ARM Group Inc.

Engineers and Scientists

December 29, 2021

Ms. Barbara Brown
Project Coordinator
Maryland Department of the Environment
1800 Washington Boulevard
Baltimore, MD 21230

Re: CPA Combined Delineation Work Plan
for Groundwater Impacts at Area B:
Parcel B10 and Parcel B18
Tradepoint Atlantic
Sparrows Point, MD 21219

Dear Ms. Brown:

ARM Group LLC (ARM), on behalf of Tradepoint Atlantic (TPA), have completed multiple phases of investigation and delineation in the vicinity of the former Coke Oven Area (COA) – Parcel B10 and Tanks 10 and 11 (Parcel B18) of the Tradepoint Atlantic property located in Sparrows Point, Maryland. The objectives of this Combined Delineation Plan are as follows:

- Define the extent of recoverable or mobile NAPL in the identified NAPL areas in B10 and B18;
- Determine whether potentially recoverable or mobile NAPL is present in areas where NAPL was previously identified in soil borings or in piezometers / monitoring wells, but where no piezometers or monitoring wells currently exist and open boring accumulation tests were not conducted by Key (Key Environmental, October 9, 2015);
- If NAPL is observed in sufficient quantities (LNAPL thickness over 0.5 ft), determine NAPL recoverability.
- Determine the extent of NAPL between Cell 6 and CO08A-PZM,
- Determine the extent of dissolved phase impacts observed at CO08-PZM005 and CO08B-PZM.
- Determine the extent of the NAPL observed at CO04-PZM004.
- Determine whether NAPL observed at CO05B-PZM and CO05D-PZM extends further upgradient (to the north). This was a regulatory comment on the Former Coke Oven Area Northeast Delineation Letter (dated September 2, 2021).

- Determine if dissolved phase impacts in the shallow zone at CO08-PZM005 and the intermediate zone at CO08-PZM036 are migrating to the southwest. This was a regulatory comment on the Former Coke Oven Area Northeast Delineation Letter (dated September 2, 2021).

A summary of some of the recent investigations and associated data gaps is presented below. **Figure 1** shows the location of all soil borings and whether or not NAPL was identified in the soil borings. **Figure 2** shows the location of current and abandoned monitoring wells in the shallow groundwater zone as well as NAPL presence. **Figure 3** shows the location of current and abandoned monitoring wells in the intermediate groundwater zone as well as NAPL presence.

Pre-Design Investigation Summary Report (Key Environmental, October 9, 2015):

- The extent of LNAPL in the vicinity of Cell 6 appears to be limited to the confines of the cell as historically defined. Multiple soil borings were advanced in and around Cell 6 to determine NAPL presence and recoverability. Piezometers were not installed to determine NAPL presence and / or thickness on the groundwater table, but several soil boreholes were left open for one to two weeks as part of the open borehole study, and then gauged for the presence of NAPL. Locations within Cell 6 indicated NAPL thickness of up to 1 feet, while locations outside of Cell 6 showed either no NAPL or trace NAPL only. The below table summarizes soil borings outside of Cell 6 with NAPL identified in the soil core (based on a review of the borehole logs and with descriptions of residual or free product), and the result of the open borehole test (if conducted).

Boring Number	Depth (feet bgs) of NAPL in SB	Open Borehole Test?	NAPL Status (2015 Key Report)
Soil Borings to the West of Cell 6			
CO146-SB016	9.4-16	Yes	None
Soil Boring to the South of Cell 6			
CO176-SB016	3.4-14.4	Yes	Trace
Soil Borings to the North of Cell 6			
CO149-SB016	6.0-14.2	Yes	None
CO152-SB016	4-16	Yes	Trace
CO153-SB016	3.4-16	No	
CO185-SB016	7.2-12.9	No	
CO186-SB016	11.0-14.6	Yes	None

Soil Borings to the East of Cell 6			
CO158-SB016	9.0-13.9	Yes	None
CO160-SB016	7.8-15.6	No	
Soil Borings to the Southeast of Cell 6			
CO177-SB016	1.9-15.0	Yes	None

The locations where NAPL was observed in soil borings are also shown on **Figure 1**. The Key Report concluded that "Some possible free product is present below the water table beyond the limits of Cell 6 but is unlikely to be recoverable based on the results of the open borehole study".

- LNAPL at various locations was found to exhibit different physical properties indicating some of the LNAPL may have a different source. The LNAPL encountered at monitoring well CO04-PZM004 is significantly different in density than that in Cell 6. Soil borings advanced between Cell 6 and CO04-PZM004 (including CO161-SB016 and CO162-SB016, refer to Figure 1) did not identify recoverable NAPL. The Key Report concluded that this provides further evidence that the LNAPL at the CO04-PZM004 location is not associated with releases at the former benzol plant.

No. 10 Tank Area Investigation Report (ARM, January 6, 2020):

- NAPL detected in multiple locations in soil bores, including along the southern Parcel boundary at B18-MMM-SB, B18-KKK-SB, and B18-JJJ-SB (no locations further south or southwest were installed, refer to **Figure 1**). There are no piezometers or monitoring wells currently to the south/southwest of the parcel boundary between Parcels B10 and B18.
- NAPL was identified in soil boring B18-S-SB, located within Parcel B10. Impacts were not delineated to the west or south, refer to **Figure 1**. There are no piezometers or monitoring wells currently in the vicinity.
- Both LNAPL and DNAPL have been identified at various locations throughout Parcel B18. During the most recent gauging event (November 2019), DNAPL was identified in multiple locations in the vicinity of Tank No. 10 and the cut off wall (B18-045-PZ, BA-81-7941, BA-81-7942, BA-81-7943, BA-81-7944, SW-084-MWS, SW-085-MWS, and SW-086-MWS, refer to **Figure 2**). Only trace LNAPL was identified in these locations. LNAPL has been previously identified at the former B18-082-PZ location with thickness of more than 1 feet detected during several gauging events. As per the recommendations in the No. 10 Tank Area Report, the source of the LNAPL impacts at B18-082-PZ appears to be independent from the DNAPL (and associated dissolved phase constituents) in the

No. 10 Tank Area. As stated in the report, additional investigation may be required in the vicinity of B18-082-PZ based on the possibility of an alternative contaminant source.

Coke Oven Interim Measures 2020 Progress Report (ARM, February 1, 2021):

- A pneumatic skimmer pump was installed in CO173 to recover LNAPL in February 2020. During 2020, the pneumatic skimmer pump in CO173 recovered an estimated 4,673 gallons (34,244 pounds) of LNAPL. There are no piezometers or monitoring wells to the north of CO173, to determine if additional LNAPL recovery wells would be beneficial from this area.

Northeast Delineation Report (ARM, September 2, 2021):

- The Northeast Delineation field work was completed in April 2021 to delineate groundwater contamination in the vicinity of groundwater monitoring locations CO05-PZM006, CO08-PZM005, CO08-PZM036, and CO212-MWS. Field work included the installation of eight shallow zone delineation piezometers and two intermediate zone delineation piezometers.
- Based on the results and regulatory comments on the Former Coke Oven Area Northeast Delineation Letter (dated September 2, 2021), additional delineation should be considered for the following areas:
    - Additional delineation of NAPL to the northeast of CO05D-PZM.
    - Additional delineation of dissolved phase impacts to the north (upgradient) of the CO05B-PZM.
    - Additional delineation of dissolved phase impacts to the west and southwest of CO08-PZM005 (shallow zone) and CO08-PZM036 (intermediate zone).
- As part of the Northeast Delineation Report, benzene and naphthalene isocontour maps were created for both shallow and intermediate zone groundwater. . Refer to **Figure 4** (Shallow Zone Groundwater Benzene Isocontours), **Figure 5** (Shallow Zone Groundwater Naphthalene Isocontours), **Figure 6** (Intermediate Zone Groundwater Benzene Isocontours), and **Figure 7** (Intermediate Zone Groundwater Naphthalene Isocontours).

<u>Delineation Scope</u>

Multiple rounds of investigation and delineation in the vicinity of the former COA – Parcel B10 and Tanks 10 and 11 (Parcel B18) have been completed. However, several data gaps remain. The proposed additional delineation includes both test pits (particularly in areas where NAPL delineation is required) and monitoring well installation (in areas where dissolved phase delineation is required). The field work will be conducted in two rounds, with the test pitting to occur first:

- Four test pits to delineate the extent of potentially recoverable or mobile NAPL north of CO173 and Cell 6 and south of the Tank 10 area in Parcel B18.
- Two test pits to the west and north of CO04-PZM004 to delineate NAPL impacts and determine if the impacts are related to an upgradient source.
- One test pit to the northeast of CO05D-PZM to delineate NAPL impacts, and one test pit to the north (upgradient) of CO05B-PZM to determine if the NAPL / dissolved phase impacts are related to a local hot spot or another source further upgradient.
- One test pit between Cell 6 and CO08A-PZM, to determine the extent of NAPL impacts.
- One test pit to investigate NAPL potential alternate source at B18-082-PZ (piezometer was previously abandoned).

The second round of field work will include monitoring well installation:

- Two shallow zone monitoring wells to the west and southwest of CO08-PZM005 and to the southwest of CO08A-PZM to delineate dissolved phase impacts.
- One intermediate zone monitoring well to the southwest of CO08-PZM036 to delineate dissolved phase impacts.

The locations of the proposed shallow test pits and monitoring wells are shown on **Figure 2**, and the locations of the proposed intermediate delineation monitoring wells are shown on **Figure 3**.

Proposed Field Work

All investigation activities will be conducted in accordance with ARM's Standard Operating Procedures (SOPs) and the property-wide Health and Safety Plan (HASP). All field work will be conducted in accordance with the Field SOPs (refer to Appendix B). Several SOPs are applicable to all field work, including **Field SOP No. 005 Investigation Derived Waste Management**, **Field SOP No. 010 Field Logbook**, **Field SOP No. 011 Sample Handling**, **Field SOP No. 016 Equipment Decontamination**, and **Field SOP No. 017 Calibration of Field Instruments**.

Field Work Round 1 – Test Pits

As previously mentioned, the field work will be conducted in two rounds. The first round of field work will include test pits in nine locations to delineate NAPL impacts. The test pits will be completed using an excavator. Each test pit will be completed with approximate dimensions of 10 feet long by 4 feet wide. Each Test Pit will be excavated to a depth of approximately 5 feet into the groundwater table. Test pitting will be conducted in accordance with the methods specified in **Field SOP No. 015 – Test Pitting**. The objectives of the test pitting investigation are to:

1. document the encountered subsurface materials with a photograph log;
2. observe and document (i.e., make a determination of) the types of encountered materials;

3. observe and document any visual/olfactory evidence of NAPL, along with the physical characteristics and apparent mobility of the NAPL; and
4. observe and document the quality of any groundwater infiltrating into test pits (observed discoloration, sheen, free product).

The final excavation boundaries will be recorded in the field using a hand-held GPS. The test pits will not be backfilled until MDE approval is received. During the waiting period prior to backfilling, the test pitting area will be secured by flagging using caution tape (or similar). The test pits will ultimately be backfilled using MDE-approved materials.

<u>Excavated Material Handling and Disposal</u>

As material is excavated, it will be screened using a hand-held photoionization detector (PID) as well as visual and olfactory methods to determine if there is evidence of NAPL contamination. Soil with PID readings greater than 10 ppm or indicators of NAPL contamination will be segregated and placed in designated stockpiles (not to exceed 500 cubic yards) adjacent to the excavation. These impacted stockpiles will be kept separate from stockpiled soil which appears to be clean based on field indicators. All impacted soil will be placed on polyethylene sheeting or concrete. All impacted stockpiles will remain covered by polyethylene when they are not being used in order to minimize dust and prevent run-on/runoff. A weighted cover system shall be used to keep the covers in place. The impacted stockpiles will be covered at the end of each day.

The material from the non-impacted stockpiles will be considered for replacement as backfill within the excavation or for placement elsewhere on the property under areas designated to be capped by approved surface engineering controls. No material will be replaced on the property without the prior approval of the MDE. Impacted material, if encountered, will be properly disposed of at an appropriate facility.

<u>Product Removal</u>

Following the completion of test pits, they will be examined for the infiltration of NAPL. If NAPL is observed to accumulate in the test pits, various material removal methods will be considered. Depending on the rate of accumulation, a vacuum truck or sorbent materials may be used to remove any accumulated NAPL in the test pits. Approximate volumes of NAPL removed from the test pits will be recorded and reported to the MDE.

Field Work Round 2 – Monitoring Wells

The second round of field work will include the installation of monitoring wells to delineate dissolved phase groundwater impacts. ARM proposed the installation of two shallow zone groundwater monitoring wells (refer to **Figure 2** for proposed locations) and one intermediate zone groundwater monitoring well (refer to **Figure 3** for proposed location). Following review of the findings from the test pit program, additional shallow zone monitoring wells may be installed in the vicinity of test pits based on discussions with TPA.

Each groundwater collection point will be installed in accordance with the procedures referenced in **Field SOPs Number 014** (Monitoring Well Construction). An ARM geologist will log and screen the soil cores at each location with a PID in accordance with **Field SOP Number 012** (Geologic Logging). A total of two 2" monitoring wells will be installed in the shallow aquifer with 20 slot screens. Borings will be advanced to at least 7 feet below the water table, with the final well depth, the screen length, and the screened interval to be determined in the field. One 2" monitoring well will be installed in the intermediate aquifer (refer to **Figure 3** for proposed locations), with borings advanced to a maximum anticipated depth of 60 ft bgs, with the final well depth, the screen length, and the screened interval to be determined in the field.

Immediately after installation, each groundwater monitoring well will be gauged to determine depth to water and NAPL presence (if applicable) using an oil-water interface probe in accordance with **Field SOP Number 019** (Depth to Groundwater and NAPL Measurements). Then, all groundwater monitoring wells will be developed in accordance with **Field SOP Number 018** (Well Development). If measurable NAPL or a sheen is present, a groundwater sample will not be collected, but additional delineation activities may be warranted in accordance with standard practices. All installed monitoring well locations will also be surveyed.

Additional existing locations will be gauged to determine depth to water and NAPL presence (if applicable) in order to gain a more complete understanding of current groundwater flow and NAPL thickness at the Site. Specifically, the following shallow groundwater locations will be gauged: BA-81-7946, BA8-7944, SW-086-MWS, CO05-PZM006, CO05A-PZM, CO05B-PZM, CO05D-PZM, CO08-PZM005, CO08A-PZM, CO212-MWS, CO212A-PZM, CO32-PZM004, CO20-PZM004, CO04-PZM004, CO21-PZM005, CO42-PZM004, CO03-PZM005, CO171, CO172, CO173, and CO174. Refer to **Figure 2** for locations of shallow groundwater wells to be gauged. The following intermediate groundwater locations will be gauged: CO08-PZM036, CO08C-PZM, CO08D-PZM, CO212-MWI, CO04-PZM048. Refer to **Figure 3** for locations of intermediate groundwater wells to be gauged.

For newly installed monitoring wells with no NAPL, ARM personnel will conduct low flow groundwater sampling in accordance with the **Field SOP Numbers 006** (Groundwater Sampling) and **007** (Groundwater Low-Flow Sampling), which includes the use of laboratory supplied sample containers and preservatives, a peristaltic pump, dedicated sample tubing, and a water quality multiparameter meter with a flow-through cell. Groundwater samples will be submitted to Pace Analytical Services Inc. (PACE) to be analyzed for Target Compound List (TCL) Volatile Organic Compounds (VOCs) via USEPA Method 8260 and TCL polynuclear aromatic hydrocarbons (PAHs) via USEPA Method 8270 SIM.

In accordance with the Site-Wide NAPL Transmissivity Work Plan (ARM, dated September 1, 2021), NAPL transmissivity testing is proposed for location CO05D-PZM in order to assess sub-surface NAPL mobility at various locations in order to support alternatives assessments in upcoming Corrective Measures Studies. If LNAPL is identified in any of the proposed new locations with thickness of over 0.5 feet during any of the gauging events (0-hour, 48-hour, or 30 day), then NAPL transmissivity testing will be conducted in accordance with the manual skimming field method described in the ASTM standard E2856-13 and the previously submitted Work Plan.

If NAPL is identified in the vicinity of B18-082-PZ, a NAPL sample will be collected and submitted to Torkelson Geochemistry Inc. for hydrocarbon matching analysis. This will allow comparison to previous analysis of NAPL in the Tank 10 area, to determine if B18-082-PZ NAPL impacts are related to the Tank 10 groundwater impacts or a separate source. In addition, if NAPL is identified in any test pits proposed to the north of Cell 6 and appears to be different than what has previously been observed in Cell 6 or the Tank 10 footprint, then a NAPL sample will also be collected and submitted for hydrocarbon matching analysis.

Any IDW generated during the supplemental sampling activities (soil cuttings, purged groundwater, decontamination fluids) will be immediately containerized in 55-gallon drums. All IDW will be appropriately characterized prior to disposal.

Reporting

The findings of this delineation will be provided in a Delineation Report. The Delineation Report will include all field forms (monitoring well installation logs, groundwater purge sheets, calibration sheets, etc), tabulated results, figures, and lab reports. The Report will be prepared and presented to the MDE and United States Environmental Protection Agency (USEPA) following receipt of the data and TPA review.

If you have questions regarding any information covered in this document, please feel free to contact Peter Haid at Tradepoint Atlantic: 443-649-5055.

Respectfully Submitted,
ARM Group Inc.

Kaye Guille, P.E., PMP
Senior Engineer

T. Neil Peters, P.E.
Senior Vice President

Attachments:

Attachment A – Figures
Figure 1: Soil NAPL Locations
Figure 2: Shallow Groundwater NAPL Locations
Figure 3: Intermediate Groundwater NAPL Locations
Figure 4: Shallow Zone Groundwater Benzene Isocontours
Figure 5: Shallow Zone Groundwater Naphthalene Isocontours
Figure 6: Intermediate Zone Groundwater Benzene Isocontours
Figure 7: Intermediate Zone Groundwater Naphthalene Isocontours

Attachment B – Field SOPs

ATTACHMENT A
FIGURES

CO121-PZM
CO37-PZM003
CO122-PZM
CO42-PZM004
CO03-PZM005
Interim Measures Cell
Soil Boring (no NAPL)
Soil Boring (NAPL)
Extraction Well
Parcel Boundary
Former Tank Location (Approximate)
Parcel B10 - Coke Oven Area
Soil NAPL Locations
December 22, 2021
Figure
1
ARM Group LLC
Engineers and Scientists
0 25 50 100
Feet
Tradepoint Atlantic
Sparrows Point
Baltimore County, MD
ARM Project 21010210

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Parcel B10 - Coke Oven Area
Intermediate Groundwater NAPL Locations
November 10, 2021

Figure 3

ARM Group LLC
Engineers and Scientists

Tradepoint Atlantic
Sparrows Point
Baltimore County, MD
ARM Project 21010210

Parcel B10 - Coke Oven Area Shallow Groundwater Benzene Isocontours

December 22, 2021

Figure 4

ARM Group LLC
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Tradepoint Atlantic
Sparrows Point
Baltimore County, MD
ARM Project 21010210

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B18-080-PZ
B18-079-PZ
B18-083-PZ
B18-034-PZ
B18-059-PZ
B18-047-PZ
SW-084-MWS
BA-81-7945
BA-81-7943
BA-81-7942
B18-045-PZ
B18-077-PZ
SW13-PZM003
SW-085-MWS
B18-044-PZ
BA-81-7941
BA-81-7946
SW-086-MWS
BA-81-7944
B18-017-PZ
B18-078-PZ
B18-081-PZ
B18-082-PZ
B18-046-PZ
CO121-PZM
CO37-PZM003
CO186-SB016
B18-061-PZ
CO122-PZM
CO42-PZM004
Cell 2
CO05B-PZM
trace
CO05D-PZM
1.11 ft
CO03-PZM005
CO152-SB016
CO171
CO22-PZM005
CO158-SB016
CO172
CO216-MWS
CO173
CO21-PZM005
CO187-MWS
CO005-PZM006
CO174
CO149-SB016
CO05A-PZM
CO04-PZM004
1.18 ft
CO176
CO126
CO18-PZM006
CO175
CO79-PZM
Cell 6
CO80-PZM
CO190-MWS
CO177-SB016
CO05C-PZM
CO100-PZM
CO02-PZM006
CO20-PZM004
trace
Cell 1
CO146-SB016
CO176-SB016
CO32-PZM004
CO93-PZM
CO19-PZM004
CO08A-PZM
0.06 ft
CO88-PZM
CO08C-PZM
CO192-MWS
CO17-PZM005
CO212A-PZM
CO16-PZM006
CO09-PZM007
CO212-MWS
CO08-PZM005
CO07-PZM008
CO212B-PZM
0.30 ft DNAPL
CO24-PZM007
CO08B-PZM
CO08D-PZM
Cell 5
LEGEND
Proposed Combined Delineation
Test Pit
Well
Well/Piezometer (abandoned; no NAPL)
Well/Piezometer (existing; no NAPL)
Well/Piezometer (abandoned; NAPL)
Well/Piezometer (existing; NAPL)
Key Open Borehole Test (no NAPL)
Key Open Borehole Test (Trace NAPL)
Former Tank Locations (approximate)
Interim Measures Cell
Naphthalene (ug/L)
<10
10-100
100-1,000
1,000-10,000
10,000-100,000
100,000-1,000,000
Parcel Boundary
Parcel B10 - Coke Oven Area Shallow Groundwater Naphthalene Isocontours
December 22, 2021
Figure 5
ARM Group LLC
Engineers and Scientists
0 25 50 100 Feet
Tradepoint Atlantic
Sparrows Point
Baltimore County, MD
ARM Project 21010210
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Cell 2
Cell 6
Cell 1
Cell 5
CO04-PZM048
CO02-PZM041
CO08C-PZM
CO212-MWI
CO08-PZM036
CO07-PZM050
CO08D-PZM
Proposed Combined Delineation Locations
Well/Piezometer (no NAPL)
Interim Measures Cell
Benzene (ug/L)
<10
10-100
100-1,000
1,000-10,000
10,000-100,000
100,000-1,000,000
Parcel Boundary
Parcel B10 - Coke Oven Area
Intermediate Groundwater Benzene Isocontours
November 10, 2021
Figure 6
ARM Group LLC
Engineers and Scientists
0 25 50 100 Feet
Tradepoint Atlantic
Sparrows Point
Baltimore County, MD
ARM Project 21010210

Parcel B10 - Coke Oven Area
Intermediate Groundwater Naphthalene Isocontours
November 10, 2021

Figure 7

Tradepoint Atlantic
Sparrows Point
Baltimore County, MD
ARM Project 21010210

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ATTACHMENT B
FIELD STANDARD OPERATING PROCEDURES

SOP No. 005
INVESTIGATION-DERIVED WASTES MANAGEMENT
STANDARD OPERATING PROCEDURE
Rev. 02

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1 SCOPE

This Standard Operating Procedure (SOP) identifies the general guidelines for the management of investigation-derived wastes (IDW). The anticipated IDW that will be generated includes, but is not limited to:

- Drill cuttings and Drilling fluids generated from soil borings or wells installations;
- Groundwater generated during well development, monitoring well purging, aquifer testing, remedial activities, or other operations;
- Light Non-Aqueous Phase Liquids (LNAPL) and Dense Non-Aqueous Phase Liquids (DNAPL);
- Waste water and sediment generated during equipment decontamination procedures;
- Used personal protective equipment (PPE); and
- Miscellaneous debris.

2 EQUIPMENT

IDW Management requires limited equipment. The following should be available on-site:

- Clean, new 55-gallon drums with lids;
- Socket and/or adjustable wrenches
- PPE
- Grease pen, paint, or paint stick for labeling
- Labels to indicate drum contents, media, and origin
- Plastic sheeting (if necessary)
- Spill containment berms (if necessary)
- Caution tape

3 PROCEDURES

3.1 Containerization

- All potentially impacted materials generated during any investigation or remedial activity must be containerized unless one of the exceptions described below under Item 10 apply. Unless directed otherwise by the client, containers (drums, frac tanks, roll-off boxes, etc.) are to be provided by the consultant or contractor.
- All potentially impacted materials shall be placed in new or reconditioned 55-gallon (DOT-UN1A2) drums. All drums brought onsite must be clean and in sound condition, free of any rust, dents, holes, or other types of damage.
- Various types of waste materials (e.g., soils, groundwater, PPE, etc.) must be containerized separately without exception. Additionally, dry and wet soils should be containerized separately, if feasible.
- Materials generated from various plant process areas, which may require potentially different waste classifications, should be containerized separately. As an example, soils generated in the vicinity of a surface impoundment which managed sludge from the treatment of wastewater from wood treating operations that use creosote and/or pentachlorophenol (EPA Hazardous Waste K001) should be containerized separately from soils generated in a creosote drip track area (EPA Hazardous Waste F034). Likewise, materials generated at off-site locations should be managed separately from those generated on-site.
- If possible, drums should be filled to approximately 90% capacity. As necessary, drums containing liquids should have enough freeboard to prevent rupture in the event of freezing.
- Containers inside of containers are not permitted by waste management regulations. As a result, PPE must be placed directly into the drum. **Do not place PPE in a plastic bag and in turn place the plastic bag into a drum.** This constitutes a violation of waste management regulations. Similarly, all soil samples must be removed from jars or plastic bags and the jars crushed or plastic bags torn prior to being placed in a drum.
- All lids and gaskets must be securely fastened prior to moving from one location to another. The consultant or subcontractor is responsible for transporting containers to an on-site temporary staging area as directed by the Facility Waste Management Director. Containers must be loaded, transported and unloaded in a safe manner.
- The exterior of all containers must be thoroughly cleaned prior to staging. All mud, dirt or debris must be removed, with no exception. Waste management facilities will not accept containers which are visibly dirty on the outside.
- Under no circumstances shall non-waste materials or general trash be placed in waste containers. The consultant/subcontractor should provide a dumpster for management of non-waste materials and general trash.
- Pending analysis, all groundwater and/or decontamination liquids may be discharged into the on-site treatment system in accordance with the existing discharge permit.

3.2 Container Designation and Labeling

- Each container will be assigned a unique designation. This designation should include a sequential number associated with each waste type, a code which identifies the type of waste (e.g., "S" for soil, "GW" for groundwater, etc.), and the date the material was placed in the container (e.g. 1-GW-12/12/15; 2-GW-12/12/15 etc...). The container designation must be clearly marked on the lid and the side of the container prior to transport to the temporary on-site staging area. The markings must be made in a manner such that the markings are legible, highly visible and permanent (i.e., weather resistant). A "Mean Streak®" grease pen or a paint stick is recommended for marking the container.
- A "Non-Hazardous Waste" label shall initially be affixed to the exterior side of the drum at a location at least two-thirds of the way up from the bottom of the container. Under the optional information section on the label, the following statement may be included "Material Classification Pending Results of Analysis".
- If IDW is known to be hazardous, the following information shall be placed on all "Hazardous Waste" labels and affixed to the container:
    - Description of contents (i.e., purge water, soil cuttings);
    - Characteristics of waste (i.e. waste code or hazard class);
    - Generator information (i.e., name, address, contact telephone number);
    - EPA identification number (supplied by on-site client representative);
    - Date when the waste was first accumulated.
- The following information is to be recorded by field personnel in the field logbook, as necessary:
    - Container Designation;
    - Contents;
    - Date that the container was filled;
    - Location where the drums are staged;
    - Location where the material was generated;
    - Relative moisture content for soils, e.g., dry, moist, wet, saturated;
    - Approximate volume or percentage of the container filled.

3.3 Container Storage

- All containers are to be transported to an on-site staging area, all container handling and moving must be conducted in a safe manner. Contractors are responsible for providing the necessary equipment (e.g., front-end loader, fork lift with drum grappler, etc.) to provide for safe and efficient staging of containers. **Figure 1** shows the location of the on-site IDW accumulation and staging area.

- All containers shall be stored in a neat and organized fashion with all labels clearly visible. Containers shall not be stacked.
- Containers holding materials of different waste classifications should be staged together to facilitate loading of the materials onto transport vehicles.
- To the extent practicable, all containers should be protected from the elements.
- If stored outdoors in an area where precipitation could accumulate, all containers must be placed on pallets.
- In accordance with DOT requirements, all containers must be rust-free and in sound condition for shipment.
- Prior to demobilization, field personnel should conduct an inspection of the container storage area to ensure all containers are clearly marked, clean and staged in a neat and organized manner.

A section of the on-site staging area shall be secured and designated as the "hazardous waste storage area". The following requirements for the hazardous waste storage area must be implemented:

- Proper hazardous waste signs shall be posted;
- Secondary containment to contain spills;
- Spill containment equipment must be available;
- Fire extinguisher;
- Adequate aisle space for unobstructed movement of personnel.

3.4 Waste Material Inventory

An inventory of IDW, stored at the project site, should be maintained in the field logbook and entered in to the Project File following demobilization at the site. Hazardous IDW may be stored in the on-site staging area for a maximum of 90 days before it must be manifested and shipped to the designated facility provided in Section 3.6 (below). MDE will be notified within 24 hours of any hazardous waste determination and the date this material entered the IDW accumulation and staging area. Information contained in the IDW inventory should include the following:

- Activity or project phase related to waste generation;
- Type of container;
- Container designation;
- Container contents;
- Generation date;
- Staged location;
- Location where IDW was generated;
- Relative moisture content for soils;
- Volume or percentage contained;

- Comments; and
- Date removed.

3.5 Waste Material Sampling and Analysis

Composite samples of the containerized materials for laboratory analysis may be collected for each IDW media. The results of the analysis may be used for waste profiling purposes required by the waste management facility and/or waste classification purposes. To the extent practicable, historical information, site-specific analytical data and knowledge of the waste composition should be utilized to minimize sampling and analysis requirements.

- Specific details regarding the number and types of samples to be collected, required laboratory turn-around time, analytical parameters and analytical methods will be determined on a project-specific basis during the initial planning phase. If applicable, this information may be presented in a project-specific waste management plan.
- At a minimum, samples must be collected and handled in accordance with standard industry protocols. If an approved project-specific Sampling and Analysis Plan or Quality Assurance Project Plan exists, then sample collection and handling procedures, as specified therein, must be followed.
- All analyses must be performed using the appropriate analytical methods specified in EPA SW846 "Test Methods for the Evaluation of Solid Wastes".
- The sampler must complete and maintain copies of all chain-of-custody documentation.
- In accordance with Subpart CC or 40CFR Par 264/265 which became effective on December 6, 1996, hazardous wastes containing greater than 500 parts per million by weight total volatile organic compounds (VOCs), are subject to the emission control requirements of this rule. Determination of VOC content may be made through laboratory analyses or generator knowledge. Thus, analysis for VOCs will likely be required by the waste disposal facility for profiling purposes in the future. Analysis is to be performed using method 25D in 40CFR Part 60 Appendix A, or through the use of an approved alternate method. Knowledge-based waste determinations must be thoroughly documented.
- Composite samples of similar waste classification of containerized materials will be profiled based on the characteristics presented in 40 CFR Part 261 Subpart C - Characteristics of Hazardous Wastes:
  - §261.21 – Characteristic of Ignitability
  - §261.22 – Characteristic of Corrosivity
  - §261.23 – Characteristic of Reactivity
  - §261.24 – Toxicity Characteristic
- All laboratory analysis for waste characterization must be performed within 45 days of the generation date.

3.6 Transportation and Disposal

All hazardous and most non-hazardous IDW will be transported off-site by Clean Venture or Clean Harbors to a permitted treatment and disposal facility. Non-hazardous drill cutting may be disposed of on-site at the Greys Landfill.

All analytical results, disposal facilities and volumes and type of IDW generated for each Parcel will be provided to MDE prior to transport off-site.

Contact:
Will Kerr – Project Manager
Clean Venture, Inc.
2931 Whittington Avenue
Baltimore, MD 21230
Phone (410) 368-9170
Fax (410) 368-9171

Kevin Malone – Project Manager
Clean Harbors Environmental Services, Inc.
EPA ID: MDD980554653
3527 Whiskey Bottom Road
Laurel, MD20724
Phone: 301.939.6000
Fax: 301.939.6066

SOP No. 006
GROUNDWATER SAMPLING
STANDARD OPERATING PROCEDURE
Rev. 03

1 SCOPE

This Standard Operating Procedure (SOP) identifies the general guidelines for the collection of groundwater samples from monitoring wells, piezometers (including those installed via direct push borings), and extractions wells. Groundwater samples are collected to gather information regarding inorganic and organic constituents in the groundwater, as well as water quality or natural attenuation indicator parameters. This SOP discusses and is limited to the procedures utilized for the physical collection of groundwater samples.

Effort must be made to ensure that the sample collected is representative of the particular zone being sampled.

Due the numerous methods and equipment that may be employed in the collection of groundwater samples, this SOP should be used in conjunction with project-specific documentation, i.e., work plans or sampling and analysis plans.

Low-flow sampling is preferred for groundwater sample collection. In certain instances, however, complete low-flow methodology may not be able to be employed (e.g., small diameter temporary piezometers). Specific low-flow sampling techniques are provided in SOP#007.

2 EQUIPMENT

Groundwater sampling may require a significant amount of equipment and materials. In general, purging and sample collection from a monitoring point can be achieved by the use of a pump or bailer. The type of pump or bailer utilized will depend on the characteristics of the well and aquifer, data quality objectives, availability of a power source, and often, which suite of parameters are being analyzed from the sample. Regardless of sampling methods, the following equipment should be mobilized at the site prior to sample collection, unless otherwise specified in project-specific documentation:

- Water Quality Multi-meter (for the measurement of temperature, pH, dissolved oxygen, conductivity, oxidation-reduction potential (ORP), and, if necessary, turbidity)
- Tubing of appropriate material for groundwater discharge
- Filtration apparatus (as needed)

- Water-level meter or depth sounder, and NAPL-level meter
- Field logbook
- Sampling/Purge sheets
- Distilled Water
- Sample containers
- Sample labels
- Indelible ink pen
- Decon materials
- 5-gallon buckets
- Twine
- PPE
- Chain-of-Custody forms (COCs)
- Coolers
- Paper Towels
- Garbage bags
- Nitrile or Latex Gloves
- Eye Protection
- Measuring Cup
- Stopwatch
- Tape
- Calibration Solutions
- Bailers
- External Power Source
- First Aid Kit
- Stop Watch
- Calculator
- Well lock key(s)

A number of pump types may be used for the collection of groundwater samples, each having inherent advantages/disadvantages. If pumps are used in groundwater sampling, the type of pump should be specified in project plan, including dedicated pumps present in the sampling monitoring points. The following presents a list of various pump types that may be used in groundwater sample collection:

- Suction Lift Pumps
    - Limited to shallow depths to water.
    - Readily available, portable, and inexpensive.
    - May cause unrepresentative volatilization of low-levels of Volatile Organic Compounds (VOCs).

- Portable Submersible Pumps
  - May be used to sample several monitoring wells in a brief period of time.
  - Relatively large pumping rates can be accommodated.
  - May be limited by size of well casing.
- Air Lift Pumps
  - Portable and light weight.
  - Can handle very deep depths to water.
  - Capable of producing very high flow rates.
  - Air contacts sample causing volatilization.
    - Not recommended for sampling of organic parameters
    - Not recommended for pH sensitive parameters
  - Requires compressed air tank or air compressor.
- Bladder pumps
  - Portable and light weight.
  - Drive gas does not touch sample.
    - Acceptable for all groundwater analyses
  - Slow pumping rate.
  - Requires compressed air tank or air compressor.

Bailers of various materials (materials should be inert or not cause interference with target parameters) are commercially available at various lengths and diameters. Bailers may be top filling or bottom draining. If bailers are to be used, the appropriate bailer type should be specified in the project-specific documentation.

3 SAMPLE LOCATIONS

Sample locations shall be specified in the project-specific documentation, if temporary points (or direct push points) are to be located in the field, these locations shall be located as close as possible to those specified in the approved work plan.

Effort should be made to ensure that the collected sample is representative of the particular zone or depths being targeted.

4 PROCEDURES

The site-specific or project-specific Health and Safety Plan (HASP) shall be reviewed prior to sampling. All requirements of the HASP should be maintained for the duration of the sampling. Any unforeseen hazards not specifically referenced in the HASP, identified by the sample shall be reported to the Project Manager prior to proceeding with field activities.

Several methods or combination of methods may be used to collect groundwater samples from monitoring wells. The chosen methodology(ies) will depend on the parameters to be analyzed, depth of the well, diameter of the well, depth to groundwater, and the required volume of water. Where practical, dedicated or disposable equipment should be used for purging and sample collection to reduce field decontamination requirements and minimize the potential for cross contamination of samples.

Several tasks need to be completed prior to actual sampling of each well. These activities are summarized as follows:

- Check that the proper sample bottles have been received from the laboratory;
- Decontaminate any non-dedicated equipment prior to sampling;
- Measure the static water level prior to purging. Water levels should be measured to nearest 0.01 foot and recorded. If water levels will be used to determine groundwater flow or hydraulic gradients, all measurements should be taken on the same work day over as short a period of time as possible. A record of the static water level shall be maintained on the sampling logs and the Field Logbook;
- The ground surface around the well shall be covered with plastic sheeting.

4.1 Equipment Calibration

Equipment Calibration shall be performed in accordance with the procedures and requirements defined in SOP No. 017 *"Calibration of Field Instruments"*. Records of equipment calibration shall be maintained in the Field Logbook.

4.2 Well Purging

Wells will be purged until at least three casing volumes of water are removed from each well or until the stabilization criteria, as follows, are met:

- pH: ± 0.1 s.u.
- Specific Conductance/Conductivity : ± 3%
- Oxidation-Reduction Potential: ± 10 millivolts
- Turbidity: ± 10% or less than 5 NTU
- Dissolved Oxygen: ± 0.3 mg/L

Measurements should be taken every three to five minutes and recorded on the groundwater sampling/purge log for the low flow sampling method. For the casing volume approach, measure and record the six field parameters after each casing volume is removed from the well. Stabilization is achieved after all parameters have stabilized for three successive readings. In addition, temperature readings shall be recorded along with the aforementioned stabilization parameters.

In order to calculate the volume of water in a well (well volume), the inner casing diameter, total depth of the well, and depth to water must be known or measured. The well volume can be calculated as follows:

Well Volume, V (gal) = π x **well radius** x (**well depth – depth to water**) x **7.48**,

Where:

Well depth, well radius, and depth to water are in feet, and
7.48 is the factor to convert ft^3 to gallons.

If a well is purged dry prior to removal of three well volumes or stabilization, purging is considered complete. Groundwater samples will be collected once a sufficient volume of groundwater has accumulated in the well to completely fill the necessary sample containers. To verify the removal of the required well volumes during purging, a graduated bucket will be used to measure purge water quantities.

Measure the necessary purge volumes by pumping or bailing into a graduated bucket. If the purged water contains a nonaqueous phase (free product) or it is required by the sampling plan, the graduated bucket should be intermittently emptied into a larger storage container (see SOP #005 *Investigation-Derived Waste Management*). If possible, this purge water can be delivered to an onsite treatment system. If an onsite treatment system is not available, options for management of the purge water will be based upon the results of analyses. If no free product is present and the water is not a hazardous waste, the purged water may be disposed of on the ground, away from the top of the well, and in the downgradient direction. If sufficient water is not present for purging of the required volumes, the well should be bailed or pumped dry and permitted to recharge prior to sampling. The time required for purging should be recorded in the field notes and on the Groundwater Well Purge Sheet.

4.3 Sample Collection

After water level recovery, the well should be sampled within 24 hours of completion of the purge event. Dedicated or decontaminated equipment should be used to collect each sample; if practical, low-flow or low-stress sampling techniques should be used (see SOP # 007). If a flow-thru cell was used for the measurement of stabilization parameters, this should be removed prior to sampling. The sampling technician should wear a clean pair of surgical gloves for each well. Samples will be collected in decreasing order of their volatility. This order is generally as follows:

- Volatile Organic Compounds (VOCs)
- Total Organic Halides (TOX)
- Total Organic Carbon (TOC)
- Semi-Volatile Organic Compounds (SVOCs)

- Pesticides and Polychlorinated Biphenyls (PCBs)
- Metals
- Total Phenols
- Cyanide
- Other inorganic parametes, e.g., chloride, nitrate, sulfide, et cetera
- Radionuclides

Samples collected for volatile organics should be carefully placed into 40 ml glass vials with Teflon® septum lids. No air bubbles should be present in the vial after sealing the septum lid; if air bubbles are present, the sampler will collect a new sample to replace the corrupted sample vial. Other common laboratory-provided sample bottles include polyethylene or clear glass for metals and amber glass for phenols and semi-volatiles.

In situations where analysis of dissolved metals is required, field filtration of each sample will be necessary.

After filtering, samples requiring preservatives are preserved and all containers are securely placed in coolers and chilled to an appropriate temperature (usually < 4°C). Each cooler containing samples will contain a completed chain-of-custody form or tag.

4.3.1 Field-filtering for dissolved metals

Groundwater samples collected for dissolved metals analyses will be filtered prior to placement in sample containers. Groundwater sample filtration will be performed using a 0.45 micron, in-line water filter which will minimize contact with air.

Filters should be pre-rinsed with groundwater to ensure the filter media has equilibrated to the sample (following manufacturer recommendations, or passing through a minimum 1 liter of groundwater prior to collecting the sample).

When sampling via bailers, filtering is performed using peristaltic pumps with disposable funnels/filters. New silicone tubing is used in the pump head for each sample filtered and new Teflon tubing is used from the pump head to the filter.

When sampling via pumps, the filtration of groundwater samples shall be performed either directly from the monitoring well or from intermediate sample containers. Groundwater shall then be filtered and discharged from the filtration apparatus directly into sample containers.

All aqueous samples collected for metals analyses must be acidified to a pH of < 2 using trace metal grade nitric acid and cooled to a temperature of ≤ 6°C. In addition, all dissolved metal samples must be filtered within 15 minutes.

5 QUALITY ASSURANCE/QUALITY CONTROL

All data must be documented on field data sheets or within field logbooks. All instrumentation must be operated in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in the work plan. Instrument and equipment manuals can be found in Appendix E of the QAPP.

Equipment calibration activities must occur prior to sampling/operation, and they must be documented in the Field Logbook.

Sample management; including COC, handling, packing, and shipping procedures shall be in accordance with the procedures and requirements of *SOP No. 011 "Sample Handling, Packing, Shipping and Chain of Custody"*.

Once samples have been placed into the appropriate sample containers, sample ID, sample location, and sample date and time of collection should be recorded on the sample label. This information shall be consistent with what is recorded on the chain-of-custody (COC).

All sample container(s) will be packed in a cooler on ice or ice packs to maintain the holding temperature of 4 degrees C or less.

Field QC samples should be collected as required per the project work plan or project planning documentation.

6 SAMPLE ANALYSIS

The project specific work plan should be consulted prior to sampling to determine which analytical methods are required and are appropriate to satisfy project data needs. Groundwater samples will generally be analyzed for the complete project analyte list for groundwater provided on Worksheet # 15 of the QAPP; however, certain project tasks will have target analyte lists limited to a subset of the complete list, as detailed in the task specific work plan. Worksheets 19 and 30 of the QAPP shall be consulted for specifications regarding sample containers, preservation, and hold times.

SOP No. 010
FIELD LOGBOOK
STANDARD OPERATING PROCEDURE
Rev. 03

1 SCOPE

This Standard Operating Procedure (SOP) describes the procedures and requirements for entering information in a field logbook maintained for environmental investigations. The field logbook will act as the primary source of documentation for field activities. Moreover, the field logbook(s) may serve as the primary legal record of field operations and any occurrences associated with those operations. The requirements and procedures set forth in this SOP are designed to ensure that all field activities are sufficiently and properly documented.

This SOP is not designed to specifically address all of the entries that may be required for a given project. It is intended to supplement project-specific documentation; including work plans, sampling and analysis plans, health and safety (H&S) plans, quality assurance project plans, and additional SOPs, as appropriate, in order to ensure proper documentation.

It is the responsibility of the project manager and the field team leader to ensure that field logbook entries provide sufficient information for the completion of a detailed and accurate description of all field operations. Complete, detailed, and accurate field log book entries are essential to:

- Ensure that the level of data collection associated with field activities is sufficient to support the successful completion of the project;
- Ensure that all changes or deviations from project work plans are documented;
- Ensure that quality control is maintain over the duration of the project;
- Ensure that the administrative requirements of the project are met;
- Ensure that there is sufficient information so that a detailed summary of field activities can be independently compiled by non-project affiliated personnel at a later date; and
- Ensure that an accurate record of field operations can be presented in any legal proceedings that may arise.

The field team leader managing field logbook(s) should have a minimum of one (1) year of field experience. In addition, all field personnel shall be versed in the SOPs relevant to their specific tasks and possess the required skills and experience necessary for the successful completion of the desired field operations.

2 EQUIPMENT

The required materials for documentation of field activities in the field are presented below.

- Permanently bound, water-resistant notebook.
- Indelible ink ball point pen or fine-tipped Sharpie® pen.
  - Ink shall not bleed through the page and become visible on the reverse side of the page,
  - In the instance where weather conditions preclude the use of a pen, indicate so in the field logbook and use an alternate writing instrument.
- Ziploc® baggie or other weather-proof container to protect the field logbook from the elements.

3 PROCEDURES

Field personnel should be familiar and compliant with the site-specific or project-specific Health and Safety Plan (HASP) prior to undertaking field operations. All requirements of the HASP should be maintained for the duration of the field work.

All entries in the field log must be legible and archivable. The field logbook should never be exposed to the elements or conditions that may moisten the pages and smear the ink. When not in the field, the field log book shall be stored in a location where it will be easily accessible to field crews. Each field crew shall maintain a single log book. The field manager is responsible for ensuring that the field crews properly follow the procedures provided herein.

All entries shall be made in English and legible non-cursive print. On the front cover of the field logbook the following shall be recorded in indelible ink:

- Project Name;
- Project Number;
- Project Location;
- Project Phase (if applicable);
- Title and Date of Work Plan being followed:
- Applicable Appendix A Field SOP referenced in the Work Plan (field personnel must have copies of these SOPs in the field);
- The date field activities associated with that logbook commenced;
- The date field activities associated with that logbook; and

- If more than one logbook is associated with the project or project phase, the record number of the logbook, e.g., Book 1 of 2, or Vol. 1 of 2.

On the inside front cover of the logbook, include the following in indelible ink:

- "If found, please return to [Company Name]";
- The appropriate return address and associated phone number;
- The name of the person to which the field logbook is assigned; and
- The name of the project manager.

The first page of the logbook shall be reserved for a table of contents. If the first page of the logbook is a title page, reserve the second page for a table of contents. The last five (5) pages of the logbook shall be reserved for important contacts, notes, reminders, health and safety information, et cetera. If the pages are not pre-numbered, the field manager or designee shall number the front and back of each page at the bottom of the page.

For each day of field work, the following should be recorded in the field logbook, as applicable:

- The month, day, and year at the top right hand corner of the next available full page;
- The project name;
- Time of arrival;
- Name and affiliation of the person keeping the logbook;
- Work site location;
- Names and affiliations of any people on-site related to the project, including contractors, subcontractors, visitors, agency personnel, client representatives, etc. and their time of arrival and time of departure;
- A brief description of the work to be performed;
- A list of active equipment on-site;
- Prevailing weather conditions and weather-related delays;
- A brief summary of any H&S meetings or tailgate meetings;
- Any special precautions taken with regard to H&S;
- A record of instrument calibrations and checks;
- A record of any approvals for field changes to the scope of work;
- A record for the basis of field changes to the scope of work;

- Sampling event descriptions, including methodologies, sample numbers and volumes, descriptions of samples, time of collection, and name of collector;
- Technical measurements made in the field including indications of anomalous measurements;
- A record of any project related phone calls;
- A record of any project related meetings on-site;
- References to GPS or survey data used or collected;
- Descriptions of equipment used in field activities;
- Maps, diagrams, or sketches as needed to document sample locations;
- A record of any downtime, the basis for such downtime, and any corrective measures employed;
- Equipment issues encountered and the resolution of such issues;
- Any pertinent factual observations, including the collection of QA/QC samples, damage to equipment or sampling locations; accidents, field personnel overtly not following direction, et cetera.
- Management and disposal of any investigation derived wastes.
- A record of significant photographs taken, including camera used, photographers name, and direction and view angle of the photographs;
- Periodic time entries on the left hand side of the page to reference entries in the field book without a timestamp; and
- Time of departure

At the end of each day, the person keeping the logbook or designee shall sign and date each page where entries were made for that day. Unused space at the end of page shall be marked with a diagonal line, signed, and dated. Entries for the subsequent day shall begin on the next full available page. The field team leader shall also sign and date the final daily entry page of each field crew's logbook, after verify the day's activities.

Field logbook entries shall be made in the field at the site, as close as possible to the correlated observation, not at a later time or different location. Supplemental entries to the logbook may be made at a later time. All supplemental entries must be clearly identified as such, with the basis for the supplemental entry clearly stated. Supplemental entries shall be signed and dated by the person making the entry and the field team leader.

If any entry to the logbook is changed, strike out the deleted text or item with a single line such that the entry remains legible, initial, and date the change. Changes should only be made by the person that made the initial entry.

Problems identified in the field logbook must be brought to the attention of the project manager or the field team leader as soon as possible. Problems may be reported in person or on the telephone and a record of the conversation shall be maintained in the logbook. In the instance that the problem does not need immediate resolution, i.e., it does not affect health, safety, the environment, or the effective continuation of work; the problem may be recorded on a daily log form and transmitted to the project manager or field team leader that day.

4 QUALITY ASSURANCE

Each completed page of the field logbook must be scanned for electronic archiving at periodic intervals, and at a minimum on weekly basis. This will ensure that copies of the field notes are available in the event the field logbook is lost or damaged, and that in such an event the loss of data is minimal. It will also ensure that field data can easily be disseminated without the risk of physically sending the field logbook. The project manager shall review the scanned copies of the field notes as they become available to ensure legibility and that data quality objectives are met. Field logbook scans will be included in applicable data reports to EPA Region III and MDE.

Completed field logbooks should be archived with the project files, if completed field logbook entries are needed in the field for continued operations, this data should be available as copies and not the original completed field logbook.

As always, project personnel should be mindful that the field logbook may be produced in court.

SOP No. 011
SAMPLE HANDLING, PACKING, SHIPPING AND CHAIN-OF-CUSTODY STANDARD OPERATING PROCEDURE
Rev. 02

1 SCOPE

This Standard Operating Procedure (SOP) describes the procedures and requirements for sample management; including chain-of-custody (COC), handling, packing, and shipping procedures. The purpose of this SOP is to specify sample management techniques so that the potential for cross-contamination, tampering, misidentification, sample loss, and breakage are minimized. Moreover, these techniques are designed to ensure that samples are maintained in a controlled environment from the time of collection until receipt by the analytical laboratory. This SOP is generally applicable for the collection of aqueous and solid samples (e.g., soil, sediment, or sludge). Detailed handling procedures for soil gas and air samples are provided in the relevant SOPs; however the shipment and chain-of-custody procedures for those samples shall be governed by the requirements herein.

2 EQUIPMENT

The following list provides materials that may be required for each project where samples are to be collected. Project-specific documents and sample collection requirements should be reviewed prior to initialize field operations:

- Indelible ink pens or markers (fine-tipped) of blue or black ink;
- Polyethylene re-sealable bags;
- Clear packing tape and duct tape;
- Chain-of-custody forms;
- Shipping labels, as applicable;
- Custody seals or tape;
- Gloves (disposable latex or nitrile);
- Appropriate sample containers and labels;
- Sample preservatives, if not provided in sampling containers;

- Insulated coolers;
- Wet ice of a sufficient amount to maintain 4°C temperatures during the collection and transfer of samples;
- Cushioning and shock-absorbent material, e.g., bubble wrap or air-filled packaging bags; and
- Field log book.

3 PROCEDURES

Field personnel should be familiar and compliant with the site-specific or project-specific Health and Safety Plan (HASP) prior to undertaking sample collection activities. All requirements of the HASP should be maintained for the duration of the sampling.

Field personnel should review project requirements and select appropriate supplies prior to field mobilization. This review includes ensuring that appropriate sample containers with applicable preservatives, coolers, and packing material have been supplied by the laboratory. Sample holding times should be familiarized prior to mobilization. Any analysis with holding times less than 48 hours should be specifically noted so that proper planning is initiated to ensure that these holding times are not exceeded.

Field personnel should be familiar with or should be notified by the project manager of any applicable dangerous goods shipping regulations relative to the samples being collected. This may include U.S. Department of Transportation (DOT) and International Air Transport Association (IATA) regulations. Potential samples requiring compliance with DOT regulations include Methanol-preserved volatile organic compound (VOC) soil samples and non-aqueous phase liquids (NAPL).

Some sample containers provided by the analytical laboratory contain preservatives. The preservatives must be retained in the sample container and should, in no instance, be rinsed out. Preservatives may be corrosive and standard care should be exercised to reduce the potential contact to personnel skin or clothing. If spillage is observed, project safety procedures should be followed. If the sample container caps are broken or missing, do not use the container for collection and discard the bottle.

Appropriate caution should be used when handling glass sample containers. 40 mL vials can be prone to breakage when tightening lids, particularly amber glass vials which are thinner.

3.1 Chain-of-Custody Procedures

- Prior to sample collection, complete the header on the chain-of-custody (COC) by filling in the project number, project name, contact person, sampler name, and other relevant project specific information. An example chain-of-custody is provided at the end of this SOP.

- COC entries must be printed legibly using indelible black or blue ink.
- After sample collection, enter the individual sample information on the COC.
  - Sample Identification indicates the sampling location. A sample identification (ID) system (or Station Designation Scheme) will be used to identify each environmental sample collected as described in the Data Management Plan (Appendix C of the QAPP). This ID system will provide a tracking procedure so that information about a particular sample collected from a specific location can be retrieved easily and accurately. This system also will ensure that each sample is unique and will not be confused with any other sample. The first part of the sample ID will represent the area of the Site (facility/site association) where the sample was collected. It will be comprised of two components: two letters, or a letter and a number. For example, sample locations within Parcel A1 will be given a label beginning "A1", while sample locations within the Coke Oven area will be given a label beginning with "CO". See **Table 5-1** in Appendix C of the QAPP for all location designations. The next three numerals designate the sample location number (sequential station number). The next two letters will represent the matrix and method of collection (station type/purpose). These will be designated as SB for Soil Boring, PZ for Piezometer, or MW for Monitoring Well. The final set of numbers will indicate the depth at which the sample was collected. Each part of the sample ID for a location will be separated by a dash. For example, a sample ID of A1-001-SB-05 would designate the soil sample was collected from a soil boring at Location 001 in Parcel A1 at a depth of five feet bgs, and A1-001-PZ-15 would designate the groundwater sample was collected from a piezometer at Location Number 1 in Parcel A1at a depth of 15 feet bgs.
  - List the date of sample collection. The date format to be followed should be mm/dd/yy (e.g., 01/10/15) or mm/dd/yyyy (e.g., 01/10/2015).
  - List the time that the sample was collected. The time value should be presented using 24-hr format, i.e., 3:20 p.m. should be entered as 15:20.
  - Mark in the appropriate column(s) on the COC if the sample is a composite sample (i.e., collected over a period of time or from several different locations and mixed prior to placing in the sample containers) or a grab sample (i.e., a single sample from a single time or location). The COC has a field prompting the sampler to indicate the sample was collected as a composite, by entering a "c", or a grab by entering a "g". Lower-case print should be used to avoid confusion.
  - Any preservative contained in the sampling container should be noted.
  - The analytical parameters that the samples are being analyzed will be pre-printed on the columns. If additional analyses are required, they should be written legibly on the extra columns. As much detail as possible should be presented to allow the analytical laboratory to properly analyze the samples. For example, semi-volatile organic compound (SVOCs) analyses should be represented by entering "SVOCs"

and "Method 8270D." Multiple methods and/or analytical parameters may be combined for each column (e.g., PCBs/8082,SVOCs/8270D). These columns should also be used to present sample-specific parameter lists (e.g., Appendix IX + Chromium VI). Each sample that requires a particular parameter analysis will be identified by placing the number of containers in the appropriate analytical parameter column. For metals, in particular, it may be necessary to indicate what metals are required.

- Indicate the number of containers for each method requested.
- If applicable, note which samples should be used for site-specific matrix spikes.
- Indicate any special project requirements.
- Indicate the requested turn-around time.
- Provide the relevant contact information (name, phone number, and e-mail) in the event problems or questions are encountered by the analytical laboratory.
- If applicable, provide the laboratory task order forms.
- The "Remarks" or "Comments" field should be used to present special analytical requirements to the laboratory. These may apply on an individual sample basis or for the entire sample deliverable group (SDG). Examples of remarks would be "extract and hold sample until notified" or "rush 3-day turn-around, this sample only."
- The "Relinquished by" field should be the signature of the sampler who relinquished custody to the shipping courier or analytical laboratory.
- The "Date" field following the signature block should be filled in with the date the samples were relinquished in mm/dd/yy format.
- The "Time" field should be filled in with the time, in 24-hr format, that the samples were relinquished.
- The "Received by" field shall be signed by the sample courier or laboratory representatives who received the samples from the sampler.
- Complete as many COCs necessary to properly document the collection and transfer of the samples to the analytical laboratory.
- Record the serial numbers of the COCs and time and date of sample relinquishment in the field log book.
- Upon completing the COCs, forward two copies to the analytical laboratory and retain one copy for field records.
- If electronic COCs are utilized, sign the form and make one copy for internal records. Forward the original with the samples to the laboratory.

3.2 Sample Handling

3.2.1 Sample Collection

- Clean, new, analytical sample containers and appropriate preservatives will be provided by the contracted analytical laboratory.
- Common preservatives include hydrochloric acid (HCl), sulfuric acid (H_2SO_4), nitric acid (HNO_3), Methanol (CH_3OH or MeOH), and sodium bisulfate ($NaHSO_4$). Samples will be preserved in accordance with method- or project- specific protocols outline.
- Disposable latex or nitrile gloves should be used to avoid cross-contamination of samples and protect against exposure to either contaminated media or preservatives.
- After the filling the respective sampling containers, with the associated sampling material and any necessary preservative, in accordance with the relevant SOP and project- or method-specific requirements, samples will be properly identified using sample container labels. The following information shall be recorded on the sample label in indelible ink:
    - Sample type or matrix, e.g., surface water (SW), soil (SO), etc.
    - Sample identification code or name;
    - Analysis required;
    - Date;
    - Time sampled;
    - Initials of the sampling personnel; and
    - Preservative added, if applicable.
- Cover the sample label with clear packing tape to secure the label onto the container and to protect the label from liquid.
- Confirm that all caps on the sample containers are secure and tightly closed.
    - It may be necessary to wrap the sample container cap with clear packing tape to prevent it from becoming loose.
- If individual custody seals are required, they should be placed on the sample container so that the cap cannot be opened without rupturing the custody seal. The custody seal should be initialed and dated prior to relinquishing the samples.
- Differing labeling procedures may be required for air samples, the relevant SOPs should be consulted for specific labeling procedures.
- After completing the sample collection procedures and sample labeling, record the following information in the field log book:
    - Project name, number and site name;
    - Sample name or identification code and sample location, if appropriate;

- Sampling method;
- Date;
- Name of the sampler(s);
- Time of collection;
- Locations of field duplicates and both sample identifications;
- Locations the field QC samples were collected including field and rinsate blanks, and additional sample volumes for matrix spikes and matrix spike duplicates; and
- Any pertinent observations or comments.

3.2.2 Packing Procedures

Following collection, all soil and aqueous samples must be placed on wet ice to initiate cooling to approximately 4°C without freezing the sample(s). Samples should be retained on ice until ready to pack for shipment to the laboratory. When preparing the samples for shipment, the following procedures shall be employed:

- If a drain plug exists on the cooler, it should secured on both the inside and outside with duct tape.
- Plastic bubble wrap or other shock absorbent material shall be placed over the bottom and corners of the cooler or shipping container.
- Wrap glass sample bottles in bubble wrap.
- Place each sample bottle upright inside the cooler. VOC vials for each sample should be rubber-banded together.
- Place cold packs or ice into the cooler. If the cooler is to be shipped via a delivery service, ensure that cold packs and ice are placed in resealable heavy-duty Ziploc® or similar.
- Samples placed on ice will be cooled and maintained at a temperature of approximately 4°C without freezing the sample(s).
- Fill the remaining space in the cooler with shock absorbent material such as bubble wrap. The cooler must be securely packed and cushioned in an upright position.
- In order to comply with 49 CFR 173.4.a.(8), the filled cooler must not exceed 64 lbs.
- Place the completed chain-of-custody(ies) in a large resealable bag and place in the cooler.
- If an independent courier service is transporting the cooler or shipping container, mark on the shipping container "Fragile" and "this side up" as appropriate. Place custody seal tape over the front and at least one side of the cooler lid, initial and date then cover with clear packing tape. Close the cooler lid and fasten the lid with packing or duct tape. Wrap packing, duct or strapping tape around both ends of the cooler.

- If project personnel or laboratory couriers are transporting the shipment directly to the analytical laboratory by automobile, periodic changes of ice may be required. In this case custody seals should not be used and limited tape should be utilized to fasten the lid. However, if the cooler is to be left unattended for any period of time, custody tape should be used.

3.2.3 Shipping Procedures

- All samples will be delivered by an express (overnight) carrier within 48 hours of sample collection or as required by analytical holding times. Alternatively, samples may be delivered directly to the analytical laboratory or a laboratory courier may be used for sample pick up.
- If parameters with short holding times are required (e.g., VOCs taken with an EnCore™ Sampler, nitrate, nitrate, and BOD), sampling personnel will take the necessary steps to ship or deliver samples to the laboratory so that the holding times will not exceeded.
- Samples must be maintained at 4° ± 2°C without freezing until receipt at the laboratory.
- All shipments must be in accordance with DOT regulations
- Upon receipt, laboratory personnel will complete the chain-of-custody by recording the data and time of receipt of the samples, measuring and noting the internal temperature of the shipping container, and ensuring sample identifications on the container labels correspond to the sample identifications and quantities provided on the chain-of-custody.
- Deviations between the chain-of-custody and the sample containers, broken containers, or temperature exceedances will be reported to the project manager immediately by the laboratory.

4 QUALITY ASSURANCE

Following each day of sample shipment, chain-of-custody records shall be transmitted to the project manager, unless otherwise directed. The sampling team leader shall retain copies of the chain-of-custody(ies) for filing in the project file. Shipping receipts and notifications, whether physical or electronic shall be maintained with the project file. A description of sample packaging and shipping information shall be made in the field log book. Laboratory reports will contain chain-of-custody records.

SOP No. 012
GEOLOGIC LOGGING
STANDARD OPERATING PROCEDURE
Rev. 01

1 SCOPE

This Standard Operating Procedure (SOP) describes the proper procedures for logging geologic descriptions of soil and rock samples during the drilling of boreholes and installation of monitoring wells or piezometers on a standardized form. The objective of logging a borehole is document the details of the soil and rock recovered from the borehole. These data are used to reconstruct the borehole's stratigraphy, which can then be correlated with similar data from other borehole. The sample collection discussed in this SOP is generally not applicable for analytical samples.

2 EQUIPMENT

Equipment may vary depending on specific project objectives. The following is a list of equipment that should, at a minimum, be present on site:

- Minimum 100' tape
- 25' tape measure
- Blank field logs/log book
- Clipboard
- Pencils and Sharpie
- Fat magic marker
- 10% HCl acid
- Pocketknife
- Pocket penetrometer (if cohesive soils are expected)
- Hard hat
- Steel-toed boots
- Hearing protection
- Safety glasses
- Orange safety vest (as appropriate)
- Work gloves
- White marking paint and/or flags and stakes
- Film and camera, digital camera, or disposable camera
- Soil Boring and Rock Coring Tracking Sheet and Daily Field Report

3 PROCEDURES

The site-specific or project-specific Health and Safety Plan (HASP) shall be reviewed prior to all subsurface exploration. All requirements of the HASP should be maintained for the duration of the field activities.

When drilling boreholes, field personnel should maintain a log that describes each borehole. An example of borehole log sheet is provided at the end of this SOP for reference. The following basic information should be entered on the heading of each log:

- Borehole/well number;
- Project name;
- Site location;
- Dates and times that the drilling was started and completed;
- Drilling subcontractor company and driller name;
- Field geologist's name;
- Drill rig type used to drill the borehole;
- Drilling Method(s) used to drill the borehole;
- Weather;
- Bit and auger size(s);
- Depth of auger/split-spoon refusal;
- Total depth of borehole;
- Water level at the time of completion, measured from the top of the inside casing,
  - 24-hr readings may be required, dependent upon project data objectives;
- Initials or name of engineer/geologist that checks the log after it is prepared; and
- A basic well location sketch, if necessary.

During the drilling of a borehole, specific technical information about the subsurface material and should be recorded on the boring log. Depending on the drilling methods, whether the material is consolidated or unconsolidated and project-specific objectives, the following technical information may be required:

- Depth that a sample was collected or encountered;
- Sample number assigned (if applicable);
- The number of blow counts required to drive the split barrel sampler 18" or 24", at 6" intervals;
- Description of soil components;
- Percent recovery of core, split-spoon, or shelby tube sample;
- Intervals where samples were taken;
- Descriptions of any anthropomorphic material observed;

- Rock Description; and
- Approximate depth of encountering the water table.

3.1 Sample Collection

Various methods can be employed for the collection of soil or rock samples for the purpose of geotechnical or analytical testing. In general, samples should be taken directly from the continuous core sampler or split spoon sampler. There are five basic types of samples to be familiar with:

- Split-spoon soil samples;
- Undisturbed Shelby-tube soil samples;
- Soil cores from direct-push or sonic drilling methods;
- Bulk soil samples; and
- Rock cores.

A record of all samples collected should also be maintained in the field logbook.

3.1.1 Split Spoon Samples

The interval at which samples are to be collected will be specified in the project documents. Follow this interval unless the Project Engineer agrees to a different one.

A 2-inch split-spoon sampler (1.5- or 2.0-foot long sampler) is driven by a 140-pound hammer free-falling through 30-inches. The field representative should be familiar with the American Society of Testing and Materials (ASTM) standard D 1586, which defines this sampling technique. The sampling spoon should have a cutting shoe in good condition, and a vented head to release air and water pressure during driving. Metal or plastic retainers should be used to retain soil samples. The ARM field representative should stay clear of this operation, so as to not interfere with the driller's work. Count the number of blows to drive the sampling spoon each 6-inch increment. This is commonly referred to as Standard Penetration Testing (SPT).

After the sampling spoon is retrieved from the borehole and opened, the ARM field representative should measure the sample recovery and note it on the Field Boring Log, a copy of which is included with this procedure. The field representative should then classify the soil. Refer to the *Sample Description* section of this document for the appropriate classification system.

A soil sample should be collected from a representative section of the spoon sample. This sample must be placed in a jar of sufficient size to hold a 5-inch long, 2-inch diameter sample, and have a cap with a gasket to seal in moisture. The jar cap must be labeled with the Project No., Boring No., Sample no., Depth of sample, Recovery, Blows per 0.5-foot penetration, and the date the sample was collected. The example below displays the appropriate format.

150115
B-1
S-2
2' – 4'
1.5' R
5-7-9-8
1/4/2015

Sample Jar Lid

3.1.2 Shelby Tube Samples

The Shelby tube is a common technique for collecting an undisturbed soil sample from a soft, cohesive layer. The appropriate ASTM standard is D 1587. One Shelby tube should be taken per site if distinct layer(s) of cohesive (clay) soil with SPT N-values consistently less than 8 blows-per-foot. The field representative should consult the Project Engineer for specific direction.

The sample tube shall be pushed hydraulically, not driven with a hammer. Record the hydraulic pressure to push the sampler if it is available.

Let the sample tube rest for approximately 10-minutes in place after termination at the bottom sample depth. The actual rest period should be estimated based on the consistency and approximate shear strength of the soils.

After the tube is retrieved from the borehole, the ends should be cleaned out sufficiently to allow packing of the ends with paraffin wax. Fill any excess air space with tightly wadded paper. Cap the ends with rubber caps and tape the caps in place. Label the top end of the tube as shown below.

150115
B-3
ST-1
8.5' – 10.5'
1.8' R
1/4/2015

Shelby Tube Cap

Label the side of the tube as shown below.

TOP
⇑
99369
B-3
ST-1
8.5' – 10.5'
1.8' R
1/4/2000
⇓
BOTTOM

Shelby Tube Label

Keep the sample vertical, orientated as it came out of the ground as much as practical during sample preparation, and always during storage and transportation. Do not allow the sample to freeze.

3.1.3 Direct Push Core Samples

Direct-push soil borings are completed by hydraulically pushing a sampling device to the top of the desired depth interval for soil sample collection. A number of sampling tools exist for direct-push borings, nearly all of which involve the collection and retrieval of the soil sample within a thin walled liner. Manufacturer and subcontractor SOPs should be followed when collecting soil cores using a direct-push rig. Three of the more common sampling methods are discussed below:

Large Bore® Sampler

The Large Bore® (LB) sampler is a solid barrel direct push sampler equipped with a piston-rod point assembly used primarily for collection of depth-discrete subsurface soil samples. The sample barrel is approximately 30-inches (762 mm) long and has a 1.5-inch (38 mm) outside diameter. The LB® sampler is capable of recovering a discrete sample core 22 inches x 1.0 inch (559 mm x 25 mm) contained inside a removable liner. The resultant sample volume is a maximum of 283 mL.

After the LB® sample barrel is equipped with the cutting shoe and liner, the piston-rod point assembly is inserted, along with the drive head and piston stop assembly. The assembled sampler is driven to the desired sampling depth, at which time the piston stop pin is removed, freeing the push point. The LB® sampler is then pushed into the soil a distance equal to the length of the LB® sample barrel. The probe rod string, with the LB® sampler attached, is then removed from the subsurface. After retrieval, the LB® sampler is then removed from the probe rod string. The drive head is then removed to allow removal of the liner and soil sample.

Macro-Core® Sampler

The Macro-Core® (MC) sampler is a solid barrel direct push sampler equipped with a piston-rod point assembly used primarily for collection of either continuous or depth-discrete subsurface soil samples. Although other lengths are available, the standard MC® sampler has an assembled length of approximately 52 inches (1321 mm) with an outside diameter of 2.2 inches (56 mm). The MC® sampler is capable of recovering a discrete sample core 45 inches x 1.5 inches (1143 mm x 38 mm) contained inside a removable liner. The resultant sample volume is a maximum of 1300 mL. The MC® sampler may be used in either an open-tube or closed-point configuration. Although the MC® sampler can be used as an open-barrel sampler, the piston point is always used to prevent the collection of slough from the borehole sides.

Dual Tube Soil Sampling System

The Dual Tube 21 soil sampling system is a direct push system for collecting continuous core samples of unconsolidated materials from within a sealed outer casing of 2.125-inch (54 mm) OD probe rod. The samples are collected within a liner that is threaded onto the leading end of a string of 1.0-inch diameter probe rod. Collected samples have a volume of up to 800 mL in the form of a 1.125-inch x 48-inch (29 mm x 1219 mm) core. Use of this method allows for collection of continuous core inside a cased hole, minimizing or preventing cross-contamination between different intervals during sample collection. The outer casing is advanced, one core length at a time, with only the inner probe rod and core being removed and replaced between samples. If the sampling zone of interest begins at some depth below ground surface, a solid drive tip must be used to drive the dual tube assembly and core to its initial sample depth.

When the liners and associated sample are removed from the sample tubes, it is important to maintain the proper orientation of the sample, in order to ensure accurate logging.

Samples collected for geotechnical testing can be collected following the procedures discussed in Section 3.1.1.

3.1.4 <u>Sonic Drilling Cores</u>

Rotasonic drilling methods retrieve continuous core samples of solid and unconsolidated material. The drill rig has a dual line of drill pipe. The inner drill pipe attaches to a ten-foot long, 3.75” ID core barrel. The core barrel also attaches to a carbide-button drill bit. The outer line of drill pipe attaches to 5.875” – 6.5” OD carbide-button drill bits. The rotasonic method has two drilling options.

Sampling of shallow subsurface material (less than 30 feet below grade) can be performed using only the inner drill pipe and core barrel. Sampling runs of one-foot to thirty-feet can be performed depending on the type of material, degree of subsurface contamination, and sampling objectives. The samples are obtained by vibrating and rotating the core barrel to a desired depth, stopping the rotation and vibration, and then pulling the core barrel to the surface. The sample is then vibrated or hydraulically extracted into plastic sleeves or sample trays. A disadvantage of this option is the retrieval of sloughed material with the sample, which often results from sampling through the uncased hole. Therefore, the identification of sloughed material is important.

Sampling of shallow and deeper unconsolidated material and bedrock can be performed using a dual line of drill pipe. Sampling is performed by advancing the inner pipe ahead of the outer pipe to obtain representative samples. The hole is then cased by advancing the outer pipe to the sampled depth. Water or air is sometimes used remove the material between the inner and outer drill pipes.

In addition to retrieving continuous core samples, soil samples can be collected using other methods. Shelby tube or split-spoon samples can be collected in three ways: 1.) the sampler can be driven at the sampling depth using hydraulic pressure or vibration of the head; 2.) the sampler can be pressed into the core barrel after the desired sample has been retrieved; or 3.) the sampler can be pressed into the sample after is has been retrieved and vibrated into the sample container. The choice of the sampling method is dependent on the type of analyses to be performed.

When the liners and associated sample are removed from the sample cores, it is important to maintain the proper orientation of the sample, in order to ensure accurate logging.

Samples collected for geotechnical testing can be collected following the procedures discussed in Section 3.1.1.

3.1.5 Bulk Samples

Bulk samples are typically collected to perform laboratory compaction and California Bearing Ratio tests on. Samples are collected from auger cuttings during the drilling operation. The depth at which to collect the samples will be specified in the project documents. If a distinct subsurface strata break occurs over the sample interval for the bulk sample, contact the Project Engineer to determine if the sample should segregate the distinct strata.

Place the bulk sample material in an appropriate bucket or bag. At least 100-pounds is required for each sample specified. A jar used for SPT sampling should also be utilized to collect a smaller portion to be used for moisture testing.

Label both the bulk sample container and the moisture jar with the Project No., Boring No., depth of sample, and the date the sample was collected.

3.1.6 Rock Coring

The appropriate standard to follow for rock coring is ASTM – D 2113. The common sizes in use today for rock coring are NX, NQ, and NQ-2. The maximum length of the first core run on any borehole should generally not exceed 3-feet, unless otherwise specified by the Project Engineer. This is to ensure that the material being sampled is intact bedrock.

After the core sampler is retrieved from the borehole, the core should be placed in core boxes. The boxes should be labeled as shown below.

Box __ of __ Project No. ______
Location: ____
Boring No(s). ______ ______ ______ ______
Depth __ to __ __ to __ __ to __ __ to __
Date __________

Top of the Core Box Lid

Box __ of __ Project No. ______

Boring	Run	Depth	Penetration	Recovery	RQD	Date

Inside of Lid

Box __ of __ Project No. ______
Boring _____ _____ _____ _____

Right End of Box Looking at the Front of Box

The field representative should classify the rock sample and record the classification on the field boring log. Refer to the *Sample Description* section of this document for the appropriate classification system.

3.2 Sample Description

3.2.1 Soil

In general, the ASTM Standards to be used by field personnel classifying soils are D 2487 and D 2488. Slight modifications are utilized to customize the soil classification system to project specifc objectives. The soil classification is described by six discrete characteristics. These characteristics – constituents, density/consistency, color, moisture, plasticity (if plastic), and other – will yield the Unified Soil Classification System group and symbol. Determine the USCS Group Name and Group Symbol from Figures 1a and 2.

1. *Constituents*

Determine the particle size distribution. The particle size distribution is the percentage by weight of certain size soil particles that are included in the representative sample. Table 1 identifies the soil component and its corresponding size in millimeters (mm), inches, and U.S. Standard Sieve numbers.

TABLE 1 – PARTICLE SIZES

mm	INCHES	U.S. STANDARD SIEVE NO.	MATERIAL
> 304	> 12		BOULDER
305 – 76	12 – 3		COBBLE
76 – 19	3 – ¾		COARSE GRAVEL
19 – 4.76	¾ - $^{3}/_{16}$		FINE GRAVEL
4.76 – 2.00	$^{3}/_{16}$ – $^{3}/_{32}$	4 – 10	COARSE SAND
2.00 – 0.42	< $^{3}/_{32}$	10 – 40	MEDIUM SAND
0.42 – 0.074		40 – 200	FINE SAND
0.074 – 0.005			SILT
< 0.005			CLAY

Reference: Department of the Navy, Facilities Engineering Command (NAVFAC) Design Manual (DM) – 7.1, Soil Mechanics, Chapter 1, Table 2.

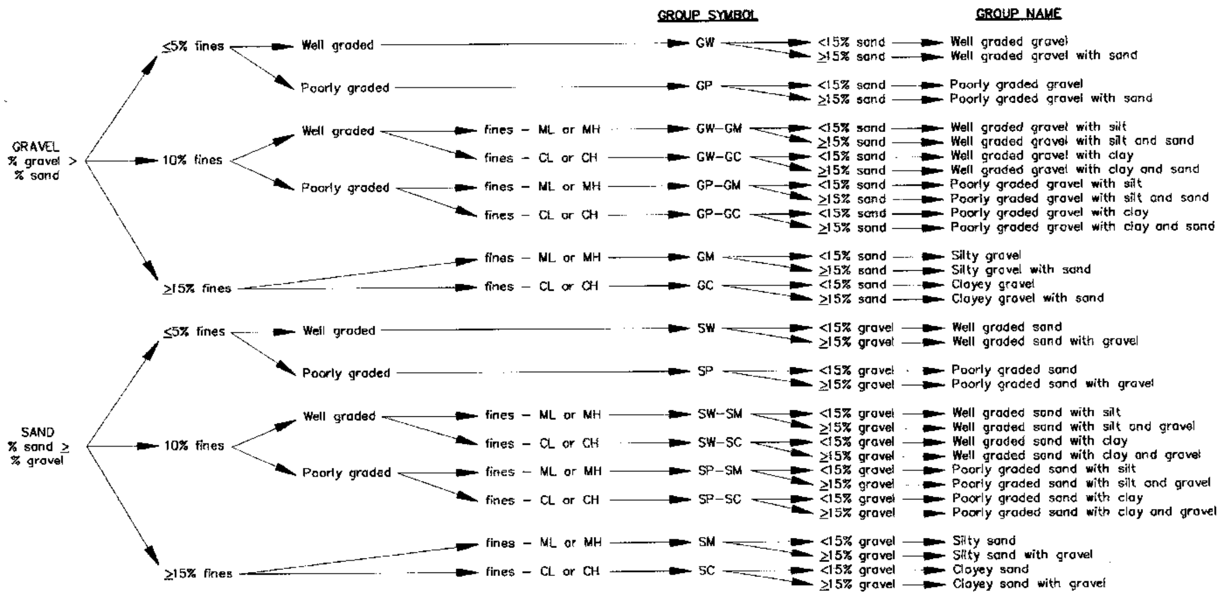
There are a variety of methods to use in the field to identify the particle size distribution. The experienced engineer or technician will be able to perform this task visually, after much practice. A simple test to use is called the shake test. Select a representative sample of the soil and place a small amount of it in a clear sample jar so that is fills approximately 1-inch in the bottom of the jar. Measure the amount of total soil volume by marking it on the jar. Fill the jar with clean water, and shake vigorously for approximately 1-minute. Set the jar on a flat, level, steady surface free of vibrations, and note the time. Most of the sand particles will fall to the bottom of the jar within 30 to 60 seconds. Most of the silt particles will fall to the bottom of the jar within 15-minutes. The remainder suspended in the water is clay. The field representative may use this test to estimate the grain size distribution, even though it is a volume-based test, not weight-based. There are many other test methods that are acceptable for use in determining the grain size distribution in the field.

In some cases, the field representative must characterize the gradation of coarse-grained soil (i.e. well-graded or gap-graded sands and gravels). A soil is well-graded if it has a wide range in grain size and substantial amount of each size. A soil is gap-graded if it has a wide range of size with intermediate sizes obviously missing. These descriptions apply to the USCS Group Symbols GW, GP, SW, and SP.

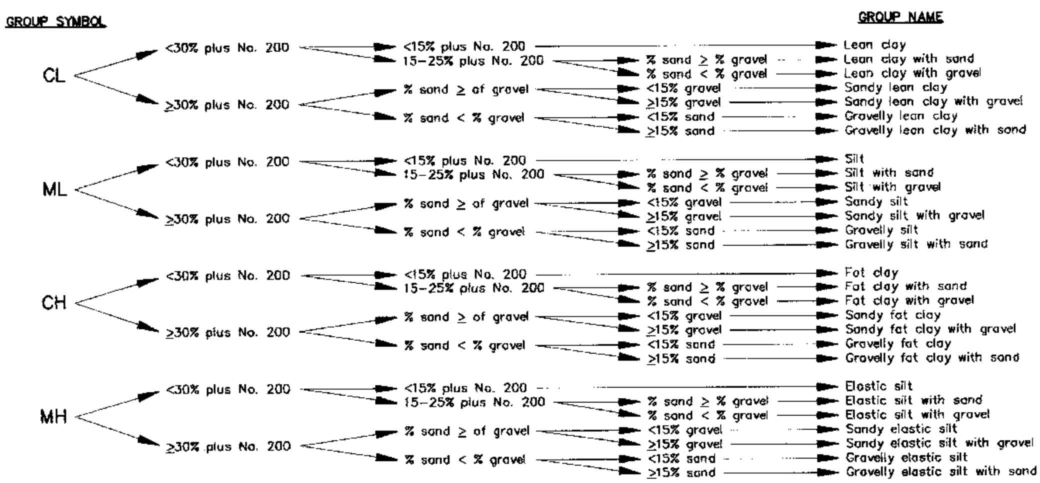
Since the human eye cannot distinguish particle sizes smaller than approximately 0.074 mm, other tests are necessary to differentiate silt and clay soils. These test classify the fine-grained soil (passing #200 sieve) based on their behavior. The simplest of these tests is the plastic thread test. To perform this test, take a representative sample from the soil, enough to create a ball approximately ½ -inch in diameter. Roll the ball on a hard surface with the palm of your hand into a thread shape. Continue rolling until the thread breaks, and note the diameter. Repeat by molding the broken thread pieces back together and re-rolling. Again, note the diameter of the thread. Also, note the relative toughness of the material during handling and rolling, particularly when the thread is approximately 1/8 –inch in diameter. Use Table 2 to identify the probable USCS Group Name.

Another common test is the dilatency test. To perform this test, take a small amount of soil from the representative sample and add enough water to make a soft, moist consistency. Smooth the soil pat in the palm of one hand and shake horizontally while striking the palm of the other hand. Note the reaction, then gently squeeze the sample in your hand and again note the reaction. If water appears on the surface during shaking and disappears quickly when squeezed, the reaction is rapid and the soil has low plasticity. If vigorous action is required to bring water to the surface and squeezing causes little change in appearance, the soil is of medium plasticity. High plasticity soil will have no visible reaction to shaking. Refer to Table 2 below for the probable USCS Group Name. A rapid reaction is indicative of silts, while a slow reaction is characteristic of clays. The water will travel through the silt particles relatively easily and the shaking causes the water to come to the surface.

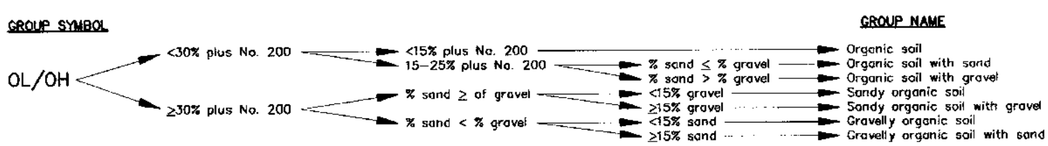
In order to differentiate between SILT (ML) and ELASTIC SILT (MH), and LEAN CLAY (CL) AND FAT CLAY (CH) one must know the liquid limit (LL) of the soil. The liquid limit is that moisture content where the soil becomes fluid. This property is very difficult to estimate in the field, and usually requires a laboratory test. It is only with practice and experience that the field representative will be able to recognize the approximate liquid limit of a sample. With this information, and the estimated laboratory plasticity index (PI), which is equal to the liquid limit minus the plastic limit (PL – moisture content at which the sample loses its plasticity), Figure 2 – Plasticity Chart can be utilized to determine the USCS Group Symbol.



Note – Percentages based on estimating amounts of fines, sand, and gravel to the nearest 5%.
FIG 2. Flow Chart for Identifying Coarse-Grained Soils (less than 50% fines)



Note – Percentages based on estimating amounts of fines, sand, and gravel to the nearest 5%.
FIG 1a. Flow Chart for Identifying Inorganic Fine-Grained Soils (50% or more fines)



Note – Percentages based on estimating amounts of fines, sand, and gravel to the nearest 5%.
FIG 1b. Flow Chart for Identifying Organic Fine-Grained Soils (50% or more fines)

FIGURE 1 – USCS FLOW CHART

Reference: American Society for Testing and Materials (ASTM) – D 2488

TABLE 2 - PLASTICITY

SMALLEST THREAD DIA ROLLED (in)	TOUGHNESS FO PLASTIC THREAD	DILATENCY REACTION	ESTIMATED LABORATORY PLASTICITY INDEX (PI)	PLASTICITY DESCRIPTION	PROBABLE USCS GROUP NAME (SYMBOL)
NONE	SOFT – WEAK	RAPID	0	NON-PLASTIC	SILT (ML)
¼	WEAK	RAPID	1 – 5	SLIGHT	SILT (ML) - ELASTIC SILT (MH)
1/8	MEDIUM	SLOW	5 –10	LOW	ELASTIC SILT (MH) – SILT (ML) – LEAN CLAY (CL)
1/16	MEDIUM STIFF	SLOW	10 – 20	MEDIUM	LEAN CLAY (CL)
1/32	STIFF	NONE	20 – 40	HIGH	LEAN CLAY (CL)
1/64	VERY STIFF	NONE	> 40	VERY HIGH	LEAN CLAY (CL) – FAT CLAY (CH)

Reference: American Society for Testing and Materials (ASTM) – D 2488, Table 12.

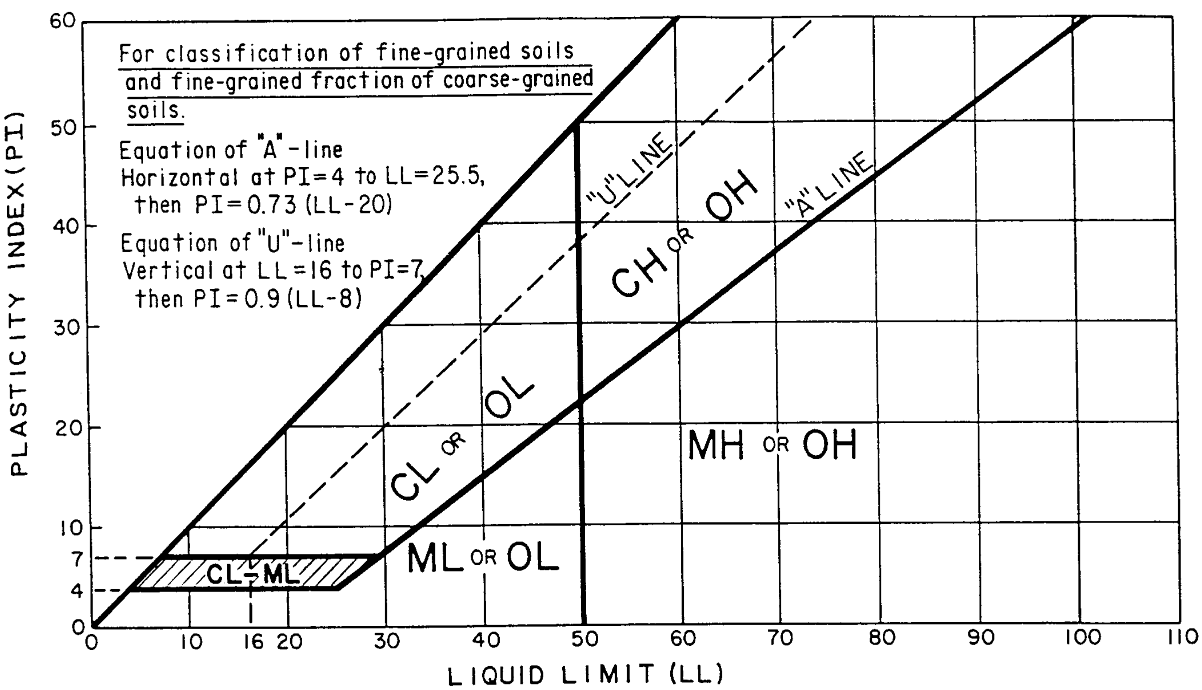


FIGURE 2 – PLASTICITY CHART

Reference: American Society for Testing and Materials (ASTM) – D 2487

2. *Density/Consistency*

The SPT N-values are used to estimate the relative density of granular soils (PI ≈ ≤ 10) and describe the consistency of fine-grained soils. Density can also be estimated by penetrating the soil with a ½ -inch diameter (#4) reinforcing bar pushed by hand. Table 3 should be used as a guide to determine a soil stratum's density.

TABLE 3 – DENSITY OF GRANULAR SOILS

SPT N-VALUE (bpf)	DESCRIPTION	RELATIVE DENSITY (D_r) (%)	FIELD TEST
0 – 4	VERY LOOSE	< 15	½-INCH (#4) BAR PENETRATED WITH LITTLE OR NO EFFORT BY HAND.
5 – 10	LOOSE	15 – 40	EASILY PENETRATED BY HAND. ROD WILL TAKE UP WITHIN 6 – 12-INCHES.
11 – 30	MEDIUM DENSE	40 – 70	DIFFICULTY IN PENETRATING BY HAND. ROD WILL TAKE UP WITHIN 3 – 6-INCHES
31 – 50	DENSE	70 – 85	ROD PENETRATED 12-INCHES DRIVEN WITH 5 POUND HAMMER.
> 50	VERY DENSE	85 – 100	ROD PENETRATED A FEW INCHES DRIVEN WITH 5 POUND HAMMER

Reference: NAVFAC DM – 7.1, Soil Mechanics, Chapter 1, Figure 1.

Fine-grained, or cohesive soils, are those soils with the majority of their soil particles passing the No. 200 sieve, and whose PI ≈ ≥ 10. The consistency of these soils is described using the SPT N-value, and the Pocket Penetrometer Test readings, to be described in a later section of this document. The consistency is related to the shear strength of the soil. The shear strength is frequently defined in terms of its unconfined compressive strength (Qu). The consistency for cohesive soils may also be estimated by comparing the effort that must be applied to the sample when squeezing between the fingers. Table 4 should be used as a guide to determine a soil stratum's consistency.

TABLE 4 – CONSISTENCY OF COHESIVE SOILS

SPT N-VALUE (bpf)	DESCRIPTION	UNCONFINED COMPRESSIVE STRENGTH (Q_u) (tsf)	FIELD TEST
< 2	VERY SOFT	< 0.25	EXTRUDED BETWEEN FINGERS WHEN SQUEEZED
2 – 4	SOFT	0.25 – 0.50	MOLDED BY LIGHT FINGER PRESSURE, EASILY PENETRATED
4 – 8	MEDIUM	0.50 – 1.00	MOLDED BY STRONG FINGER PRESSURE, WITH MODERATE EFFORT.
8 – 15	STIFF	1.00 – 2.00	READILY INDENTED BY THUMB, PENETRATED WITH GREAT EFFORT.
15 – 30	VERY STIFF	2.00 – 4.00	READILY INDENTED BY THUMBNAIL
> 30	HARD	> 4.00	INDENTED WITH DIFFICULTY BY THUMBNAIL

Reference: NAVFAC DM – 7.1, Soil Mechanics, Chapter 1, Table 4.

3. *Color*

The color used to describe a soil stratum should be indicative of a stratum change. There are references available such as a Munsel soil color chart to use to describe the color. The exact color is not as important as the identification of a stratum change. Use common color terms to describe the soil.

4. *Moisture*

The moisture content of soils is indicative of many factors. It may suggest a temporary or static ground water elevation, perched water, stratum change, or a transition to a confining layer. In cohesive soils, the moisture content influences the shear strength. The relative moisture content should be described using one of the three following terms.

DRY	SAMPLE IS AIR-DRY, NO VISIBLE MOISTURE
MOIST	VISIBLE MOISTURE, BUT NO FREE WATER
WET	FREE WATER VISIBLE, SATURATED

5. *Plasticity*

Refer to Table 2 to describe plasticity of the soil, *if* it is a cohesive soil

6. *Other*

Description pertinent to a thorough classification or characterization of the soil stratum may be included. Examples include mottling, weathering, or a quantity of a constituent not represented in the USCS Group Name. Use "Trace" for an amount less than 15%, if notable.

3.2.2 Rock

The format for classifying rock samples field personnel should use for this procedure is based on the Pennsylvania Department of Transportation (PA DOT) standard BC – 795. The ARM field representative should be familiar with the information contained in this standard, as it is a valuable reference.

Samples should be described with the following characteristics:

1. Rock Type – Examples include but are not limited to shale, sandstone, siltstone, limestone, diabase, etc.

2. Color – Indicative of stratum changes; use common terms.

3. Hardness – Describe the hardness according to Table 5.

4. Degree of Weathering – Describe according to Table 6.

5. Structural Features — Describe the bedding / lamination / foliation / flow-banding / cleavage thickness and relative dip of rock specimens according to Table 7.

6. Spacing of Joints / Faults / Fractures – Describe the thickness and relative dip of broken features of rock specimens according to Table 7.

Relative Dip (RD) is the angle of the features measured from horizontal.

TABLE 5 – HARDNESS CLASSIFICATION OF INTACT ROCK FROM CORE SPECIMENS

HARDNESS	FIELD TEST
EXTREMELY HARD	MANY BLOWS WITH GEOLOGIC HAMMER REQUIRED TO BREAK INTACT SPECIMEN
VERY HARD	HAND HELD SPECIMEN BREAKS WITH HAMMER END OF PICK UNDER MORE THAN ONE BLOW; LEAVES FAINT GROOVE WHEN SCRATCHED WITH KNIFE
HARD	CANNOT BE SCRAPED OR PEELED WITH KNIFE; HAND-HELD SPECIMEN CAN BE BROKEN WITH SINGLE MODERATE BLOW WITH PICK.
SOFT	CAN JUST BE SCRAPED OR PEELED WITH KNIFE; INDENTATIONS 1 – 3 MM SHOW IN SPECIMEN WITH MODERATE BLOW WITH PICK; SIMILAR TO CONCRETE.
VERY SOFT	MATERIAL CRUMBLES UNDER MODERATE BLOW WITH PICK AND CAN BE PEELED WITH KNIFE; CAN BE SCRATCHED WITH FINGERNAIL.

Reference: NAVFAC, DM-7.1, Soil Mechanics, Chapter 1, Table 9.

TABLE 6 – WEATHERING CLASSIFICATION

GRADE	DIAGNOSTIC FEATURES
FRESH	NO VISIBLE SIGN OF DECOMPOSITION OR DISCOLORATION; SPECIMEN RINGS UNDER HAMMER IMPACT.
SLIGHTLY WEATHERED	SLIGHT DISCOLORATION INWARDS FROM OPEN FRACTURES, OTHERWISE SIMILAR TO FRESH.
MODERATELY WEATHERED	DISCOLORATION THROUGHOUT; WEAKER MINERALS SUCH AS FELDSPAR DECOMPOSED; STRENGTH SOMEWHAT LESS THAN FRESH ROCK BUT CORES CANNOT BE BROKEN BY HAND OR SCRAPED WITH KNIFE; TEXTURE PRESERVED.
HIGHLY WEATHERED	MOST MINERALS SOMEWHAT DECOMPOSED; SPECIMENS CAN BE BROKEN BY HAND WITH EFFORT OR SHAVED WITH KNIFE; CORE STONES PRESENT IN ROCK MASS; TEXTURE BECOMING INDISTINCT BUT FABRIC PRESERVED.
COMPLETELY WEATHERED	MINERALS DECOMPOSED TO SOIL BUT FABRIC AND STRUCTURE PRESERVED (AKA SAPROLITE); SPECIMENS EASILY CRUMBLED OR PENETRATED.

Reference: NAVFAC, DM-7.1, Soil Mechanics, Chapter 1, Table 7.

TABLE 7 – DISCONTINUITY SPACING

DESCRIPTION FOR STRUCTURAL FEATURES	SPACING	DESCRIPTION FOR JOINTS, FAULTS, OTHER FEATURES
VERY THICKLY	> 6 FEET	VERY WIDELY
THICKLY	2 – 6 FEET	WIDELY
MEDIUM	8 – 24 INCHES	MEDIUM
THINLY	2 ½ - 8 INCHES	CLOSELY
VERY THINLY	¾ - 2 ½ INCHES	VERY CLOSELY
INTENSELY	¼ - ¾ INCHES	EXTREMELY CLOSE
VERY INTENSELY	< ¼ INCH	

Reference: NAVFAC, DM-7.1, Soil Mechanics, Chapter 1, Table 8.

The Rock Quality Designation (RQD) is a quantifiable description of the rock core specimens. RQD is applicable to NX, NQ, or NQ-2 size rock cores. Record the rock core size on the Field Boring Log. It is based on the total aggregate length of all core pieces greater than 4-inches long, measured along the core's axis, for a given core run. The field representative should read and be familiar with the procedure originally developed by Deere and Deere. Use the formula below to calculate RQD.

$$RQD = \frac{\sum LENGTH\ OF\ CORE\ PIECES \geq 4INCHES}{TOTAL\ LENGTH\ OF\ CORE\ RUN} \times 100\%$$

The RQD pieces greater than 4 inches long are measured along the centerline axis of the core, and include pieces broken by mechanical means during the drilling process.

(Reference: ASTM – D 6032, Standard Test Method for Determining Rock Quality Designation (RQD) of Rock Core; "The Rock Quality Designation (RQD) Index in Practice," Deere and Deere, *Rock Classification Systems for Engineering Purposes*, ASTM STP 984, 1988.)

RQD should be recorded in the appropriate column on the Field Boring Log, a copy of which is included in this procedure.

In order to further assess the rock, drillability should be qualified. This can be done with descriptive terms. The field representative should also record the time required for a given length of core run and calculate a penetration per unit of time on the Field Boring Log.

Example: Limestone, gray, hard, slightly weathered, thickly bedded (RD=0°), widely spaced fractures (RD=40°).

Upon completion of a core box, the field representative shall take a photograph of the box showing the rock core and the data recorded on the inside of the lid.

3.2.3 Additional Logging Descriptors

1. **Pocket Penetrometer Test Reading**

As its name suggests, the pocket penetrometer is a small, hand-held device that estimates the unconfined compressive strength of a cohesive soil. The Pocket Penetrometer Test (PPT) should only be performed on cohesive soil samples. If the sample crumbles or breaks easily during testing, the PPT readings are invalid.

During testing, the field representative should fully support the soil sample in his or her hand, or in one side of the sampling spoon, and advance the pocket penetrometer at a slow but steady pace until it penetrates the sample ¼-inch as marked on the shaft of the penetrometer. Note or record the value read on the penetrometer. Several trials should be made for each sample and an average value used. Record the average for the corresponding sample on the field boring log.

2. *Remarks*

The field representative has the freest use of the Remarks column of the field boring log to provide supplementary information that is pertinent to thorough understanding of the subsurface conditions at the test boring location. Some items that should be considered to be included are:

- Surface conditions,
- Deviation from original location of test boring,
- Boring cave depth,
- Drilling resistance,
- Loss of drilling fluid,
- Backfill material,
- Soil strata origin (fill, residual, alluvial, colluvial, glacial till, etc.),
- Rock coring technique, if used, and
- Rock coring penetration per unit of time at a specified depth.
- Odor

  - Effort should not be made to smell samples by placing near ones nose since this can result in unnecessary exposure to hazardous materials. However, odors should be noted if they are detected during the normal sampling procedures. Odors should be based upon such descriptors as those used in NIOSH "Pocket Guide to Chemical Hazards", e.g., "pungent", "sweet", etc., and should not indicate specific chemicals such as "BTEX" or "Phenol-like" odor.

- Presence of roots, root holes, organic material, anthropomorphic material, minerals, etc.
- NAPL presence characteristics, including sheen, etc.
- Reaction with HCl, if applicable.

Additionally, the following terms may be used to describe the soil structure.

TABLE 8 – TERMS USED TO DESCRIBE SOIL / ROCK STRUCTURE

TERM	**DESCRIPTION**
PARTING	PAPER THIN
SEAM	1/8 – 3-INCH THICK
LAYER	> 3-INCHES
SENSITIVE	PERTAINING TO COHESIVE SOILS THAT ARE SUBJECT TO APPRECIABLE LOSS OF STRENGTH WHEN REMOLDED.
INTERBEDDED	COMPOSED OF ALTERNATE LAYERS OF DIFFERENT SOIL TYPES
LAMINATED	COMPOSED OF THIN LAYERS OF VARYING COLOR AND TEXTURE
CALCAREOUS	CONTAINING APPRECIABLE QUANTITIES OF CALCIUM CARBONATE
SLICKENSIDED	HAVING INCLINED PLANES OF WEAKNESS THAT ARE SLICK AND GLOSSY IN APPEARANCE.

4 QUALITY ASSURANCE

The field representative will keep thorough notes of activities performed in the field as prescribed in the *Field Log Book* SOP. References to all boring logs and samples collected shall be maintained in the field log book along with any record of photographs taken. All photos should include a ruler or common object for scale. Photo orientation, location, and depth must be recorded in the field log book with notation.

Soil descriptions should be completed only by appropriately trained personnel. Descriptions should be reviewed by an experienced field geologist or engineer for content, format, and consistency. Edited boring logs should be reviewed by the original author to assure that content has not changed.

Soil Boring Log

Boring ID:

Project Name: Project Number: Client: Site: Borehole Location: Weather:	Date/Time Started: Date/Time Completed: Logged by: Checked by: Driller: Drill Rig Type/Method: Bit/Auger Size:	Northing (ft): Easting (ft): Surface Elevation (ft): Depth of Refusal (ft): Total Depth (ft): Depth to Water (ft):

Depth (ft):	Sample No:	Recovery (%):	PID (ppm):	PP reading (tsf):	Blow Count	DESCRIPTION	USCS	REMARKS
0								
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								

Soil Boring Log

Boring ID:

Depth (ft):	Sample No:	Recovery (%):	PID (ppm):	PP reading (tsf):	Blow Count	DESCRIPTION	USCS	REMARKS
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								
26								
27								
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SOP No. 013
SOIL BORING METHODS
STANDARD OPERATING PROCEDURE

1 SCOPE

This Standard Operating Procedure (SOP) identifies the general guidelines for performing soil borings. The purpose of soil borings is to provide access to subsurface soils at specified locations and depths. Borings may be installed for the collection of geotechnical or hydrologic data; the installation of groundwater monitoring wells or in-situ remediation systems. This SOP is intended to provide a description of generally accepted industry practices for common methods of overburden drilling. The collection of subsurface soil samples is discussed in *SOP No. 009 Subsurface Soil Sampling*, the geologic logging of borings is covered in *SOP No. 012 Geologic Logging*.

No oils or grease will be used on equipment introduced into the boring (e.g., drill rods, casings, or sampling tools).

2 EQUIPMENT

Equipment may vary depending on specific project objectives and drilling methods to be employed. The following is a list of equipment that should, at a minimum, be present for the installation of soil borings:

Geologist

- Personal Protective Equipment (PPE)
    - Hard hat, steel- or composite-toed boots, gloves, hearing protection, safety googles.
    - A complete list of project-specific PPE should be available in the Health and Safety Plan (HASP) or Work Plan
- Boring logs and, if applicable, well completion forms
- Field logbook
- Site Plan with proposed boring/well locations and Work Plan
- Digital camera
- HASP
- Sampling equipment (e.g., buckets, trowels, spatulas, sample jars)
- Pocket penetrometer
- Equipment cleaning materials (e.g. decon solutions, paper towels, contractor bags, water)
- Any applicable laboratory sample containers, sample labels, chain-of-custody forms

- Insulated coolers with ice, when collecting samples requiring preservation by chilling
- If applicable, a photoionization detector (PID)
- Soil logging assistance tools (e.g., grain size charts, color charts, water)
- Measuring tapes and acoustic water level meters
- Indelible ink pens or markers
- Hand-held GPS unit

Drilling Contractor

- Drilling Equipment (dependent upon the drilling method employed)
- PPE (the Geologist or Project Manager should ensure that contractor PPE conforms with project-specific documentation and is used correctly by the contractor at all times)
- Well drilling supplies, as necessary (drilling mud)
- Decontamination Pad construction supplies
- Decontamination materials
- Well construction supplies, as necessary (screen, riser, well casing, well permits, sand pack, bentonite chips, bentonite, cement grout, water)
- Health and safety records required for working on-site
- Water supply
- Ancillary support vehicles
- Drilling logs
- Measuring tapes
- Tools
- Appropriate soil sampling equipment as specified in *SOP No. 009*

3 LOCATIONS

Borings should be collected at or as close as possible to the locations and depths provided in project work plan. Locations shall be confirmed via the use of a hand-held GPS unit and staked prior to drilling or excavating. Otherwise, sample locations shall be staked by a licensed surveyor prior to mobilization.

If required, the proposed locations may be adjusted in the field, based on site access, property boundaries, and surface obstructions. Sample locations where refusal is encountered prior to reaching target depths shall be relocated as close as reasonably possible to the original sample location, unless otherwise directed by the project manager. The location of the boring shall be recorded on the boring log via the use of a hand-held GPS unit or with survey coordinates, where available. The project manager shall be notified if a representative boring cannot be located near the locations provided in the project work plan.

3.1 Cautions

Underground utility locating will be conducted prior to all subsurface exploration. All public and privately owned utilities will be marked out on the ground surface prior to subsurface activities. No subsurface activities will be conducted within three (3) feet of a utility mark-out, and specific utility clearances should be confirmed with the utility owner prior to subsurface activities in the vicinity.

Prior to beginning excavation or drilling, underground utilities in the vicinity of the working areas shall be identified via one of the following three lines of evidence

- Contact the State One Call
- Obtain a detailed site utility plan drawn to scale, preferably an "as-built" plan
- Conduct a detailed visual site inspection

In the event that one or more of the above lines of evidence cannot be conducted, or if the accuracy of utility location is questionable, a minimum of one additional line of evidence will be utilized as appropriate or suitable to the conditions. Examples of additional lines of evidence include but are not limited to:

- Private utility locating service
- Research of state, county, municipal, or private utility records and maps including computer drawn maps or geographical information systems (GIS)
- Contact with the utility provider to obtain their utility location records
- Hand augering or digging
- Hydro-knife
- Air-knife
- Radio Frequency Detector (RFD)
- Ground Penetrating Radar (GPR)
- Any other method that may give ample evidence of the presence or location of subgrade utilities.

Overhead power lines also present risks and the following safe clearances must be maintain from them in accordance with American National Standards Institute (ANSI) Standard B30.5-1994, 5-3.4.5.

Power Line Voltage Phase to Phase (kV)	Minimum Safe Clearance (feet)
50 or below	10
51 to 200	15
201 to 350	20
351 to 500	25
501 to 750	35
751 to 1000	35

4 PROCEDURES

The site-specific or project-specific Health and Safety Plan (HASP) shall be reviewed prior to sampling. All requirements of the HASP should be maintained for the duration of the sampling. Any unforeseen hazards not specifically referenced in the HASP, identified by the sample shall be reported to the Project Manager prior to proceeding with field activities.

4.1 Site Reconnaissance

Selection of the proper drilling equipment for environmental and geotechnical sampling and monitoring well installation is a critical part of the field investigation. Project specific documentation including work plans, sampling and analysis plans, standard operating procedures, and quality assurance project plans should be reviewed by the Project Manager and Field Geologist prior to mobilization in order to determine the proper type of drilling technology and the tools and equipment required to meet project objectives. Drilling activities shall conform to all state regulations and the contractor or drilling subcontractor shall obtain all permits, applications, and other documents required by state or local authorities and the client. In addition, the following general guidelines should be thoroughly considered during the planning and implementation of all drilling operations:

- Review of background information for the investigation area. This should include identifying any contamination, the manner of release, and affected areas;
- Review of existing data on site geology and hydrogeology;
- Determination of potential and probable investigation derived wastes (IDW) and the methods required for the proper containment, disposal, and tracking of such IDW;
- Performing a site visit to determine field conditions, assess potential problems for a drill rig, and, if necessary, secure a potential water supply for drilling;
- Determine the volume of media required for requisite sampling;
- Determine if boreholes will be drilled through more than one water-bearing zone or aquifer, and what measures will be necessary to prevent cross-connection or cross-contamination of the zones and aquifers;
- Determine, to the extent possible, the level of contamination that will be encountered by each boring. Borings should be drilled in the order of no or low anticipated contamination and progress towards areas of increasing contamination. If practicable, upgradient areas with no anticipated contamination should be performed first; and
- Avoid using drilling mud, synthetic drilling fluids, petroleum or metal based pipe joint compounds, and other potential contaminants unless necessary. If their use is necessary, drilling fluids must not introduce or mask contaminants. Provide material safety data sheets

for all drilling fluids proposed for downhole use before field work and, if required determine procedures for containment and disposal of fluids. If it is necessary to add drilling mud to the borehole during drilling to stabilize the hole or control down-hole fluid losses, use only high-yield sodium bentonite clay, free of organic polymer additives.

4.2 Pre-Drilling Procedures

Working around drill rigs is dangerous. As a result, increased consciousness and oversight of drilling activities are critical, to reduce the risk of injury to workers involved with drilling. Safe work requires that good communication is maintained between the driller and the Field Geologist during drilling activities. Encourage the driller to notify the Field Geologist routinely of the depth(s) at which changes in drilling rates become evident and immediately of any other drilling observations that may indicate subsurface obstructions. At a minimum, the following activities should be conducted as part of the drilling program:

- Conduct a project kickoff meeting. Describe tasks to be conducted and a tentative schedule for the project at the beginning. As the project progresses, discuss the remaining tasks and revised schedule with the drill crew daily. Communicate progress and issues with the Project Manager.
- Hold a health and safety tailgate meeting to review the project- or site-specific HASP.
- Review and discuss with the driller the task specific activities identified in the drilling subcontractors Job Hazard Analysis (JHA).
- Wear proper PPE at all times.
- Visit the drilling locations with the driller prior to starting work to identify all potential site hazards and obstacles.
- Verify that the drilling locations have proper clearance from all underground and overhead utilities.
- Set up proper traffic controls if working in an area where traffic hazards are possible or anticipated.
- Establish any necessary exclusion zones using barriers, caution tape, or other methods to prevent unauthorized access to the drilling location.
- Inspect the drill rig for leaking lines or other hazards. No fluids should leak from the rig.
- Identify the locations of the fire extinguisher(s) and first aid kit(s), and verify that they are readily available for use.
- Maintain good housekeeping on and around the rig at all times.
- Establish a staging area for storing IDW and decontaminating augers, rods, and/or sampling equipment.
- Establish a core logging and sample collection area at a safe location within sight of the drill rig.

- Place sampling equipment and soil recovered from the subsurface on plastic sheeting or similar dedicated material to avoid potentially contaminating the ground surface.
- Carefully log any downtime that occurs due to subcontractor equipment failure, weather, site-access, or other issues, and any time where the field geologist is causing a significant delay in field activities in the field log book.

4.3 Drilling Equipment Cleaning and Decontamination

Prior to mobilization, the drill rig and all associated equipment should be thoroughly cleaned to remove all oil, grease, mud, etc. Any equipment that is not required at the site should be removed from the rig prior to entering the site. To the greatest extent possible, drilling should proceed from the least to most contaminated sections of the work site.

Before drilling each boring, all the down-the-hole drill equipment, the rig, and other equipment (as necessary) should be steam cleaned, or cleaned using high-pressure hot water, and rinsed with pressurized potable water to minimize cross contamination, if appropriate. Special attention should be given to the thread section of the casings and to the drill rods. Additional cleaning may be necessary during the drilling of individual holes to minimize the carrying of contaminated materials from shallow to deeper strata by contaminated equipment.

Equipment with porous surfaces, such as rope, cloth hoses, and wooden blocks or tool handles cannot be thoroughly decontaminated. These should be disposed of properly at appropriate intervals. These intervals may be the duration of drilling at the site, between individual wells, or between stages of drilling a single well, depending upon characteristics of the tools, site contamination, and other considerations.

Cleaned equipment should not be handled with soiled gloves. Surgical gloves, new clean cotton work gloves, or other appropriate gloves should be used and disposed of when even slightly soiled. The use of new painted drill bits and tools should be avoided since paint chips will likely be introduced to the monitoring system.

All drilling equipment should be steam cleaned or cleaned using high-pressure hot water, if appropriate, at completion of the project to ensure that no contamination is transported from the sampling site.

IDW should be handled in accordance with *SOP No. 005 Investigation-Derived Wastes.*

4.4 Drilling Methods

The following presents a description of some common drilling methods utilized for overburden drilling. The drilling method will be selected based upon the physical properties of the subsurface materials and project specific objectives.

4.4.1 Hollow Stem Auger Methods

Hollow stem auger drilling is a form of rotating auger drilling, consisting of continuous-casing, segmented auger sections with screw-flights that are rotated into the subsurface under downward pressure. The auger section is typically equipped with a drill bit and cutting teeth. Drill cuttings are brought to the surface by a conveyor action created by rotating screw flights and the drill bit. The auger sections maintain borehole stability, even in unconsolidated material. Generally, hollow steam auger drilling is limited to depths less than 100 feet where lithology is unconsolidated. Multiple auger sections are connected in series to create a "drill string" with clamping pins or screw fittings.

In-situ soils may be sampled through the center of the hollow stem auger drill stem. An advantage of this type of drilling is that auger sections can be left in place to hold the borehole open and reduce slough in unconsolidated soils. If installing a monitoring well, the well casing, filter pack and seal are installed inside the auger. The auger is removed slightly ahead of backfilling as filter pack, bentonite and grout are added.

Hollow stem augers are specified by the internal diameter of the hollow stem, rather than the size of the hole they drill. Augers with a minimum inner diameter of 4.25" should be used to install 2" diameter monitoring wells, to give clearance around the well for filter pack sand and bentonite seals. If a 4" diameter monitoring well is required, the inner auger diameter must be 6" to 8".

Auger flights and sampling equipment (e.g., split spoon samplers, shelby tubes) should be pre-cleaned and decontaminated prior to boring.

4.4.2 Direct Push

Direct push systems involve a category of drilling equipment that hydraulically pushes or drives small-diameter, hollow steel rods into the subsurface without rotation. Some drill rigs may be "combo rigs," capable of conducting both direct push and rotating hollow stem auger drilling operations. Direct push drilling uses a combination of a hydraulically powered percussion hammer, a downward hydraulic push, and the weight of the vehicle on which the system is mounted to drive rods into the subsurface by laterally displacing soil to make a path for the sampler, so no cuttings are generated. Direct push drilling is commonly used for shallow applications; however, depending on the lithographic conditions, it may be used as deep as 120 feet.

Direct push technology is typically limited to unconsolidated formations that are relatively free of cobbles or boulders. Refusal may occur if there are too many cobbles, boulders, consolidated formation materials, or anthropomorphic debris. However, since direct push drilling is relatively fast, refusal at a desired location may be mitigated by abandoning the hole, moving to a nearby location, and re-drilling.

Direct push boreholes generally cannot be sampled deeper than the water table because unconsolidated materials cave in once the drive rods are removed. However, caving may be mitigated by advancing a casing with an inner drill rod used for sampling, allowing for sampling and well installation far below the water table. Outside diameters of samplers and boring tools generally range from 0.75” to 3.5”. If installation of monitoring wells is planned, the inside diameter of the boring should typically ranges from 1.5” to 3.5” (for 1” to 2” wells).

Direct push technologies offer the following advantages over conventional drilling methods:

- Minimal ground disturbance, with a small diameter boring that is easy to abandon;
- No cuttings, i.e., minimal Investigation Derived Wastes (IDW) generation;
- Faster boring advancement;
- Faster monitoring well installation if small diameter wells (0.75” to 1” diameter) with pre-packed screens are installed.

Boreholes should be completed using pre-cleaned and decontaminated (or disposable) drive points, rods, and sampling equipment.

4.4.3 Mud Rotary Drilling

During fluid-rotary drilling, the borehole is drilled by a rotating bit; cuttings are removed by continuous circulation of a drilling fluid as the bit penetrates the formation. The bit is attached to a string of drill rods that transmits the rotating action and drilling fluid from the rig to the bit.

There are a variety of fluids that can be used in conjunction with this drilling method. The usual drilling fluid is water or water mixed with bentonite (referred to as “mud-rotary”). Under some geologic conditions, it may be necessary to add other compounds to the drilling fluid to increase the fluid weight or viscosity. These additions may include inorganic compounds such as barite or organic polymers. For monitoring wells constructed to sample groundwater quality, the use of any organic polymers in the drilling fluid should be avoided and inorganic additions made only if they will not interfere with the groundwater sampling protocol. The Project Manager should be consulted before a drilling fluid other than clear water is to be used. The decision as to whether drilling fluid additives should be used should be based on consultation with the client and review of any guidance documents used by the lead regulatory agency, if appropriate. Even if an agency is not currently involved with the project, it may be advisable to utilize their method of preference so environmental data and analytical results cannot be questioned at a later date.

There are two general types of fluid-rotary drilling methods: direct circulation rotary drilling and reverse circulation rotary drilling. In direct circulation rotary drilling, the drilling fluid is circulated down through the drill rods, out the bit, and up the annular space to the settling pit at the surface. In the reverse circulation rotary method, the drilling fluid and cuttings move down the annulus and upward inside the drill rod to be discharged into the settling pit. Upon boring completion, clean water should be circulated through the system to remove residual additives from the borehole and facilitate subsequent well development.

Advantages to rotary drilling methods include:

- The ability to advance a hole in most formations at a relatively quick pace;
- Split-barrel samples, Shelby tubes, and rock cores can be obtained;
- Casing may not be needed because the drilling fluids may keep the borehole open;
- They are relatively common methods that are used by water well drillers in most areas; and
- The open hole can be geophysically logged.

Disadvantages to this method include:

- Formation logging is difficult if split-barrel samples are not taken;
- Drilling fluid reduces formation permeability to some degree, may circulate contaminants, or alter groundwater quality in the vicinity of the well;
- Limited or no information on depth to water and/or occurrence of water-bearing zones is obtainable while drilling;
- Development techniques for wells may be more extensive when compared to other drilling methods;
- Drill rigs are usually large and heavy and need proper access;
- Federal and state regulatory agencies may prohibit the use of this method for some applications because of the addition of fluids in the hole; and
- Potable water is required for mixing drill fluids. This water should be sampled and the water source should remain the same throughout the program. This method may require a large volume of water. The availability of a potable water source should always be considered in the selection of this method.

4.4.4 Air Rotary Drilling

This method is similar to fluid-rotary drilling, except that compressed air is used to cool the drill bit and remove cuttings. Two drilling methods that use air as the primary drilling fluid are direct air-rotary and down-the-hole air hammer. Applications of air-rotary methods include:

- Rapid drilling of semi-consolidated and consolidated rock;
- Good quality/reliable formation samples (particularly if small quantities of water and surfactant are used);
- Equipment generally available;
- Allows easy and quick identification of lithologic changes;
- Allows identification of most water-bearing zones; and
- Allows estimation of yields in strong water-producing zones with short "down time".

Limitations of this method include the following:

- Surface casing is frequently required to protect the top of the hole from washout and collapse;
- Its use is restricted to semi-consolidated and consolidated formations;
- Samples are reliable but due to small size are difficult to interpret;
- Drying effect of the air may mask low yield water producing zones;
- Air stream may require filtration to prevent introduction of contaminants from the air compressor; and
- The injected air may modify the chemical or biological conditions of the aquifer in the immediate vicinity of the borehole.

4.4.1 Rotosonic Drilling

Rotosonic is a core drilling method that employs simultaneous high frequency vibration and low speed rotational motion along with downward pressure to advance the core barrel without use of drilling fluid or air. The core barrel can generally advance from five to twenty feet at one time, depending on the length of the core barrel. The drill cuttings are brought to the surface by removal of the entire core barrel from the borehole and the cuttings are vibrated out of the barrel. If required for logging purposes, the cuttings are collected in plastic sleeves. An outer casing is generally washed-down with water to stabilize the borehole from collapse and heaving sand. The outer casing prevents cross-contamination and formation mixing. The advantage of rotosonic core drilling is that no drilling fluids or muds are required to bring the cuttings to the surface and the aquifer is less likely to be contaminated by the drilling method. Split-barrel and Shelby tube samples can be collected using Rotosonic methods.

4.5 Heaving and Flowing Soils

The presence of heaving and flowing soils within the deeper saturated zone is a known issue at the Sparrows Point Terminal Site. When encountered, use appropriate drilling techniques to minimize potential impacts; these includes using drilling fluids or a drill-stem plug. Minimize the use of drilling fluids if possible. However, when necessary, it is permissible to add potable water from a documented, clean source and/or drilling mud to the borehole to control heaving and flowing soils as long as identification of the saturated zones during drilling is not compromised and the drilling fluid can be removed during development so that representative water levels can be obtained. All drilling fluid volume added to a borehole must be developed from the well. If potable water is added to the borehole, develop an equal volume of water from the borehole, in addition to the standard well development volume. If a drill-stem plug is used, slowly release the plug from the end of the drill-string while at total borehole depth.

5 QUALITY ASSURANCE

All field activities shall follow guidelines presented in the project specific documents. Any changes required based on conditions encountered in the field are to be documented in the field logbook and shall be approved by the project manager.

Logging of soil borings shall be consistent with the requirements of *SOP No. 012 Geologic Logging.* Soil sampling for the purposes of geotechnical and analytical testing shall following the requirements of *SOP No. 012* and *SOP No. 009 Subsurface Soil Sampling.* Monitoring Well Construction shall be consistent with the requirements of *SOP No. 014 Monitoring Well Construction in Unconsolidated Formations.*

SOP No. 014
MONITORING WELL CONSTRUCTION IN UNCONSOLIDATED FORMATIONS STANDARD OPERATING PROCEDURE
Rev. 03

1 SCOPE

This Standard Operating Procedure (SOP) provides procedures for the proper construction of groundwater monitoring wells in unconsolidated formations. Groundwater extraction, or pumping test wells, will be constructed using the same general procedures.

Monitoring wells are used for many purposes: collection of groundwater for chemical analysis; measurement of groundwater levels; detection of free-phase constituents; and aquifer testing. The specific purpose for which the well was constructed, the regulatory framework applicable to the well construction, the expected useful life of the well, and other factors may have significant bearing on the construction technique employed. However, all wells, regardless of intended purpose, should be constructed to minimum standards to ensure the following:

- Good hydraulic connection is established between the well and the water-bearing zone of interest;
- Water from separate zones or aquifers are not interconnected, and well construction activities do not facilitate cross-contamination;
- Well construction activities do not alter the chemical characteristics of the aquifer;
- The well is properly sealed to prevent entry of surface water; and
- The well is properly identified.

In general, the monitoring well construction will adhere to the SOP listed below. However, modification to the SOP may occasionally be required based on actual conditions encountered in the field. Justification of field modifications can be provided, as needed.

2 EQUIPMENT

Equipment and materials used for drilling and constructing monitoring wells in unconsolidated formations will depend upon the chosen drilling and subsurface sampling methods, and well design. Based upon the chosen methods, the drilling subcontractor will be responsible for providing a drilling rig, support equipment, and trained drilling crew capable of performing the requested drilling and installation activities. The qualified driller will typically know, based on experience, what equipment will be required for specific situations. It is necessary, therefore, to provide the driller with as much information as possible regarding the requirements and objectives for the drilling and monitoring well installation, as well as the anticipated subsurface conditions.

Besides the general equipment necessary to drill the boring, well installation equipment will likely include the following:

- Various pumps, e.g., mud, trash, grout, etc.
- Various hoses for fluids and air
- Casing lifts (cables, clamps, hoists)
- Portable water tank, transfer lines, and pump (as needed)
- Cutting torch and welder
- Grout and slurry mixing machines
- Tremie lines and drop pipes

The driller will also obtain the required materials for well installations. Material specifications will be the responsibility of the overseeing field personnel or project manager. The specifications are dependent upon anticipated subsurface conditions. The process by which the proper materials are selected is presented in the following section.

Well construction materials typically will include the following:

- Temporary casing
- Well screen
- Riser pipe (to extend from the screen to the surface)
- Centralizers
- Sand and/or gravel pack
- Sealing materials (bentonite chip, powders, etc.)
- Grouting materials
- Protective steel casings, manholes, and/or flush-mount caps
- Compression caps
- Locks and keys
- Concrete for pad construction

In addition to the equipment and material needs of the driller, the field manager overseeing the monitoring well construction activities will require particular items to assist in documenting construction activities. Equipment and materials likely to be used by oversight personnel may include:

- Field logbook and indelible ink pens
- Personal protective equipment (PPE) as prescribed in the Health and Safety Plan (HASP)
- Digital camera
- Mud balance (for grout density measurements)
- Weighted tape for measuring borehole depths and well construction material placement
- Tape measure and/or ruler
- Water-level and/or interface probe
- Multi-parameter meter to measure pH, temperature, specific conductance, and turbidity during well development.

3 PROCEDURES

The site-specific or project-specific Health and Safety Plan (HASP) shall be reviewed prior to monitoring well installation. All requirements of the HASP should be maintained for the duration of the installation. Any unforeseen hazards not specifically referenced in the HASP, identified by field personnel shall be reported to the Project Manager prior to proceeding with field activities.

3.1 Borehole Installation

Drilling methods and borehole construction practices are discussed in *SOP No. 013 – Soil Boring Methods*. When a boring may be used for the construction of a monitoring well, the drill should use a high-pressure, hot water, power washer, i.e., steam cleaner to clean all bits, pipe augers, and any other drilling or sampling tools that may be used in the advance of the borehole (*SOP No. 016 Equipment Decontamination*). No grease or other machine lubricants should be used during the well construction (some regulatory agencies will allow selected lubricants with prior approval). The borehole must be of suitable diameter (the diameter of the boring should be at least four inches greater than the outside diameter of the well pipe for permanent monitoring wells) and depth for the monitoring well planned. If the boring extends more than a few feet below the planned depth of the monitoring well, the lower portion of the boring should be sealed with a structurally suitable bentonite seal (i.e. bentonite pellets) to provide a base for the well. Cement grouts should not be used to seal borings because of possible effects on groundwater chemistry.

3.2 Well Casing and Screen

The well casing (riser pipe) and screen for most permanent monitoring well installations will be two- or four-inches in diameter. Two-inch diameter wells are generally used because:

- They require smaller borehole diameters, which reduce drilling costs;
- The smaller diameter reduces the volume of cuttings, which may have to be disposed;
- Construction material costs are lower; and
- The volume of water that must be purged during well sampling is less.

A four-inch diameter well may be preferred when wells are built to collect groundwater samples from silt and/or clay sediments. Wells screened in these sediments tend to produce turbid samples. Increasing the well screen diameter reduces the groundwater entrance velocity, which helps to reduce the turbidity of the samples. Using "wire wrapped" as opposed to slotted screens will also help to reduce sample turbidity for the same reason. Increasing the well diameter also reduces the surge energy that reaches the formation when a snug fitting bailer is dropped into the well to collect samples. The selection of well diameter for low yielding silt and/or clay aquifers should take into account the volume of water to be purged from the well during sampling. Costs associated with disposal of purge water and slow labor requirements for purging/sampling wells recharge wells may negate the advantage of installing a larger diameter well. A four-inch diameter well may also be preferred when wells are built to collect groundwater samples from sand and/or gravel material. Wells screened in highly transmissive aquifers are occasionally difficult to fully develop without pumping. For this reason, well diameters may be increased to accommodate a submersible pump. Deeper wells may also require a submersible pump to efficiently lift groundwater during development and purging.

For most groundwater monitoring applications, polyvinyl chloride (PVC) is a suitable material for both well casing and screens. It is readily available, is low in cost, and generally unaffected by the chemistry of most groundwaters. However, when sampling for chlorinated organic compounds, PVC pipe and screens may be unacceptable. Also, some phase-separate liquids, including some petroleum products or high concentrations of some solvents, may have an adverse effect on the integrity of PVC pipe and screens. The material supplier can usually provide information regarding material incompatibilities if the nature and concentration of the contaminants are known. Some regulatory agencies require specific well construction materials for monitoring well use. Wells intended for the collection of monitoring data subject to regulatory review must be constructed of materials and in a manner approved by the designated agency.

Stainless steel pipe and screens are usually an acceptable alternative when PVC cannot be used. Stainless steel is more expensive than PVC and will usually require one or two weeks lead time to assure delivery of materials.

In some cases, where metals are a contaminant of concern, stainless steel is unacceptable and PVC or other well screen and casing materials (e.g., Teflon®) should be used. Combinations of materials may also be used in some cases (for example, using stainless steel or Teflon® for those portions of the well below the water table and PVC through the unsaturated zone). Attention must be given to the joints of these hybrid wells. To eliminate corrosion where dissimilar construction materials connect (for example, if a well is constructed of stainless and black steel pipe) nonconductive joint rings may be necessary at the fittings. The material supplier can usually provide information regarding material incompatibilities. Terminating the well with a section of PVC pipe may also make the well completion easier to accomplish, especially where the top of the well pipe must be cut to fit inside a surface-mounted well cover.

Threaded well casing and screens shall be used for monitoring well applications. Glued joints shall not be used for any monitoring well construction. The threaded joints typically include an O-ring that, when properly installed, assures a leak-tight joint. Threaded joints also reduce the chance of introducing organic constituents to the well, which may occur when solvents are used to weld PVC pipe. The threaded joints also provide a smooth interior, which reduces the likelihood that sampling tools or measuring tapes will become hung up inside the well. Teflon® tape may be used to lubricate threads, and clean water or hydrated bentonite may be used to lubricate O-rings.

The well casing and screens should always be new material. Proper storage, both at the site and before delivery, is required to assure the pipe is clean.

A threaded, slip-over or an expanding-type well cap should top each well. The well cap should have a small hole drilled through it to maintain atmospheric pressure at all times. This allows wells to recover more quickly to static conditions after sampling and will help prevent the cap from sticking due to a low-pressure condition in the well. A threaded plug should be installed in the bottom of the well. A small hole should be drilled through the plug to allow the well to completely drain should the water table drop below the bottom of the well, if applicable.

Centralizers should be used depending upon the depth of the well to assure the well casing is centered in the borehole, unless the well is installed through hollow stem augers. Hollow stem augers will keep the well reasonably centered without the use of centralizers. One centralizer should be placed at the bottom of the well screen and another approximately 10 feet below the top of the well. Additional centralizers should be placed at 25-foot intervals.

Well screen slot size should be selected based on the grain size of the formation to be sampled. The well screen should retain 90 percent of the formation sand for naturally developed wells or 90 percent of the filter-pack sand. If a grain size distribution is not available for the formation, the following guideline (Gass, 1988) should be followed.

Anticipated Strata	*Well Screen Size (inches)*	*Filter Pack Material (Approximate Range of Standard United States Sieve Sizes)*
Sand and gravel	0.030	20 to 4
Silt and sand	0.020	30 to 8
Clay and silt	0.010	50 to 16

3.3 Annulus Filling

Naturally developing a monitoring well (allowing the natural formation sands to cave around the well screen) is acceptable when the grain size distribution of the formation is known and the well screen was properly selected to retain the formation sand. However, this information is not usually available before the well is constructed. Consequently, most monitoring wells will be filter packed.

Filter pack sand should be clean, well-rounded, uniformly sized (uniformity coefficient of 3.0 or less) silica sand, free of organic matter and carbonate grains. The filter pack should be placed from the bottom of the well to no less than 1 foot nor more than 2 feet above the well screen. A 0.5-foot thick layer of very fine sand (sand blotter) should be placed at the top of the filter pack to separate the filter pack from the overlying bentonite seal. If using mud rotary drilling methods, the filter pack sand should be washed into place through a tremie pipe with water from a potable source.

A bentonite seal should be placed in the well above the filter pack sand. Bentonite pellets or chips may be used if they are installed below the water table and do not have to free fall through more than approximately 15 feet of water. Where the bentonite is installed through more than 15 feet of water, the bentonite should be hydrated and emplaced as a slurry under pressure through a tremie pipe. The slurry should consist of approximately 15 pounds of powdered bentonite to 7 gallons of portable water. The tremie pipe should have a deflector at the bottom to prevent the grout from being jetted into the filter pack sand.

The bentonite seal should extend from the top of the sand blotter up the annular space to the water table surface for a minimum of 3 feet. A second 0.5-foot thick sand blotter should top the bentonite seal. The annular space above the water table should be filled to within 3 feet of the surface with a cement/bentonite grout consisting of 2 to 5 pounds of powdered bentonite per bag of Portland cement mixed with 5 to 6 gallons of potable water. The cement/bentonite grout should be properly mixed using appropriate grouting equipment. The cement/bentonite grout should be tremied into place from the bottom of the annulus to the top using a grout pump. The tremie pipe should have a deflector at the bottom to prevent jetting of the grout into the bentonite seal.

Where the concentration of total dissolved solids in the groundwater is high (greater than approximately 500 parts per million), the chloride concentration is high, or when substantial thickness of phase-separated liquids are present, neither bentonite nor cement/bentonite grouts may be suitable. Under these cases, the grouting material must be selected based on the specific characteristics present at the site.

The upper five feet of the annulus (or to the top of the bentonite seal when it terminates at depth less than five feet) should be filled with concrete. This portion of the annulus seal needs the structural strength of concrete to protect the casing and the well cover. The concrete should extend below the frost depth. The concrete should be no more than a few inches larger in diameter than the well borehole. This will prevent frost action from lifting the well. The top of the concrete should slope away from the well to direct rain water away. Where a concrete apron surrounding the well is desired or required by regulation, it should be constructed with a joint around the concrete that fills the top of the annulus to assure separation of the well from the apron.

3.4 Well Covers and Surface Finishing

A well cover should be set in the concrete at least three feet below the ground surface and extend one to two inches above the well pipe. The diameter of the well cover should be sufficient to allow room to remove the well cap with gloved hands. The well cover should have a locking, hinged lid that prevents the entrance of rain water. A small hole should be drilled in the side of the well cover approximately six inches above the ground surface to allow moisture to drain from the well cover, if applicable. The space between the well cover and the well pipe should be filled with coarse sand or fine gravel.

Alternately, the well may terminate in a specifically-built surface mount well cover. The surface mount well cover should never be used when the ground surface is low and storm water could pond over the well. When the existing surface is low and a flush-mounted well is designed, the surface should be regraded to prevent water from standing over the well. In paved parking lots or driveways, a small mound two to three inches high sloping away from the well may be sufficient to divert storm runoff away from the well opening.

Permanent labels should be affixed on both the inside and outside of the well cover lid. The label should include a unique well identification code and the elevation of the water level measuring point. The label may also include the date the well was drilled. A notch should be cut or filed in the top of the well pipe to mark the water level measuring point.

3.5 Grouting Techniques

There are several methods for monitoring well grouting. In determining the specific grouting requirements for a monitoring well, considerations must be given to existing subsurface geologic and groundwater conditions. The most effective grouting method should be selected by the site hydrogeologist based on the particular site conditions. Selection of the grouting technique and material may be limited by state or local regulations. Consultation with appropriate agencies prior to beginning grouting activities is advisable. Site-specific methodologies should be stipulated in the project work plan.

Prior to grouting, the annular space should always be flushed to assure that the space is open and able receive the sealing material. This is performed by circulating water or other drilling fluid in the annular space. Grouting should be performed in one continuous operation in which the annular space is filled. Grout containing cement should be placed entirely before the occurrence of the initial set. It is essential that the grout always be introduced at the bottom of the space being grouted such that positive displacement of any water in the annular space occurs.

The grout may be forced into the annular space by suitable pumps or by air or water pressure. Under certain conditions (*i.e.*, when no water exists in the annular space), placement by gravity is practical and satisfactory.

The following sealing and grouting procedure is recommended for most monitoring wells. Following placement of the filter pack, a 2-foot bentonite seal should be placed above the filter pack. Granular bentonite, bentonite pellets, or bentonite chips are suitable for this application. For monitoring wells that are less than 30 feet deep, the bentonite may be dropped directly down the borehole within the annular space. This should be performed gradually and uniformly in order to prevent bridging. In addition, a tamping device should be used to prevent bridging. For monitoring wells that are greater than 30 feet deep, bentonite should be delivered using a tremie pipe. If a bentonite seal is installed in the unsaturated zone, granular bentonite should be used, gradually hydrated with potable water, and allowed to cure prior to grouting.

Grouting of the remaining annular space should be performed using a tremie pipe with side discharge ports, a grout pump, and the neat cement grout or bentonite/cement grout in slurry form. The grout slurry should be pumped to the bottom of the borehole through the tremie pipe which should be kept full of grout for the duration of the procedure. The tremie pipe should be raised slowly as the annular space fills with grout. As the tremie pipe is raised, the discharge ports should be kept submerged within the grout until the desired zone is completely grouted. An annular space of at least 2 inches between the borehole wall and the well casing should exist, and the minimum inside diameter of the tremie pipe should be 1.5 inches.

3.6 Direct Push Methods for Monitoring Well Installation

A variety of Direct Push methods are available for installing temporary or permanent monitoring wells. The two main installation methods used are exposed-screen and protected-screen wells. These methods are discussed in detail in ASTM D-6724 and D-6725 (ASTM, 2003a and 2003b) and are summarized here.

3.6.1 Exposed-Screen Well Installation Methods

With exposed-screen well installation methods, the well casing and screen are driven to the target depth using a single string of rods. Because the screen is exposed to formation materials while it is advanced, proper well development is important to remove soil from screen slots. This method is not recommended for installing well screens within or beneath contaminated zones because dragdown of contaminants with the screen may cross-contaminate sampling zones and make acquisition of samples representative of the target zone impossible. Exposed-screen well installation methods should only be used in upgradient areas that are known to be uncontaminated. Also, some states prohibit allowing the formation to collapse around a well screen in the construction of a monitoring well. Therefore, state regulations should be consulted before selecting exposed-screen techniques.

In one type of exposed-screen installation, the PVC well screen and casing are assembled and placed around a shaft of a drive rod connected to a metal drive tip. The casing and screen, which rest on top of the drive tip, are advanced to the target depth by driving the rod to avoid placing pressure on the screen. The drive tip slightly enlarges the hole to reduce friction between the formation and the well screen and casing, and remains in the hole plugging the bottom of the screen. The filter pack surrounding the well screen commonly is derived from formation materials that are allowed to collapse around the screen. Rigorous well development improves the hydraulic connection between the screen and the formation and generally is necessary to remove formation fines and the effects of well installation, which may include borehole smearing or the compaction of formation materials. Due to the very small annulus (if any) that surrounds a well, constructed using the exposed-screen method, it is not generally possible to introduce a filter pack or annular seal from the surface.

Exposed-screen methods also can be used to install well points (simple wells used for rapid collection of water level data, groundwater samples, and hydraulic test data in shallow unconfined aquifers). Well points are generally constructed of slotted steel pipe or continuous-wrap, wire-wound, steel screens with a tapered tip on the bottom. They can be driven into unconsolidated formations and used for either point-in-time sampling and decommissioned after the sample is collected, or left in place for the duration of the sampling program possibly requiring the installation of a seal to prevent infiltration of water from the ground surface to the screened interval.

The optimum conditions for well point installations are shallow sandy materials. Predominantly fine-grained materials such as silt or clay can plug the screen slots as the well point is advanced. Because well points are driven directly into the ground with little or no annular space, the formation materials are allowed to collapse around the screen, and the well point needs to be developed to prepare it for sampling.

3.6.2 Protected-Screen Well Installation Methods

When installing a protected-screen well, the well casing and screen are either advanced within or lowered into a protective outer drive rod that has already been driven to the target depth. Once the well casing and screen are in place, the drive rod is removed. Alternatively, the casing, screen, and a retractable shield may be driven simultaneously to the target depth. Once in place, the screen is exposed and the entire unit remains in the ground. If there is sufficient clearance between the inside of the drive rod and the outside of the well casing and screen, a filter pack and annular seal may be installed by tremie from the surface as the drive casing is removed from the hole. Several filter packing and annular sealing approaches are available, depending on the equipment used for the installation (ASTM D5092 and D6725; ASTM, 2003b and 2003c). Regardless of the method of installation, the filter pack should be sized appropriately to retain most of the formation materials.

The most common protected-screen method for installing direct push method wells is to advance an outer drive casing equipped with an expendable drive tip to the target depth. The well casing and screen are then assembled, lowered inside the drive casing, and anchored to the drive tip. The drive casing seals off the formations through which it has been advanced, protecting the well casing and screen from clogging and from passing through potentially contaminated intervals. The position and length of the screen should be selected to match the thickness of the monitoring zone, which can be determined by using additional information, such as CPT logs or continuous soil boring logs.

When direct push method wells are installed in non-cohesive, coarse-grained formations, the formation can be allowed to collapse around the screen (if this technique is not prohibited by state well installation regulations) after it is placed at the target depth since turbidity problems are unlikely. When turbidity is likely to pose a problem for groundwater sample quality, a number of methods for installing filter packs are available. The filter pack can be poured or tremied into place as the drive casing is removed. Depending on the relative size of the drive casing and well, however, it may be difficult to introduce filter pack or annular seal materials downhole unless the hole is in a cohesive formation that will remain open as the drive casing is removed. Typical inside diameters of direct push wells range from 0.5-inch (schedule 80 PVC) to 2 inches (schedule 40 PVC), and the maximum inside diameter of drive casing is 3.5 inches. The table below provides a reference for understanding the relationship between inside diameters of direct push drive casing, the outside diameter of well casing and screen, and the annular space available for filter packs.

ID Of Well Casing (in.)	OD of Well Casing (in)	Annular Space with 1.8 in OD Drive Casing (in)	Annular Space with 3.5 in OD Drive Casing (in)
0.5	0.84	0.66	2.16
0.75	1.05	0.45	1.95
1.0	1.32	0.18	1.68
1.25	1.66	NA	1.34

For the best control of filter pack placement and grain size, "sleeved" or "prepacked" well screens can be used. Pre-packed screens are generally composed of a rigid Type I PVC screen surrounded by a pre-sized filter pack. The filter pack is held in place by a stainless-steel wire mesh (for organic contaminants) or food-grade plastic mesh (for inorganic contaminants), such as polyethylene, that is anchored to the top and bottom of the screen. Sleeved screens consist of a stainless-steel wire mesh jacket filled with a pre-sized filter-pack material, which can be slipped over a PVC pipe base with slots of any size.

Annular seals and grout should be placed above the filter pack to prevent infiltration of surface runoff and to maintain the hydraulic integrity of confining or semi-confining layers, where present.

The sealing method used depends on the formation, the well installation method, and the regulatory requirements of state or local agencies. Most protected-screen installations tremie a high-solids (at least 20% solids) bentonite slurry or neat cement grout into place as the drive casing is removed from the hole. A barrier of fine sand or granular or pelletized bentonite (where water is present) may be placed above the primary filter pack before grouting to protect it from grout infiltration, which could alter the water chemistry in the screened zone. Similar to the pre-packed and sleeved screens mentioned above, modular bentonite sleeves that attach to the well screens and are advanced with the well during installation are also available. Some manufacturers provide a foam seal that expands immediately when the casing is withdrawn to form a temporary seal above the screen. A bentonite sleeve above the seal expands more slowly after the casing is withdrawn but forms a permanent seal once it hydrates. To ensure a complete seal of the annular space from the top of the annular seal to the ground surface, the grout or slurry should be placed from the bottom up. By using a high pressure grout pump and nylon tremie tube it is possible to perform bottom-up grouting in the small annular spaces of Direct Push equipment. Slurries of 20-30% bentonite or neat cement grout are most commonly used to meet state regulatory requirements. A properly constructed Direct Push installed monitoring well can provide representative water quality samples and protect groundwater resources. In addition, as with conventional wells, a properly constructed Direct Push well should have a flush-mount or above-ground well protection to prevent physical damage or tampering of the well. Small locking well plugs are also available for even 0.5-inch nominal PVC casing.

3.7 Well Completion Log:

A boring log should be completed for each boring as presented in *SOP No. 012 Geologic Logging*. A well completion log (which can be combined with the boring log) should also be completed and present, at a minimum the following:

- Well name
- Well type, i.e, piezometer, monitoring well, pumping well, etc.
- Name of individual logging the well
- Project specific information
- Well permit number
- Well survey coordinates
- 24-hour depth to water

- Completion Diagram
  - Detailed monitoring well schematic which indicates but is not limited to:
    - Borehole diameter and depth
    - Type, diameter, and depth of well
    - Type and length of casing and screen
    - Slotted screen size
    - Grain size of sand pack
    - Depth to top of screen, sand pack and bentonite seal
    - Top of the well casing in mean sea level (MSL) elevation in feet. Elevation measurements should be determined by a Professional Land Surveyor following completion of the monitoring well.
    - Top of screen, bottom of screen, and bottom of well in feet below ground surface.

Monitoring Well Construction Log

Well ID: **Well Permit No:** Page 1 of

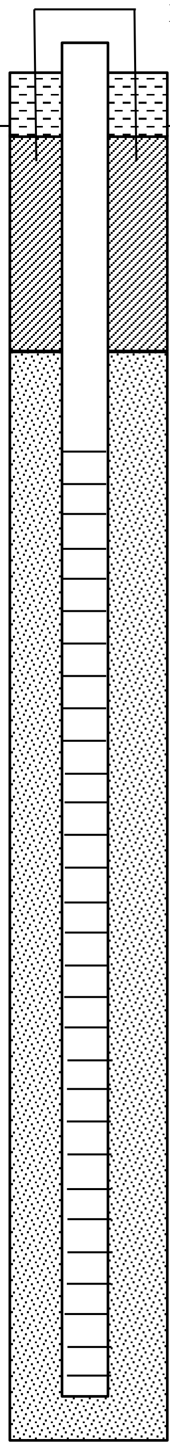
Project Name:
Project Number:
Client:
Site:
Borehole Location:
Well Type:

Date/Time Started:
Date/Time Completed:
Logged by: Checked by:
Driller:
Development Amount (gal):
Start/End - Time/Date:

Northing (ft):
Easting (ft):
Surface Elevation (ft), AMSL:
Total Depth (ft):
Depth to Water (ft):
Borehole Diameter (in):

Depth (ft):

WELL CONSTRUCTION DIAGRAM



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LITHOLOGIC DESCRIPTION

COMPLETION DETAILS

Well Pad
___ ft x ___ ft

Protective Cover w/Locking Lid: _____ in dia.

Outer Casing Type:
Diameter: _______ in.
Casing Amount:
________ in. __________ lf
Casing Stickup (AGS): _____ in.
Top of Casing Elev., ft (AMSL)
____

Riser Type:
Riser Diameter: _______ in.
Riser Amount:
________ in. __________ lf
Riser stickup (AGS): _____ in.
Top of Riser Elev., ft (AMSL):
____

Screen Type:
Screen Diameter: _______ in.
Screen Amount:
________ in. __________ lf
Slot Size:

Grout Quantity:
top: bottom:
Grout Type:

Bentonite Seal
top: bottom:

Filter Pack:
top: bottom:
Grain size:

SOP No. 015
TEST PITTING
STANDARD OPERATING PROCEDURE
Rev. 03

1 SCOPE

The purpose of this Standard Operating Procedure (SOP) is to describe procedures for the collection of representative surface soil or sub-surface samples **from test pits**. Sampling depths are assumed to be those that can be reached without the use of a drill rig, direct-push technology, or other mechanized equipment (except for a back-hoe). Test pitting may be used for delineation of contamination and/or waste material that can be identified using field identification methods, investigation of subsurface anomalies identified by remote sensing technologies, or collection of soil samples for laboratory analysis to determine concentrations of contaminants.

These are standard (i.e., typically applicable) operating procedures which may be varied or changed as required, dependent upon site conditions, equipment limitations, or limitations imposed by the procedure. In all instances, the ultimate procedures employed should be documented and associated with a final report.

1.1 References

SOP 005 Investigation-Derived Wastes Management
SOP 008-Surface Soil Sampling

2 EQUIPMENT

- Bound field logbook
- Sample tags
- Appropriate sample containers and labels
- Insulated cooler and ice
- Decontamination equipment and supplies
- Personal protective clothing and equipment as required by the site-specific HASP
- Stainless steel or aluminum trays or bowls
- Stainless steel shovels, trowels, spoons, or spatulas
- Backhoe Equipment

3 PROCEDURES

Reference SOP No. 008, Surface Soil Sampling, for details concerning surface soil sampling.

3.1 General Procedures-Test Pitting

A backhoe can be used to remove sections of soil when a detailed examination of stratigraphy and soil characteristics is required. The following procedures are used for collecting soil samples from test pits or trenches:

1. Prior to any excavation with a backhoe, it is imperative to ensure that all sampling locations are clear of overhead and buried utilities.

2. Review the site specific HASP and ensure that all safety precautions including appropriate monitoring equipment are installed as required.

3. Using the backhoe, excavate a trench at least three feet wide.to the specified depth. Place excavated soils on plastic sheets. Excavated material must be managed in accordance with SOP 005 INVESTIGATION-DERIVED WASTES MANAGEMENT.

4. Do not enter an unprotected trench! Trenches greater than five feet deep must be sloped or protected by a shoring system, as required by Occupational Safety and Health Administration (OSHA) regulations. OSHA standards require that trenches greater than 5 feet deep be inspected daily and as conditions change by a competent person prior to worker entry to ensure elimination of excavation hazards. A competent person is an individual who is capable of identifying existing and predictable hazards or working conditions that are hazardous, unsanitary, or dangerous to employees and who is authorized to take prompt corrective measures to eliminate or control these hazards and conditions.

5. A shovel is used to remove a one to two inch layer of soil from the vertical face of the pit where sampling is to be done.

6. Samples are taken using a trowel, scoop, or coring device at the desired intervals. Coring devices are preferred due to the instability of pit faces. Be sure to scrape the vertical face at the point of sampling to remove any soil that may have fallen from above, and to expose fresh soil for sampling. In cases where sampling points cannot be reached from the surface and entry into the pit may be unsafe, samples can be collected directly from the backhoe bucket.

7. If VOC analyses are required, consideration must be given to the procedure used to collect the volatile organic compound sample. If the soil being sampled is cohesive and holds its in situ texture in the spoon, the syringe used to collect the sub-sample for Method 5035A should be plugged directly from the spoon. If, however, the soil is not cohesive and crumbles when

removed from the ground surface for sampling, consideration should be given to plugging the sample for Method 5035A directly from the sample location.

8. Abandon the pit or excavation according to applicable state regulations.

3.2 Additional Backhoe Sampling Information

- Samples collected to a depth of 5 feet (ft) will be collected from the side walls and floor of the trench/test pit, as long as the side wall can be safely accessed at that depth. In some instances, safely reaching the sidewall at 5 ft bgs may not be possible and the bucket of the backhoe will be used to access soil material. If samples are being collected to represent soil concentrations at a specified depth, then the sample should consist of a composite sample from equally-spaced locations on the pit side walls (or, if present, from areas of apparent contamination based on field indicators) at the specified depth. If samples are being collected to define soil concentrations in the material surrounding the test pit (such as for confirmation of removal of contaminated material), then a separate composite sample should be collected from three equally-spaced locations (or, if present, from areas of apparent contamination based on field indicators) from each wall and the pit floor.

- Samples collected deeper than 5 ft bgs will be collected directly from the backhoe bucket using soil material contained in the bucket that is not in contact with the bucket walls. If collected from the backhoe bucket, the sample should be a composite from three equally-spaced locations within the bucket.

3.3 Field Log Information

At a minimum, field logs for test pit excavation will include the following documentation:

- Plan and profile sketches of the test pit showing materials encountered, the depth of material, and sample locations
- Sketch of the test pit and distance and direction from permanent, identifiable location marks as appropriate
- Photographs of the test pit
- GPS coordinates for the test pit
- A description of the material removed from the excavation
- A record of samples collected
- The presence or absence of water in the test pit and the depth encountered
- Other readings, or measurements taken during excavation, including field screening reading

Unless otherwise specified and the site-specific Health and Safety Plan discusses appropriate procedures, no personnel will enter the test pit. In addition, all test pits will be backfilled on the day of excavation. In most cases, excavation materials will be used to fill the test pit. In the event that highly contaminated soil is excavated and it is expected that it will be more cost-effective to remove the soil from the site rather than use it as back fill, excavated soils may be stockpiled on polypropylene and the excavation will be filled with clean soil.

4 REFERENCES

Kasper, K. *STANDARD OPERATING PROCEDURE FOR TEST PIT SAMPLING AT THE WEST KINGSTON TOWN DUMP/ URI DISPOSAL AREA SITE*. Rep: Woodard and Curran, 2002.

Sobol, J. *Backhoe Trenching/Test Pits for Sample Collection*. Rep. Boston: CDM Smith, 2012.

SERAS. *Standard Operating Procedures*. Rep: Scientific Engineering Response and Analytical Services, 2001.

SOP No. 016
EQUIPMENT DECONTAMINATION STANDARD OPERATING PROCEDURE
Rev. 02

1 SCOPE

This Standard Operating Procedure (SOP) presents general guidelines and step-by-step methods for on-site decontamination of sampling equipment, heavy equipment, and personal protective equipment. Decontamination is performed as a quality assurance measure and a safety precaution. Decontamination prevents cross-contamination between samples, minimizes contaminant transport, and also helps to maintain a clean working environment for the safety of the field personnel.

Although this SOP defines on-site decontamination procedures, it is highly recommended that (1) dedicated disposable sampling implements are used whenever possible, and (2) sufficient dedicated sampling implements are taken to the field so that the need for field decontamination is eliminated or reduced. For example, in collecting groundwater samples, dedicated, disposable bailers should be used, where practicable.

Decontamination is mainly achieved by washing and rinsing with liquids which include; soap and/or detergent solutions, tap water, distilled water, hexane, and nitric acid. The actual procedure will vary depending on project-specific requirements as listed in the project-specific work plan, the type of equipment to be used, and the analytical parameters of interest.

Each task work plan will include a brief list of the decontamination procedures described in this SOP that will be required and will provide a figure showing all proposed equipment decontamination areas to be used for that task.

1.1 Referenced SOPs

SOP 005 - Management of Investigation-Derived Wastes

2 EQUIPMENT

This section contains a general list of materials that may be required to conduct field decontamination of sampling equipment. A particular project may have slightly different requirements; the -project-specific work plan should be consulted prior to gathering and shipping equipment to the site.

- Concrete or lined decontamination pad (as required by project planning documents)

- Plastic sheeting
- Garden-type water sprayers
- Pressure washer, if required
- Portable steam cleaner, if required
- Cleaning brushes
- Distilled water
- Phosphate-free detergent (e.g., Liquinox® or Alconox®)
- Potable water supply
- Hexane (pesticide grade)
- 10% Nitric acid
- Chemical-free paper towels or shop cloths
- Cleaning brushes and scrapers
- Aluminum foil
- Drop cloth or plastic sheeting
- Gloves; safety glasses, protective clothing
- Cleaning containers (e.g., buckets, basins, pans)
- Chemically-compatible dedicated squirt or spray bottles for each solvent above and/or distilled water

Additional supplies such as those listed below could be required for waste disposal:

- Trash bags
- Trash containers
- 55-Gallon drums
- Metal or plastic buckets with lids for storage and disposal of decontamination liquids

3 METHODOLOGIES

Where feasible, all sampling equipment should be cleaned prior to use and dedicated to one sampling location for each sampling event to minimize the need for cleaning equipment in the field. In some instances, the use of dedicated sampling equipment may not be a practical option, depending on the scope of the project.

In general, decontamination is accomplished by manually scrubbing, washing, or spraying equipment with one or more of the following: detergent solutions, tap water, distilled water, steam, acids, or solvents. Equipment can be allowed to air dry after being decontaminated or may be wiped dry with chemical-free paper towels, if immediate use is necessary.

A decontamination area should be set up before any personnel or equipment enters areas of potential exposure. The contaminants encountered and type of equipment used will dictate the type of field decontamination procedures required.

At a minimum, the following procedures will be used for decontamination of sampling equipment that comes in direct contact with the sample:

1. Remove adhered material from the sampling equipment by brushing and/or rinsing with tap water.
2. Wash with non-phosphate detergent and tap water.
3. Rinse with distilled water.
4. Repeat the first three steps as necessary until all residue is removed.
5. If metals are a constituent of interest, rinse with 10% nitric acid.
6. Rinse with distilled water.
7. If organics are constituents of interest, rinse with pesticide-grade hexane and allow to air dry on a clean surface.
8. Rinse with distilled water.
9. Air dry or dry with clean, chemical free paper towels or shop cloths.

If metals are not a constituent of interest for sample analysis, the nitric acid rinse and the subsequent distilled water rinse steps can be eliminated. If organics are not a constituent of interest for sample analysis, the hexane rinse and the subsequent distilled water rinse steps can be eliminated.

3.1 Decontamination Area

During the project planning activities, a localized decontamination area was established and is provided on **Figure 1** (attached). The location of the decontamination area will be such that fluids and solids wastes can be managed in a controlled area with minimal risk to the surrounding environment. Should adverse weather conditions occur, the decontamination area may be moved indoors to the alternate location provided on **Figure 1**.

Smaller decontamination tasks, such as the cleaning of soil or water sampling equipment, and Geoprobe drive rods and Macro-Core barrels, may take place at the sampling location. In this case, all required decontamination supplies and equipment must be brought to the sampling location. This decontamination will use various containment systems to capture the decontamination IDW, which can then be transferred to larger containers as needed and transported to the IDW storage facility.

3.1.1 Large Equipment Decontamination Area

In some cases, for heavy equipment such as earthmoving equipment, an existing concrete pad can be used for decontamination activities. In other cases, one may need to be constructed. This determination will be made prior to the use of heavy equipment for earthmoving. The concrete pad, shall be lined with heavy-gauge plastic sheeting and include a collection system to capture decontamination Investigation Derived Waste (IDW). The decontamination fluids may then be transferred to 55-gallon drums (with lids) or 5-gallon buckets with tight fitting lids and transported to the IDW storage facility.

3.1.2 Drilling Equipment Decontamination Area

Decontamination of downhole drilling equipment (drill bits, hollow-stem augers, and drilling rods) shall be completed using a decontamination pad; which will be constructed in the decontamination area (**Figure 1**). The decontamination pad should be constructed in an area known or believed to be free of contamination; in a manner that prevents leakage; constructed on level ground; and lined with heavy plastic sheeting.

3.2 Health and Safety Precaution

Decontamination procedures may involve:

- Potential exposure to constituents within the medium being investigated or solvents employed
- Physical hazards associated with the operation of the decontamination equipment

When decontamination is performed on equipment which has been in contact with the constituents of interest or when the quality assurance objectives of the project require decontamination with chemical solvents, the measures necessary to protect personnel should be addressed in the Health and Safety Plan. The Health and Safety Plan must be approved by the project Health and Safety Officer before work commences, must be distributed to all personnel performing equipment decontamination and must be adhered to as field activities are performed. Material Safety Data Sheets for any solvents stored or used on-Site should be should be available at the Site.

At a minimum, eye protection, safety shoes, and gloves are to be worn. There are several types of gloves that may be worn, depending on equipment being cleaned, type and extent of equipment contamination, and cleaning solutions or solvents being used.

Polyvinyl gloves may be worn when the equipment to be decontaminated is not heavily coated with constituents such as tars/oils. In cases where heavy accumulations of tars/oils are present on the equipment, neoprene or similar chemically compatible gloves are recommended. If a potential for skin contact exists, protective clothing should be worn.

3.3 General Equipment Decontamination Procedures

All sampling equipment must be decontaminated before use to ensure that contaminants have not been introduced to the sample during the sampling process through contact with the sampling device. Monitoring well riser pipes, screens and drilling augers must also be decontaminated, as appropriate, to prevent the introduction of constituents.

Unless the decontaminated sampling devices that will come in contact with samples are to be used immediately, they should be wrapped in aluminum foil, shiny side out, and stored in a designated "clean" area. Field equipment can also be stored in plastic bags to eliminate the potential for contamination. Larger size equipment, such drill rods, augers, backhoe buckets, etc. need not be wrapped or covered. This equipment should be stored on horses or otherwise, kept from storage directly on the ground surface. Field equipment should be inspected and decontaminated prior to use if the equipment has been stored for long periods of time.

3.4 Personnel and Personal Protective Equipment (PPE)

Decontamination of personnel and PPE prevents undesired human-health exposure to contaminants via ingestion, absorption, and inhalation.. Any further concerns regarding personnel and PPE decontamination procedures may be addressed directly with the Health and Safety Officer and/or Project Manager.

3.5 Decontamination of Sampling Equipment

Conduct consistent decontamination of sampling equipment to ensure the quality of the samples collected. Decontaminate all sampling equipment that comes into contact with potentially contaminated samples. Disposable equipment intended for one-time use that is factory-wrapped generally does not need to be decontaminated before use, unless evidence of contamination is present.

Disposable equipment, such as disposable bailers, spoons, TerraCore® or Encore® VOC samplers, is preferred over reusable equipment; use wherever appropriate. Decontaminate sampling equipment, including split-spoon samplers, Geoprobe Macro-Core cutting shoes, hand augers, reusable bailers, spoons, trowels, and shovels used to collect samples for chemical analyses before sampling at a new sampling location. All decontamination fluids will be captured in a containment system as appropriate. The decontamination fluids may then be transferred to 55-gallon drums (with lids) or 5-gallon buckets with tight fitting lids and transported to the IDW storage facility.

Take the following steps to decontaminate non-dedicated, non-disposable sampling equipment:

1. Remove as much gross contamination (such as pieces of soil) as possible off equipment at the sampling site.
2. Wash water-resistant equipment thoroughly and vigorously with potable water containing non-phosphate laboratory-grade detergent such as Liquinox®, Alconox®, or equivalent, and using a bristle brush or similar utensil to remove any remaining residual contamination.
3. Rinse equipment thoroughly with potable water.
4. Rinse equipment thoroughly with distilled water.
5. Repeat the first three steps as necessary until all residue is removed.
6. Rinse with 10% nitric acid, if metals are a constituent of interest.
7. Rinse with distilled water.
8. If organics are constituents of interest, rinse with pesticide-grade hexane and allow to air dry on a clean surface.
9. Rinse with distilled water.

10. Air dry at a location where dust or other fugitive contaminants may not contact the sample equipment. Alternatively, wet equipment maybe dried with a clean, disposable paper towel to assist the drying process. All equipment should be dry before reuse.
11. If the equipment is not used soon after decontamination, it should be covered or wrapped in new, oil-free aluminum foil or new, unused plastic bags to protect the decontaminated equipment from fugitive contaminants before reuse.
12. Store decontaminated equipment at a secure, unexposed location out of the weather and any potential contaminant exposure.

If metals are not a constituent of interest for sample analysis, the nitric acid rinse and the subsequent distilled water rinse steps can be eliminated. If organics are not a constituent of interest for sample analysis, the hexane rinse and the subsequent distilled water rinse steps can be eliminated.

3.6 Decontamination of Groundwater Sampling Pumps

(Note: This procedure does not apply to dedicated submersible pumps which have been permanently installed in wells.)

Proper decontamination between wells is essential to avoid introduction contaminants from the sampling equipment to another well. If peristaltic pumps are being used, it is necessary only to replace the pump head tubing after sampling each well. If sampling with submersible pumps that come into direct contact with groundwater, the equipment must be decontaminated. The following procedure will be used to decontaminate submersible pumps before and between groundwater sample collection points, as well as the end of each day of use.

Field-site cleaning procedure for submersible pumps and pump tubing:

Step 1: Preparation.

a. Pre-clean standpipes (one standpipe for each cleaning solution to be used). The standpipes need to be of sufficient height to supply necessary head for proper pump operation. Separate standpipes are designated for detergent solution and tap water rinse, distilled (DIW) rinse, and blank water. Double-bag each cleaned standpipe for transport to the field site.

b. Estimate the volumes of cleaning solutions and blank water that will be needed for the decontamination process.

c. Prepare the volumes of cleaning solutions needed for the field effort, using appropriate bottles for short-term storage and transport.

Step 2: Detergent wash and tap water rinse.

a. Put on disposable, powderless gloves. Rest pump in a washbasin or pail partially filled with detergent solution and clean exterior of pump and tubing with a soft brush. Rinse thoroughly with tap water. (DIW can be used instead of tap water, but is less efficient in detergent removal and requires a greater volume of water than tap water.)

b. Place pump into standpipe, add detergent solution to level above pump intake, and route the intake and discharge ends of pump tubing to the standpipe.

c. Begin pumping:

i. Record the pumping rate.

ii. Record the time it takes to fill the sample tubing.

iii. Calculate the time it takes for a segment of solution to complete one cycle.

d. Circulate detergent solution for about three cycles through the tubing and back to the standpipe. If possible, pump detergent solution through tubing at alternating high and low speeds, and (or) introduce air segments between aliquots of the detergent solution to increase cleaning efficiency.

e. Remove the discharge end of tubing from the standpipe and pump about two tubing volumes of detergent solution to 5-gallon bucket, adding fresh solution to the standpipe as needed. Remove pump from standpipe.

f. Rinse detergent from standpipe with tap water until sudsing stops.

g. Rinse pump exterior with tap water. Place rinsed pump into the tap water/DIW standpipe; add tap water/DIW to level above pump intake. Begin pumping through sample tubing. Do not recirculate rinse water, but add water as needed to maintain water level above pump intake. Continue for five or more tubing volumes. Direct rinse water to 5-gallon bucket, away from the vicinity of the wellhead and sampling area and (or) contain as required for disposal.

h. Collect rinse water into a small bottle and stop the pump. Shake the bottle—if sudsing is observed in the rinse water, continue the rinse procedure until no suds appear in the rinse water. Change gloves.

Step 3: Check sampling requirements.

— If a pump will be used to collect samples for inorganic-constituent analysis, go to Step 4.

—Complete Step 4 if a pump will be used to collect samples for analysis of both inorganic and organic analytes and then go to Step 5.

—If a pump will be used to collect samples for organic-compound analysis only, go to Step 5.

Step 4: DIW rinse.

A separate DIW rinse is not required if DIW was substituted for tap water.

a. Use a clean DIW-dedicated standpipe (not the tap water standpipe) and rinse the standpipe with DIW. Rinse pump exterior with DIW. Place pump into the DIW standpipe and add DIW to level above pump intake. Change gloves.

b. Start pumping DIW. Rinse DIW through sample tubing without recirculating, using about three tubing volumes of DIW. Keep the DIW level above pump intake.

c. If collecting field blanks to verify that the pump has been adequately cleaned:

i. Change gloves. Rinse clean blank-water standpipe with DIW. Rinse pump exterior with blank water.

ii. Place pump into the standpipe and add DIW to cover the pump intake.

iii. Turn on pump and displace any water residing in the pump and tubing. Continue pumping DIW for one tubing volume before collecting the blank sample.

The decontamination fluids may then be transferred from 5-gallon buckets and/or standpipes described above to 55-gallon drums (with lids) or 5-gallon buckets with tight fitting lids and transported to the IDW storage facility.

Storage of the cleaned submersible pump and tubing:

1. Place pump into two clean, non-contaminating storage bags and tie the bags shut.

2. Cover the pump reel and tubing with doubled plastic bags or sheeting for transport to the next site.

3. On reaching the next monitoring well, place the pump in the well casing and wipe dry both the power and discharge lines with a chemical-free paper towel as the pump is lowered.

For long-term storage (longer than 3 days), the pump and exterior and interior of the tubing must be dry before being placed into plastic bags. Tubing can be dried by blowing filtered air or filtered (inert) gas through the tubing. If tubing cannot be dried, store chilled to prevent bacterial growth. If bacterial growth has occurred, re-clean before use.

3.7 Decontamination of Measurement Devices & Monitoring Equipment

For water quality instruments, oil-water interface indicators, water level indicators, continuous water level data loggers, and other field instruments that have the potential to come into contact with site media, at a minimum, wash with dilute laboratory-grade detergent (Liquinox® or similar) and double rinse with potable and distilled water before and after each use or by using a similar procedure as discussed in Section 3.5. All decontamination fluids will be captured in a containment system as appropriate. The decontamination fluids may then be transferred to 55-gallon drums (with lids) or 5-gallon buckets with tight fitting lids and transported to the IDW storage facility.

3.8 Decontamination of Subsurface Drilling Equipment

Drilling equipment and associated materials (that is, drill bits, augers, and drilling stems) will be decontaminated by the drilling contractor prior to any drilling operations and between borings. These decontamination activities shall be performed using the decontamination pad located in the decontamination area as described in Section 3.1.2 above. The decontamination shall be performed using the following basic sequence:

1. Remove as much gross contamination as possible off equipment at the sampling site.
2. Wash equipment thoroughly and vigorously with potable water using a high-pressure washer and/or steam cleaner. A bristle brush is also suggested to remove any persistent gross contamination.
3. Air dry at a location where dust or other fugitive contaminants may not contact the sample equipment. All equipment should be dry before reuse.
4. Store decontaminated equipment at a location away from any potential exposure from fugitive contamination.

The decontamination fluids will then be transferred from the decontamination pad to 55-gallon drums (with lids) or 5-gallon buckets with tight fitting lids and transported to the IDW storage facility.

All down-hole Geoprobe tools (drive rods, Macro-Core barrels, etc.) that come in direct contact with potentially contaminated soil or groundwater shall be decontaminated between each sampling location, and may take place at the sampling location using a mobile decontamination platform with a containment system to capture the decontamination IDW. The decontamination fluids may then be transferred to 55-gallon drums (with lids) or 5-gallon buckets with tight fitting lids and transported to the IDW storage facility.

Take the following steps to decontaminate the down-hole Geoprobe tools:

1. Remove as much gross contamination as possible off equipment at the sampling site.
2. Wash equipment thoroughly and vigorously with potable water using a high-pressure washer and/or steam cleaner. A bristle brush is also suggested to remove any persistent gross contamination.
3. Air dry at a location where dust or other fugitive contaminants may not contact the sample equipment. All equipment should be dry before reuse.
4. Store decontaminated equipment at a location away from any potential exposure from fugitive contamination.

3.9 Decontamination of Heavy Equipment

Wash earthwork equipment (such as excavators and back-hoes) with high-pressure potable water, if possible, before leaving a contaminated area using similar steps as outlined in Section 3.8, otherwise the equipment may be moved to the decontamination area discussed in Section 3.1.1. Hand washing with a brush and detergent, followed by a potable water rinse, can also be used. In some instances, tires and tracks of equipment maybe only need to be thoroughly brushed with a dry brush. Take particular care with the components in direct contact with contaminants, such as tires and backhoe buckets. Any part of earthwork equipment that may come in direct contact with analytical samples (that is, sampling from the excavator bucket) must be thoroughly decontaminated before excavation activities and between sample locations.

4 QUALITY ASSURANCE/QUALITY CONTROL

To ensure that sampling equipment is cleaned properly and sample cross-contamination does not occur, field rinsate blanks will be collected as required by the Sampling and Analysis Plan. A rinsate blank will consist of pouring deionized organic-free water over the specific sampling device or pouring it through the device after it has been cleaned. The rinsate sample is collected in the field under the same conditions as occurred for the sampling activity, and is handled exactly like any other samples collected that day.

Generally, one rinsate blank is collected each day of sampling or at a rate of 1 per 20 for each parameter, whichever is less, for each matrix being sampled or for each type of sampling instrument decontaminated and reused per day. The rinsate samples are analyzed for the specific parameters of concern (for each matrix). Rinsate blanks should be labeled like a routine environmental sample, and laboratory analysis instructions should be included on the chain-of-custody form.

Rinsate blanks are not required if dedicated sampling equipment is used. Additional quality assurance samples may be collected if deemed necessary by project specific requirements. All project specific quality assurance sampling are defined in the QAPP.

5 DOCUMENT AND RECORD KEEPING

The field team leader will maintain a record of the decontamination procedures. Notations shall be made in the field logbook concerning the decontamination procedures and which equipment was decontaminated.

The following information should be recorded in the Field Logbook:

- Decontamination personnel
- Decontamination solutions used
- Start and finish date and time
- Location of decontamination activities
- General methods used, tools used, and observations, including any deviations from this SOP
- Location and amount of decontamination IDW collected, stored, and/or disposed, including the sources (e.g., well or boring numbers) of the IDW (see SOP *05 – Management of Investigation-Derived Wastes*)
- Any spills or releases, and associated corrective actions taken.

6 REFERENCES

United States Environmental Protection Agency, January 1991, Compendium of ERT Groundwater Sampling Procedures: Washington, D.C., EPA 540/P-91/007.

United States Environmental Protection Agency, December 1987, A Compendium of Superfund Field Operations Methods: Washington, D.C., EPA 540/P-87/001.

SOP No. 017
CALIBRATION OF FIELD INSTRUMENTS STANDARD OPERATING PROCEDURE
Rev. 03

1 SCOPE

The purpose of this standard operating procedure (SOP) is to provide a framework for calibrating field instruments. Water quality parameters for groundwater and surface waters include temperature, pH, dissolved oxygen, specific conductance, oxidation/reduction potential (ORP), and turbidity. This SOP supplements, but does not replace, EPA analytical methods listed in 40 CFR 136 and 40 CFR 141 for temperature, dissolved oxygen, conductivity/specific conductance, pH and turbidity. The probe readings for pH, dissolved oxygen, and specific conductance are automatically corrected for temperature.

With the exception of turbidity, the remaining water quality parameters are measured using probes included on the YSI ProPlus multimeter and Horiba Water Quality Meter U-50 Series multimeter. For groundwater monitoring, the instrument must be equipped with a flow-through-cell (Horiba Flow Through Cell U-50 Series) and the display/logger or computer display screen needs to be large enough to simultaneously contain the readouts of each probe in the instrument. Turbidity is measured using a separate instrument. It must not be measured in a flow-through-cell because the flow-through-cell acts as a sediment trap. This procedure is applicable for use with the *EPA Region I Low Stress (low flow) Purging and Sampling Procedure for the Collection of Ground Water Samples from Monitoring Wells.*

Other instruments requiring calibration checks or field calibration include the XRF meter, used for the detection of lead based paint, and PID meter, used for the detection of volatile organic and inorganic compounds. The calibration checks for these additional pieces of equipment are also described in this SOP.

2 HEALTH AND SAFETY WARNINGS

Read all labels on the standards and note any warnings on the labels. Wear appropriate personal protection equipment (e.g., gloves, eye shields, etc.) when handling the standards. If necessary, consult the Material Safety Data Sheets (MSDS) for additional safety information on the chemicals in the standards.

3 GENERAL

All monitoring instruments must be calibrated before they are used to measure environmental samples. For instrument probes that rely on the temperature sensor (pH, dissolved oxygen, specific conductance, and oxidation/reduction potential [ORP]), each temperature sensor needs to be checked for accuracy against a thermometer that is traceable to the National Institute of Standards and Technology (NIST). Before any instrument is calibrated or used to perform environmental measurements, the instrument must stabilize (warm-up) according to manufacturer's instructions and must have no air bubbles lodged between the probe and probe guard.

Most projects will require at least two standards to bracket the expected measurement range. This means that one standard is less than the expected value and one is higher. When an environmental sample measurement falls outside the calibration range, the instrument must be recalibrated to bracket the new range before continuing measurements. Otherwise, the measurements that are outside the calibration range will need to be qualified.

This SOP requires that the manufacturer's instruction manual (including the instrument specifications) accompany the instrument into the field.

4 FREQUENCY OF CALIBRATION

At a minimum, the instrument is calibrated prior to use on the day the measurements are to be performed. A post calibration check at the end of the day is performed to determine if the instrument drifted out of calibration. Some projects may require more frequent calibration checks throughout the day in addition to the check at the end of the day. For these checks, the instrument can be recalibrated during the day if the instrument drifted out of calibration and only the data measured prior to the check would need to be qualified. The calibration/post calibration data information is recorded in Table 1.

Instruments (e.g., sonde) that monitor continuously over a period of time are calibrated before deployment. When these instruments are recovered, the calibration is checked to determine if any of them drifted out of calibration.
Some instruments lose their calibration criteria when they are turned off. Those instruments can either be left on all day (battery dependent) or calibrated at each sampling location. If they are calibrated at each sampling location, a post calibration check is not needed.

Ideally, the temperature of the standards should be close to the temperature of the ambient water that is being measured.

5 CALIBRATION PROCEDURES

Prior to calibration, all instrument probes and cable connections must be cleaned and the battery checked according to the manufacturer's instructions. Failure to perform these steps (proper maintenance) can lead to erratic measurements.

If a multi-probe instrument is to be used, program the instrument to display the parameters to be measured (e.g., temperature, pH, percent dissolved oxygen, mg/L dissolved oxygen, specific conductance, and ORP).

The volume of the calibration solutions must be sufficient to cover both the probe and temperature sensor (see manufacturer's instructions for the volume to be used).

Check the expiration date of the standards. Do not use expired standards.

All standards are stored according to manufacturer instructions.

5.1 Temperature

SOP Reference: Current

Equipment Manual: YSI ProPlus; Horiba Water Quality Meter U-50 Series

Introduction:

Most instrument manuals state there is no calibration of the temperature sensor, but the temperature sensor must be checked to determine its accuracy. This accuracy check is performed at least once per year and the accuracy check date/information is kept with the instrument. If the accuracy check date/information is not included with the instrument or the last check was over a year, the temperature sensor accuracy needs to be checked at the beginning of the sampling event. If the instrument contains multiple temperature sensors, each sensor must be checked. This procedure is not normally performed in the field. If the instrument is obtained from a rental company, the rental company should performed the calibration check and include with the instrument documentation that it was performed.

Calibration (Verification) Procedure:

1. Fill a container with water and adjust the water temperature to below the water body's temperature to be measured. Use ice or warm water to adjust the temperature.
2. Place a thermometer that is traceable to the National Institute of Standards and Technology (NIST) and the instrument's temperature sensor into the water. Wait for both temperature readings to stabilize.
3. Compare the two measurements. The instrument's temperature sensor must agree with the reference thermometer measurement within the accuracy of the sensor (e.g., ±0.2 °C). If the measurements do not agree, the instrument may not be working properly and the manufacturer needs to be consulted.
4. Adjust the water temperature to a temperature higher than the water body to be measured.
5. Compare the two measurements. The instrument's temperature sensor must agree with the reference thermometer measurement within the accuracy of the sensor (e.g., ± 0 .2 ° C). If the measurements do not agree, the instrument may not be working properly and the manufacturer needs to be consulted.

5.2 pH (electrometric)

SOP Reference: Current

Equipment Manual: YSI ProPlus; Horiba Water Quality Meter U-50 Series

Introduction:

The pH of a sample is determined electrometrically using a glass electrode.

Choose the appropriate buffered standards that will bracket the expected values at the sampling locations. If the water body's pH is unknown, then three standards are needed for the calibration: one close to seven, one at least two pH units below seven, and the other at least two pH units above seven. Instruments that will not accept three standards will need to be re-calibrated if the water sample's pH is outside the initial calibration range described by the two standards.

Calibration Procedure:

1. Allow the buffered standards to equilibrate to the ambient temperature.
2. Fill calibration containers with the buffered standards so each standard will cover the pH probe and temperature sensor.
3. Remove probe from its storage container, rinse with deionized water, and remove excess water.
4. Select measurement mode. Immerse probe into the initial standard (e.g., pH 7).
5. Wait until the readings stabilize. If the reading does not change within 30 seconds, select calibration mode and then select "pH". Enter the buffered standard value into instrument.
6. Remove probe from the initial standard, rinse with deionized water, and remove excess water.
7. Immerse probe into the second standard (e.g., pH 4). Repeat step 5.
8. Remove probe from the second standard, rinse with deionized water, and remove excess water. If instrument only accepts two standards, the calibration is complete. Go to step · 11. Otherwise continue.
9. Immerse probe in third buffered standard (e.g., pH 10) and repeat step 5.
10. Remove probe from the third standard, rinse with deionized water, and remove excess water.
11. Select measurement mode, if not already selected. To ensure that the initial calibration standard (e.g., pH 7) has not changed, immerse the probe into the initial standard. Wait for the readings to stabilize. The reading should read the initial standard value within the manufacturer's specifications. If not, re-calibrate the instrument. If re-calibration does not help, the calibration range may be too great. Reduce calibration range by using standards that are closer together.
12. The calibration is complete. Rinse the probe with deionized water and store the probe according to manufacturer's instructions.
13. Record the calibration information on Table 1.

5.3 Dissolved Oxygen

SOP Reference: Current

Equipment Manual: YSI ProPlus; Horiba Water Quality Meter U-50 Series

Introduction:

Dissolved oxygen (DO) content in water is measured using a membrane electrode. To insure proper operation, the DO probe's membrane and electrolyte should be replaced prior to calibration for the sampling event. The new membrane may need to be conditioned before it is used; consult manufacturer's manual on how the conditioning is to be performed. Failure to perform this step may lead to erratic measurements. Before performing the calibration/measurements, inspect the membrane for air bubbles and nicks.

Note: some manufacturers require an altitude correction instead of a barometric correction. In that case, enter the altitude correction according to the manufacturer's directions in Step 5 and then proceed to Step 6.

Note: some instruments have a built-in barometer. Follow the manufacturer's instructions for entering the barometric value in step 5.

Calibration Procedure:

1. Gently dry the temperature sensor and remove any water droplets from the DO probe's sensor membrane according to manufacturer's instructions. Note that the evaporation of moisture on the temperature sensor or DO probe may influence the readings during calibration.
2. Create a 100 percent water-saturated air environment by placing a wet sponge or a wet paper towel on the bottom of the DO calibration container. Place the DO probe into the calibration container. The probe is loosely fitted into the calibration container to prevent the escape of moisture evaporating from the sponge or paper towel while maintaining ambient pressure (see manufacturer's instructions). Note that the probe and the temperature sensor must not come in contact with these wet items.
3. Allow the confined air to become saturated with water vapor (saturation occurs in approximately 10 to 15 minutes). During this time, tum on the instrument to allow the DO probe to warm-up. Select the measurement mode. Check the temperature readings. Readings must stabilize before continuing to the next step.
4. Select calibration mode; then select "DO %".
5. Enter the local barometric pressure (usually in mm of mercury) for the sampling location into the instrument. This measurement must be determined from an on-site barometer. Do not use barometric pressure obtained from the local weather services unless the pressure is corrected for the elevation of the sampling location. [Note: inches of mercury times 25.4 mm/inch equals mm of mercury or consult Oxygen Solubility at Indicated Pressure chart attached to the SOP for conversion at selected pressures].
6. The instrument should indicate that the calibration is in progress. After calibration, the instrument should display percent saturated DO.

Continued on next page…

7. Select measurement mode and set the display to read DO mg/L and temperature. Compare the DO mg/L reading to the Oxygen Solubility at Indicated Pressure chart attached to the SOP. The numbers should agree. If they do not agree within the accuracy of the instrument (usually ± 0.2 mg/L), repeat calibration. If this does not work, change the membrane and electrolyte solution.
8. Remove the probe from the container and place it into a 0.0 mg/L DO solution (see footnote). Check temperature readings. They must stabilize before continuing.
9. Wait until the "mg/L DO" readings have stabilized. The instrument should read less than 0.5 mg/L (assuming an accuracy of ± 0.2 mg/L). If the instrument reads above 0.5 mg/L or reads negative, it will be necessary to clean the probe, and change the membrane and electrolyte solution. If this does not work, try a new 0.0 mg/L DO solution. If these changes do not work, contact the manufacturer. Note: some projects and instruments may have different accuracy requirements. The 0.5 mg/L value may need to be adjusted based on the accuracy requirements of the project or instrument.
10. After the calibration has been completed, rinse the probe with tap or deionized water and store the probe according to manufacturer's instructions. It is important that all of the 0.0 mg/L DO solution be rinsed off the probe so as not to effect the measurement of environmental samples.
11. Record calibration information on Table 1.

Note: You can either purchase the 0.0 mg/L DO solution from a vendor or prepare the solution yourself. To prepare a 0.0 mg/L DO solution, follow the procedure stated in Standard Methods (Method 4500-0 G). The method basically states to add excess sodium sulfite (until no more dissolves) and a trace amount of cobalt chloride (read warning on the label before use) to water. This solution is prepared prior to the sampling event. Note: this solution can be made without cobalt chloride, but the probe will take longer to respond to the low DO concentration.

5.4 Specific Conductance

SOP Reference: Current

Equipment Manual: YSI ProPlus; Horiba Water Quality Meter U-50 Series

Introduction:

Conductivity is used to measure the ability of an aqueous solution to carry an electrical current. Specific conductance is the conductivity value corrected to 25 °C.

Most instruments are calibrated against a single standard which is near the specific conductance of the environmental samples. The standard can be either below or above the specific conductance of the environmental samples. A second standard is used to check the linearity of the instrument in the range of measurements.

When performing specific conductance measurement on groundwater or surface water and the measurement is outside the initial calibration range defined by the two standards, the instrument will need to be re-calibrated using the appropriate standards.

Calibration Procedure:

1. Allow the calibration standards to equilibrate to the ambient temperature.
2. Fill calibration containers with the standards so each standard will cover the probe and temperature sensor. Remove probe from its storage container, rinse the probe with deionized water or a small amount of the standard (discard the rinsate), and place the probe into the standard.
3. Select measurement mode. Wait until the probe temperature has stabilized.
4. Select calibration mode, then specific conductance. Enter the specific conductance standard value. Make sure that the units on the standard are the same as the instrument units. If not, convert the units on the standard to the instrument units.
5. Select measurement mode. The reading should remain within manufacturer's specifications. If it does not, re-calibrate. If readings continue to change after recalibration, consult manufacturer or replace calibration solution.
6. Remove probe from the standard, rinse the probe with deionized water or a small amount of the second standard (discard the rinsate), and place the probe into the second standard. The second standard will serve to verify the linearity of the instrument. Read the specific conductance value from the instrument and compare the value to the specific conductance on the standard. The two values should agree within the instrument specifications. If they do not agree, re-calibrate. If readings do not compare, then the second standard may be outside the linear range of the instrument. Use a standard that is closer to the first standard and repeat. If values still do not compare, try cleaning the probe or consult the manufacturer.
7. After the calibration has been completed, rinse the probe with deionized water and store the probe according to manufacturer's instructions.
8. Record the calibration information on Table 1.

Note: for projects where specific conductance is not a critical measurement it may be possible to calibrate with one standard in the range of the expected measurement.

5.5 Oxidation / Reduction Potential (ORP)

SOP Reference: Current

Equipment Manual: YSI ProPlus; Horiba Water Quality Meter U-50 Series

Introduction:

The oxidation/reduction potential is the electrometric difference measured in a solution between an inert indicator electrode and a suitable reference electrode. The electrometric difference is measured in millivolts and is temperature dependent.

Calibration Procedure:

1. Allow the calibration standard (a Zobell solution: read the warning on the label before use) to equilibrate to ambient temperature.
2. Remove the probe from its storage container and place it into the standard.
3. Select measurement mode.
4. Wait for the probe temperature to stabilize, and then read the temperature.
5. If the instrument is to be calibrated, do Steps 6 and 7. If the instrument calibration is to be verified, then go to Step 8.
6. Look up the millivolt (mv) value at this temperature from the millivolt versus temperature correction table usually found on the standard bottle or on the standard instruction sheet. You may need to interpolate millivolt value between temperatures. Select "calibration mode", then "ORP". Enter the temperature-corrected ORP value into the instrument.
7. Select measurement mode. The readings should remain unchanged within manufacturer's specifications. If they change, re-calibrate. If readings continue to change after re-calibration, try a new Zobell solution or consult manufacturer. Go to Step 9.
8. If the instrument instruction manual states that the instrument is factory calibrated, then verify the factory calibration against the Zobell solution. If they do not agree within the specifications of the instrument, try a new Zobell solution. If it does not agree, the instrument will need to be re-calibrated by the manufacturer.
9. After the calibration has been completed, rinse the probe with deionized water and store the probe according to manufacturer's instructions.
10. Record the calibration information on Table 1.

5.6 Turbidity

SOP Reference: 027

Equipment Manual: LaMotte 2020 we-wi Turbidimeter; LaMotte Turbidity Kit
Hach 2100 and 2100Qis Turbidity Meter

Introduction:

The turbidity method is based upon a comparison of intensity of light scattered by a sample under defined conditions with the intensity of light scattered by a standard reference suspension. A turbidimeter is a nephelometer with a visible light source for illuminating the sample and one or more photo-electric detectors placed ninety degrees to the path of the light source. Note: the below calibration procedure is for a turbidimeter which the sample is placed into a cuvette.

Some instruments will only accept one standard. For those instruments, the second, third, etc., standards will serve as check points.

Calibration Procedure:

1. Allow the calibration standards to equilibrate at the ambient temperature. The use of commercially available polymer primary standards (AMCO-AEPA-1) is preferred; however, the standards can be prepared using Formazin (read the warning on the label before use) according to the EPA analytical Method 180.1. Other standards may be used if they can be shown that they are equivalent to the previously mentioned standards.
2. If the standard cuvette is not sealed, rinse a cuvette with deionized water. Shake the cuvette to remove as much water as possible. Do not wipe dry the inside of the cuvette because lint from the wipe may remain in the cuvette. Add the standard to the cuvette.
3. Before performing the calibration procedure, make sure the cuvettes are not scratched and the outside surfaces are dry and free from fingerprints and dust. If the cuvette is scratched or dirty, discard or clean the cuvette respectively. Note: some manufacturers require the cuvette to be orientated in the instrument in a particular direction for accurate reading.
4. Select a low value standard such as a zero or 0.02 NTU and calibrate according to manufacturer's instructions. Note: a zero standard (approximately 0 NTU) can be prepared by passing distilled water through a 0.45 micron pore size membrane filter.
5. Select a high standard and calibrate according to manufacturer's instructions or verify the calibration if instrument will not accept a second standard. In verifying, the instrument should read the standard value to within the specifications of the instrument. If the instrument has range of scales, check each range that will be used during the sampling event with a standard that falls within that range.
6. Record calibration information on the Turbidity Calibration Log in SOP No. 027.

5.7 XRF Meter

SOP Reference: 023

Equipment Manual: INNOV-X Systems XRF Meter

Introduction:

A handheld X-Ray Fluorescence (XRF) detector can be used to conduct lead-based paint inspections on various combinations of paints and underlying substrates. The XRF detector emits high-energy X-rays which bombard a sample, causing it to fluoresce and emit secondary X-rays which are detected. Secondary X-rays are characteristic of each specific element, allowing for quantification of the materials in the sample. XRF instruments operate at a high speed and low cost per sample, and measure the sample without destructive sampling or paint removal.

The instrument is calibrated in the factory, but an accuracy check is necessary to determine if the equipment is operating properly prior to the data collection. A calibration check should be performed before the start of each testing period

Calibration (Verification)Procedure:

1. Remove the XRF from its casing and turn it on.
2. Take at least three calibration check readings of the provided paint chips with known lead concentrations. Make sure the XRF shutter lies flat against the test chip. Do not hold the chip while testing, or else the operator will be exposed to X-ray radiation. Typical paint chips for verification checks include a 0.0 mg/cm^2 negative control and a 1.02 mg/cm^2 reference material.
3. If the average (rounded to 1 decimal place) of the readings is outside of the calibration check range for the given paint chips, follow the manufacturers guidelines to correct the instrument.
4. Calibration rechecks should be completed every 4 hours or when testing is completed for the day, whichever is more frequent.

5.8 PID Meter

SOP Reference: 026

Equipment Manual: MiniRAE 3000 PID Meter

Introduction:

The PID is a portable, nonspecific, vapor/gas detector employing the principle of photoionization to detect a variety of chemical compounds, both organic and inorganic, in air. A PID is similar to a flame ionization detector (FID) in application; however, the PID can detect certain inorganic vapors but is unable to respond to certain low molecular weight hydrocarbons (such as methane and ethane).

The PID employs the principle of photoionization. The analyzer will respond to most vapors that have an ionization potential less than or equal to that supplied by the ionization source, which is an ultraviolet (UV) lamp. Photoionization occurs when an atom or molecule absorbs a photon of sufficient energy to release an electron and form a positive ion. Ions formed by the adsorption of photons are driven to the collector electrode. The current produced is then measured and the corresponding concentration displayed.

Calibration Procedure:

1. Press and hold [MODE] and [N/-] until you see the Password screen.
2. In Basic User Level, you do not need a password to perform calibrations. Instead of inputting a password, enter calibration by pressing [MODE]. If you inadvertently press [Y/+] and change any of the numbers, simply press [MODE] and you will be directed to the calibration menu. Zero calibration should be highlighted ([N/-] will toggle the calibration type).
3. Turn on the Zero calibration "fresh air" gas, which may be a include a gas from a cylinder, Tedlar bag, or clean ambient air
4. Press [Y/+] to start calibration. No action is required during the calibration. When Zero calibration is complete the instrument will then show the Calibration menu on its display, with Span highlighted.
5. To complete the span calibration, a cylinder of standard reference gas fitted with a 500 cc/min. flow-limiting regulator or a flow-matching regulator is the simplest way to perform this procedure. Alternatively, the span gas can first be filled into a Tedlar bag or delivered from a demand-flow regulator. Another option is to use a regulator with >500 cc/min flow but allow the excess to escape through a T or open tube.
6. You will see the name of your Span gas (the default is isobutylene) and the span value in parts per million (ppm).
7. Turn on your span calibration gas.
8. Press [Y/+] to initiate calibration. There is a 30-second countdown and the instrument performs the Span calibration automatically. It requires no actions on the part of the operator. The instrument automatically exits Span calibration and shows the Zero calibration menu. Press [MODE], which corresponds with "Back" to exit.

6 POST CALIBRATION CHECK

After the initial calibration is performed, the instrument's calibration may drift during the measurement period. As a result, you need to determine the amount of drift that occurred after collecting the measurements. The difference in value is then compared to the drift criteria or post calibration criteria described in the quality assurance project plan or the sampling and analysis plan for the project. If the check value is outside the criteria, then the measurement data will need to be qualified.

For parameters measured by the multiprobe, this is performed by placing the instrument in measurement mode (not calibration mode) and placing the probe in one or more of the standards used during the initial calibration. Wait for the instrument to stabilize and record the measurement (Table 1). Compare the new measurement value to the initial calibration value. For turbidity, place the standard in a cuvette and then into the turbidimeter, and record a measurement. For the dissolved oxygen calibration check, follow the calibration instructions steps one through three while the instrument is in measurement mode. Record dissolved oxygen value (mg/L), temperature, and barometric pressure. Compare the measurement value to the Oxygen Solubility at Indicated Pressure chart attached to this SOP. For the XRF, the post calibration check is the same as the initial check using the provided standard paint chips. For the PID meter, the span gas can be measured with the instrument in measurement mode.

The drift value should be within the criteria specified for the project, and if the drift value is outside the established criteria the data will need to be qualified. The drift criteria or the post-calibration criteria are shown below.

Measurement	Post Calibration Criteria
Dissolved Oxygen	± 0.5 mg/L of sat. value*
Specific Conductance	< 0.5 mg/L for the 0 mg/L solution, but not a negative value
pH	±5% of standard or ± 10µS/cm (whichever is greater
Turbidity	± 5% of standard
ORP	±10 mv*
XRF	Average of 3 measurements within the provided calibration check range
PID	±10% of standard

Note: * Table 8.1, USEPA Region 1 *YSI 6-Series Sondes and Data Logger SOP,* January 30, 2007, revision 9.

7 DATA MANAGEMENT AND RECORD MANAGEMENT

All calibration records must be documented in the project's log book. At a minimum, include the instrument manufacturer, model number, instrument identification number (when more than one instrument of the same model is used), the standards used to calibrate the instruments (including source), the calibration date, the instrument readings, the post calibration check, and the name of the person(s) who performed the calibration. An example of a calibration log sheet is shown in Table 1.

8 REFERENCES

Standard Methods for the Examination of Water and Wastewater, 20th edition, 1998.

Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020, Revised March 1983.

Turbidity - Methods for the Determination of Inorganic Substances in Environmental Samples,

EP A/600/R-93/100, August 1993.

USEPA Region 1YSI6-Series Sondes and Data Logger SOP, January 30, 2007, revision 9:

USGS Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Station Operation, Record Computation, and Data Reporting, Techniques and Methods 1-D3.

TABLE 1
MULTIPARAMETER CALIBRATION LOG

Project Name____________________ Date______________________
Weather____________

Calibrated by_____________________ Instrument_________________
Serial Number____________

Parameters	Morning Calibration	Morning Temperature	End of Day Calibration Check*	End of Day Temperature
Specific Conductance Standard #1				
Specific Conductance Standard #2				
pH (7)				
pH (4)				
pH(10)				
ORP Zobel Solution				
Dissolved Oxygen 100% water saturated air mg/L				
Dissolved Oxygen Zero Dissolved Oxygen Solution mg/L				
Barometric Pressure mm Hg		NA		NA
Turbidity Standard #1				
Turbidity Standard #2				
Turbidity Standard #3				

* For each Parameter, chose one standard as your check standard. If possible, choose the one that is closest to the ambient measurement value.

Oxygen Solubility at Indicated Pressure

Temp.				Pressure (Hg)				
	760	755	750	745	740	735	730	mm
°C	29.92	29.72	29.53	29.33	29.13	28.94	28.74	in
0	14.57	14.47	14.38	14.28	14.18	14.09	13.99	mg/l
1	14.17	14.08	13.98	13.89	13.79	13.7	13.61	
2	13.79	13.7	13.61	13.52	13.42	13.33	13.24	
3	13.43	13.34	13.25	13.16	13.07	12.98	12.9	
4	13.08	12.99	12.91	12.82	12.73	12.65	12.56	
5	12.74	12.66	12.57	12.49	12.4	12.32	12.23	
6	12.42	12.34	12.26	12.17	12.09	12.01	11.93	
7	12.11	12.03	11.95	11.87	11.79	11.71	11.63	
8	11.81	11.73	11.65	11.57	11.5	11.42	11.34	
9	11.53	11.45	11.38	11.3	11.22	11.15	11.07	
10	11.28	11.19	11.11	11.04	10.96	10.89	10.81	
11	10.99	10.92	10.84	10.77	10.7	10.62	10.55	
12	10.74	10.67	10.6	10.53	10.45	10.38	10.31	
13	10.5	10.43	10.36	10.29	10.22	10.15	10.08	
14	10.27	10.2	10.13	10.06	10	9.93	9.86	
15	10.05	9.98	9.92	9.85	9.78	9.71	9.65	
16	9.83	9.76	9.7	9.63	9.57	9.5	9.43	
17	9.63	9.57	9.5	9.44	9.37	9.31	9.24	
18	9.43	9.37	9.3	9.24	9.18	9.11	9.05	
19	9.24	9.18	9.12	9.05	8.99	8.93	8.87	
20	9.06	9	8.94	8.88	8.82	8.75	8.69	
21	8.88	8.82	8.76	8.7	8.64	8.58	8.52	
22	8.71	8.65	8.59	8.53	8.47	8.42	8.36	
23	8.55	8.49	8.43	.8.38	8.32	8.26	8.2	
24	8.39	8.33	8.28	8.22	8.16	8.11	8.05	
25	8.24	8.18	8.13	8.07	8.02	7.96	7.9	
26	8.09	8.03	7.98	7.92	7.87	7.81	7.76	
27	7.95	7.9	7.84	7.79	7.73	7.68	7.62	
28	7.81	7.76	7.7	7.65	7.6	7.54	7.49	
29	7.68	7.63	7.57	7.52	7.47	7.43	7.36	
30	7.55	7.5	7.45	7.39	7.34	7.29	T24	
31	7.42	7.37	7.32	7.27	7.22	7.16	7.11	
32	7.3	7.25	7.2	7.15	7.1	7.05	7.01)	
33	7.08	7.13	7.08	7.03	6.98	6.93	6.88	
34	7.07	7.02	6.97	6.92	6.87	6.82	6.78	
35	6.95	6.9	6.85	6.8	6.76	6.71	6.65	

36	6.84	6.79	6.76	6.7	6.65	6.6	6.55
37	6.73	6.68	6.64	6.59	6.54	6.49	6.45
38	6.63	6.58	6.54	6.49	6.44	6.4	6.35
39	6.52	6.47	6.43	6.38	6.35	6.29	6.24
40	6.42	6.37	6.33	6.28	6.24	6.19	6.15
41	6.32	6.27	6.23	6.18	6.14	6.09	6.05
42	6.22	6.18	6.13	6.09	6.04	6	5.95
43	6.13	6.09	6.04	6	5.95	5.91	5.87
44	6.03	5.99	5.94	5.9	5.86	5.81	5.77
45	5.94	5.9	5.85	5.81	5.77	5.72	5.68

Source: Draft EPA Handbook of Methods for Acid Deposition Studies, Field Operations for Surface.Water Chemistry, EP A/600/4-89/020, August 1989.

Oxygen Solubility at Indicated Pressure (continued)

Temp			Pressure	(Hg)					
	725	720	715	710	705	700	695	690	mm
°C	28.54	28.35	28.15	27.95	27.76	27.56	27.36	27.17	in
0	13.89	13.8	13.7	13.61	13.51	13.41	13.32	13.22	mg/l
1	13.51	13.42	13.33	13.23	13.14	13.04	12.95	12.86	
2	13.15	13.06	12.07	12.88	12.79	12.69	12.6	12.51	
3	12.81	12.72	12.63	12.54	12.45	12.36	12.27	12.18	
4	12.47	12.39	12.3	12.21	12.13	12.04	11.95	11.87	
5	12.15	12.06	11.98	11.89	11.81	11.73	11.64	11.56	
6	11.84	11.73	11.68	11.6	11.51	11.43	11.35	11.27	
7	11.55	11.47	11.39	11.31	11.22	11.14	11.06	10.98	
8	11.26	11.18	11.1	11.02	10.95	10.87	10.79	10.71	
9	10.99	10.92	10.84	10.76	10.69	10.61	10.53	10.46	
10	10.74	10.66	10.59	10.51	10.44	10.36	10.29	10.21	
11	10.48	10.4	10.33	10.28	10.18	10.11	10.04	9.96	
12	10.24	10.17	10.1	10.02	9.95	9.88	9.81	9.46	
13	10.01	9.94	9.87	9.8	9.73	9.66	9.59	9.52	
14	9.79	9.72	9.65	9.68	9.51	9.45	9.38	9.31	
15	9.58	9.51	9.44	9.58	9.31	9.24	9.18	9.11	
16	9.37	9.3	9.24	9.17	9.11	9.04	8.97	8.91	
17	9.18	9.11	9.05	8.98	8.92	8.85	8.79	8.73	
18	8.99	8.92	8.86	8.8	8.73	8.67	8.61	8.54	
19	8.81	8.74	8.68	8.62	8.56	8.49	8.43	8.37	
20	8.63	8.57	8.51	8.45	8.39	8.33	8.27	8.21	
21	8.46	8.4	8.34	8.28	8.22	8.16	8.1	8.04	

22	8.3	8.24	8.18	8.12	8.06	8	7.95	7.89
23	8.15	8.09	8.03	7.97	7.91	7.86	7.8	7.74
24	7.99	7.94	7.88	7.82	7.76	7.71	7.65	7.59
25	7.85	7.79	7.74	7.68	7.6	7.57	7.51	7.46
26	7.7	7.65	7.59	7.54	7.48	7.43	7.37	7.32
27	7.57	7.52	7.46	7.41	7.35	7.3	7.25	7.19
28	7.44	7.38	7.33	7.28	7.22	7.17	7.12	7.06
29	7.31	7.26	7.21	7.15	7.1	7.05	7	6.94
30	7.19	7.14	7.08	7.03	6.98	6.93	6.88	6.82
31	7.06	7.01	6.96	6.91	6.86	6.81	6.76	6.7
32	6.95	6.9	6.85	6.8	6.7	6.7	6.64	6.59
33	6.83	6.78	6.73	6.68	6.83	6.58	6.53	6.48
34	6.73	6.68	6.63	6.58	6.53	6.48	6.43	6.38
35	6.61	6.56	6.51	6.47	6.42	6.37	6.36	6.27
36	6.51	6.46	6.41	6.36	6.31	6.27	6.22	6.17
37	6.4	6.35	6.31	6.26	6.21	6.16	6.12	6.07
38	6.3	6.26	6.21	6.16	6.12	6.07	6.02	5.98
39	6.26	6.15	6.11	6.06	6.01	5.97	5.92	5.87
40	6.1	6.06	6.01	5.96	5.92	5.86	5.83	5.78
41	6	5.96	5.91	5.87	5.82	5.78	5.73	5.69
42	5.91	5.86	5.82	5.77	5.73	5.69	5.64	5.6
43	5.82	5.78	5.73	5.69	5.65	5.6	5.56	5.51
44	5.72	5.68	5.64	5.59	5.55	5.51	5.46	5.42
45	5.64	5.59	5.55	5.51	5.47	5.42	5.38	5.34

Source: Draft EPA Handbook of Methods for Acid Deposition Studies, Field Operations for Surface.Water Chemistry, EP A/600/4-89/020, August 1989.

SOP No. 018
WELL DEVELOPMENT
STANDARD OPERATING PROCEDURE

1 SCOPE

This Standard Operating Procedure (SOP) provides guidance for developing monitoring wells or extraction wells following installation and prior to their designated use for data acquisition (e.g., groundwater sampling, aquifer testing). Some of these procedures may also apply to well purging conducted prior to collection of water quality samples. However, development should not be confused with purging, the purpose of which is to evacuate the monitoring well of stagnant water which may not be representative of the aquifer.

Monitoring well development is necessary to ensure that complete hydraulic communication is made and maintained between the well screen and the water-bearing formation. Development is necessary after original installation of a monitoring well to:

- Restore aquifer properties near the boring that were disturbed during drilling by reducing the compaction and mixing of grain sizes that occurred during drilling
- Remove fine-grained materials from the filter pack that were introduced during drilling and well installation, which could potentially affect water quality analyses
- Improve the hydraulic characteristics of the filter pack and the hydraulic communication between the well and the screened hydrogeologic unit by removing any drilling fluids or mud that cake the sides of the borehole or that may have invaded the adjacent natural formation
- Remove all water introduced into the borehole while drilling.

Formation characteristics change during drilling and well installation, and usually include the compaction of unconsolidated particles surrounding the annulus. In fine-grained soils, this can result in a mudwall around the boring annulus, which can impede free flow of formation water into the well. Monitoring well development physically agitates the formation around the well boring by pushing and pulling water through the filter pack and surrounding formation. This repetitive process flushes fine-grained soils into the well, where they either settle within the filter pack or are removed from the well during development and purging.

Common well development methods include surging, pumping, and bailing. The most effective technique involves using both a surge block in combination with pumping or bailing, so that water moves in both directions through the filter pack and the native formation surrounding the well screen.

This well development procedure also applies to rehabilitation of monitoring wells in which siltation has occurred. After a well has been in place for some period of time, the well depth may decrease due to accumulation of fine soil particles (siltation), and rehabilitation will be necessary to reestablish complete hydraulic communication with the aquifer.

1.1 Referenced SOPs

016 – Equipment Decontamination

019 – Depth to Groundwater and NAPL Measurements

1.2 Definitions

(Reserved)

2 REQUIRED MATERIALS

The following equipment may be required when performing well development. Not all equipment may be required, depending on the well development method used.

- Surge block on a cable or line
- Appropriate pump (centrifugal pump, submersible pump, or peristaltic pump)
- Bailers and bailer cord
- Compressed gas source and air discharge line; water discharge line
- Storage containers for the purge water
- Water level probe and/or oil-water interface probe
- Copy of the well construction diagram
- Field logbook
- Well development sheets
- Personal protective equipment as specified in the Health and Safety Plan
- Water quality monitoring instrument capable of measuring dissolved oxygen (DO), conductivity, pH, turbidity, temperature and oxidation-reduction potential (ORP)

The various specific development procedures discussed in Section 3.2 identify the different types of equipment which may be used to develop monitoring wells or extraction wells. Exact equipment needs will be specific to the monitoring well and will depend upon the diameter of the well, the depth to water, and other factors such as project objectives and intended use of the well.

3 METHODOLOGIES

Newly installed monitoring wells shall be developed no sooner than 48 hours after installation. The entire vertical screened interval should be developed using surge blocks, bailers, pumps or other equipment that frequently reverse the flow of water through the screen and prevent bridging of the formation or filter pack particles.

3.1 General Well Development Procedures

1. The depth to water in the well and the possible presence of NAPLs are measured in accordance with *SOP 019 – Depth to Groundwater and NAPL Measurements*. The total depth of the well should be measured with a weighted tape and the result compared to the original depth reported in on the well construction form and/or the field notes.
2. Remove a small quantity of water from the well using a decontaminated pump or bailer. Measure and record initial pH, temperature, conductivity, DO, ORP, and turbidity.
3. Begin well development by surging the bottom of the well and removing any sediment that has accumulated. To do this, slowly lower a decontaminated surge block into the well so that the block is approximately 6 to 12 inches from the bottom of the well or the measured sediment level. Slowly raise and lower the surge block approximately 1 to 2 feet to create a mild surging effect at the bottom of the well. This will re-suspend accumulated sediment. Do not agitate the water violently. After several surge strokes, remove the surge block and immediately begin to pump or bail the sediment-laden water. Repeat this process until accumulated sediment is removed from the bottom of the well and total well depth is as reported on the well construction diagram and/or field notes.
4. Work upwards from the bottom of the screened interval using the same alternating techniques of surging and pumping or bailing. If an air compressor is used to remove the sediment-laden water, a filter must be installed on the compressor to prevent introduction of oil into the well.
5. The minimum volume of water (*e.g.*, three casing volumes) which must be removed during development is usually specified in the project work plan. In practice, development of the well is continued until the water removed is essentially free of suspended silt and clay particles, to the extent practicable. In some aquifers, it may not be possible to remove all suspended solids regardless of the extent of development activities. The supervising hydrogeologist is ultimately responsible for the determination that the well has been sufficiently developed and that development can be terminated.
6. Field measurements (pH, DO, ORP, specific conductance, temperature, and turbidity) can be taken as a confirmation of sufficient development. Adequate development can be verified by stable readings of these field parameters.
7. Measure and record a final depth to water and a total well depth after development. Record all well development data on the Well Development form and/or in the field logbook.

3.2 Specific Well Development Procedures

The appropriate development method will be selected for each project on the basis of the specific circumstances, objectives and requirements of that project. Further, some agencies have developed comprehensive guidelines for groundwater monitoring and subsurface investigation procedures. The provisions of this SOP will be adapted to these project-specific requirements in the project work plan. The work plan will specify the well development method(s) to be used and the rationale, including trade-offs associated with the nature of the aquifer formation, analytical objectives, well use, and client or agency requirements.

Aside from agency requirements, the criteria for selecting a well development method include well diameter, total well depth, static water depth, screen length, the intended well use, and the type of geologic materials in the aquifer.

The limitations, if any, of each specific procedure, are discussed in each of the following procedure descriptions.

3.2.1 Surging

A surge block consists of a rubber (or leather) and metal plunger attached to a rod or pipe of sufficient length to reach the bottom of the well. Well drillers usually can provide surge blocks for large diameter wells (greater than 6 inches). Surge blocks for smaller diameter wells can be constructed easily of materials readily accessible in any hardware store. A recommended design is shown in Figure 1. Surging alone will not cause sufficient well development; however, surging used in conjunction with groundwater removal *via* pumping, bailing, or air-lifting effectively develops most monitoring and extractions wells.

The procedure to be followed when using the surge block is:

1. Construct a surge block using the design in Figure 1 as guidance. Specific materials will depend upon the diameter of the well to be developed. The diameter of the plunging apparatus must be sufficient to force the groundwater in the well out through the well screen, and the rods must be of sufficient length to reach the bottom of the monitoring well.
2. Insert the surge block into the well and lower it slowly to the level of static water. Start the surge action slowly and gently above the well screen using the water column to transmit the surge action to the screened interval. A slow initial surging, using plunger strokes of 3 to 5 feet, will allow material which is blocking the well screen to disengage from the screen and become suspended.
3. After a number (5 to 10) of surge strokes, remove the surge block and purge the well using a pump or bailer. The returned water should be heavily laden with suspended fine particles. As development continues, slowly increase the depth of surging to the bottom of the well screen. For wells with long screens (greater than 10 feet) surging should be undertaken along the entire screen length in short intervals (2 to 3 feet) at a time.

Continue this cycle of surging and pumping/bailing until well development is complete.

3.2.2 Pumping

Groundwater pumping is necessary to remove large quantities of sediment-laden groundwater from a well after using the surge block. In some situations, pumping is performed without surging. Since the primary purpose of well development is to remove suspended solids from a well, the pump must be capable of moving some solids without damage. The preferred type of pump is a centrifugal pump because of its ability to pump solids. However, a centrifugal pump will work only where the depth to groundwater is less than approximately 25 feet. If depth to groundwater is too great, a positive-displacement pump such as a submersible or bladder pump will be necessary.

Well development using a pump is more effective in those wells that will yield water continuously. Effective development may not be accomplished if the pump has to be shut off to allow the well to recharge.

The procedure to be followed for well development *via* pumping is:

1. Set the intake of the pump in the center of the screened interval of the monitoring well.

2. When appropriate, use the pump to fill the monitoring well to the top of the casing and allow the water level to decline to the static level, thereby forcing water back into the formation. This action will cause water to exit the well screen and reduce the bridging of materials caused by water flowing in one direction through the well screen while pumping.

3. The water used to fill the monitoring well should be the same water removed from the well during the previous pumping cycle. The sediment previously pumped from the well must be removed from the water prior to re-introduction to the well. A steel drum can be used as a sediment-settling vessel.

Continue pumping water out from the well until well development is complete.

3.2.3 Bailing

A bailer is an effective tool for development of small diameter monitoring wells where removal of only a relatively small volume of water is required for development. A bottom-filling bailer can also be used to remove sediment-laden water from wells after using the surge block.

The procedure to be followed for well development *via* bailing is:

1. Lower the bailer into the screened interval of the monitoring well.
2. Using long, slow strokes, raise and lower the bailer in the screened interval simulating the action of a surge block.
3. Periodically bail standing water from the well to remove fine particles drawn into the well.

Continue surging the well and removing water from the well until well development is complete.

3.2.4 Air-lifting

Air-lifting with compressed air can be used to both surge and purge a monitoring well. An air compressor is used to inject gas at the bottom of the water column, driving sediment-laden water to the surface. Compressed air can also be used for "jetting" - a process by which the air stream is directed at the slots in the well screen to cause turbulence (thereby disturbing fine materials in the adjacent filter pack). Compressed air is not limited to any depth range.

The hose or pipe which will be installed in the well for jetting should be equipped with a horizontal (side) discharge nozzle and one or more small holes in the bottom of the hose to enhance the lifting of sediment during jetting.

Provisions must be made for controlling the discharge from the wells. This is generally accomplished by attaching a "tee" discharge to the top of the casing and providing drums or other containers to collect the discharged water.

Although the equipment used to develop a well using this method is more difficult to handle and use, well development using compressed air for jetting the well screen is considered to be a very effective method. This method also is the most generally applicable because it is not limited by well depth, well diameter, or depth to static water.

The procedure to be followed for well development *via* air-lifting is:

1. Lower the gas line from the gas cylinder into the well, setting it near the bottom of the screened interval. Install the water discharge control equipment at the well head.
2. Set the gas flow rate to allow continuous discharge of water from the well. The discharge will contain suspended clay and silt material.
3. At intervals during gas-lifting, especially when the discharge begins to contain less suspended material, shut off the air flow and allow the water in the well to flow out through the screened interval to disturb any bridging that may have occurred. Restart the gas flow when the water level in the well has returned to the pre-development level.
4. Jetting of the screened interval also can be done during gas-lifting of water and sediment from the well. This is accomplished by using a lateral-discharge nozzle on the gas pipe or hose and slowly moving the nozzle along the length of the screened interval. Jetting should be done beginning at the bottom of the well screen and moving slowly upwards along the screened interval. To enhance gas lifting of sediment, occasionally raise the discharge nozzle into the cased portion of the well and discharge sediment-laden water.

Continue air-lifting and/or jetting until well development is complete.

4 QUALITY ASSURANCE/QUALITY CONTROL

Development of new monitoring wells or extraction wells is the responsibility of the hydrogeologist involved in the original installation of the well. The geologist may, in fact, contract with the well driller to develop new wells under the geologist's guidance and oversight. If the project involves sampling of existing monitoring wells, the hydrogeologist is also responsible for verifying the original well construction details and determining if a previously installed well requires rehabilitation.

Monitoring Well Construction Details

A copy of the original well construction diagram for the well to be developed must be obtained from the Project Manager. This form provides critical information regarding the construction of the monitoring well and must be in the possession of the well development crew so that pertinent well construction details, such as total well depth and screened interval, are known.

Equipment Decontamination

All equipment which contacts development water or is placed inside a well should either be dedicated for use on only a single monitoring well or should be decontaminated, in accordance with *SOP 016 - Equipment Decontamination*, to prevent cross-contamination between monitoring wells or recovery wells.

Successful Development Criteria

A well has been successfully developed when one or more of the following criteria are met:

- The well yields clear, sediment-free water to the extent possible
- field measurements of pH, specific conductance, temperature, and turbidity have stabilized
- aquifer response and well yield are observed to be representative of the type of lithologic formation over which the well is screened
- the well is free of sediment, the measured well depth is consistent with the well construction diagram, and that depth is maintained for some extended period of time

Development Water Management

The work plan must specify the means for managing development and purge water. At active facilities, an active water treatment facility may be available for management of development and purge water. Otherwise, the water should be containerized until analytical results are available to determine the applicable management options.

5 DOCUMENTATION AND RECORD KEEPING

If required, a Well Development Form will be completed by the geologist or hydrogeologist conducting the development. In addition, a Field Log Book should be maintained detailing any problems or unusual conditions which may have occurred during the development process.

All documentation will be retained in the project files following completion of the project. In addition to the hard copies, files will be scanned and placed in the permanent digital project files.

6 REFERENCES

American Society of Testing and Materials, 1996, ASTM Standard D5521-05: Standard Guide for Development of Ground-Water Monitoring Wells in Granular Aquifers: West Conshohocken, Pennsylvania.

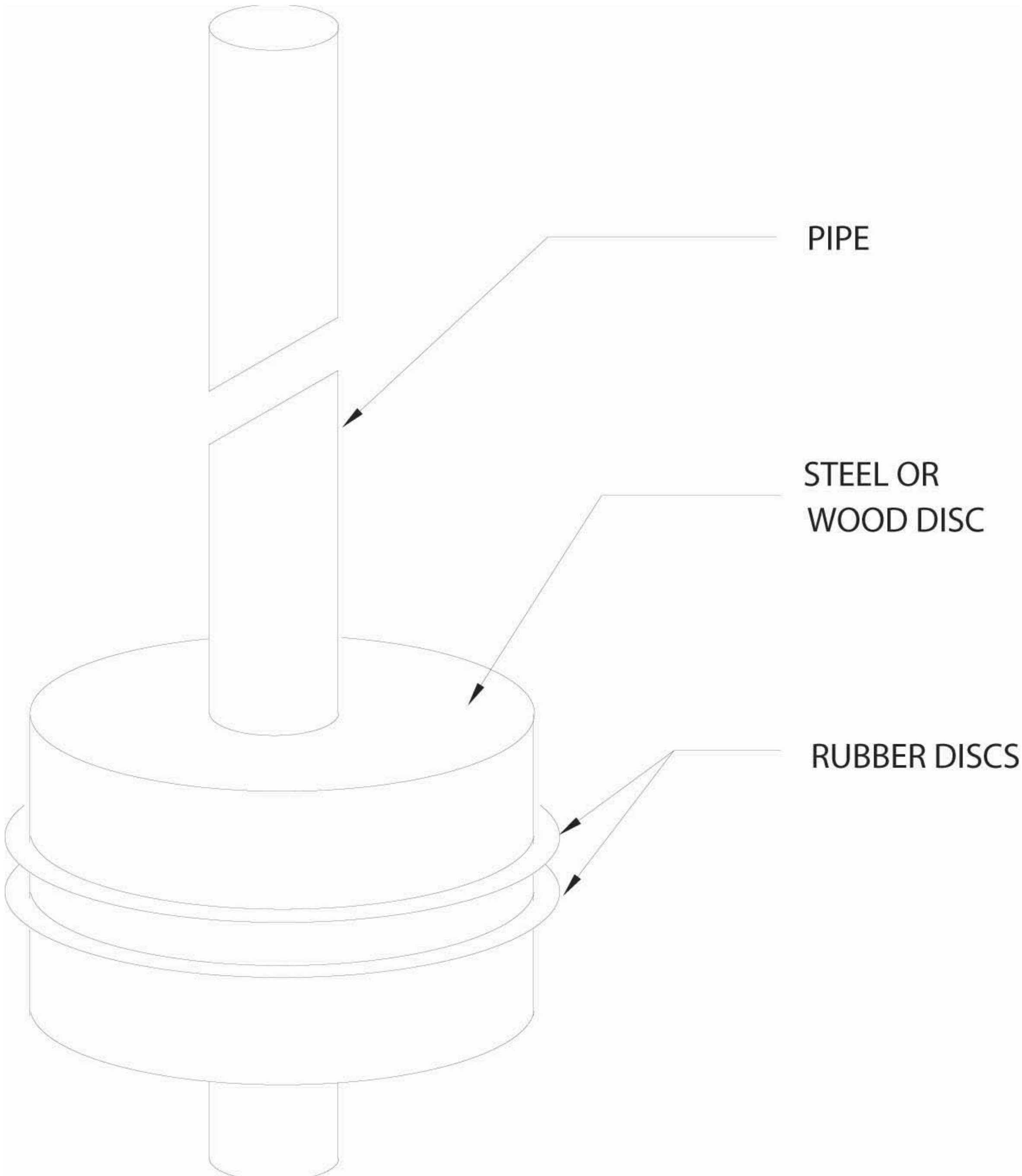

Figure 1. Example Surge Block Design

SOP No. 019
DEPTH TO GROUND WATER AND NAPL MEASUREMENTS
STANDARD OPERATING PROCEDURE

1 SCOPE

This Standard Operating Procedure (SOP) describes standard procedures to be followed for determining depth to groundwater, as well as a description of the procedures to be followed for determining the depth to and apparent thickness of any non-aqueous phase liquid (NAPL) in monitoring wells.

Generally, water level measurements from boreholes, piezometers, or monitoring wells are used to construct potentiometric surface maps and product elevation maps. These maps are used in evaluating groundwater and product migration. Potentiometric surface maps are also used to assess potential seasonal variations in groundwater movement when measurements can be made over several sampling intervals.

In order to ensure an accurate representation of groundwater and product elevations, ideally all measurements will be collected within a 24-hour period. The site-specific planning documents (Work Plan, Sampling and Analysis Plan, Scope of Work or other similar planning documents) shall be consulted to identify the specific wells to be investigated and the types and frequency of required measurements.

1.1 Referenced SOPs

SOP 010 – Field Logbook
SOP 016 – Equipment Decontamination
SOP 026 – Photoionization Detector

1.2 Definitions

(Reserved)

2 REQUIRED MATERIALS

The following list identifies the preferred types of materials to be used when measuring depth to water, depth to light NAPL (LNAPL), or depth to dense NAPL (DNAPL):

- Personal safety equipment (hard hat, steel-toed boots, safety vests, etc)
- Electronic water level meter (for water level measurements only)
- Interface probe (suitable for groundwater, LNAPL and DNAPL measurements)

- Photoionization detector (see *SOP 26 – •	Photoionization Detector*)
- Field logbook and/or sampling forms
- Indelible ink pens
- Clipboard
- Decontamination solutions in dedicated squirt bottles
- Paper towels

3 METHODOLOGY

The wells to be gauged will be identified in the project planning documents. In the field, the sampling team must verify the list of wells to be sampled with the well number on the casing. Prior to opening the well, the condition of the well casing and pad should be noted on the sampling forms and in the field logbook (see *SOP 010 – Field Logbook*). If there is any damage, particularly any that threaten the integrity of the sampling point, the Project Manager and Field Team Leader should be notified immediately.

3.1 Depth to Groundwater Measurements

1. Open the well and monitor the headspace with the appropriate monitoring instrument to determine the presence of volatile organic compounds if there is information to suggest that volatiles may be present at levels to warrant an upgrade in the level of PPE. Record the measurement in the field logbook and/or sampling forms.

2. Locate the surveyed measuring point of the well. The surveyed measuring point location is typically the top of the inner well riser, and should be clearly marked in permanent ink on the well riser or identified in previous sample collection records. The measuring point location should be described in the Field Logbook and should be the same point used for all subsequent measurements.

3. To obtain a water level measurement, lower a decontaminated water level meter into the monitoring well. Care must be taken to assure that the water level measuring device hangs freely in the monitoring well and is not adhering to the wall of the casing. The water level measuring tape will be lowered into the well until the audible sound of the unit is detected or the light on an electronic sounder illuminates. At this time, the precise measurement should be determined (to one hundredth of a foot) by repeatedly raising and lowering the tape to converge on the exact measurement. The water level measurement should be entered in the Field Logbook and/or sample log sheets.

4. The water level measuring device shall be decontaminated in accordance with *SOP 16 – Equipment Decontamination* immediately after use. Generally, only that portion of the measuring tape which penetrates the water table will require decontamination. If NAPL is encountered, use of a solvent (*e.g.,* hexane) will be required to clean the probe before it is used in another well.

3.2 NAPL Measurements

NAPL measurements should be made using an interface probe. Interface probes are commonly used to detect the presence of any floating (LNAPL) or sinking (DNAPL) immiscible layers. These probes can also be used to measure the water levels inside wells.

1. Using the grounding cable attached to the interface probe, ground the probe to a metal object (*i.e.,* protective steel locking well cover) to prevent electric shock.

2. The probe should be lowered slowly inside each well. When LNAPL is detected, the probe will make a solid tone. Record the measurement from the surveyed point on the top of the well casing to the top of the LNAPL. Continue lowering the probe (observing the calibrated drop line) until the steady tone stops. When water is detected, the probe will make a beeping noise to signify the beginning of the water column. When the beeping noise is heard, observe the calibrated drop line to determine the water level. Record this measurement. The measurement on the drop line between when the steady tone began (*i.e.*, LNAPL was encountered) and when it stopped (*i.e.,* groundwater was encountered) will determine the apparent thickness of the LNAPL layer.

3. The depth to DNAPL can also be determined using the interface probe. Lower the probe through the water column to the bottom of the well. The probe will make a solid tone if a DNAPL is encountered. Record the depth to the top of the DNAPL layer, and the depth to the bottom of the well to determine the apparent thickness of the DNAPL layer.

4. The NAPL measuring device should be thoroughly cleaned after each use in accordance with the Sampling Equipment Decontamination SOP. If NAPL is encountered, use of a solvent (*e.g.,* hexane) will be required to clean the probe before it is used in another well.

4 QUALITY ASSURANCE/QUALITY CONTROL

Quality assurance and quality control for water level and NAPL measurements shall consist of several steps. First it is important to verify the well identification number, check transcription to the Field Logbook and/or sample log sheets, and ensure that the well is one that is included in the project planning documents as a point of interest.

Additional quality control measures include repetitive measurements of the depth to water or NAPL to ensure that accurate and precise results are obtained. Once the measuring device indicates that the water level or NAPL layer has been encountered, the probe should be raised slightly and lowered several times to check and confirm the measurement. A single final reading should be recorded in the field logbook or on the project specific form.

Water levels in piezometers and monitoring wells should be allowed to stabilize for a minimum of 24 hours after well construction and development, prior to measurement. Also, measurements should always be taken from the least to the most contaminated wells while decontaminating the equipment between each well.

If water level data are to be used for groundwater flow direction determination, all measurements should be taken within the shortest time frame feasible. Typically, this is within 24 hours; however, with large numbers of wells, one day may not be adequate.

5 DOCUMENTATION AND RECORD KEEPING

Proper field data collection and management is important. Data may either be entered into a bound field logbook or other form specified in a site-specific work plan, as described in *SOP 03 – Field Logbook*.

6 REFERENCES

United States Environmental Protection Agency, January 1991, Compendium of ERT Groundwater Sampling Procedures: Washington D.C., EPA/540/P-91/007.

United States Environmental Protection Agency, September 1986, RCRA Ground-Water Monitoring Technical Enforcement Guidance Document: Office of Waste Programs Enforcement, Washington, D.C., EPA/530/SW-86/055