth 1922).
3) This terminology can also be used to describe clast size in rock cores.

Estimated Plasticity for Silt and Clay Content		
Thread Diameter (inches)	**Plasticity Index (PI)**	**Identification**
1/4	0	Silt
1/8	5 – 10	Clayey Silt
1/16	10 – 20	Clay and Silt
1/32	20 – 40	Silty Clay
1/64	40	Clay

Relative Proportions of Components	
Descriptive Term	**Percent**
Trace	1 – 10
Little	11 – 20
Some	21 – 30
And	30 – 50

Adapted from ASTM D2488-06

STANDARD DESCRIPTORS – VISUAL OBSERVATIONS OF NAPL

Descriptive Term	Definition
No Visible Evidence	No visible evidence of oil on soil or sediment sample
Sheen	Any visible sheen in the water on soil or sediment particles or the core
Staining	Visible brown or black staining in soil or sediment; can be visible as mottling or in bands; typically associated with fine-grained soil or sediment
Coating	Visible brown or black oil coating soil or sediment particles; typically associated with coarse-grained soil or sediment such as coarse sand, gravels, and cobbles.
Oil Wetted	Visible brown or black oil wetting the soil or sediment sample; oil appears as a liquid and is not held by soil or sediment grains

Author:	T. Gilles	Q2R & Approval By:	C. Barry	Q3R & Approval By:	M. Kelley

STANDARD OPERATING PROCEDURE NO. SAS-05-03

WELL INSTALLATION Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for the installation of monitoring wells, observation wells, and recovery/injection wells as described in the Site-Specific Work Plan, or as otherwise specified. Monitoring and observations wells are installed to 1) determine depth to groundwater and monitor fluctuations in groundwater elevation, 2) determine and monitor the depth and thickness of free-phase products (if present), 3) obtain groundwater and/or free-phase product samples for laboratory analysis, and 4) facilitate aquifer characterization. Recovery wells are installed to conduct testing and operation of systems for groundwater pumping, free-phase product recovery, and aquifer injection.

2.0 EQUIPMENT AND MATERIALS

Field personnel shall use the well construction equipment and materials required by the Site- Specific Work Plan, or as otherwise specified.

3.0 HEALTH AND SAFTEY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 CONSIDERATIONS

4.1 General requirements

Well installation procedures should meet regulatory agency requirements. In addition, licensing and/or certification of the driller may be required. A trained supervising technician (e.g. geologist, hydrogeologist, engineer, or environmental scientist) should be present during well installation to document the subsurface stratigraphy and construction details for each well.

The well designs should meet two basic criteria: 1) groundwater and/or other fluids (e.g. free-phase product) must move freely into the well, and 2) vertical migration of surface water or undesired groundwater to the well intake zone must, to the extent possible, be eliminated. In addition to these criteria, factors that influence the location of wells should be considered and include the following:

- Project objectives of the Site-Specific Work Plan;
- Data Quality Objectives outlined in the Quality Assurance Project Plan (QAPP);
- Location of facilities and/or source areas to be monitored;
- Groundwater gradient;
- Location of aboveground and underground utilities and manmade features; and
- Accessibility to desired well location sites.

4.2 Well Installation Materials Selection

Materials used in the construction of wells must remain essentially chemically inert with respect to free-phase products and dissolved contaminants in the groundwater for the duration of the investigation period remedial action.

The most commonly used well construction materials are PVC and stainless steel. PVC is the least expensive and easiest material to use. It is generally believed that PVC does not decompose in contact with groundwater containing low concentrations of organics. Stainless steel is chemically inert, provides greater structural strength, and its use may be advantageous for large-diameter wells or groundwater containing high concentrations of organics or free-phase products. Teflon casing is chemically inert but is very expensive.

Well casing and screen are available in threaded or unthreaded sections and typically in lengths of 5, 10, and 20 feet. Threaded pipe joints may be wrapped with Teflon tape to facilitate joining and to improve the seal. Sections of casing and screen should be assembled onsite to allow inspection immediately before installation. No solvents or adhesive compounds should be used on the threaded PVC or Teflon pipe.

4.3 Well Types and Construction Specifications

4.3.1 Monitoring and Observation Wells

Monitoring and observation wells construction should be performed as outlined in the Site-Specific Work Plan or as otherwise specified. In general, the design of the wells consists of a section of slotted well casing or well screen connected to a riser pipe that extends above the ground surface. Typically, a gravel or sand filter pack is placed in the annular space between the screen and the borehole wall. A 3-foot seal composed of hydrated bentonite pellets/chips is placed on top of the filter pack. The remaining height of annulus is sealed and/or grouted to the surface with a cement, bentonite/cement, or high solid bentonite grout; this annular space will be at least 3-feet in height. A lockable protective casing is constructed over the stick-up portion of the wells. Borehole diameters will be chosen in accordance with state regulations and SSWP specification and will meet the following minimum conditions:

- The diameter of the borehole shall be at least 4 inches greater than the inside diameter of the well casing, unless hollow stem augers are utilized.
- The inside diameter of hollow stem augers should generally be at least 2-¼ inches greater than the inside diameter of the well casing and screen.
- These annular clearances facilitate the placement of the filter pack and grout around the outside of the well screen and casing.

The screens for water table observation wells, typically 10 to 15 feet long, are installed with the center of the screen set at the level of the water table to monitor seasonal fluctuation of the water table. Monitoring screens for wells constructed below the water table, typically 5 feet long, are installed at the chosen monitoring elevation as specified in SSWPs. This SOP discusses stick-up well construction; however, flush-mount well construction may also be used as outlined in the Site-Specific Work Plan or otherwise specified.

4.3.2 Recovery/Injection Wells

Construction specifications for recovery/injection wells can vary based several factors including, but not limited, to 1) the type(s) of recovery/injection to be performed, 2) engineering evaluation objectives, 3) data quality objectives, and 3) site geology. Recovery/injection wells should be constructed as outlined in the Site-Specific Work Plan, or otherwise specified.

4.4 Borehole Advancement

4.4.1 General

Boreholes used to install wells should be drilled with the following objectives:

- To provide geological data on subsurface conditions, namely stratigraphy, occurrence of groundwater, and depth to bedrock;
- To obtain representative disturbed or undisturbed samples for identification and laboratory testing; and
- To install wells.

Prior to drilling, the following steps must be taken:

- Obtain permits from appropriate local, state, and/or federal agencies. If there is a fee for permits, drilling subcontractors usually include this as part of their fee.
- Notify (verbally or in writing) the appropriate local, state, and/or federal authorities, as appropriate, in advance of the date that drilling and installation is scheduled to begin;
- Perform a subsurface utility clearance, as outlined in SOP ENV-05-01, at all planned drilling locations;
- Prepare and implement field health and safety procedures as outlined in the HASP(s); and
- Make provisions for containment, storage, and disposal of all cuttings, drilling fluids, discharge water, and other refuse generated during well installation. Note: Permitting and waste characterization may be necessary prior to disposal activities.

4.4.2 Selection of Drilling Method

Drilling methods should be selected based on the following factors:

- The expected nature of the subsurface materials to be encountered in the boring;

- Site accessibility, considering the size, clearance, and mobility of the drilling equipment;
- Availability of drilling water and the acceptability of drilling fluids (e.g., bentonite based drilling mud) in the well;
- Diameter and depth of the well desired, including consideration of the need to set casing to prevent commingling of different transmissive zones; and
- The nature and effects of contaminants expected during the drilling.

5.0 MONITORING AND OBSERVATION WELL INSTALLATION

5.1 Well Components

Typical well components in general order of placement are as followings:

1. Surface casing (if used);
2. Well casing;
3. Screen(s);
4. Filter pack (gravel or sand pack)
5. Filter pack seal (fine sand; and bentonite seal when grout is placed as the annular seal);
6. Annular seal (bentonite chips or grout);
7. Well head protector casing; and
8. Well head apron and guard posts.

Surface casing, if needed, should be installed during borehole advancement for sealing the ground surface and subsurface transmissive zones not desired to be intercepted by the well from the borehole. Surface casing may also be needed to provide lateral support for loose unconsolidated formations that may slough into or collapse around the borehole during drilling or well installation. Casing may be extended in a telescopic fashion to permit casing through intermittent transmissive zones at greater depths to limit casing size and cost requirements.

The well casing is the primary conduit to the desired borehole interval to be monitored. It serves to seal off other stratigraphic zones from the groundwater inside the well and provides unobstructed access to the well screens. The well casing extends from the top of the well screen to either above or flush with the ground surface. It is typically a single-walled pipe, flush-threaded, of the smallest diameter to facilitate sampling equipment and to support its own weight during installation.

Screens are perforated or slotted sections of casing typically of the same size and material as the well casing. The purpose of the well screen is to allow water and/or other fluids (i.e., product) to enter the well easily while preventing entry of large amounts of sediment. The slot size of the well screen is usually determined based on selection of the filter pack material. Both are commonly related to the grain size analysis of the formation material. Methods of determining appropriate screen slot size are listed in the EPA Manual of Water Well Construction Practices (USEPA 1976). Typically, 10-slot (0.010 inch slot width) or 20-slot (0.020 inch slot width) screens are used. The length of the screen depends on the sampling objective, water level fluctuations, product thickness, and thickness of the transmissive zone of the formation.

A filter pack consisting of clean silica sand or pea gravel is placed in the annular space extending to at least 2 feet above the top of the screen. Filter pack grain size, sand or pea gravel, is determined based on the well screen slot size selected and the nature of the surrounding native material. The filter pack will stabilize the aquifer formation, minimize the entry of fine-grained material into the screen, permit use of screens with different sizes of slot, and will increase the effective well diameter and water collection zone. A filter pack seal, consisting of at least 2 feet of fine sand, will be placed on top of the filter pack to prevent the intrusion of overlying grout material.

For wells with that utilize grout as an annular space seal, an additional filter pack seal, consisting of bentonite pellets or chips, should be installed above the fine-sand filter pack seal to prevent the intrusion of overlying grout material into the filter pack. The bentonite pellets or chips should be slowly poured from the top of the borehole to prevent bridging. At least 3 feet of bentonite seal should be placed on top of the fine-sand filter-pack seal. If the bentonite seal is above the saturated zone, the bentonite pellets or chips should be hydrated with distilled water before grouting the remaining annular space. The source and volume of water used must be recorded in field notes. The hydrated pellets or chips should be allowed to set for a minimum of 15 minutes. Bentonite chips are preferred over pellets or balls when the seal is below the water table because the chips hydrate less rapidly and bridging is less common.

The annular space above the bentonite seal should be grouted with cement high-solids bentonite, bentonite/cement grout, or bentonite chips, up to 30 inches below the ground surface and shall be at least 2 feet in thickness. The primary purpose of grouting is to minimize the vertical migration of water to the groundwater intake zone and to increase the integrity of the well casing.

A 30 inch concrete plug should be installed above the annular grout, when the surface seal is less than 5-feet in depth. The concrete plug is used to set the protective well cover and to prevent frost heave of the concrete pad or apron. The concrete apron should be at least 3.5 inches thick, and it should be sloped to allow water drainage away from the well.

A protective cover with a locking cap should be installed after the well has been set. This cover will protect the exposed well casing from damage and will provide security against tampering with the well. The protective cover typically consists of a steel pipe or box around the well casing. The protective cover is set at least 5 feet into the surface seal and may be reduce to 2 feet if a flush-mount well cover is placed or a shorter protective cover is required to ensure well construction space for a 2 foot minimum annular space seal.. Weep holes (approximately ¼-inch diameter) may be drilled into the base of the protective cover above the concrete apron to allow drainage. Alternatively, one to two inches of fine-grained sand may be placed at the base of the flush-mounted protective cover to facilitate drainage.

Well-head aprons and guard posts, when used, provide additional surface protection to the well and are generally used for wells in high traffic areas or where a more permanent structure is desired.

5.2 Installation Procedures

The decision to install a well at a particular location is often decided in the field upon completion of the boring and subsurface sampling. If the borehole diameter is not sufficient to install a well, either the borehole should be reamed using a larger diameter auger or a new borehole should be drilled. The new borehole should be at least 5 feet away from the initial boring. The initial soil boring should be abandoned according to the procedures outlined in SOP ENV-05-05. If a well is not installed, the boring should be abandoned in accordance with SOP ENV-05-05.

Over-drilling generally should not be conducted to provide room for a well sump or additional filter pack material at the bottom of the borehole beneath the well casing. However, for wash rotary boreholes drilled in soft or highly plastic sediments, loose cuttings may fall to the borehole bottom after backwashing. In this case, it may be necessary to install a 2-foot layer of sand or gravel at the bottom of the boring to provide a firm base on which to set the well assembly to limit settling of the well casing and screen under its own weight.

For mud rotary boreholes, excess drilling fluids should be flushed from the borehole before installing the filter pack and grout seal. This can be accomplished by one or both of the following means:

- Flush the well using the drilling equipment by pumping clean water down the drill pipe without circulating the returned fluid. This should be accomplished at low pump pressure and with care to avoid scouring or fracturing of the formations. The source and volume of water added to the well must be recorded in field notes.
- Insert casing and screens with a backwash valve on the bottom end, and then flush the borehole via the well casing at low pressures. The backwash valve not only provides an outlet for flushing, but also provides pressure relief so the screens are not damaged by the backwash fluid pressures.

The latter method should be conducted only if it is determined that the former is not possible, or if the drilling fluid must remain in place in order to install the filter pack.

Connect the screen and well casing while wearing latex gloves. Insert and lower the screen and well casing into the borehole in 10-foot increments. Hand-tighten connections to prevent them from leaking or becoming loose. The final section of pipe should be measured and field cut, if necessary, before connecting to allow for a stick-up of at least 2 feet. The cut end should be rasped and/or sanded smooth, taking care not to let fillings of casing material cling to the inside.

Backwash the boring, if necessary, and pour in sand or gravel to seat and support the casing and screen. Based on boring and casing diameters, determine volume of filter pack material required to place the filter approximately 2 feet above the top of the screens. Install filter pack using the following methods, as appropriate.

- Slowly pour filter material down annulus, being careful to evenly distribute the material around the casing and to avoid the material becoming packed between the sidewall and casing. Use a small-diameter pipe to dislodge packed material and to ensure adequate height and settlement of the filter pack.

- Pour filter material down tremie pipe placed between boring sidewall and casing. In this method, clean potable or distilled water should be poured in along with the sand or gravel to prevent packing within the tremie. The source and volume of water added must be recorded in field notes. The bottom of the tremie should be kept above the filter material top by at least 5 feet to permit the filter material to evenly fall around the screens. Pack the material with the tremie pipe to ensure adequate height and settlement of the filter pack.

Pour bentonite pellets or chips down the annulus on top of the filter pack. The bentonite should be placed rapidly to prevent swelling and bridging around the casing when it hydrates. The bentonite should be allowed to hydrate for at least 15 minutes before grouting.

The remaining annulus should be sealed by pumping grout via a tremie pipe from the bottom of the annular space of the borehole until the grout returns to the surface displacing all remaining drilling fluid and formation water. The bottom of the tremie pipe should not be placed within 4 feet of the bentonite seal. Grouting mixture and technique should be in accordance with Site-Specific Work Plan requirements, or as otherwise specified. Grout will typically settle 1 to 2 feet. Remove excess grout to allow 30 inches of annular space for the concrete plug or native material.

After the grout has stiffened sufficiently, install the concrete plug up to the ground surface. Set the protective cover, if possible, such that at least 2 feet of its length is embedded in the concrete below the ground surface. It should also be set such that it is not more than approximately 30 to 36 inches above the level where the sampling personnel must stand. A concrete pad approximately 3 feet in diameter and 3.5 inches thick should be formed around the base of the protective cover. The concrete pad should be sloped away from the protective cover to allow flow away from the well. Weep holes should be drilled through the protective cover nominally 1 inch above the top of the concrete apron.

The protective casing should be marked with identifying decals. A locking device should be installed to prevent unauthorized entry or vandalism of the well. The top of the well casing should be notched with a file to provide a reference point in which to measure water and/or product levels. The elevation of the top of the well casing (reference point) and ground surface at the well should be surveyed relative to a benchmark. The location of the well should also be surveyed in reference to the site coordinate system as required by the Site-Specific Work Plan, or as otherwise specified.

Develop well within 24 to 72 hours following well installation according to the well development procedures outlined in ENV-05-04.

6.0 DOCUMENTATION

Documentation of well installation should be the responsibility of the supervising field technician. A well completion report should be prepared after the well is installed. The Illinois Department of Public Health Well Completion Report is provided as a well completion report example in Attachment A. If the work is performed in a different state, the relevant forms must be obtained.

The drilling and well installation activities should be recorded in the field logbook and/or on the appropriate field forms. The following information should be recorded during and upon completions of every well installation:

- Project name and number;
- Well location identification;
- Date of installation and time completed;
- Drilling method, crew names, and rig identification;
- Drilling depths;
- Generalized subsurface stratigraphy;
- Total length of casing and screens;
- Depth to and length of screened intervals;
- Depth to top of filter pack;

- Depth to top of bentonite seal;
- Depth to top of grout;
- Depth of surface casing (if applicable);
- Elevation of top of well casing and ground surface; and
- Name of supervising field technician.

The driller should also prepare any state-required well completion forms in accordance with state regulatory requirements.

7.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, 2004, D5092-04 Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers.

ASTM International, 2005, D6001-05 Guide for Direct-Push Ground Water Sampling for Environmental Site Characterization.

ASTM International, 2004, D6724-04 Guide for Installation of Direct-Push Ground Water Monitoring Wells.

ASTM International, 2004, D67-25-04 Practice for Direct-Push Installation of Prepacked Screen Monitoring Wells in Unconsolidated Aquifers.

USEPA, 1976, Manual of Water Well Construction Practices, EPA/570/9-75/001.

USEPA, 2002, Ecological Assessment Standard Operating Procedures and Quality Assurance Manual, SESD, Region 4, Ecological Assessment Branch, Athens, Georgia.

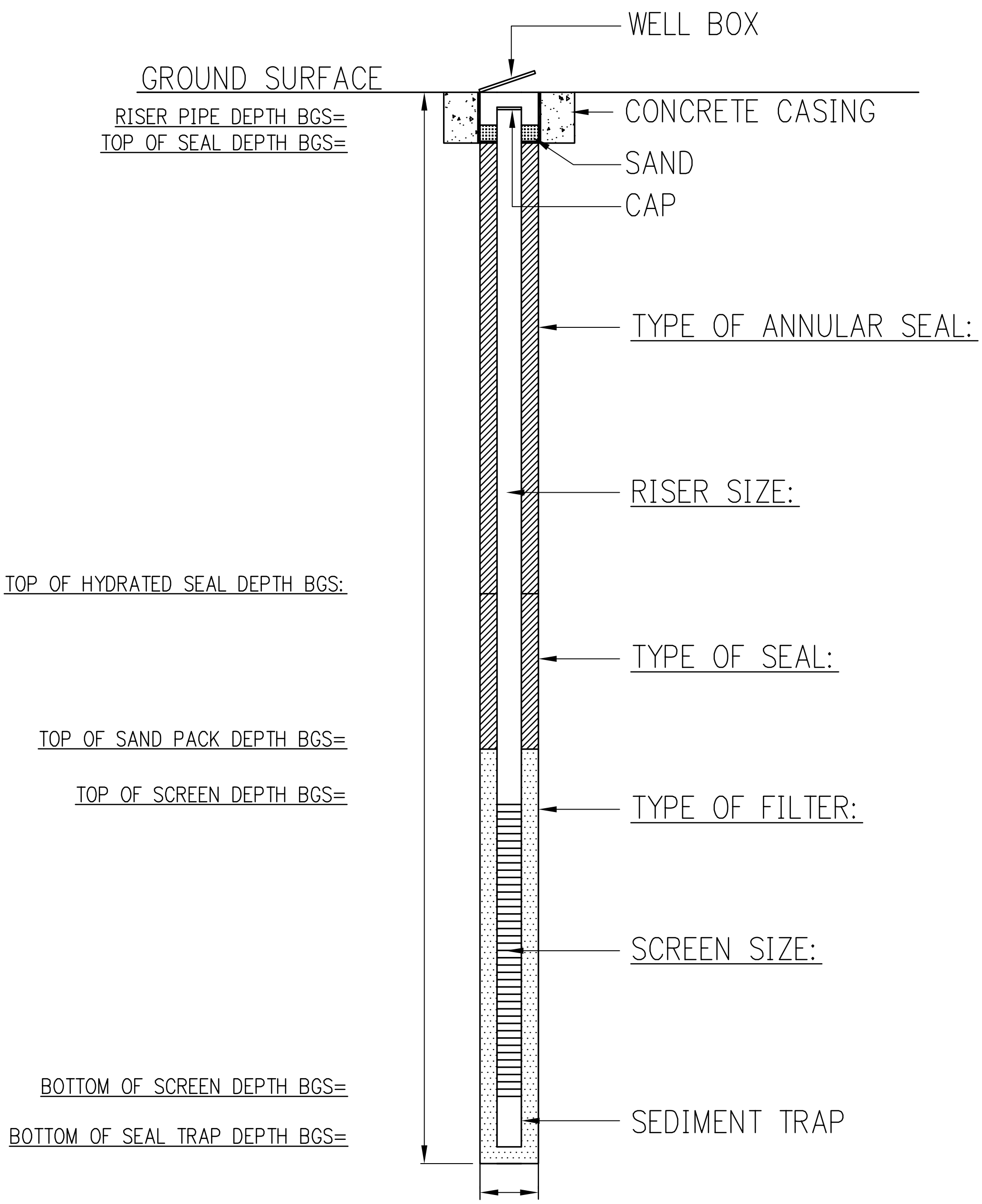
USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

ATTACHMENT A
WELL INSTALLATION LOGS

WELL INSTALLATION LOG

No. ________

CLIENT	COORDINATES N E	PROJECT	PROJECT NO.
PROJECT LOCATION		TOP OF RISER ELEVATION (DATUM)	DATE
STRATUM MONITORED		LOGGED BY	
DRILLING COMPANY		APPROVED BY	



NOT TO SCALE

METHOD OF INSTALLATION:

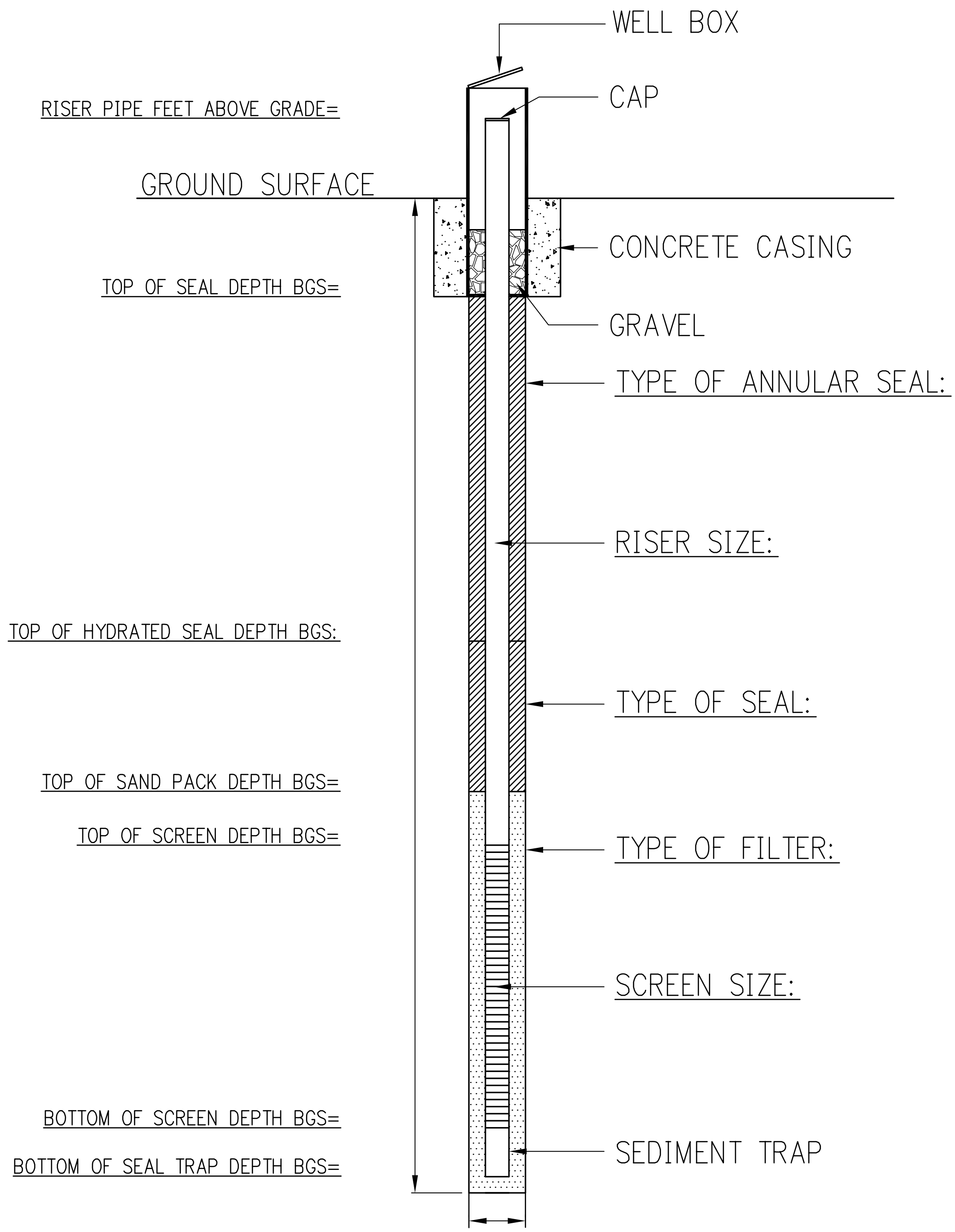
REMARKS:

I:\CAD\BMC\TEMPLATES\FLUSH MOUNT WELL LOG NL

WELL INSTALLATION LOG

No. __________

CLIENT	COORDINATES N E	PROJECT	PROJECT NO.
PROJECT LOCATION		TOP OF RISER ELEVATION (DATUM)	DATE
STRATUM MONITORED		LOGGED BY	
DRILLING COMPANY		APPROVED BY	



NOT TO SCALE

METHOD OF INSTALLATION:

REMARKS:

Author:	T. Gilles	Q2R & Approval By:	C. Barry	Q3R & Approval By:	M. Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-05-04

WELL DEVELOPMENT
Revision 2

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for developing wells. Well development is conducted to 1) remove drilling fluids or mudcake from the filter pack, borehole wall, and formation materials, 2) remove any loose, fine-grain, formation materials (e.g. fine sand, silt, and clay) from the filter pack and well screen to eliminate, to the extent possible, impact the integrity of groundwater and/or product samples and aquifer characterization test results, and 3) restore the natural permeability of the formation adjacent to the borehole.

2.0 EQUIPMENT AND MATERIALS

Equipment and materials will vary by development method. Field personnel should use the equipment and materials required by the Work Plan or otherwise specified for the development method(s) selected for the project. All non-disposable equipment, including pumps, hoses, containers, and bailers, shall be decontaminated before and after introduction into wells. Equipment decontamination should be performed in accordance with SOP ENV-04-05 and/or requirements of the Site-Specific Work Plan.

3.0 HEALTH AND SAFETY WARNING

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 DEVELOPMENT METHODS

4.1 Air Lifting

The airlift method involves pumping compressed air down an eductor pipe placed inside the well casing. Due to its inert characteristic, nitrogen is the preferred gas for air lifting. Pressure is applied intermittently and for short periods causing the water to surge up and down inside the casing. Once the desired surging is accomplished, continuously applied air pressure should be used to blow water and suspended sediments upward and out of the well.

The use of standard air for well development may impact permeability of the formation surrounding the well screen and groundwater quality. Considerable care must be exercised to avoid injecting air directly through the well screen. Air can become trapped in the formation materials outside the well screen and affect subsequent chemical analyses of water samples and hydraulic conductivity measurements. The bottom of the air pipe should not be placed below the top of the screened section of casing.

Another restriction of the use of air is the submergence factor. The submergence factor is defined as the height of the water column above the bottom of the air pipe (in feet) divided by the total length of the air pipe. To result in efficient airlift operation, the submergence factor should be at least 20 percent. This may be difficult to achieve in shallow monitoring wells or wells that contain small volumes of water.

4.2 Surging or Plunging

A surge block is a round plunger with pliable edges (constructed of a material such as rubber belting) that will not catch on the well screen. Moving the surge block forcefully up and down inside the well screen causes the water to surge in and out through the screen accomplishing the desired cleaning action. The amount of pressure generated by the surging must be closely monitored to prevent cracking of the well casing or screen.

A well slug may also be used to create a surging effect through the filter pack and formation. A slug consists of a PVC rod or pipe (with capped ends) sufficiently weighted to rapidly sink in water. The slug is alternately lowered into and retrieved from the water in the casing to create a water level differential that induces flow into or out of the well to accomplish the desired cleaning action. This method is less aggressive than using a surge block. For shallow wells or wells in which the water column in the casing is small, care must be exercised when lowering the slug so as not to drive the slug into the bottom of the casing or against the screens.

4.3 Bailing or Pumping

Bailers may be used for development of low-yielding wells or wells with a significant amount of sediment (approximately 10% in the well screen) to remove excess sediment. A bailer that is heavy enough to sink rapidly through the water can be raised and lowered through the water column to produce the surging action that is similar to that caused by a surge block or well slug. The bailer, however, has the added capability of removing turbid water and fines each time it is brought to the surface. Bailers are very useful for developing shallow and slow yielding wells. As with surge blocks, it is possible to produce pressure great enough to crack PVC casing. Bailers are the simplest and least costly method of developing a well, but are time-consuming.

Pumping can be used effectively in wells where recharge is rapid. The pump may be used to back flush and overpump (at rates that exceed purging and sampling rates) water in and out of the well screen. The type and size of the pump used is contingent upon the well design. Pumps also allow removal of turbid water and fines. However, pumps are more difficult to decontaminate than a bailer is.

5.0 EXECUTION

The following procedures shall be adhered to unless well development requirements are otherwise specified in the Site-Specific Work Plan:

1. Measure the depth to groundwater in accordance with the guidelines described in SOP ENV-08-02. The standing water volume (V) in the well to be developed shall be calculated using one of the following formula in accordance with the Site-Specific Work Plan:

   Borehole Volume Calculation

   $V = nA (B - C) + CD$

   Where, n = porosity of the filter pack;
   A = height (in feet) of the saturated filter pack;

B = volume (in gallons per foot) of water in the borehole (see Table below);
C = volume (in gallons per foot) of water in the well casing (see Table below); and
D = height of standing water column (in feet) in the well.

Well Volume Calculation

V = CD

Where, C = gallons per foot of water in the well casing (see Table below); and
D = height of standing water column (in feet) in the well.

Diameter-Specific Volume Per One Foot of Casing/Borehole				
Diameter (Inches)	**Volume Per Foot of Casing/Borehole (Gallons)**		**Diameter (Inches)**	**Volume Per Foot of Casing/Boring (Gallons)**
0.25	0.0026		4.0	0.6528
0.50	0.0102		6.0	1.469
0.75	0.0230		8.0	2.611
1.0	0.0408		10.0	4.081
2.0	0.1632		12.0	5.876

2. Measure water quality parameters immediately prior to and during well development at a minimum frequency of once per well volume removed in accordance with SOP ENV-08-03. The water quality parameters should generally include pH, specific conductance and/or actual conductivity, temperature, dissolved oxygen, and turbidity, unless otherwise specified in the Work Plan. Record water quality parameters, as well as visual turbidity and evidence of impact (e.g. free phase product, sheen, odors, etc.) observations in the field logbook and/or on the appropriate field form.
3. Remove 10 standing water volumes or the volume required to achieve water quality parameter stabilize and visual clarity is achieved, whichever is less. A well that will not yield sufficient volume must be slowly bailed or pumped, allowed to recover to within 90% of the pre-development standing water volume, and then slowly bailed or pumped a second time, with a maximum of five purge periods. The criteria for parameter stability are summarized below.

4. Increase the minimum development water volume when drilling water and/or fluids are lost prior to well development. This additional purge volume shall be at least three times the volume of lost fluid.

Water Quality Parameter	Stability Criteria[1]
pH	+/- 0.1 Std. Units
Temperature	+/- 0.1°C
Specific Conductance or Actual Conductivity	+/- 3% microsiemens/cm
Dissolved Oxygen	+/- 0.3 milligrams/Liter
Turbidity	<10 NTUs or + 10% when turbidity is greater than 10 NTUs and/or visually clear water

5. Containerize development water in approved, labeled containers (e.g. 55-gallon drums, polyethylene storage tanks, baker tanks, etc.) as required by the Site-Specific Work Plan or otherwise specified.

6.0 DOCUMENTATION

Well development activities will be documented in the field logbook and/or appropriate field form included in Appendix B of the FSP, describing the procedures used and any significant occurrences that are observed during development such as apparent recharge rates in the well, condition of the groundwater, and organic vapor readings. Well development data including the depth to static water, standing water volume in the well, standing water volume calculations, total volume of water removed, number of well volumes removed, and water quality parameters will be recorded in the field logbook and/or on the field activity form (Appendix B of the FSP).

7.0 REFERENCES AND ADDITIONAL RESOURCES

USEPA, April 1992, Monitoring Well Development Guidelines for Superfund Project Managers, Office of Solid Waste and Emergency Response, http://www.epa.gov/tio/tsp/download/welldevelp.pdf.

USEPA, 2002, Ecological Assessment Standard Operating Procedures and Quality Assurance Manual, SESD, Region 4, Ecological Assessment Branch, Athens, Georgia.

[1] USEPA, May 2002, Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers, Revision 2, EPA/542/S-02/001.

USEPA, May 2002, Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers, Regions 5 and 10, EPA/542/S-02/001.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

Author:	**T. Gilles**	**Q2R & Approval By:**	**C. Barry**	**Q3R & Approval By:**	**M. Kelley**

STANDARD OPERATING PROCEDURE NO. SAS-05-05

BOREHOLE AND WELL ABANDONMENT Revision 2

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for borehole and well abandonment. When boreholes and wells are no longer needed to complete project goals and objectives, they must be properly abandoned to prevent them from acting as a conduit for migration of contaminants from the ground surface to the water table or between transmissive zones.

2.0 EQUIPMENT AND MATERIALS

Equipment and materials may vary based on borehole and well accessibility and depth and well construction. Field personnel should use the equipment and materials required by the Site-Specific Work Plan or otherwise specified for the project. All non-disposable equipment shall be decontaminated before and after introduction into borehole or well. Equipment Decontamination should be performed in accordance with SOP SAS-04-05 and/or requirements of the Site-Specific Work Plan.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 CONSIDERATIONS

Borehole and well abandonment procedures should meet applicable regulatory agency requirements. In addition, licensing and/or certification of the driller may be required. A trained supervising technician (e.g. geologist, hydrogeologist, engineer, or environmental scientist) should be present during well abandonment to document the activities. The supervising technician should complete and submit a well abandonment form, if required, to the appropriate regulatory agency. Attachment A contains the Illinois Department of Public Health Water Well Sealing Form as an example. If wells are abandoned in other states, the relevant forms and procedures shall be implemented.

5.0 EXECUTION

Unless otherwise specified in the Site-Specific Work Plan, the following guidelines shall be followed. The preferred well abandonment method is to completely remove the well casing and screen from the borehole. This may be accomplished by auguring with a hollow-stem auger over the well casing down to the bottom of the borehole, thereby removing the grout, bentonite seal, and filter pack from the hole. The well casing shall be then removed from the borehole with the drill rig. The remaining borehole and boreholes not utilized for the construction of a monitoring well, is subsequently backfilled with the appropriate backfill material. The backfill material (e.g. bentonite, Portland cement, etc) shall be placed into the borehole from the bottom to the top by pressure grouting with the positive displacement method (tremie method) to within 30 inches of the ground surface. . The annular space shall be filled with bentonite chips, grout, or granules to at least 30 inches bgs unless land use requires a design modification to use native material (gravel, soil, etc.) or material in adjacent areas (asphalt, concrete, etc.) to bring the former well location to grade. If the area has heavy traffic and/or construction use, the location will be barricaded until the plug has cured or concrete plug recessed below ground surface will be used to maintain the surface seal. This abandonment method can typically be accomplished on small-diameter wells (4-inches or less in diameter) without much difficulty.

The use of hollow-stem augers for casing removal on large-diameter wells (diameter greater than 4-inches) typically ranges from very difficult to almost impossible. On large-diameter wells with little to no grout, a drill stem with a tapered wedge assembly or solid-stem auger should be used to ream out the borehole and extract the well materials. Wells that are badly corroded and/or have thickly grouted annular space have a tendency to twist and/or break off in the borehole. Should this occur, the well would be grouted with the remaining casing left in the borehole. In this case, the well and borehole shall be pressure grouted by placing a tremie pipe in bottom of the well casing, which will be the well screen or bottom sump area below the well screen. The pressurized grout will be forced out through the well screen into the filter pack and up the inside of the well casing sealing holes and breaks that are present. The tremie pipe shall be retracted slowly as the grout fills the casing. The annular space shall be filled with bentonite chips, grout, or granules to at least 30 inches bgs. The well casing shall then be cut off at least 30 inches below. Native material (gravel, soil, etc.) or material in adjacent areas (asphalt, concrete, etc.) may be used to bring the former well location to grade. If the casing has been broken off below the surface, the grout shall be tremied to within 30 inches of the ground surface and then finished similar to the surrounding features.

Brittle polyvinyl chloride (PVC) well casings may be more difficult to remove from the borehole than stainless-steel casings. If the PVC well casing breaks during removal, the borehole shall be cleaned out by using a drag bit or roller cone bit with the wet rotary method to grind the casing into small cuttings that will be flushed out of the borehole by the drilling fluid. Another method is to use a solid-stem auger with a carbide auger head to grind the PVC casing into small cuttings that will be brought to the surface by the rotating flights. After the casing materials have been removed from the borehole, the borehole shall be cleaned out and pressure grouted with the approved grouting materials. As previously stated, the borehole shall be finished with a concrete surface plug or site-specific surface restoration material with adequate surface protection, unless otherwise directed or required by the Site-Specific Work Plan.

6.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, 2005, D5299-99 (2005) Standard Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities.

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual, Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

ATTACHMENT A
BOREHOLE / WELL ABANDONMENT FORM

BOREHOLE / WELL ABANDONMENT FIELD FORM

PROJECT INFORMATION

Site: ______________________ Client: ______________________

Project Number: ____________ Task #: __________ Start Date: ____________ Time: ________

Field Personnel: ______________________ Finish Date: ____________ Time: ________

GENERAL INFORMATION

Ownership (Controlling Party): ______________________

Street Address: ______________________

City: ______________________

County: ______________________

State: ______________ Zip: __________

Township: ________ Range: ________ Section: ________

________ 1/4 of the ________ 1/4 of the ________ 1/4

If Known, Latitude: ____________ Longitude: ____________

If Known*, Northing: ____________ Easting: ____________

*Coordinate System: ______________________

Reason for Abandonment:

Permit Number (If applicable): ______________________

BOREHOLE / WELL INFORMATION

Borehole / Well ID: ____________

Unique Well ID:

Installation Date: ____________

☐ Borehole

☐ Monitoring Well

☐ Water Well

Attach Well Completion Report, if available

☐ Other (specify): ______________________

Construction Type:

☐ Drilled ☐ Driven (Sandpoint)

☐ Other (specify): ______________________

Formation Type:

☐ Unconsolidated Materials ☐ Bedrock

Borehole/Well Details:

Borehole Diameter: ________ Inches

Total Borehole Depth: ________ FT BGS

Casing Diameter: ________ Inches ☐ Not Applicable

Total Casing Depth: ________ FT BGS ☐ Not Applicable

Depth to Water: FT BGS ☐ Not Encountered

SEALING INFORMATION

Pump & Piping Removed? ☐ Yes ☐ No ☐ Not Applicable

Liner(s) Removed? ☐ Yes ☐ No ☐ Not Applicable

Screen Removed? ☐ Yes ☐ No ☐ Not Applicable

Entire Casing Removed? ☐ Yes ☐ No* ☐ Not Applicable

If No, Upper 2 feet Removed? ☐ Yes ☐ No

Method of Sealing Material Placement:

☐ Conductor Pipe - Gravity ☐ Tremie Pipe - Pumped

☐ Screened & Poured ☐ Other (specify): ____________

Sealing Material Rose to Surface? ☐ Yes ☐ No

Material Settled After 24 Hours? ☐ Yes* ☐ No

*If Yes, Was Hole Re-Topped? ☐ Yes ☐ No

Sealing Material Used	From	To	Volume/Quantity
	Surface		

SEALING WORK PERFORMED BY

Individual's Name: ____________

License Number:

Company Name: ____________

Street Address: ____________

City: ____________ State: ________ Zip: ________

Author:	T. Gilles	Q2R & Approval By:	C. Barry	Q3R & Approval By:	M. Kelley

STANDARD OPERATING PROCEDURE NO. SAS-05-06

TEST PIT EXCAVATION, LOGGING AND SAMPLE COLLECTION Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for conducting test pit excavation, logging and sample collection as described in the Site-Specific Work Plan, or as otherwise specified, for the purposes of characterizing subsurface conditions at the site.

2.0 EQUIPMENT AND MATERIALS

- General:
  - Excavator or backhoe;
  - Metal shovel;
  - Spray paint or survey lathe and tape;
  - Visquene sheeting;
  - Tape measure in 0.01-foot increments;
  - Field logbook and field boring log forms;
  - Pen(s) with waterproof, non-erasable ink;
  - 5-gallon bucket and wire or nylon brushes, decontamination water, laboratory grade detergent (Alconox or similar), and paper towels;
  - Aluminum foil or roll-plastic wrap;
  - Stakes and fluorescent flagging tape;
  - Camera; and
  - Personnel protective equipment, as appropriate.
- Soil Logging:
  - Knife, spatula, carpenter's 5-in-1 tool or similar cutting tool;
  - Soil color chart;
  - Comparative charts; and

- Pocket penetrometer.
- Soil Sampling:
    - Sample containers and labels;
    - Sample cutting/extracting equipment (scoops, trowels, shovels, hand augers);
    - Metal mixing bowls;
    - Coolers and ice;
    - Chain of custody forms;
    - Custody seals;
    - Gallon size sealable plastic bags; and
    - Clear plastic packaging tape.

3.0 HEALTH AND SAFETY WARNING

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 GENERAL PROCEDURES

Test pit procedures shall be conducted only by a trained logging technician. Subsurface utilities shall be cleared prior to mobilization to the site in accordance with SOP ENV-05-01. Field data and observations associated with test pit activities shall be documented in accordance with SOP ENV-01-01, if not otherwise specified in this SOP. All test pit excavation activities should be recorded in a field logbook and/or on a test pit excavation field form. In addition, equipment used while logging shall be decontaminated between test pit locations in accordance with the SOP ENV-04-05 or as otherwise specified in the Quality Assurance Project Plan (QAPP) and/or Site-Specific Work Plan.

5.0 DOCUMENTATION PROCEDURES

The field technician shall record all pertinent excavation information in the field logbook and/or on the appropriate field form. At a minimum, the following technical information with respect to excavation operations and observations shall be recorded, if applicable:

- Project name and number;
- Location (e.g. test pit number) or other sample station identification, including a rough sketch;
- Name of the logging technician overseeing the excavation operations;
- Excavating equipment manufacturer and model;
- Excavating company name and city and state of origin;
- Equipment operator and assistant(s) names;
- Excavation start time and date;
- Excavation completion time and date;
- Excavation dimensions (length and width, and depth)
- Description of soil and/or rock classification and lithology;
- Lithologic changes and boundaries;
- Depth to water first encountered during excavation
- Depth to stabilized water level following excavation
- Sample identifications; depths and time collected for chemical and geotechnical samples;
- Evidence of impact (e.g. staining, odors, free-phase product, etc.); and
- Problems with the excavating equipment or process.

6.0 TEST PIT EXCAVATION PROCEDURES

- Identify the test pit locations and mark limits of excavation using spray paint or survey lathe and tape.
- Confirm absence of subsurface utilities in the test pit excavation areas. If subsurface utilities are present in test pit location, contact the project manager to discuss alternative locations for test pit.

- Lay visquene sheeting to be used for soil stockpiling on ground next to test pit location and secure in place. If topsoil is present, it may be stockpiled separately for restoration of ground surface when test pit is completed.
- Begin excavation making shallow cuts of 6 inches to 1 foot to allow descriptive logging of soil and soil transitions. Stockpile soil on visquene sheeting.
- Sketch the development of the test pit in the field notebook. Complete vertical profiles at multiple locations along the length of the test pit if variation of subsurface materials occurs along the length. Sketch a cross section of the longitudinal length of the test pit.
- Record physical characteristics of the material excavated including Unified Soil Classification System (USCS) soil type, litho logy, color, odor, moisture, structures, foreign objects and observations of environmental impacts in the field logbook or field form. Follow soil description, classification, and visual observations of affected soil procedures provided in SOP ENV-05-02.
- Take photographs to document excavation and log photographs in the field logbook or on the field form.
- If soil samples are required for chemical or geotechnical analysis, collect samples from the base or side walls. If the test pit depth has unsafe conditions (deeper than can be safely accessed, unstable walls, or other safety concerns), collect samples directly from the excavation bucket or soil stockpile. Samples will be collected as soon as possible to minimize potential volatilization from soil in the bucket of the excavator or soil stockpile. Have communication signals set up with excavator operator and/or other subcontractor personnel to indicate that a soil sample will be taken so that the equipment can be stopped for safe sample retrieval. Do not at any time go into the test pit.
- Soil samples shall be collected in accordance with SOP ENV-06-01. Decontaminate sampling equipment between each sample collected in accordance with SOP ENV-04-04. Samples shall be prepared for analysis in accordance with SOP ENV-03-01.
- Once the excavation is complete, record the depth, length and width of the excavation in the field logbook or on the field form.
- Backfill the test pit with the material excavated from the test pit unless other backfilling instructions are specified in the Site-Specific Work Plan. If topsoil was set aside for ground surface restoration, place it on top of the excavation area.
- Decontaminate excavator or backhoe bucket between each test pit in accordance with SOP ENV-04-04.

- Test pits must be backfilled before the end of the work day; no test pits shall be left open overnight.
- Replace markings for limits of test pit excavations if they are to be located by survey at a later date.

7.0 REFERENCES AND ADDITIONAL RESOURCES

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

Author:	**T. Gilles**	**Q2R & Approval By:**	**C. Barry**	**Q3R & Approval By:**	**M. Kelley**

STANDARD OPERATING PROCEDURE
NO. SAS-05-07

TEST PIT BACKFILLING AND COMPACTION
Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for backfilling and compacting test pits. When test pits are no longer need to complete project goals and objectives, they must be properly backfilled and compacted to minimize health and safety liabilities, prevent them from acting as a conduit for migration of contaminants, and return the location to pre-excavation conditions.

2.0 EQUIPMENT AND MATERIALS

Equipment and materials may vary based on test pit accessibility and depth. Field personnel should use the equipment and materials required by the Site-Specific Work Plan or otherwise specified for the project. All non-disposable equipment shall be decontaminated after introduction into the test pit. Equipment decontamination should be performed in accordance with SOP ENV-04-04 and/or requirements of the Site-Specific Work Plan.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 CONSIDERATIONS

The preference for test pit backfilling is generally to return excavated materials to the test pit in the order in which they were excavated. However, the presence of suspected contaminants may require another source of backfill material. The selection of backfill material will be based on several factors, including but not limited to, concentrations of contaminants in excavated materials, test pit location (e.g. street, landscaped area, etc.), subsurface site features, ability to mechanically compact backfill materials, engineering evaluations, health and safety concerns, and access agreements. If the test pit extends below the water table, 3-inch stone shall be used to backfill the excavation to the top of the water table. Backfill material(s) will be specified in the Site-Specific Work Plan. The excavation area shall be returned to pre-excavation conditions or as otherwise specified in the Site-Specific Work Plan, applicable permit(s), and/or access agreement(s). As necessary, a qualified engineer will be consulted prior to selection of backfill and compaction material(s), equipment and method(s).

5.0 BACKFILLING AND COMPACTION

5.1 Trench Box Methods

The test pit excavated using a trench box will be backfilled, as the trench box is systematically raised, to ground surface. Care will be taken to minimize bridging as the backfill is placed. When test pit excavations exceed 4 feet in depth and self-compacting backfill material is not used, the backfill material will be placed in lifts and compacted using the excavator bucket, excavator track/wheel, or vibratory plate compactor or as specified in the Site-Specific Work Plan, applicable permit(s), and/or access agreement(s).

5.2 End Dump Methods

Test pits excavated without a trench box could be backfilled using end dump methods. When test pit excavations exceed 4 feet in depth and self-compacting backfill material is not used, the backfill material will be placed in lifts and compacted using the excavator bucket, excavator track/wheel, or vibratory plate compactor or as specified in the Site-Specific Work Plan, applicable permit(s) and/or access agreement(s).

6.0 REFERENCES AND ADDITIONAL RESOURCES

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

SOP SERIES SAS-06

SOIL SAMPLING AND MEASUREMENT PROCEDURES

Author: T. Gilles Q2R & Approval By: C. Barry Q3R & Approval By: M. Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-06-01

SOIL SAMPLING FOR CHEMICAL ANALYSES AND GEOTECHNICAL TESTING
Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for obtaining surface and subsurface soil samples as stated in the Site-Specific Work Plan or as otherwise specified. Soil sampling is conducted for the purpose of chemical analyses and geotechnical testing to evaluate surface and subsurface conditions.

2.0 EQUIPMENT AND MATERIALS

In addition to materials provided by a subcontractor, the field personnel should have the following:

- Sample bottles/containers and labels;
- Sample cutting/extracting equipment (scoops, trowels, shovels, hand augers);
- Field logbook and/or the appropriate field form(s);
- Depth and length measurement devices with 0.01-foot measurement units;
- Camera;
- Stakes and fluorescent flagging tape;
- Decontamination materials;
- Coolers and ice;
- Chain of custody forms;
- Custody seals;
- Gallon size sealable plastic bags;
- Clear plastic packaging tape; and
- Personal protective equipment.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 SAMPLE TYPE, METHOD, AND EQUIPMENT SELECTION

4.1 Preparation

Site-Specific Work and/or Field Sampling Plans (FSP) which involve soil sampling shall be carefully conceived with respect to data quality objectives (DQOs) and cost effectiveness. Soil samples shall be strategically located to collect a representative fraction of soils with the minimum number of samples. To facilitate complete and successful sampling efforts by minimizing uncertainties with respect to site characterization the following factors shall, at a minimum, by considered during preparation activities:

- Project goals and DQOs;
- Location and duration of historical property uses (if available);
- Location and duration of current property uses;
- Chemical properties of contaminants of potential concern (COPCs);
- Anticipated location(s) of COPCs (e.g. surface, subsurface, etc.);
- Anticipated geologic conditions including presence and elevation of groundwater;
- Site accessibility; and
- Results of previous site reconnaissance and investigations (if available).

4.2 Field Considerations

Field personnel shall review and be familiar with Site-Specific Work and/or FSPs prior to commencement of sampling activities. Field personnel will also facilitate complete and successful sampling efforts by calibrating and operating field instruments/meters used for sample media screening in accordance with SOP ENV-02-01. In addition, field personnel shall be cognizant of the following during investigative activities:

- Indications of COPCs not previously anticipated;
- Evidence (e.g. visual, olfactory, etc.) of COPCs in locations not previously anticipated;
- Geologic conditions not anticipated;
- Changes in site accessibility; and
- Meteorological conditions (e.g. high humidity, rain, etc.) that have the potential to negatively impact operation and performance of field screening instruments, and sample quality.

Field personnel shall notify the Project Manager when field conditions and observations deviate from those anticipated during sampling event preparations. The Project Manager shall approve any deviation from the Work and/or Sampling Plans prior its occurrence. Deviations and approval to deviate from Site-Specific Work and/or FSPs shall be documented in the field logbook and/or on the appropriate field form by the field personnel.

5.0 SAMPLE TYPES

5.1 Grab Samples

Grab samples are collected to identify and quantify compounds at a specific location or interval. Grab samples are limited in areal and vertical extent. A grab sample shall be comprised of no more than the minimum amount of soil necessary to obtain the volume of sample dictated by the required sample container.

5.2 Composite Samples

Composite samples are a mixture of a given number of sub-samples/aliquots and are collected to characterize the average composition of a given surface area, vertical interval, etc. The number of sub-samples/aliquots forming a composite sample shall remain consistent with the context of the investigation. The number and pattern for collection of sub-samples/aliquots within a grid, interval, etc. shall be selected based on project goals and DQOs and shall not change. Composite sampling is associated with two potential interferences:

1. Low concentrations, if present in individual sub-samples/aliquots, may be diluted to the extent that the total composite concentration is below the analytical reporting limits.
2. Sub-samples/aliquots that are predominantly moist clay can be difficult to composite to produce a homogenous mixture. The resulting sample, as represented by the portion selected by the analytical chemist, may not be representative of an average of all the sub-samples/aliquots.

6.0 SAMPLING METHOD

6.1 Random

Random sampling removes the subjective collection of samples based on personal judgment. Soil samples are typically selected from all investigation area(s) when a suspected area of contamination is unknown. Generally, this method is utilized with site screening investigations when there is no strong indication of contamination or distinct depositional areas are present that provide excellent screening samples.

6.2 Biased

Biased sampling involves the collection of samples based on evidence of contamination (e.g. staining, stressed vegetation, elevated field screening results, etc.). Background and control samples are also considered biased, since they are collected from locations anticipated to be impacted or expected to be clean.

6.3 Grid-Based

Grid-based sampling involves the systematic collection of samples based on the size and configuration of an area. This approach is used to characterize the presence and distribution of contaminants and is commonly utilized for large areas. Grid size will be selected during the preparation phase and shall be specified in the Work or Sampling Plan. Common grid sizes shall be developed based on the size and configuration of the area, project goals, and DQOs. It may be appropriate and acceptable to integrate several different grid sizes in a single investigation.

When a Site is extremely large (typically over several acres), it may not be practical and cost-effective to consider sampling every grid. In this case, it will be necessary to statistically select a sub-set of the total number of grids in order to reduce the number of samples collected. On the other hand, it may be more appropriate to use relatively inexpensive screening level analytical techniques to define the areas that will need to be sampled and analyzed for a higher level of data quality. In all cases, grid points shall be located using a site survey and shall be semi-permanently marked to facilitate relocating the sample locations for subsequent sampling.

7.0 SAMPLING EQUIPMENT AND PROCEDURES

7.1 Manual Sampling

In general, hand sampling using manually operated equipment is a quick and inexpensive sampling technique for shallow depths when precise data or high quality control is generally not required. The most common hand-operated samplers are hand augers, plugs, tubes, split-barrel or fixed piston samplers that are pushed or driven by hand.

Hand augers are easily used at depths less than 10 feet. The most commonly used, manually-operated hand augers include the ship, closed-spiral, and open-spiral augers. In operation, a hand auger shall be attached to the bottom of a length of pipe that has a cross-arm at the top. The hole shall be drilled by turning this cross-arm at the same time the operator presses the auger into the ground. As the auger is advanced and becomes filled with soil, it shall be taken from the hole, and the soil shall be removed. Additional lengths of pipe will be added as required to reach the sampling depth as required by the Site-Specific Work Plan or otherwise specified. Care shall be taken to prevent (to the extent possible) mixing of the soil from upper portions of the hole with lower samples. This is most likely to be a problem when augers are used to advance a hole and obtain samples from soil cuttings.

Pushed samplers can be used to obtain samples within about 3 feet of the surface or, with appropriate extensions, ahead of an augured hole. The sampler will be pushed to the desire depth by the operator. The pusher sampler shall be used with extension(s) and/or in combination with a hand auger to reach sample depths greater than 3 feet below ground surface. When the sampler becomes filled with soil, it shall be taken from the hole and the soil removed. Care shall be taken to prevent mixing of soil from upper portions of the hole with lower samples.

Because of the unpredictable operations that may have been used at many uncontrolled waste sites, sampling devices will never be forced into an abruptly hard material. The stiffness may be a natural lithology change, a rock ledge or cobble, or a buried drum. If resistance is encountered while auguring or pushing a sampler, the procedure will be stopped. The depth at which resistance was met should be recorded into the field logbook and/or on the appropriate field form.

7.2 Split-Spoon Sampler

The split-spoon sampler is a thick-walled steel tube that is split lengthwise. A cutting shoe is attached to the lower end of the barrel; the upper end contains a check valve and is connected to the drilling rods. When a boring is advanced to the point that a sample is to be taken, drill tools are removed, and the sampler is lowered into the hole attached to the bottom of the drill rods.

The split-spoon sampler is driven by a 140-lb hammer falling 30 inches. The split-spoon sampler shall be driven 18 inches into the ground or until 50 blows have been applied in a 6-inch increment, a total of 100 blows have been applied, or there is no observable advance of the sampler after 10 successive blows. The effort taken to drive the sampler shall be recorded at 6-inch intervals and the sampler shall be removed from the boring. The density of the sampled material shall be determined by summing the blow counts for the second and third 6 inches of penetration (“standard penetration resistance” or “N-value”) per ASTM D 1586-99. Only disturbed samples are obtained using this procedure.

The standard size split-spoon sampler is 2-inch outside diameter (OD), $1^{3}/8$-inch inside diameter (ID), and 24 inches long. When soil samples are taken for chemical analysis, a 2- or 2½-inch ID sampler shall be used to provide a larger volume of material, but cannot be used to calculate strength or density properties as stated in the ASTM D 1586-99 test method.

Upon retrieval, excess soil or drilling fluid shall be rinsed or wiped from the sampler’s exterior, the cutting shoe removed, and sampler broke open into the two halves. The sample shall be logged and classified in accordance with SOP ENV-05-03. Samples for chemical analyses and/or geotechnical testing shall be collected using the laboratory-approved and analytical-method required sample containers. The sampler tube shall then be decontaminated. The split-spoon sampler shall be decontaminated between sample intervals in accordance with SOP ENV-04-05.

Liner tubes or sleeves may be incorporated in certain samplers to contain samples temporarily. The liner tubes may be constructed from brass, plastic, or other inert materials used to store and transport the samples. If a sample is to be stored in the liner tube, the tube ends shall first be covered with Teflon film, followed by a plastic slip cap. On each sample end, the Teflon film shall be trimmed, and the cap sealed with vinyl tape to the liner tube. If the sampler is not to be stored in the liner, it will be transferred from the sampler to the appropriate sample container using either the liner tube or a stainless steel or plastic spoon or spatula.

When taking samples for geotechnical testing, the disturbed soil samples shall be removed from the sampler are placed in a sealable glass jar or other containers approved by the geotechnical laboratory and labeled to indicate the project name and number, boring number, sample number, and depths at top and bottom of the sample interval. This information shall be marked on the jar lid using a permanent marker. Other information required by the Site-Specific Work and/or FSP shall be recorded in the field logbook and/or on the appropriate field form.

7.3 Continuous Core Barrel Sampler (CME-Type)

A continuous core barrel sampler (CME-Type) is 5 feet long and fits inside the lead auger of the hollow-stem auger column. The sampler retrieves a 5-foot section of partially disturbed soil samples. The sampler assembly consists of either a split barrel or solid barrel that can be used with or without liners. The split-barrel sampler is most commonly used because it is easier to access and remove the core samples. The core barrel sampler takes the place of the pilot bit, thereby reducing sampling time. The sampler is most efficient in clays, silts, and fine sand.

The sampler shall be attached to the drill rod and locked in-place inside the auger column. The open end of the sampler shall extend a short distance ahead of the cutting head of the lead auger. The hollow-stem auger column shall be advanced 5 feet while the soil enters the non-rotating core sampling barrel. The barrel shall then be retrieved with the drill rod, and the core extruded from the sampler. The sample shall be logged and classified in accordance with SOP ENV-05-03. Samples for chemical analyses and/or geotechnical testing shall be collected using the laboratory-approved and analytical-method required sample containers. The sampler tube shall then be decontaminated in accordance with SOP ENV-04-05.

7.4 Thin-Walled (Shelby) Tube Samplers

Thin-walled samplers, such as a Shelby tube, should be used to collect relatively undisturbed samples of soil from borings. The samplers are constructed of steel tubing about 1 to 3 mm thick, depending upon its diameter. The lower end has a tapered cutting edge. The upper end is fastened to a sample head adapter with a check valve to help hold the sample in the tube when the tube is being withdrawn from the ground. Thin-walled tube samples are obtained by any one of several methods including pushed-tube, Pitcher sampler, Denison sampler, and piston sampler methods.

In obtaining pushed-tube samples, the tube shall be advanced by hydraulically pushing it in one continuous movement with the drill rig. At the end of the designated push interval and before lifting the sample, the tube shall be twisted to break the bottom of the sample. The tube shall be retrieved from the boring using the drill rig. One of two methods shall be employed for handling the sample once it is retrieved from the boring:

1. Extruding the sample from the sample tube in the field using an extruding device on the drilling rig, and subsequently handling and containerizing the specimen at the drilling site.
2. Leaving the sample in the sampling tube, preparing it for transportation, with subsequent extrusion and handling elsewhere.

A hydraulic extruder shall be used in all cases to minimize disturbance. To extrude the sample from the tube, the tube shall be connected to the extruding device in the appropriate fashion for that type extruder. Some extruding devices push the sample in the same direction that the sample entered the tube, pushing out the top, while others push it out the bottom. It does not matter for environmental sampling, but the orientation of the sample shall be known and kept clear by the sampling personnel. The sample shall be caught on a split section of PVC pipe lined with polyethylene sheeting or aluminum foil. Waxed paper will not be used. Drilling fluids shall be carefully poured off and cuttings or slough material at the top end of the sample raked away, leaving only the true sample interval. The sample shall be transferred to a cutting board by lifting with the poly/sheeting or aluminum foil and length of the sample shall be measured. The sample shall be logged and classified in accordance with SOP ENV-05-02. Samples for chemical analyses and/or geotechnical testing shall be collected using the laboratory-approved and analytical-method required sample containers. The sampler tube shall then be decontaminated in accordance with SOP ENV-04-04.

Shelby tubes will not be reused for subsequent sampling intervals. A sufficient number of decontaminated sampling tubes shall be brought to the sampling location to complete the required scope of work and protected from being contaminated before use.

7.5 Cuttings or Wash Samples

Drill cuttings or wash samples may be taken as the boring is advanced. A stainless steel or plastic scoop shall be used to obtain a sample from the cuttings pile. The shovel used by drilling personnel to move cuttings shall be stainless steel. The sample shall be logged and classified in accordance with SOP ENV-05-02. Samples for chemical analyses and/or geotechnical testing shall be collected using the laboratory-approved and analytical-method required sample containers. The sampling equipment shall then be decontaminated in accordance with SOP ENV-04-04.

7.6 Test Pit Excavation and Sampling

Test pits, including trenches, consist of open shallow excavations used to determine the subsurface conditions for engineering and geological purposes. Test pits are typically conducted for subsurface characterization and to investigate underground structures that may contain impacts. Test pits shall be excavated manually or by machine (e.g. backhoe, bulldozer, or trackhoe), as required by the Site-Specific Work Plan or otherwise specified, and will be in accordance with OSHA regulations, 29 CFR 1926, 29 CFR 1910.120, and 29 CFR 1910.134. Test pit shall be logged and classified in accordance with SOP ENV-05-06.

Soil samples shall be collected from the backhoe/trackhoe bucket or directly from the wall or base of the test pit, depending on the depth of the pit. Disturbed samples shall be collected using a stainless steel scoop, shovel, or trowel. Undisturbed samples shall typically be collected using a hand auger and/or other coring tool. Samples for chemical analyses and/or geotechnical testing shall be collected using the laboratory-approved and analytical-method required sample containers. The sampling equipment shall then be decontaminated in accordance with SOP ENV-04-04.

7.7 Surface Soil Sampling

Surface soil samples are collected to determine the surface soil conditions. Surface soil samples are generally collected at depths of less than 1 to 3 feet below the ground surface or as defined in SSWPs, considering DQOs. The use of discrete or composite samples will be determined in the SSWPs.

Before sample collection, all surface materials (i.e., excess gravel, vegetation, etc.) shall be removed from the sample location. Soil samples shall be collected using a stainless steel scoop, trowel, hand auger, or other equipment as required by the Site-Specific Work Plan or otherwise specified. Samples for chemical analyses and/or geotechnical testing shall be collected using the laboratory-approved and analytical-method required sample containers. The sampling equipment shall then be decontaminated in accordance with SOP ENV-04-04. The sample appearance, depth, and location should be recorded in the field logbook and/or on appropriate field form using the standardized descriptions in SOP ENV-05-03, Attachment E.

8.0 ANALYTICAL SAMPLE PREPARATION

Sections of the sample representative of the entire sampling interval shall be selected for chemical analyses and/or geotechnical testing. Based on analytical requirement and contracted laboratory specifications, chemical analysis samples shall be placed in appropriate sample containers. Specific analytical sample preparation procedures are as follows.

- Using a decontaminated sampling instrument, remove the desired thickness and volume of from the sample retrieval device.
- Conduct a direct screening of the sample with a photoionization detector (PID).
- Visual observations of affected soil will use the descriptors from SOP ENV-05-02 Attachment E.
- Describe and classify the sample in accordance with SOP ENV-05-02, Field Logging of Soil and Rocks.
- **Volatile Organic Compounds (VOCs) –** Discrete soil samples for VOC analyses will be collected as soon after sample retrieval as possible. Unless otherwise specified, soil samples for VOC analyses shall be collected by either Powerstop Handle^{TM} or EnCore^{TM} sampler methods in conformance to USEPA

Method 5035 requirements. Attachment A presents procedures for Powerstop Handle™ and EnCore™ sample collection. Secure container lid, apply label containing sample identification information and place in cooler with ice.

- **Semivolatile Organic Compounds (SVOCs), Metals, Cyanide, PCBs, Pesticides, Herbicides, and Organic Carbon –** Soil samples for these analytes will be collected after collecting VOCs. Place soil in a container for homogenization. Samples will be homogenized using clean stainless steel mixing bowls, spoons, knifes, etc. Sample aliquots will be placed directly from the sample retrieval device into the stainless steel bowl. The soil will be thoroughly mixed in the bowl to homogenize the sample and then placed directly into appropriate sample containers. Secure container lid, apply label containing sample identification information and place in cooler with ice.
- **Physical Characteristics –** For geotechnical testing of cohesive samples, cut minimally disturbed sections of the specimen and place it in the appropriate sample container. Samples for geotechnical testing, including Shelby tubes shall be handled and packaged in accordance with standard practices for geotechnical investigations or as required by the Site-Specific Work Plan or otherwise specified. If contamination potentially exists, samples shall be identified as potentially containing hazardous or toxic chemicals.
- Samples shall be identified, labeled, documented and prepared for transport in accordance with SOP ENV-03-01, Sample Identification, Labeling, Documentation and Packaging for Transport.
- SOP ENV-03-2 Chain-of-Custody procedures shall be followed in preparing the samples for transport to the analytical laboratory.
- Sampling equipment and tools shall be decontaminated between each sample in accordance with SOP ENV-04-05.

Containerize any investigation-derived solid and liquid waste, including decontamination water, label and store for disposal at an appropriate disposal facility. Consult with Project Manager regarding disposal of waste.

Samples should be preserved and holding times should be observed according to analytical requirements and laboratory specifications, as required by the Site-Specific Work and/or FSPs, or as otherwise specified. If replicate or split samples are required, adjust the sections so that the additional samples are essentially identical.

9.0 DOCUMENTATION

Sample identification, labeling, and custody control shall be performed in accordance with requirements specified in SOP ENV-03-01 and ENV-03-02. Specific procedures for describing the samples and logging subsurface soil samples are presented in SOP ENV-05-03. Soil sampling activities shall be recorded in the field logbook and/or on the appropriate field form as specified in SOP ENV-01-01 or as required by the Site-Specific Work Plan.

10.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, 1999, D1586-99 Standard Method for Penetration Test and Split-Barrel Sampling of Soils.

ASTM International, 2000, D4220-95 (2000) Practices for Preserving and Transporting Soil Samples.

ASTM International, 2004, D5730-04 Guide for Site Characterization for Environmental Purposes with Emphasis on Soil, Rock, the Vadose Zone, and Ground Water.

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual, Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

ATTACHMENT A
ENCORE™ AND POWERSTOP HANDLE™ SAMPLING PROCEDURES

ENCORE™ SOIL SAMPLING PROCEDURE

- Remove EnCore™ sampler and cap from its re-sealable pouch and attach T-handle to sampler body. (**Note**: when dealing with soft or sandy solid, it may be necessary to retract the plunger in the sampler before sample collection.)
- Using the T-handle for leverage, push the sampler into a freshly exposed surface of soil until the sampler is full.
- Brush any soil off the sampler head and securely attach the sampler cap by pushing with a twisting motion.
- Complete the sample label and attach to the sampler body; place labeled sampler in its re-sealable pouch and seal the pouch.
- Repeat the procedure for two additional samples collected from the same soil stratum or the same area. (**Note:** this step may be eliminated or the number of samples reduced if the suspected level of VOCs is known [i.e., low or high concentration sample]. Consult method 5035 or discuss procedure with an analytical laboratory for further details.)
- Use a stainless steel spoon or similar tool to collect an additional sample from the same soil stratum or the same area. Place collected material in a 2-ounce, wide-mouth jar with no preservatives. (**Note:** this additional soil volume is for dry weight and percent moisture determination. This step is not necessary if additional soil from the sample location is collected for other parameter analyses upon which dry weight and percent moisture will be determined.)
- Immediately place samples in a cooler with ice.

Ship EnCore™ samples (next day priority delivery) to the contract laboratory the day they are collected. Alternatively, arrange to have samples picked-up by the laboratory or delivered to the laboratory by field personnel within 24 hours of collection. These sample shipment or pickup timelines must be achieved to ensure the laboratory performs sample preservation or analysis within 48 hours of sample collection.

POWERSTOP HANDLE™ SAMPLING PROCEDURES

1. Load Sampling Device

Insert EasyDraw Syringe™ into the appropriate slot (5 or 10-gram heavy, 5 or 10-gram medium, 5 or 10-gram light or 13 gram position) on the Powerstop Handle™ device and remove end cap from syringe.

EPA Method 5035 Recommended 5-gram slot positions:

- Use the heavy position for dense clay;
- Use the light position for dry sandy soil; and
- Use the medium position for all others.

2. Collect Sample

Push EasyDraw Syringe™ into a freshly exposed surface of soil until the syringe is full. Continue pushing until the soil column inside the syringe has forced the plunger to the stopping pint. (**Note**: unlike other sample collection devices, there is no headspace air in the syringe to displace.) EasyDraw Syringe™ delivers approximately 5, 10, or 13 grams. Actual weight will be determined at the laboratory. No scale or balance required in the field.

3. Eject Sample Into Vial

Remove the syringe from the Powerstop Handle™ device and insert the syringe into the open end of 40-ml vial, and eject sample into pre-tared vial by pushing on the syringe plunger. Avoid getting dirt on the threads of the 40-ml vial. Cap vial immediately and put on ice. Sample must be received by within 48 hours of sampling if samples are not chemically preserved in the field.

Author:	T. Gilles	Q2R & Approval By:	A.Bazan	Q3R & Approval By:	M. Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-06-02

SOIL SAMPLING FOR MICROORGANISMS
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for the collection of soil samples for analysis of their microbial constituents. While samples are generally collected from uncontaminated soils, samples collected from contaminated soils may be used to evaluate the feasibility and/or progress of natural or enhanced biotreatment activities. This SOP shall be used in conjunction with SOP ENV-06-01 (Soil Sampling for Chemical Analyses and Geotechnical Testing), which describe general soil sample collection techniques.

2.0 EQUIPMENT AND MATERIALS

Any of the equipment used to collect surface or subsurface soil samples may be used to obtain a volume of soil from which a sub-sample can be extracted using sterile techniques for microbial analysis. A stainless steel spoon or trowel, as described in the following sections, shall be used to collect the sub-sample. Sample containers must be sterile. Wide-mouthed 500-mL Pyrex or polypropylene bottles with autoclavable screw caps, which have been autoclaved for 15 minutes at 250^{o}F and 15 psi or 530-mL sterile Whirl-pak® bags (Fisher Scientific Company) shall be used unless otherwise specified by the Work and/or Sampling Plan(s).

3.0 SPECIAL CONSIDERATIONS

The stainless steel spoon or towel used to collect the sample or sub-sample shall be decontaminated prior to sampling and following the collection of each sample or sub-sample in accordance with SOP ENV-04-05. Following the decontamination, either of the two sterilization procedures may be followed.

- <u>Sterilization Procedure 1</u> - Spoons or trowels shall be individually packaged in aluminum foil and autoclaved for 30 minutes and 250^{o}F at 15 psi. Each sterile sampler shall be used only once, decontaminated, and then re-sterilized.

- Sterilization Procedure 2 – The spoon or scoop portion of the trowel shall be dipped in denatured alcohol, shaken gently, and then ignited. Please note that this procedure may only be used if no flammable, ignitable, or explosives are present on Site.

4.0 EXECUTION

4.1 Surface Sample Collection

If samples are desired directly at the surface, sterile spoons or trowels shall be used to collect the samples. Samples shall be collected in accordance with the procedures outlined in SOP ENV-06-01 with the following exceptions:

1. In order to facilitate the collection of a representative sample, the top one-inch of soil shall be scraped from approximately one-square foot and the sample collected from the underlying material.
2. Samples will be placed into sterile containers, which shall be closed immediately and placed on ice. Please note that microbial samples are not to be frozen.

4.2 Subsurface Sample Collection

Shovels, core samplers, backhoes, split-spoon samplers, and thin wall tube samplers may be used to collect subsurface samples for microbial analysis. Augers or any method that disturbs the soil column shall not be used. Sample shall be collected in accordance with the procedures outlined in SOP ENV-06-01 with the following exceptions:

1. Once the volume of soil is collected by one of the above procedures, a sub-sample shall be collected from the center of the soil sample, avoiding all surfaces which have been in contact with the non-sterile sampling device.
2. Samples will be placed into sterile containers, which shall be closed immediately and placed on ice. Please note that microbial samples are not to be frozen.

5.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, 2004, D3694-94(2004) Standard Practices for Preparation of Sample Containers and for Preservation of Organic Constituents.

USEPA, 1978, Microbiological Methods for Monitoring the Environment, EPA-600/8-78-017.

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual, Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

SOP SERIES SAS-07

SEDIMENT SAMPLING AND MEASUREMENT PROCEDURES

Author: T. Gilles **Q2R & Approval By:** C. Barry **Q3R & Approval By:** M. Kelley

STANDARD OPERATING PROCEDURE NO. SAS-07-01

SEDIMENT THICKNESS DETERMINATION Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for the poling method of determining the thickness of soft sediments. Measurements shall be determined to assist in determining suitability of soft sediment for sample collection and information on the depositional environment in the sample collection location.

2.0 EQUIPMENT AND MATERIALS

- 2-inch diameter graduated aluminum pole or pole sections that can be placed together marked in one-foot increments that are subdivided into one-inch increments;
- Field logbook and/or the appropriate field form(s);
- Decontamination materials;
- Personal protective equipment; and
- Camera.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 EXECUTION

The following procedure shall be followed unless otherwise specified by the Site-Specific Work Plan:

1. Maneuver the boat or wade to the sampling location. When wading, take care to minimize disturbance of soft sediment as much as possible by moving slowly.
2. Slowly lower the pole to the sediment surface to avoid disturbance of any flocculent sediment.
3. Stop when slight resistance is encountered, read the pole at the water surface to the nearest inch and record the measurement as the depth to top of sediment from water surface.
4. Push the pole into the sediment until refusal occurs.
5. Read pole at the water surface to the nearest inch and record the measurement as the depth to refusal measurement.
6. Slowly withdraw the pole from the sediment and water to keep sediment disturbance to a minimum.
7. Record any observations, such as type of sediment adhering to the pole and visible signs of contamination.
8. Decontaminate the pole or pole sections in accordance with SOP ENV-04-04.
9. Calculate the soft sediment thickness by subtracting the depth of top of sediment measurement from the depth of refusal measurement and record the calculation and result.

5.0 DOCUMENTATION

Sampling activities shall be documented in the field logbook or on an appropriate field form as outline in SOP ENV-01-01 and/or specified the Site-Specific Work Plan. Visual observations, as discussed above, shall also be recorded in the field logbook or on the field form.

6.0 REFERENCES AND ADDITIONAL RESOURCES

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

Authors:	M. Skyer / T. Gilles	Q2R & Approval By:	C. Barry	Q3R & Approval By:	M. Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-07-02

DESCRIPTION AND CLASSIFICATION OF SEDIMENTS
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the procedure for field description and classification of sediments by means of visual inspection and manual testing.

2.0 EQUIPMENT AND MATERIALS

- Field logbook and/or appropriate field forms;
- Pens with waterproof, non-erasable ink;
- Munsell Soil Color Chart, GSA Rock Color Chart, or equivalent;
- Slim stainless-steel spatula or carpenter's 5-in-1 tool;
- Hand lens (optional);
- Camera;
- Decontamination supplies and equipment; and
- Personal protective equipment.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Work on water requires that marine health and safety procedures are used in addition to standard health and safety procedures. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 SEDIMENT DEFINITIONS

Sediments can be granular or chemical in composition. NOAA (1998) defines granular sediment as material for which percentages of individual components that make up the sediment can be determined by gross or microscopic inspection. Granular sediment can be composed of particulates from three classes of material: biogenic, mineral/lithic, and glass. The glass referred to is volcanic glass and is likely to be present in significant quantities only in areas of active or recent volcanic activity. Since areas with volcanic activity are rare on the North American continent, methods for describing volcanic glass sediments will be determined on a site-specific basis and will not be further discussed in this SOP. Biogenic material is the remains or traces of once-living organisms. Mineral/lithic material is all mineral grains not included in other granular sediment classes. Precipitates and carbonaceous materials occurring in quantities greater than 50 % are classified as chemical sediments and will not be discussed in this SOP.

5.0 GENERAL PROCEDURES

Sediment logging and material classification shall be conducted only by a trained logging technician (e.g. geologist, hydrogeologist, engineer, or environmental scientist). Field data and observations associated with field logging and material classification shall be documented during logging and for all investigation and sampling activities in accordance with SOP ENV-01-01, if not otherwise specified in this SOP. All field drilling activities shall be recorded in a field logbook or on the appropriate field form. In addition, tools and equipment used while logging sediment shall be decontaminated between sampling locations/stations and prior to each sampling event in accordance with the Quality Assurance Project Plan (QAPP).

6.0 SEDIMENT CLASSIFICATION PROCEDURES

6.1 General Classification

Determine if the sediment is primarily biogenic or mineral/lithic. If the sediment contains 30% or more of a single fossil group or 50% or more total biogenic content, classify the sediment as biogenic. This classification cannot always be determined in the field and may require additional microscopic inspection of the sediment by a paleontologist or biologist. (Note: Classification of types of biogenic sediment beyond general terms of percentage composition and general physical characteristics by visual inspection is outside the scope of this SOP and will not be discussed further.) If the sediment contains mineral/lithic particles in excess of 50% by visual inspection, use a field classification of mineral/lithic.

6.2 Sediment Physical Classification

Classify the sediment sample similarly to soil using the ASTM visual-manual procedure (ASTM D2488-06). (See SOP ENV-05-02, Field Logging and Classification of Soil and Rocks for additional guidance.) If sample is biogenic, some of the following parameters may not apply. Record the following physical parameters, if applicable, in the field logbook or field form:

- Sample color, using Munsell color descriptors and identification numbers, immediately after sample collection;
- Sample color, using Munsell descriptors and numbers, after exposure to the air, if a color change occurs;
- Odor (identify organic odors by particular type if possible [e.g. petroleum-based]);
- Major sediment class (biogenic or mineral/lithic);
- Major mineral/lithic type (e.g. SAND, silty CLAY) or biogenic type (if possible);
- Other granular components and qualitative description of percentage using “with”, “some” or “trace”;
- Particle shape and angularity;
- Any depositional structures (stratification, lamination, etc.)
- Sample consistency;
- Sample grading (sorting) for coarse-grained samples;
- Dry strength, dilatancy, toughness and plasticity for fine-grained samples;
- Evidence of environmental impacts, if encountered (e.g. staining, sheen, or free-phase product) or any foreign materials (brick fragments, manufactured glass, coal fragments, etc.).

7.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, 2006, D2488-06 Standard Practice for Description and Identification of Soils (Visual-Manual Procedure).

U.S. Department of Commerce, National Oceanographic and Atmospheric Agency (NOAA) 1998, Proposed NGDC/Curators' Classification for Granular Sediments (Modified from the ODP Sediment Classification Scheme), web address: http://www.ngdc.noaa.gov/mgg/curator/paula1.htm.

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/60/B-07/001.

Author:	**C. Barry**	**Q2R & Approval By:**	**J. Gonzalez**	**Q3R & Approval By:**	**M. Kelley**

STANDARD OPERATING PROCEDURE
NO. SAS-07-03

SEDIMENT SAMPLING
Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) presents guidelines for selecting sediment sampling locations and general procedures for the collection of sediment samples. This SOP addresses continental sediments only. Estuarine and oceanic sediment sampling is beyond the scope of this document and will not be discussed. This SOP addresses sample collection for characterization of chemical or physical parameters. Requirements for collection of samples for biological characterization are addressed in a separate SOP.

2.0 EQUIPMENT AND MATERIALS

Sampling equipment and materials vary be collection method. However, some standard equipment and materials are required regardless of collection method:

- Ruler or tape measure in 0.01 –foot increments;
- Sample containers and labels;
- Sample cutting/extracting equipment (scoops, spatulas, trowels, shovels, etc.);
- Field logbook and/or the appropriate field form(s);
- Depth measurement devices;
- Decontamination materials;
- Chain of custody forms;
- Custody seals;
- Coolers and ice packs;
- Personal protective equipment;
- Camera; and
- Global positioning system (GPS) (optional).

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Work on water requires that marine health and safety procedures are used in addition to standard health and safety procedures. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 PERMITTING

Sampling performed within navigable waters and critical habitats may fall under the jurisdiction of one or more federal, state, or local agencies, including by not limited to the United States Army Corp of Engineers (USACOE), US Department of Fish and Wildlife, and state Department of Natural Resources. Prior to the commencement of sampling activities, appropriate permit(s), if applicable, shall be obtained.

5.0 SAMPLE SITE SELECTION

The sediment sampling site will be selected based on a number of factors including among others the presence of environmental impacts on adjacent land, presence of water discharge or outfall area, type of water body (e.g. lake, river, pond, etc.), sediment type, and depth to sediment. In water that is generally navigable, the only requirement for site selection may be ability to access the investigational site by boat. Sediment investigations in rivers, creeks or canals, will usually require additional information for sample site selection including such factors as stream flow velocity; depth, cross section and plan view of stream, and man-made and natural structures that affect stream flow, among others. In many cases, the USACOE and state geological surveys have extensive records for US waters and should be consulted prior to sediment sampling site selection. An experienced geologist or hydrologist should also be consulted prior to site selection.

A pre-sampling site visit is necessary to determine access points and best locations for sampling. Current aerial or satellite photographs of the site may be viewed prior to the initial site visit to obtain a general overview of possible access and sampling locations. Sampling sites may be selected during the site reconnaissance. Sampling locations can be indicated by reference to onshore features, such as buildings, fence lines, trees, etc. If natural features, such as trees are used, they will be marked by paint or colored flags for easy identification. A sketch map will be drawn in the field logbook or on a field form showing reference points and any measurements to be used to locate sampling points. If offshore sites are selected, a GPS can be used to find latitude and longitude coordinates for sampling points. These coordinates will be recorded on a site sampling map or field form, and in the field logbook.

6.0 SEDIMENT SAMPLING EQUIPMENT

Sediment sampling devices will be selected based on depth to sediment, type of sediment, type and size of sample required. Shallow sediment samples can be collected by trowel, scoop or shovel, which is decontaminated before use and between use at each specific sampling location. Manual augering equipment (tube or bucket auger); manual coring devices with Teflon or acetate liners; or barge-mounted machine augering (e.g., hollow-stem) equipment can be used to collect samples. Dredging equipment can be used for larger samples including Peterson, Eckman, and Ponar dredges. Selected sediment sampling methods have been outlined below.

Additionally, a sediment sampling equipment selection table (Attachment A), which was adapted from Ohio EPA, Sediment Sampling Guide (Ohio EPA 2001) and USEPA SOP #2016 – Sediment Sampling provides (USEPA 1994), provides alternative information for selection and use of sediment sampling equipment. The Site-Specific Work Plan will specify the sampling equipment and method(s) to be used. Sampling equipment should be selected to minimize disturbance of potentially impacted sediments.

6.1 Shallow Sediment Sampling Methods

If the water is wadeable, a sediment sample may be collected by scooping the sediment using a stainless steel spoon or scoop, reducing the potential for cross-contamination. This can be accomplished by wading into the stream, and while facing upstream (into the current), scooping the sample along the stream bottom in the upstream direction. If the stream is too deep to wade but less than eight feet deep, a stainless steel scoop attached to a piece of conduit can be used either from the banks if the stream is narrow or from a boat.

If the stream has a significant flow and is too deep to wade, a BMH-60 sampler may be used. It is not particularly efficient in mud or other soft substrates because its weight will cause penetration to deeper sediments, which are not desired when sampling for priority pollutants. It is also difficult to release secured samples in an undisturbed fashion that would readily permit sub-sampling. The BMH-60 may be used for priority pollutant sampling provided that caution is exercised by only taking sub-samples that have not been in contact with the metal walls of the sampler.

6.2 Core Sampling Methods

Core Sampling Methods are used to sample vertical columns of sediment. They are particularly useful when a historical approach to sediment deposition is desired for they preserve the sequential layering of the deposit. Many types of coring devices have been developed depending on the depth of water from which the sample is to be obtained, the nature of the bottom material, and the length of core to be collected. They vary from hand push tubes to weight or gravity driven devices.

Coring devices are particularly useful in pollutant monitoring because the "shock wave" created by descent is minimal, thus the fines of the sediment-water interface are only minimally disturbed; the sample is withdrawn intact permitting the removal of only those layers of interest; core liners manufactured of glass or Teflon® can be purchased, thus reducing possible sample contamination; and the samples are easily delivered to the lab for analysis in the tube in which they were collected. The disadvantage of coring devices is that a relatively small surface area and sample size is obtained often necessitating repetitive sampling in order to obtain the required amount for analysis. Because it is felt that this disadvantage is offset by the advantages, coring devices are recommended in sampling sediments for trace organic compounds or metals analyses.

Hand / Push Coring Devices may be used in shallow, wade-able waters. This method involves the direct use of a core liner or tube manufactured of Teflon® or glass is recommended for the collection of sediment samples. Their use can also be extended to deep waters when SCUBA equipment is available. Teflon® is preferred to avoid glass breakage and possible sample loss. Stainless steel push tubes are also acceptable and provide a better cutting edge and higher strength than Teflon®. The use of the glass or Teflon® tube by itself eliminates any possible metal contamination from core barrels, cutting heads, and retainers. The tube should be approximately 12 inches if only recently deposited sediments (8 inches or less) are to be sampled. Longer tubes should be used when the depth of the substrate exceeds eight inches. Soft or semi-consolidated sediments such as mud and clays have a greater adherence to the inside of the tube and thus can be sampled with larger diameter tubes. Because coarse or unconsolidated sediments such as sands and gravel tend to fall out of the tube, a small diameter is required for them. A tube about two inches in diameter is usually the best size. The wall thickness of the tube should be about 1/3 inch for either Teflon® or glass. The inside wall may be filed down at the bottom of the tube to facilitate entry of the liner into the substrate.

Caution should be exercised not to disturb the area to be sampled when the sample is obtained by wading in shallow water. The core tube is pushed into the substrate until only four inches or less of the tube is above the sediment-water interface. When sampling hard or coarse substrates, a gentle rotation of the tube while it is pushed will facilitate greater penetration and cut down on core compaction. The tube is then capped with a Teflon® plug or a sheet of Teflon® held in place by a rubber stopper or cork. After capping, the tube is slowly extracted, the negative pressure and adherence of the sediment keeping the sample in the tube. Before pulling the bottom part of the core above the water surface, it too is capped. With a few modifications, this method can also be applied to sample collection from the edge of a boat or barge.

Vibro-core sampling is described as an electrical powered sediment sampling system featuring a vibrator head that drives a core tube liner into the sediment. Liners, often containing cellulose acetate butyrate (CAB), can be up to 20 feet (6 meters) long and 4 inch inside diameter (ID); lengths are selected based on sediment measured. The sampling vessel should be triple anchored, moored to a secure fixture, or spudded prior to collecting cores. The following procedure is a suggested method to collect sediment core samples:

1. Measure the water depth and soft sediment thickness.
2. Insert core catcher into CAB tube.
3. Position core catcher, drill holes, and rivet into place with aluminum rivets.
4. Lift the vibrating head with the winch to a vertical position so that it is suspended just off the bow of the sampling vessel.
5. Insert the core tube into the vibrating head, making sure that the tube slides in all the way.

6. Tighten the collar to the vibro-core (two bolts on each side).
7. Lower the entire assembly until the core nose is just above the sediment surface. Care should be taken to ensure that the cutter head or end of the core tube does not come into contact with the vessel during deployment. Verify that the generator is on. Turn on the vibrating head.
8. Slowly lower the vibro-core by running out 6-10 inches of cable at a time. Monitor core tube penetration by feeling for slack in the cable. Note appropriate rate of penetration in field log (Appendix B).
9. When the vibro-core ceases to penetrate the sediment (stops lowering or is "refused"), or the vibrating head is near the sediment surface, reverse the winch and pull the unit from the sediment. Do not allow the vibrating head to become imbedded into the sediment.
10. Turn off the power to the vibrating head when the core breaks free of the sediment.
11. During retrieval, the coring device and core tube need to be maintained in a vertical position to minimize disturbance of the collected sediments. Lift the assembly so that the sediment/water interface is visible. Wash the excess sediment from the outside of the tube. Once out of the water, the cutter head should be inspected and a physical description of the material at the mouth of the core entered into the core log. Drill holes through tube at the sediment/water interface and decant water from tube.
12. Tie line around tube in a single or double clove hitch.
13. Disengage the tube and lay the sediment core on the deck. Saw off excess core tube at the sediment surface, and cap the top of the tube with a red cap plug. Both ends should then be secured tightly with duct tape to prevent leakage. The amount of sediment in the tube should be measured and recorded in the sample log, along with the overall condition of the core. The core tube then should be marked to denote: Location, Recovery Length, Top of Core, Date, and Time.
14. Handle and sub-sample core as desired, on board, or at a shore based location.

Ogeechee / Open Barrel Punch Corer. The core unit will be deployed from the sampling vessel by hand to collect an undisturbed sediment sample to a depth of approximately 4 feet below the sediment/surface water interface. The open barrel punch-core will be manned by a minimum of two crewmembers: one staff member or contractor will handle the deployment and retrieval of the core while the vessel operator controls the boat and records the sampling location.

1. Make field notes and logbook entries as necessary throughout the sampling process to ensure thorough and accurate record keeping.
2. Maneuver the boat to the sampling location as identified in the project SSWP or based on field encountered conditions/data.
3. Measure and record the depth to sediment and sediment thickness using poling methods. This information will be used for comparison with any hydrographic survey results.
4. Place the liner (thin-walled tube) inside the core-barrel sampler followed by the core catcher. Open the check valve located atop the core unit. Attach lengths of rod to the core unit to enable the operator to push the core down to the appropriate depth. The rods also allow for the use of weights to help drive the core if needed.
5. Guide the core overboard.
6. Lower the core to the sediment surface at approximately 1.0 feet per second (ft/sec) so as to minimize sediment surface disturbances.
7. Record the location of the boat when sampler reaches bottom.
8. Push or use the weights to drive the sampler to the depth specified in the SSWP or based on field encountered conditions/data.
9. Close the check valve on the barrel core sampler and begin retrieving the sampler, raising it at approximately 1.0 ft/sec.
10. Guide the core on board the vessel and place it on the worktable on the deck; use care to avoid jostling that might disturb the integrity of the sample. Remove the core liner from the barrel.
11. Examine the sample for the following sediment acceptance criteria:
    - The sampler is not overfilled so that the sediment is present in the retrieval rods;
    - No leakage has occurred, as indicated by the presence of sediment at the end of the core tube;
    - No sample disturbance has occurred, as indicated by limited turbidity in the overlying water;
    - If sample acceptance criteria are not achieved, the sample will be rejected and the location re-sampled. If unable to obtain a sample that meets the appropriate acceptance criteria within 50 feet of the proposed location, the sample will be relocated as determined by the Project Manager or Task Manager, as appropriate.
12. Decant or siphon off free water from the surface of the sediment. Care should be taken to not disturb the integrity of the sediment surface. Extrude the sediment from the core liner.

13. Visually classify sediment, record the descriptions on the sediment sampling form, and photograph sample.
14. Repeat the sampling process (if necessary) until sufficient volume is obtained to satisfy the sampling requirements for each location. Collect successive core samples within a radius of 10 feet of the initial sampling location.
15. Handle and sub-sample core as desired, on board, or at a shore based location.

6.3 Dredge Sampling Methods

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

The Eckman dredge has only limited usefulness. It performs well where bottom material is unusually soft, as when covered with organic sludge or light mud. It is unsuitable, however, for sandy, rocky, and hard bottoms and is too light for use in streams with high velocities. It should not be used from a bridge more than a few feet above the water, because the spring mechanism which activates the sampler can be damaged by the messenger if dropped from too great a height.

The Ponar dredge is a modification of the Peterson dredge and is similar in size and weight. It has been modified by the addition of side plates and a screen on the top of the sample compartment. The screen over the sample compartment permits water to pass through the sampler as it descends thus reducing the "shock wave." The Ponar dredge is easily operated by one person in the same fashion as the Peterson dredge. The Ponar dredge is one of the most effective samplers for general use on all types of substrates.

1. Make field notes and logbook entries as necessary throughout the sampling process to ensure thorough and accurate record keeping.
2. Maneuver the boat to the sampling location as identified in the SSWP or based on field encountered conditions/data.
3. Measure and record the depth to sediment and sediment thickness using the poling methods. This information will be used for comparison with any hydrographic survey results.
4. Open the sampler and slide the locking pin into place.

5. Guide the sampler overboard.
6. Lower the sampler to the sediment surface at approximately 1.0 feet per second (ft/sec).
7. Record the location of the boat when sampler reaches bottom.
8. Begin retrieving the sampler and raise it at approximately 1.0 ft/sec.
9. Guide the sampler on board the vessel and place it on the worktable on the deck; use care to avoid jostling that might disturb the integrity of the sample.
10. Examine the sample for the following sediment acceptance criteria:
    - Sampler jaw is closed and the sample does not contain foreign objects
    - Desired penetration depth has been achieved
    - The sampler is not overfilled so that the sediment surface presses against the top of the sampler
    - No leakage has occurred, as indicated by overlying water on the sediment surface
    - No sample disturbance has occurred, as indicated by limited turbidity in the overlying water
    - No winnowing has occurred, as indicated by a relatively flat undisturbed surface
    - If sample acceptance criteria are not achieved, the sample will be rejected and the location re-sampled. If unable to obtain a sample that meets the appropriate acceptance criteria within 50 feet of the proposed location, the sample will be relocated as determined by the Project Manager or Task Manager, as appropriate.
11. Decant or siphon off free water from the surface of the sediment. Care should be taken to not disturb the integrity of the sediment surface.
12. Visually classify sediment, record the descriptions on a sediment sampling form, and photograph sample.
13. Collect the sediment from the sampler using a stainless steel implement and care not to include any material that has been in contact with any interior sampler surface. Place this sediment into an appropriate-sized stainless steel homogenization bowl.
14. Thoroughly rinse the interior of the sampler until all loose sediment has been washed off.
15. Repeat the sampling process (if necessary) until sufficient volume is obtained to satisfy the sampling requirements for each location. Collect successive grab samples within a radius of 10 feet of the initial sampling location.
16. Homogenize the bulk sediment until it has uniform color and texture.
17. Place samples into containers in accordance with SSWP.

18. Clean the exterior of all sample containers and store them in a cooler with ice.

7.0 SAMPLE COLLECTION PROCEDURES

- Prior to mobilization to the field, consult with the contracted analytical laboratory to ascertain if they require any sediment-specific sample collection procedures to be followed to ensure that samples are acceptable for the analyses to be conducted and provided in adequate volume for analyses.
- Sampling locations will be located horizontally using a Global Positioning System (GPS) receiver in the field. Either Real Time Kinematic (RTK), or Differential GPS (DGPS) may be used to achieve sub-foot accuracy.
- Sampling locations will be estimated vertically using a graduated pole in combination with site staff gauge. If a staff gauge has not been established at the site, a staff gauge shall be established and surveyed accurate to ±0.01 feet. Prior to sample collection, a graduated pole will be used to measure the top of sediment relative to surface water. The estimated elevation each sediment sample will be calculated in the office using the surface water elevations measured from the site staff gauge. Measurements shall be collected from the site staff gauge multiple times throughout each day of sampling to account for fluctuating water levels.
- Using a decontaminated sampling instrument, remove the desired thickness and volume of sediment from the sampling location.
- When coring sediments, the penetration depth, recovery depth, and percent recovery shall be recorded on a sediment sampling field form (Appendix B)
- If sediment is not saturated, conduct a direct screening of the sample with a photoionization detector (PID).
- Describe and classify the sample in accordance with SOP ENV-07-02, Description and Classification of Sediments and record observations on a sediment sampling field form (Appendix B).
- **Volatile Organic Compounds (VOCs) –** Discrete sediment samples for VOC analyses will be collected as soon after sample retrieval as possible. Any surface water should be decanted from the sediment before collecting the samples. Pre-preserved vials or jars with Teflon-lined lids will be used if moisture content of soil is too high to allow collection of 5-gram samples for vials. Attachment B provides a detailed sampling procedure for pre-preserved vials. If jars are used, they will be filled to provide zero-headspace samples. Secure container lid, apply label containing sample identification information and place in cooler with ice.

- **Semivolatile Organic Compounds (SVOCs), Metals, Cyanide, PCBs, Pesticides, Herbicides, and Organic Carbon –** Sediment samples for these analytes will be collected after collecting VOCs. Any surface water should be decanted from the sediment before placing it in a container for homogenization. Samples will be homogenized using clean stainless steel mixing bowls, spoons, knifes, etc. Sample aliquots will be placed directly from the sample retrieval device into the stainless steel bowl. The soil will be thoroughly mixed in the bowl to homogenize the sample and then placed directly into appropriate sample containers. Secure container lid, apply label containing sample identification information and place in cooler with ice.
- **Physical Characteristics –** Sediment samples collected for physical characterization should be carefully placed into a large glass jar directly from the sampler to mitigate sample disturbance. Secure container lid, apply label containing sample identification information and place in transportation container.
- Samples shall be identified, labeled, logged, stored and prepared for shipment in accordance with SOP ENV-03-01, Sample Labeling, Logging, Storage and Shipment.
- SOP ENV-03-02 Chain-of-Custody procedures shall be followed in preparing the samples for transport to the analytical laboratory.
- Sampling equipment and tools shall be decontaminated between each sample in accordance with SOP ENV-04-04.
- Containerize any investigation-derived solid and liquid waste, including decontamination water, label and store for disposal at an appropriate disposal facility. Consult with Project Manager regarding disposal of waste.

8.0 DOCUMENTATION

Sampling activities shall be documented as outline in SOP ENV-01-01 and as specified the Site-Specific Work Plan. Visual observations are particularly important and may prove invaluable in interpreting sediment quality study results. Visual observations of affected sediment will use the descriptors from SOP ENV-05-02, Attachment E. These visual observations, including weather and water body conditions during the sampling event, shall also be recorded in the field logbook and/or on the appropriate field form (Appendix B).

9.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, 2003, D3975-93(2003) Standard Practice for Development and Use (Preparation) of Samples for Collaborative Testing of Methods for Analysis of Sediments.

ASTM International, 2005, D3976-92(2005) Standard Practice for Preparation of Sediment Samples for Chemical Analysis.

ASTM International, 2003, D4823-95(2003)e01 Guide for Core Sampling Submerged, Unconsolidated Sediments.

Ohio Environmental Protection Agency, Division of Surface Water, 2001, Sediment and Sampling Guide and Methodologies, 2nd Ed., November.

USEPA Region V, 1984, Methods Manual for Bottom Sediment Sample Collection, EPA-905-4-004, May.

USEPA, 1994, SOP #2016 – Sediment Sampling, November 17.

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual, Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

ATTACHMENT A
SEDIMENT SAMPLING EQUIPMENT SELECTION TABLE

SEDIMENT SAMPLING EQUIPMENT SELECTION TABLE[1,2]

Sample Type	Model	Current	Substrate	Remarks
GRAB	Spoon Scoop	Zero To Slight	All	• Use only in relatively calm and shallow water • Relatively little sample disturbance • Simple and inexpensive • Fines may washout when retrieved through water column
CORE	Tube Auger	Zero To Slight	Clay and Silt	• Use only in relatively calm and shallow water • Extension handles can be used for deeper waters. • Relatively little sample disturbance • Simple and inexpensive • Fines may washout when retrieved through water column
CORE	Bucket Auger	Zero To Slight	Clay to Fine Gravel	• Use only in relatively calm and shallow water • Extension handles can be used for deeper waters. • Relatively little sample disturbance • Simple and inexpensive • Fines may washout when retrieved through water column
GRAB	Eckman	Zero To Very Slight	Clay and Silt	• Use in relatively calm water • Pebbles and branches may interfere with jaw closure • Excellent jaw shape and cut • Relatively little sample disturbance • Poor stability – Light weight allows for tendency to “swim” in a current, which sometimes causes miss triggers • 0.02 square meter sample area • Weight with sample is 10 kilograms

[1] Ohio Environmental Protection Agency, Division of Surface Water, 2001, Sediment and Sampling Guide and Methodologies, 2nd Ed., November.
[2] USEPA, 1994, SOP #2016 – Sediment Sampling, November 17.

SEDIMENT SAMPLING EQUIPMENT SELECTION TABLE[1,2]
(Continued)

Sample Type	Model	Current	Substrate	Remarks
GRAB	Petite Ponar Peterson	Zero To Very Slight	Clay to Fine Gravel	• Needs relatively calm/sheltered waters • Good stability • Poor jaw shape and cut • Sample disturbance • Less washout if extra weights are used • More cumbersome than an Eckman – Requires a winch • 0.1 – 0.2 square meter sample area • Weight with sample is 30 – 50 kilograms
CORE	Manual	Zero To Strong	Clay to Sand (Inserts needed for sandy samples)	• Recommended for use in shallow water • Deployed by hand or driver (hammer) • Extension handles can be used for deeper waters.
CORE	Coring Tubes	Zero To Moderate	Clay to Sand (Inserts needed for sandy samples)	• Quick and easy • Relatively undisturbed sample • Small sample volume • Samples sometimes compressed
CORE	Gravity	Zero To Moderate	Clay and Silt	• Recommended for rivers • Depths up to 10 meters
CORE	Split Spoon	Zero To Moderate	Clay to Sand (Inserts needed for sandy samples)	• Recommended for use in shallow water • Deployed by hand or driver (hammer) • Vertical profile remains intact and is visible • Point design can reduce sample compaction • Stones can interfere with collection • Equipment is heavy

[1] Ohio Environmental Protection Agency, Division of Surface Water, 2001, Sediment and Sampling Guide and Methodologies, 2nd Ed., November.
[2] USEPA, 1994, SOP #2016 – Sediment Sampling, November 17.

ATTACHMENT B
ENCORE AND POWERSTOP SAMPLING PROCEDURES

ENCORE™ SOIL SAMPLING PROCEDURE

- Remove EnCore™ sampler and cap from its re-sealable pouch and attach T-handle to sampler body. (**Note**: when dealing with soft or sandy solid, it may be necessary to retract the plunger in the sampler before sample collection.)

- Using the T-handle for leverage, push the sampler into a freshly exposed surface of sediment until the sampler is full.

- Brush any soil off the sampler head and securely attach the sampler cap by pushing with a twisting motion.

- Complete the sample label and attach to the sampler body; place labeled sampler in its re-sealable pouch and seal the pouch.

- Repeat the procedure for two additional samples collected from the same soil stratum or the same area. (**Note:** this step may be eliminated or the number of samples reduced if the suspected level of VOCs is known [i.e., low or high concentration sample]. Consult Method 5035 or discuss procedure with an analytical laboratory for further details.)

- Use a stainless steel spoon or similar tool to collect an additional sample from the same sediment stratum or the same area. Place collected material in a 2-ounce, wide-mouth jar with no preservatives. (**Note:** this additional soil volume is for dry weight and percent moisture determination. This step is not necessary if additional soil from the sample location is collected for other parameter analyses upon which dry weight and percent moisture will be determined.)

- Immediately place samples in a cooler with ice.

Ship EnCore™ samples (next day priority delivery) to the contract laboratory the day they are collected. Alternatively, arrange to have samples picked-up by the laboratory or delivered to the laboratory by field personnel within 24 hours of collection. These sample shipment or pickup timelines must be achieved to ensure the laboratory performs sample preservation or analysis within 48 hours of sample collection.

POWERSTOP HANDLE SAMPLING PROCEDURE

1. Load Sampling Device

Insert EasyDraw Syringe™ into the appropriate slot (5 or 10-gram heavy, 5 or 10-gram medium, 5 or 10-gram light or 13 gram position) on the Powerstop Handle™ device and remove end cap from syringe.

EPA Method 5035 Recommended 5-gram slot positions:

- Use the heavy position for dense clay;
- Use the light position for dry sandy soil; and
- Use the medium position for all others.

2. Collect Sample

Push EasyDraw Syringe™ into a freshly exposed surface of soil until the syringe is full. Continue pushing until the soil column inside the syringe has forced the plunger to the stopping pint. (**Note**: unlike other sample collection devices, there is no headspace air in the syringe to displace.) EasyDraw Syringe™ delivers approximately 5, 10, or 13 grams. Actual weight will be determined at the laboratory. No scale or balance required in the field.

3. Eject Sample Into Vial

Remove the syringe from the Powerstop Handle™ device and insert the syringe into the open end of 40-ml vial, and eject sample into pre-tared vial by pushing on the syringe plunger. Avoid getting dirt on the threads of the 40-ml vial. Cap vial immediately and put on ice. Sample must be received by within 48 hours of sampling if samples are not chemically preserved in the field.

SOP SERIES SAS-08

GROUNDWATER SAMPLING AND MEASUREMENT PROCEDURES

Author:	J. Sapp / T. Gilles	Q2R & Approval By:	A. Bazan	Q3R & Approval By:	M. Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-08-01

GROUNDWATER AND NON-AQUEOUS PHASE LIQUID MEASUREMENT
Revision 1

1.0 PURPOSE

The purpose of this standard operating procedure (SOP) is to describe method(s) to measure groundwater, Light Non-Aqueous Phase Liquids (LNAPL) and Dense Non-Aqueous Phase Liquids (DNAPL) elevations and thicknesses in groundwater monitoring wells, observation wells, and recovery wells as required in the Site-Specific Work Plan or as otherwise specified.

2.0 EQUIPMENT AND MATERIALS

- Notebook, field logbook, and/or the field activity form;
- Steel add-on tape or electronic water level indicator;
- Electronic water level indicator;
- Electronic oil/water interface probe;
- Pressure transducer (as appropriate for the conditions);
- Gasket adapted to the diameter of the transducer cable;
- Data logger;
- Decontamination equipment and supplies (in accordance with the guidelines in SOP ENV-04-05).
- Personal protective equipment; and
- Chalk

3.0 HEALTH AND SAFETY WARNINGS

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 GENERAL REQUIREMENTS

Water level, LNAPL, and DNAPL (if present) measurements should be obtained at wells designated in the Site-Specific Work Plan. Water level, LNAPL, and DNAPL levels should be measured in referenced to a common elevation or datum, preferably to a USGS benchmark located at the site. Water level, LNAPL, and DNAPL depths should be measured from a reference point marked on the top of the casing, which, in turn, is referenced to a permanent benchmark.

Water and product level measurement devices shall be decontaminated as per SOP ENV-04-05 or as specified in the Site-Specific Work Plan before and after measuring at each location.

Care shall be exercised to avoid direct skin contact while measuring water level and product depth. All equipment should be decontaminated before and after each measurement as per SOP ENV-04-05. Water and product level measurements should be recorded in the field logbook and/or the field activity form.

5.0 MEASUREMENT METHODS AND PROCEDURES

5.1 Discrete Groundwater Level Measurement

Discrete water level measurements should be made by determining the depth to the water surface from the top of the well casing at the fixed reference point. The fixed reference point is established by permanently marking a point on the outer edge (lip) of the well casing. Caution should be exercised so that filings do not fall into the well.

The depth to water can be determined using a steel add-on tape or electronic water level indicator. The steel add-on tape consists of a measuring tape that has 1-foot increments and a 1-foot section at the end of the tape with 0.01-foot increments. The end of the tape is coated with chalk and lowered into the well. The water depth is read from the saturated mark on the chalked tape and added to the depth interval measured at the top of the well casing

Electronic water level indicators are conducting probes that activate an alarm and a light when they intersect the water. The sounder wire is marked in 0.01-foot intervals to indicate depth. All sounders are equipped with weights to maintain line tension for accurate readings. The typical operating procedures for an electronic water level indicator are as follows:

- Lower the sounder wire until it just makes contact with the water in the well and the indicator light goes on or the pulsating alarm is sounded. Record the position of the wire relative to the reference point at the top of the well casing. Record the actual water level reading to the nearest 0.01-foot. Repeat to confirm depth.
- Withdraw the sounder from the well.
- Record the water depth in the field logbook and/or the field activity form.
- Decontaminate the sounder wire and electrode in accordance with SOP ENV-04-05.

Discrete water levels are typically required from a series of wells when data for preparing groundwater contour maps are needed. However, discrete water levels may also be required when monitoring the changes in water level during aquifer testing if aquifer response is sufficiently slow. Continuous water level measurements are discussed in Section 5.4 of this SOP.

5.2 Discrete LNAPL Level Measurement

Discrete LNAPL or product level measurements should be made by determining the depth to the product and water surface from the top of the well casing at the fixed reference point. The fixed reference point is established by permanently marking a point on the outer edge (lip) of the well casing. Caution should be exercised so that filings do not fall into the well.

The depth of the product and water level may be obtained using an electronic oil/water interface probe. An oil/water interface probe has a multi-conducting probe that activates different signals, typically pulsating beeps and continuous alarms, when they intersect the product and water, respectively. The sounder wire is marked in 0.01-foot increments to indicate depth. The interface probe is equipped with a weight to maintain line tension and obtain accurate readings. The typical operating procedures for an electronic oil/water interface probe are as follows:

- Check the interface probe battery by pressing the test button to ensure the device is operating properly before and after taking the level measurement. Daily battery checks should also be made and documented in the logbook.
- Lower the interface probe until it makes contact with the product in the well and the product indicator light goes on or the continuous alarm is sounded. Record the position of the wire relative to the reference point to the nearest 0.01-foot. Repeat to confirm the depth of the product.
- Continue to lower the interface probe, through the product layer, until it makes contact with the water level in the well and the water indicator light goes on or the pulsating alarm is sounded. Record the position of the wire to the reference point to the nearest 0.01-foot. Repeat to confirm the depth of the water.
- Withdraw the probe from the well.
- Record the product and water depth in the field logbook and/or the field activity form.
- Decontaminate the sounder wire and probe in accordance with the guidelines in SOP ENV-04-05.

Alternatively, the depth to the top of LNAPL may be approximated to the tenth of an inch with a weighted standard measuring tape. The thickness of LNAPL will be approximated using a bottom filling, clear, disposable bailer. The bailer may be slowly lowered into the water column, just below the approximate surface and allowed to fill. The bailer will be gently removed from the well to minimize disturbance. Measurements of the observed thickness of LNAPL will be measured to the nearest 0.1-foot using a standard measuring tape and recorded in the field logbook and/or the field activity form.

5.3 Discrete DNAPL Level Measurement

Discrete DNAPL or product level measurements should be made by determining the depth to the product and water surface from the top of the well casing at the fixed reference point. The fixed reference point is established by permanently marking a point on the outer edge (lip) of the well casing. Caution should be exercised so that filings do not fall into the well.

The depth of the water and product level may be obtained using an electronic oil/water interface probe. An oil/water interface probe has a multi-conducting probe that activates different signals, typically continuous alarms and pulsating beeps, when they intersect the water and product, respectively. The sounder wire is marked in 0.01-foot increments to indicate depth. The interface probe is equipped with a weight to maintain line tension and obtain accurate readings. The typical operating procedures for an electronic oil/water interface probe are as follows:

- Check the interface probe battery by pressing the test button to ensure the device is operating properly before and after taking the level measurement. Daily battery checks should also be made and documented in the logbook.
- Lower the interface probe until it makes contact with the water in the well and the water indicator light goes on or the beeping alarm is sounded. Record the position of the wire relative to the reference point to the nearest 0.01-foot. Repeat to confirm the depth of the water.
- Continue to lower the interface probe, through the water, until it makes contact with the product level in the well and the product indicator light goes on or the continuous alarm is sounded. Record the position of the wire to the reference point to the nearest 0.01-foot. Repeat to confirm the depth to the product.
- Withdraw the probe from the well.
- Record the water and product depth in the field logbook and/or the field activity form.
- Decontaminate the sounder wire and probe in accordance with the guidelines in SOP ENV-04-05.

Alternatively, the measurements of DNAPL may be approximated using a bottom filling, clear, disposable bailer. The bailer may be slowly lowered into the water column, to the bottom of the well and allowed to fill. The bailer will be gently removed from the well to minimize disturbance. Measurements of the observed thickness of DNAPL will be measured to the nearest 0.1-foot using a standard measuring tape and recorded in the field logbook and/or the field activity form.

5.4 Continuous Water Level Measurement

Continuous water level measurements are made by determining the height of the water column above a pressure transducer and electronically recording fluctuations in this height with a data logger. The continuous recording of height of water above the transducer is used for aquifer testing where rapid changes in water level are anticipated. The typical operating procedures for a continuous water level system are as follows:

- Enter the program into a data logger that has fully charged batteries. Alkaline batteries are preferred. During use, the battery voltage should not drop below the minimum voltage specified by the manufacturer; damage to the data logger and loss of recorded data could result.

- Select a pressure transducer for use in a given well that is compatible with both water quality and anticipated pressure sensitivity range (i.e., 5 psi, 30 psi, etc.). The pressure range selected is dictated by the anticipated range in the water column above the transducer and by the desired precision in measurement.
- Connect the transducers to the data logger in the field following manufacturer's instructions. Typically, four to eight input channels are available on the system. Other factors affecting the sampling configuration include cable length; distance between monitored wells; terrain; local human activities (traffic, plant operations); and the ability to secure the system from weather and vandals.
- Attach the transducer cable to the data logger and calibrate in air according to manufacturer's instructions. If multiple data loggers are used, internal clock synchronization should also be performed.
- Measure water level and depth to the bottom of the well before lowering the transducer into the well. Water levels are measured with an electrical water level indicator; total depth of the well is measured with a device compatible with well depth.
- Secure a sanitary fitting (commonly a gasket adapted to the cable diameter) at the surface of the well. Lower transducer into the well through the sanitary fitting to a depth between the water level and the bottom of the well. The transducer must be kept submerged during the period of measurement. Take care to keep the piezometric crystal at the tip of the transducer out of any fine sediment that has accumulated in the bottom of the well. On some transducers, the crystal is protected from sediment intrusion. Measure water level again; record the time indicated on the data logger digital display and water level. From these readings (and other periodic manual water level measurements), the water levels can be converted to elevations.
- Transfer data stored in the data logger periodically to a portable computer. The frequency of data transfer depends on available memory and conditions encountered in the field. Data may be transferred as frequently as daily. If the data logger has a wrap-around memory, the information should be transferred so that records are not recorded over.

6.0 REFERENCES AND ADDITIONAL RESOURCES

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

Author: T. Gilles Q2R & Approval By: E. Hanis Q3R & Approval By: M. Kelley

STANDARD OPERATING PROCEDURE NO. SAS-08-02

LOW-FLOW GROUNDWATER SAMPLING Revision 2

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the procedures and guidelines for conducting low-flow groundwater sampling. This SOP provides a method that minimizes the impact of the purging process on groundwater chemistry and volume of water for disposal.

2.0 EQUIPMENT AND MATERIALS

- Map of well locations;
- Well construction information;
- Tools and well keys, as required to facilitate access to wells;
- Water level measuring device (electronic water level indicator, interface probe, or weighted steel tape);
- Adjustable rate peristaltic pump or an adjustable rate low-flow submersible or positive displacement bladder pump (Note: The Site-Specific Work and/or Field Sampling Plan (FSP) shall specify the type of pump required);
- 1/4 to 3/8-inch Teflon®, polyvinyl chloride (PVC), or polypropylene tubing;
- Flow measurement supplies (e.g. graduated cylinder and stop watch);
- Power source, if applicable;
- Compressed inert gas source (for use with bladder pump), if applicable;
- Flow-through cell;
- Groundwater quality/indicator parameter monitoring instruments (flow-through cell capable);
- Instrument operation manual(s);
- Instrument calibration standard(s);
- Container(s) for purge water storage (e.g. 5-gallon buckets, polyethylene storage tank, etc.);
- Sample containers and labels, as appropriate for the analytical method(s) selected;
- Field filtration equipment, if applicable;

- Chain of custody forms and seals;
- Cooler(s) with double-bagged ice;
- Polyethylene sheeting, as appropriate;
- Decontamination materials;
- Personal protection equipment; and
- Field logbook and/or appropriate field form.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 APPLICATION OF SAMPLING METHOD

Low-flow is one of several acceptable sampling procedures and may be performed using bladder or peristaltic pumps. Peristaltic pumps may be used when the well depth is less than or equal to fifteen feet, in zones of high contamination, or as approved in a SSWP. The sampling method may be modified to demonstrate attainment of cleanup goals in the future. Low-flow sampling shall not be used when one or more of the following conditions are present:

- Well will not accept or allow placement of the sampling device;
- Non-aqueous phase liquids (NAPLs). Reference SOP SAS-08-07 when sampling wells with NAPL;
- Formation screened will not allow drawdown to stabilize; and
- Water column is less than 2 feet in height.

5.0 EXECUTION

To the extent practical, sampling shall begin at the monitoring well with the least contamination and proceed systematically to the monitoring wells with the most contamination using the procedure outlined in the following subsections unless otherwise required by the Site-Specific Work and/or FSPs.

5.1 Preparation

The sampler shall create a work area around the monitoring well to minimize the potential for cross-contamination. Work area preparations may include the placement of polyethylene sheeting prevent sampling equipment from coming in contact with the ground surface. The sampler shall barricade and/or flag the work area, if required by the Site-Specific HASP. The sampler shall also arrange the sampling equipment and supplies to facilitate efficient execution of groundwater sampling procedures.

5.2 Well Gauging

Groundwater and NAPL, if present, elevation measurements shall be obtained in accordance with SOP SAS-08-01 or as otherwise specified in the Site-Specific Work and/or FSPs. Following sampling, the sampler may obtain the total well depth from top of casing (in feet to the nearest 0.01-foot) using a water level indicator, interface probe, or steel tape, as detailed in SOP SAS-08-05 and as required by the Site-Specific Work and/or FSP or otherwise specified. Measuring the total well depth prior to sampling should be avoided. Total well depths may be obtained following sampling activities or at least two weeks prior to the sampling. If total well depth is required to be measured immediately prior to sampling, the sampler will take precautions to minimize the displacement of sediments, if present, within the well during gauging activities. In general, the use of an interface probe shall be limited to wells containing NAPL or elevated concentrations of constituents of concern. Groundwater and NAPL elevation measurements and total well depth measurements shall be recorded in the field logbook and/or on the appropriate field form.

5.3 Pump/Tubing Intake Positioning

The sampler should determine and place or position the pump/tubing intake as appropriate relative to the position of the water level, screened interval, and constituents of concern. The position the pump/tubing intake should be a minimum of one foot above the well sump to the extent practical and preferably at an elevation near the center of the well screen. The sampler shall slowly raise or lower the pump or tubing when placing or positioning intake in order to minimize the displacement of sediments, if present, within the well. The pump model/type, tubing (type, inner diameter, and length), and pump/tubing intake depth/elevation shall be recorded in the field logbook and/or on the appropriate field form. If the water quality instruments can be programmed to calculate the one tubing volume, the data collected during pump/tubing intake placement/positioning shall be entered into the instrument. If the instrument cannot be programmed to calculate the tubing volume, this volume shall be calculated by the sampler using the following formula.

Tubing Volume $_{(Gallons)}$ = Tubing Length $_{(Feet)}$ x Volume per One Foot of Tubing ^{TDS} $_{(Gallons/Foot)}$

Where: ^{TDS} = Tubing inner diameter-specific; tubing manufacturer provided information.

The calculated tubing volume shall also be recorded in the field logbook and/or on the appropriate field form.

5.4 Equipment Assembly and Calibration

The sampler shall connect the tubing from the well to the inflow fitting at the bottom of the flow-through cell. A length of tubing shall be connected to the outflow fitting at the top of the flow-through cell with the other end extending into a 5-gallon bucket. The 5-gallon bucket shall be used to collect the purge water. Groundwater quality/indicator parameter monitoring instruments will be calibrated in accordance with the instrument operation manual(s) and SOP SAS-02-01 using the manufacturer prescribed calibration standards. During instrument calibration, the instrument shall be set up to measure and record data in the units (e.g. microsiemens per centimeter (uS/cm), milligrams per liter (mg/L), etc.) specified in the Site-Specific Work and/or Sampling Plan(s). Calibration shall be documented in the field logbook and/or on the appropriated field form. Following calibration, the instruments shall be connected to the flow-through cell.

5.5 Flow Rate and Drawdown Determination

The sampler shall re-gauge the depth to groundwater from the top of well casing. The sampler shall turn on the pump at its lowest setting and determine the flow rate by measuring the volume of water removed over a one-minute period using a graduated cylinder and stop watch or other approved flow rate measuring device. The sampler shall monitor the water column drawdown and shall adjust the pump to avoid a drawdown of more than 0.1 meter or 0.3 feet (4 inches). The flow rate of the pump shall generally be adjusted to between 0.2 and 0.5 liters per minute (L/min). During pump start-up, drawdown may exceed 0.3 feet provided the drawdown stabilizes and the groundwater level does not fall below the intake level. The water level shall not fall below the top of the well screen if the water level was greater than 0.5 feet above the well screen prior to commencing pumping activities. Pump adjustments shall be made within the first 15 minutes of purging. The final flow rate and stabilized drawdown shall be recorded in the field logbook and/or on the appropriated field form.

5.6 Purging and Groundwater Quality/Indicator Parameter Monitoring

The Site-Specific Work and/or FSPs shall specify the groundwater quality/indicator parameters to be monitored, which typically include temperature, pH, specific conductance or actual conductivity, oxidation-reduction potential, dissolved oxygen, and turbidity. Parameter monitoring will begin after a minimum of tubing volume has been purged from the well. The sampler shall monitor and record in the field logbook and/or on the appropriate field form parameters every three to five minutes (during continuous purging) until parameters have stabilized. A generic groundwater sampling field form is provided in Appendix B. Five-minute intervals are typical; three-minute intervals are used during flow rates in highly permeable media that will allow pumping rates that exceed typical low-flow rates. Parameter stabilization is considered to be achieved when three consecutive readings, spaced approximately 2 to 10 minutes, or 0.5 well volumes or more apart, are within the parameter-specific limit listed in the table below or as specified in the Site-Specific Work and/or Sampling Plan(s).

Parameter	Stabilization Criteria[1]
Conductance, Specific Electrical	+/- 3% µS/cm @ 25°C
Conductivity, Actual[2]	+/- 3% µS/cm
Dissolved Oxygen	+/- 0.3 mg/L
Oxidation-Reduction Potential	+/- 10 mV
pH	+/- 0.1 standard units
Temperature	+/- 0.1 °C
Turbidity	<u><10 NTUs or</u> ± 10% when turbidity is greater than 10 NTUs and/or visually clear water

[1] USEPA, 2002, Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers, EPA 542-S-02-001
[2] Based on the stabilization criteria for specific electrical conductance as published in the documented cited above

Once the parameters have stabilized, purging is considered complete and sample collection shall commence.

5.7 Sample Collection

While water is being purged from the well, groundwater samples shall be collected directly into the laboratory provided sample containers from the tubing, before the water has passed through the flow-through cell. This shall be accomplished by using a by-pass assemble or disconnecting the flow-through cell to obtain the sample. Water collected for analysis requiring field filtration will be filtered with an in-line Nalgene© disposable 0.45 micron (µm) filter, or equivalent. Water will be discharged directly from the in-line filter into the sample container following a filter pre-rinse, which will be performed by passing water through the filter, minimum of 500 milliliter (mL), and discharging prior to collection of the sample(s). Samples collected with bailers will be collected in intermediated unpreserved laboratory-provided containers and immediately field filtered as previous described with in-line filters.

Samples shall be collected in order of analyte stability, as summarized below, unless otherwise specified by the Site-Specific Work and/or FSPs:

- Volatile organic compounds (VOCs);
- Semi-volatile organic compounds (SVOCs);
- Non-filtered, non-preserved samples (e.g. PCBs, sulfate, etc.);
- Non-filtered, preserved samples (e.g. phenols, nitrogen, cyanide, total metals, etc.);
- Filtered, non-preserved samples;
- Filtered, preserved samples (e.g. dissolved metals); and
- Miscellaneous parameters.

Quality Control (QC) samples, if required, will be collected consecutively to ensure appropriate duplicate sample collection in accordance with SOP SAS-04-03. Immediately following collection, samples shall be placed in an iced cooler.

5.8 Post-Sample Collection

Non-Dedicated and dedicated sampling equipment, which does not remain within the well casing, shall be removed from the monitoring well. The reusable and/or dedicated equipment and instruments shall be decontaminated in accordance with SOP SAS-04-04 or as otherwise specified by the Site-Specific Work and/or Sampling Plan(s). Disposable equipment and supplies shall be disposed of in accordance with procedures outlined in the Site-Specific Work and/or FSPs. The sampler shall secure the well casing using a slip or expandable well cap. The flush-mount lid shall be bolted down or the protective cover closed and locked, as appropriate.

6.0 DOCUMENTATION

Sample information, labeling, and custody control shall be performed in accordance with requirements specified in SOP SAS-03-01 and SAS-03-02. Sampling activities shall be recorded in the field logbook and/or on the appropriate field form as specified in SOP SAS-01-01 or as required by the Site-Specific Work and/or FSPs. A generic groundwater sampling field form is provided in Appendix B.

7.0 REFERENCES AND ADDITIONAL RESOURCES

USEPA, 2002, Ground-Water Sampling Guidelines for Superfund and RCRA Project Manager, Region 5 and Region 10, EPA 542-S-02-001.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/60/B-07/001.

Author: J. Sapp Q2R & Approval By: A. Bazan / T. Gilles Q3R & Approval By: M. Kelley

STANDARD OPERATING PROCEDURE NO. SAS-08-03

WELL-VOLUME APPROACH GROUNDWATER SAMPLING Revision 2

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for obtaining groundwater samples using the well-volume approach from groundwater monitoring wells, recovery wells, or observation wells as described in the Site-Specific Work Plan or as otherwise specified for the purpose of determining groundwater quality. The well-volume approach involves the purging of the stagnant water within the well and stabilization of water quality indicator parameters prior to sampling.

2.0 EQUIPMENT AND MATERIALS

- Map of well locations;
- Tools and well keys, as required to facilitate access to wells;
- Water level measuring device (e.g. electronic water level indicator, interface probe, or weight steel tape);
- Well construction information, as appropriate;
- Calculator / Conversion Chart
- Pump, if required by the Site-Specific Work and/or Field Sampling Plan (FSP);
- Teflon®, polyvinyl chloride (PVC), or polypropylene pump-specific tubing, if applicable;
- Power Source, if applicable;
- Bailer – Disposable (disposable for purging and sampling), PVC (for purging only), and/or stainless steel (for purging and/or sample collection), if required by the Site-Specific Work and/or FSP;
- Rope, if applicable;
- Disposable plastic cups or stainless steel cup;
- Groundwater quality/indictor parameter monitoring instruments;
- Instrument operation manual(s);
- Instrument calibration standard(s);

- Container(s) for purge water volume measurements and storage (e.g. 5-gallon bucket, polyethylene storage tank, etc.);
- Sample containers and labels, as appropriate for the analytical method(s) selected;
- Field filtration equipment, if applicable;
- Chain of custody forms and seals;
- Cooler(s) with double-bagged ice;
- Polyethylene sheeting, as appropriate;
- Personal protective equipment;
- Decontamination materials and supplies;
- Field logbook and/or appropriate field form; and

3.0 HEALTH AND SAFETY WARNINGS

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 APPLICATION

The well-volume approach is one of several acceptable sampling procedures. The well-volume approach involves the purging of the stagnant water within the well and stabilization of water quality indicator parameters prior to sampling. While this method can be used in wells screened in any formation, it is generally used to sample low-permeability formations (i.e., low-yielding wells).

Newly constructed and developed wells shall be allowed a minimum of 48 to72 hours to stabilize before sampling is performed. Once a well is purged, it should be sampled within 2 hours. If a purged well is allowed to sit longer than the prescribed 2 hours the water contained in the well casing may no longer be representative of aquifer conditions and the well shall be re-purged with one exception. If a water table well is purged dry, it should be sampled when a sufficient volume of water is present. In general, the sample collection shall take place within 24 hours of bailing or pumping the well dry. Purging a water table well dry should be avoided if possible. Wells screened below the water table should never be purged dry. Purging wells screened across water table must be performed at a rate that prevents significant reduction in the water table elevation. Wells that are purged dry should be sampled at least 2 hours after purging activities. Sampling of wells that are known to contain NAPL will follow procedures in SOP SAS-08-07.

5.0 EXECUTION

To the extent practical, sampling shall begin at the monitoring well with the least contamination and proceed systematically to the monitoring wells with the most contamination using the procedure outlined in the following subsections unless otherwise required by the Site-Specific Work and/or FSPs.

5.1 Preparation

The sampler shall create a work area around the monitoring well to minimize the potential for cross-contamination. Work area preparations may include the placement of polyethylene sheeting prevent sampling equipment from coming in contact with the ground surface. The sampler shall barricade and/or flag the work area, if required by the Site-Specific HASP. The sampler shall also arrange the sampling equipment and supplies to facilitate efficient execution of groundwater sampling procedures.

5.2 Well Gauging

Groundwater and non-aqueous phase liquid (NAPL), if present, elevation measurements shall be obtained in accordance with SOP SAS-08-01 or as otherwise specified in the Site-Specific Work and/or FSP. The sampler shall also obtain the total well depth from top of casing (in feet to the nearest 0.01-foot) using a water level indicator, interface probe, or steel tape, as required by the Site-Specific Work and/or FSP or otherwise specified. Total well depths may be obtained prior to the sampling and provided to the sampler. If total well depth is required to be measured immediately prior to sampling, the sampler will take precautions to minimize the displacement of sediments, if present, within the well during gauging activities. In general, the use of an interface probe shall be limited to wells containing NAPL or elevated concentrations of constituents of concern. Groundwater and NAPL elevation measurements and total well depth measurements shall be recorded in the field logbook and/or on the appropriate field form.

5.3 Standing Water Column Calculation

The sampler shall calculate the standing water column using the following formula:

Standing Water Column $_{\text{(Feet)}}$ = TD $_{\text{(FT BTOC)}}$ – DTW $_{\text{(FT BTOC)}}$

Where: TD = Total Well Depth
FT BTOC = Feet below top of well casing
DTW = Depth to Water

The sampler shall record the calculation in the field logbook and/or on the appropriate field form.

5.4 Volume Calculations

The sampler shall calculate the volume of water required to be purged prior to sampling. Depending on data quality objectives, state- or regulatory program-specific requirements, and the Site-Specific Work and/or FSP, one of two methods may be used: casing volume or borehole volume. In general, a minimum of three volumes of water, casing or borehole, shall be purged prior to sample collection (see section 5.6 below) in addition to stabilization of groundwater quality indicator parameters.

5.4.1 Casing Volume Calculation:

The sampler shall calculate the casing volume, which is the volume of water inside the well casing only, using the following formula.

One Casing Volume $_{\text{(Gallons)}}$ = Standing Water Column $_{\text{(Feet)}}$ X Volume per One Foot of Casing $^{\text{WDS}}_{\text{(Gallons/Foot)}}$

Where: $^{\text{WDS}}$ = Well diameter-specific (see table below)

Well Diameter-Specific Volume Per One Foot of Casing				
Well Diameter (Inches)	**Volume Per Foot of Casing (Gallons)**		**Well Diameter (Inches)**	**Volume Per Foot of Casing (Gallons)**
0.25	0.0026		4.0	0.6528
0.50	0.0102		6.0	1.469

Well Diameter-Specific Volume Per One Foot of Casing				
0.75	0.0230		8.0	2.611
1.0	0.0408		10.0	4.081
2.0	0.1632		12.0	5.876

The sampler shall record the calculation in the field logbook and/or on the appropriate field form.

5.4.2 Borehole Volume Calculation

The sampler shall calculate the borehole volume, which is the volume of water inside the well casing and volume of water inside the filter pack, using the following formula. Please note that this calculation requires the sampler to know the borehole diameter, filter pack height/elevation, and filter pack porosity.

One Borehole Volume $_{\text{(Gallons)}}$ = n ((A X B) – (A X C)) + (C X D)

Where: n = porosity of the filter pack (generally assumed to be 25% or 0.25)

A = height (in feet) of saturated filter pack

B = borehole diameter-specific volume (see table below)

C = well diameter-specific volume (see table below)

D = standing water column (see Section 5.4.1 above)

Diameter-Specific Volume Per One Foot of Borehole or Casing				
Diameter (Inches)	**Volume Per Foot of Borehole or Casing (Gallons)**		**Diameter (Inches)**	**Volume Per Foot of Borehole or Casing (Gallons)**
0.25	0.0026		4.0	0.6528
0.50	0.0102		6.0	1.469
0.75	0.0230		8.0	2.611
1.0	0.0408		10.0	4.081
2.0	0.1632		12.0	5.876

The sampler shall record the calculation in the field logbook and/or on the appropriate field form.

5.5 Equipment Assembly and Preparation

5.5.1 Pumps

Extreme caution should be exercised to ensure that the equipment does not cause cross-contamination from one well to the next. Therefore, dedicated tubing and pumps are preferred. Peristaltic pumps may be used when the well depth is less than or equal to fifteen feet, in zones of high contamination, or as approved in a SSWP. If it is not practical to dedicate a pump to a specific well, the pump shall be decontaminated in accordance with SOP ENV-04-04. Tubing should always be dedicated and never used for more than one well.

The sampler shall place or position the pump/tubing intake not greater than 6 feet below the dynamic water level in the well and a minimum of one foot above the well sump to the extent practical. Ideally, in non-water table wells, the pump shall be placed within the well screen section. The sampler shall slowly raise or lower the pump or tubing when placing or positioning intake in order to minimize the displacement of sediments, if present, within the well. The pump model/type, tubing (type, inner diameter, and length), and pump/tubing intake depth/elevation shall be recorded in the field logbook and/or on the appropriate field form.

5.5.2 Bailers

Bailers will be used for sampling activities when site-specific work plans provide rational and justification for the use. If a non-dedicated PVC and/or stainless steel bailer(s) is/are used, the bailer(s) must be decontaminated in accordance with SOP ENV-04-04 prior to well purging. The bailer shall be secured using rope to a purge water storage container, protective cover, flush-mount lid, or other object such that the bailer can be retrieved from the well. The rope that will enter the well casing shall not come in with the ground. Bailer samples will be collected using bottom valve sampling devices to limit sample aeration.

5.6 Purging and Groundwater Quality/Indicator Parameter Monitoring

The Site-Specific Work and/or FSP shall specify the groundwater quality/indicator parameters to be monitored, which typically include temperature, pH, specific conductance or actual conductivity, oxidation-reduction potential, dissolved oxygen, and turbidity. Parameter monitoring will begin after a minimum of one volume, casing or borehole (as specified by the Site-Specific Work and/or FSP) has been purged from the well. The sampler shall monitor and record in the field logbook and/or on the appropriate field form parameters a minimum of every well volume until parameters have stabilized. A generic Groundwater Sampling Field Form is provided in Appendix B. When pumps are utilized for purging, stabilization parameters will be monitored with a flow through cell in accordance with SOP SAS-08-02. Parameter stabilization is considered to be achieved when three consecutive readings, taken every well volume with bailer purging, are within the parameter-specific limit listed in the table below or as specified in the Site-Specific Work and/or FSP and a minimum of three volumes, casing or borehole (as specified by the Site-Specific Work and/or FSP), have been evacuated from the well or the well is purged dry, whichever occurs first. Purging methods are discussed in Sections 5.6.1 and 5.62 below.

Parameter	Stabilization Criteria[1]
Conductance, Specific Electrical	+/- 3% µS/cm @ 25°C
Conductivity, Actual[2]	+/- 3% µS/cm
pH	+/- 0.1 standard units
Dissolved Oxygen	+/- 0.3 mg/L
Oxidation-Reduction Potential	+/- 10 mV
Temperature	+/- 0.1 °C
Turbidity	<u><</u>10 NTUs or ± 10% when turbidity is greater than 10 NTUs and/or visually clear water

Once the parameters have stabilized and a minimum of three volumes, casing or borehole (as specified by the Site-Specific Work and/or FSP), have been evacuated from the well or the well is purged dry, sample collection shall commence (see Section 5.7 below).

5.6.1 Pumps

Following pump/tubing intake placement, the sampler shall commence with purging by turning on the pump. During pumping, intermittently collect pump discharge in a container of known volume for a period of not less than 1 minute to determine the pump flow rate. The approximate pump flow rate shall be documented in the field logbook and/or on the appropriate field form. The sampler shall monitoring groundwater quality/indicator parameters, as described in above, preferably using a flow through cell in accordance with

[1] USEPA, 2002, Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers, EPA 542-S-02-001
[2] Based on the stabilization criteria for specific electrical conductance as published in the documented cited above

SOP SAS-08-03. Groundwater quality/indicator parameters shall be recorded in the field logbook and/or on the appropriate field form along with the time and volume of water purged (to the gallon). Periodic measurements of the flow rate will also be recorded during sampling. The evacuated/purged water shall be containerized in an approved storage container as required by the Site-Specific Work and/or FSP.

5.6.2 Bailers

The sampler shall slowly lower and raise the bailer in the well in order to minimize the displacement of sediments, if present, within the well. The sampler shall monitoring groundwater quality/indicator parameters by collecting bailer discharge in a disposable plastic cup, stainless steel cup, or other manner befitting the monitoring instruments (e.g., down-hole probe). Groundwater quality/indicator parameters shall be recorded in the field logbook and/or on the appropriate field form along with the time and volume of water purged. The evacuated/purged water shall be containerized in an approved storage container as required by the Site-Specific Work and/or FSP.

5.7 Sample Collection

5.7.1 Pumps

In general, groundwater samples shall only be collected from adjusted rate peristaltic pumps or adjustable rate low-flow submersible or positive displacement pumps. Groundwater samples shall be collected directly into the laboratory provided sample containers from the tubing, before the water has passed through the flow-through cell. This shall be accomplished by using a by-pass assemble or disconnecting the flow-through cell to obtain the sample. Samples shall be collected in order of analyte stability, as summarized below, unless otherwise specified by the Site-Specific Work and/or FSP:

- Volatile organic compounds (VOCs);
- Semi-volatile organic compounds (SVOCs);
- Non-filtered, non-preserved samples (e.g. Polychlorinated biphenyls (PCBs), sulfate, etc.);
- Non-filtered, preserved samples (e.g. phenols, nitrogen, cyanide, total metals, etc.);
- Filtered (reference SAS-SOP-08-02), non-preserved samples;
- Filtered (reference SAS-SOP-08-02), preserved immediately samples (e.g. dissolved metals); and
- Miscellaneous parameters.

Immediately following collection, samples shall be placed in a cooler with double-bagged ice.

5.7.2 Bailers

In general, groundwater samples shall only be collected from disposable or stainless steel bailers, when pumps are not applicable for sample collection (e.g., low-yielding wells). Groundwater samples shall be collected directly into the laboratory provided sample containers from the bailer. Samples shall be collected in order of analyte stability, as summarized below, unless otherwise specified by the Site-Specific Work and/or FSP:

- VOCs;
- SVOCs;
- Non-filtered, non-preserved samples (e.g. PCBs, sulfate, etc.);
- Non-filtered, preserved samples (e.g. phenols, nitrogen, cyanide, total metals, etc.);
- Filtered (reference SAS-SOP-08-02), non-preserved samples;
- Filtered, (reference SAS-SOP-08-02) preserved samples (e.g. dissolved metals); and
- Miscellaneous parameters.

Immediately following collection, samples shall be placed a cooler with double-bagged ice.

5.7.3 Quality Control Samples

Quality Control (QC) samples, if required, will be collected consecutively to ensure appropriate duplicate sample collection in accordance with SOP SAS-04-03. Immediately following collection, samples shall be placed in a cooler with double-bagged ice.

5.8 Post-Sample Collection

Non-dedicated and dedicated sampling equipment, which does not remain within the well casing, shall be removed from the monitoring well. The reusable and/or dedicated equipment and instruments shall be decontaminated in accordance with SOP SAS-04-04 or as otherwise specified by the Site-Specific Work and/or FSP. Disposable equipment and supplies shall be disposed of in accordance with procedures outlined in the Site-Specific Work and/or FSP. The sampler shall secure the well casing using a slip or expandable well cap. The flush-mount lid shall be bolted down or the protective cover lid closed and locked, as appropriate.

6.0 DOCUMENTATION

Sample information, labeling, and custody control shall be performed in accordance with requirements specified in SOP SAS-03-01 and SAS-03-02. Sampling activities shall be recorded in the field logbook and/or on the appropriate field form as specified in SOP SAS-01-01 or as required by the Site-Specific Work and/or FSP. A generic Groundwater Sampling Field Form is provided in Appendix B.

7.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, D4448-01 Standard Guide for Sampling Groundwater Monitoring Wells

ASTM International, D5903-96(2001) Standard Guide for Planning and Preparing for a Groundwater Sampling Event

ASTM International, D6089-97(2003)e1 Standard Guide for Documenting a Ground-Water Sampling Event

ASTM International, D6301-03 Practice for the Collection of Samples of Filterable and Nonfilterable Matter in Water

ASTM International, D6452-99(2005) Standard Guide for Purging Methods for Wells Used for Ground-Water Quality Investigations

ASTM International, D6564-00(2005) Standard Guide for Field Filtration of Ground-Water Samples

ASTM International, D6634-01 Guide for the Selection of Purging and Sampling Devices for Ground- Water Monitoring Wells

ASTM International, D6771-02 Practice for Low-Flow Purging and Sampling for Wells and Devices Used for Ground-Water Quality Investigations

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia, www.epa.gov/region4/sesd/eisopqam/eisopqam.html.

USEPA, 2002, Ground-Water Sampling Guidelines for Superfund and RCRA Project Manager, Region 5 and Region 10, EPA 542-S-02-001.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/60/B-07/001.

STANDARD OPERATING PROCEDURE
NO. SAS-08-04

AQUIFER TESTING
Revision 2

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for field evaluation of aquifer hydraulic conductivity. Variations in the hydraulic conductivity within or between formations or strata can create irregularities in groundwater flow paths. Formations of high hydraulic conductivity represent areas of greater groundwater flow and, therefore, zones of potential preferred contaminant migration. Further, anisotropy within strata or formations affects the magnitude and direction of groundwater flow. Thus, information on hydraulic conductivities is necessary to evaluate preferential flow paths and groundwater velocity.

Hydrogeologic assessments should contain data on the hydraulic conductivities of the significant formations underlying the site as measured in monitoring wells. It may be beneficial to use numerical or laboratory methods to augment results of field tests. However, field methods provide the best definition of the horizontal hydraulic conductivity in most cases. Field methods differ from laboratory methods which measure vertical hydraulic conductivity, typically in Shelby tube samples.

2.0 EQUIPMENT AND MATERIALS

- Pump (and generator if required) capable of withdrawal at a constant or predetermined variable rate that can meet the designed pumpage rate and lift requirements
- Water pressure transducers and data logger (bring transducers for the pumping well and each observation well as well as extras in case of malfunction)
- A flow meter or other type of water measuring device to accurately measure and monitor the discharge from the pumping well
- Sufficient hose or pipe to convey discharge outside the recharge area of the pumping well and observation wells
- Electric water level indicator(s) capable of measurement to the hundredth of a foot
- Watch or stopwatch with second hand

- Barometer (some groundwater multiprobes include a barometer)
- Tape Measure of appropriate length based on distance to observation wells.
- Flashlights, lanterns, alarm clock, electrical tape
- Semi-log graph paper, pens, and field book

3.0 HEALTH AND SAFETY WARNINGS

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 FIELD METHODS

Varieties of procedures are available for evaluating hydraulic conductivity in the field. ASTM D4043-96(2004) Guide for Selection of Aquifer Test Method in Determining Hydraulic Properties by Well Techniques should be consulted in selecting an appropriate test method. Field methods for collecting hydraulic conductivity data are described in a number of ASTM standard practices:

- D2434-68(2000) Test Method for Permeability of Granular Soils (Constant Head)
- D4044-96(2002) Test Method (Field Procedure) for Instantaneous Change in Head (Slug) Tests for Determining Hydraulic Properties of Aquifers
- D4050-96(2002) Test Method (Field Procedure) for Withdrawal and Injection Well Tests for Determining Hydraulic Properties of Aquifer Systems
- D4104-96(2004) Test Method (Analytical Procedure) for Determining Transmissivity of Nonleaky Confined Aquifers by Overdamped Well Response to Instantaneous Change in Head (Slug Tests)
- D4105-96(2002) Test Method (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of Nonleaky Confined Aquifers by the Modified Theis Nonequilibrium Method

- D4106-96(2002) Test Method (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of Nonleaky Confined Aquifers by the Theis Nonequilibrium Method
- D4511-00 Test Method for Hydraulic Conductivity of Essentially Saturated Peat
- D4630-96(2002) Test Method for Determining Transmissivity and Storage Coefficient of Low-Permeability Rocks by In Situ Measurements Using the Constant Head Injection Test
- D4631-95(2000) Test Method for Determining Transmissivity and Storativity of Low Permeability Rocks by In Situ Measurements Using Pressure Pulse Technique
- D5269-96(2002) Test Method for Determining Transmissivity of Nonleaky Confined Aquifers by the Theis Recovery Method
- D5270-96(2002) Test Method for Determining Transmissivity and Storage Coefficient of Bounded, Nonleaky, Confined Aquifers
- D5472-93(2005) Test Method for Determining Specific Capacity and Estimating Transmissivity at the Control Well
- D5473-93(2000) Test Method for (Analytical Procedure for) Analyzing the Effects of Partial Penetration of Control Well and Determining the Horizontal and Vertical Hydraulic Conductivity in a Nonleaky Confined Aquifer
- D5720-95(2002) Practice for Static Calibration of Electronic Transducer-Based Pressure Measurement Systems for Geotechnical Purposes
- D5785-95(2000) Test Method for (Analytical Procedure) for Determining Transmissivity of Confined Nonleaky Aquifers by Underdamped Well Response to Instantaneous Change in Head (Slug Test)
- D5786-95(2000) Practice for (Field Procedure) for Constant Drawdown Tests in Flowing Wells for Determining Hydraulic Properties of Aquifer Systems
- D5850-95(2000) Test Method for (Analytical Procedure) Determining Transmissivity, Storage Coefficient, and Anisotropy Ratio from a Network of Partially Penetrating Wells
- D5855-95(2000) Test Method for (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of a Confined Nonleaky or Leaky Aquifer by Constant Drawdown Method in a Flowing Well
- D5881-95(2005) Test Method for (Analytical Procedure) Determining Transmissivity of Confined Nonleaky Aquifers by Critically Damped Well Response to Instantaneous Change in Head (Slug)
- D5912-96(2004) Test Method for (Analytical Procedure) Determining Hydraulic Conductivity of an Unconfined Aquifer by Overdamped Well Response to Instantaneous Change in Head (Slug)

- D5920-96(2005) Test Method (Analytical Procedure) for Tests of Anisotropic Unconfined Aquifers by Neuman Method
- D6028-96(2004) Test Method (Analytical Procedure) for Determining Hydraulic Properties of a Confined Aquifer Taking into Consideration Storage of Water in Leaky Confining Beds by Modified Hantush Method
- D6029-96(2004) Test Method (Analytical Procedure) for Determining Hydraulic Properties of a Confined Aquifer and a Leaky Confining Bed with Negligible Storage by the Hantush-Jacob Method
- D6030-96(2002) Guide for Selection of Methods for Assessing Groundwater or Aquifer Sensitivity and Vulnerability
- D6034-96(2004) Test Method (Analytical Procedure) for Determining the Efficiency of a Production Well in a Confined Aquifer from a Constant Rate Pumping Test
- D6391-99(2004) Test Method for Field Measurement of Hydraulic Conductivity Limits of Porous Materials Using Two Stages of Infiltration from a Borehole

5.0 SINGLE WELL TESTS

Hydraulic conductivity can be determined in the field using a variety of test methods, each addressing specific conditions, and/or data collection objectives. These methods are commonly referred to as bail down or slug tests and are performed by adding or removing a slug (known volume of water or solid inert material) from a well and observing the recovery of the water surface to its original level. Similar results can be achieved by pressurizing the well casing, depressing the water level, and suddenly releasing the pressure to simulate removal of water from the well. One method is described by McLane, et. al. (1990) and is contained in references to the Standard Practices.

When reviewing information obtained from slug tests, several criteria should be considered. First, they are run on one well and, as such, the information is limited to the geologic area directly adjacent to the screen. Second, the vertical extent of screen will control the part of the geologic formation that the test analyzes. Portions of the geologic formation(s) above or below the screen and sand filter pack and seal intervals may also require separate hydraulic conductivity testing. Third, the methods used to collect single well test data should accurately measure parameters such as changing static water (prior to initiation, during, and following completion of the test), the amount of water removed from the well (or slug volume introduced), and the elapsed time of recovery. The use of pressure transducers and high speed recording equipment is critical in highly permeable formations.

Observation wells with screens that intersect the water table (i.e. water table wells) will be tested only by methods involving removal of water or a slug from the well in order to minimize the potential for well screen filter pack interference. The addition of water to any monitoring well shall be avoided whenever possible, since the addition may affect water quality in sampling events. When addition of water to a well is unavoidable, the water must be of documentable quality and three times the volume added to the well must be removed immediately upon completion of the test. Addition of water to an observation well is appropriate only to piezometer installation when the dynamic water level is above the well screen and sand filter pack and seal elevations.

Full development of the well screen and filter pack adjacent to the interval under examination, in accordance with SOP SAS-05-04, should be completed following well construction to ensure the removal of fines or correct deleterious drilling effects. Determination of well integrity, SOP SAS-08-05, should be determined prior to performance of the well test.

It is important that slug tests be of sufficient duration to provide representative measures of hydraulic conductivity. Slug tests will range in length from less than a minute to several hours. The time required for a test is a function of the volume of the slug added or removed the formation hydraulic conductivity, and well construction.

Slug tests should be performed at least twice to ensure the accuracy of data collection. General procedures for a slug test are summarized below. The procedures required for a slug test may vary, depending on site-specific-conditions. Modifications to the test procedures will be contained in site-specific work plans.

5.1 Slug Test Procedures with Pressure Transducer and Data Logger

An individual Slug Test Field Form (Appendix B) should be completed for each well tested and should contain at least:

- Project ID - A number assigned to identify a specific site.
- Well ID - The location of the well in which water level measurements are being taken.
- Personnel - The personnel conducting the pumping test.
- Measurement Methods - Type of pump, type of data logger(s) used to record water levels, transducer ID number, and acquisition rate (i.e. data recorded on a log scale). The transducer psi range should be appropriate to the test (e.g. 0 to 5 or 0 to 10 psi).
- Initial Static Water Level (Test Start) - Depth to water, to the nearest 0.01 feet, in the observation well at the beginning of the slug test.
- Slug Withdrawal / Addition Start Time - The date when the test began, and start time using a 24-hour clock.
- Test End Date/Time - The date and time when water level readings were discontinued.
- Final Static Water Level (Test End) - Depth to water, to the nearest 0.01 feet, in the observation well at the end of the slug test.
- Elapsed Time (min) - Time of manual measurement record from time 0.00 (start of test) recorded in minutes and seconds.
- Notes - Appropriate observations or information that has not been recorded elsewhere, including notes on sampling, pH readings, and conductivity readings.

Prior to commencing the slug test, enter site-specific information in the data logger per manufacturer instructions. Store all logger data internally; and on laptop computer and/or portable data key. The data should be transferred to the chosen backup storage device as soon as practical after the test is completed.

Water levels should be measured as specified in the SOP SAS-08-02. Manual measurements are required as a backup to and verification of the data logger(s). It is critical that depth to water readings be measured accurately and the exact time of readings is recorded. Determine the static water level in the well; measure the depth to water periodically for several minutes to several hours, and taking the average of the readings (see SOP SAS-07-02). Record information on the Slug Test Field Form (Attachment B). Additional information should be recorded on the Daily Activity Log in SOP SAS-01-04.

5.2 Slug Test Preparation

- Lower the transducer and cable in the well below the estimated target drawdown depth, ensuring the depth of submergence is within the transducer design range.
- Tape the transducer cable to the exterior of the well casing or protective cover to hold the transducer at a constant depth
- Connect the transducer cable to the data logger.
- Check the transducer accuracy by raising and lowering the transducer and comparing the change in water level from the transducer reading to the distance the transducer is raised or lowered.
- Enter the initial water level and transducer design range into the recording device according to the manufacturer's operating instructions.
- Allow the static water level to equilibrate to within 0.1 feet of the initial water level.

5.3 Slug Test with Transducer Procedure

- Turn the data logger on and begin collecting data points.
- Smoothly lower the slug/bailer into the well and allow the water level to stabilize within 0.1 feet of the initial water level.
- Remove the slug/bailer as quickly and smoothly as practical. A smooth, rapid removal is required as slug test analysis assumes an instantaneous change in volume is created in the well when the slug is removed.
- The moment the volume is removed is time zero. Collect hand measured water level measurements (Table 1) as a data backup and to verify transducer data.
- Continue measuring and recording depth/time measurements until the water level returns to equilibrium conditions or a sufficient number of readings have been made to show a trend on a plot of water level recovery versus the logarithm of time in accordance with the chosen analysis method. Time will range from less than 1 minute to a few hours.
- Repeat the slug test once the static water level has recovered to within 95 % of the original water level.

Table 1: Time Intervals for Measuring Recovery in Slug Test Well

Elapsed Time Since Start or Stop of Test (Minutes)	OR (which ever is greater)	Percent Water Level Recovery (%)	Interval Between Measurements (Minutes)
0-2		0-30	0.1
2-5		30-50	0.5
5-10		50-60	1
10-60		60-70	5
60-120		70-80	10
120-240		80-100	30

5.4 Slug Test with Water Level Meter

This slug test method should only be used if a transducer/data recorder cannot be obtained or are malfunctioning. This method cannot be used for saturated zones with high hydraulic conductivities because stabilization of groundwater will occur rapidly. Slug test data should be recorded on the Slug Test Data form (Attachment B) in accordance with the completion instructions. Follow the same procedures for Slug Test with Transducer with increased data collection frequency.

Table 2: Time Intervals for Measuring Recovery in Slug Test Well

Elapsed Time Since Start or Stop of Test (Minutes)	Interval Between Measurements (Minutes)
0-2	0.1
2-10	0.5
10-30	1
30-60	5
60-120	10
120-240	30

The interpretation of the single well test data should be consistent with the existing geologic information (boring log data). Staff should be aware of initial rapid water level recovery during a slug test may represent drainage of the filter pack material around the well screen. This is of particular concern in wells screened in low hydraulic conductivity formations (e.g. silty clay, shale). These data points should be ignored when selecting the appropriate data points to establish a water level recovery slope.

6.0 MULTIPLE WELL TESTS

Multiple well tests, more commonly referred to as pumping tests, are performed by pumping water from one well and observing the resulting drawdown in nearby wells. Tests conducted with wells screened in the same water-bearing formation provide hydraulic conductivity data. Tests conducted with wells screened in different water-bearing zones furnish information concerning hydraulic communication between units. Multiple well tests for hydraulic conductivity are advantageous because they characterize a greater proportion of the subsurface and thus provide a greater amount of detail. Multiple well tests are subject to similar constraints to those listed above for single well tests. Some additional problems that should have been considered in conducting a multiple well test include: (1) storage of potentially contaminated water pumped from the well system, and (2) potential effects of groundwater pumping on existing waste plumes. The geologic constraints should be considered to interpret the pumping test results. Incorrect assumptions regarding geology may translate into incorrect estimations of hydraulic conductivity.

7.0 LABORATORY METHODS

Laboratory analysis of undisturbed samples (e.g. Shelby tube) provides values of vertical hydraulic conductivity. When laboratory methods are to be used, the specific ASTM Standard Practice shall be referenced in samples provided to subcontractors. ASTM methods shall be consulted to assure that test methods specified are applicable to the sample to be tested.

8.0 CONTROLLED PUMPING TESTS

The most representative method for determining aquifer characteristics is by controlled aquifer pumping tests, because these tests stress a much larger volume of the formation than slug tests and laboratory tests. Pumping tests require a higher level of effort and expense than other types of aquifer tests, and are not always justified.

As an example, slug tests may be acceptable for site characterization, whereas pumping tests may be performed to support remedial design or modeling.

Aquifer characteristics that may be obtained from pumping tests include transmissivity (T), hydraulic conductivity (K), specific yield (Sy) for unconfined aquifers, and storage coefficient (S) for confined aquifers. These parameters can be determined by graphical solutions and computerized programs, such as Aqtesolv®.

These are standard (i.e., typically applicable) operating procedures which may be varied or changed as required dependent on site conditions, equipment limitations, or limitations imposed by the procedure. In all instances, the ultimate procedures employed should be documented and associated with the final report.

8.1 Summary

If possible, continuously monitor pre-test water levels at the test site for about one week prior to performance of the pump test. This information allows for the determination of the barometric efficiency of the aquifer, as well as noting changes in head due to recharge or pumping in the area adjacent to the well. Prior to initiating the long-term pump test, a step test (Section 5.5) is performed to estimate the greatest flow rate that may be sustained by the pump well.

After the pumping well has recovered from the step test, the long-term pumping test begins. At the beginning of the test, the discharge rate is set as quickly and accurately as possible. The water levels in the pumping well and observation wells are recorded following a set schedule. The duration of the test is determined by project needs and aquifer properties; typically three days or until water levels becomes constant.

8.2 Interferences and Potential Problems

Prior to conducting a pumping test, efforts should be made to anticipate and resolve interferences and potential problems that could affect the aquifer or the test. These problems could be caused by changing atmospheric conditions, impact of local potable wells, contaminants in the aquifer, etc. Note that if it is necessary for a neighboring well to pump during the test, pumping should commence as early as feasible prior to start of the test at a constant rate and not started or stopped for the duration of the test.

8.3 Pumping Discharge

If a pumping test will be conducted in an area with contaminated groundwater, special arrangements must be made for proper handling, treatment, and disposal of the water. The preferred method is to discharge to a sanitary sewer, with prior approval.

Uncontaminated groundwater discharge generated during a pumping test should be sent to storm or sanitary sewers, abiding by all applicable regulations. If there are no sewers in the vicinity of the pumping well, the discharge may be sent to a river or pond. If the previously mentioned discharge options are not available, the groundwater may be discharged to the ground surface under either of the following conditions:

- The aquifer being tested is confined; or
- The end of the discharge hose/pipe is outside of the cone of depression created by the pumping well when testing an unconfined aquifer.

8.4 Pre-Test Procedures

The hydrostratigraphy of the aquifer should be fully characterized prior to performance of the test to identify formation thickness, whether it is confined or unconfined, whether confining layers are leaky and to identify any lateral boundaries that may influence results.

If the pumping test occurs at a site where existing production and/or monitoring wells will be used, confirm that the locations and screened intervals of the wells are within the same aquifer, and meet the requirements of the method of analysis.

If possible, continuously measure water levels in the pumping well and all observation wells for a period at least equal to the length of the test. Trends should be similar in all wells. A well with an unusual trend may indicate some local stress in the aquifer.

The magnitude of water-level fluctuations due to changes in barometric pressure will change throughout the test and should be adjusted based on the changes in the barometric pressure recorded during the test. Changes in barometric pressure will be recorded during the test in order to correct water levels for any possible fluctuations that may occur due to changing atmospheric conditions. These barometric changes are used to "correct" water levels during the test so they are representative of the hydraulic response of the aquifer due to pumping of the test well. Ideally, water levels should be measured in a well outside of the cone of depression before, during, and after pumping to determine background changes in water levels during the test and to establish correction factors for the wells within the cone of depression.

8.5 Step Test

The step drawdown test is performed to determine the maximum pumping rate that the pumping well can sustain and the minimum pumping rate necessary to assure drawdown in the observation wells. The pumping and observation wells are equipped with transducers prior to the test. Check the transducer accuracy by raising and lowering the transducer and comparing the change in water level from the transducer reading to the distance the transducer is raised or lowered.. The test is then performed by pumping at a low rate, relative to the expected final rate of pumpage, until drawdown in the pumping well stabilizes. The rate is then increased again until drawdown in the pumping well stabilizes (step 2). A minimum of three steps will be tested; the duration of each step will be similar, and should be between 30 minutes and 2 hours.

The data are then plotted on semi-log paper or on a computer. The maximum sustainable pumping rate that yields drawdown in the closest observation wells will be used as the target-pumping rate for the long-term test. These data may also be used to determine aquifer properties and well loss in the pumping well.

8.6 Pump Test Time Intervals

Commence the long-term pumping test after the pumping well has fully recovered from the step test. Place transducers into the observation wells prior to starting the test and allow time for them to equilibrate to the water temperature within the well and to collect pre-test water level data. At the beginning of the test, the discharge rate should be set as quickly and accurately as possible. Record the pumping and observation well water levels with transducers and a data logger(s) set to record logarithmically. As backup in case of transducer malfunction, manually record water levels on field forms and/or field notebooks according to the schedules in Tables 3 and 4:

Table 3: Time Intervals for Measuring Drawdown in the Pumped Well

Elapsed Time Since Start or Stop of Test (Minutes)	Interval Between Measurements (Minutes)
0-10	0.5-1
10-15	1
15-60	5
60-300	30
300-1440	60
1440-termination	480

Table4: Time Intervals for Measuring Drawdown in an Observation Well

Elapsed Time Since Start or Stop of Test (Minutes)	Interval Between Measurements (Minutes)
0-60	2
60-120	5
120-240	10
240-360	30
360-1440	60
1440-termination	480

For wells with a transducer malfunction, water levels records should be manually recorded on field forms and/or field notebooks according to the schedule in Table 5:

Table 5: Time Intervals for Measuring Drawdown in the Observation Wells with Transducer Malfunction

Elapsed Time Since Start or Stop of Test (Minutes)	Interval Between Measurements (Minutes)
0-2	0.1
2-10	0.5
10-20	1
20-100	5
100-200	10
200-300	30
300-1440	60
1440-termination	480

8.7 Water Level Measurements

Water levels will be measured as specified in the SAS-08-02. During the early part of the test, sufficient personnel are required to initiate the pumping test data loggers and assist with manual water level measurements of the pumping well and flow rate measurements. Manual measurements are required as a backup to and verification of the data logger(s). After the first two hours, one to two people are usually sufficient to continue the test. It is not necessary that readings at the wells be taken simultaneously. It is very important that depth to water readings be measured accurately and the exact time of readings is recorded.

During a pumping test, the following data must be recorded accurately on the log book and/or the aquifer test data form.

- Project ID - A number assigned to identify a specific site.
- Well ID - The location of the well in which water level measurements are being taken.
- Distance and Direction from Pumped Well - Distance and azimuth to each observation well from the pumping well in feet.
- Personnel - The personnel conducting the pumping test.

- Pumping Start and End Date/Time - The date when the pumping began, and start time using a 24-hour clock.
- Initial Static Water Level (Test Start) - Depth to water, to the nearest 0.01 feet, in the observation well at the beginning of the pumping test.
- Test End Date/Time - The date and time when water level readings were discontinued.
- Final Static Water Level (Test End) - Depth to water, to the nearest 0.01 feet, in the observation well at the end of the pumping test.
- Target Pumping Rate
- Measurement Methods - Type of pump, type of data logger(s) used to record water levels, transducer ID number, and acquisition rate (i.e. data recorded on a log scale). The transducer psi range should be appropriate to the test (e.g. 0 to 5 or 0 to 10 psi).
- Notes - Appropriate observations or information that has not been recorded elsewhere, including notes on sampling, pH readings, and conductivity readings.
- Elapsed Time (min) - Time of manual measurement record from time 0.00 (start of test) recorded in minutes and seconds.
- Depth to Water (ft) – Manual depth to water measurement, to the nearest 0.01 feet, in the observation well at the time of the water level measurement.
- Flow Rate (gal/min) - Flow rate of pump measured from an orifice, weir, flow meter, container, or other type of water measuring device.

8.8 Pump Test Duration

The duration of the test is determined by the needs of the project and properties of the aquifer. One simple test for determining adequacy of data is when the log-time versus drawdown for the most distant observation well begins to plot as a straight line on the semi-log graph paper. There are several exceptions to this simple rule of thumb; therefore, it should be considered a minimum criterion. Different hydrogeologic conditions can produce straight-line trends on log-time versus drawdown plots. In general, longer tests produce results that are more definitive. Duration of one to three days is desirable, followed by a similar period of monitoring the recovery of the water level. Unconfined aquifers and partially penetrating wells may have shorter test durations. Knowledge of the local hydrogeology, combined with a clear understanding of the overall project objectives is necessary in judging appropriate test duration. There is no need to continue the test once the water levels in the observation wells stabilize.

The recovery of water levels following pumping phase may be measured and recorded for a period equal to the pumping phase. The frequency of the water level measurements should be similar to the frequency of water level measurements during the pumping phase (Table 1).

9.0 POST OPERATION

The following activities are performed after completion of water level recovery measurements following a slug or pumping/recovery test:

- Decontaminate and/or dispose of equipment per SAS-04-05.
- When using an electronic data-logger, use the following procedures:
    - Stop logging sequence
    - Check file size, print data, and/or save memory to a reliable storage device (i.e. hard drive or USB drive): Backup the data as soon as possible upon completion of a test!
    - Do not clear the memory of the transducer until the data has been saved onto a hard drive
- Review field forms for completeness.
- Replace testing equipment in storage containers
- Check sampling equipment and supplies. Repair or replace all broken or damaged equipment.
- Interpret slug or pumping/recovery test field results.

10.0 CALCULATIONS

Upload the data from the test into a spreadsheet to be entered into a computerized program, such as Aqtesolv®. Use the information entered into the Data Acquisition Form to complete the computer analysis of the data. There are several accepted methods for determining aquifer properties such as transmissivity, storativity, and conductivity. The appropriate method to use is dependent on the characteristics of the aquifer being tested (confined, unconfined, leaky confining layer etc.). When reviewing slug and pump test data, the following text and/or documents may be used to determine the method most appropriate to your case:

- Analysis and Evaluation of Pumping Test Data (Kruseman and Ridder, 1989)
- Applied Hydrogeology (Fetter, 2000)

- Groundwater and Wells (Driscoll, 1986)
- ASTM D4105-96(2002)
- ASTM D4106-96(2002)

11.0 QUALITY ASSURANCE/ QUALITY CONTROL (QA/QC)

Gauges, transducers, flow meters, and other equipment used in the pumping tests will be calibrated before use at the site. Copies of the documentation of instrumentation calibration will be filed with the test data records. The calibration records will consist of laboratory measurements and, if necessary, any on-site zero adjustment and/or calibration that were performed. Where possible, all flow and measurement meters will be checked on-site using a container of measured volume and stopwatch; the accuracy of the meters must be verified before testing proceeds. For QA/QC purposes, a minimum of two single well tests (slug test) should be performed in each well that hydraulic conductivity testing is performed.

12.0 DATA REDUCTION AND INTERPRETATION

Slug and multiple well test data can be analyzed by a variety of methods, depending on the responses observed, geologic conditions, and specific well parameters. Texts such as Driscoll (1986) or other well hydraulics references should be consulted for selection of the proper method of data analysis. In reviewing hydraulic conductivity measurements, the following criteria should be considered to evaluate the accuracy or completeness of information.

- Values of hydraulic conductivity between wells in similar lithologies should generally not exceed one order of magnitude difference.
- Hydraulic conductivity determinations based upon multiple well tests are preferred. Multiple well tests provide more complete information because they characterize a greater portion of the subsurface.
- Use of single well tests will require that more individual tests be conducted at different locations to sufficiently define hydraulic conductivity variation across the site.
- Hydraulic conductivity information generally provides average values for the entire area across a well screen. For more depth discrete information, well screens will have to be shorter. If the average hydraulic conductivity for a formation is required, entire formations may have to be screened, or data taken from overlapping clusters.

It is important that measurements define hydraulic conductivity both vertically and horizontally across the site. Laboratory tests may be necessary to ascertain vertical hydraulic conductivity in saturated formations or strata. Results from boring logs should also be used to characterize the site geology. Zones of high permeability or fractures identified from drilling logs should be considered in the determination of hydraulic conductivity. Additionally, information from boring logs can be used to refine the data generated by single well or pumping tests.

13.0 REFERENCES AND ADDITIONAL RESOURCES

Bouwer, H., and Rice, R.C., "A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with completely or Partially Penetrating Wells", Water Res. Res., 12 p. 423-428, 1976.

Driscoll, F. G., 1986, Groundwater and Wells, Johnson Division, St. Paul, MN, 1089 p.

McLane, G. A., D. A. Harrity, K. O. Thomsen, "Slug Testing In Highly Permeable Aquifers Using a Pneumatic Method", Hazardous Materials Control Research Institute, Conference Proceedings, November, 1990, pp 300-303.

ASTM International, D2434-68(2000) Test Method for Permeability of Granular Soils (Constant Head)

ASTM International, D4043-96(2004) Guide for Selection of Aquifer Test Method in Determining Hydraulic Properties by Well Techniques

ASTM International, D4044-96(2002) Test Method (Field Procedure) for Instantaneous Change in Head (Slug) Tests for Determining Hydraulic Properties of Aquifers

ASTM International, D4050-96(2002) Test Method (Field Procedure) for Withdrawal and Injection Well Tests for Determining Hydraulic Properties of Aquifer Systems

ASTM International, D4104-96(2004) Test Method (Analytical Procedure) for Determining Transmissivity of Nonleaky Confined Aquifers by Overdamped Well Response to Instantaneous Change in Head (Slug Tests)

ASTM International, D4105-96(2002) Test Method (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of Nonleaky Confined Aquifers by the Modified Theis Nonequilibrium Method

ASTM International, D4106-96(2002) Test Method (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of Nonleaky Confined Aquifers by the Theis Nonequilibrium Method

ASTM International, D4511-00 Test Method for Hydraulic Conductivity of Essentially Saturated Peat

ASTM International, D4630-96(2002) Test Method for Determining Transmissivity and Storage Coefficient of Low-Permeability Rocks by In Situ Measurements Using the Constant Head Injection Test

ASTM International, D4631-95(2000) Test Method for Determining Transmissivity and Storativity of Low Permeability Rocks by In Situ Measurements Using Pressure Pulse Technique

ASTM International, D5269-96(2002) Test Method for Determining Transmissivity of Nonleaky Confined Aquifers by the Theis Recovery Method

ASTM International, D5270-96(2002) Test Method for Determining Transmissivity and Storage Coefficient of Bounded, Nonleaky, Confined Aquifers

ASTM International, D5472-93(2005) Test Method for Determining Specific Capacity and Estimating Transmissivity at the Control Well

ASTM International, D5473-93(2000) Test Method for (Analytical Procedure for) Analyzing the Effects of Partial Penetration of Control Well and Determining the Horizontal and Vertical Hydraulic Conductivity in a Nonleaky Confined Aquifer

ASTM International, D5720-95(2002) Practice for Static Calibration of Electronic Transducer-Based Pressure Measurement Systems for Geotechnical Purposes

ASTM International, D5785-95(2000) Test Method for (Analytical Procedure) for Determining Transmissivity of Confined Nonleaky Aquifers by Underdamped Well Response to Instantaneous Change in Head (Slug Test)

ASTM International, D5786-95(2000) Practice for (Field Procedure) for Constant Drawdown Tests in Flowing Wells for Determining Hydraulic Properties of Aquifer Systems

ASTM International, D5850-95(2000) Test Method for (Analytical Procedure) Determining Transmissivity, Storage Coefficient, and Anisotropy Ratio from a Network of Partially Penetrating Wells

ASTM International, D5855-95(2000) Test Method for (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of a Confined Nonleaky or Leaky Aquifer by Constant Drawdown Method in a Flowing Well

ASTM International, D5881-95(2005) Test Method for (Analytical Procedure) Determining Transmissivity of Confined Nonleaky Aquifers by Critically Damped Well Response to Instantaneous Change in Head (Slug)

ASTM International, D5912-96(2004) Test Method for (Analytical Procedure) Determining Hydraulic Conductivity of an Unconfined Aquifer by Overdamped Well Response to Instantaneous Change in Head (Slug)

ASTM International, D5920-96(2005) Test Method (Analytical Procedure) for Tests of Anisotropic Unconfined Aquifers by Neuman Method

ASTM International, D6028-96(2004) Test Method (Analytical Procedure) for Determining Hydraulic Properties of a Confined Aquifer Taking into Consideration Storage of Water in Leaky Confining Beds by Modified Hantush Method

ASTM International, D6029-96(2004) Test Method (Analytical Procedure) for Determining Hydraulic Properties of a Confined Aquifer and a Leaky Confining Bed with Negligible Storage by the Hantush-Jacob Method

ASTM International, D6030-96(2002) Guide for Selection of Methods for Assessing Groundwater or Aquifer Sensitivity and Vulnerability

ASTM International, D6034-96(2004) Test Method (Analytical Procedure) for Determining the Efficiency of a Production Well in a Confined Aquifer from a Constant Rate Pumping Test

ASTM International, D6391-99(2004) Test Method for Field Measurement of Hydraulic Conductivity Limits of Porous Materials Using Two Stages of Infiltration from a Borehole

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/60/B-07/001.

Author:	T.Gilles	Q2R & Approval By:	A. Bazan	Q3R & Approval By:	M. Kelley

STANDARD OPERATING PROCEDURE NO. SAS-08-05

WELL INTEGRITY INSPECTION, MAINTENANCE, AND REHABILITATION Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for inspecting groundwater monitoring well integrity. The well integrity inspection identifies wells that in their current condition are not suitable for obtaining groundwater/product elevations, water quality and/or hydraulic information, groundwater/product samples and/or other data obtained using the well. The results of the evaluation shall be used to ensure the integrity of wells over extended periods of time by identifying conditions that warrant well maintenance and/or rehabilitation. This SOP also describes well maintenance and rehabilitation.

2.0 EQUIPMENT AND MATERIALS

- Map of well locations;
- Tools and well keys, as required to facilitate access to wells;
- Water level measuring device (electronic water level indicator, interface probe, or weighted steel tape);
- Adjustable rate pump, adjustable rate submersible or positive displacement bladder pump (Note: The Site-Specific Work and/or Field Sampling Plan (FSP) shall specify the type of pump required);
- 1/4 to 3/8-inch Teflon®, polyvinyl chloride (PVC), or polypropylene tubing, if applicable;
- Power source, if applicable;
- Compressed inert gas source (for use with bladder pump), if applicable;
- PVC or stainless steel bailer or solid slug;
- Rope;
- Pressure transducer and automatic data logger, if applicable;
- Container(s) for purge water storage (e.g. 5-gallon buckets, polyethylene storage tank, etc.);
- Existing well boring/construction logs, if available;
- Groundwater elevation table, if available;
- Polyethylene sheeting, as appropriate;

- Camera;
- Personal protection equipment; and
- Field logbook and/or appropriate field forms.

3.0 HEALTH AND SAFETY WARNINGS

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 EXECUTION

Inspections shall be performed at the frequencies described below or as required by the Site-Specific Work Plan to 1) verify the structural integrity of the wells above and below ground, 2) identify significant silt/sediment buildup in wells, and 3) identify biofouling that could contribute to corrosion of structures or decrease in the efficiency of recovery and pumping operations.

4.1 Well Location Verification

The location of each well shall be compared to that given on the site map. If the well location is found to be in error, the well shall be resurveyed and/or re-delineated relative to site features and its position adjusted on the map.

4.2 Aboveground Structural Integrity Inspection

The physical condition of the well will be determined by visually inspecting aboveground components during each monitoring and/or sampling event. Components to be inspected include:

- Protective casing/flush-mount cover;
- Bumper posts, if applicable;
- Concrete pad or apron, if applicable;
- Well cap (expandable or slip);
- Locking mechanism;
- Exposed top of casing; and
- Surface drainage around the wells.

If the aboveground components are damaged, well maintenance or rehabilitation is required (see Section 4.3).

4.3 Below Ground Well Structural Integrity Inspection

4.3.1 General

Total depth measurements shall be obtained annually in accordance with SOP ENV-08-01 and compared to the baseline total depth measurements obtained at the time of well installation, development, and/or start of the project. If a significant amount of silt/sediment is present, well maintenance or rehabilitation is required (see Section 4.4). Additionally, single well aquifer testing may be performed to determine if silt/sediment has decreased the well hydraulic conductivity, indicating well maintenance or rehabilitation is necessary for collection of representative data. Use of this test will be determined on a site-specific basis or as otherwise determine in the SSWPs.

4.3.2 Monitoring Wells

A stainless steel or PVC bailer or slug, with a diameter and length equivalent to a sampling pump or bailer, shall be lowered the entire length of the well to identify obstructions or damage to the well casing and screen. If the bailer or slug cannot be lowered to within the screened interval, an obstruction or damage exists that requires well maintenance or rehabilitation (see Section 4.4). If well yield decreases significantly, well integrity may be assessed using a single well aquifer test to determine if well maintenance or rehabilitation is required.

4.3.3 Vapor Extraction Wells

Vacuum and air flow rates shall be measured periodically in accordance with system-specific procedures and compared to previous steady-state measurements and the current operational status of the system. If a significant change in vacuum and/or air flow rates is observed and not substantiated by the current operational status of the system, well maintenance or rehabilitation is required (see Section 4.4).

4.3.4 Recovery Wells

Recovery rates shall be evaluated at least once every quarter and compared to previous measurements. If a significant change in rates is observed and not substantiated by current product/water levels, well maintenance or rehabilitation is required (see Section 4.4).

4.4 Well Maintenance or Rehabilitation

Deficiencies or damage identified during aboveground and below ground well integrity inspections shall be evaluated on a case-by-case basis. Well maintenance or rehabilitation that cannot be implemented at the time of inspection shall be implemented within a reasonable period of time. Well maintenance or rehabilitation may include, but is not limited to, the following:

- Replacement of aboveground components;
- Silt/sediment removal;
- Well surging and redevelopment;
- Biomass removal and/or cleaning with an approved biocide; and
- Equipment (e.g. pumps, etc.) repair or replacement.

If deficiency or damage cannot be corrected through well maintenance or rehabilitation, the well shall be abandoned in accordance with SOP ENV-05-05 and applicable federal, state, and local regulations. Wells critical to site activities and/or operations shall be replaced in accordance with SOPs ENV-05-03 and ENV-05-04, applicable federal, state, and local regulations, and the Site-Specific Work Plan.

4.5 Decontamination

Non-Dedicated and dedicated equipment used for inspection and/or corrective action activities, which does not remain within the well casing, shall be removed from the well. The reusable and/or dedicated equipment and instruments shall be decontaminated in accordance with SOP ENV-04-04 or as otherwise specified by the Site-Specific Work Plan. Disposable equipment and supplies shall be disposed of in accordance with procedures outlined in the Site-Specific Work Plan.

5.0 DOCUMENTATION

Inspection, maintenance, and rehabilitation activities shall be recorded in the field logbook and/or on the appropriate field form as specified in SOP ENV-01-01 or as otherwise required by the Site-Specific Work Plan.

6.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, D6089-97(2003) Standard Guide for Documenting a Ground-Water Sampling Event

ASTM International, D4448-01 Standard Guide for Sampling Groundwater Monitoring Wells

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia, www.epa.gov/region4/sesd/eisopqam/eisopqam.html.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

Authors:	J. Sapp / T.Gilles	Q2R & Approval By:	A. Bazan	Q3R & Approval By:	M. Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-08-06

POTABLE WATER WELL SAMPLING
Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for the collection of water samples from water supply wells. Potable water samples are collected to evaluate the potable water supply. In some cases, potable water samples may be collected to evaluate the delivery system (e.g. well casing, pump, piping, etc.). The sampling guidelines described in the SOP are intended to facilitate the collection of representative samples.

2.0 EQUIPMENT AND MATERIALS

- Hand tools (e.g. crescent wrenches, pipe wrenches, and slip joint pliers), as needed;
- Garden water hose;
- Plastic sheeting;
- Graduated cylinder;
- Stopwatch;
- Sample containers and labels;
- Cooler with ice;
- Chain of custody forms and seals; and
- Personal protective equipment.

3.0 HEALTH AND SAFETY WARNINGS

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 PREPARATIONS

4.1 Sample Location Selection

In general, the installation of a sampling tap to obtain samples shall not be warranted. Potable water samples shall be collected from taps or spigots on the existing delivery system. Prior to sampling, the tap closest to the well shall be identified for sample collection. This location, to the extent practical, should be upstream of any filtration or water treatment device(s). If the location is not upstream of any filtration or water treatment device, the sampler shall recorded the type, manufacturer, and model of each filtration or water treatment device in the field logbook and/or on the appropriate field form. On rare occasions a tap or spigot may not be available for sampling. In these instances, the closest access point to the wellhead shall be selected for sampling. When project objectives include an evaluation of the water delivery, a representative location downstream of filtration or water treatment devices, may be selected. The selected or preferred sample locations shall be described in the Site-Specific Work and/or Field Sampling Plan (FSP).

4.2 Groundwater Elevation and Well Depth Measurements

In general, it is preferred to not obtain groundwater elevations and well depth measurements from public or private water supply wells. In most cases, groundwater elevation and well depth shall be estimated based on the driller's log and/or well completion report. In rare instances it may be necessary to measure groundwater elevation. In these cases, measurements shall be obtained using an electronic water level indicator or an un-weighted steel tape with the loop removed, which has been dedicated for use in potable water wells only and has been properly decontaminated and stored to prevent the introduction of contamination into the well. In addition, the water level indicator shall not be lowered any deeper than is necessary to obtain the groundwater elevation measurement. The need to use chlorine pellets to sanitize the well after measurements are collected will be evaluated on a site-specific basis, as described in SSWPs.

4.3 Calculation of the Pre-Sample Purge Volume

When potable water samples are being collected to evaluate the potable water source, all standing/stagnant water shall be purged from the delivery system immediately prior to sample collection. The volume of water contained in the well casing, pressure or holding tanks, and other plumbing and appurtenances (pipes, hoses, etc.) shall be estimated by the sampler. All estimated volumes of water contained in plumbing and appurtenances, assumptions, and calculations shall be recorded in the field logbook and/or on the appropriate field form.

5.0 EXCUTION

5.1 Pre-Sample Purging

If sample(s) are being collected to evaluate the delivery system, a first draw sample shall be collected prior to the purging (see Section 5.3 below). If samples are being collected to evaluate the potable water supply, the system shall then be purged with a minimum of three times the calculated purge volume before sampling commences. If no information regarding well depth is available, purging shall be performed a minimum of 15 minutes after the well pump engages prior to sampling in addition to the time required to evacuate pre-sample port systems (e.g. pressure tank, water softener, etc.). Pre-sample purging shall also take into account the following, if known:

- Pump intake level;
- Specific capacity of the aquifer; and
- Well efficiency.

Purged water if discharged to the ground surface shall be done in a manner that prevents icy conditions or damage on the property. In addition, the sampler shall divert purge water away from the wellhead or building using hoses, plastic sheeting, irrigation pipe, or other appropriate means, to the extent practical. Purge waters shall be disposed at the nearest sump or drain available whenever possible.

If samples are being collected to evaluate the delivery system, the initial/first draw sample shall be collected prior to purging activities.

5.2 Groundwater Quality/Indicator Parameter Monitoring

The Site-Specific Work and/or Sampling Plan(s) shall specify the groundwater quality/indicator parameters to be monitored, which typically include temperature, pH, specific conductance or actual conductivity, oxidation-reduction potential, dissolved oxygen, and turbidity. Parameter monitoring will begin at the start of purging from the delivery system. The sampler shall monitor and record in the field logbook and/or on the appropriate field form parameters every five to ten minutes (during continuous purging) until parameters have stabilized. Parameter stabilization is considered to be achieved when three consecutive readings, taken within 2 to 3 minute intervals are within the parameter-specific limit listed in the table below or as specified in the Site-Specific Work and/or Sampling Plan(s).

Parameter	Stabilization Criteria[1]
Conductance, Specific Electrical	+/- 3% µS/cm @ 25^{o}C
Conductivity, Actual[2]	+/- 3% µS/cm
Dissolved Oxygen	+/- 0.3 mg/L
Oxidation-Reduction Potential	+/- 10 mV
pH	+/- 0.1 standard units
Temperature	+/- 0.1 ^{o}C
Turbidity	+/- 10% NTUs or three consecutive readings less than or equal to 10 NTUs

Once the parameters have stabilized, purging is considered complete and sample collection shall commence, with the exception of the collection of a first draw sample. The first draw sample shall be collected prior to delivery system purging.

[1] USEPA, 2002, Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers, EPA 542-S-02-001
[2] Based on the stabilization criteria for specific electrical conductance as published in the documented cited above

5.3 SAMPLING PROCEDURES

The sampler shall collect the potable water sample(s) from a tap or spigot on the existing delivery system, which is closest to the well. This location, to the extent practical, should be upstream of any filtration or water treatment device(s). If the location is not upstream of any filtration or water treatment device, the sampler shall recorded the type, manufacturer, and model of each filtration or water treatment device in the field logbook and/or on the appropriate field form. The location, including a sketch, shall also be documented in the field logbook and/or on the appropriate field form.

Following purging activities, the sampling tap shall be shut off. The tap shall be turned on and adjusted to an approximate flow of 100 ml/min using a graduated cylinder and a stopwatch. The flow rate shall be recorded in the field logbook and/or on the appropriate field form. Sample bottles shall be filled in a manner which minimizes aeration. The sample bottles shall be filled as required in order of decreasing volatility. Any pertinent field observations (e.g. odors, discoloration, etc.) shall also be recorded in the field logbook and/or on the appropriate field form.

6.0 POST-SAMPLING PROCEDURES

Following sample collection, any filters, aerators, and/or treatment systems disconnected prior to sampling activities shall be reconnected. In addition, the sampling site shall be cleaned before leaving the vicinity.

7.0 DECONTAMINATION

Following sample collection, all equipment shall be decontamination as described in SOP ENV-04-04 or as otherwise specified by the Site-Specific Work and/or Sampling Plan(s).

8.0 DOCUMENTATION

Sample information, labeling, and custody control shall be performed in accordance with requirements specified in SOP ENV-03-01 and ENV-03-02. Sampling activities, including pertinent field information and observations, shall be recorded in the field logbook and/or on the appropriate field form as specified in SOP ENV-01-01 or as required by the Site-Specific Work and/or FSP including, but not limited to, the following:

- Condition of the well and dedicated equipment;
- Owner’s and occupant’s name(s);

- Facility name and address;
- Sampling location (specific tap or spigot);
- Filtering or treatment systems on delivery systems (if applicable);
- Aerator or filter on sampling tap;
- Pressure on holding tank volume (if applicable);
- Purge flow rate;
- Purge time;
- Total purge volume;
- Sample appearance (odor, color, turbidity, etc.); and
- Calculations for purge volumes.

9.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, 1994, D5612-94R03 Guide for Quality Planning and Field Implementation of a Water Quality Measurement Program

ASTM International, 1995, D5851-95R00 Guide for Planning and Implementing a Water Monitoring Program

ASTM International, 2001, D5903-96(2001) Standard Guide for Planning and Preparing for a Groundwater Sampling Event

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

Author:	T. Gilles	Q2R & Approval By:	A. Bazan	Q3R & Approval By:	M. Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-08-07

NON-AQUEOUS PHASE LIQUID SAMPLING
Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for the collection of non-aqueous phase liquid (NAPL) samples from monitoring, observation, and/or recovery wells. NAPL samples are collected to support plume characterization and/or treatment/recovery system design. Light and dense NAPL, also referred to as LNAPL and DNAPL, may be collected for physical parameter determination (e.g. density, viscosity, etc.), simulated distillation, fingerprinting, waste characterization, etc.

2.0 EQUIPMENT AND MATERIALS

Equipment and materials may vary based on the type of NAPL being sampled (light or dense). In general, the following equipment and materials shall be required unless otherwise specified by the Site-Specific Work and/or Field Sampling Plan (FSP):

LNAPL Sample Collection:

- Bailer (disposable or dedicated);
- Rope;
- Peristaltic pump;
- Polyvinyl chloride or Teflon tubing (disposable or dedicated), as appropriate; and
- Silicone tubing (disposable or dedicated).

DNAPL Sample Collection:

- Solinst Model 425 Discrete Interval Sampler or equivalent;
- Low density polyethylene (LDPE) tubing;
- Solinst Reel or equivalent;
- High pressure hand pump or compressed air source with regulator; and
- Rope.

General:

- Water and NAPL gauging equipment (see SOP ENV-08-01);
- 5-gallon bucket;
- Approved storage container(s) (55-gallon drum, polyethylene tank, etc.);
- Sample containers and labels;
- Chain of custody forms and seals;
- Decontamination materials/equipment;
- Personal protective equipment; and
- Field logbook and/or appropriate field form.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 EXECUTION

4.1 Preparation

The sampler shall create a work area around the monitoring well to minimize the potential for cross-contamination. Work area preparations may include the placement of polyethylene sheeting prevent sampling equipment from coming in contact with the ground surface. The sampler shall barricade and/or flag the work area, if required by the Site-Specific HASP. The sampler shall also arrange the sampling equipment and supplies to facilitate efficient execution of NAPL sampling procedures.

4.2 Well Gauging

Groundwater and NAPL elevation measurements shall be obtained in accordance with SOP ENV-08-01 or as otherwise specified in the Site-Specific Work and/or FSP. Following sampling activities, the sampler shall also obtain the total well depth from top of casing (in feet to the nearest 0.01-foot) using a water level indicator, interface probe, or steel tape, as required by the Site-Specific Work and/or FSP or otherwise specified. Total well depths may be obtained prior to the sampling (at least one to two weeks in advance) and provided to the sampler. Groundwater and NAPL elevation measurements and total well depth measurements shall be recorded in the field logbook and/or on the appropriate field form.

4.3 Standing NAPL Column and Casing Volume Calculations

The sampler shall calculate the standing NAPL column and casing volume using the following formulas:

4.3.1 LNAPL Column

$$\text{Standing LNAPL Column}_{\text{(Feet)}} = \text{DTW}_{\text{(FT BTOC)}} - \text{DTP}_{\text{L (FT BTOC)}}$$

Where: DTW = Depth to Water
FT BTOC = Feet below top of well casing
DTP_L = Depth to Product (LNAPL)

4.3.2 DNAPL Column

$$\text{Standing DNAPL Column}_{\text{(Feet)}} = \text{TD}_{\text{(FT BTOC)}} - \text{DTP}_{\text{D (FT BTOC)}}$$

Where: TD = Total Well Depth
FT BTOC = Feet below top of well casing
DTP_D = Depth to Product (DNAPL)

4.3.3 Casing Volume

$$\text{Casing Volume}_{\text{(Gallons)}} = \text{Standing NAPL Column}_{\text{(Feet)}} \times \text{Volume per One Foot of Casing}^{\text{WDS}}_{\text{(Gallons/Foot)}}$$

Where: ^{WDS} = Well diameter-specific (see table below)

Well Diameter-Specific Volume Per One Foot of Casing				
Well Diameter (Inches)	**Volume Per Foot of Casing (Gallons)**		**Well Diameter (Inches)**	**Volume Per Foot of Casing (Gallons)**
0.25	0.0026		4.0	0.6528
0.50	0.0102		6.0	1.469
0.75	0.0230		8.0	2.611
1.0	0.0408		10.0	4.081
2.0	0.1632		12.0	5.876

The sampler shall recorded calculations in the field logbook and/or on the appropriate field form.

4.4 Bailer/Tubing/Sampler Intake Position Determination

The sampler should determine the position/depth of the bailer/tubing/sampler intake, using the water and NAPL elevation measurements, such that the intake will be positioned within the bottom quarter of the NAPL column. The intake position (depth/elevation) shall be recorded in the field logbook and/or on the appropriate field form. In addition, the sampling equipment shall also be recorded in the field logbook and/or on the appropriate field form.

4.5 Well Evacuation

In order to obtain a representative NAPL sample from an existing well, the product that has stagnated and/or may have chemically changed in the well casing shall be removed prior to sampling. The evacuation will allow fresh NAPL to enter the well from the formation.

4.5.1 LNAPL Evacuation

If using a bailer, the sampler shall slowly lower the bailer to the intake position. The bailer shall be slowly retrieved from the well and the contents emptied into a 5-gallon bucket or an approved storage container. This process shall continue until no measurable amount (< 0.01 foot) of LNAPL remains or one casing volume of LNAPL has been removed, whichever occurs first. If using a peristaltic pump, the sampler shall slowly lower the tubing to the intake position. The pump shall be turned on and the removed LNAPL shall be collected in a 5-gallon bucket or an approved storage container. The pump process shall continue until no measurable amount (< 0.01 foot) of LNAPL remains or one casing volume of LNAPL has been removed, whichever occurs first.

The volume of LNAPL evacuated from the well shall be recorded in the field logbook and/or on the appropriate field form.

4.5.2 DNAPL Evacuation

The discrete interval sampler shall be connected to the tubing and reel. The high pressure hand pump or compressed air shall be connected to the reel. The sampler shall be pressured to the recommended operating pressure for the intake position/depth according to the following unless otherwise specified by the sampler operations manual and/or Site-Specific Work and/or FSP.

Recommended Operating Pressure[1]			
Depth		Pressure	
Feet	Meters	psi	kPa
25	8	20	148
50	15	30	217
100	30	50	364
200	61	95	670
300	90	140	952
500	150	225	1,495

Notes: 1. Operating pressure = (Sample depth in feet X 0.43) + 10 psi
2. Operating pressure = (Sample depth in meters X 9.8) + 70 kPa
3. psi = pounds per square inch
4. kPa = kiloPascals

[1] http://www.groundwatersoftware.com/Equipment/solinst_model_425.htm

While pressurized, the sampler shall then be lowered to the intake position/depth. At the desire depth, the pressure shall be released, which will allow the sampler to fill by hydrostatic pressure. The sampler shall then be re-pressurized to the recommended operating pressure. Following, re-pressurization, the sampler shall be slowly raised to the surface. The contents shall be transferred to the 5-gallon bucket or approved storage container via the sample release device. This process shall continue until no measurable amount (< 0.01 foot) of DNAPL remains or one casing volume of DNAPL has been removed, whichever occurs first.

4.6 Post NAPL Evacuation Activities

Groundwater and NAPL elevation measurements shall be measured and monitored in accordance with SOP ENV-08-01 or as otherwise specified in the Site-Specific Work and/or FSP. Once the NAPL column has recovered to a level equivalent or greater than the prescribed sample volume, sampling may commence.

4.7 Sample Collection

4.7.1 LNAPL Sample Collection

If using a bailer, the sampler shall slowly lower the bailer to the intake position. The bailer shall be slowly retrieved from the well and the contents emptied into the appropriate sample container(s).

If using a peristaltic pump, the sampler shall slowly lower the tubing to the intake position. The pump shall be turned on and the removed LNAPL shall be emptied into the appropriate sample container(s).

4.7.2 DNAPL Sample Collection

The discrete interval sampler shall be connected to the tubing and reel. The high pressure hand pump or compressed air shall be connected to the reel. The sampler shall be pressured to the recommended operating pressure for the intake position/depth according to the following unless otherwise specified by the sampler operations manual and/or Site-Specific Work and/or FSP (see Section 4.5.2). While pressurized, the sampler shall then be lowered to the intake position/depth. At the desire depth, the pressure shall be released, which will allow the sampler to fill by hydrostatic pressure. The sampler shall then be re-pressurized to the recommended operating pressure. Following, re-pressurization, the sampler shall be slowly raised to the surface. The contents shall be transferred to the appropriate sample container(s) via the sample release device.

4.8 Post Sample Collection

Non-Dedicated and dedicated sampling equipment, which does not remain within the well casing, shall be removed from the monitoring well. The reusable and/or dedicated equipment and instruments shall be decontaminated in accordance with SOP ENV-04-04 or as otherwise specified by the Site-Specific Work and/or FSP. Disposable equipment and supplies shall be disposed of in accordance with procedures outlined in the Site-Specific Work and/or FSP. The sampler shall secure the well casing using a slip or expandable well cap. The flush-mount lid shall be bolted down or the protective cover lid closed and locked, as appropriate.

5.0 Documentation

Sample information, labeling, and custody control shall be performed in accordance with requirements specified in SOP ENV-03-01 and ENV-03-02. Sampling activities shall be recorded in the field logbook and/or on the appropriate field form as specified in SOP ENV-01-01 or as required by the Site-Specific Work and/or FSP.

6.0 REFERENCES AND ADDITIONAL RESOURCES

http://www.groundwatersoftware.com/Equipment/solinst_model_425.htm

USEPA, 2002, Ground-Water Sampling Guidelines for Superfund and RCRA Project Manager, Region 5 and Region 10, EPA 542-S-02-001.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/60/B-07/001.

SOP SERIES SAS-09

SURFACE WATER SAMPLING AND MEASUREMENT PROCEDURES

Authors: J. Sapp / T.Gilles **Q2R & Approval By:** C. Barry **Q3R & Approval By:** M. Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-09-01

SURFACE WATER SAMPLING FOR CHEMICAL AND BIOLOGICAL ANALYSIS
Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for the collection of grab surface water samples for chemical and biological analysis using manual sampling techniques. The collection of composite surface water samples using automatic samplers shall be address in an equipment-specific SOP or the Site-Specific Work Plan, as needed. Surface water samples are utilized for the characterization of surface water and assessment of human and ecological receptors.

2.0 EQUIPMENT AND MATERIALS

Sampling equipment and materials vary by collection method. However, some standard equipment and materials are required regardless of collection method:

- Hip or chest waders, as appropriate;
- Boat and personal floatation devices (PFDs), as needed;
- Sample bottles/containers and labels;
- Field logbook and/or the appropriate field form(s);
- Pens with waterproof, non-erasable ink;
- Chain of custody forms;
- Depth and length measurement devices;
- Survey stakes, flags, or buoys and anchors;
- Decontamination materials;
- Coolers and ice packs/double-bagged ice;
- Personal protective equipment; and
- Camera.

3.0 HEALTH AND SAFETY WARNINGS

Aquatic environments present unique health and safety concerns ranging from accessibility to water depth and velocity to indigenous species. Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Work on water requires that marine health and safety procedures are used in addition to standard health and safety procedures. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 PERMITTING

Sampling performed within navigable waters and critical habitats may fall under the jurisdiction of one or more federal, state, or local agencies, including by not limited to the United States Army Corp of Engineers (USACOE), US Department of Fish and Wildlife, and State Departments of Natural Resources. Prior to the commencement of sampling activities, appropriate permit(s), if applicable, shall be obtained.

5.0 EXECUTION

5.1 General Considerations

The scope or extent of the sampling effort, data quality objectives, type(s) of samples (e.g. surface or depth grab), and sampling technique shall be determined prior to sample site selection and sample collection. In addition, the hydrology and morphometrics of a stream or impoundment shall be determined to the extent practical prior to sample collection. Water quality data (e.g. dissolved oxygen, pH, and temperature, etc.) shall be collected prior to sample collection, to the extent practical, to determine if stratification is present. These sampling activities should be restricted to seasons when ice is not present, unless specified by a Site-Specific Work Plan and/or Field Sampling Plan (FSP). The Site-Specific Work Plan and/or FSP, as appropriate, shall specify the type(s) of samples to be collected and the collection technique(s).

5.2 Sample Site Selection

An initial reconnaissance shall be performed, to the extent practical, identify suitable sampling locations. Bridges and piers shall generally be deemed acceptable sampling locations since they provide ready access and permit water sampling at any point across the width of the water body. However, data quality objectives (DQOs) must be reviewed prior to final acceptance of these structures as sampling locations, since these structures alter the nature of water flow. When samples will be collected by wading in lakes, ponds, and slow-moving rivers and streams, sampling locations shall be selected that allow the sampler to approach the location from downstream in order to minimize the disturbance of sediments. Sampling station locations shall be selected without regard to other means of access if the stream is navigable by boat. However, other factors including but not limited to the following shall be considered in the sample site selection process:

- Project goals and DQOs;
- Field personnel health and safety;
- Manmade structures that alter the nature of water flow and mixing;
- General water environment characteristics (e.g. flow, depth, stratification, etc.);
- Potential disturbance of threatened or endangered species or critical habitat; and
- Type of water environment: river, streams, creeks; lakes, ponds, impoundments, estuarine, etc.

5.3 Surface Grab Sample Collection Procedures

Surface grab samples shall be collected from the top 12 inches of the water column. Samples shall be collected in a manner that avoids skimming of the surface and disturbance of sediments. If sample collection is performed by wading in the stream, the location shall be approached from a downstream location and efforts shall be made to minimize sediment disturbance, which has the potential to bias the sample. Wading shall be deemed acceptable if a noticeable current is present and the samples can be collected directly into the bottle from a location upstream of the field personnel. The field personnel shall approach the sample location slowly from downstream in order to minimize sediment disruption and sample corruption.

5.3.1 Direct Grab Sampling

Where practical, use of the actual sample container as the collection device is preferred since the same container can be submitted for laboratory analysis. This procedure reduces sample handling and potential loss of analytes or contamination from the sample from other sources. The following procedure shall be used for direct grab sample collection using unpreserved sample containers:

1. Remove the container cap or lid.
2. Slowly submerge the container, opening first, into the water.
3. Invert the container so the opening is upright and pointing towards the direction of water flow (if applicable) and allow water to slowly run into and fill the container.
4. Return the filled container to the surface.
5. If field preservation is required, proceed to Step 6; otherwise, secure the container cap or lid and proceed to Step 10.
6. Pour out a small volume of sample away from and downstream of the sampling location. (Do not use this step for volatile organics or other analytes that require zero headspace.)
7. Add the appropriate volume of the analytical method-prescribed preservative and secure the container cap or lid.
8. Invert the container several times to ensure sufficient mixing of the sample and preservative.
9. Check the preservation of the sample; adjust the pH of the sample with additional preservative, if necessary; and re-secure the cap or lid.
10. Label the sample container in accordance with SOP ENV-03-01 and place in cooler with double-bagged ice for in preparation for transportation to the analytical laboratory.

5.3.2 Sampling with an Intermediate Vessel or Container

If the sample cannot be collected directly in the sample container(s), an unpreserved sample container or an intermediate vessel (e.g. beaker, bucket, or dipper with or without an extension arm) shall be used to obtain the sample using the following procedure:

1. Decontamination the intermediate vessel in accordance with SOP ENV-04-04 or use certified clean, laboratory provided, unpreserved bottles.
2. Fill the intermediate vessel or container by slowly dipping it into the water with the opening pointing towards the direction of water flow (if applicable);

3. Allow water to slowly run into and fill the intermediate vessel or container in a manner that minimizes agitation of the sample;
4. If field preservation is required, ensure the preservative is present in the sample container prior to transfering water from the intermediate vessel;
5. Remove the sample container lid and fill the sample container(s) from the intermediate vessel or container while avoid direct contact between them;
6. Secure the sample container lid.
7. Label the sample container in accordance with SOP ENV-03-01 and place in cooler with double-bagged ice for in preparation for transportation to the analytical laboratory.

5.3.3 Sampling with a Pump and Tubing

The following procedure shall be used for the collection of a surface grab sample using a pump and dedicated tubing:

1. Decontaminate the pump in accordance with SOP ENV-04-04, as appropriate.
2. Lower the tubing or pump intake to a depth of 6 to 12 inches below the water surface, where possible. The pump intake or intake tubing shall be maintained below the water surface during sample collection.
3. Pump several tubing volumes through the system prior to collecting the first sample.
4. If field preservation is required, ensure the preservative is present in the sample container prior to filling the sample container;
5. Fill the sample container(s) from the discharge tubing.
6. Secure the sample container lid.
7. Label the sample container in accordance with SOP ENV-03-01 and place in cooler with double-bagged ice for in preparation for transportation to the analytical laboratory.

5.4 Depth Grab Sample Collection Procedures

Depth grab samples shall be collected from at least below the top 12 inches of the water column to within 6 inches of the stream or impoundment bed, at depths to satisfy the DQOs specified by a Site-Specific Work Plan and/or determined in the field based on field encountered conditions (i.e., stratification, water column depth, etc.). Specific sample collection procedures for depth grab samples are presented below. If sample collection is performed by wading in the stream, the location shall be approached from a downstream location and efforts made to minimize sediment disturbance, which has the potential to bias the sample. Wading shall be deemed acceptable if a noticeable current is present and the samples can be collected from a location upstream of the field personnel. The field personnel shall approach the sample location slowly from downstream in order to minimize sediment disruption and sample corruption.

5.4.1 Sampling with Kemmerer, Niskin, or Van Dorn Type Devices

To the extent practical, devices constructed of stainless steel or Teflon or with Teflon-coated surfaces shall be used. Samplers that are constructed of plastic and rubber shall not be used to collect samples for extractable organics or volatile organic compound (VOC) analysis. The following procedure shall be used to collect depth grab samples using these devices:

1. Decontaminate the device in accordance with SOP ENV-04-04;
2. Measure the water column to determine the maximum depth and sampling depths;
3. Mark the line attached to the device with depth increments so that the sampling depth can be accurately recorded;
4. Slowly lower the device to the desired sampling depth in a manner that minimizes sediment disturbance;
5. At the desired depth, send the messenger weight down to trip the closure mechanism;
6. Slowly retrieve the device;
7. Rinse the outside of the device with distilled water;
8. Remove the sample container cap or lid and fill the container via the discharge tube;
9. If field preservation is required, follow Step 6 through Step 9 in Section 5.3.1 above; otherwise, proceed to Step 10 below.
10. Secure the sample container lid.
11. Label the sample container in accordance with SOP ENV-03-01 and place in cooler with double-bagged ice for in preparation for transportation to the analytical laboratory.

5.4.2 Sampling with Double Check-Valve Bailers

If DQOs do not necessitate a sample from a strictly discrete interval of the water column, a double check-valve bailer may be used. The following procedure shall be used to collect a depth grab sample with a double check-valve bailer:

1. Decontaminate the bailer in accordance with SOP ENV-04-04, or use a clean disposable bailer at each sampling location.
2. Measure the water column to determine the maximum depth and sampling depths.
3. Mark the line attached to the bailer with depth increments so that the sampling depth can be recorded.
4. Slowly lower the bailer to the desired sampling depth in a manner that minimize sediment disturbance.
5. Slowly retrieve the bailer.
6. Rinse the outside of the bailer with distilled water.
7. Remove the sample container cap or lid and fill the containers via the discharge port.
8. If field preservation is required, follow Step 6 through Step 9 in Section 5.3.1 above; otherwise, proceed to Step #9 below.
9. Secure the sample container lid.
10. Label the sample container in accordance with SOP ENV-03-01 and place in cooler with double-bagged ice for in preparation for transportation to the analytical laboratory.

5.4.3 Sampling with a Pump and Tubing

The following procedure shall be used for the collection of a depth grab sample using a pump and dedicated tubing:

1. Decontaminate the pump in accordance with SOP ENV-04-04, as appropriate.
2. Measure the water column to determine the maximum depth and sampling depths.
3. Secure the pump intake or intake tubing to a stiff pole or weight.
4. Lower the pump intake or intake tubing to the desire sample depth.
5. Pump several tubing volumes through the system prior to collecting the first sample.
6. Remove the sample container cap or lid and fill the sample container from the discharge tubing.
7. If field preservation is required, follow Step 6 through Step 9 in Section 5.3.1 above; otherwise, proceed to Step 8 below;
8. Secure the sample container lid.
9. Label the sample container in accordance with SOP ENV-03-01 and place in cooler with double-bagged ice for in preparation for transportation to the analytical laboratory.

5.5 Sampling for Biological Analysis

When sampling for biological or bacteriological examination, the procedures described above shall be followed with one exception, unless otherwise specified in the Site-Specific Work and/or FSP. Samples shall be collected in bottles properly sterilized and protected against contamination. As with any sample collection procedure, while the bottle is open, both the bottle and stopper shall be protected against contamination from other sources and the bottle closed at once following sample collection.

6.0 DOCUMENTATION

Sample information, labeling, and custody control shall be performed in accordance with requirements specified in SOP ENV-03-01 and ENV-03-02. Sampling activities shall be recorded in the field logbook and/or on the appropriate field form as specified in SOP ENV-01-01 or as required by the Site-Specific Work and/or FSP.

7.0 REFERENCES

ASTM International, D3977-97 (2002), Standard Test Methods for Determining Sediment Concentration in Water Samples.

ASTM International, D4581-86 (2005), Guide for Measurement of Morphologic Characteristics of Surface Water Bodies.

ASTM International, D5073-02, Practice for Depth Measurement of Surface Water.

Florida Department of Environmental Protection, February 2004, DEP-SOP-001/01 FS 2100 Surface Water Sampling.

USEPA, November 1994, SOP 2013: Surface Water Sampling, Rev. 0.0, Environmental Response Team.

USEPA, July 2002. Standard Operating Procedures for the Collection of Chemical and Biological Ambient Water Samples. Revision 1.

USEPA. 40 CFR Part 136.3 (e) Table II

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

Author: C. Barry **Q2R & Approval By:** T. Gilles **Q3R & Approval By:** M. Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-09-02

STREAMFLOW MEASUREMENT
Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes guidelines for the calculation of velocity and stream discharge measurements in rivers and streams. Procedures are given for measurements that can be conducted from water vessels (i.e. boats or barges), bridges (if traversing a representatives section of the river) or by wading with assistance from other field personnel working from the stream bank.

2.0 EQUIPMENT AND MATERIALS

- Flow Meter;
- Top-setting wading rod (measured in tenths of a foot);
- Tape measure or tagline (long enough to traverse the stream bed)
- Stakes to anchor tape to shore;
- Mallet or hammer;
- Field logbook and applicable field data sheets;
- Pen(s) with waterproof, non-erasable ink;
- Waders; and
- Personal protective equipment.

3.0 HEALTH AND SAFETY WARNINGS

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Work on water requires that marine health and safety procedures are used in addition to standard health and safety procedures. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 GENERAL PROCEDURES

4.1 Standard Field Procedures

Streamflow measurements shall be conducted only by a trained technician. Field data and observations associated with streamflow measurements shall be documented in accordance with SOP ENV-01-01, if not otherwise specified in this SOP. All activities should be recorded in a field logbook and/or on a streamflow measurement field form.

4.2 Site Selection

The stream transect location is a critical component of streamflow measurement. A site where the stream is most consistent in depth and flow rate across its width is easier to sample and provides more accurate results. Flow sites should be free of eddies, slack water, and excessive turbulence. Avoid areas where islands, ox-bows, piles of debris, aquatic plants or tributaries are present.

4.3 Flow Meter Selection

Several flow meters are available for measuring stream velocity. Some specific meters are the Price Model #1210 (AA); Price Model #1205 (Pygmy) for small, shallow streams; the March-McBirney 201D; and the March-McBirney Flo-Mate 2000. Selection of an appropriate flow meter will depend on the width and depth of the stream being measured, as well as stream features and irregularities. Additional guidance for selection of flow meters may be given in the Site-specific Work Plan.

4.4 Calculation of Stream Discharge

Stream discharge is determined by multiplying the mean stream velocity by the cross sectional area of the flow. The general form of the discharge equation is:

$$Q = A \text{ x } v$$

Where: Q = discharge in cubic feet per second (cfs)
A = cross section area of the channel at the transect in square feet (ft^2)
v = mean water column velocity at the transect in feet per second (ft/s)

To measure discharge (Q), a transect of the stream is divided into subsections and velocity, width and depth measurements are made within each subsection. Discharge of the stream at the transect is calculated by a form of the general equation:

$$Q = \sum_{i=1}^{n} (A_i \, x \, v_i)$$

Where: Q = discharge (cfs)
A_i = cross-sectional area of subsection I (ft^2)
v_i = velocity of subsection (ft/s)

A variation of this equation for mid-section method from Rantz (1982) is presented is Section 7.0 below. Other variations can be found in references listed at the end of this SOP and may be used as specified in the Site-specific Work Plan.

5.0 FIELD MEASUREMENT PROCEDURES

1. Calibrate the flow meter as specified in the manufacturer's instructions.
2. Attach the flow meter to the top set wading rod.
3. Measure the width of the stream at the selected transect location is measured by staking one end of the tape measure or pre-measured and incrementally marked tagline on the right bank. Pull the tape measure across the stream keeping it perpendicular to the flow and stake it on the left bank or use GPS to establish a transect location if sampling from a vessel. Measure the width of the stream from left edge of water (LEW) to right edge of water (REW). LEW is defined as the point where water flow begins on the transect as you face downstream. REW is where water flows ends on the transect.

4. Determine the spacing of transect subsections to be used for velocity measurements. Each subsection should have a width of 5% to 10% of the stream width. For an accurate measurement of discharge, velocity should be measured in 20 to 30 subsections. If inconsistencies in flow rate or streambed topography are present, the number and sizes of subsections can be adjusted to accommodate the differences. Additional guidance on subdividing the transect may be given in the Site-specific Work Plan.
5. Determine the mid-point of each subsection. Use a cumulative measurement. If the stream is 30 feet wide with 20 subsections, the first mid-point is located at 0.75 feet from LEW, the second is located at 2.25 feet from LEW, etc. Draw a rough sketch of the transect with subsections and mid-point measurements in the field logbook and/or on the appropriate field form.
6. Begin the velocity and depth measurements at the first subsection mid-point as measured from the LEW. Measure the total depth of water using the scale on the lower portion of the wading rod or 2-inch diameter graduated aluminum pole. Single indentations on the rod indicate 0.1 foot, double indentations indicate 0.5 foot and triple indentations indicate 1.0 foot. Depending on water depths, velocity measurements will be taken at one or two depths as follows:
    - Depths ≤ 2.5 feet – one measurement is taken at 60% of the total depth when measured from the surface of the water. To set the sensor of the flow meter at 60% of the depth, line up the foot scale on the sliding rod with the tenth scale on the top of the depth gauge rod. For example, if the first subsection is 1.5 feet deep, line up the 1 foot indentation on the sliding rod with the 5 on the tenth scale on the depth gauge rod.
    - Depths > 2.5 feet – two measurements are taken: one at 20% of the total depth and one at 80% of the total depth when measured from the surface of the water. To set the 20% depth point, multiply the depth of the water by two and move the sliding rod so that the foot measurement on it lines up with the tenth of a foot measure on the depth gauge rod. For example, if the first subsection is 2.8 feet deep, twice the depth is 5.6 feet. Line up the number 5 on the sliding rod with the 6 on the depth gauge rod. To set the 80% depth point, divide the depth of the water by two and move the sliding rod to line up with the depth gauge rod based on the results. For example, 2.8 feet divided by 2 equals 1.4 feet. Line up the number 1 on the sliding rod with the 4 on the depth gauge rod. The average of the two velocity measurements are used in the flow calculation.

Take the velocity measurement(s) following the manufacturer's instructions and record them in the field logbook or on the field log form. Proceed to the next subsection of the transect and repeat the procedure across the stream towards the REW.

7. If required, continue to next transect location and repeat the measurement procedures.

6.0 DISCHARGE CALCULATIONS

Calculate the discharge in each transect subsection by multiplying the average velocity (>2.5-foot depth subsection) or single velocity (≤ 2.5-foot depth) by the subsection width and average depth using the equation:

$$Q = \left(\frac{D_1 + D_2}{2}\right)\left(\frac{v_1 + v_2}{2}\right)W_1 + \ldots + \left(\frac{D_m + D_n}{2}\right)\left(\frac{v_m + v_n}{2}\right)W_m$$

Where: Q = discharge (cfs)
v = velocity of subsection (ft/s)
W = width of subsection (ft)

Note: The first and last subsections are located at the edges of the stream and have a depth and velocity of zero (D_1, D_n, v_1 and v_n).

7.0 QUALITY ASSURANCE/QUALITY CONTROL

7.1 Equipment Calibration, Operation, and Maintenance

All field equipment shall be calibrated, operated, and maintained in accordance with SOP ENV-02-01 and manufacturer's instructions.

7.2 Calculations

All calculations shall be checked by another person for correctness and use of appropriate equations. Any corrections required will be made by the person originally performing the calculations. These corrections will be checked for correctness and approved for publication.

8.0 REFERENCES AND ADDITIONAL RESOURCES

Carter, R. W. and Davidian, J., 1969, General Procedure for Gaging Streams: Techniques of Water Resources Investigations of the U.S. Geological Survey, Book 3.

California Department of Pesticide Regulation, Environmental Monitoring Branch, 2004, Standard Operating Procedure for Determining Wadable Stream Discharge with Price Current Meters, SOP Number: FSWA009.01.

Rantz, S.E., 1982, *Measurement and Computation of Streamflow: Volumes 1 and 2*, "Measurement of Stage and Discharge", U.S. Geological Survey Water-Supply Paper 2175.

Florida Department of Environmental Protection, Bureau of Watershed Management, Watershed Assessment Section, February 2004, FT 1800 Field Measurement of Water Flow and Velocity. DEP-SOP-001/01.

USEPA, Region 6, January 2003, Standard Operating Procedure for Streamflow Measurement.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

SOP SERIES SAS-10

WITHHELD - NOT RELEVANT TO STUDY ACTIVITIES

SOP SERIES SAS-11

SOIL VAPOR SAMPLING AND MEASUREMENT PROCEDURES

Author:	**M. Gossett**	**Q2R & Approval By:**	**D. Marquez**	**Q3R & Approval By:**	**M. Kelley**

STANDARD OPERATING PROCEDURE
NO. SAS-11-01

SUB-SLAB SAMPLE PORT INSTALLATION, SAMPLING, AND ABANDONMENT
Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for installation and sampling of sub-slab sample ports. Soil gas sampling is a useful tool to evaluate the potential for vapor intrusion at sites with subsurface chemical impacts and existing buildings. Sub-slab sampling is conducted directly beneath the building's slab to provide measurements of soil gas that may potentially enter a building.

2.0 EQUIPMENT AND MATERIALS

- Rotary hammer drill (or equivalent) with 1-inch and 5/16-inch diameter bits;
- Hand tools, including a hammer, needle-nose pliers, and trowel;
- "T" Swagelok® (compression) or equivalent fitting;
- 3-way and 2-way stopcocks;
- ¼-inch O.D. Teflon™ tubing;
- Tedlar™ bags;
- Plastic helium shroud;
- Broom and dust pan or hand vacuum;
- Beeswax;
- Nitrile gloves;
- Summa™ canisters with flow controllers, particulate filters, vacuum gauges, and shipping container;
- Sample labels;
- Chain of custody forms and seals;
- Field air monitoring instruments, as specified in the Work Plan (e.g. photoionization detector (PID), multi-gas monitors, etc.)
- Location markers (e.g. pin flags, wooden stakes, flagging tape, etc.);

- Asphalt cold patch or cement, as appropriate for site restoration; and
- Field logbook and/or appropriate field forms

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 CONSIDERATIONS

Variations in chemical-specific characteristics, geologic conditions, and atmospheric influences can affect soil-gas sampling results. For this reason, it is important to understand factors the may influence the reported data when collecting soil-gas data. In all cases, site-specific factors should be carefully evaluated prior to initiation of sampling to obtain representative soil-gas data.

Prior to any soil-gas sampling, soil type must be evaluated for suitability of sampling. Soils with smaller grain sizes have smaller pore spaces and are less permeable, which may reduce the ability for soil gas to be released from the subsurface. For example, clays have the smallest grain size and significantly restrict soil gas migration. Soil moisture also limits the ability for soil gas to be released from the subsurface because moisture trapped in the pore space of sediments can inhibit or block soil-gas flow. Seasonal and geographical variations in soil moisture content can affect air permeabilities. In addition, manmade and naturally occurring preferential pathways (e.g. utility corridors, lenses of coarse-grained materials within fine-grained materials, etc.) may also affect soil-gas migration and shall be considered prior to soil-gas sampling.

Reliability of soil-gas sampling may be improved by using fixed probes and by ensuring that leakage of atmospheric air into the samples is avoided during purging or sampling. To avoid dilution of the sampling region from leakage, the minimum purge volume deemed adequate to flush the sampling system should be removed, and soil-gas samples should be collected from the most permeable zones in the vadose zone when possible. Site-specific information concerning soil lithology, grain size analysis, soil moisture, and soil-gas permeability may be obtained by performing three soil borings in the immediate area of the sampling locations in advance of the soil-gas sampling. In addition, previous site investigation sample results, when available, should be used to determine the placement of the soil-gas sampling locations.

Since oxygen, carbon dioxide, and nitrogen can be sampled using a multi-gas monitor to give real-time results, parallel analysis of oxygen, carbon dioxide, and nitrogen in soil-gas may also be used to help assess the reliability of a given sample result.

5.0 EXECUTION

The active soil-gas sampling approach consists of withdrawing an aliquot of soil gas from the subsurface, followed by the analysis of the withdrawn gas. Active soil-gas systems use mechanical equipment to create a small-diameter hole in the ground and then use a vacuum to "actively" withdraw a soil gas sample through Teflon tubing within the vadose zone. The soil gas sample is collected in a Summa canister and sent to a laboratory for analysis. Samples are analyzed using USEPA's Ambient Air Compendium Method TO-15 (USEPA, 1999) for determining organic compounds in ambient air. The results provided by active soil-gas systems are quantitative and are reported in units of concentration per volume (micrograms per cubic meter [$\mu g/m^3$], or parts per billion volume [ppb_v]).

The following active soil-gas sampling methodologies (port installation and sampling) are based on established methods as outlined in the *USEPA Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance)* (USEPA, 2002) and the ASTM International (ASTM) standard guide D 5314-01 (ASTM, 2001). Additional guidelines were provided from the San Diego County Site Assessment and Mitigation (SAM) Manual, "Overview of Soil Vapor Survey Methods" (San Diego County, 2002 and 2004) and the California Regional Water Quality

Control Board (CRWQCB), Los Angeles Region (LARWQCB) (CRWQCB, 2002 and 2003) and the Department of Toxic Substances Control (DTSC) guidelines (DTSC, 2004).

5.1 PRE-SAMPLING ACTIVITIES

Before starting field activities, attempts should be made to obtain as-built drawings for each building to determine foundation thickness and utility locations. The as-built drawings should be used to finalize probe placement in each of the buildings.

Prior to installing the sub-slab vapor probes, a building survey will be completed. The purpose of the building survey is to document general building structural and use information, including describing the general building uses, presence/absence of wells or sumps, presence/absence of a basement, and documenting potential indoor VOC sources by identifying what chemicals are used or are present in the building. Rooms where probes are proposed should be screened with a PID. If available, Material Safety Data Sheets (MSDSs) for products used in the building will be obtained. The initial building survey will also include identifying the points at which subsurface utilities enter the building. A Building Questionnaire (See Attachments) form should be used for the initial building survey.

5.2 SUB-SLAB SOIL VAPOR PROBE CONSTRUCTION AND INSTALLATION

The sub-slab soil vapor probe installation procedures were derived primarily from the USEPA's *Draft Standard Operating Procedure for Installation of Sub-Slab Vapor Probes and Sampling Using EPA Method TO-15 to Support Vapor Intrusion Investigations* (USEPA, 2002). The sub-slab probes described in the USEPA SOP and in the following procedures are permanent sampling probes that will remain in place after completion of the sampling event. Permanent sampling probes are preferred because they provide higher quality and more consistent data. The individual probes will be removed and the holes sealed upon determining that further sub-slab soil vapor sampling will not be required at a given location.

Use a rotary hammer drill and a clean drill bit to create a shallow (2.5 centimeters (cm) or 1 inch) outer hole that partially penetrates the slab. Areas of visible staining or known previous chemical spills will be avoided. Use a small brush and dust pan or hand vacuum to collect concrete dust and cuttings from the hole. Since the outer hole does not penetrate the floor slab, a dedicated drill bit is not required.

After completing the outer hole, a rotary hammer drill will be used to create a smaller diameter inner hole (0.8 cm or 5/16 inch) through the remainder of the slab and approximately 7 to 8 cm or 3 inches into sub-slab material. The inner hole should be drilled using a dedicated drill bit. Drilling into sub-slab material will create an open cavity which will prevent obstruction of probe inlets during vapor sampling. After completing drilling, the outer hole should be cleaned using a towel moistened with deionized water to increase the potential of obtaining a good seal during cement application.

Probes should be constructed of stainless steel, brass, or Teflon™ tubing and fittings to ensure that construction materials are not a source of VOCs. Metal probe materials should be cleaned with detergent and water prior to installation to remove cutting oils that may have been used in manufacturing. Once the thickness of the slab is known, stainless steel or Teflon™ tubing should be cut to ensure that probes “float” in the slab to avoid obstruction of the probe with sub-slab material. Construct sub-slab vapor probes from small diameter (0.64 cm or 1/4 inch outer diameter x 0.46 cm or 0.18 inch inner diameter) chromatography grade 316 stainless steel or brass tubing and stainless-steel or brass compression to thread fittings (e.g., 0.64 cm or 1/4 inch outer diameter x 0.32 cm or 1/8 inch NPT (National Pipe Tapered) Swagelok® female thread connectors). The probes will be closed using 0.32 cm (1/8 inch) recessed stainless steel or brass socket plugs.

Set sub-slab vapor probes in holes such that the fittings rest at the base of the outer hole and the top of the probes are completed flush with the slab. Each probe will have recessed stainless steel or brass plugs so as not to interfere with day-to-day use of buildings. Mix a quick-drying portland cement that expands upon drying (to ensure a tight seal) with deionized water to form a slurry and inject or push into the annular space between the probe and outside of the outer hole. Allow cement to cure for at least 24 hours prior to sampling.

5.3 SUB-SLAB SAMPLING PROCEDURES

Subsurface vapor will not be sampled if measurable precipitation or irrigation near the sampling location has occurred within the previous five days. The increased soil moisture can reduce soil permeability and cause the soil vapor sample results to be biased low.

5.3.1 Sample Train Assembly

Samples will be collected from the previously installed soil vapor probes using evacuated batch-certified 1 liter (L) or smaller Summa™ canisters equipped with dedicated flow regulators and integrated particulate filters. A flow regulator/particulate filter and vacuum gauge will be attached to each canister as described in the Summa Canister Instructions provided by the laboratory. Canisters, flow regulators/particulate filters, and vacuum gauges will be supplied by the laboratory.

A helium shroud, consisting of a solid plastic container with a height of less than 6 inches and a volume less than 6L, will be placed around the exposed portion of the soil vapor probe. A dedicated stainless-steel fitting and Teflon™ tubing will be connected to the soil vapor probe while passing through a ¼-inch hole in the side of the helium shroud, no more than three inches above the base of the shroud. All fittings and tubing will be dedicated in order to avoid cross-contamination between probes. A second length of Teflon™ tubing will be inserted into the side of the shroud and connected to a helium cylinder on the outside of the shroud. The Teflon™ tubing attached to the soil vapor probe will be connected to a two-way stopcock. The two-way stopcock will be attached to a three-way stopcock. The other two outlets on the three-way stopcock will be attached to Teflon™ tubing. The tubing from one outlet of the three-way stopcock will be connected to the Summa™ canister assembly, and the tubing from the other outlet will be connected to a 1L Tedlar™ (or equivalent) bag. The Tedlar™ bag will be placed in a lung box. An air pump will be used to evacuate the air inside the lung box and collect a sub-slab soil gas sample in the 1L Tedlar™ bag. A new pair of Nitrile gloves should be worn while connecting the sample assembly for each soil vapor probe. The total length of Teflon™ tubing should not exceed 5 feet.

When collecting duplicate or QA split samples, two separate canister assemblies are connected using a stainless steel "T" fitting, and the "T" fitting is then connected to the three-way stopcock using Teflon™ tubing. The "T" fitting will be provided by the laboratory.

5.3.2 Helium Leak Testing

The purpose of the chemical leak test is to ensure that the sub slab sample port and probe assembly is properly set and not leaking. A leaking sub slab probe assembly could result in a leakage of indoor air into the sub slab sample, potentially biasing the sample. Prior to sampling, a chemical leak test will be performed using helium as a tracer gas. The ambient air inside the shroud will be replaced with helium graded at 99.9 percent purity or higher until the atmosphere consists of a minimum of 20 percent helium. It should be noted that concentrations of 60 percent to 80 percent helium have routinely been observed in the shroud during prior field testing. This will be accomplished by inserting Teflon™ tubing through a ¼ inch hole in the shroud and attaching the other end to the helium canister. The helium canister will then be opened, and the shroud atmosphere will be continuously monitored by a Dielectric Technologies Model MGD-2002 Multi-Gas Detector (or equivalent) until the percentage of helium inside the shroud reaches a minimum of 20 percent and the readings on the Multi-Gas Detector (or equivalent) stop increasing. The final helium concentration inside the shroud will be recorded on the Field Data Air Sampling Form. The final helium concentration inside the shroud will be multiplied by 10 percent (0.1) to determine the allowable concentration of helium in the Tedlar™ bag sample. Both the final helium concentration inside the shroud and the calculated allowable concentration in the Tedlar™ bag will be recorded on the Field Data Air Sampling Form (See Attachments).

After the target atmosphere is established, the two-way and three-way stopcocks will be opened to the lung box, which contains a 1 L Tedlar™ bag. An air pump attached to the lung box via Teflon™ tubing will be used to evacuate the existing air inside the lung box, which will in turn cause the 1 L Tedlar™ bag to fill. Once filled, the 1 L Tedlar™ bag will be removed from the lung box and the air inside will be measured using the Model MGD-2002 Multi-Gas Detector (or equivalent) for the presence of helium. The concentration of helium measured inside the Tedlar™ bag will be recorded on the Field Data Air Sampling Form. If the concentration of helium in the sample is below the calculated allowable concentration (i.e., less than 10 percent of the concentration inside the helium shroud), proceed with the mechanical leak test and sample collection as described in Sections 5.3.3 and 5.3.4.

Corrective actions to mitigate leaks in the sub-slab soil vapor probe will be performed when the helium concentration in the Tedlar™ bag sample exceeds 10 percent of the starting concentration in the helium shroud. Corrective actions will be performed in the field and will initially involve resealing the probe base with beeswax and repeating the helium leak test. If resealing and retesting fails to produce acceptable leak test results after two attempts, the probe will be abandoned and a new probe will be installed. Samples will not be collected for submittal for laboratory analysis when the helium concentration in the Tedlar™ bag sample exceeds 10 percent of the starting helium concentration in the shroud.

5.3.3 Mechanical Leak Testing

The mechanical leak test will be performed immediately after completing the helium leak test. The mechanical leak test will be completed by closing the two-way stopcock and turning the valve on the three-way stopcock to close the tubing connected to the lung box assembly. This will close the connection between the two-way stopcock and the lung box assembly and open the connection between the two-way stopcock and the Summa™ canister. Vacuum test the connections between the Summa™ canister and stopcock by opening the canister valve to place a test vacuum on the assembly for 10 minutes. The start time and initial vacuum, as well as the stop time and final vacuum, will be recorded on the Field Data Air Sampling Form and in the field logbook. If gauge vacuum can not be maintained for 10 minutes, work shall be suspended and all fittings in the sample assembly will be checked. Retest the sample assembly. If vacuum still can not be maintained by 10 minutes, sampling activities will be discontinued until leak can be identified and addressed.

If gauge vacuum was maintained for 10 minutes, close the canister valve and immediately proceed with sample collection as described in Section 5.3.4. Since the fitting that connects the tubing from the sub-slab probe to the two-way stopcock cannot be leak tested through either the helium or mechanical leak tests, this fitting will be sealed with Teflon™ tape and beeswax.

5.3.4 Sample Collection

Sample location information and meteorological conditions (temperature, barometric pressure, wind speed/direction, and relative humidity) shall be recorded on a Field Data Air Sampling Form. Meteorological data will be obtained online from the nearest National Weather Service measuring station. Digital photos will be taken of each sample location and sample assembly.

Open the two-way stopcock connecting the Summa™ canister assembly to the soil vapor probe. Open the canister valve to begin sample collection. The time and initial vacuum when sample collection starts shall be recorded on the Field Data Air Sampling Form. The laboratory-provided flow regulators will be calibrated for a 5- to 10-minute sample duration, which correlates to a flow rate of 100 to 200 mL/min. Close the sample canister valve when the vacuum gauge indicates approximately 3-5 inches Hg (mercury) of vacuum remain in the canister. Sample collection should take approximately 5 minutes for a 1L Summa™ canister connected to a 200 mL/min flow regulator. The time sample collection was stopped and final vacuum shall be recorded on the Field Data Air Sampling Form. Remove the flow regulator/particulate filter and vacuum gauge assembly and replace the laboratory-supplied brass plug on the canister. Disconnect the sample tubing assembly and replace the plug on the soil vapor probe.

Label the sample canister and record on the COC the sample name, date and time the sample was collected, the canister and flow controller serial numbers, and the final vacuum gauge reading. Samples shall not be chilled or subjected to extreme temperature or pressure fluctuations. Samples will be shipped to the laboratory for analysis of VOCs by USEPA Method TO-15.

5.3.5 Quality Control

Trip blanks, field duplicates, and QA samples will be collected during soil vapor sampling activities. Field duplicates and QA split samples will be collected at the rate of one duplicate/QA sample per 10 soil vapor samples (i.e., 10 percent). Normally, field duplicates and QA samples are collected from the same location; however, the "T" connectors used to collect duplicate samples can not be used to collect three simultaneous samples. Therefore, the duplicate and QA samples will be collected from separate locations.

A trip blank, consisting of an unopened evacuated canister, will be sent with each shipment of sub-slab vapor samples. Trip blanks can consist of either unopened fully evacuated canisters or canisters that have been fully charged with zero grade air by the laboratory. Since a fully charged canister has no vacuum with which to pull contaminants into the canister, a fully evacuated canister has a better likelihood of capturing potential transit-related contamination. The trip blank will be provided by the laboratory.

6.0 EQUIPMENT DECONTAMINATION PROCEDURES

All decontamination will be performed according to SAS-04-04.

7.0 INVESTIGATION-DERIVED WASTE (IDW)

The sub-slab vapor probe installation and sampling will generate small amounts of solid IDW including concrete dust, gloves, drill bits, and tubing. This material will be bagged and disposed of as a municipal waste in accordance with applicable regulations. No liquid IDW will be generated. Further discussion of IDW can be found in Section 9 of the *Multi-Site Field Sampling Plan, Former Manufactured Gas Plant Sites, Revision 3", February 20, 2008.*

8.0 REFERENCES

ASTM International, 2001, ASTM Standard D 5314-92 (2001) Standard Guide for Soil Gas Monitoring in the Vadose Zone.

California Regional Water Quality Control Board, Los Angeles Region, 2002, General Laboratory Testing Requirements for Petroleum Hydrocarbon Impacted Sites.

California Regional Water Quality Control Board, Los Angeles Region, 1997, Interim Guidance for Active Soil Gas Investigation, Advisory issued January 28, 2003.

Department of Toxic Substance Control-California Environmental Protection Agency, 2004, Interim Final Guidance to the Evaluation and Mitigation of Subsurface Vapor Intrusion to Indoor Air, Revised February 7, 2005.

San Diego County, Site Assessment and Mitigation (SAM) Manual, “Overview of Soil Vapor Survey Methods” Final Draft 8/20/2002.

San Diego County, 2004, Site Assessment and Mitigation (SAM) Manual, “Overview of Soil Vapor Survey Methods”.

United States Environmental Protection Agency (USEPA), 2002. *Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance)*. Office of Solid Waste and Emergency Response. November 29.

USEPA, 1999, Compendium Method TO-15, Determination of Volatile Organic Compounds (VOCs) in Air Collected In Specially-Prepared Canisters and Analyzed By Gas Chromatography/Mass Spectrometry GC/MS) in *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air,* 2nd Ed., EPA Publication 625/R-96/010b.

Author:	T. Gilles	Q2R & Approval By:	K. Kniola / C. Barry	Q3R & Approval By:	M. Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-11-02

POST-RUN TUBING SYSTEM SAMPLING
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for Post-Run Tubing (PRT) System sampling. Soil-gas (soil vapor) sampling is a useful tool to evaluate potential subsurface soil and groundwater impacts that can partition into gas and affect indoor air quality. PRT sampling is conducted above the water table at a depth of five feet below ground surface (bgs) or deeper to provide measurements of soil-gas that may potentially enter a building and affect indoor air quality.

2.0 EQUIPMENT AND MATERIALS

- Rotary hammer drill (or equivalent) with a 1 3/8-inch diameter bit;
- Retractable gas vapor tip (GVP);
- Expendable GVP replacements;
- Hand Tools, including a hammer, needle-nose pliers, and trowel;
- Tubing receptacle;
- Teflon compression fittings to connect sampling points at “T” connection;
- “T” Swagelok (compression) or equivalent fitting;
- Gas sampling pump capable of extracting 200 milliliters per minute (mL/min);
- 4-way Teflon micro-valve;
- 1/4-inch O.D. Teflon tubing;
- VOC-free caulk;
- Nitrile gloves;
- Summa canisters with flow controllers, vacuum gauge, and shipping container;
- Sample labels;
- Chain of custody forms and seals;

- Field air monitoring instruments, as specified in the Work Plan (e.g. photo ionization detector, multi-gas monitors, etc.);
- Location markers (e.g. pin flags, wooden stakes, flagging tape, etc.);
- Granular bentonite;
- Asphalt cold patch or cement, as appropriate for site restoration;
- Decontamination materials;
- DOT-specified 55-gallon drum; and
- Field logbook and/or appropriate field form(s);

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 CONSIDERATIONS

Variations in chemical-specific characteristics, geologic conditions, and atmospheric influences can affect soil-gas sampling results. For this reason, it is important to understand factors the may influence the reported data when collecting soil-gas data. In all cases, site-specific factors should be carefully evaluated prior to initiation of sampling to obtain representative soil-gas data.

Prior to any soil-gas sampling, soil type must be evaluated for suitability of sampling. Soils with smaller grain sizes have smaller pore spaces and are less permeable, which may reduce the ability for soil gas to be released from the subsurface. For example, clays have the smallest grain size and significantly restrict soil gas migration. Soil moisture also limits the ability for soil gas to be released from the subsurface because moisture trapped in the pore space of sediments can inhibit or block soil-gas flow. Seasonal and geographical variations in soil moisture content can affect air permeabilities. In addition, manmade and naturally occurring preferential pathways (e.g. utility corridors, lenses of coarse-grained materials within fine-grained materials, etc.) may also affect soil-gas migration and shall be considered prior to soil-gas sampling.

Reliability of soil-gas sampling may be improved by using fixed probes and by ensuring that leakage of atmospheric air into the samples is avoided during purging or sampling. To avoid dilution of the sampling region from leakage, the minimum purge volume deemed adequate to flush the sampling system should be removed, and soil-gas samples should be collected from the most permeable zones in the vadose zone when possible. Site-specific information concerning soil lithology, grain size analysis, soil moisture, and soil-gas permeability may be obtained by performing three soil borings in the immediate area of the sampling locations in advance of the soil-gas sampling. In addition, previous site investigation sample results, when available, should be used to determine the placement of the soil-gas sampling locations.

Since oxygen, carbon dioxide and nitrogen can be sampled using a multi-gas monitor to give real-time results, parallel analysis of oxygen, carbon dioxide and nitrogen in soil-gas may also be used to help assess the reliability of a given sample result.

5.0 EXECUTION

The active soil-gas sampling approach consists of withdrawing an aliquot of soil gas from the subsurface, followed by the analysis of the withdrawn gas. Active soil-gas systems use mechanical equipment to create a small-diameter hole in the ground and then use a vacuum to “actively” withdraw a soil gas sample through stainless steel or Teflon tubing within the vadose zone. The soil gas sample is collected in a Summa canister and sent to a laboratory for analysis. Samples are analyzed using USEPA’s Ambient Air Compendium Method TO-15 (USEPA 1999) for determining organic compounds in ambient air. The results provided by active soil-gas systems are quantitative and are reported in units of concentration per volume (micrograms per cubic meter [$\mu g/m^3$], or parts per billion volume [ppb_v]).

The following active soil-gas sampling methodologies (emplacement, purging, sampling, leak testing, field screening, and abandonment) are based on established methods as outlined in the USEPA Standard Operating

Procedure (SOP) Number 2042 (USEPA 1996) and the ASTM International (ASTM) standard guide D 5314-01 (ASTM 2001). Additional guidelines were provided from the San Diego County Site Assessment and Mitigation (SAM) Manual, "Overview of Soil Vapor Survey Methods" (San Diego County 2002 and 2004) and the California Regional Water Quality Control Board (CRWQCB), Los Angeles Region (LARWQCB) (CRWQCB 2002 and 2003) and the Department of Toxic Substances Control (DTSC) guidelines (DTSC 2004 and 2005).

5.1 Summa Canister Preparation, QA/QC, and Set Up

A Summa canister is a stainless steel container which has had its internal surfaces passivated using a "Summa" process. The process uses an electro polishing step in conjunction with chemical deactivation. The overall process results in a chemically inert interior surface of the media which allows for the collection and subsequent analysis of samples containing very low concentrations of volatile organic compounds (VOCs). The Summa media is available in a number of different sizes. Typically, 6-liter Summa media are used for the collection of soil-gas because this volume should allow for low detection limits and facilitate more complex analyses.

Once the laboratory cleaning process is completed per USEPA SOP 1703 (USEPA 1994), the Summa media are prepared by the laboratory for use in the field. Each canister is evacuated to achieve a vacuum pressure of approximately -30 inches of mercury (" Hg). The pressure differential between the canister and atmosphere allows for the Summa media to sample without the use of a separate sample pump. Depending on the project requirements, either grab or integrated samples may be collected. The holding time (shelf life) for Summa canisters that have been prepared for use in the field is 30 days. If the canister has not been used within this time-period, it shall be returned to the contracted laboratory for re-conditioning.

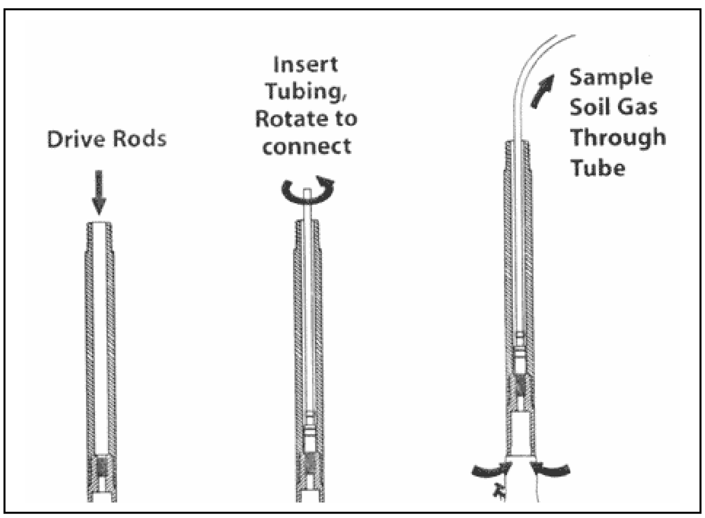
Prior to collection, check all canisters for the proper certification issued by the analytical laboratory, as per USEPA SOP 1703 (USEPA 1994). The sampler shall complete the sample set-up of a Summa (or equivalent) canister prior to sample collection. Each six-liter (6.0 L) Summa (or equivalent) canister shall be fitted with a dedicated sample flow controller (regulator). After verification that the valve on the canister is in the "off" position, the brass cap shall be removed from the canister inlet fitting and the sample flow controller shall be attached to the canister inlet. The brass cap shall then be installed onto the inlet of the flow controller and tighten. *Note: The sample flow controller (regulator) is a complete assembly that shall be attached directly to the canister*. The assembly shall then be leak-checked by opening the canister valve and noting the initial vacuum reading. The vacuum should indicate between -25" Hg and -30" Hg. The canister shall not be used if the starting vacuum is less than -25" Hg. The vacuum may fall a very small amount (1 to 2" Hg) due to the evacuation of the flow controller and then quickly stabilize. If the vacuum does not stabilize, the flow controller or associated fittings are leaking. If necessary, determine the location of the leak, and repair it accordingly. Any necessary repairs shall be document in the field logbook and/or on the appropriate field form.

5.2 Temporary Soil-Gas Probe Emplacement

The PRT system sampling methodology (see Figure below) shall be utilized to collect soil-gas samples within the vadose zone at a minimum sampling depth of 5 feet bgs.

FIGURE 1

PRT System Soil Gas Sampling



The sampler shall follow the general procedure for PRT system sampling as detailed below, unless otherwise required by the Site-Specific Work and/or Sampling Plan(s):

1. All subsurface activities shall only be performed following the clearance of each location for underground utilities in accordance with SOP ENV-05-01. In addition, a qualified contractor shall locate and mark private subsurface utilities.
2. Prior to drilling, the sampler shall clear vegetation or remove any floor coverings present, as appropriate.
3. If concrete or asphalt is present, a 1 3/8-inch diameter core hole shall be drilled through the entire thickness of the material until bare soil is reached.
4. Utilizing direct push technology, the sampler shall advance the 1.1-inch outer diameter (O.D.) expendable drive point attached to the 1.25-inch O.D. hollow push rods to target depth, which shall be a minimum of 5 feet bgs. Sample depths shall be chosen to minimize the transient effects of changes in barometric pressure, temperature, precipitation or breakthrough of ambient air from the surface to ensure that representative samples are collected. Sample depths shall be specified in the Site-Specific Work and/or Sampling Plan(s). No soil-gas sampling shall be conducted within 48 hours of a rainfall/irrigation event, due to excessive soil moisture content anticipated in the exposed surfaces.
5. Once the target depth is reached, the sampler shall insert the PRT and pull back the tool string approximately 3 inches (0.25 feet) thereby exposing the vapor inlet.
6. The sampler shall extend the 1/4-inch O.D. Teflon tubing through the slotted opening of the extension driver adapter, leaving 4 feet of tubing extending beyond the ground surface.
7. The sampler shall seal the end of the tubing with a protective cap to prevent air infiltration.
8. The sampler shall seal around the drive rods at the ground surface with hydrated bentonite slurry to prevent ambient air intrusion from occurring.
9. The sampler shall record the date and probe emplacement time in addition to the sample location in the field logbook and/or on the appropriate field form.

5.3 Pre-Sample Collection Activities

To help ensure a representative soil gas sample is being collected, the PRT system shall be purged of all ambient air and field screening shall be performed using a multiple gas detection monitor to establish that acceptable sampling conditions have been attained prior to sample collection. During probe emplacement, subsurface conditions are disturbed. To allow subsurface conditions to equilibrate, the sample system purge and soil gas screening shall not be conducted for at least 20 minutes following probe emplacement.

5.3.1 PRT System Purge

For a representative soil gas sample to be obtained, enough air shall be withdrawn prior to sample collection to purge the sampling system of all ambient air. The purge volume or "dead space volume" shall be estimated based on the internal volume of the tubing used and the annular space around the probe tip. Only the volume of air sufficient to flush the probe and sampling line shall be extracted before collecting the sample. The air contained in the Teflon tubing, vapor point holder and fittings forming the "sampling train" shall be evacuated using an air-sampling pump set at a rate not to exceed 200 ml/min. for the calculated period of time. System purging shall be performed consistently at each sampling location. An example of typical purge volumes and times is shown below.

Purge Volumes for PRT System

		5-foot Sample Depth	**10-foot Sample Depth**
One Purge Volume	**Volume**	46.14 ml	68.44 ml
	Time	13.8 sec	20.5 sec

The sampler shall calculate the volume of ambient air to be purged using the following factors and equations:

<u>Purge Calculation Factors</u>

1. Tubing (0.25-inch O.D., 0.17-inch I.D.) Volume = 4.46 ml per foot internal volume
2. Vapor Point Holder and Post Run Tubing Adapter Volume = 6 ml internal volume
3. Calculations assume a 4-foot section of tubing extends from the boring surface to the canister.

<u>Volume Equation:</u>

A x ((B x C) + D) = E

Where:

A = Number of Purge Volumes
B = 1 foot of tubing, 4.46 ml
C = Depth
D = Point Holder Volume, 6 ml
E = Volume to be purged

<u>Time Equation:</u>

(E ÷ F) x G = H

Where:

E = Volume to be purged
F = Purge Rate, 200 ml/min.
G = 60 seconds
H = Purge Time in seconds at 200 ml/min.

5.3.2 Screening with Field Instruments

Analysis of oxygen, carbon dioxide and nitrogen in soil-gas samples can often be used to help assess the reliability of a given sample result. It is recommended that one or all of the aforementioned analytes be monitored using a multiple gas detector. After completion of the system purge, the monitoring instrument shall be connected at the "T" connection using the 0.25-inch O.D. Teflon tubing. When the monitoring instrument readings are stable or peak, the values shall be recorded in the field logbook and/or on the appropriate field form.

5.4 Sample Collection

After the sampling train has been adequately purged and field screened; samples shall be collected using a 6-liter Summa canister. Due to the disruption of soil gas equilibrium during purging and field screening, a period of equilibrium (at least 20 minutes in length) shall be allowed for subsurface conditions to equilibrate. To minimize the potential desorption of contaminants from the soil, Summa canisters should be filled at a rate that minimizes the vacuum applied to the soil and the turbulent flow at the probe tip. The San Diego County Site Assessment and Mitigation (SAM) Manual, "Overview of Soil Vapor Survey Methods" guidance (San Diego County 2004) requires this rate to be less than 200 ml/min. Summa canisters shall be filled using a flow regulator set at a constant rate within the range of 50 to 200 ml/min. The sampler shall follow the step-by-step procedure for PRT system sampling as outlined below, unless otherwise required by the Site-Specific Work and/or Sampling Plan(s):

1. The sampler shall attach an in-line particulate filter to the sample train, if deemed necessary given site conditions.
2. The sampler shall record the initial Summa canister vacuum reading from the line gauge in the field logbook and/or on the appropriate field form.
3. The valve on the Summa canister shall be opened allowing the soil-gas sample to be drawn into the canister by pressure equilibration. If condensation is observed in the sample tubing, the sample shall be discarded and the observation shall be documented in the field logbook and/or on the appropriate field form.
4. When the line gauge reads approximately -4 to -5" Hg remaining, the sampler shall close the Summa canister valve.

5. The sampler shall record the final Summa canister vacuum reading from the line gauge in the field logbook and/or on the appropriate field form.
6. The sampler shall fill out and attach the sample tag to the Summa Canister along with any additional information requested by the laboratory. This information shall also be recorded in the field logbook and/or on the appropriate field form.
7. The sample shall be packaged and shipped under chain of custody to the laboratory for analysis. The samples shall not be chilled during storage or transport to the laboratory. To minimize potential effects on the sample integrity, the sample analysis shall be conducted within 72 hours of the collection time.

5.5 Temporary Probe Removal and Borehole Abandonment

After sample collection, both the drive rod and tubing shall be removed. Soil-gas probes shall then be sealed using granular bentonite to fill the annular space of the hole. Soil-gas probes performed within residential or industrial/commercial structures shall also be filled with granular bentonite to the base of the core hole and a 1-inch thick caulk vapor seal shall be applied at the base of the core hole. The remainder of the core hole shall be filled with a neat cement (coarse aggregate free) mix or asphalt cold patch, as appropriate for site restoration. Any floor covering removed shall be replaced and the area restored to its pre-sampling condition to the extent practicable.

All investigation-derived waste is placed in Department of Transportation (DOT)-specified 55-gallon drums and properly labeled. The drums are placed in a secure on-site location for temporary storage prior to appropriate off-site disposal. Disposable sampling equipment and health & safety materials that are not visibly impacted are double-bagged in plastic trash bags and disposed of in a solid waste disposal location (i.e. trash dumpster or container).

6.0 QUALITY ASSURANCE/QUALITY CONTROL

6.1 Equipment Calibration, Operation, and Maintenance

Field air monitoring instruments, as specified in the Work Plan (e.g. photo ionization detector, multi-gas monitors, etc.) shall be calibrated, operated, and maintained in accordance with SOP ENV-02-01.

6.2 Leak Testing

Leakage during soil vapor sampling may dilute samples with ambient air and produce results that underestimate actual site soil vapor concentrations. Leak testing, if any is required, shall be based on data quality objectives as specified in the Site-Specific Work Plan. The following paragraph describes a direct leak detection method that is suitable for use during soil gas sampling.

Seal integrity can be evaluated directly using an inert tracer gas (e.g. laboratory grade helium). Inert gas selection shall be conducted in conjunction with the laboratory. The sampler shall construct an air tent using polyethylene sheet or assemble a commercially available air tent which encompasses the top of the probe/well casing and the entire sample train. During sampling, the tracer gas shall be allowed to flow around the sample train connections and the bentonite or grout seal at the ground surface. Following sample collection, the air tent shall be dismantled. The soil vapor sample shall be analyzed for inert trace gas in addition to the other requested analysis. If the tracer gas is detected in the soil vapor sample, the seal integrity was compromised and the analytical results, which are not representative of the stratigraphic unit or zone within the stratigraphic unit, shall be considered invalid.

6.3 Decontamination

Equipment decontamination procedures shall be implemented, in accordance with SOP ENV-04-04, to avoid cross-contamination between sampling locations.

6.3.1 Sample Probe Decontamination

Sample probe contamination shall be checked between each sample by drawing ambient air through the probe via a gas sampling pump and checking the response of the PID. If readings are higher than background, replacement or decontamination shall be necessary. Sample probes shall be decontaminated simply by drawing ambient air through the probe until the PID reading is at background. More persistent contamination shall be washed out using methanol and water, and then air drying. For persistent volatile contamination, use of a portable propane torch may be needed. If use of a portable propane torch is deemed necessary, the sampler shall use a pair of pliers to hold the probe while running the torch up and down the length of the sample probe for approximately 1 to 2 minutes. The probe shall be allowed cool before handling. When using this method, the sampler shall wear gloves that are capable of preventing burns. Having more than one probe per sample team is advisable as it will reduce lag times between sample stations while probes are decontaminated.

6.3.2 Drive Rod Decontamination

After each use, drive rods and other reusable components are properly decontaminated to prevent cross contamination in accordance with SOP ENV-04-04.

6.3.3 Sample Train Decontamination

All elements of the sample train shall be dedicated to each sampling location to avoid potential cross-contamination. If visible contamination (soil or water) is drawn into the sampling train, it shall be changed immediately.

6.4 Duplicate Samples

If required by the Site-Specific Work and/or Sampling Plan(s), duplicate samples shall be collected with the addition of a "T" splitter being attached to the 4-way micro valve with a Teflon nut, and one canister attached to each end of the "T" Swagelok (compression) or equivalent fitting and in accordance with SOP ENV-04-03.

7.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, 2001, ASTM Standard D 5314-92 (2001) Standard Guide for Soil Gas Monitoring in the Vadose Zone.

California Regional Water Quality Control Board, Los Angeles Region, 2002, General Laboratory Testing Requirements for Petroleum Hydrocarbon Impacted Sites.

California Regional Water Quality Control Board, Los Angeles Region, 1997, Interim Guidance for Active Soil Gas Investigation, Advisory issued January 28, 2003.

Department of Toxic Substance Control-California Environmental Protection Agency, 2004, Interim Final Guidance to the Evaluation and Mitigation of Subsurface Vapor Intrusion to Indoor Air, Revised February 7, 2005.

Hartman, Dr. Blayne; June 2002 - LUSTLine #41 Reevaluating the Upward Vapor Migration Risk Pathway, Synopsis: *An Updated Article on Upward Vapor Migration & a Recommended Sampling Protocol.*

Hartman, Dr. Blayne; October 2002 - LUSTLine #42 "How to Collect Reliable Soil Vapor Data for Risk Based Applications" Synopsis: *Part 1: Active Soil-Gas Method*

San Diego County, Site Assessment and Mitigation (SAM) Manual, "Overview of Soil Vapor Survey Methods" Final Draft 8/20/2002.

San Diego County, 2004, Site Assessment and Mitigation (SAM) Manual, "Overview of Soil Vapor Survey Methods".

USEPA, 1994, SOP 1703, Rev. 0.0, Summa Canister Cleaning Procedure.

USEPA, 1995, SOP 1704, Rev. 0.0, Summa Canister Sampling.

USEPA, 1996, SOP 2042, Rev. 0.0, Soil Gas Sampling

USEPA, 1999, Compendium Method TO-15, Determination of Volatile Organic Compounds (VOCs) in Air Collected In Specially-Prepared Canisters and Analyzed By Gas Chromatography/Mass Spectrometry GC/MS) in *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air,* 2nd Ed., EPA Publication 625/R-96/010b.

USEPA, 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

Author:	T.Gilles	Q2R & Approval By:	E. Gasca	Q3R & Approval By:	J. Pope

STANDARD OPERATING PROCEDURE
NO. SAS-11-03

INSTALLATION OF PROBES/WELLS FOR SVE SYSTEM EFFECTIVENESS AND VAPOR MIGRATION MONITORING
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for the installation of semi-permanent to permanent soil vapor monitoring probes/wells for the evaluation of Soil Vapor Extraction (SVE) system effectiveness and subsurface vapor migration. This SOP also describes selection, including advantages and disadvantages, of drilling methods, probe/well materials and construction/configuration.

2.0 EQUIPMENT AND MATERIALS

- Drilling equipment and supplies (Drilling method specific);
- Well casing and screen materials (See Sections 4.3 & 4.4 below);
- Filter pack sand;
- Bentonite;
- Grout (optional);
- Portland cement;
- Asphalt (as necessary for surface restoration);
- Stick-up or flush-mount protective well covers;
- 4-way micro-valve (Probe/well less than 1 inch in diameter);
- Zip ties (Probe/well less than 1 inch in diameter);
- ¼-inch outside diameter (O.D.) silicone, Tygon, or Teflon tubing (Probe/well less than 1 inch in diameter);

- Expandable well cap retrofitted with a with a 1/8-Inch, NPT, chrome-plated brass, non-valved, coupling insert (herein referred to as "coupling insert") and vinyl slip cap (Probe/wells 1 inch or more in diameter);
- Metal well ID tag (optional);
- Probe/well location maps;
- Miscellaneous tools;
- Chain of custody forms and seals; and
- Field logbook and/or appropriate field form.

Coupling Insert

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

Underground utilities, whether private, commercial, or public, shall be cleared in accordance with SOP ENV-05-01 prior to commencing drilling activities.

4.0 PROBE/WELL INSTALLATION

4.1 Considerations

Prior to the selection of drilling method(s), materials and diameters, screen length(s), and configuration, and installation of probes/wells, several key factors must be considered.

4.1.1 Project Objectives and Costs

Short- and long-term objectives shall be defined in the early stages of the project with respect to the type of data required, purpose, and mean(s) of evaluating the data. The project objectives shall define whether probes/wells shall be utilized for purposes other than SVE system effectiveness and vapor migration monitoring. While multiple purpose probes/wells can reduce drilling costs, effects on data quality shall be evaluated with respect to project objectives.

4.1.2 Site Conditions and Access

Site conditions and access shall also be considered to prevent project delays, increased project costs, and deviations from project objectives.

4.1.3 Surface and Subsurface Geological and Hydrologic Conditions

Geologic and hydrologic conditions are critical factors in the selection of drilling method(s), materials and diameters, screen length(s), and configuration, and installation of probes/wells. To the extent practical, surface and subsurface geologic and hydrologic conditions shall be characterized prior to probe/well material and construction/configuration selection and installation. Soil materials, variability within stratigraphic units, preferential pathways, confined/unconfined conditions, actual or potential perched water conditions, water table elevation and variability, and presence of constituents of concern or free phase product shall be considered prior to selection of probe/well material, diameter, screen length and configuration. If geologic and hydrologic conditions cannot be characterized prior to probe/well installation, anticipated conditions shall be discussed with the field staff prior to the commencement of field activities.

4.2 Drilling Method Selection

Common drilling methods include auger, rotary, and direct push technologies. Both hollow-stem and solid-stem auger methods can be used in unconsolidated soils and semi-consolidated (e.g. weathered rock) soils, but not in competent rock. Each method can be employed without introducing foreign materials (e.g. drilling fluids, etc.) into the borehole, thus minimizing the potential for cross contamination. This method consists of a drill pipe or drill stem coupled to a drilling bit that rotates and cuts through soils and competent rock. The cuttings produced from the rotation of the drilling bit are transported to the surface by drilling fluids (e.g. water, drilling mud, or air) in all cases except for sonic rotary. Sonic rotary methods do not require the addition of any fluids in unconsolidated material because the vibration of the sonic rotary head allows the drill bit to cut without fluids. Consolidated materials may require some water to cool the drill bit. Direct push technology (DPT) use a hydraulic system to advance a 2- or 4-foot stainless steel sampler with a liner, typically acetate, attached to small-diameter, hollow drill rods into the subsurface. The sampler can be configured to allow for discrete interval sampling. Since the sampler is advanced hydraulically, soil cuttings generated by this method are minimal. DPT can be employed without introducing foreign materials (e.g. drilling fluids, etc.) into the borehole and in locations not accessible to most drill rigs. This method can be used in most unconsolidated soils, but not depositions consisting primarily of coarse gravel, cobbles, and/or weathered bedrock. Boreholes can be augured to depths of 40 feet or more (depending on the Geoprobe™ size and stratigraphy), but generally boreholes are advanced to depths of less than 30 feet. Due to the borehole diameter, probe/well installation is limited to small-diameter materials.

In general, air, water, and mud rotary drilling methods shall not be selected for probe/well installation since they introduce foreign materials into the borehole that have the potential to alter or inhibit vapor migration in the immediate vicinity of the probe/well and inhibit vapor migration into the probe/well screen. Table 1 (see Attachment A) shall be used as a guide in selecting drilling method(s).

4.3 Selection of Probe/Well Material and Diameter

Material and diameter selection shall be primarily based on well purpose (single or multiple uses), geologic and hydrologic conditions, and the anticipated probe/well construction/configuration. In general, well diameters greater than four inches, regardless of material, shall be deemed unsuitable due to the volume of air required to purge prior to sample collection. Table 2 (see Attachment B) shall be used as a guide in selecting probe/well materials and diameters.

4.4 Probe/Well Screen Length Selection

Screen length selection shall be based on probe/well purpose (single or multiple uses), geologic and hydrologic conditions, and type of data desired (discrete or composite). Single use probes/wells, those dedicated to SVE system effectiveness and vapor migration monitoring, generally offer more flexibility in screen length selection. Multiple use probes/wells generally offer less flexibility in screen length selection and typically require longer screen lengths to fulfill its various functions. Geologic and hydrologic conditions (e.g. zones of increased permeability/preferential contamination migration or groundwater pathways within a stratigraphic unit, variability in groundwater elevation, etc.) combined with the type of data desired strongly influence screen length selection.

Shorter screen lengths, generally one half to two feet in length, shall be preferred for the monitoring of zones of increased permeability/preferential pathways or discrete intervals with a stratigraphic unit, or the entire thickness of a thinner layer of soil material. Shorter screen lengths are generally preferred for single use probes/wells because they minimize 1) the potential to screen more than one stratigraphic unit or preferential pathway and 2) purge volumes required prior to sampling.

Medium screen lengths, generally two to ten feet in length, shall be preferred for the monitoring of the entire thickness of a stratigraphic unit or stratigraphic units prone to perched water and/or relatively moderate to high fluctuations in groundwater elevation. Medium screen lengths are generally preferred for multi-use probes/wells because they minimize the potential to screen more than one stratigraphic unit.

Long screen lengths, general ten feet or more in length, shall be preferred for multi-use probes/wells intended for regular groundwater and/or product monitoring and/or sampling, especially when relatively moderate to high fluctuations in groundwater elevation are anticipate. In general, probes/wells with screen lengths fifteen feet or longer shall not be deemed adequate for SVE system effectiveness and vapor migration monitoring because they 1) increase the potential to screen more than stratigraphic unit, 2) may not allow for the collection of a sample representative of the entire screened interval, and 3) require a larger purge volume prior to soil vapor sample collection.

4.5 Probe/Well Configuration Selection

The vertical and horizontal configuration of probes/wells shall be a function of their intended purpose(s). Probes/wells intended to evaluate vapor migration across a plane/boundary or within area may be installed within the anticipated radius of influence (ROI) of one or more soil vapor extraction wells. Probes/wells intended to evaluate the actual ROI of a soil vapor extraction well shall be, to the extent possible, installed within the anticipated ROI of only the soil vapor extraction well to be evaluated. In both cases, probes/wells shall generally be installed at set horizontal distances from soil vapor extraction well(s) (e.g. distances equivalent to ½, ¾, and/or the anticipated ROI). Single probes/wells, nested probes/wells, or a combination thereof shall be utilized to achieve project and data quality objectives. Single probes/wells are utilized to monitor one stratigraphic unit or one zone of increased permeability/preferential contamination migration or groundwater pathways within a stratigraphic unit. Nested probes/wells are utilized to monitor multiple stratigraphic units or zones of increased permeability/preferential contamination migration or groundwater pathways within a stratigraphic unit.

4.6 Execution

4.6.1 General

Probes/wells intended for SVE system effectiveness and vapor migration monitoring shall be installed in a manner similar to the installation of wells intended for groundwater monitoring/sampling with the following exceptions:

1. Water shall not be utilized to settle the filter pack (especially in confined stratigraphic units);
2. Bentonite grout shall generally be preferred over placing and then hydrating bentonite pellets/chips;
3. Probe/well screens and associated filter pack shall not, to the extent possible, extend into more than one stratigraphic unit;
4. Probe/well screens and associated filter pack shall not, to the extent possible, extend into more than one confining unit (e.g. clay layer);
5. To the extent possible, a minimum of five (5) feet of bentonite should be placed between the screens and filter packs of individual probes/wells that have been nested within the same borehole to prevent short-circuiting between probes/wells;

6. Probes/wells installed within or adjacent to utility corridors or building foundations shall be protected, to the extent possible, against short-circuiting with the ground surface.
7. Probes/wells installed with screens and/or filter pack within five (5) feet of ground surface shall be protected with impermeable materials (e.g. geotextile, plastic blankets, etc), to the extent possible, against short-circuiting with the ground surface; and
8. Probes/wells shall generally be installed using hollow-stem auger, sonic rotary, or direct push technology methods, unless otherwise required by the Site-Specific Work Plan or the Engineer of Record for the SVE System.

4.6.2 SVE System Effectiveness Monitoring

Probes/wells intended for SVE system effectiveness monitoring shall undergo pre-system start up (a.k.a. baseline) monitoring following the procedures described SOP ENV-11-03 to 1) establish a representative set of baseline data and 2) facilitate a defensible evaluation of post-system start up data set.

5.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, 2001, ASTM Standard D 5314-92 (2001) Standard Guide for Soil Gas Monitoring in the Vadose Zone.

USEPA, 1994, SOP # 1703, Rev #: 0.0, Summa Canister Cleaning Procedure.

USEPA, 1995, SOP #1704, Rev. #: 0.0, Summa Canister Sampling.

USEPA, 1996, SOP # 2042, Rev. #: 0.0, Soil Gas Sampling

USEPA, 1999, Compendium Method TO-15, Determination of Volatile Organic Compounds (VOCs) in Air Collected In Specially-Prepared Canisters and Analyzed By Gas Chromatography/Mass Spectrometry GC/MS) in *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air,* 2nd Ed., EPA Publication 625/R-96/010b.

USEPA, 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

ATTACHMENT A
TABLE 1 – DRILLING METHOD SELECTION

TABLE 1
Drilling Method Selection

SOP SAS-11-03 - ATTACHMENT A

DRILLING METHOD	ADVANTAGES	DISADVANTAGES	NOTES
Hollow-Stem Auger	• Can be used in unconsolidated and semi-consolidated soils • No Introduction of foreign materials into the borehole • Suited for soils that tend to collapse • Probe/well can be installed inside the auger • Can facilitate the installation of larger diameter probes/wells • Can facilitate the installation of more than one small diameter probe/well in a single borehole • Boreholes can be drilled to depths of 100 feet or more	• Cannot be used in competent rock • Retracting augers in caving sand conditions can be extremely difficult • Generates large amounts of soil cuttings	• Generally deemed suitable for the installation of probes/wells, intended for SVE system effectiveness and vapor migration monitoring, in unconsolidated and semi-consolidated soils • Preferred drilling method for the installation of probes/wells with a diameter equal to or greater than one inch and/or nested probes/wells in a single borehole in unconsolidated and semi-consolidated soils
Solid-Stem Auger	• Can be used in unconsolidated and semi-consolidated soils • No Introduction of foreign materials into the borehole • Can facilitate the installation of larger diameter probes/wells • Can facilitate the installation of more than one small diameter probe/well in a single borehole • Boreholes can be drilled to depths of 150 feet or more	• Cannot be used in competent rock • Not suited for soils that tend to collapse • Generates large amounts of soil cuttings	• Generally deemed suitable for the installation of probes/wells, intended for SVE system effectiveness and vapor migration monitoring, in unconsolidated and semi-consolidated soils

TABLE 1
Drilling Method Selection

SOP SAS-11-03 - ATTACHMENT A

DRILLING METHOD	ADVANTAGES	DISADVANTAGES	NOTES
Air Rotary	• Can be used in unconsolidated and semi-consolidated soils and rock • Can facilitate the installation of larger diameter probes/wells • Can facilitate the installation of more than one small diameter probe/well in a single borehole • Boreholes can be drilled to depths of 150 feet or more	• Introduces foreign materials into the borehole • Generates large amounts of soil cuttings • Conventional method does not control the blowing of cuttings out of the borehole	• Generally deemed unsuitable for the installation of probes/wells intended for SVE system effectiveness and vapor migration monitoring
Water Rotary	• Can be used in unconsolidated and semi-consolidated soils and rock • Can facilitate the installation of larger diameter probes/wells • Can facilitate the installation of more than one small diameter probe/well in a single borehole • Boreholes can be drilled to depths of 150 feet or more	• Introduces foreign materials into the borehole • Generates large amounts of soil cuttings • Drilling fluids can carry contamination from a contaminated zone to an uncontaminated zone	• Generally deemed unsuitable for the installation of probes/wells intended for SVE system effectiveness and vapor migration monitoring
Mud Rotary	• Can be used in unconsolidated and semi-consolidated soils and rock • Can facilitate the installation of larger diameter probes/wells • Can facilitate the installation of more than one small diameter probe/well in a single borehole • Boreholes can be drilled to depths of 150 feet or more	• Introduces foreign materials into the borehole • Generates large amounts of soil cuttings • Drilling fluids can carry contamination from a contaminated zone to an uncontaminated zone	• Generally deemed unsuitable for the installation of probes/wells intended for SVE system effectiveness and vapor migration monitoring

TABLE 1
Drilling Method Selection

SOP SAS-11-03 - ATTACHMENT A

DRILLING METHOD	ADVANTAGES	DISADVANTAGES	NOTES
Sonic Rotary	• Can be used in unconsolidated and semi-consolidated soils and rock • Minimal smearing of formation materials • Can facilitate the installation of larger diameter probes/wells • Can facilitate the installation of more than one small diameter probe/well in a single borehole • Boreholes can be drilled to depths of 150 feet or more	• Requires large open spaces for rig and support equipment • Expensive compared to other methods • In flowing sands, introduction of a foreign materials (potable water) is required	• Generally deemed suitable for the installation of probes/wells intended for SVE system effectiveness and vapor migration monitoring • Preferred drilling method for the installation of probes/wells with a diameter equal to or greater than one inch and/or nested probes/wells in a single borehole in competent rock
Direct Push Technologies	• Can be used in unconsolidated and semi-consolidated soils and rock • No Introduction of foreign materials into the borehole • Can access locations not accessible by other drilling equipment • Generates minimal amounts of soil cuttings	• Cannot be used in depositions consisting of coarse gravel, cobbles, and/or weathered or competent rock • Cannot facilitate the installation of larger diameter probes/wells • Cannot facilitate the installation of more than one small diameter probe/well in a single borehole • Drilling depth is limited compared to other drilling methods	• Generally deemed suitable for the installation of small-diameter probes/wells intended for SVE system effectiveness and vapor migration monitoring • Preferred drilling method for the installation of probes/wells with a diameter less than one inch in unconsolidated and semi-consolidated soils
Hand Auger	• Can be used in unconsolidated soils • No Introduction of foreign materials into the borehole • Can access locations not accessible by other drilling equipment • Generates minimal amounts of soil cuttings	• Cannot be used in depositions consisting of coarse gravel, cobbles, and/or weathered or competent rock • Cannot facilitate the installation of larger diameter probes/wells • Cannot facilitate the installation of more than one small diameter probe/well in a single borehole • Drilling depth is limited compared to other drilling methods	• Generally deemed suitable for the installation of shallow, small-diameter probes/wells intended for SVE system effectiveness and vapor migration monitoring, but is not the preferred drilling method

ATTACHMENT B
TABLE 2 – PROBE/WELL MATERIAL AND DIAMETER SELECTION

TABLE 2
Probe/Well Material and Diameter Selection

SOP SAS-11-03 - ATTACHMENT B

WELL MATERIAL	WELL DIAMETER	ADVANTAGES	DISADVANTAGES	NOTES
Polyvinyl Chloride (PVC)	1-Inch I.D.	• Suitable for single probe/well construction in small to large diameter boreholes • Suitable for nested probes/wells in medium to large diameter boreholes • Relatively low purge volume per foot of casing/screen • Can be fitted with various screen lengths (1, 5, and 10 foot screens) • Allows for fluid level gauging to confirm well screen masking by fluids • Limited suitability for other purposes (e.g. groundwater/product gauging and sampling) • Relatively inexpensive material	• Unsuitable for nested probes/wells in small diameter boreholes • Limited suitability for other purposes	• Generally deemed suitable for the installation of single or nested probes/wells, intended for SVE system effectiveness and vapor migration monitoring, in unconsolidated and semi-consolidate soils and competent rock. • Preferred material and diameter for monitoring within most depositional environments including fine grained materials, confined conditions, and the caprillary fringe
Polyvinyl Chloride (PVC)	2-Inch I.D.	• Suitable for single probe/well construction in large diameter boreholes • Can be fitted with various screen lengths (1, 5, and 10 foot screens) • Allows for fluid level gauging to confirm well screen masking by fluids • Suitable for other purposes (e.g. groundwater/product gauging and sampling) • Relatively inexpensive material	• Limited suitability for single probe/well construction in small and medium diameter boreholes • Generally, unsuitable for nested probes/wells • Relatively moderate purge volume per foot of casing/screen	• Generally deemed suitable for the installation of single or nested probes/wells, intended for SVE system effectiveness and vapor migration monitoring, in unconsolidated and semi-consolidate soils and competent rock. • Preferred material and diameter for probes/wells intended for multiple uses in most depositional environments

TABLE 2
Probe/Well Material and Diameter Selection

SOP SAS-11-03 - ATTACHMENT B

WELL MATERIAL	WELL DIAMETER	ADVANTAGES	DISADVANTAGES	NOTES
Polyvinyl Chloride (PVC)	4-Inch I.D.	• Suitable for single probe/well construction in large diameter boreholes • Can be fitted with various screen lengths (5, and 10 foot screens) • Allows for fluid level gauging to confirm well screen masking by fluids • Suitable for other purposes (e.g. groundwater/product gauging and sampling) • Relatively inexpensive material	• Unsuitable for nested probes/wells • Relatively high purge volume per foot of casing/screen	• Generally deemed unsuitable for SVE system effectiveness and vapor migration monitoring due to the high purge volume per foot of casing/ screen • Limited suitability for vacuum/ pressure gauging
Stainless Steel	1/8-Inch O.D.	• Suitable for single probe/well construction in small to large diameter boreholes • Suitable for nested probe/well construction in small to large diameter boreholes • Minimal purge volume per foot of casing/screen	• Does not allow for fluid level gauging to confirm well screen masking by fluids • Generally limited to a 0.5-foot well screen • Extremely difficult to rehabilitate the well, when necessary • Unsuitable for other purposes	• Generally deemed suitable for the installation of single or nested probes/wells, intended for SVE system effectiveness and vapor migration monitoring, in unconsolidated and semi-consolidate soils and competent rock. • Preferred material and diameter for monitoring within depositional environments characterized by fine-grained materials and unconfined conditions well above the water table

TABLE 2
Probe/Well Material and Diameter Selection

SOP SAS-11-03 - ATTACHMENT B

WELL MATERIAL	WELL DIAMETER	ADVANTAGES	DISADVANTAGES	NOTES
Stainless Steel	1/4-Inch O.D.	• Suitable for single probe/well construction in small to large diameter boreholes • Suitable for nested probe/well construction in small to large diameter boreholes • Minimal purge volume per foot of casing/screen	• Does not allow for fluid level gauging to confirm well screen masking by fluids • Generally limited to a 0.5-foot well screen • Extremely difficult to rehabilitate the well, when necessary • Unsuitable for other purposes	• Generally deemed suitable for the installation of single or nested probes/wells, intended for SVE system effectiveness and vapor migration monitoring, in unconsolidated and semi-consolidate soils and competent rock. • Preferred material and diameter for monitoring within depositional environments characterized by fine-grained materials and unconfined conditions well above the water table
Stainless Steel	2-Inch I.D.	• Suitable for single probe/well construction in medium to large diameter boreholes • Can be fitted with various screen lengths (1, 5, and 10 foot screens) • Allows for fluid level gauging to confirm well screen masking by fluids • Suitable for other purposes (e.g. groundwater/product gauging and sampling)	• Limited suitability for single probe/well construction in small diameter boreholes • Generally, unsuitable for nested probes/wells • Relatively moderate purge volume per foot of casing/screen • Relatively expensive material	• Generally deemed suitable for the installation of single or nested probes/wells, intended for SVE system effectiveness and vapor migration monitoring, in unconsolidated and semi-consolidate soils and competent rock. • Preferred diameter for probes/wells intended for multiple uses in most depositional environments

TABLE 2
Probe/Well Material and Diameter Selection

SOP SAS-11-03 - ATTACHMENT B

WELL MATERIAL	WELL DIAMETER	ADVANTAGES	DISADVANTAGES	NOTES
Stainless Steel	4-Inch I.D.	• Suitable for single probe/well construction in large diameter boreholes • Can be fitted with various screen lengths (5, and 10 foot screens) • Allows for fluid level gauging to confirm well screen masking by fluids • Suitable for other purposes (e.g. groundwater/product gauging and sampling)	• Unsuitable for nested probes/wells • Relatively high purge volume per foot of casing/screen • Relatively expensive material	• Generally deemed unsuitable for SVE system effectiveness and vapor migration monitoring due to the high purge volume per foot of casing/ screen • Limited suitability for vacuum/ pressure gauging

Author:	**T.Gilles**	**Q2R & Approval By:**	**E. Gasca**	**Q3R & Approval By:**	**J. Pope**

STANDARD OPERATING PROCEDURE
NO. SAS-11-04

SVE SYSTEM EFFECTIVENESS AND VAPOR MIGRATION MONITORING
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for the monitoring of semi-permanent to permanent soil vapor monitoring probes/wells for the evaluation of Soil Vapor Extraction (SVE) system effectiveness and subsurface vapor migration. This SOP also describes field measurements and soil vapor collection methods, and quality assurance procedures.

2.0 EQUIPMENT AND MATERIALS

- Digital manometer (Dwyer Series 475 Mark III Digital Manometer or equivalent) or magnehelic differential pressure gauge (0-20 inches of water);
- Digital manometer (Dwyer Series 475 Mark III Digital Manometer or equivalent)or magnehelic differential pressure gauge (0-200 inches of water);
- 1-liter Tedlar™ bags;
- Tygon™ or silicone tubing (cut to length);
- ¼-inch O.D. Teflon™, Polyethylene, or PVC tubing (cut to length);
- GeoTech Peristaltic Pump or equivalent;
- BIOS DC-LITE flow calibrator, calibrated rotometer, or equivalent;
- 60-mL syringe for purging (Probe/well less than 1 inch in diameter);
- Stainless-steel manual pump for purging (Probe/well equal to or greater than 1 inch in diameter);
- Extra vinyl slip covers;
- Clean (dedicated) 3/16-Inch hose barb, chrome-platted brass, non-valved, in-line coupling body (herein referred to as “coupling body”);
- New or dedicated 4-way valves for purging and sampling;
- Summa (or equivalent) canisters;

Coupling Body

- Sample flow controller;
- ¼-inch O.D. Teflon sample line;
- ¼-inch O.D. Teflon or stainless-steel compression fittings;
- Probe/well location maps;
- Miscellaneous tools (i.e. socket set to remove well/probe caps);
- Chain of custody forms and seals; and
- Field logbook and/or appropriate field form.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 EXECUTION

Probes/wells intended for SVE system effectiveness monitoring shall undergo pre-system start up (a.k.a. baseline) monitoring to 1) establish a representative set of baseline data and 2) facilitate a defensible evaluation of post-system start up data set. Procedures for baseline and post-system start up monitoring are described in the following sections.

4.1 Vacuum/Pressure Gauging

In order to evaluate the degree of influence that a soil vapor extraction (SVE) wells have on surrounding area, vacuum measurements shall be collected from designated monitoring locations prior to any soil vapor sampling. The Dwyer digital manometer or magnehelic differential pressure gauge or equivalent (herein referred to as the “gauging instrument”) shall be used for this measurement. Immediately prior to use, the gauging instrument shall be zeroed at atmospheric pressure. Vacuum/pressure measurements shall be obtained using the of the following probe/well diameter-specific procedures.

4.1.1 Probe/Well Diameters Less Than One Inch

At probes/wells with a diameter of less than one-inch, the positive fitting on the gauging instrument shall be connected to the 4-way valve, previously installed to the top of the well riser, using small diameter silicone tubing of appropriate size. The negative fitting on the gauging instrument shall remain open to the atmosphere. The 4-way valve shall be opened to the well and closed to the atmosphere. The gauging instrument shall be allowed a maximum of thirty (30) minutes to stabilize before the vacuum/pressure is recorded. If the gauging instrument does not stabilize within the 30-minute period, the range in which the vacuum/pressure reading fluctuates over an additional one (1) minute period will be documented in the field logbook and/or on the appropriate field form. The highest reading observed within the observed range will be recorded in the field logbook and/or on the appropriate field form as the primary measurement. (*Please note: If the gauging instrument reading fluctuates between two vacuums, the lowest/weakest vacuum observed will be recorded as the primary measurement. If the gauging instrument reading fluctuates between a vacuum and a pressure, the highest pressure observed will be recorded as the primary measurement. If the manometer reading fluctuates between two pressures, the highest/strongest pressure observed will be recorded as the primary measurement. In all cases, the range in the gauging instrument readings over the additional one-minute period will be recorded in the field logbook and/or on the appropriate field form.)* The vacuum/pressure measurement shall be recorded to the nearest hundredth of an inch of water column in the field logbook and/or on the appropriate field form first, followed by any secondary data entry devices (i.e. PDA, laptop, etc.). Please note a field form, if used, is considered the record document. Immediately following the recording of the vacuum/pressure measurement, the 4-way valve shall be closed to the well and open to the atmosphere and the gauging instrument shall be detached from the silicone tubing and 4-way valve *(see Attachment A: Guide to the 4-Way Micro-Valve).*

A picture of a typical vacuum/pressure gauging set-up is provided below.

4.1.2 Probe/Well Diameters Equal to or Greater Than One Inch

At probes/wells with a diameter equal to or greater than one-inch, the positive fitting on the gauging instrument shall be connected to a dedicated coupling body using silicone (or equivalent) tubing. The negative fitting on the gauging instrument shall remain open to the atmosphere. The coupling body shall then be connected to the coupling insert located on the expandable well cap, which will open the well to the gauging instrument. The gauging instrument shall be allowed a maximum of thirty (30) minutes to stabilize before the vacuum/pressure is recorded. If the gauging instrument does not stabilize within the 30-minute period, the range in which the vacuum/pressure reading fluctuates over an additional one (1) minute period will be documented in the field logbook and/or on the appropriate field form. The highest reading observed within the observed range will be recorded as the primary measurement. (*Please note: If the gauging instrument reading fluctuates between two vacuums, the lowest/weakest vacuum observed will be recorded as the primary measurement. If the gauging instrument reading fluctuates between a vacuum and a pressure, the highest pressure observed will be recorded as the primary measurement. If the manometer reading fluctuates between two pressures, the highest/strongest pressure observed will be recorded as the primary measurement. In all cases, the range in the gauging instrument readings over the additional one-minute period will be recorded in the field logbook and/or on the appropriate field form.)* The vacuum/pressure measurement shall be recorded to the nearest hundredth of an inch of water column in the field logbook and/or on the appropriate field form first, followed by any secondary data entry devices (i.e. PDA, laptop, etc.). Please note a field form, if used, is considered the record document. Immediately following the recording of the vacuum/pressure measurement, the coupling body shall be disconnected from the coupling insert, which will close the well to the gauging instrument and the atmosphere. The gauging instrument and associated tubing shall then be detached from the dedicated coupling body.

4.2 Probe/Well Purging

Upon completion of any vacuum / pressure measurements and prior to soil vapor sample collection, each probe/well shall be purged a predetermined volume (in Liters or milliliters) based on the volume of the probe/well riser and screen. The purge volume shall be equivalent to a minimum of three probe/well volumes. The actual purge volume removed shall be recorded in the field logbook and/or on the appropriate field form. If the probe/well would not yield the full purge volume or water and/or product are encountered during purging, this observation shall be documented in the field logbook and/or on the appropriate field form.

4.2.1 Probe/Well Diameters Less Than One Inch

To purge the monitoring locations with a diameter less than one-inch, a 60-ml plastic syringe shall be attached to the 4-way valve, previously installed to the top of the well riser and the valve shall be configured (opened to the well and closed to the atmosphere) to allow the removal of the required purge volume. The syringe plunger shall be drawn back to evacuate a purge volume. The valve gate shall then be configured (closed to the well and opened to the atmosphere) and the syringe plunger shall be pushed in allowing the purged volume to be expelled to atmosphere. This process shall continue until a minimum of three probe/well volumes have been removed from the monitoring location. Care shall be taken to prevent the purged air from being reintroduced into the probe/well. At the completion of purging, the 4-way valve shall remain attached to the monitoring location with the valve configured so that the well is closed to atmosphere. Failure to close the 4-way valve to atmosphere prior to attaching the Tedlar™ bag or Summa canister will result in a volume of ambient air infiltrating back into the well riser and subsequently being collected as a sample *(see Attachment A: Guide to the 4-Way Micro-Valve)*.

4.2.2 Probe/Well Diameters Equal to or Greater Than One Inch

Purging probes/wells with diameters equal to or greater than one inch requires the use of a stainless steel hand pump in conjunction with silicone (or equivalent) tubing and a dedicated coupling body. The hand pump shall be tested prior to each sampling event by attaching a 1-liter Tedlar™ test bag to the hand pump outlet. The inlet of the hand pump shall remain open to atmosphere. Two strokes of a properly working hand pump should fill a 1-liter bag to approximately 75-percent of capacity. The 1-liter bag should not be completely filled because the bags are typically oversized in order to allow for expansion of the sample during shipment, storage, etc. The hand pump shall be rebuilt in accordance with manufacturer specifications if the hand pump fails to adequately fill the test bag.

The stainless steel hand pump shall be used in conjunction with silicone (or equivalent) tubing and a dedicated coupling body. The vacuum side of the hand pump shall be attached to a dedicated coupling body using silicone (or equivalent) tubing. The dedicated coupling body shall then be connected to the coupling insert located on the expandable well cap, which will allow for the removal of purge volumes from the probe/well. The hand pump has an internal one-way valve and, therefore, manipulation of the coupling body and coupling insert shall not be necessary. The purged volume is expelled to atmosphere from the positive side of the hand pump with every downward stroke of the pump handle (piston). Every upward stroke of the pump handle should remove approximately ½-liter of the purge volume from the well. Care shall be taken to fully extend the hand pump handle to ensure that the appropriate volume is removed from the probe/well with each pump stroke. When a minimum of three well volumes have been removed from the monitoring location, the coupling body shall be disconnected from the coupling insert, which closes the probe/well to atmosphere.

4.3 Soil Vapor Sample Collection

Upon completion of probe/well purging (evacuation of a minimum of three probe/well volumes of air), soil vapor sample collection using Tedlar™ sample media and/or summa (or equivalent) canisters shall commence. If water and/or product are encountered during sample collection, this observation shall be documented in the field logbook and/or on the appropriate field form.

4.3.1 Tedlar™ Bag Sample Media

Soil vapor samples for on-site analysis/field screening shall be collected using a Tedlar™ bag media and a peristaltic pump. For probes/wells with a diameter less than one-inch, the peristaltic pump shall be attached to a 4-way plastic micro valve using a combination of Tygon™ and silicone (or their respective equivalent) tubing. The valve, which was used for the well purging, should already be attached to the top of the well riser. For probes/wells with a diameter greater than or equal to one-inch, the peristaltic pump shall be attached to the dedicated coupling body using a combination of Tygon™ and silicone (or their respective equivalent) tubing. The outlet of the peristaltic pump shall be attached to the inlet side of the flow calibrator (or rotometer) using a combination of Tygon™ and silicone (or their respective equivalent) tubing. Prior to flow rate adjustment and sample collection, the sample identification, date, time, and vacuum/pressure reading (if applicable) shall be clearly documented on the Tedlar™ Bag.

4.3.1.1 Flow Rate Adjustment

The flow calibrator or calibrated rotometer shall be used to adjust the flow rate of the peristaltic pump to allow a flow rate of less than 200 mL/minute. For probes/wells with a diameter less than one-inch, this adjustment shall be performed by 1) configuring the micro valve to allow for sample removal from the well, 2) depressing the read button on the flow meter and noting the rate of sample flow or if a calibrated rotometer is used, simply observe the flow rate indicated by the ball height, and 3) quickly adjusting the peristaltic pump to allow a flow rate of 200-ml/minute or less. For probes/wells with a diameter greater than or equal to one-inch, this adjustment shall be performed by 1) connecting the coupling body to the coupling insert to allow for sample removal from the well, 2) depressing the read button on the flow meter and noting the rate of sample flow or if a calibrated rotometer is used, simply observe the flow rate indicated by the ball height, and 3) quickly adjusting the peristaltic pump to allow a flow rate of 200-ml/minute or less. *Notes: The initial settings on the pump should be set to allow for the minimum flow possible. It is important to set the flow rate as quickly as possible in order to minimize the amount of additional sample volume. An advantage that the use of a rotometer has over a flow meter is that an instantaneous flow reading will be displayed, allowing for a much quicker flow-rate adjustment to the peristaltic pump.* After setting the sample flow, sample collection shall be immediately initiated. Care shall be taken at this time to avoid unintentionally adjusting (by bumping or handling) the pump speed control.

4.3.1.2 Sample Collection

After setting the sample flow, the flow calibrator or calibrated rotometer shall be removed from the sample train and a new, clean, pre-labeled, one-liter Tedlar™ bag shall be connected to the tubing exiting from the positive-pressure (output) side of the peristaltic pump. A wire tie shall be used, if necessary, to make the connection between the bag and the pump a leak proof fitting. Immediately open the valve on the Tedlar™ bag approximately one turn. *Please note: Unless a vacuum/pressure reading was not collected, the sample time is the same time as the acquisition of the primary vacuum/pressure measurement. If a vacuum/pressure measurement was not collected, the sample-start time shall be documented in the field logbook and/or on the appropriate field form.* Based on the flow rate to collect a 1-liter vapor sample, the peristaltic pump shall be allowed approximately five (5) minutes to collect the sample. Total sample collection time, which may exceed five (5) minutes, is dependent on the soil characteristics of the stratigraphic unit (a.k.a. stratum) from which the sample is being collected. Upon retrieval of the one-liter sample volume, the valve on the Tedlar™ bag shall be closed and the peristaltic pump turned off. The micro valve shall then be configured such that the valve is closed to the well and open to the atmosphere (well diameters less than one-inch) or the coupling body shall be disconnected from the coupling insert (well diameters greater than or equal to one-inch). The sample bag shall be placed in a black trash bag or container that will not allow sunlight to pass through.

Duplicate samples shall be collected by repeating the preceding procedure detailed above. The duplicate sample shall be collected immediately after the first sample (original/main sample) has been collected. Due to the nature of the coarse-adjustment valves that are typically installed on Tedlar™ bags, the use of a sample splitter is not recommended since this will often result in the collection of unequal sample volumes.

4.3.1.3 Post-Sample Collection

The sample train shall be dismantled and all non-dedicated lines used for sample collection shall be disposed of. New sample lines at each sample location shall be used, except for dedicated equipment (4-way micro valves, fittings, and coupling bodies, etc.). The micro valve shall remain attached to probes/wells with a well diameter less than one-inch, however; the valve shall be configured so that the probe/well is closed to atmosphere *(see Attachment A: Guide to the 4-Way Micro-Valve)*. For probes/wells with a diameter equal to or greater than one inch, the vinyl slip cover shall be fitted over the coupling insert on the expandable well cap following sampling collection. The dedicated equipment (coupling body) used for the monitoring locations with a probe/well diameter equal to or greater than one-inch shall be placed into a labeled, re-sealable bag. Non-dedicated, reusable equipment shall be cleaned / decontaminated in accordance with SOP ENV-04-04 or as otherwise required by the Site-Specific Work Plan.

4.3.2 Summa™ Canister Sample Media

Soil vapor samples for commercial laboratory analysis shall be obtained using Summa™ or equivalent canisters. For probes/wells with a diameter less than one-inch, the Summa (or equivalent) canister shall be attached directly to a 4-way plastic micro valve using silicone tubing. The valve, which was used for the well purging, should already be attached to the top of the well riser. For probes/wells with a diameter greater than or equal one-inch, the Summa™ (or equivalent) canister shall be attached directly to the dedicated coupling body located on the expandable well cap using silicone tubing.

4.3.2.1 Canister Preparation and QA/QC

A Summa canister is a stainless steel container which has had its internal surfaces passivated using the “Summa” process. The process uses an electro polishing step in conjunction with chemical deactivation. The overall process results in a chemically inert interior surface of the media which allows for the collection and subsequent analysis of samples containing very low concentrations of VOCs. The Summa media is available in a number of different sizes. Typically, 6-liter Summa canisters are used for the collection of soil vapor samples because this volume should allow for low detection limits and facilitate more complex analyses.

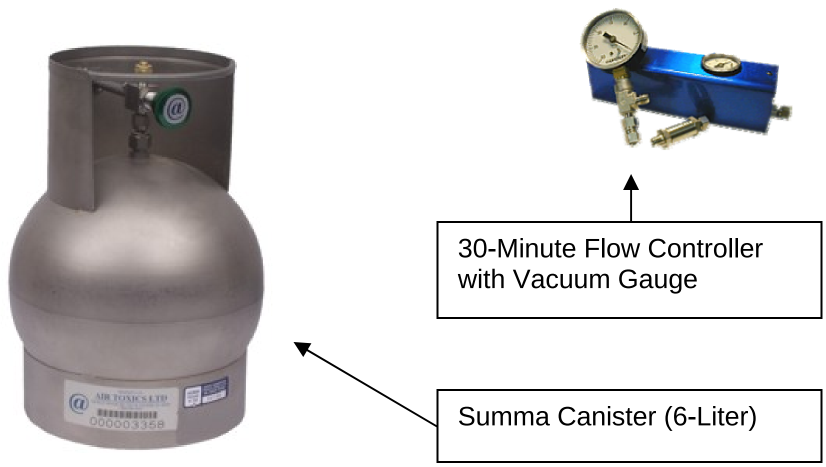
Once the laboratory cleaning process is completed, the Summa canisters are prepared by the laboratory for use in the field. Each canister is evacuated to achieve a vacuum pressure of approximately 30-inches of mercury. The pressure differential between the canister and atmosphere allows for the Summa canister to sample without the use of a separate sample pump. Depending on the project requirements, either grab or integrated samples may be collected. The holding time (shelf life) for Summa canisters that have been prepared for use in the field is 30-days. If the canister has not been used within this time-period, it shall be returned to the contracted laboratory for re-conditioning.

Summa canisters undergo either an individual or batch certification process. The individual certification process requires that each canister undergo a comprehensive Quality Assurance/Quality Control (QA/QC) procedure that results in analysis documentation for each canister, verifying that there are no residual compound concentrations above a pre-determined level. Typically, individually certified canisters are used for ambient air sampling programs that require a high level of QA/QC. Batch certified canisters undergo the same re-conditioning process as the individually certified canisters. However, only 5-percent of randomly chosen canisters are analyzed for residual constituents. If any of the selected canisters do not meet specific certification criteria, all of the canisters in that batch are required to undergo the entire cleaning and QA/QC process again. This process is repeated until all QA/QC re-conditioning criteria are met.

4.3.2.2 Sample Set Up

Field sampling staff shall complete the sample set-up of a Summa (or equivalent) canister prior to sample collection. Each six-liter (6.0 L) Summa (or equivalent) canister shall be fitted with a dedicated sample flow controller (regulator). After verification that the valve on the canister is in the “off” position, the brass cap shall be removed from the canister inlet fitting and the sample flow controller shall be attached to the canister inlet. The brass cap shall then be installed onto the inlet of the flow controller and tighten. *Note: The 30-minute sample flow controller (regulator) is a complete assembly that shall be attached directly to the canister.* The assembly shall then be leak-checked by opening the canister valve and noting the initial vacuum reading. The vacuum should indicate between 20 and 30-inches of mercury. The canister shall not be used if the starting vacuum is less than 20-inches of mercury. The vacuum may fall a very small amount (1 to 2-inches) due to the evacuation of the flow controller and then quickly stabilize. If the vacuum does not stabilize, the flow controller or associated fittings are leaking. If possible, determine the location of the leak, and repair it accordingly. Any necessary repairs shall be document in the field logbook and/or on the appropriate field form. If the leak cannot be quickly identified and repaired, the Summa canister and flow controller shall not be used.

A picture of a typical 6-liter Summa canister and a 30-minute sample flow controller are provided below.



4.3.2.3 Sample Collection

Upon completion of sample set up, soil vapor sample collection shall begin. A short length of dedicated Teflon™ tubing shall then be installed onto the top of the flow regulator with a Teflon™ Swagelok fitting or equivalent to form a leak proof connection. The Summa (or equivalent) canister shall be connected via the Teflon™ tubing and a small length of silicon tubing to the 4-way micro valve (probes/wells with a diameter less than one-inch or the dedicated coupling body (probes/wells with a diameter equal to or greater than one inch). If necessary, a wire tie shall be used on each connection where different tubing attaches to form a leak-proof seal. For probes/wells with a diameter less than one-inch, the 4-way micro valve shall then be configured to allow sample collection (valve open to the well and sample flow controller / regulator and closed to the atmosphere) and the valve on the canister opened approximately two (2) turns. For probes/wells with a diameter greater than or equal to one-inch, the coupling body shall be connected to the coupling insert located on the expandable well cap and the valve on the canister opened approximately two (2) turns. The sample start time and beginning canister vacuum (inches of mercury [Hg]) shall be recorded in the field logbook and/or on the appropriate field form. *Note: The typical initial canister vacuum is between 20 and 30 inches of Hg.*

A picture of a typical 6-liter Summa canister, 30-minute sample flow controller, and sample train is provided below for a probe/well with a diameter less than one-inch.

When the sampler has identified a minimum change/decrease of 15 inches of Hg in canister vacuum (Initial Vacuum – Final Vacuum) and the final canister vacuum is equal to or below five (5) inches of Hg, but above two (2) inches of Hg, the valve to the canister shall be closed. For probes/wells with a diameter less than one inch, the 4-way micro valve shall then be configured to be closed to the probe/well, sample flow controller / regulator, and the atmosphere. For probes/wells with a diameter equal to or greater than one inch, the coupling body shall be disconnected from the coupling insert. *NOTE: Based on the approximate flow rate (200 milliliters per minute [mL/min], approximately thirty (30) minutes is required to collect the specified sample volume.* The sample time, canister number, and sample flow controller / regulator number shall be recorded on the chain of custody and the final canister vacuum and sample end time recorded in the field logbook and/or on the appropriate field form. The sample flow controller / regulator shall be removed from the canister and the Teflon™ sample tubing shall be discarded after a single use to prevent cross-contamination between samples. Finally, the brass cap (used earlier) shall be attached to the inlet fitting on the Summa canister and a sample identification tag/label attached to the canister.

Duplicate samples shall be collected by repeating the procedure detailed above, with the addition of a "T" splitter, and one canister attached to each end of the "T" Swagelok (compression) or equivalent fitting.

A picture of a typical set-up for the collection of a duplicate sample at a probe/well with a diameter of less than one-inch is provided below.

4.3.2.4 Post-Sample Collection

The sample train shall be dismantled and all non-dedicated lines used for sample collection shall be disposed of. New sample lines at each sample location shall be used, except for dedicated equipment (4-way micro valves, fittings, and coupling bodies, etc.). The micro valve shall remain attached to probes/wells with a well diameter less than one-inch, however; the valve shall be configured so that the probe/well is closed to atmosphere *(see Attachment A: Guide to the 4-Way Micro-Valve)*. For probes/wells with a diameter equal to or greater than one inch, the vinyl slip cover shall be fitted over the coupling insert on the expandable well cap following sampling collection. The dedicated equipment (coupling body) used for the monitoring locations with a probe/well diameter equal to or greater than one-inch shall be placed into a labeled, re-sealable bag. Non-dedicated, reusable equipment shall be cleaned / decontaminated in accordance with SOP ENV-04-04 or as otherwise required by the Site-Specific Work Plan.

4.4 Soil Vapor Sample Handling

Tedlar™ bag samples shall be transported to the onsite field screening location. Field screening shall be performed in accordance with the SOP ENV-11-05. The holding time for a Tedlar™ bag sample shall not exceed thirty-six (36) hours.

Summa canisters samples shall be shipped to the contracted laboratory under strict chain of custody procedures for offsite laboratory analysis. The holding time for a Summa sample shall not exceed fourteen (14) days.

5.0 Quality Assurance/Quality Control

5.1 Leak Testing

Leakage during soil vapor sampling may dilute samples with ambient air and produce results that underestimate actual site soil vapor concentrations. Leak testing can be conducted using direct and indirect methods to evaluate seal integrity. The type of leak testing, if any, shall be based on data quality objectives as specified in the Site-Specific Work Plan.

5.1.1 Direct

Seal integrity can be evaluated directly using an inert tracer gas (e.g. laboratory grade helium). Inert gas selection shall be conducted in conjunction with the laboratory. The sampler shall construct an air tent using polyethylene sheet or assemble a commercially available air tent which encompasses the top of the probe/well casing and the entire sample train. During sampling, the tracer gas shall be allowed to flow around the sample train connections and the bentonite or grout seal at the ground surface. Following sample collection, the air tent shall be dismantled. The soil vapor sample shall be analyzed for inert trace gas in addition to the other requested analysis. If the tracer gas is detected in the soil vapor sample, the seal integrity was compromised and the analytical results, which are not representative of the stratigraphic unit or zone within the stratigraphic unit, shall be considered invalid.

5.1.2 Indirect

Seal integrity can be evaluated indirectly by measuring oxygen and carbon dioxide levels in the soil vapor sample. Oxygen and carbon dioxide levels shall be compared to levels in ambient air, project-specific criteria, and/or data trend(s). If the soil vapor sample levels are comparable to ambient air and/or project-specific criteria and/or do not fit data trend(s), the sample results shall be considered suspect. If soil vapor analysis is being performed by an offsite laboratory, this data shall be qualified appropriately. If soil vapor analysis is being performed onsite (either by a mobile laboratory or as field screening), then the probe/well shall be re-sampled within 24 to 36 hours of the original sample. The duplicate and original sample results shall be compared and evaluated based on project-specific criteria and data trend(s) to determine if the seal integrity was compromised and validity of the data collected. The reasons supporting the qualification or invalidation of data shall be documented in the field logbook and/or on the appropriate field form or as otherwise required by the Site-Specific Work Plan or Quality Assurance Project Plan (QAPP).

6.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, 2001, ASTM Standard D 5314-92 (2001) Standard Guide for Soil Gas Monitoring in the Vadose Zone.

USEPA, 1994, SOP # 1703, Rev #: 0.0, Summa Canister Cleaning Procedure.

USEPA, 1995, SOP #1704, Rev. #: 0.0, Summa Canister Sampling.

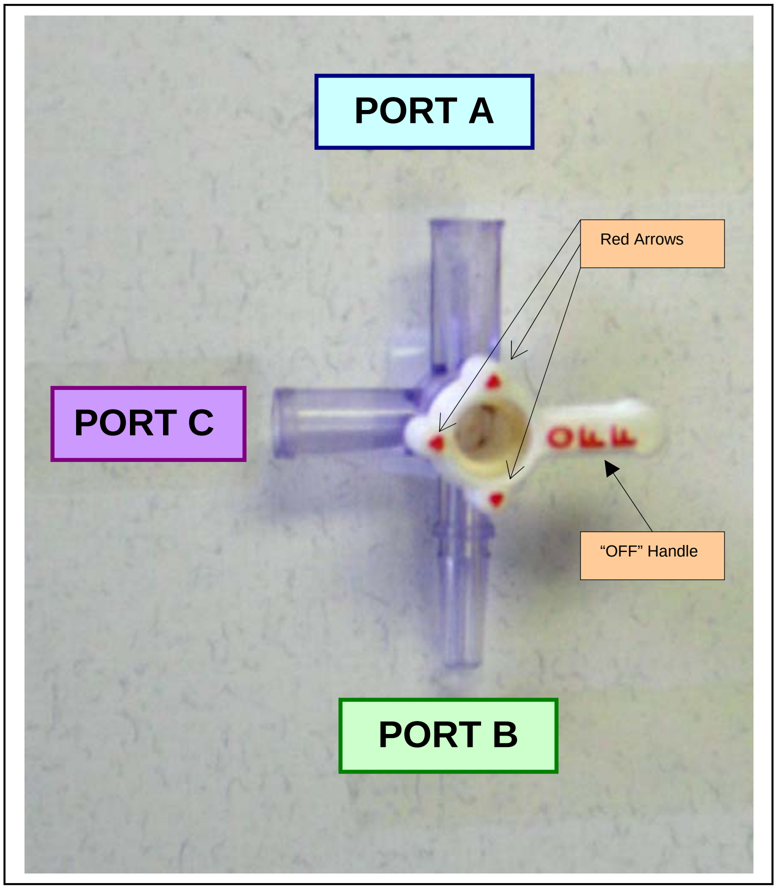
USEPA, 1996, SOP # 2042, Rev. #: 0.0, Soil Gas Sampling

USEPA, 1999, Compendium Method TO-15, Determination of Volatile Organic Compounds (VOCs) in Air Collected In Specially-Prepared Canisters and Analyzed By Gas Chromatography/Mass Spectrometry GC/MS) in *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air,* 2nd Ed., EPA Publication 625/R-96/010b.

USEPA, 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

ATTACHMENT A
GUIDE TO THE 4-WAY MICRO-VALVE

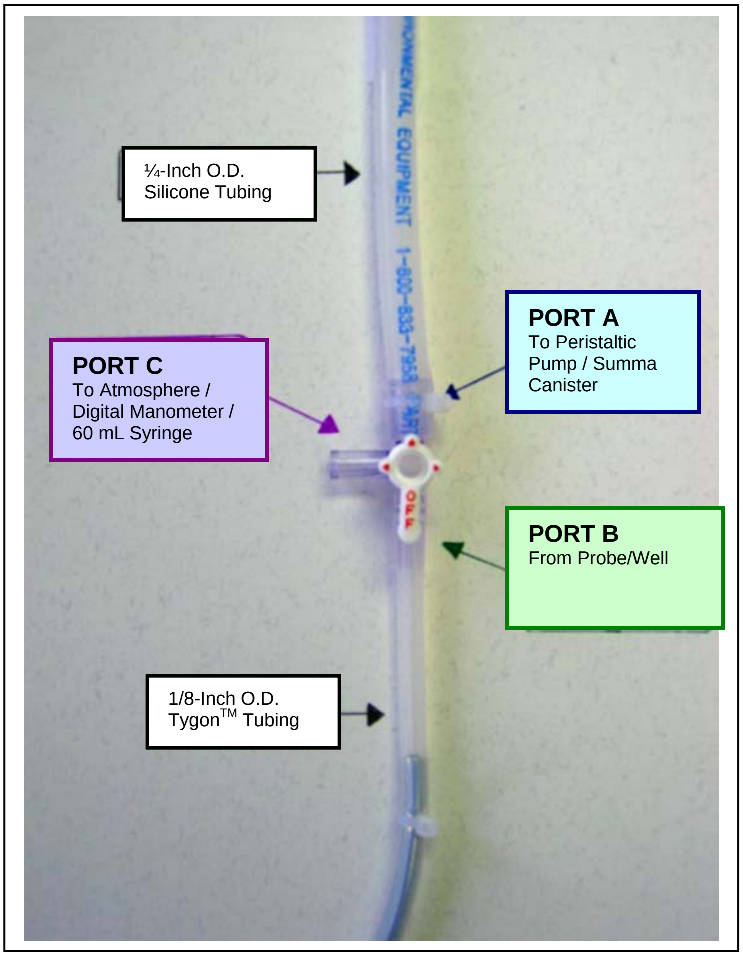
GUIDE TO THE 4-WAY MICRO-VALVE

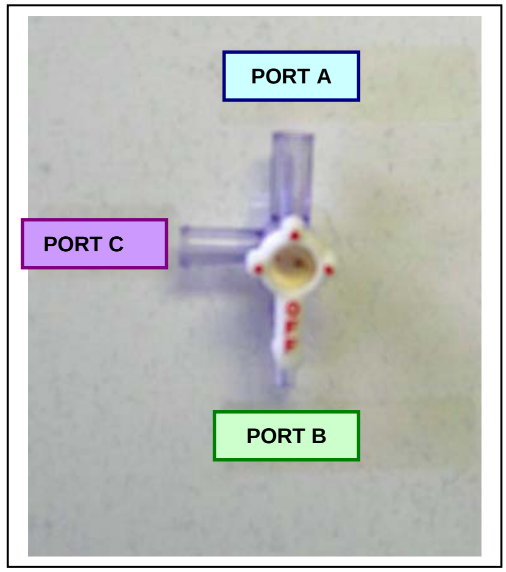


Notes:

1. Red arrows on the 4-way micro-valve indicate the ports that are currently open.
2. The "OFF" handle indicates the port that is currently closed.
3. The designation of ports is alphabetical from the top (opposite the probe/well) going in a clockwise direction.

Valve Position #1: Closed to Probe/Well





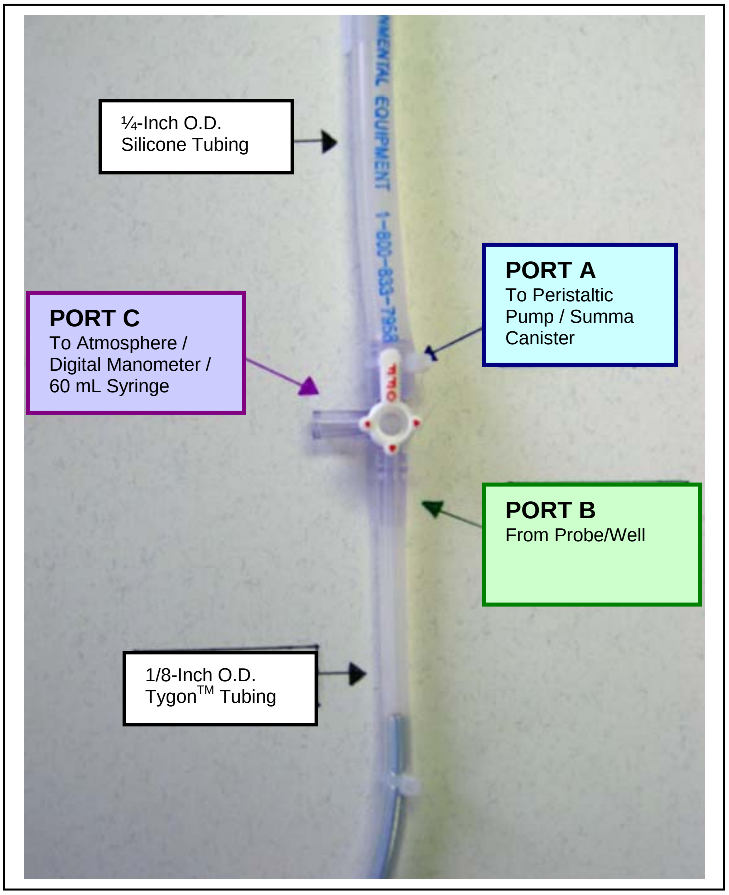
Valve Position #1:

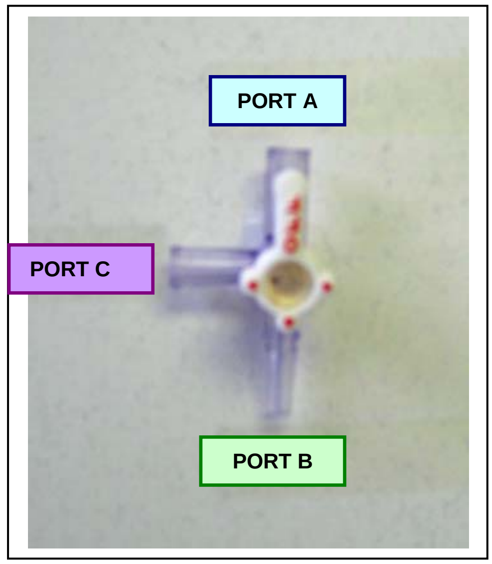
Closed to Port B (Probe/Well);
Open to Port A (Peristaltic Pump / Summa Canister)
Open to Port C (Atmosphere / Digital Manometer / 60 mL Syringe)

The "OFF" handle is turned in such a way that it is directly over Port B. The three small, red arrows opposite the "OFF" handle indicate which ports are open (Ports A & C).

In this valve position, the probe/well is not open to the atmosphere and, therefore, will not vent. If the valve is not in this position prior to the start of the monitoring (vacuum/pressure gauging, Tedlar™ bag sample collection, and/or summa canister sample collection, set the valve to Position #1 and return to this location at least 30 minutes later.

Valve Position #2: Open for Vacuum/Pressure Gauging & Purging





Valve Position #2:

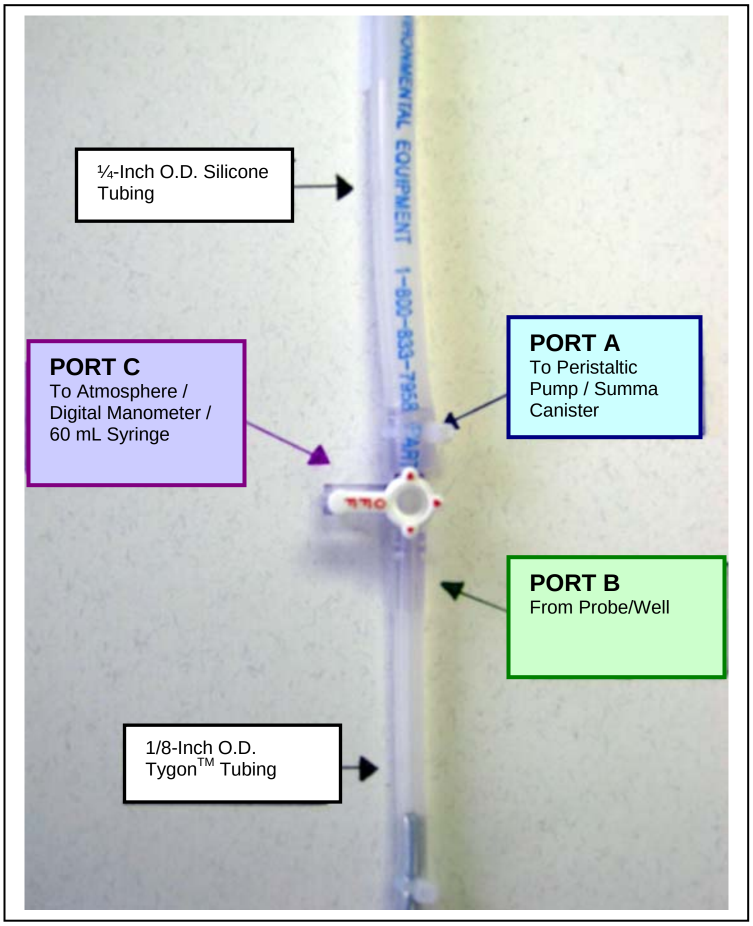
Closed to Port A (Peristaltic Pump / Summa Canister);
Open to Port B (Probe/Well)
Open to Port C (Atmosphere / Digital Manometer / 60 mL Syringe)

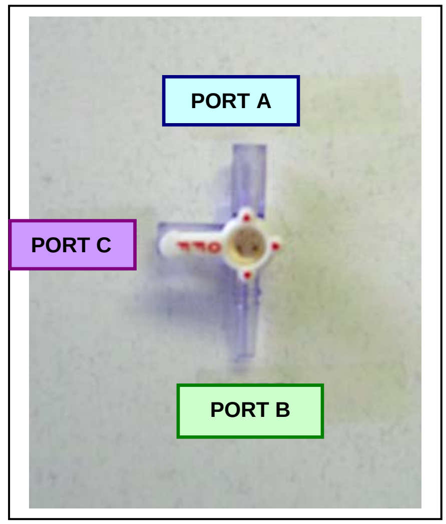
The "OFF" handle is turned in such a way that it is directly over Port A. The three small, red arrows opposite the "OFF" handle indicate which ports are open (Ports B & C).

In this valve position when the digital manometer is connected to Port C, a vacuum/pressure reading can be obtained from the probe/well. If the valve is in this position prior to the start of the monitoring (vacuum/pressure gauging, Tedlar™ bag sample collection, and/or summa canister sample collection, set the valve to Position #1 and return to this location at least 30 minutes later.

Author:	T. Gilles	Q2R & Approval By:	E. Gasca	Q3R & Approval By:	J. Pope

Valve Position #3: Open for Soil Vapor Sample Collection





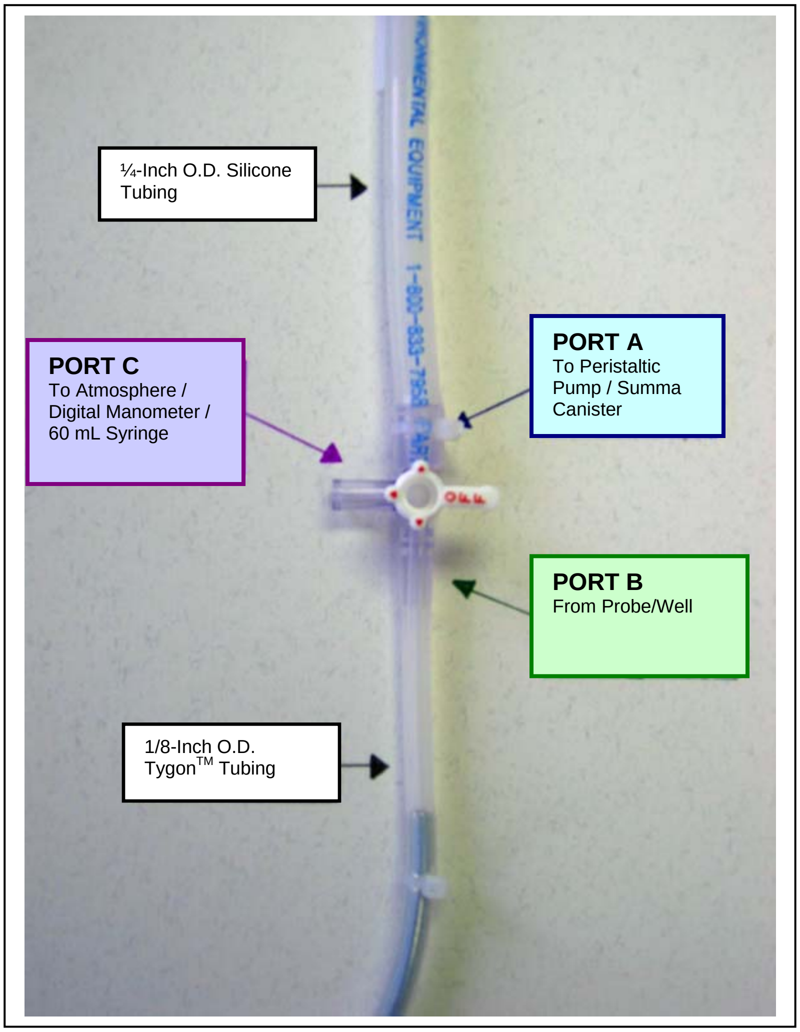
Valve Position #3:

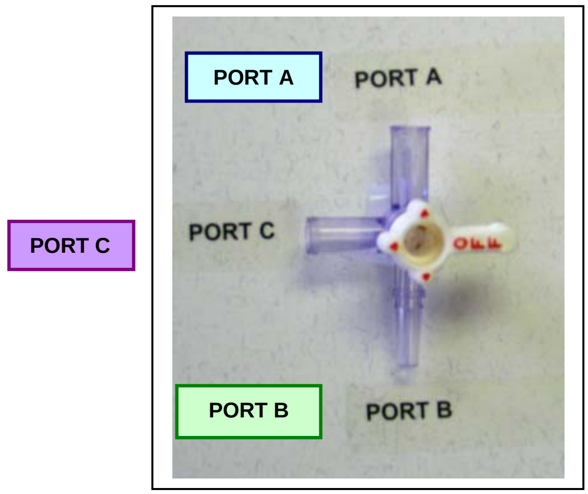
Closed to Port C (Atmosphere / Digital Manometer / 60 mL Syringe);
Open to Port A (Peristaltic Pump / Summa Canister)
Open to Port B (Probe/Well)

The "OFF" handle is turned in such a way that it is directly over Port C. The three small, red arrows opposite the "OFF" handle indicate which ports are open (Ports A & B).

In this valve position, a soil vapor sample can be collected from the probe/well using the peristaltic pump and Tedlar™ bag or a summa canister. If the valve is in this position prior to the start of the monitoring (vacuum/pressure gauging, Tedlar™ bag sample collection, and/or summa canister sample collection, set the valve to Position #1 and return to this location at least 30 minutes later.

Valve Position #4: Improper Valve Position





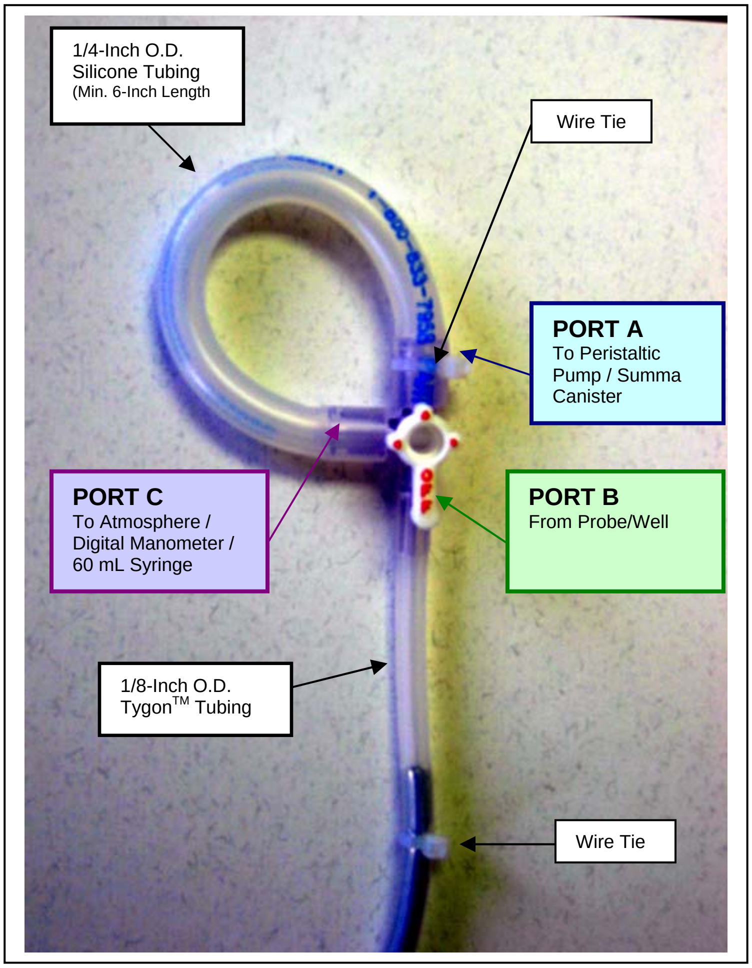
<u>Valve Position #4</u>:

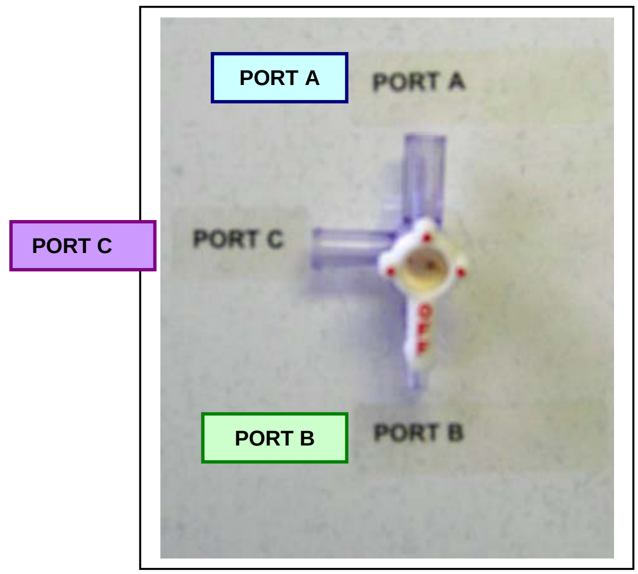
Open to Port A (Peristaltic Pump / Summa Canister);
Open to Port B (Probe/Well)
Open to Port C (Atmosphere / Digital Manometer / 60 mL Syringe)

The “OFF” handle is turned in such a way that it is opposite of Port C. The three small, red arrows opposite the “OFF” handle indicate all ports are open (Ports A, B & C).

In this valve position, the probe/well is open to the atmosphere and, therefore, will vent. In addition, this valve position will allow ambient air into the sample train and invalidate the data. If the valve is in this position prior to the start of the monitoring (vacuum/pressure gauging, Tedlar™ bag sample collection, and/or summa canister sample collection, set the valve to Position #1 and return to this location at least 30 minutes later. The valve should never be in this position.

Post-Monitoring Valve and Tubing Configuration





<u>Post-Monitoring Valve and Tubing Configuration</u>:

Closed to Port B (Probe/Well)
Open to Port A (Peristaltic Pump / Summa Canister);
Open to Port C (Atmosphere / Digital Manometer / 60 mL Syringe)

The 4-way micro-valve is set to position #1. The "OFF" handle is turned in such a way that it is directly over Port B. The three small, red arrows opposite the "OFF" handle indicate which ports are open (Ports A & C). In addition, the silicone tubing (minimum length of six (6) inches) is configured such that it forms a loop between Port A and Port C and a wire tie is used to secure the silicone tubing to Port A.

In this configuration, the probe/well is not open to the atmosphere and, therefore, will not vent. In addition, this configuration minimizes the water infiltration into the 4-way micro-valve. The valve and tubing should be placed in this configuration following vacuum/pressure gauging and soil vapor sample collection.

Author: T. Gilles **Q2R & Approval By:** E. Gasca **Q3R & Approval By:** J. Pope

STANDARD OPERATING PROCEDURE
NO. SAS-11-05

FIELD SCREENING FOR FIXED GASES AND SOIL VAPOR CONCENTRATIONS
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for conducting the field screening soil vapor samples collected using Tedlar™ bag media. The field screening consists of instrument calibration, real-time determination of fixed gases (oxygen and carbon dioxide) levels, percent of lower explosive limit (% LEL), and soil vapor concentrations (as determined using a photoionization detector [PID] and flame ionization detector [FID]), and documentation of field screening results.

2.0 EQUIPMENT AND MATERIALS

- LandTec GA-90 Landfill Gas Analyzer or equivalent
- RAE Systems ppbRAE continuous monitoring PID or equivalent
- Thermo Electron TVA 1000B PID and FID or equivalent
- Calibration Gases:
    - Zero Gas – Hydrocarbon (HC) Free Air
    - Carbon dioxide (CO_2) at 35% by volume
    - Oxygen (O_2) at 4% by volume
    - Isobutylene at 0.5% by volume
    - Methane (CH_4) at 3.25% by volume
    - Isobutylene in air at concentrations of 10, 50 and 1,000 ppmv
    - Methane (CH_4) in air at concentrations of 50, 500, and 5,000 ppmv

- Regulators for gas cylinders
- 1-liter Tedlar™ bag sample media
- ¼-inch outer diameter (O.D.) Teflon™ or Tygon™ tubing cut to length
- Thermo Electron Dilutor Orifice 10:1 (a.k.a. 10-to-1 dilution probe)
- Thermo Electron Dilutor Orifice 25:1 (a.k.a. 25-to-1 dilution probe)

- Thermo Electron Dilutor Orifice 50:1 (a.k.a. 50-to-1 dilution probe)
- Metering valves
- Field Screening Calibration Forms
- Field Screening Spreadsheet and/or Forms
- Miscellaneous tools

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 CONSIDERATIONS

- Calibration gas cylinders shall be stored in accordance with OSHA and site-specific regulations/guidelines.
- Field screening instruments shall be stored between uses and maintained in accordance with manufacturer guidelines.
- Field screening shall be performed at a fixed location, when practical, with adequate ventilation.
- A ppbRAE or equivalent may be used as an optional screening tool to confirm low level volatile organic compound (VOC) concentrations.

5.0 INSTRUMENT SPECIFICATIONS

Instrument specifications are intended as general guidelines only. Instruments may be substituted based on project/task specific needs.

5.1 LandTec GA-90 or Equivalent

A LandTec GA-90 or equivalent shall be used to measure O_2 and CO_2 levels as percent by volume (%) in soil vapor samples. If required by project/task specific requirements, this instrument may be used to measure the % LEL in soil vapor samples.

5.2 ppbRAE or Equivalent

A ppbRAE or equivalent may be used as an optional screening tool to measure and confirm low level VOCs in soil vapor samples. The ppbRAE or equivalent, when used, shall measure VOCs as parts per billion by volume (ppbv) and/or parts per million by volume (ppmv).

5.3 TVA 1000B or Equivalent

A Toxic Vapor Analyzer (TVA 1000B) or equivalent shall be used to measure low to high level VOCs as ppmv in soil vapor samples. The TVA 1000B or equivalent shall also be used to measure low to high level total hydrocarbons (THC) as ppmv or percent by volume ($\%_V$) in soil vapor samples.

6.0 INSTRUMENT CALIBRATION

In order to ensure the collection of valid levels of fixed gases, O_2 and CO_2, and soil vapor concentrations as total hydrocarbons (THC), proper calibration of the instruments is important. Instruments shall be calibrated prior to field screening in accordance with the manufacturers recommended procedures. Calibration gases shall be introduced directly at a rate of 0.5 liters per minute to the LandTec GA-90 or equivalent since the instrument pump is not required for calibration. Calibration standard gases shall be introduced to the ppbRAE, TVA 1000B PID, and TVA 1000B FID using Tedlar™ bag media which will allow the instrument pump to draw in the calibration gas at the appropriate flow. Following screening activities each day, a post-screening calibration check shall be performed. If the screening instruments are to be used continuously throughout the workday, mid-screening calibration checks shall also be performed. One-point bump calibration checks shall also be performed on the TVA 1000B or equivalent and associated dilution probe(s) at a frequency of one per two-hours of field screening. Calibration gases with concentrations within the linear range of the instrument shall be used for the pre-screening calibration and post-screening calibration check in addition to the mid-screening and one-point bump calibration checks, when required.

6.1 Pre-Screening Calibration

6.1.1 LandTec GA-90 or equivalent

Prior to the start of field screening, the LandTec GA-90 or equivalent shall be calibrated in accordance with the manufacturers recommended procedures using 4.0% $_V$ O_2 and 35% $_V$ CO_2 standard gases (see Attachment A). The pre-screening calibration shall be documented on the appropriate instrument calibration form (see Attachment A).

6.1.2 ppbRAE or equivalent

Prior to the start of optional, confirmatory low level PID field screening, the ppbRAE or equivalent shall be calibrated in accordance with the manufacturers recommended procedures using hydrocarbon free air (0 ppmv THC by volume) and 10 ppmv isobutylene standard gas (see Attachment A). The pre-screening calibration shall be documented on the appropriate instrument calibration form (see Attachment A).

6.1.3 TVA 1000B or equivalent

Prior to the start of field screening, the PID portion of the TVA 1000B or equivalent shall be calibrated in accordance with the manufacturers recommended procedures using hydrocarbon free air (0% $_V$ THC) and 50 and 1,000 ppmv isobutylene standard gases. The FID portion of the TVA 1000 or equivalent shall be calibrated in accordance with the manufacturers recommended procedures using hydrocarbon free air (0% $_V$ THC) and 50, 500, and 5,000 ppmv methane standard gases (see Attachment A). The pre-screening calibration shall be documented on the appropriate instrument calibration form (see Attachment A).

6.1.4 Dilution Probes

Following the calibration of the TVA 1000B PID and FID, each dilution probe shall be calibrated by adjusting the associated metering valve until the concentration displayed on the instrument is within (+/-) 15% of the target concentration of the designated calibration gases. The following table summarizes the type and concentration of calibration gas, target displayed concentration, and acceptable range for each dilution probe and instrument. The pre-screening calibration shall be documented on the appropriate instrument calibration form (see Attachment A).

Instrument	Dilution Probe	Calibration Gas		Concentration Displayed on Instrument	
		Type	Concentration	Target (ppmv)	Acceptable Range (ppmv)
TVA 1000B PID	10-to-1	Isobutylene	0.5 $\%_V$	500	425 – 575
TVA 1000B FID	10-to-1	Methane	3.25$\%_V$	3,250	2,762 – 3,738
	25-to-1	Methane	3.25$\%_V$	1,300	1,105 – 1,495
	50-to-1	Methane	3.25$\%_V$	650	552 – 748

6.2 Mid- and Post-Screening Calibration Checks

Properly calibrated instruments may drift during the field screening period. In order to ensure the collection of valid data, calibration accuracy checks will be conducted at the conclusion of the field screening each day. If the screening instruments are to be used throughout the workday, mid-screening calibration checks shall also be performed.

6.2.1 LandTec GA-90 or equivalent

The calibration of the LandTec GA-90 or equivalent shall be checked using 4.0 $\%_V$ O_2 and 35$\%_V$ CO_2 standard gases. If the observed concentration/level is within (+/-) 15% of the standard gases, the calibration shall be considered adequate. If the observed concentration/level is outside that range, the LandTec GA-90 or equivalent shall be recalibrated. Data obtained since the previous calibration check shall be flagged as estimated values. The following table summarizes the type and concentration of calibration gas, target displayed concentration, and acceptable range for each fixed gas. The calibration checks shall be documented on the appropriate instrument calibration form (see Attachment A).

Fixed Gas	Calibration Gas		Concentration Displayed on Instrument	
	Type	Concentration	Target (%)	Acceptable Range (%)
Oxygen	O_2 Standard	4.0%$_V$	4.0	3.4 – 4.6
Carbon Dioxide	CO_2 Standard	35.0%$_V$	35.0	29.75 – 40.25

6.2.2 ppbRAE or equivalent

The calibration of the ppbRAE or equivalent shall be checked using hydrocarbon free air (0 ppmv THC by volume) and 10 ppmv isobutylene standard gases, if the observed concentration/level is within (+/-) 15% of the calibration gases, the calibration shall be considered adequate. If the observed concentration/level is outside that range, the ppbRAE or equivalent shall be recalibrated. Data obtained since the previous calibration check shall be flagged as estimated values. The following table summarizes the type and concentration of calibration gas, target displayed concentration, and acceptable range for the ppbRAE. The calibration checks shall be documented on the appropriate instrument calibration form (see Attachment A).

Instrument	Calibration Gas		Concentration Displayed on Instrument	
	Type	Concentration	Target (ppmv)	Acceptable Range (ppmv)
ppbRAE	HC Free Air	0.0 ppmv	0.0	0.08 – 0.15
	Isobutylene	10.0 ppmv	10.0	8.5 – 11.5

6.2.3 TVA 1000B or equivalent

Given the wide range of hydrocarbons anticipated, the linearity of the PID response shall be checked using hydrocarbon free air (0%$_V$ THC) and 50 and 1,000 ppmv isobutylene standard gases. The FID response shall be checked using 50, 500, and 5000 ppmv methane standard gases. If the observed concentration/level is within (+/-) 15% of the standard gases, the calibration shall be considered adequate. If the observed concentration/level is outside that range, the TVA 1000B or equivalent shall be recalibrated. Data obtained since the previous calibration check shall be flagged as estimated values. The following table summarizes the type and concentration of calibration gases, target displayed concentration, and acceptable range for each instrument. The calibration checks shall be documented on the appropriate instrument calibration form (see Attachment A).

Instrument	Dilution Probe	Calibration Gas		Concentration Displayed on Instrument	
		Type	Concentration	Target (ppmv)	Acceptable Range (ppmv)
TVA 1000B PID	None	HC Free Air	0.0 ppmv	0.0	0.08 – 0.15
		Isobutylene	50.0 ppmv	50.0	42.5 – 57.5
			1,000 ppmv	1,000	850 – 1150
TVA 1000B FID	None	HC Free Air	0.0 ppmv	0.0	0.08 – 0.15
		Methane	50.0 ppmv	50.0	42.5 – 57.5
			500 ppmv	500	425 – 575
			5,000 ppmv	5,000	4250 – 5750

6.2.4 Dilution Probes

Following the calibration check of the TVA 1000B PID and FID, each dilution probe and associated metering valve shall be shall be verified using designated type and concentration of standard gas. The dilution probe calibration is considered adequate if the concentration displayed on the instrument is within (+/-) 15% of the target concentration of the designated calibration gas. The following table summarizes the type and concentration of calibration gas, target displayed concentration, and acceptable range for each dilution probe and instrument. The calibration checks shall be documented on the appropriate instrument calibration form (see Attachment A)

Instrument	Dilution Probe	Calibration Gas		Concentration Displayed on Instrument	
		Type	Concentration	Target (ppmv)	Acceptable Range (ppmv)
TVA 1000B PID	10-to-1	Isobutylen e	$0.5\%_V$	500	425 – 575
TVA 1000B FID	10-to-1	Methane	$3.25\%_V$	3,250	2,762.5 – 3,737.5
	25-to-1	Methane	$3.25\%_V$	1,300	1,105 – 1,495
	50-to-1	Methane	$3.25\%_V$	650	552.5 – 747.5

6.3 Periodic Bump Calibration Checks

Due to the negligible (< 5%) instrument drift throughout a day, the LandTec GA-90 and ppbRAE or equivalent(s) will not undergo periodic bump calibration checks. Given the wide range of hydrocarbons anticipated, one-point, calibration bump checks shall be performed on the TVA 1000B PID and FID, dilution probes, and associated metering valves or equivalents. The period bump calibration check shall be performed at a frequency of one per two-hours of field screening. The calibration is considered adequate if the concentration displayed on the instrument is within (+/-) 15% of the target concentration of the designated calibration gas. If the observed concentration is outside this range, the instrument and/or dilution probe and metering valve shall be recalibrated as appropriate. Data obtained since the previous bump calibration check shall be flagged as estimated values. The following table summarizes the type and concentration of calibration gas, target displayed concentration, and acceptable range for each dilution probe and instrument. The calibration checks shall be documented on the appropriate instrument calibration form (see Attachment A).

Instrument	Dilution Probe	Calibration Gas		Concentration Displayed on Instrument	
		Type	Concentration	Target (ppmv)	Acceptable Range (ppmv)
TVA 1000B PID	None	Isobutylene	50.0 ppmv	50.0	42.5 – 57.5
	10-to-1	Isobutylene	0.5% $_V$	500	425 – 575
TVA 1000B FID	None	Methane	5,000 ppmv	5,000	4250 – 5750
	10-to-1	Methane	3.25%$_V$	3,250	2,762 – 3,738
	25-to-1	Methane	3.25%$_V$	1,300	1,105 – 1,495
	50-to-1	Methane	3.25%$_V$	650	552 – 748

7.0 SAMPLE SCREENING

Soil vapor samples collected in Tedlar™ bags shall be screened at a fixed location, whenever practical. Since samples may have 1) concentrations above the measurement range of the instrument or 2) insufficient oxygen content to analyze reliably, the order of the screening is important to the identification of these situations. The screening order is also dictated by the sample flow rates, which vary by instrument, and the sample volume.

7.1 Screening Procedures

Prior to field screening, the well/sample ID, sample date, and sample time shall be recorded on the appropriate field form and/or spreadsheet (see Attachment C). Once the screening data and time have also been recorded on the appropriate field form and/or spreadsheet (see Attachment C), the field screening shall commence. The soil vapor samples shall be analyzed in the following order:

- Fixed gases (O_2 and CO_2)
- Percent of lower explosive limit (% LEL) - If required by the project or task
- Soil vapor concentrations (VOCs) as determined using a PID
- Soil vapor concentrations (THC) as determined using a FID

The field screening shall adhere to the procedure outlined in the Field Screening Procedure Flow Chart provided in Attachment B. Following screening the Tedlar™ bag sample media shall be discarded.

7.2 Reporting

Field screening results as observed on the instruments, fixed gases levels (O_2 & CO_2), percent lower explosive limit, and soil vapor concentrations, as determined using a PID and FID, shall be recorded in the appropriate spreadsheet or on the appropriate field form (see Attachment C). The use of a dilution probe shall also be documented in the appropriate spreadsheet or on the appropriate field form (see Attachment C). *Please note: Concentrations as determined using a PID and FID shall be corrected for the use of dilution probe(s).* If the concentration of the vapor sample exceeds the operating range of the instrument, with or without the use of a dilution probe, it shall be marked as "estimated". If a flame-out of the FID occurs, "FO" shall be recorded as the default value for the affected sample. If the flame-out was not the result of 1) insufficient sample flow, 2) FID capsule contamination, or 3) insufficient oxygen in the sample (<14% when adjusted to account for the use or absence of a dilution probe), the upper dynamic range of the instrument, which has been adjusted for the use of or absence of a dilution probe, shall be used as the corrected FID reading. In this case, the reading shall be flagged as estimated. These situations shall be documented in the appropriate spreadsheet or on the appropriate field form.

8.0 SAMPLE HOLD TIMES

Soil vapor samples collected using Tedlar™ bag media shall be field screened at a fixed location, if practical, within thirty-six (36) hours of sample collection.

9.0 REFERENCES AND ADDITIONAL RESOURCES

Field Environmental Instruments, LANDTEC GA-90 Gas Analyzer Specifications and Features.

LANDTEC, GA-90 Landfill Gas Analyzer Operation Manual, Version MK2C1.12.

RAE Systems, 1999, Portable Continuous ppb VOC Detector Monitor Specifications and Features.

RAE Systems, 1999, Using the MiniRAE 2000 & ppbRAE plus.

Thermo Electron Corporation, 2003, Product Overview TVA-1000B Toxic Vapor Analyzer.

Thermo Electron Corporation, 2003, TVA-1000B Toxic Vapor Analyzer Instruction Manual P/N BK3500, December.

USEPA, 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

ATTACHMENT A
INSTRUMENT CALIBRATION FORMS

ATTACHMENT A-1
LANDTEC GA-90 LANDFILL GAS ANALYZER OR EQUIVALENT

FIELD SCREENING INSTRUMENT CALIBRATION FORM
LandTec GA-90 or Equivalent

Form Revision 0

PROJECT INFORMATION

Project Name: ______________________ **Task Name:** ______________________
Project Number: ______________________ **Task/Project Manager:** ______________________

FIELD SCREENING TEAM INFORMATION	**INSTRUMENT INFORMATION**
Date: ______________	**Make:** ______________
Screener: ______________	**Model:** ______________
Assistant: ______________	**Serial #:** ______________

CALIBRATION GAS INFORMATION

Manufacturer	Cal. Gas Type	Lot Number	Expiration Date

CALIBRATION AND CALIBRATION CHECK INFORMATION

Time	Type of Calibration or Calibration Check	Calibration Standard		Instrument Response	Response within Tolerances (circle one)	Comments
		Type	Conc.			
	Pre-Screening Calibration[R]	O2	4.0%		Yes / No	
		CO2	35.0%		Yes / No	
	Mid-Screening Calibration Check*	O2	4.0%		Yes / No	
		CO2	35.0%		Yes / No	
	Post-Screening Calibration Check[R]	O2	4.0%		Yes / No	
		CO2	35.0%		Yes / No	
	Mid-Screening Recalibration*	O2	4.0%		Yes / No	
		CO2	35.0%		Yes / No	
	Mid-Screening Recalibration*	O2	4.0%		Yes / No	
		CO2	35.0%		Yes / No	

Notes: 1. [R] = Required 2. * = If necessary 3. % = percent by volume

ATTACHMENT A-2
ppbRAE or EQUIVALENT

FIELD SCREENING INSTRUMENT CALIBRATION FORM
ppbRAE or Equivalent

Form Revision 0

PROJECT INFORMATION

Project Name: ______________________ Task Name: ______________________

Project Number: ______________________ Task/Project Manager: ______________________

FIELD SCREENING TEAM INFORMATION | **INSTRUMENT INFORMATION**

Date: ______________________ Make: ______________________

Screener: ______________________ Model: ______________________

Assistant: ______________________ Serial #: ______________________

CALIBRATION GAS INFORMATION

Manufacturer	Cal. Gas Type	Lot Number	Expiration Date

CALIBRATION AND CALIBRATION CHECK INFORMATION

Time	Type of Calibration or Calibration Check	Calibration Standard Type	Calibration Standard Conc.	Instrument Response	Response within Tolerances (circle one)	Comments
	Pre-Screening Calibration[R]	Free Air	0.0 ppmv		Yes / No	
		Isobutylene	10.0 ppmv		Yes / No	
	Mid-Screening Calibration Check*	Free Air	0.0 ppmv		Yes / No	
		Isobutylene	10.0 ppmv		Yes / No	
	Post-Screening Calibration Check[R]	Free Air	0.0 ppmv		Yes / No	
		Isobutylene	10.0 ppmv		Yes / No	
	Mid-Screening Recalibration*	Free Air	0.0 ppmv		Yes / No	
		Isobutylene	10.0 ppmv		Yes / No	
	Mid-Screening Recalibration*	Free Air	0.0 ppmv		Yes / No	
		Isobutylene	10.0 ppmv		Yes / No	
	Mid-Screening Recalibration*	Free Air	0.0 ppmv		Yes / No	
		Isobutylene	10.0 ppmv		Yes / No	

Notes: 1. [R] = Required 2. * = If necessary 3. ppmv = parts per million by volume

ATTACHMENT A-3
TVA-1000B TOXIC VAPOR ANALYZER OR EQUIVALENT

FIELD SCREENING INSTRUMENT CALIBRATION FORM
TVA 1000 (FID) or Equivalent

Form Revision 0

PROJECT INFORMATION

Project Name: ______________________ **Task Name:** ______________________
Project Number: ______________________ **Task/Project Manager:** ______________________

FIELD SCREENING TEAM INFORMATION

Date: ______________________
Screener: ______________________
Assistant: ______________________

INSTRUMENT INFORMATION

Make: ______________________
Model: ______________________
Serial #: ______________________

CALIBRATION GAS INFORMATION

Manufacturer	Cal. Gas Type	Lot Number	Expiration Date

CALIBRATION AND CALIBRATION CHECK INFORMATION

Time	Type of Calibration or Calibration Check	Calibration Standard		Instrument Response				Response(s) within Tolerances (circle one)	Comments
		Type	Conc.	w/o Dilution Probe	w/ 10-to-1 Dilution Probe	w/ 25-to-1 Dilution Probe	w/ 50-to-1 Dilution Probe		
	Pre-Screening Calibration[R]	Free Air	0.0 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	50.0 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	500 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	5,000 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	32,500 ppmv	N/A				Yes / No	
	Mid-Screening Calibration Check*	Free Air	0.0 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	50.0 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	500 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	5,000 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	32,500 ppmv	N/A				Yes / No	

CALIBRATION AND CALIBRATION CHECK INFORMATION (Continued)									
Time	Type of Calibration or Calibration Check	Calibration Standard		Instrument Response				Response(s) within Tolerances (circle one)	Comments
		Type	Conc.	w/o Dilution Probe	w/ 10-to-1 Dilution Probe	w/ 25-to-1 Dilution Probe	w/ 50-to-1 Dilution Probe		
	Post-Screening Calibration Check[R]	Free Air	0.0 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	50.0 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	500 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	5,000 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	32,500 ppmv	**N/A**				**Yes / No**	
	Mid-Screening Recalibration*	Free Air	0.0 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	50.0 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	500 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	5,000 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
	Mid-Screening Recalibration*	Free Air	0.0 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	50.0 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	500 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	5,000 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
	Bump Calibration Check*	Free Air	0.0 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	5,000 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	32,500 ppmv	**N/A**				**Yes / No**	
	Bump Calibration Check*	Free Air	0.0 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	5,000 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	32,500 ppmv	**N/A**				**Yes / No**	
	Bump Calibration Check*	Free Air	0.0 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	5,000 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	32,500 ppmv	**N/A**				**Yes / No**	
	Bump Calibration Check*	Free Air	0.0 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	5,000 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	32,500 ppmv	**N/A**				**Yes / No**	
	Bump Calibration Check*	Free Air	0.0 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	5,000 ppmv		**N/A**	**N/A**	**N/A**	**Yes / No**	
		Methane	32,500 ppmv	**N/A**				**Yes / No**	

Notes: 1. [R] = Required 2. * = If necessary 3. ppmv = parts per million by volume 4. N/A = Not Applicable

FIELD SCREENING INSTRUMENT CALIBRATION FORM
TVA 1000 (PID) or Equivalent

Form Revision 0

PROJECT INFORMATION

Project Name: ____________________ **Task Name:** ____________________
Project Number: ____________________ **Task/Project Manager:** ____________________

FIELD SCREENING TEAM INFORMATION | **INSTRUMENT INFORMATION**

Date: ____________________ **Make:** ____________________
Screener: ____________________ **Model:** ____________________
Assistant: ____________________ **Serial #:** ____________________

CALIBRATION GAS INFORMATION

Manufacturer	Cal. Gas Type	Lot Number	Expiration Date

CALIBRATION AND CALIBRATION CHECK INFORMATION

Time	Type of Calibration or Calibration Check	Calibration Standard		Instrument Response		Response within Tolerances (circle one)	Comments
		Type	Conc.	w/o Dilution Probe	w/ 10-to-1 Dilution Probe		
	Pre-Screening Calibration[R]	Free Air	0.0 ppmv		N/A	Yes / No	
		Isobutylene	50.0 ppmv		N/A	Yes / No	
		Isobutylene	1,000 ppmv		N/A	Yes / No	
		Isobutylene	5,000 ppmv	N/A		Yes / No	
	Mid-Screening Calibration Check*	Free Air	0.0 ppmv		N/A	Yes / No	
		Isobutylene	50.0 ppmv		N/A	Yes / No	
		Isobutylene	1,000 ppmv		N/A	Yes / No	
		Isobutylene	5,000 ppmv	N/A		Yes / No	
	Post-Screening Calibration Check[R]	Free Air	0.0 ppmv		N/A	Yes / No	
		Isobutylene	50.0 ppmv		N/A	Yes / No	
		Isobutylene	1,000 ppmv		N/A	Yes / No	
		Isobutylene	5,000 ppmv	N/A		Yes / No	

CALIBRATION AND CALIBRATION CHECK INFORMATION (Continued)							
Time	Type of Calibration or Calibration Check	Calibration Standard		Instrument Response		Response within Tolerances (circle one)	Comments
		Type	Conc.	w/o Dilution Probe	w/ 10-to-1 Dilution Probe		
	Mid-Screening Recalibration*	Free Air	0.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	50.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	1,000 ppmv		**N/A**	**Yes / No**	
		Isobutylene	5,000 ppmv	**N/A**		**Yes / No**	
	Mid-Screening Recalibration*	Free Air	0.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	50.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	1,000 ppmv		**N/A**	**Yes / No**	
		Isobutylene	5,000 ppmv	**N/A**		**Yes / No**	
	Single-Point Bump Calibration Check*	Isobutylene	50.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	5,000 ppmv	**N/A**		**Yes / No**	
	Single-Point Bump Calibration Check*	Isobutylene	50.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	5,000 ppmv	**N/A**		**Yes / No**	
	Single-Point Bump Calibration Check*	Isobutylene	50.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	5,000 ppmv	**N/A**		**Yes / No**	
	Single-Point Bump Calibration Check*	Isobutylene	50.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	5,000 ppmv	**N/A**		**Yes / No**	
	Single-Point Bump Calibration Check*	Isobutylene	50.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	5,000 ppmv	**N/A**		**Yes / No**	
	Single-Point Bump Calibration Check*	Isobutylene	50.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	5,000 ppmv	**N/A**		**Yes / No**	
	Single-Point Bump Calibration Check*	Isobutylene	50.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	5,000 ppmv	**N/A**		**Yes / No**	
	Single-Point Bump Calibration Check*	Isobutylene	50.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	5,000 ppmv	**N/A**		**Yes / No**	
	Single-Point Bump Calibration Check*	Isobutylene	50.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	5,000 ppmv	**N/A**		**Yes / No**	
	Single-Point Bump Calibration Check*	Isobutylene	50.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	5,000 ppmv	**N/A**		**Yes / No**	

Notes: 1. ^{R} = Required 2. * = If necessary 3. ppmv = parts per million by volume

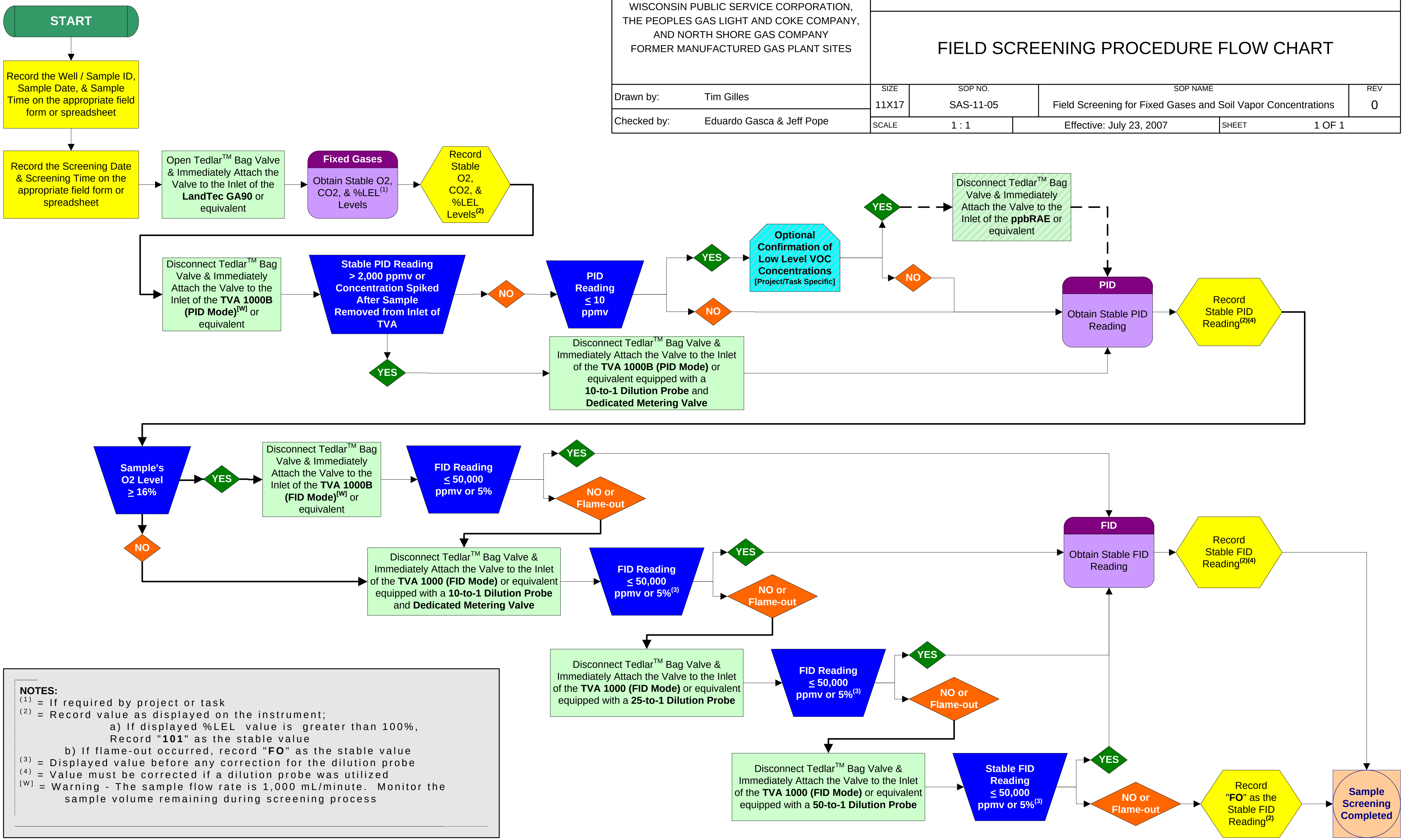
ATTACHMENT B
FIELD SCREENING PROCEDURE FLOW CHART

WISCONSIN PUBLIC SERVICE CORPORATION,
THE PEOPLES GAS LIGHT AND COKE COMPANY,
AND NORTH SHORE GAS COMPANY
FORMER MANUFACTURED GAS PLANT SITES

SOP SAS-11-05 ATTACHMENT B

FIELD SCREENING PROCEDURE FLOW CHART

Drawn by: Tim Gilles	SIZE 11X17	SOP NO. SAS-11-05	SOP NAME Field Screening for Fixed Gases and Soil Vapor Concentrations	REV 0
Checked by: Eduardo Gasca & Jeff Pope	SCALE 1 : 1		Effective: July 23, 2007	SHEET 1 OF 1



NOTES:
(1) = If required by project or task
(2) = Record value as displayed on the instrument;
a) If displayed %LEL value is greater than 100%, Record "**101**" as the stable value
b) If flame-out occurred, record "**FO**" as the stable value
(3) = Displayed value before any correction for the dilution probe
(4) = Value must be corrected if a dilution probe was utilized
[W] = Warning - The sample flow rate is 1,000 mL/minute. Monitor the sample volume remaining during screening process

ATTACHMENT C
FIELD SCREENING RESULTS SPREADSHEET/FORM

FIXED GASES AND SOIL VAPOR CONCENTRATION FIELD SCREENING DATA

PROJECT INFORMATION	GENERAL INSTRUMENT INFORMATION	SCREENER INFORMATION
Project Name:	Fixed Gases:	Screener's Name:
Project Number:	PID (Low Level Confirmation):	Screener's Title:
Task Name:	PID (Low-High Level):	Assistant's Name:
Task/Project Manager:	FID (Low-High Level):	Assistant's Title:

FIELD SCREENING RESULTS

WELL ID or SAMPLE ID	SAMPLE DATE	SAMPLE TIME (24-Hour)	SCREENING DATE	SCREENING TIME (24-Hour)	Observed Field Screening Values[1], Units, and Dilution Values[2]									Corrected Value[3]		COMMENTS
					O_2 (%)	CO_2 (%)	% LEL[4] (%)	PID	PID UNITS (circle one)	PID Dilution Value[2] (circle one)	FID	FID UNITS (circle one)	FID Dilution Value[2] (circle one)	PID (ppmv)	FID (ppmv)	
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			

FIELD SCREENING RESULTS

					Observed Field Screening Values[1], Units, and Dilution Values[2]									Corrected Value[3]		
WELL ID or SAMPLE ID	SAMPLE DATE	SAMPLE TIME (24-Hour)	SCREENING DATE	SCREENING TIME (24-Hour)	O_2 (%)	CO_2 (%)	% LEL[4] (%)	PID	PID UNITS (circle one)	PID Dilution Value[2] (circle one)	FID	FID UNITS (circle one)	FID Dilution Value[2] (circle one)	PID (ppmv)	FID (ppmv)	COMMENTS
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			

FIELD SCREENING RESULTS

WELL ID or SAMPLE ID	SAMPLE DATE	SAMPLE TIME (24-Hour)	SCREENING DATE	SCREENING TIME (24-Hour)	Observed Field Screening Values[1], Units, and Dilution Values[2]									Corrected Value[3]		COMMENTS
					O_2 (%)	CO_2 (%)	% LEL[4] (%)	PID	PID UNITS (circle one)	PID Dilution Value[2] (circle one)	FID	FID UNITS (circle one)	FID Dilution Value[2] (circle one)	PID (ppmv)	FID (ppmv)	
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			

Notes: (1) = As observed on the instrument's display; If flame-out occurs, record "FO" as the default value.
(2) = Dilutions Values (Dilution Probe Specific): No Dilution Probe Used - Circle "1"; 10-to-1 Dilution Probe Used - Circle "10"; 25-to-1 Dilution Probe Used - Circle "25"; 50-to-1 Dilution Probe Used - Circle "50"
(3) = Calculated based on the units and dilution value or, in the case of a flame-out when sufficient oxygen is present, the upper dynamic range of the instrument multiplied by the dilution value.
(4) = If required by project or task
E = Estimated Value: Corrected value exceeds the upper dynamic range of the instrument or flame-out due to concentrations above the instruments range occurred.
ppbv = Parts per billion volume
ppmv = Parts per million volume
% = Percent by volume
N/A = Not Applicable
FO = Instrument Flame Out (FID Only)

Author:	M. Gossett	Q2R & Approval By:	D. Marquez	Q3R & Approval By:	M. Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-11-06

SOIL GAS SAMPLING
Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) provides information on soil-gas sampling using an active sampling approach to assess the vapor intrusion pathway. Soil gas will be sampled using dedicated gas vapor tips and the associated installation kit or direct-push rig. Soil gas samples will be collected from the unsaturated zone to provide measurements of soil gas that may potentially enter a building.

2.0 EQUIPMENT AND MATERIALS

- Rotary hammer drill (or equivalent) with a 1 3/8-inch diameter bit;
- Retractable gas vapor tip (GVP);
- Expendable GVP replacements;
- Hand Tools, including a hammer, needle-nose pliers, and trowel;
- Tubing receptacle;
- Teflon compression fittings to connect sampling points at “T” connection;
- “T” Swagelok (compression) or equivalent fitting;
- Stainless steel tubing;
- Gas sampling pump capable of extracting 200 milliliters per minute (mL/min);
- 4-way Teflon micro-valve;
- 1/4-inch O.D. Teflon tubing;
- VOC-free caulk;
- Nitrile gloves;
- Summa canisters with flow controllers, vacuum gauge, and shipping container;
- Sample labels;
- Chain of custody forms and seals;

- Field air monitoring instruments, as specified in the Work Plan (e.g. photo ionization detector, multi-gas monitors, etc.);
- Location markers (e.g. pin flags, wooden stakes, flagging tape, etc.);
- Granular bentonite;
- Asphalt cold patch or cement, as appropriate for site restoration;
- Decontamination materials;
- DOT-specified 55-gallon drum; and
- Field logbook and/or appropriate field form(s);

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 CONSIDERATIONS

Variations in chemical-specific characteristics, geologic conditions, and atmospheric influences can affect soil-gas sampling results. For this reason, it is important to understand factors the may influence the reported data when collecting soil-gas data. In all cases, site-specific factors should be carefully evaluated prior to initiation of sampling to obtain representative soil-gas data.

Prior to any soil-gas sampling, soil type must be evaluated for suitability of sampling. Soils with smaller grain sizes have smaller pore spaces and are less permeable, which may reduce the ability for soil gas to be released from the subsurface. For example, clays have the smallest grain size and significantly restrict soil gas migration. Soil moisture also limits the ability for soil gas to be released from the subsurface because moisture trapped in the pore space of sediments can inhibit or block soil-gas flow. Seasonal and geographical variations in soil moisture content can affect air permeabilities. In addition, manmade and naturally occurring preferential pathways (e.g. utility corridors, lenses of coarse-grained materials within fine-grained materials, etc.) may also affect soil-gas migration and shall be considered prior to soil-gas sampling.

Reliability of soil-gas sampling may be improved by using fixed probes and by ensuring that leakage of atmospheric air into the samples is avoided during purging or sampling. To avoid dilution of the sampling region from leakage, the minimum purge volume deemed adequate to flush the sampling system should be removed, and soil-gas samples should be collected from the most permeable zones in the vadose zone when possible. Site-specific information concerning soil lithology, grain size analysis, soil moisture, and soil-gas permeability may be obtained by performing three soil borings in the immediate area of the sampling locations in advance of the soil-gas sampling. In addition, previous site investigation sample results, when available, should be used to determine the placement of the soil-gas sampling locations.

Since oxygen, carbon dioxide, and nitrogen can be sampled using a multi-gas monitor to give real-time results, parallel analysis of oxygen, carbon dioxide, and nitrogen in soil-gas may also be used to help assess the reliability of a given sample result.

5.0 SOIL VAPOR PROBE INSTALLATION

Prior to installation at each soil vapor probe location, the area will be inspected for clearance of existing utility lines and other obstructions near the sample location. The soil vapor probes will then be installed into the ground surface using a hammer drill connected to drive rods or a direct-push rig. Installation using a hammer drill should be used when depths of less than 10 feet are desired. For depths greater than 10 feet, a direct-push rig will more efficiently drive the probe rods. The soil vapor probes consist of a stainless steel drive tip which is connected to a screen with a length between 2 to 6 inches and diameter of at least 1/8-inch but no larger than 1/2-inch. At the top of the screen, a stainless steel hose barb allows for a connection to Teflon™ or stainless steel tubing for purging and sample collection. Soil gas probes installed at depths greater than 10 feet should be constructed with stainless steel tubing for durability and stability. After the probe is driven to the desired depth, the rods will be removed and a filter pack containing sand will be set to within 2 inches above and below the vapor probe. Above the sand filter pack, granular bentonite will be placed and hydrated in two-foot lifts to ground surface. This bentonite will provide an airtight seal between the soil gas probe and the ambient air. Probes should not be installed shallower than two feet below ground surface (bgs). Each probe will be allowed to set for at least 24 hours before sampling takes place.

6.0 SOIL VAPOR SAMPLING PROCEDURES

Subsurface soil vapor will not be sampled if measurable precipitation or irrigation near the sampling location has occurred within the previous five days. The increased soil moisture can decrease soil permeability and cause the soil vapor sample results to be biased low.

6.1 SAMPLE TRAIN ASSEMBLY

Samples will be collected using evacuated batch-certified 1 liter (L) or smaller Summa™ canisters equipped with dedicated flow regulators and integrated particulate filters. A flow regulator/particulate filter and vacuum gauge will be attached to each canister as described in the *Summa Canister Instructions* provided by the laboratory. Canisters, flow regulators/particulate filters, and vacuum gauges will be supplied by the laboratory.

When probe installation is complete, Teflon™ tubing will extend from the probe to the ground surface. The Teflon™ tubing will be connected to a two-way and three-way stopcock assembly. One output of the stopcock assembly will be connected to the Summa™ canister using a Swagelok™ fitting. The other output of the stopcock assembly will be connected to a lung box containing a Tedlar™ bag. Use of dedicated tubing will avoid cross-contamination between probes. A new pair of Nitrile gloves should be worn while connecting the sample assembly for each soil vapor probe.

When collecting duplicate or QA split samples, two separate canister assemblies are connected using a stainless steel “T” fitting, and the “T” fitting is then connected to the Teflon™ tubing assembly described in the previous paragraph. The “T” fitting will be provided by the laboratory.

6.2 PURGING SOIL VAPOR PROBES

Allow the probe to equilibrate for a minimum of 24 hours from the time of installation before initiating purge procedures. Teflon™ tubing coming from the soil vapor probe will be connected to a lung box containing a Tedlar™ bag. The vapor probe will be purged during the chemical leak test by removing a volume of air equal to three times the volume of the sample probe and tubing. Purging will be conducted using a flow rate of 100 to 200 milliliters per minute (mL/min). Given the small volume of the sample probes, purge air can be discharged to the atmosphere.

6.3 HELIUM LEAK TESTING

The purpose of the chemical leak test is to ensure that the sub slab sample port and probe assembly is properly set and not leaking. A leaking probe assembly could result in a leakage of ambient air into the sample, potentially biasing the sample. Prior to sampling, a chemical leak test will be performed using helium as a tracer gas. The ambient air inside the shroud will be replaced with helium graded at 99.9 percent purity or higher until the atmosphere consists of a minimum of 20 percent helium. It should be noted that concentrations of 60 percent to 80 percent helium have routinely been observed in the shroud during prior field testing. This will be accomplished by inserting Teflon™ tubing through a ¼ inch hole in the shroud and attaching the other end to the helium canister. The helium canister will then be opened, and the shroud atmosphere will be continuously monitored by a Dielectric Technologies Model MGD-2002 Multi-Gas Detector (or equivalent) until the percentage of helium inside the shroud reaches a minimum of 20 percent and the readings on the Multi-Gas Detector (or equivalent) stop increasing. The final helium concentration inside the shroud will be recorded on the Field Data Air Sampling Form. The final helium concentration inside the shroud will be multiplied by 10 percent (0.1) to determine the allowable concentration of helium in the Tedlar™ bag sample. Both the final helium concentration inside the shroud and the calculated allowable concentration in the Tedlar™ bag will be recorded on the Field Data Air Sampling Form (See Attachments).

After the target atmosphere is established, the two-way and three-way stopcocks will be opened to the lung box, which contains a 1 L Tedlar™ bag. An air pump attached to the lung box via Teflon™ tubing will be used to evacuate the existing air inside the lung box, which will in turn cause the 1 L Tedlar™ bag to fill. Once filled, the 1 L Tedlar™ bag will be removed from the lung box and the air inside will be measured using the Model MGD-2002 Multi-Gas Detector (or equivalent) for the presence of helium. The concentration of helium measured inside the Tedlar™ bag will be recorded on the Field Data Air Sampling Form. If the concentration of helium in the sample is below the calculated allowable concentration (i.e., less than 10 percent of the concentration inside the helium shroud), proceed with the mechanical leak test and sample collection as described in Sections 6.4 and 6.5.

Corrective actions to mitigate leaks in the sub-slab soil vapor probe will be performed when the helium concentration in the Tedlar™ bag sample exceeds 10 percent of the starting concentration in the helium shroud. Corrective actions will be performed in the field and will initially involve resealing the probe base with beeswax and repeating the helium leak test. If resealing and retesting fails to produce acceptable leak test results after two attempts, the probe will be abandoned and a new probe will be installed. Samples will not be collected for submittal for laboratory analysis when the helium concentration in the Tedlar™ bag sample exceeds 10 percent of the starting helium concentration in the shroud.

6.4 MECHANICAL LEAK TESTING

The mechanical leak test will be performed immediately after completing the helium leak test. The mechanical leak test will be completed by closing the two-way stopcock and turning the valve on the three-way stopcock to close the tubing connected to the lung box assembly. This will close the connection between the two-way stopcock and the lung box assembly and open the connection between the two-way stopcock and the Summa™ canister. Vacuum test the connections between the Summa™ canister and stopcock by opening the canister valve to place a test vacuum on the assembly for 10 minutes. The start time and initial vacuum, as well as the stop time and final vacuum, will be recorded on the Field Data Air Sampling Form and in the field logbook. If gauge vacuum can not be maintained for 10 minutes, work shall be suspended and all fittings in the sample assembly will be checked. Retest the sample assembly. If vacuum still can not be maintained by 10 minutes, sampling activities will be discontinued until leak can be identified and addressed.

If gauge vacuum was maintained for 10 minutes, close the canister valve and immediately proceed with sample collection as described in Section 6.5. Since the fitting that connects the tubing from the sub-slab probe to the two-way stopcock cannot be leak tested through either the helium or mechanical leak tests, this fitting will be sealed with Teflon™ tape and beeswax.

6.5 SAMPLE COLLECTION

Sample location information, meteorological conditions (temperature, barometric pressure, wind speed/direction, and relative humidity), and results of the field screening analysis shall be recorded on a Field

Data Air Sampling Form. Meteorological data will be obtained online from the nearest National Weather Service measuring station. Digital photos will be taken of each sample location and sample assembly.

Open the sample canister valve to begin sample collection. The time and initial vacuum when sample collection starts shall be recorded on the Field Data Air Sampling Form. The laboratory-provided flow regulators will be calibrated for a 5- to 10-minute sample duration, which correlates to a flow rate of 100 to 200 mL/min. Close the sample canister valve when the vacuum gauge indicates approximately 5 inches Hg (mercury) of vacuum remain in the canister. Sample collection should take approximately 5 minutes for a 1L Summa™ canister connected to a 200 mL/min flow regulator. The time sample collection was stopped and final vacuum shall be recorded on the Field Data Air Sampling Form. Remove the flow regulator/particulate filter and vacuum gauge assembly and replace the laboratory-supplied brass plug on the canister. Disconnect the sample tubing assembly and replace the plug on the soil vapor probe.

Label the sample canister and record on the COC the sample name, date and time the sample was collected, the canister and flow controller serial numbers, and the final vacuum gauge reading. Samples shall not be chilled or subjected to extreme temperature or pressure fluctuations. Samples will be shipped for analysis of VOCs by USEPA Method TO-15.

6.6 QUALITY CONTROL

QC samples will be collected during soil vapor sampling activities. Trip blanks and field duplicates will be collected as necessary. Field duplicates will be collected at the rate of one duplicate sample per 20 soil vapor samples.

A trip blank, consisting of an unopened evacuated canister, will be shipped with the sub-slab vapor samples with each sample shipment. Trip blanks can consist of either unopened fully evacuated canisters or canisters that have been fully charged with zero grade air by the laboratory. Since a fully charged canister has no vacuum with which to pull contaminants into the canister, a fully evacuated canister has a better likelihood of capturing potential transit-related contamination. The trip blank will be provided by the laboratory.

7.0 EQUIPMENT DECONTAMINATION PROCEDURES

All decontamination will be performed according to SAS-04-04.

8.0 INVESTIGATION-DERIVED WASTE (IDW)

The vapor probe installation and sampling will generate small amounts of solid IDW including, concrete dust, gloves, and tubing. This material will be bagged and disposed of as a municipal waste in accordance with applicable regulations. No liquid IDW will be generated. Further discussion of IDW can be found in Section 9 of the *Multi-Site Field Sampling Plan, Former Manufactured Gas Plant Sites, Revision 3", February 20, 2008.*

APPENDIX B

FIELD FORMS

BOREHOLE / WELL ABANDONMENT FIELD FORM

PROJECT INFORMATION

Site: ______________________ Client: ______________________

Project Number: ______________ Task #: __________ Start Date: ______________ Time: ________

Field Personnel: ______________________ Finish Date: ______________ Time: ________

GENERAL INFORMATION

Ownership (Controlling Party): ______________________

Street Address: ______________________

City: ______________________

County: ______________________

State: ______________ Zip: __________

Township: ________ Range: ________ Section: ________

________ 1/4 of the ________ 1/4 of the ________ 1/4

If Known, Latitude: ____________ Longitude: ____________

If Known*, Northing: ____________ Easting: ____________

*Coordinate System: ______________________

Reason for Abandonment:

Permit Number (If applicable): ______________________

BOREHOLE / WELL INFORMATION

Borehole / Well ID: ______________ Unique Well ID:

Installation Date: ______________

☐ Borehole

☐ Monitoring Well

☐ Water Well

(Monitoring Well / Water Well: Attach Well Completion Report, if available)

☐ Other (specify): ______________

Construction Type:

☐ Drilled ☐ Driven (Sandpoint)

☐ Other (specify): ______________

Formation Type:

☐ Unconsolidated Materials ☐ Bedrock

Borehole/Well Details:

Borehole Diameter: ________ Inches

Total Borehole Depth: ________ FT BGS

Casing Diameter: ________ Inches ☐ Not Applicable

Total Casing Depth: ________ FT BGS ☐ Not Applicable

Depth to Water: FT BGS ☐ Not Encountered

SEALING INFORMATION

Pump & Piping Removed? ☐ Yes ☐ No ☐ Not Applicable

Liner(s) Removed? ☐ Yes ☐ No ☐ Not Applicable

Screen Removed? ☐ Yes ☐ No ☐ Not Applicable

Entire Casing Removed? ☐ Yes ☐ No* ☐ Not Applicable

If No, Upper 2 feet Removed? ☐ Yes ☐ No

Method of Sealing Material Placement:

☐ Conductor Pipe - Gravity ☐ Tremie Pipe - Pumped

☐ Screened & Poured ☐ Other (specify): ______________

Sealing Material Rose to Surface? ☐ Yes ☐ No

Material Settled After 24 Hours? ☐ Yes* ☐ No

*If Yes, Was Hole Re-Topped? ☐ Yes ☐ No

Sealing Material Used	From	To	Volume/Quantity
	Surface		

SEALING WORK PERFORMED BY

Individual's Name: ______________ License Number:

Company Name: ______________

Street Address: ______________

City: ______________ State: ________ Zip: ________

Request for Chemical Analysis and Chain of Custody Record

Send Results to: Attention:	Laboratory: Address: City/State/ZIP: Telephone:	Document Control No.: Lab. Reference No. or Episode I

Project Number:	Sample Type
Site Name:	Matrix

Sample Number			Sample Event		Sample Depth (in feet)		Sample Collected		Liquid	Solid	Gas	Number of Containers	Parameter/Method Code						Remarks
Group or SWMU Name	Sample Point	Sample Designator	Round	Year	From	To	Date	Time											

Sampler *(Print Name)*:		Sampler *(signature)*:	Custody Seal Number	Special Instructions	
Relinquished By *(signature)*: 1.	Date/Time	Received By *(signature)*: 1.	Date/Time	Ice Present in Container: Yes ☐ No ☐	Temperature Upon Receipt:
Relinquished By (signature): 2.	Date/Time	Received By (signature): 2.	Date/Time	Laboratory Comments:	

DISTRIBUTION
Owner
Project Manager

Construction Progress Report

Owner ______________________________ Page ________ of ________

Project Name ______________________________ Project No. ______________

Contract Name ______________________________ Contract No. ______________

Contractor ______________________________

Construction Progress Report: Period ______________ to ______________

NOTES	REPORTED BY
1. Construction Progress Reports to be on daily, weekly, or monthly basis as determined by the project manager and owner. 2. Attach Project Weather Report, if applicable. 3. Report contractor's daily labor and equipment as required by the project manager and owner.	______________________ Date ________

Drilling Log

	Project Name	Project No.	Boring/Monitoring Well Number
	Site-Specific Coordinates	Ground Elevation	Page 1 of 1
	Total Depth (feet) / Hole Size (inches)	Driller (s)	
Drilling Rig		Drilling Company	
Date / To	Logged By:	Reviewed by:	Approved by:

Elevation (feet)	Depth (feet)	Description	Graphic Log	SAMPLING: Sample Type	Sample Interval	Blow Counts per 0.5'	N Value	Sample Recovery/Length (feet)	Penetro-meter (TSF)	PID Reading (PPM)	Remarks
	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	10										
	11										
	12										
	13										

▽ Depth to water while drilling

▼ Depth to water after drilling

ENVIRONMENTAL LOG COPY OF OSI 2003.GPJ BURNS_MO.GDT 8/30/07

FIELD SCREENING INSTRUMENT CALIBRATION FORM
LandTec GA-90 or Equivalent

Form Revision 0

PROJECT INFORMATION

Project Name: ______________________ **Task Name:** ______________________

Project Number: ______________________ **Task/Project Manager:** ______________________

FIELD SCREENING TEAM INFORMATION	INSTRUMENT INFORMATION
Date: ______________	**Make:** ______________
Screener: ______________	**Model:** ______________
Assistant: ______________	**Serial #:** ______________

CALIBRATION GAS INFORMATION

Manufacturer	Cal. Gas Type	Lot Number	Expiration Date

CALIBRATION AND CALIBRATION CHECK INFORMATION

Time	Type of Calibration or Calibration Check	Calibration Standard		Instrument Response	Response within Tolerances (circle one)	Comments
		Type	Conc.			
	Pre-Screening Calibration[R]	O2	4.0%		Yes / No	
		CO2	35.0%		Yes / No	
	Mid-Screening Calibration Check*	O2	4.0%		Yes / No	
		CO2	35.0%		Yes / No	
	Post-Screening Calibration Check[R]	O2	4.0%		Yes / No	
		CO2	35.0%		Yes / No	
	Mid-Screening Recalibration*	O2	4.0%		Yes / No	
		CO2	35.0%		Yes / No	
	Mid-Screening Recalibration*	O2	4.0%		Yes / No	
		CO2	35.0%		Yes / No	

Notes: 1. R = Required 2. * = If necessary 3. % = percent by volume

FIELD SCREENING INSTRUMENT CALIBRATION FORM
ppbRAE or Equivalent

Form Revision 0

PROJECT INFORMATION

Project Name: ____________________ **Task Name:** ____________________
Project Number: ____________________ **Task/Project Manager:** ____________________

FIELD SCREENING TEAM INFORMATION | **INSTRUMENT INFORMATION**

Date: ____________________ **Make:** ____________________
Screener: ____________________ **Model:** ____________________
Assistant: ____________________ **Serial #:** ____________________

CALIBRATION GAS INFORMATION

Manufacturer	Cal. Gas Type	Lot Number	Expiration Date

CALIBRATION AND CALIBRATION CHECK INFORMATION

Time	Type of Calibration or Calibration Check	Calibration Standard		Instrument Response	Response within Tolerances (circle one)	Comments
		Type	Conc.			
	Pre-Screening Calibration[R]	Free Air	0.0 ppmv		Yes / No	
		Isobutylene	10.0 ppmv		Yes / No	
	Mid-Screening Calibration Check*	Free Air	0.0 ppmv		Yes / No	
		Isobutylene	10.0 ppmv		Yes / No	
	Post-Screening Calibration Check[R]	Free Air	0.0 ppmv		Yes / No	
		Isobutylene	10.0 ppmv		Yes / No	
	Mid-Screening Recalibration*	Free Air	0.0 ppmv		Yes / No	
		Isobutylene	10.0 ppmv		Yes / No	
	Mid-Screening Recalibration*	Free Air	0.0 ppmv		Yes / No	
		Isobutylene	10.0 ppmv		Yes / No	
	Mid-Screening Recalibration*	Free Air	0.0 ppmv		Yes / No	
		Isobutylene	10.0 ppmv		Yes / No	

Notes: 1. R = Required 2. * = If necessary 3. ppmv = parts per million by volume

FIELD SCREENING INSTRUMENT CALIBRATION FORM
TVA 1000 (FID) or Equivalent

Form Revision 0

PROJECT INFORMATION

Project Name: ____________________ Task Name: ____________________

Project Number: ____________________ Task/Project Manager: ____________________

FIELD SCREENING TEAM INFORMATION

Date: ____________________

Screener: ____________________

Assistant: ____________________

INSTRUMENT INFORMATION

Make: ____________________

Model: ____________________

Serial #: ____________________

CALIBRATION GAS INFORMATION

Manufacturer	Cal. Gas Type	Lot Number	Expiration Date

CALIBRATION AND CALIBRATION CHECK INFORMATION

Time	Type of Calibration or Calibration Check	Calibration Standard		Instrument Response				Response(s) within Tolerances (circle one)	Comments
		Type	Conc.	w/o Dilution Probe	w/ 10-to-1 Dilution Probe	w/ 25-to-1 Dilution Probe	w/ 50-to-1 Dilution Probe		
	Pre-Screening Calibration[R]	Free Air	0.0 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	50.0 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	500 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	5,000 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	32,500 ppmv	N/A				Yes / No	
	Mid-Screening Calibration Check*	Free Air	0.0 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	50.0 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	500 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	5,000 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	32,500 ppmv	N/A				Yes / No	

CALIBRATION AND CALIBRATION CHECK INFORMATION (Continued)									
Time	Type of Calibration or Calibration Check	Calibration Standard		Instrument Response				Response(s) within Tolerances (circle one)	Comments
		Type	Conc.	w/o Dilution Probe	w/ 10-to-1 Dilution Probe	w/ 25-to-1 Dilution Probe	w/ 50-to-1 Dilution Probe		
	Post-Screening Calibration Check[R]	Free Air	0.0 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	50.0 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	500 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	5,000 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	32,500 ppmv	N/A				Yes / No	
	Mid-Screening Recalibration*	Free Air	0.0 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	50.0 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	500 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	5,000 ppmv		N/A	N/A	N/A	Yes / No	
	Mid-Screening Recalibration*	Free Air	0.0 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	50.0 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	500 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	5,000 ppmv		N/A	N/A	N/A	Yes / No	
	Bump Calibration Check*	Free Air	0.0 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	5,000 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	32,500 ppmv	N/A				Yes / No	
	Bump Calibration Check*	Free Air	0.0 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	5,000 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	32,500 ppmv	N/A				Yes / No	
	Bump Calibration Check*	Free Air	0.0 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	5,000 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	32,500 ppmv	N/A				Yes / No	
	Bump Calibration Check*	Free Air	0.0 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	5,000 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	32,500 ppmv	N/A				Yes / No	
	Bump Calibration Check*	Free Air	0.0 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	5,000 ppmv		N/A	N/A	N/A	Yes / No	
		Methane	32,500 ppmv	N/A				Yes / No	

Notes: 1. [R] = Required 2. * = If necessary 3. ppmv = parts per million by volume 4. N/A = Not Applicable

FIELD SCREENING INSTRUMENT CALIBRATION FORM
TVA 1000 (PID) or Equivalent

Form Revision 0

PROJECT INFORMATION

Project Name: ______________________ **Task Name:** ______________________
Project Number: ______________________ **Task/Project Manager:** ______________________

FIELD SCREENING TEAM INFORMATION	INSTRUMENT INFORMATION
Date: ______________________	**Make:** ______________________
Screener: ______________________	**Model:** ______________________
Assistant: ______________________	**Serial #:** ______________________

CALIBRATION GAS INFORMATION

Manufacturer	Cal. Gas Type	Lot Number	Expiration Date

CALIBRATION AND CALIBRATION CHECK INFORMATION

Time	Type of Calibration or Calibration Check	Calibration Standard		Instrument Response		Response within Tolerances (circle one)	Comments
		Type	Conc.	w/o Dilution Probe	w/ 10-to-1 Dilution Probe		
	Pre-Screening Calibration^R	Free Air	0.0 ppmv		N/A	Yes / No	
		Isobutylene	50.0 ppmv		N/A	Yes / No	
		Isobutylene	1,000 ppmv		N/A	Yes / No	
		Isobutylene	5,000 ppmv	N/A		Yes / No	
	Mid-Screening Calibration Check*	Free Air	0.0 ppmv		N/A	Yes / No	
		Isobutylene	50.0 ppmv		N/A	Yes / No	
		Isobutylene	1,000 ppmv		N/A	Yes / No	
		Isobutylene	5,000 ppmv	N/A		Yes / No	
	Post-Screening Calibration Check^R	Free Air	0.0 ppmv		N/A	Yes / No	
		Isobutylene	50.0 ppmv		N/A	Yes / No	
		Isobutylene	1,000 ppmv		N/A	Yes / No	
		Isobutylene	5,000 ppmv	N/A		Yes / No	

CALIBRATION AND CALIBRATION CHECK INFORMATION (Continued)

Time	Type of Calibration or Calibration Check	Calibration Standard: Type	Calibration Standard: Conc.	Instrument Response: w/o Dilution Probe	Instrument Response: w/ 10-to-1 Dilution Probe	Response within Tolerances (circle one)	Comments
	Mid-Screening Recalibration*	Free Air	0.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	50.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	1,000 ppmv		**N/A**	**Yes / No**	
		Isobutylene	5,000 ppmv	**N/A**		**Yes / No**	
	Mid-Screening Recalibration*	Free Air	0.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	50.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	1,000 ppmv		**N/A**	**Yes / No**	
		Isobutylene	5,000 ppmv	**N/A**		**Yes / No**	
	Single-Point Bump Calibration Check*	Isobutylene	50.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	5,000 ppmv	**N/A**		**Yes / No**	
	Single-Point Bump Calibration Check*	Isobutylene	50.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	5,000 ppmv	**N/A**		**Yes / No**	
	Single-Point Bump Calibration Check*	Isobutylene	50.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	5,000 ppmv	**N/A**		**Yes / No**	
	Single-Point Bump Calibration Check*	Isobutylene	50.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	5,000 ppmv	**N/A**		**Yes / No**	
	Single-Point Bump Calibration Check*	Isobutylene	50.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	5,000 ppmv	**N/A**		**Yes / No**	
	Single-Point Bump Calibration Check*	Isobutylene	50.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	5,000 ppmv	**N/A**		**Yes / No**	
	Single-Point Bump Calibration Check*	Isobutylene	50.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	5,000 ppmv	**N/A**		**Yes / No**	
	Single-Point Bump Calibration Check*	Isobutylene	50.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	5,000 ppmv	**N/A**		**Yes / No**	
	Single-Point Bump Calibration Check*	Isobutylene	50.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	5,000 ppmv	**N/A**		**Yes / No**	
	Single-Point Bump Calibration Check*	Isobutylene	50.0 ppmv		**N/A**	**Yes / No**	
		Isobutylene	5,000 ppmv	**N/A**		**Yes / No**	

Notes: 1. ^{R} = Required   2. * = If necessary   3. ppmv = parts per million by volume

FIXED GASES AND SOIL VAPOR CONCENTRATION FIELD SCREENING DATA

PROJECT INFORMATION		GENERAL INSTRUMENT INFORMATION		SCREENER INFORMATION	
Project Name:		Fixed Gases:		Screener's Name:	
Project Number:		PID (Low Level Confirmation):		Screener's Title:	
Task Name:		PID (Low-High Level):		Assistant's Name:	
Task/Project Manager:		FID (Low-High Level):		Assistant's Title:	

FIELD SCREENING RESULTS

WELL ID or SAMPLE ID	SAMPLE DATE	SAMPLE TIME (24-Hour)	SCREENING DATE	SCREENING TIME (24-Hour)	Observed Field Screening Values[1], Units, and Dilution Values[2]									Corrected Value[3]		COMMENTS
					O_2 (%)	CO_2 (%)	% LEL[4] (%)	PID	PID UNITS (circle one)	PID Dilution Value[2] (circle one)	FID	FID UNITS (circle one)	FID Dilution Value[2] (circle one)	PID (ppmv)	FID (ppmv)	
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			

FIELD SCREENING RESULTS

WELL ID or SAMPLE ID	SAMPLE DATE	SAMPLE TIME (24-Hour)	SCREENING DATE	SCREENING TIME (24-Hour)	Observed Field Screening Values[1], Units, and Dilution Values[2]									Corrected Value[3]		COMMENTS
					O_2 (%)	CO_2 (%)	% LEL[4] (%)	PID	PID UNITS (circle one)	PID Dilution Value[2] (circle one)	FID	FID UNITS (circle one)	FID Dilution Value[2] (circle one)	PID (ppmv)	FID (ppmv)	
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			

FIELD SCREENING RESULTS

WELL ID or SAMPLE ID	SAMPLE DATE	SAMPLE TIME (24-Hour)	SCREENING DATE	SCREENING TIME (24-Hour)	Observed Field Screening Values[(1)], Units, and Dilution Values[(2)]									Corrected Value[(3)]		COMMENTS
					O_2 (%)	CO_2 (%)	% LEL[(4)] (%)	PID	PID UNITS (circle one)	PID Dilution Value[(2)] (circle one)	FID	FID UNITS (circle one)	FID Dilution Value[(2)] (circle one)	PID (ppmv)	FID (ppmv)	
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			
									ppbv ppmv %	1 10		ppmv %	1 10 25 50			

Notes: [(1)] = As observed on the instrument's display; If flame-out occurs, record "FO" as the default value.
[(2)] = Dilutions Values (Dilution Probe Specific): No Dilution Probe Used - Circle "1"; 10-to-1 Dilution Probe Used - Circle "10"; 25-to-1 Dilution Probe Used - Circle "25"; 50-to-1 Dilution Probe Used - Circle "50"
[(3)] = Calculated based on the units and dilution value or, in the case of a flame-out when sufficient oxygen is present, the upper dynamic range of the instrument multiplied by the dilution value.
[(4)] = If required by project or task
E = Estimated Value: Corrected value exceeds the upper dynamic range of the instrument or flame-out due to concentrations above the instruments range occurred.
ppbv = Parts per billion volume
ppmv = Parts per million volume
% = Percent by volume
N/A = Not Applicable
FO = Instrument Flame Out (FID Only)

SOIL VAPOR SAMPLING FIELD FORM

PROJECT INFORMATION

Site: ______________________ Client: ______________________

Project Number: ______________ Task #: __________ Date of Sampling: ______________________

Field Personnel: ______________________

SUMMA CANISTER SAMPLE INFORMATION

Probe / Well / Location ID	Sample ID	Canister ID Number	Flow Regulator ID Number	Canister Vacuum (In. Hg)		Sample Time (24-Hour)		Comments
				Initial	Final	Start	Finish	

NOTES

ABBREVIATIONS

In. Hg - Inches of Mercury
NA - Not Applicable
NM - Not Measured

PROJECT NAME:	PROJECT NO.:	LOGGER:	COMMENTS:	TEST PIT NO.: SHEET OF
LOCATION:				DATE EXCAVATED:
ELEVATION:	EXCAVATION METHOD:	CONTRACTOR:		
APPROXIMATE DIMENSIONS: LENGTH: WIDTH: DEPTH:				

DEPTH BELOW SURFACE	SAMPLE INTERVAL	SAMPLE TYPE & NUMBER	PLAN VIEW (1' × 1')	N
			0' 5' 10' 15' 20' 25' 30' 35' 40'	REMARKS/ WATER LEVEL
0' 2' 4' 6' 8'			CROSS-SECTION (1' × 1')	WATER TABLE

ADDITIONAL COMMENTS:

WELL DEVELOPMENT AND GROUNDWATER SAMPLING FIELD FORM

PROJECT INFORMATION

Site: ______________________ Client: ______________________

Project Number: ______________ Task #: __________ Start Date: ______________ Time: ________

Field Personnel: ______________________ Finish Date: ______________ Time: ________

WELL INFORMATION

Well ID: ______________

Casing ID: __________ Inches

Screen Interval: ______________

Borehole Diameter: __________ Inches

Filter Pack Interval: ______________

EVENT TYPE

☐ Well Development

☐ Low-Flow / Low-Stress Sampling

☐ Well Volume Approach Sampling

☐ Other (Specify below)

____

PURGE INFORMATION

Purge Method: ☐ Bailer ☐ Pump

Bailer Type: ______________

Pump Type and Serial #: ______________

Tube/Pump Intake Depth: ______________

Stabilized Pumping Rate: ______________

DEPTH MEASUREMENTS

	INITIAL		FINAL	
	Depth	Time	Depth	Time
	(__________)	(24-Hour)	(__________)	(24-Hour)
LNAPL				
Groundwater				
DNAPL				
Casing Base				

VOLUME CALCULATION AND PRODUCTION INFORMATION

Volume Calculation Type: ☐ Well Casing ☐ Borehole

Volume Per Foot: ______________

Standing Water Column: ______________ feet

1 Well Volume: __________ Gallons 3 Well Volumes: __________ Gallons

5 Well Volumes: __________ Gallons 10 Well Volumes: __________ Gallons

Total Volumes Produced: __________ Gallons

Well Purged Dry? ☐ Yes ☐ No

Water Level Serial #: ______________ Water Quality Probe Type and Serial # ______________

WATER QUALITY INDICATOR PARAMETERS

Sampling Stage pre, purge, etc.	Time (24-Hour)	Volume Removed (________)	Depth to Water (________)	Drawdown (Feet)	Temp (________)	pH (Std. Units)	SEC or Cond. (________)	Dissolved Oxygen (________)	Turbidity (________)	ORP (________)	Visual Clarity

NOTES

ABBREVIATIONS

Cond. - Actual Conductivity
FT BTOC - Feet Below Top of Casing
NA - Not Applicable
NM - Not Measured
ORP - Oxidation-Reduction Potential
SEC - Specific Electrical Conductance
Std. Units - Standard Units
Temp - Temperature

WELL DEVELOPMENT AND GROUNDWATER SAMPLING FIELD FORM

PROJECT INFORMATION

Site: ______________________ Client: ______________________

Project Number: ______________ Task #: __________ Start Date: ______________ Time: __________

Field Personnel: ______________________ Finish Date: ______________ Time: __________

WELL INFORMATION

Well ID: ______________

Casing ID: ______________ inches

EVENT TYPE

- ☐ Well Development
- ☐ Low-Flow / Low Stress Sampling
- ☐ Well Volume Approach Sampling
- ☐ Other (Specify):

WATER QUALITY INDICATOR PARAMETERS (continued)

Sampling Stage pre, purge, etc.	Time (24-Hour)	Volume Removed (______)	Depth to Water (______)	Drawdown (Feet)	Temp. (______)	pH (Std. Units)	SEC or Cond. (______)	Dissolved Oxygen (______)	Turbidity (______)	ORP (______)	Visual Clarity

NOTES (continued)

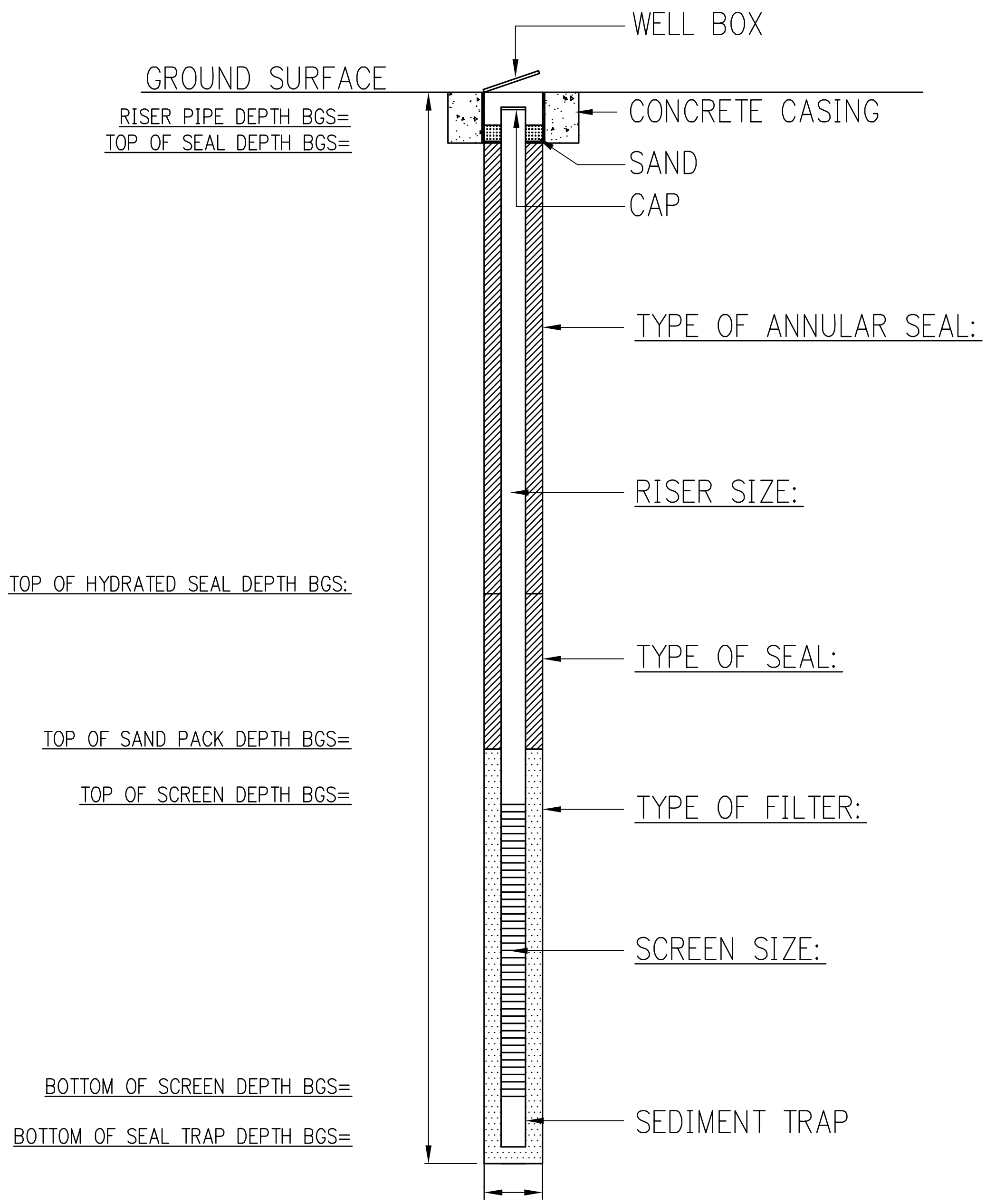
ABBREVIATIONS

Cond. - Actual Conductivity
FT BTOC - Feet Below Top of Casing
NA - Not Applicable
NM - Not Measured
ORP - Oxidation-Reduction Potential
SEC - Specific Electrical Conductance
Std. Units - Standard Units
Temp - Temperature

WELL INSTALLATION LOG

No. ________

CLIENT	COORDINATES N	PROJECT	PROJECT NO.
PROJECT LOCATION	E	TOP OF RISER ELEVATION (DATUM)	DATE
STRATUM MONITORED		LOGGED BY	
DRILLING COMPANY		APPROVED BY	



NOT TO SCALE

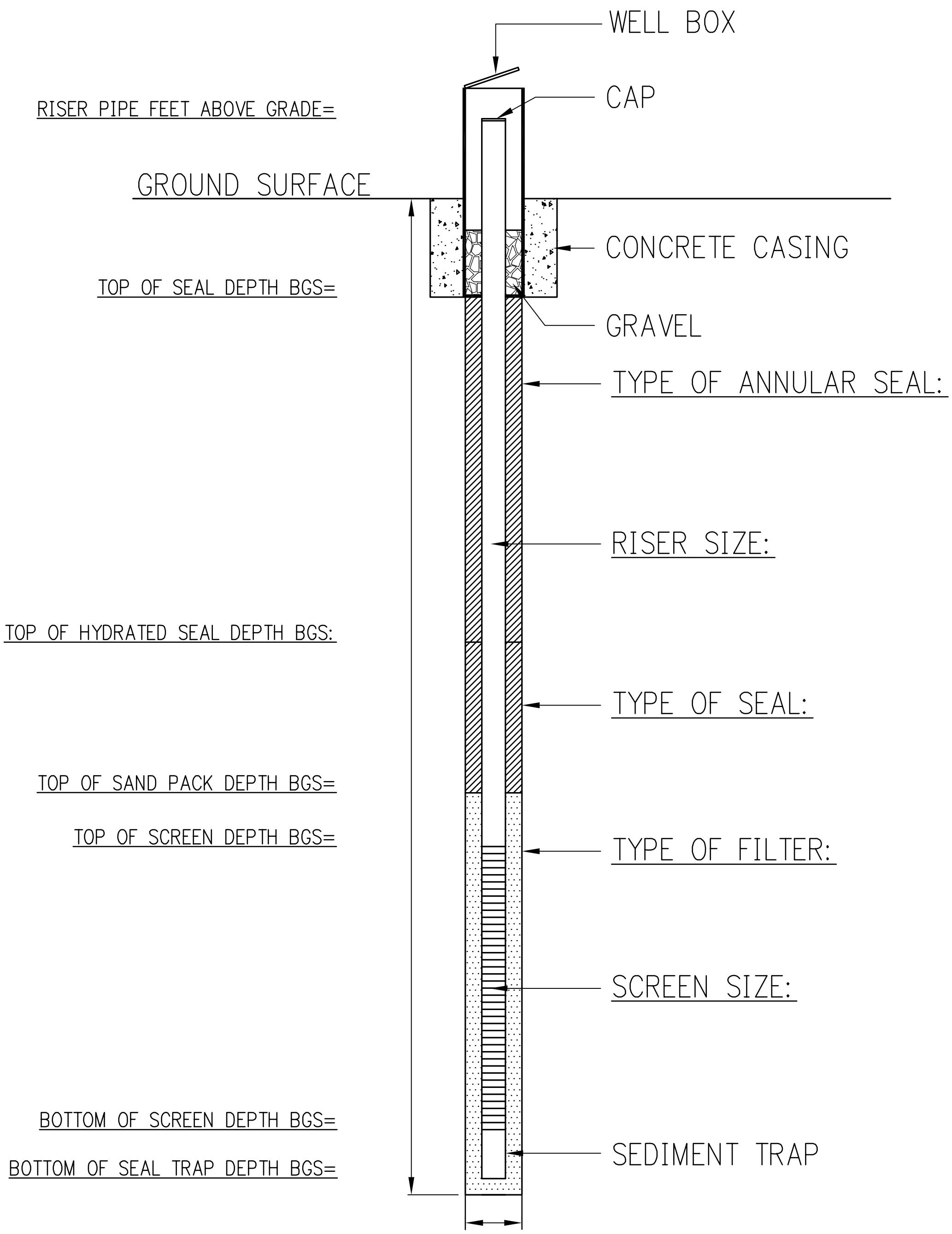
METHOD OF INSTALLATION:

REMARKS:

WELL INSTALLATION LOG

No. __________

CLIENT	COORDINATES N	PROJECT	PROJECT NO.
PROJECT LOCATION	E	TOP OF RISER ELEVATION (DATUM)	DATE
STRATUM MONITORED		LOGGED BY	
DRILLING COMPANY		APPROVED BY	



METHOD OF INSTALLATION:

REMARKS:

Number : ______ Start : ______ End : ______ Site : ______ Project # : ______ Task # : ______

Weather : ______ Logger(s) : ______ comments : ______

Total Depth (ft) : ______ Borehole Dia. : ______ Drilling Type : ______

Sampling Type : ______ Abandonment : ______

2. Depth (ft)	Symbol / Name		Percent, Number, Name		15. D 16. T 14. P	17. CONS	18. GRD	19-25. Particle Size (% and grn size)					26-27. ANG	STRC note thickness	CMT	HCl	Shape Enter %	Geologic Characteristic (sorting, HCl reaction, etc...)	Geologic Interpretation (till, outwash, overbank, etc...)	25. Odor	27-28. MST Min-Max	Additional Information
	1st	2nd	9-10. color	11-13. mottling				Trace <5%	Few 5-10%	Little 15-25%	Some 30-45%	Mostly 50-100%										

FIELD DATA AND OBSERVATIONS

PID, Pocket Penetrometer, Recovery, RQD, Sample Interval, etc...

EXAMPLE

Sample Interval	Recov. (ft)	Blow Counts	Pock. Pen	PID eV __	Field Observ
0-2	1.9	1/2/3/4	4.2	1.6	
2-4	1.3	1/2/3/4	5.1	0.2	
4-6	1.2	1/2/3/4	4.2	1.6	
6-8	0.9	2(50)	1.1	0.2	rough drilling, cobble in drill cuttings

Grn (Grain Size): **FS** (fine sand - ≥75 µm; <425 µm) ; **MS** (medium sand - ≥425 µm; <2 mm) ; **CS** (coarse sand - ≥2 mm; <4.75 mm) ; **FG** (fine gravel - ≥4.75 mm (0.9"); <3/4") ; **CG** (coarse gravel - ≥3/4"; <3") ; **CC** (cobbles - ≥3"; <12") ; **BB** (boulders - ≥12")

D (Dilatency): **N**(none) ; **S**(slow) ; **R**(rapid)

T (Toughness): **L**(low) : **M**(medium) ; **H**(high)

P (Plasticity): **N**(non) ; **L**(low) ; **M**(medium) ; **H**(high)

CONS (Consistency): VS(very soft) ; **S**(soft) ; **F**(firm) ; **H**(hard) ; **VH**(very hard) (fine grained material only)

GRD (Grading): **W**(well-graded) ; **P**(poorly-graded)

%: **T**(trace <5%) ; **F**(few 5-10%) ; **L**(little 15-25%) ; **S**(some 30-45%) ; **M**(mostly 50-100%)

ANG (Angularity): **A**(angular) ; **SA**(subangular) ; **SR**(subrounded) ; **R**(rounded)

CMT (Cementation): **W**(weak) ; **M**(moderate) ; **S**(strong)

Shape (gravel, cobbles, & boulders only): **F**(flat) ; **E**(elongated) ; **FE**(flat & elongated)

STRC (Structure): **S**(Stratified - >6 mm) ; **LA**(laminated - <6 mm) ; **F**(fissured) ; **SS**(slickensided) ; **B**(blocky) ; **LE**(lensed) ; **HO**(homogenous) ; **HE**(heterogenous)

HCl (Reaction with HCl): **N**(none) ; **W**(weak) ; **S**(strong)

PP Pocket Penetrometer (fine grained material only)

Core Collection and Processing Log

General Information

Project Name/Site : ______________________________

Project # : ______________________________

Task # : ______________________________

Date : ______________________________

Samplers : ______________________________

Sampling Equipment: ______________________________

Coordinate System: ______________________________

Datum: ______________________________

Weather: ______________________________

River Section/DMU: ______________

Sample Location	Time (military)	Water Elevation (ft)	Water Depth (ft)	Core Penetration (ft)	Sediment Recovered (ft)	% Recovery	Proposed Sample Location (Northing)	Proposed Sample Location (Easting)	Actual Sample Location (Northing)	Actual Sample Location (Easting)	Sample Description/Notes (Color, Texture, Odor, etc.)

Core Intervals (in)	Core Description	Date Processed	Sample Core Intervals (in)		COC Sample ID Number
			TOP	BOTTOM	

Additional Comments: ______________________________

____

____

____

____

n/a : Not Applicable

COC: Chain of Custody

Sampling/Processing Personnel Signature: ______________________________

APPENDIX C

LIF FIELD OPERATING PROCEDURES

TarGOST® User's Guide

The Tar-specific Green Optical Screening Tool (TarGOST®) is a laser-induced fluorescence (LIF) screening tool that is specifically designed to detect non-aqueous phase liquid (NAPL) in the subsurface. It responds almost exclusively to the NAPL found at former manufactured gas plants (MGPs) and creosote/pentachlorophenol sites. It does this by sensing the fluorescence of polycyclic aromatic hydrocarbons (PAHs) found in MGP and creosote NAPLs. TarGOST is a modification of the Ultra-Violet Optical Screening Tool (UVOST™). Dakota developed the UVOST early in the 1990's with U.S. Air Force funding. The UVOST platform is a mature technology that has been applied at hundreds of petroleum, oil, and lubricant (POL) contaminated sites in the U.S., Europe, and Japan since 1994. TarGOST has been in commercial use since March 2003.

General TarGOST Principles

The TarGOST system is, in its simplest sense, a front-face fluorometer that is coupled via fiber optics to a sapphire-windowed probe that is shoved into the ground. A front-face fluorometer is a device that shines excitation light onto, and collects emission from, the same surface. This is different from standard fluorometers, which operate with the excitation and emission beams at 90°. The TarGOST system makes continuous front-face fluorescence measurements of the soil matrix as the windowed probe is pushed slowly down into the subsurface.

The fluorescence measurements are made 20 to 50 times each second (20 to 50 Hz). Each individual measurement begins with a pulse of laser excitation light being launched into one of two fiber optic cables that are strung through the drill/push rod string. As the rod is advanced into the subsurface, the very fast pulses of laser light (10 nanoseconds in duration) are directed out the sapphire window and onto the soil surface that is pressed very firmly against the outside of the window. The pulses of green light strike whatever is present just outside the surface of the window. Most of the laser light is simply reflected by the soil matrix. However, if oil-like material (OLM) or tar-like material (TLM) associated with former MGP processes is present, the PAHs that exist in these NAPLs absorb some of the light and are driven into an electronically excited state. When these PAHs eventually return to the ground state (this typically takes less than 10 ns), a portion of the PAHs emit red-shifted light (longer wavelength light than the excitation laser). Some of this fluorescence, along with a small portion of the reflected excitation laser light, are collected by a mirror and focused into the second collection fiber optic for return to the TarGOST instrument for detection.

The return light is directed into a spectrometer located inside the TarGOST system. A grating in the spectrometer disperses this light into a "rainbow" across the back plane of spectrometer. Four optical fibers are located in this backplane. One of the fibers collects a small portion of the relatively intense laser light (more about this laser scatter channel later) while the other three fibers capture bands of the fluorescence (~10nm wide) emitted by any PAHs present in the NAPL. The four fibers are different lengths so that each fiber delivers its 'packet' of fluorescence photons to the photomultiplier tube (PMT) at delayed time intervals. The result is a "train" of time delayed photon packets all arriving at the same PMT over a period of 300 nano-seconds (ns). The PMT is a device that converts photons into a current pulse. This current pulse is wired into a fast digital storage oscilloscope where it is converted into a transient voltage signal, is digitized, and recorded. This digitized transient is called a waveform. The laser light that is being reflected from the soil matrix is monitored in the first channel (left-most) and the three fluorescence bands are observed in the three right-most channels.

Figure 1 illustrates waveforms that are typical of those generated with TarGOST. If the soil is clean of NAPL, the laser scatter channel (leftmost) is far more intense than the three fluorescence channels. The Clean Sand waveform in Figure 1 illustrates what clean (or very low NAPL) soil typically looks like on the TarGOST system. If NAPL is present, the fluorescence channels begin to grow in comparison to the laser channel. The 1000 ppm waveform in Figure 1 illustrates such a condition. The more coal tar present, the lower the scatter channel gets and the higher the three fluorescence channels get. Finally, with pure NAPL on the window, the greatest increase in the fluorescence channels is observed, along with maximum loss of signal in the laser reflectance channel – due to absorbance by the PAH-laden NAPL. The NAPL waveform in Figure 1 illustrates the waveform resulting from such a condition.

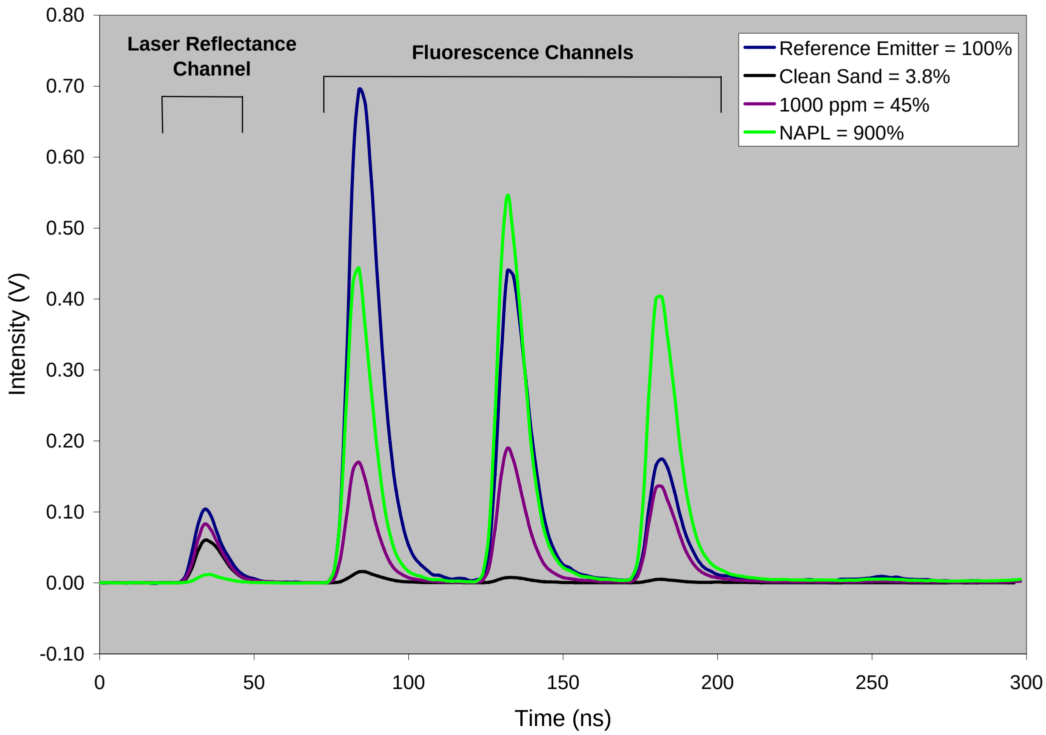


Figure 1. Example TarGOST waveforms.

Calibration/Normalization

The waveform shapes (the relative amount of signal in each channel and the decay time on the right side of each peak) tell us quite a bit about the qualitative nature of what's happening outside the window. But what interests people most is the **amount** of NAPL that is present vs. depth. We do this by portraying the fluorescence vs. depth (FVD) in a continuous log format. To accomplish this we must reduce the 2-D waveform to a single quantitative number. We also need to normalize for any energy drift of the laser and optical alignment changes, so it is necessary to calibrate the system prior to each sounding and plot the downhole data relative to a known fluorescence emitting reference (RE) material. The RE is a stable and known material that can be applied to the window and measured just prior to each sounding. The fluorescence of the downhole data, relative to this RE, is then plotted as a function of depth.

Figure 2 graphically illustrates the calibration procedure. The RE both reflects some of the laser light and fluoresces at levels that are in the same general range as soils that are moderately to heavily contaminated with MGP NAPL. The Reference Emitter waveform shown in Figure 1 is an actual RE waveform taken with the TarGOST. Notice that the RE fluoresces in the same general intensity range as the pure NAPL, but it also (by design) reflects a high degree of scatter due to its buff gray color and lack of photon absorbing PAHs. The RE is designed to do this so that both the system's fluorescence and scatter components can be properly gauged and recorded on the same scaling of the oscilloscope. Once the RE is measured, all subsequent downhole (or laboratory) measurements can be normalized by this RE waveform, providing an apples-to-apples presentation of the data regardless of laser energy drift or other changes that would cause a difference in raw signal amplitude over time. It is useful to think of the RE waveform as the equivalent of the single-point 100ppm isobutylene calibration used for hand-held photo-ionization detectors.

To calculate the %RE, the area under the three fluorescence channels of the waveform is determined. The fluorescence area is then divided by the area under the laser scatter channel. This is called scatter correction. This is necessary because at very high concentrations the fluorescence does not continue to scale with concentration. This is due to complicated processes such as energy transfer, photon cycling, and other phenomenon that "quench" the fluorescence in high NAPL concentration soils. The uncorrected TLM curve in Figure 3 illustrates the problem. The addition of more and more NAPL to a soil sample should result in increasing fluorescence, but for some reason it only increase up to a certain point, at which the fluorescence response flattens out, or even worse, begins to fall. This poor type of response is called non-monotonic behavior and is obviously undesirable behavior for a screening tool. The laser scatter correction system is designed to prevent this "roll-over" affect. The scatter correction keeps this from occurring at the high end of concentrations (where soil is heavily contaminated or even saturated with NAPL). The scatter-corrected curves in Figure 3 illustrate the desired effect of scatter correction.

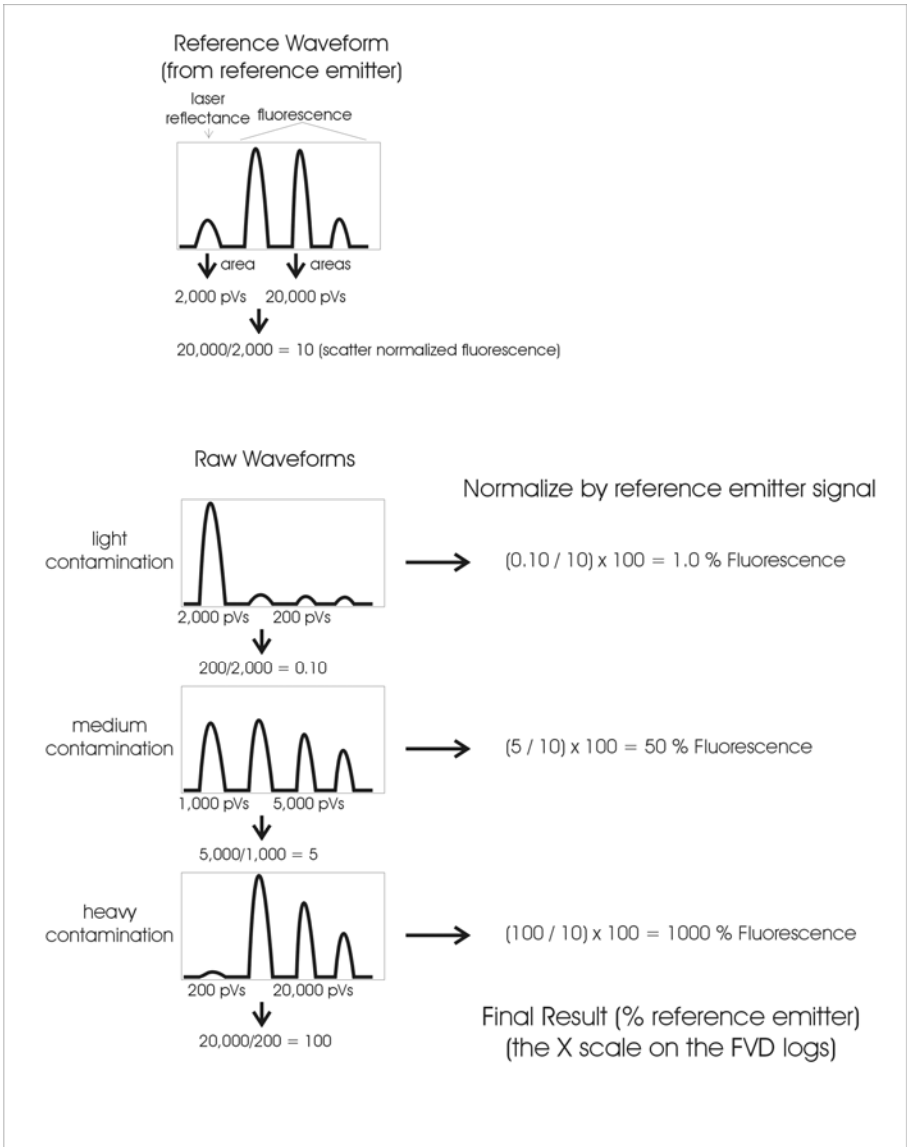


Figure 2. Single point RE calibration made prior to each TarGOST log.

The laser scatter intensity is relatively unaffected until NAPL concentrations reach the tens or hundreds of thousands PPM level, where the quenching (non-linearity of fluorescence response) is most pronounced. Laser scatter correction generally doesn’t “kick in” until high concentrations are being measured, where fluorescence response flattens out or rolls over. In this way, the scatter corrected fluorescence readings scale relatively well across a wide range of concentrations, from the typical limit of detection (LOD) of 250-500 ppm, to the almost neat NAPL encountered in soil saturated with free product. Remember that TarGOST is designed to respond only to the NAPL impacted soils, not the PAHs attached in “dry” form to soot or dissolved phase PAHs. This makes it ideal for delineating source term areas of mobile MGP NAPL.

The scatter correction works well, but it isn’t perfect. The TarGOST system is not an analytical instrument like a laboratory GC that sits in a clean, stable environment and only gets fed ultraclean matrix-isolated analytes. Instead, it is asked to respond faithfully to an analyte that exists in a thousand different forms in an endless number of different environments. Variation in optical

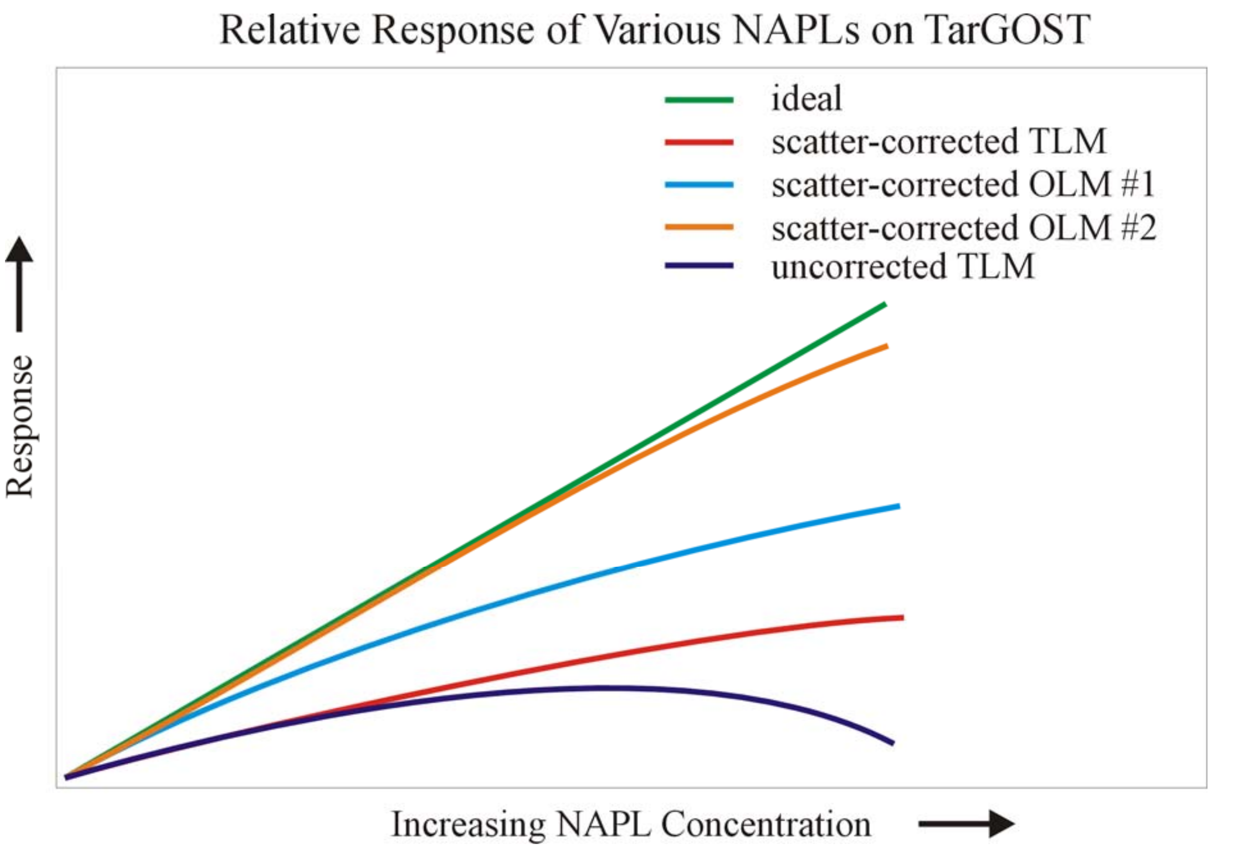


Figure 3. Variability of TarGOST response to NAPL products.

design (CPT vs. Geoprobe), mirror angle, and spectrometer settings can vary the amount of scatter present, especially at very high NAPL concentrations when the scatter is getting weak and difficult to measure relative to the much more intense fluorescence.

At high NAPL concentrations, even small variations in the laser scatter greatly influences the %RE number, especially when the laser scatter gets close to zero. For instance, let's imagine that with neat NAPL in front of the window, the fluorescence channels are averaging around 10,000 pico-Volt seconds (pVs) in area with each pulse of the laser. The laser scatter may be dancing around 400 and 800 pVs, because the scattered light is dim from being absorbed so highly by the PAHs. Now, even if the fluorescence stays almost exactly at 10,000 pVs every measurement, the relatively large variation in the tiny laser scatter that occurs will create a two or three-fold increase/decrease in %RE, even with the same NAPL sitting dead still on the window. That's why very high readings (500-1500%) often look unstable and jagged – because the laser scatter signal is so weak it "jitters" a lot compared to the fluorescence, causing large variations in %RE, even though the fluorescence portion of the waveform is relatively stable. For this reason, any wide swings in signals over 500% should "be taken with a grain of salt".

The TarGOST operators do their best to adjust the amount of launched laser light, the spectrometer position, and mirror angle in the probe to achieve a consistent waveform for the RE at each job site and strives to maintain the same optical arrangement and a consistent RE signal for the entire project. Even though there are small differences in the setup from location to location, the variations in NAPL viscosity, soil matrix, and signal magnitude can swing the signal up or down by a factor of two or three, which dwarfs the calibration differences.

The limitations in the current calibration technique can lead to the case of significant differences in the maximum signal generated by the same NAPL from one platform to another. For instance, even if the technician adjusts the system to achieve the exact same signal with RE on both a CPT and a Geoprobe platform, the same NAPL may yield 500% on one of the platforms and 1000% on the other. This is not typical but it can and does happen for reasons that aren't fully understood. Our goal is to stay consistent at a particular site so that the entire data set from that site can be viewed consistently. TarGOST data is relatively consistent and semi-quantitative across all the data generated **at one site** and **for a particular NAPL product,** but significant cross-platform or lab-to-field variations can and have taken place. While this may alarm users, and we're not happy with it, it's not as serious as it seems. As an example, let us imagine a site that is contaminated with a single origin homogeneous NAPL product. With TarGOST, 100% response does indeed represent approximately twice as much NAPL as a 50% response at that site. Even if the laser energy or optics alignments change, the RE will do a reasonable job of normalizing the log-to-log data variation for that site. Dakota is currently working on an improved system that will better normalize across all systems/platforms regardless of design or conditions.

Lab studies with MGP NAPL on moist Fisher® sea sand consistently demonstrate that TarGOST is capable of linear response vs. NAPL concentration, but some NAPLS are better behaved than others. Figure 4 is one example of the TarGOST response vs. MGP NAPL concentration on sand.

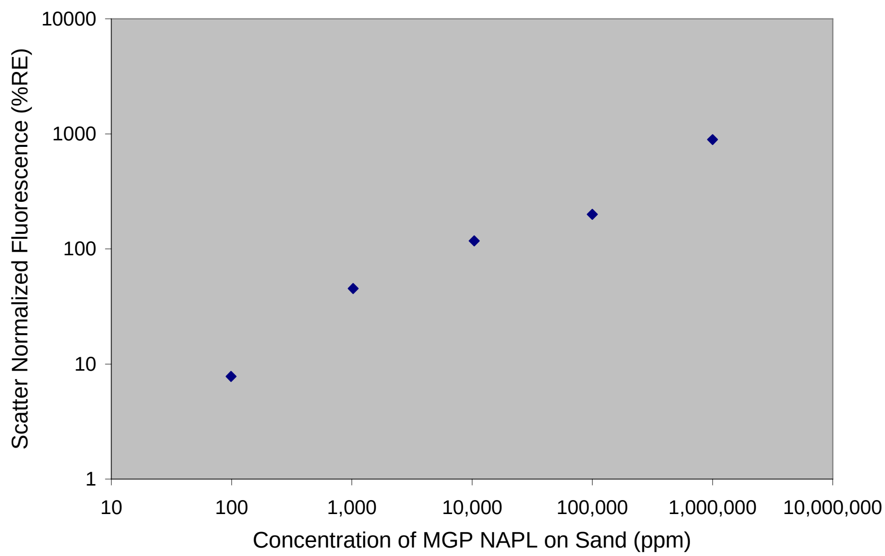


Figure 4. Calibration curve for MGP NAPL on Fisher Sea Sand

NAPLs do vary in their ability to fluoresce, even NAPLs found at the same site. Figure 3 illustrates conceptually that TarGOST often responds with varying sensitivity (ΔTarGOST Signal/ΔNAPL Concentration) toward different NAPLs, depending on their origin and/or variances in the conditions under which they've been exposed in the decades they've spent in the subsurface. For instance, a more ashaltine TLM will typically fluoresce much less intensely than a runny, less viscous OLM. This may well be due to the relative abundance of solvent in one matrix vs. the other. The more solvent available (i.e. the less viscous the NAPL), the higher the likelihood of the PAHs being able to emit photons (fluoresce) before a non-radiative mechanism allows the PAH to come back down to the ground state without emitting a photon (quenching).

The preferential sensitivity of TarGOST toward the runnier (more mobile) OLMs is welcomed by most users, since TarGOST seems to accentuate the presence of the more mobile NAPLs. It is these more mobile NAPLs that are of the highest regulatory/compliance concern. There is an abundance of anecdotal evidence that suggests that some NAPLs may fractionate in the subsurface into OLM and TLM or even DNAPL and LNAPL. Dakota has participated in a number of investigations where a single NAPL body seems to have 'split' into two distinct NAPLS, with both NAPLs having similar but distinct waveform shapes as we moved away from the suspected release point and they appear to form two separate horizons (a "high" and "low" layer). Although there has been plenty of speculation, the exact mechanism for this phenomenon (if it actually occurs) is not known.

As previously described, TarGOST uses a green laser to excite the larger (4 -5 rings and higher) PAHs that exist almost exclusively in NAPL form, as opposed to smaller (2-3 ring) PAHs that can more readily partition into the groundwater due to their much higher solubilities in water. UVOST on the other hand employs ultra-violet (UV) light which can and does excite the smaller 2-3 ring aqueous phase PAHs and therefore detects dissolved phase PAHs such as naphthalenes in the groundwater. When this behavior is combined with UVOST's non-monotonic response for many NAPLs, extremely complicated logs are generated that need to be computer analyzed to separate the NAPL fluorescence contribution from that of the dissolved phase. The dissolved phase signals can even surpass NAPL signals, making confident NAPL delineation almost impossible at many sites. This is especially true for those sites with sand/gravel, where pockets of NAPL are perched in or amongst slow-moving or stagnant groundwater.

It should also be mentioned that TarGOST was designed to exclusively detect heavy PAH NAPLs. It has, by design, a very limited, if any, response to lighter POLs. For instance, fresh diesel applied to the window will not elicit even a small response from the TarGOST. However, if the diesel has co-mingled with coal tar, the mixture will fluoresce brightly and TarGOST will respond well.

To better appreciate the qualitative information that TarGOST provides, the FVD logs are color-coded by "filling in" the FVD's x-axis (%RE) with colors generated from the waveform at each and every depth. The color is determined by "mixing" the amount of red, green, and blue (RGB) channels and applying the resulting color to the area under the curve on the FVD. This makes the interpretation of the logs easier to see "at-a-glance" as opposed to relying solely on the few selected waveforms to understand the qualitative nature of the data vs. depth. Color-coding alerts the observer to shifts in NAPL types and can also help identify weak interfering compounds like calcium rich (crushed limestone) soils and rotting wood/vegetation, both of which can sometimes (rarely) be mistaken for MGP waste.

Figure 5 shows the resulting colors for differing amounts of signal in each channel of the waveforms. Clean soil shows up blue (nearly 100% laser scatter), low-to-medium contamination often shows up orange or maroon (mostly red with some blue and green), and highly contaminated soils or neat NAPL typically shows up yellow (nearly all red and green with very little blue makes yellow). The color is simply another way of representing the information contained in the associated waveforms (shown in sub-panels at right in the figure). Just think of the color-coding as mixing paints in amounts equal to that contained under each associated red, green, and blue channel of the waveform. The standard for TarGOST is to use blue, red, and green in channels 1, 2, and 3 - leaving the fourth channel unused. The fourth channel was chosen to be the non-contributor to the color scheme because it varies the least in intensity across differing classes of NAPL.

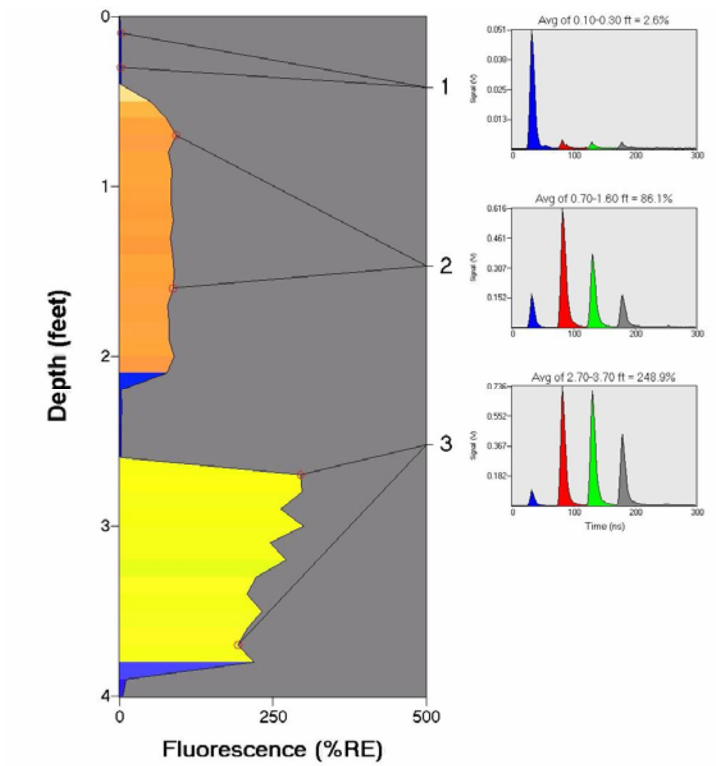


Figure 5. Example waveforms showing colors generated from RGB channel ratios.

The list below summarizes some of what we've learned in this section.

- TarGOST specifically targets the PAHs found in former MGP and creosote NAPLs
- TarGOST does detect staining and residual levels of NAPL as well as free phase
- TarGOST is "blind" to aqueous phase PAHs
- TarGOST is not able to reliably detect "dry" PAHs that are sorbed to soot, wood chips, and ash. They can generate a signal but it is often weak and not easily teased out of the background. Many times we're left wondering whether a small signal is caused by very

high concentrations of “dry” PAHs on purifier chips or ash/soot or very low (100s of ppm) residual NAPL levels.

- TarGOST’s typical lab-determined LOD for NAPL on site soil (or Fisher sea sand) is 250-500 ppm (weight of NAPL/weight of soil matrix). Note that this is not the same as weight of Total PAHs /weight of soil matrix, since not all of a NPAL is PAHs
- TarGOST has, on rare occasions, responded to mineral or plant interference enough to be a nuisance. One incident involved crushed limestone gravel fill while another involved buried rotting wood/brush debris (the result of major flooding on a gravelly river)
- TarGOST has not been observed to significantly respond to peat material (but this does not guarantee it won’t on some future occasion)
- TarGOST does not respond to typical lighter end fuels like gasoline, kerosene, or diesel – unless they contain MGP waste or creosote that they are co-mingled with
- TarGOST is single-point calibrated with a reference emitter (RE) immediately prior to each sounding and the results are always plotted relative to RE in percent
- TarGOST calibration/setup isn’t perfect and the response for an identical NAPL can vary with optical platform (CPT vs. Geoprobe) and from lab to field. However, once set up on site, the response remains stable over time and from log-to-log.
- NAPLs can vary greatly in their fluorescence response – even those found on the same site.
- Thinner, less viscous NPALS typically fluoresce much more than the more viscous TLMs. Asphalt-like TLMS which are solid/plastic fluoresce very poorly.
- Scatter-correction is applied to TarGOST data to reduce/eliminate “response rollover” at high concentrations
- Color-coding is deduced from the first 3 waveform channel areas and provides “at-a-glance” recognition of waveform consistency or changes
- The waveforms contain both quantitative and qualitative information

On-site TarGOST Fundamentals

So now that we understand the fundamentals of how TarGOST works, let’s examine the logging procedure at the site. When the system first arrives on site, it is powered up and tested for proper function. If it is in Dakota’s Geoprobe, the TarGOST is simply powered up and we’re ready to begin probing after proper warm-up. If CPT deployment is involved, the TarGOST system is integrated into the CPT truck and proper data flow connections are made (about a 2 hour procedure). Once the system is warmed up and tested for proper function, the actual logging can begin.

The delivery platform (CPT, Geoprobe truck, or track-rig) is positioned over the flag/mark as directed by the controlling geologist/consultant. Clients typically start out in an area where NAPL is known to (or strongly believed to) exist. Pushing in “the heart” of the source term at the start gives everyone involved a feel for how well the NAPL is going to respond to TarGOST delineation. From there, the effort often moves out and away from the “hot zone” toward the edges, with hopes of bounding the extent of the NAPL source term.

TarGOST productivity can range anywhere from 200 to over 500 ft/day. If the pushes are fairly deep (>30 ft), and the obstructions or rubble are minimal, then the average is on the higher end because we spend a lot more time actually probing, not moving around from location to location and/or trying multiple times to get holes started through rubble. On jobs with lots of shallow holes and/or numerous subsurface obstructions, like brick/rubble from previous demolitions, the production obviously slows down. This is due to spending lots of time making attempts to “get a straight hole going” or from break-offs and the subsequent repair they entail. We typically can achieve between 10 and 20 locations a day, again depending on the site conditions.

Buried utility clearance is often an overlooked issue, until the first day of the project when everyone realizes we can’t probe without it. Weeks or months of planning are often stalled the first day due to improper preparations with regard to utility clearance. The TarGOST crew has been instructed NOT TO PROCEED if there is even a remote chance that the proper precautions have not been made to clear the location for underground utilities.

Once the location has been cleared for utilities, the RE material is put on the cleaned window, any necessary tweaks are made to the TarGOST, and an RE waveform is acquired. The probe is then positioned in the push platform for advancement into the soil. In the case of percussion or “jack-hammering” delivery such as Dakota’s Geoprobe, the window is approximately 8 inches above the tip of the probe. In the case of cone-penetrometer test (CPT) delivery, the window is approximately 16 inches above the tip of the probe. When using Geoprobe delivery, the log is initiated when the window is at the ground surface. In CPT delivery, the log is initialized when the CPT tip is in contact with the ground. In both cases, the software automatically corrects for the window position and all logs are depth correct.

A unique name for the current log location is entered into the control computer and logging is started (probe advance begins). As the probe is pushed into the ground (at ~2cm/sec) the laser fires continuously, generating waveform after waveform on the detection system oscilloscope as the probe advances. We don’t store every waveform that the oscilloscope records. We instead average the waveforms over every 1-2 inches, depending on the probe speed and laser repetition rate. The averaged waveforms are downloaded from the oscilloscope every second or two by the control software. These waveforms are immediately ‘tagged’ with the current depth, which is constantly being sent to the TarGOST system by depth monitoring systems built into the Geoprobe or CPT truck. All the averaged waveforms from the logging event are stored to the hard-drive for later viewing and presentation if necessary or desired. The scatter and fluorescence areas are calculated and these are normalized to the RE waveform’s areas. The fluorescence response is plotted vs. depth in real time as the probe is advanced. Logging continues until “refusal” is met due to bedrock or very tight sands/gravels, or the client wishes to terminate.

The technician then uses the TarGOST software to highlight the waveforms at “depths of interest” for display in the print out. The waveforms are located in panel plots at the right of the FVD log to guide the viewer’s interpretation of the log. These waveforms contain the qualitative information and are often chosen from depths with peak signal, signal changes, or other zones of interest along the log’s Y depth axis. The technician immediately prints a hard copy, which is usually printed out before the probe is completely retrieved from the subsurface. The technician also saves an electronic image of the printed log in JPG format. At the end of the project the technician typically writes all the data and image logs to a CD, which is given to the lead geologist before departure.

Once the rods are all up and out of the hole, the hole is grouted (if necessary) and the probe tip and sapphire window is wiped clean in preparation for the next RE calibration. Time and money can often be saved by hiring a second crew/rig to grout the holes, instead of relying on the more expensive TarGOST system to do an otherwise routine task such as grouting. The next location is chosen and the procedure is repeated. The site investigation is often started with a grid or transect in mind, but it is common for the controlling geologist to modify the initially proposed investigation plan due to unforeseen “dirty” or “clean” zones encountered during the project. It is actually rare for the original transect or grid pattern to remain unchanged during the entire investigation, since the TarGOST regularly reveals previously unknown conditions at the site, including NAPL-free areas where significant NAPL was expected.

We recommend that the client conduct validation/confirmation sampling to bolster confidence in the body of evidence generated with TarGOST. Validation sampling of 10% of the TarGOST locations seems to be the most common co-sampling effort. Once the client gets familiar with TarGOST and becomes more comfortable with interpreting the results, they typically only sample where results are confusing or fly in the face of previous site understanding/information.

It is recommended that the client also conduct a few side-by-side tests of TarGOST for site heterogeneity assessment. Some sites yield nearly identical TarGOST logs when they are conducted a few feet apart because the NAPL is lying in well-behaved, homogeneously distributed layers. Other sites have extremely complex and heterogeneous NAPL distribution and yield side-by-side TarGOST logs with significant differences. In these conditions it is certainly unfair to conduct co-sampling efforts for TarGOST validation and expect TarGOST to “match” the traditional sampling results. In this case, even though the NAPL is scattered here and there, the validation hole is considered to be “right” and the TarGOST log, if not matching, is considered “wrong”. In such heterogeneous environments even two side-by-side traditional sampling efforts might not come close to matching each other. So which one of the two traditional sampling locations is “right” and which one is “wrong” in this instance? Clearly neither is right or wrong, the site NAPL is simply heterogeneously distributed. Please keep this in mind when validation sampling against TarGOST as well.

The list below summarizes key aspects of deploying TarGOST at a former MGP or creosote site.

- TarGOST production averages between 10 and 20 locations/day and 200-500 ft/day, depending to large degree on subsurface conditions and difficulty in positioning the push platform over the desired location
- Proper utility clearance is the most important step in assuring a timely start and to prevent delays
- Start pushing in the “heart” of the source term to get a feel for the responsiveness of the TarGOST to your particular site’s NAPL, then work your way out to find the edges and bound the source term NAPL
- Be prepared to adapt your transect and grid to ever-changing site model as TarGOST logs are reviewed

- On large-scale projects, consider hiring a second crew to pre-probe and/or grout with a small Geoprobe or drill rig if regulations/conditions warrant. While we don't mind doing the pre-probing or grouting ourselves, we want to spend the majority of our time doing what it is we're getting paid to do – delineate the site's NAPL
- Can TarGOST tell the difference between residual and free phase NAPL? The answer is clearly "No". There is no exact concentration where all NAPLs make a magical transition from "heavy residual" to "saturated or free-phase". Likewise, there is no set %RE that we can cite as being representative of saturated or free phase NAPL, since the response is continuous with concentration. With that said, it is certainly possible to determine a certain cutoff or signal range that is representative of the residual to free-phase transition for your site. For instance, let's say that after examining all the TarGOST logs and comparing them to previous efforts and the validation sampling, the geologist notes that free phase existed at depths/locations where the TarGOST logs exceeded 50%. It's certainly reasonable then to make the assertion that the 50% RE level is a general cutoff for the absence/presence of free-phase. Just remember that the entire body of evidence for any particular site should be used to come up with your %RE number

If you have any questions regarding your past or future project, feel free to call or write to your TarGOST operator or Randy St. Germain at stgermain@dakotatechnologies.com.

UVOST™ USER'S GUIDE

Note: Dakota Technologies' ultra-violet wavelength laser-induced fluorescence tool is now named Ultra-Violet Optical Screening Tool (**UVOST™**). UVOST detects typical bulk petroleum, fuels, and light oils while TarGOST® is specifically designed to respond to coal tars and creosotes.

LASER-INDUCED FLUORESCENCE (LIF)

Fluorescence spectroscopy is one of the most widely applied spectroscopic techniques in use today. It is, by nature, a fast, sensitive and typically reversible process that makes it ideal for incorporation into a continuous screening technique that uses an optically transparent window as the conduit between the sensor and the analyte. Luminescence is the emission of light from any substance that returns to the ground state after being excited into an electronically excited state. If the bulk of the molecules emit their photons in less than a microsecond the emission is referred to as fluorescence. Emissions that take longer than this are called phosphorescence.

Fluorescence is typically observed in molecules that have an aromatic structure. One class of aromatics is the PAH found in quantity in typical petroleum products. The PAHs found in coal tars, creosotes and even sediments are also fluorescent, but they fluoresce much less efficiently than PAHs dissolved in more solvent-rich environments, such as the aliphatic body that makes up the bulk of fuels/petroleums. Dakota Technologies (Dakota) has observed that the less solvent available, the less efficiently the PAHs fluoresce. The PAHs continue to absorb the excitation light, but there is a much higher likelihood of the PAHs finding a non-radiative mechanism with which to shed the additional energy they picked up during the absorption of the excitation photon(s). In spite of this, the PAHs in sediments can still be coaxed into fluorescing well enough to allow in-situ laser-induced fluorescence screening via a sapphire-windowed probe.

A plot of the relative distribution of the different colors (or energies) of the photons being emitted by an excited sample of PAH is called the spectrum (or spectra when referring to more than one). Figure 1 illustrates the concept of PAH absorbance and fluorescence spectra. The spectra of individual PAH species (such as naphthalene and anthracene) can contain enough structure (peaks and valleys) to be identified in simple mixtures in the lab. The fluorescence of PAHs in sediments however, is originating from such a wide variety and concentrations of PAHs and differing local environments (dissolved phase, sorbed to particles, microcrystals, etc.) that the resulting spectra are very broad and contain very little "structure" that one might use to determine which individual PAHs are responsible for the fluorescence. The spectra do shift enough to recognize that the distribution of species or environments are changing, but individual speciation is impossible.

Another property of fluorescence that can be measured is the varying amount of time it takes for the molecules to emit the photons after exposure to a pulsed excitation source, such as a laser is illustrated in Figure 2. If we use a time sensitive detector to observe the number of photons being emitted over time, we can derive more information about the nature of the fluorophores and their environment. The different PAHs and the differing environments that exist in sediments all combine to change the decay times observed. This information is readily obtained when using a pulsed source such as the laser we used in this application. UVOST allows us to investigate not only what colors are being emitted, but also how long it takes for the excited population of PAHs to emit the fluorescence photons. We use a patented method of combining the photons from four regions of the emission spectrum optically collected over 20 nm wide sections of the emission spectra at 340, 390, 440, and 490 nm.

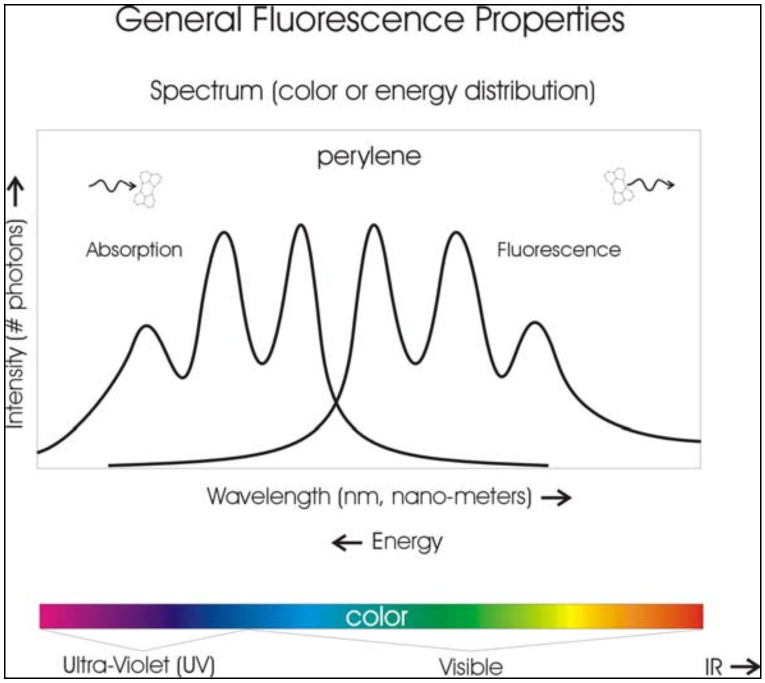


Figure 1. Spectral property of fluorescence

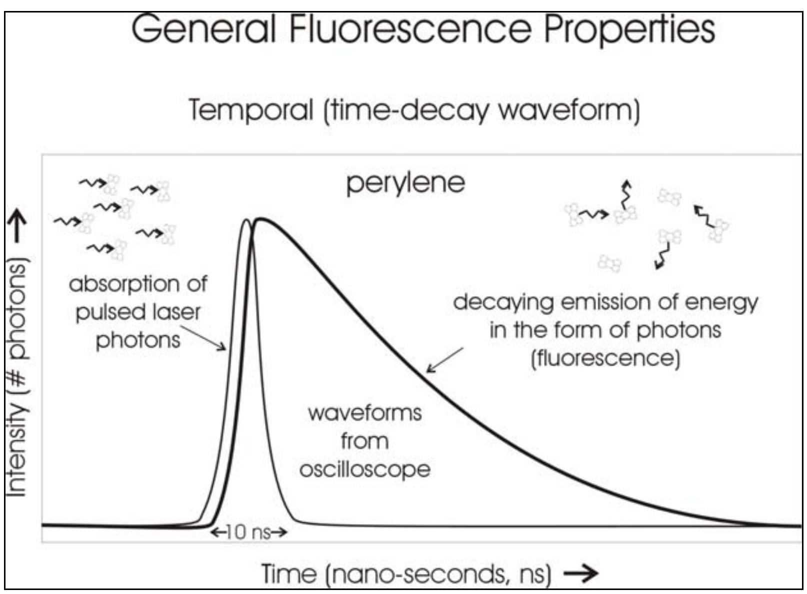


Figure2. Temporal property of fluorescence

These four "channels" are delayed in time through successively longer fiber optic delay lines and eventually arrive at the detector (photomultiplier tube or PMT). The resulting waveform is a unique measurement of both the spectral and temporal components of the fluorescence. This allows us to simultaneously observe the spectral and temporal qualities of the fluorescence. This technique is described in detail later in this report. It is these multi-wavelength waveforms, measured continuously and stored vs. depth, that ultimately serve as our indicator of PAH concentration vs. depth in the sediment.

Interferences

Nature has co-deposited a myriad of additional fluorescent materials in sediments that will also absorb the laser light and fluoresce intensely enough to complicate the measurement of the PAH fluorescence. Example materials include minerals such as calcites and a variety of biological materials. Both living organisms and their associated breakdown products (humic and fulvic acids) fluoresce well enough to interfere with the observation of the fluorescence of the target PAHs. This fluorescence, along with scattered excitation laser light and Raman light generated throughout the optical train (fiber optics) will ultimately make it back to the detector, mixed in with true PAH fluorescence, and must be accounted for in some fashion. Throughout this document we will refer to all these sources of non-PAH emitted photons as "background" fluorescence, even though the true source might well be non-fluorescent (scatter) in nature.

UNDERSTANDING UVOST FLUORESCENCE WAVEFORMS

Spectroscopic techniques involve probing the target matrix with light and learning about the contents of that matrix by analyzing the light that is emitted or absorbed by the target matrix. For screening tools it is crucial to glean as much information from this light as one can in as little time as possible. UVOST accomplishes this task in a novel fashion. The fluorescence data from UVOST is deceptively simple. There is a lot more going on in a UVOST waveform than one would imagine at first glance. It is actually a two-dimensional data set that contains three-dimensional fluorescence information. To complicate this, some of the information is overlapping. A full description of the multi-wavelength waveform data follows in order to give the reader an understanding of the data acquired during this study.

PAH time decay waveforms

Each type of PAH molecule (such as phenanthrene, naphthalene, or anthracene) emits fluorescence over a unique time period after being excited by a pulsed excitation source such as the laser used in UVOST. The emission starts out at maximum intensity, and then decays away at a rate unique to each type of PAH. The number of rings, the bonding between them, the amount of substitution on the rings, and other structural features of the molecule determine, to a great extent, the decay rate exhibited by a particular PAH. One class of molecule, the PCBs, have a structure that would seem to fluoresce well, but the chlorine substitution on the rings causes what is referred to as the heavy-atom effect, resulting in non-radiative relaxation from the excited state and a dramatic reduction in fluorescence. In fact the reduction is so significant that PCBs are essentially non-fluorescent molecules.

The environment in which the PAH exists also has a substantial influence on the decay rate. Quenching, which refers to any process that causes a decrease in the decay time (as well as the intensity) of the fluorescence, is dependent on conditions like oxygen levels, solvent availability, solvent viscosity, and a myriad of other matrix dependent conditions. An example of this can be found with the fluorescence of PAHs in fuels (gasoline, diesel, or kerosene) vs. coal tar oil. The coal tar oil can often contain more PAHs than the fuels, but the fluorescence lifetime is much shorter and the total fluorescence of fuels is often 2 to 3 orders of magnitude more intense. If one were to dissolve coal tar in a solvent such as hexane, its fluorescence intensity would rival that of fuels because the solvent matrix is simply more suited to allow fluorescence to occur.

Figure 3 illustrates the differing decay times one might observe for 4 different PAHs, along with the time profile of the laser pulse that excited them. Now remember, these are large populations of PAHs being excited and while some begin emitting immediately, other individual PAH molecules "wait" many nanoseconds before emitting a photon. What is plotted here is a picture of the distribution of times that the PAHs are remaining in the excited state before emitting photons. Now in our case (sediments) we have many different PAHs of differing ring number and substitution levels. The bold curve in Figure 3 illustrates the fluorescence decay profile that would result if we observed the fluorescence of all four PAHs simultaneously. This is the fluorescence waveform that would result if all 4 different PAHs fluoresced with equal intensity (normalized to keep it on scale). This same concept is happening in the sediments. We are observing the sum of all the decay profiles for all the different PAHs that are absorbing and emitting photons with each pulse of the excitation laser. It should be noted that there is no predictable trend between decay rate and structure like the trend that exists between spectrum and structure as described below.

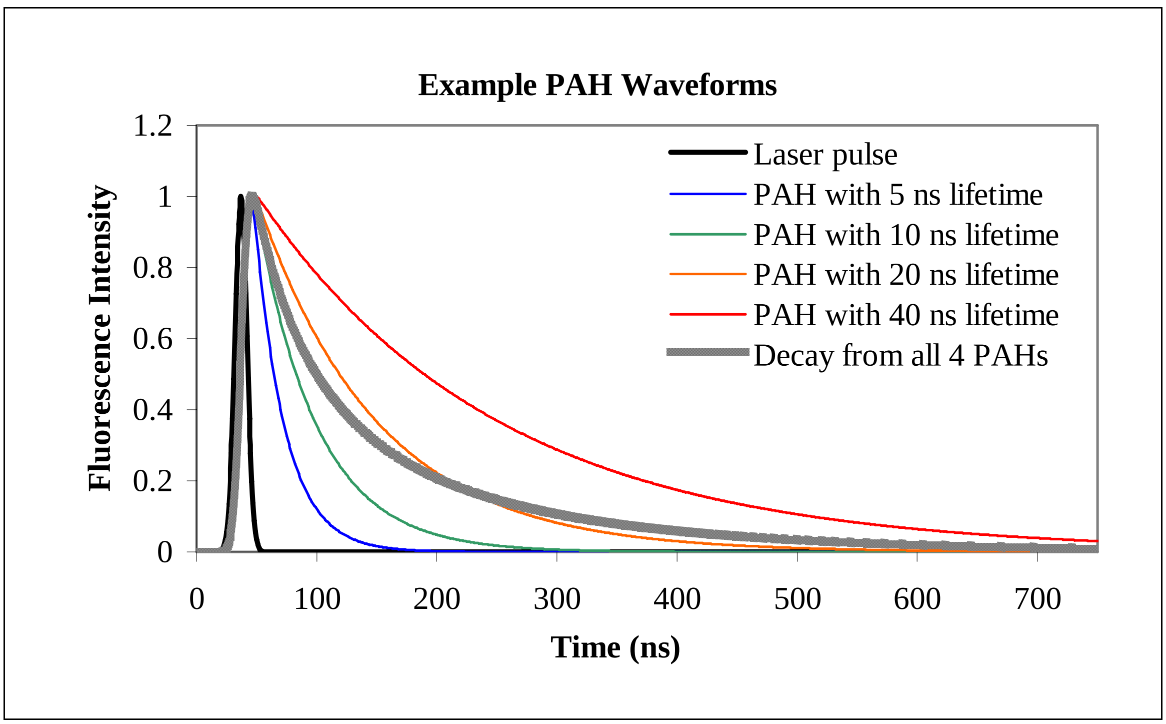


Figure 3. Temporal fluorescence examples

Of course the fluorescence decay profile observed in sediments is not made up of equal amounts of fluorescence from the various PAHs found in them. The wavelengths of light being emitted by (spectra) and the relative fluorescence yields of the different PAHs are all quite different, but the concept is still valid. The decay profile of the PAHs observed in the sediment results from the decay profiles of a mixture of different PAHs, along with fluorescence from other materials in the matrix.

PAH spectra

Let's take a look at the other property of the fluorescence emission of the same 4 example PAHs we showed at in Figure 3. This time we'll examine not the time over which they fluoresce, but instead the distribution of energies found in the photons they emit. Remember that the fluorescence emission spectrum of a pure PAH is simply a graphical representation of the energy distribution of photons that are emitted from a large population of the PAHs as they release energy that was absorbed from the excitation beam of light (in our case, a laser). Spectra of pure PAHs are typically acquired by dissolving a sample of the pure PAH in a pure solvent that does not fluoresce.

Figure 4 depicts the fluorescence emission spectra of the same 4 PAHs used in the temporal example in Figure 3. The laser wavelength is also shown in Figure 4, demonstrating the principle that fluorescence occurs at longer wavelength (lower energy) than the excitation wavelength (also known as Stokes' shift). The basic trend is toward longer wavelength emission as more rings are added or substitution increases. Naphthalene emits at around 340 nm and the spectra "red-shift" as the number of rings increase. Another general property of fluorescence is that for a pure PAH the emission spectrum remains the same irrespective of what wavelength of light is used to excite them (Kasha's rule). This is not true for mixtures however, because changing the excitation wavelength might well change which PAH are being excited and to what degree. The bold spectrum in Figure 4 is the combined spectra of all 4 PAHs. This is a simplified illustration of what generally happens if we observe the total fluorescence of a mixture of different PAHs. Any change in the relative amounts of the differing PAHs or changes in the matrix in which they exist will cause a change in the spectrum of light actually emitted.

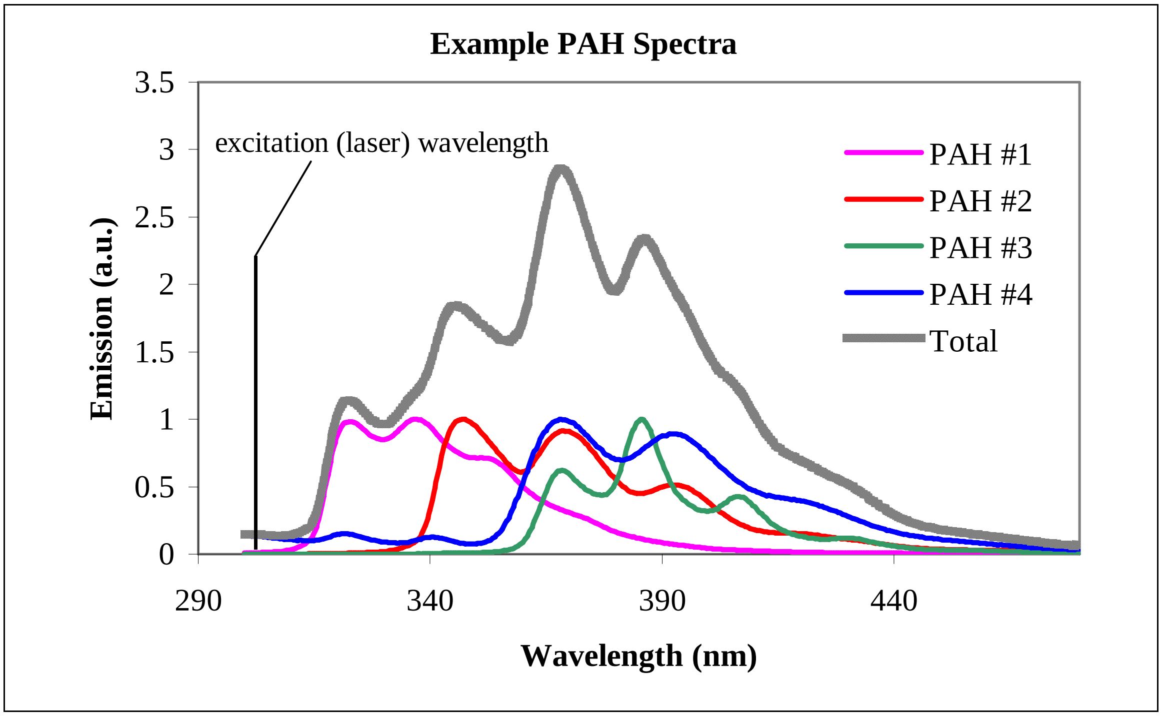


Figure 4. Spectral fluorescence examples

The fairly well defined structure (multiple peaks, valleys, and their various positions) of the spectra in Figure 4 suggests that perhaps one could use algorithms to extract information about the relative concentrations of the individual PAHs. While this is possible for very simple mixtures (2 to 3 PAHs) under controlled conditions, the algorithms quickly fail when many PAHs are present and interference fluorescence from humics, fulvics, and minerals is introduced. At best, one is able to use the overall shape of the total fluorescence spectrum to predict the *type* of mixture (diesel, coal tar, crude oil, etc.) and, in fact, this is routinely accomplished in environmental fluorescence forensics.

PAH multi-wavelength waveform (MWW)

The fluorescence of PAHs has both a spectral and temporal component. Real-world environmental samples typically contain at least several (if not dozens) of different PAHs along with other fluorophores, and the PAH fluorescence spectra overlap to form broad and fairly featureless spectral and temporal emission (compared to pure PAH spectra). If we were to record the temporal decay waveforms across the entire spectrum we would record what is called a wavelength-time matrix (WTM) that would describe the fluorescence emission completely. To create this we scan the emission selection monochromator from wavelength to wavelength, monitoring the pulsed emission vs. time at each wavelength with an oscilloscope.

Figure 5 contains the WTMs of diesel, jet, creosote, and gasoline on sand at several thousand ppm. The difference between the contaminants is clear and identification is straightforward. Dakota once employed these matrix style data sets to completely analyze the fluorescence of petroleum, oil, and lubricant (POL) contaminated soils. WTMs were (and still are) excellent for identifying/classifying the PAH fluorescence of environmental samples because of the unique information that both dimensions of PAH fluorescence exhibit when acquired in unison. While

WTMs make different contaminants readily discernable from one another, they are 3-dimensional and large. Also, the screening tool must be held still while the measurement is being made. All of these qualities make WTMs unwieldy for environmental screening tools that are designed to continuously log (typically 1 Hz) the presence of PAHs vs. time or depth.

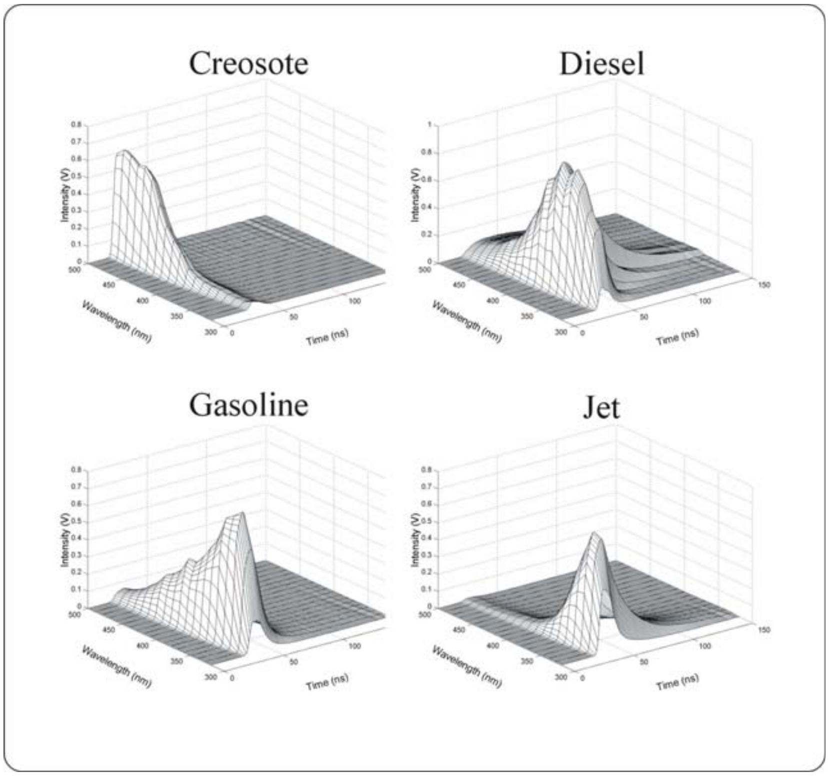


Figure 5. Example WTMs of common contaminants on sand

Because WTMs are so difficult to implement in screening mode, Dakota developed (and patented) a multiple-wavelength waveform (MWW) technique that allows multi-dimensional PAH fluorescence measurements to be acquired "on the fly". Figure 6 illustrates the concept. Select regions of the spectrum are monitored for their temporal response. The responses are optically delayed and recombined, and the resulting responses converge to form one two-dimensional waveform. There is sometimes overlap between the "channels" with long decay times, and the spectral regions being monitored are fewer and farther between than WTMs, but the resulting waveform still retains a unique combination of spectral and temporal fluorescence information that makes speciation and identification of PAH mixtures possible. Figure 7 illustrates the unique waveform produced by a variety of common PAH-containing environmental contaminants.

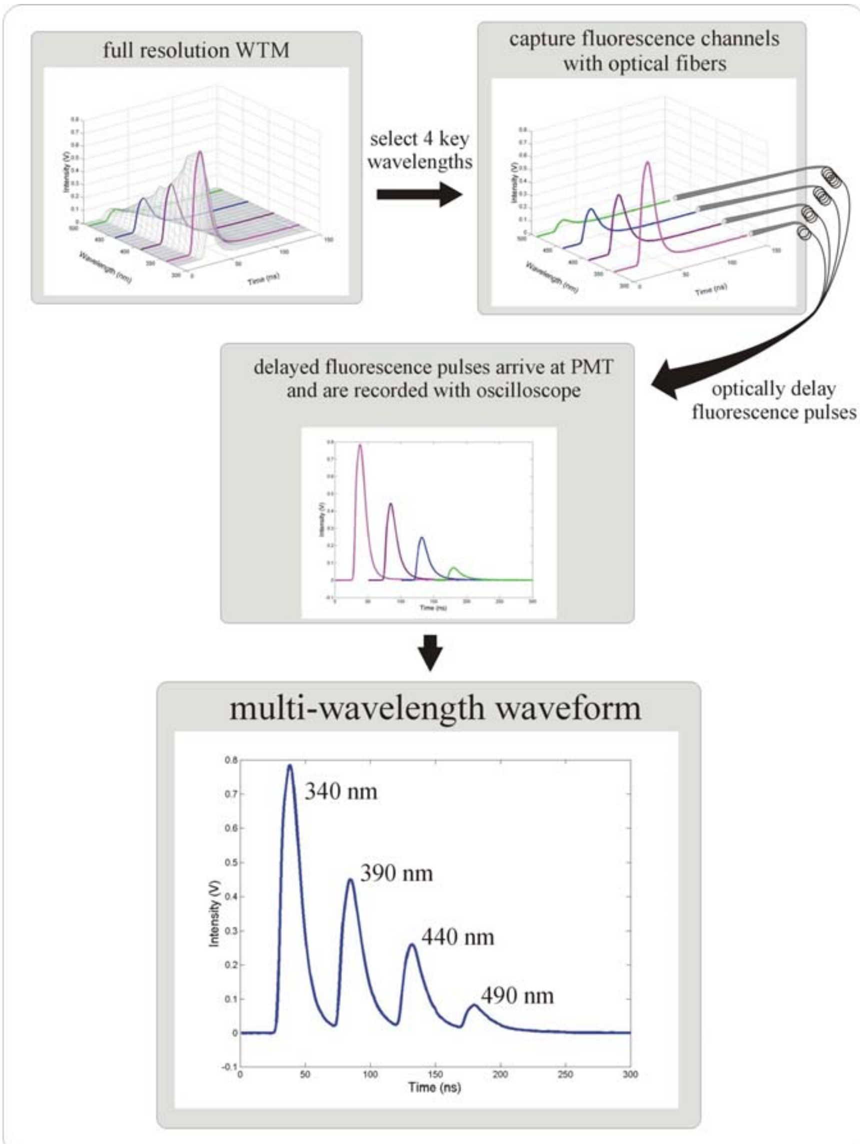


Figure 6. Multi-wavelength waveform concept

The UVOST system acquires waveforms at ~1 Hz and logs them to the hard drive continuously. As described below (see Calibration and normalization) the waveforms are integrated to achieve a quantitative result that is plotted vs. depth. The shape of the waveform yields information on the nature of the fluorescing material. With experience the analyst learns to look for changes or similarities in the waveform and is able to assess changes in the analyte concentration or the matrix. For instance, are the decay times for the various channels changing due to changes in the PAHs or perhaps changes in oxygen levels that affect quenching? Is the emission shifting to shorter or longer wavelengths due to changes in the amount of degradation via biological activity, weathering, or volatilization? Is the first channel (closest to the laser) getting more or less contribution from laser scatter due to improper mirror alignment? These and a myriad of other questions and answers can be gleaned from the shape of this simple, yet informative, data format.

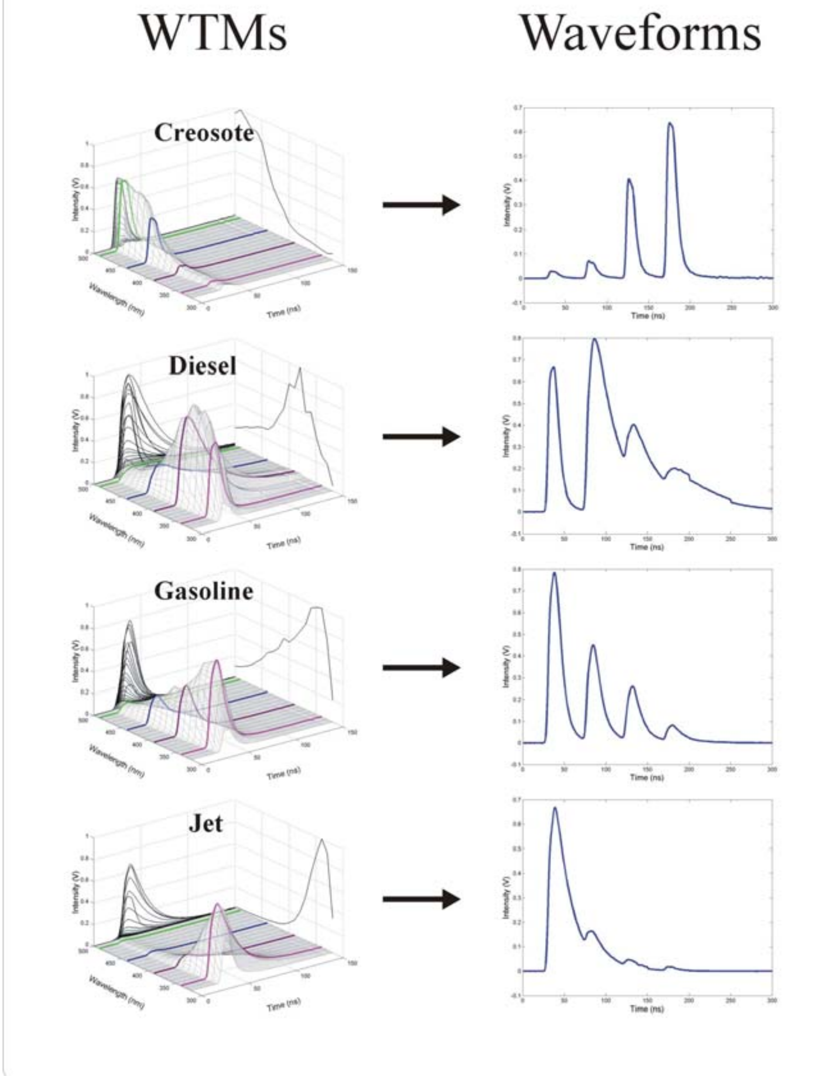


Figure 7. Waveforms of common contaminants

FVD colorization

The waveforms that are continuously logged vs. depth with UVOST contain a wealth of information, but to make this information easily interpretable in fluorescence vs. depth (FVD) log format, we need to further reduce the data to a one-dimensional data set that we can plot vs. depth. As discussed, the quantitative information is contained within the area under the waveform (total fluorescence) but how do we convert a waveform's shape into a singular entity? To accomplish this, Dakota has developed and implemented a novel technique that effectively converts the shape of the waveforms into colors. These colors are then used to fill in the area under the FVD that represents the total fluorescence measured at each point in the FVD. Figure 8, derived from data from a coal tar delineation project, illustrates the technique of colorizing the FVD according to the shape of the waveforms.

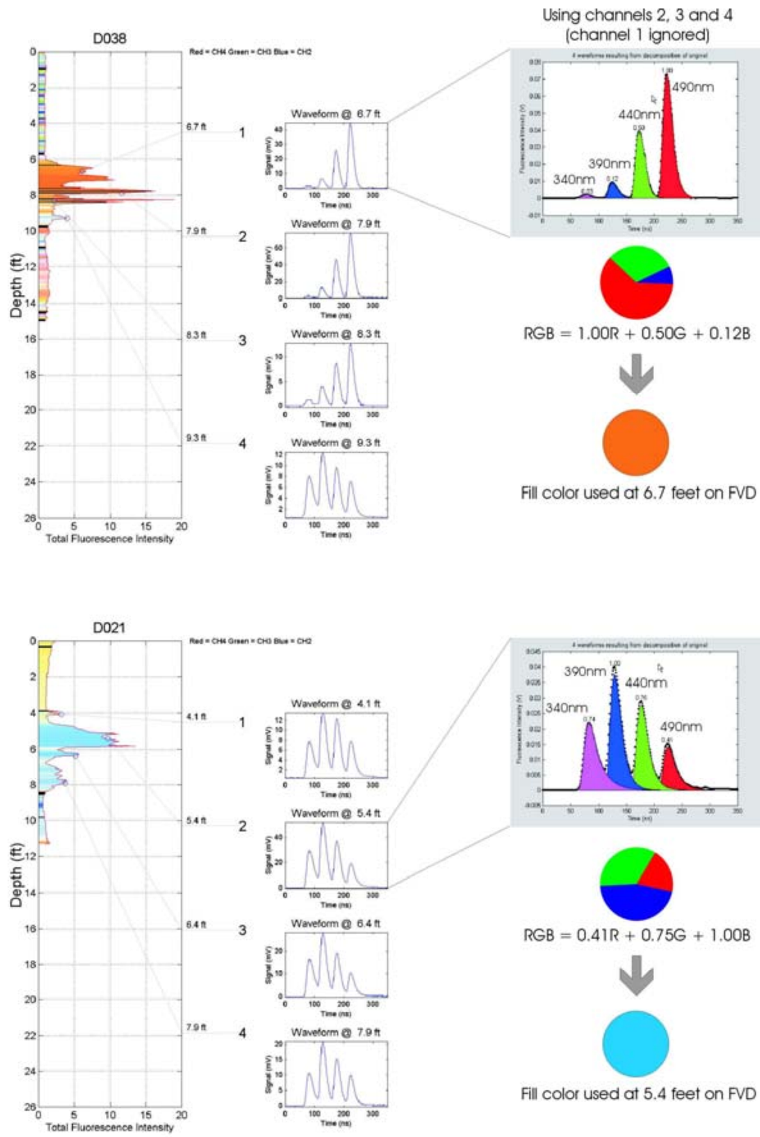


Figure 8. How color-coding is calculated

The result is a data presentation technique that allows the user to assess similarities or changes in the waveform shapes vs. depth by simply observing the colors that represent the shape of each and every waveform in the data set. This technique was used on the sediment measurements made in this project, both in the lab and in the field. It should be noted that the color black indicates that the algorithm that calculates the color failed to deconvolve the waveform successfully.

The colorization technique is limited to using three of the channels as a result of the red, green, and blue (RGB) color definition which computer colorization systems typically implement. A cyan, yellow, magenta, and black colorization system (CYMK) might allow the use of all four channels and is currently being considered as a replacement for RGB. The first three channels (340, 390, and 440 nm) were used to colorize the data in this study. The 490 nm channel was used in a quantitative sense, but was ignored for the colorization. It should be noted that a strictly temporal change (where only the decay times change, not the spectrum) would not necessarily result in a color change, since the ratios of the 3 channels used might remain constant even though the area under the waveform itself will increase or decrease.

An added benefit of this technique is that it provides insight in situations where non-linear response behavior is encountered. Many contaminants such as coal tars, heavy crudes, and creosotes do not fluoresce with concentration in a linear fashion. For instance, a 10 fold increase in PAH concentration might produce very little or no increase in total fluorescence intensity. However, a spectral or temporal shift often does continue to occur with changes in concentration due to energy transfer, photon cycling, and other phenomenon. The color of the FVD fill continues to darken or shift in color, acting as an indicator of a change in the fluorescence of the sample, alerting the analyst to a possible increase in concentration. While this technique is less than analytical it does provide the analyst with additional insight into the distribution of PAHs in the soil vs. depth.

Calibration and normalization

The UVOST system response depends on a host of factors. These include laser energy, fiber termination quality, neutral density filter selection, parabolic mirror efficiency, and fiber length, just to name a few. To account for changes in these over time and location, a single point calibration and system check is performed. A reference emitter (coined M1) is placed on the sapphire window and the response is measured. The M1 solution is permanently stored in a quartz cuvette for convenience and the measurement takes place through the wall of the cuvette. This proprietary mix of hydrocarbons fluoresces efficiently across the entire system and serves as both an indicator of system function and as a data normalization benchmark.

The total fluorescence intensity (area under the waveform) of M1 serves to normalize the data from the push that immediately follows the reference emitter measurement. All the FVD logs are presented as a percentage of the signal achieved with M1. The area under every waveform in the data set is integrated, resulting in a pico-Volt-seconds unit (picoseconds * V or pVs). These values are divided by the pVs measured for M1, and the result is multiplied by 100. The result is a log with x-axis units of percent of M1. This creates a normalized data set that takes into account the entire system performance, from end to end (laser to oscilloscope). The shape of the M1 waveform acts to guide the operator in assessing proper alignment of the detection system. The relative contribution for each channel and the shape of M1 waveform is monitored for consistency to insure that the waveforms remain consistent from day to day.