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# SAMPLING AND ANALYSIS PLAN
# NYSDEC – LUSTER-COATE METALLIZING CORP.
## Churchville, New York
## NYSDEC Site No. 8-28-113

Prepared for:

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# 1.0 INTRODUCTION

The purpose of this Sampling and Analysis Plan (SAP) is to detail the scope and investigation methods to be employed during the Preliminary Site Assessment (PSA) to be conducted at the Luster-Coate Metallizing Corporation (Luster-Coate) Site Number 8-28-113.

**Section 1.0** provides an introduction and a summary of activities to be conducted at the Luster-Coate site. **Section 2.0** presents the Field Sampling Plan (FSP). The FSP details the number, location and types of environmental samples to be collected. The FSP also includes sample depths, sampling methodology, sample container requirements and holding times, sample packaging and shipping instructions, sample documentation and operating procedures for field sampling and decontamination. **Section 3.0** includes the Quality Assurance/Quality Control (QA/QC) Plan.

## 1.1 Site Description

The Luster-Coate site is located in the Village of Churchville, Town of Riga, Monroe County, New York at 32 East Buffalo Street. The surrounding area is mainly residential with some commercial properties along Buffalo Street west of the Site. Black Creek is located along the west and northwest portion of the Site, in close proximity to the main building.

The property consists of a main building where manufacturing occurred and warehouse buildings for storage of parts and material. The main building consists of two levels with a footprint of approximately 36,000 square feet with portions reportedly dating to the early 1800's. There are also four warehouse buildings of varying sizes ranging from approximately 2,400 to 3,600 square feet reportedly built during the 1900's. The site is approximately 4.5 acres with the majority covered by the structures and pavement.

### 1.1.1 Surficial Geology

The United States Department of Agriculture, Soil Conservation Service classifies the soils in the vicinity of the Site as the following: Hilton and Ontario loams and Fresh Water Marsh.

The Hilton series is made up of deep, moderately well drained, medium-textured and moderately coarse textured soils that formed in calcareous glacial till. The till was derived mainly from local sandstone and limestone. These soils are generally associated with ground moraines and drumlin landscapes. A seasonal high water table rises to within 18 to 24 inches of the surface and is perched above the less permeable underlying till. The Hilton loam on the Site is mapped as having a 3 to 8 percent slope.

A representative profile of the Hilton loam includes the following:

- 0 to 10 inches: brown to dark-brown loam, abrupt, smooth boundary;
- 10 to 17 inches: dark grayish brown fine sandy loam; stained with light yellowish brown along root channels, 10 to 15 percent gravel, clear wavy boundary;
- 17 to 30 inches: reddish-brown loam, few fine faint reddish-yellow mottles, 10 to 15 percent gravel, clear wavy boundary;
- 30 to 41 inches: reddish-brown gravelly loam, 15 to 20 percent gravel, clear wavy boundary; and
- 41 to 50 inches: brown gravelly loam till, massive and platey structure, very firm; calcareous.

The Ontario series soils are made up of deep, well drained, medium textured and moderately coarse textured soils formed in calcareous glacial till dominated by red sandstone and limestone with minor quantities of shale. These soils are generally associated with till plains, glacial moraines or on drumlins. Permeability is moderate to a depth of about 25 inches and moderate to slow below that depth. The Ontario loam on the Site is mapped as having a 3 to 8 percent slope.

A representative profile of the Ontario loam includes the following:

- 0 to 8 inches: dark-brown sandy loam, smooth boundary;
- 8 to 25 inches: reddish-brown fine sandy loam; 5 to 10 percent coarse fragments, including cobbles, clear irregular boundary;
- 25 to 39 inches: dark reddish-brown gravelly loam, 15 to 30 percent gravel, abrupt wavy boundary; and
- 39 to 50 inches: reddish-brown gravelly loam, platey structure, 25 to 30 percent gravel, calcareous.

The Fresh Water Marsh series consists of level, wet, periodically flooded areas where water is on or near the surface most of the year. The level of water fluctuates with the adjacent bodies of water. Cattails, rushes and other water-tolerant herbaceous plants make up the dominant vegetation.

### 1.1.2 Glacial Geology

Approximately 5,000 to 8,000 years ago the final stage of glaciation, the Wisconsin, shaped the prominent features of Monroe County. Evidence of glacial lakes, drumlins, moraines, eskers and kames occur throughout the county and point to the glacial and glaciofluvial processes which shaped the landscapes observed today. The Hilton-Ontario series soils have been formed from glacial till without reworking by moving water. The *Surficial Geologic Map of New York*, Niagara Sheet (Caldwell, 1988) indicates that the area of the Site is covered by ground moraine deposits, "dominantly lodgment till; silty clay till and sandy till; compact and generally impermeable". This type of till is transported by, and lodged beneath actively flowing ice of the continental ice sheet and typically consists of varying amounts of clay, silt, sand and larger clasts mixed together and deposited by the glacier. Glaciofluvially derived deposits, consisting of lake-laid sand, silt and clay, are mapped to the south and west of the Village of Churchville.

### 1.1.3 Bedrock Geology

The *Geologic Map of New York*, Niagara Sheet (Rickard and Fisher 1970) depicts the Churchville area as being underlain by the Upper Silurian aged Vernon Formation, the lowest member of the Akron Dolostone, Cobleskill Limestone and Salina Group. This formation consists of interbedded shales and dolostone. In this area of Monroe County, the Vernon consists of massive, poorly stratified brick-red shale with some gray-green shale, shaly dolostone, sandstone and green-black shale. Salt beds occur in the middle of the Vernon in the Genesee River Valley. A review of logs from gas wells drilled across New York State indicate a facies change from red shale in the east, mixed red and green shale, then green or gray shale and dolostones and finally dolostones with anhydrite and halite in the west (Rickard, 1966).

The contact of the Lockport Dolostone, principal member of the Lockport Group, underlying the Vernon Formation is mapped near the Village of Churchville.

## 1.2 Operational/Disposal History

Luster-Coate was reported to provide application of metal film and paint coatings to plastic materials manufactured off-site. Prior to this activity, the site was reportedly used for a variety of industrial purposes including condiment bottle processing, canary propagation and wooden toy manufacturing with industrial activity dating to at least 1929. Luster-Coate is currently undergoing Chapter 7 liquidation. Operations at the site appear to have ceased in rapid fashion and drums, pails and vats of chemicals were abandoned on-site.

## 1.3 Investigative History

Details on previous investigations of the Site were not located or of limited value, but may provide some indication of areas of concern. The New York State Department of Environmental Conservation (NYSDEC) was provided a copy of an environmental site assessment completed by ENSR International in 2001 on behalf of a third party. This report references another site assessment completed by Secor International Inc. on behalf of the Site in 1998, but the NYSDEC does not have a copy of the report. At the request of the NYSDEC, the United States Environmental Protection Agency (USEPA) provided a characterization of chemicals abandoned on-site in contemplation of a removal response. The characterization and inventory confirmed hazardous waste was abandoned on-site.

The ENSR investigation included eight soil borings, four of which were completed as temporary wells (**Figure 2**). Groundwater samples were obtained from two of the temporary wells with the two additional points dry. In addition, two cooling water supply wells were located and sampled. Eight soil samples were analyzed in this investigation. The investigation identified several areas of concern outside the manufacturing building including former waste storage area, former aboveground storage tanks and a possible off-site fuel tank that could be impacting the Site. In addition, a chemical storage area, ventilation system sump and caustic rinse from the manufacturing building were investigated. These analyses detected elevated Semivolatile Organic Compound (SVOC) contamination in the soils near the area of the caustic rinse sump. SVOC and Volatile Organic Compounds (VOCs) were detected in the soil and groundwater analyses near the off-site fuel storage tank. Elevated VOCs were detected in the groundwater analyses from the existing water supply wells and near the manufacturing building's storage area. Elevated metals including zinc, nickel, thallium and mercury were detected in the soil or groundwater.

## 2.0 FIELD SAMPLING PLAN

This section of the SAP presents the FSP for the PSA to be conducted at the Luster-Coate site. The FSP describe the number, location and types of environmental samples to be collected, the procedures that will be employed to collect the samples, sample container requirements and holding times, sample packaging and shipping requirements, sample documentation and standard operating procedures for field sampling, monitoring, field instrument calibration, and equipment decontamination methods. Methods used by Shaw personnel and subcontractors to perform these tasks will be as specified in appropriate NYSDEC or USEPA reference documents.

The PSA will include six phases of field activities at the Luster-Coate site. Each phase of the sampling/field activities is described below. **Table 1** details the number of anticipated samples to be collected for analysis during this investigation.

<u>Soil Gas Samples</u>

Twenty soil gas points will be installed throughout the property (**Figure 3**). All points will be field screened with a Photoionization Detector (PID). At the following locations, air samples will be collected for TO-15 laboratory analysis: SG-03, SG-18, and SG-20. These locations are subject to change based upon field observations.

<u>Surface Soil Samples</u>

Nine surface soil samples will be collected from the 0- to 2-inch interval to determine if any surficial impacts exist at the Site (**Figure 4**). Areas to be sampled will include historic storage areas, tank location, transformer pad and other suspected source areas. One upgradient location will be chosen to represent background conditions.

<u>Subsurface Soil Samples</u>

Seven subsurface soil samples will be collected to determine if any impacts exist at depth beneath the Site (**Figure 5**). Boring will be installed to approximately 30 feet in depth or refusal at bedrock. Selected locations include historic waste storage areas and other suspected source areas. Three selected locations will be finished as piezometers in order to determine groundwater flow direction across the Site.

Groundwater Samples

Groundwater samples will be collected from all existing wells (four temporary wells and two water supply wells) and four newly installed wells to assess the existing groundwater quality across the site (**Figure 6**).

Dye Testing

Dye tests will be performed on all located sumps, drains and catch basins at the Site (**Figure 7**). This will determine that all drainage structures are intact and lead to the appropriate destination.

Sediment Samples

Sediment samples will be collected from within Black Creek at five locations (**Figure 8**) to determine if former activities have impacted the creek.

## 2.1 Field Investigation

The primary goal of the PSA is to obtain the information necessary to properly classify the site according to the NYS Hazardous Waste Site Classification system. A secondary goal is to begin investigating the nature and extent of contamination. Where feasible, the investigation and sampling phases will be combined in order to increase efficiency during this project.

### 2.1.1 Sample Identification

Each sample collected will be designated by an alphanumeric code that will identify the location of the sample and sample depth. For example, SB-01 for soil boring 1, MW-02 for monitoring well 2.

### 2.1.2 Sample Containers and Analytical Requirements

**Table 2** summarizes the container requirements, sample preservation, holding times and analytical requirements for both soil and water samples.

### 2.1.3 Sample Documentation

Sampling crews performing this PSA will be required to keep a field notebook while conducting field activities and sampling. Entries will be completed at the sampled location immediately following sample collection. Entries will include the following information:

- Sample number,
- Sample collection time,
- Sample location,
- Sample description,
- Sample collection methodology,
- Daily weather conditions,
- Field measurements, and
- Other site-specific observations.

### *2.1.4 Sample Packaging and Shipping*

Immediately following collection, analytical samples will be place in coolers containing bagged ice to keep the samples at 4 degrees Centigrade (°C). Prior to shipment of the samples to the selected laboratory, glass jars will be wrapped in bubble-wrap or equivalent material to prevent breakage during shipment. The wrapped glass jars will then be placed in a plastic bag and sealed. Polyethylene jars will be placed in a plastic bag and sealed. The analytical samples in every cooler will be packed with bagged ice to maintain 4°C and then stabilized to minimize sample container movement during shipment by utilizing appropriate packing material. Samples will be shipped via overnight delivery to the selected laboratory to allow for laboratory analysis within the analytical parameter holding times.

The chain-of-custody (COC) forms will be signed by the field sampler, placed in a plastic bag and sealed. Additional forms, such as the NYSDEC Contract Lab Sample Information Sheets, will also be placed in the plastic bag. The bags with the forms will then be attached to the inside of the cooler lid. The shipping coolers will then be sealed with duct tape to prevent accidental discharge of their contents during shipment. A custody seal will be placed across the lid opening of each cooler to ensure that the integrity of the contents of the cooler has not been compromised during shipment. The coolers will then be delivered or picked up at the site location by the selected delivery firm for overnight shipment to the laboratory.

### *2.1.5 Field Screening*

Field screening for organic compounds will be performed as part of the Health and Safety monitoring program and as a criterion for selecting samples for chemical analysis. Screening with a calibrated PID meter will be performed during the field investigation during sample collection activities. Field instrument calibration procedures are located in **Section 3.1** of this SAP.

### *2.1.6 Decontamination*

As presented below, field sampling equipment and drilling equipment will be decontaminated prior to sampling.

Decontamination of Field Sampling Equipment

Sampling equipment (bowls, spoons, trowels, split spoon samplers, etc.) used to obtain environmental samples will be decontaminated prior to use and between sampling points. Decontamination procedures for field equipment are as follows:

1. Potable water rinse,
2. Alconox and potable water scrub,
3. Potable water rinse, and
4. Distilled/deionized water rinse.

Decontamination of Drilling Equipment

Drilling equipment will be cleaned with a hot water pressure washer prior to use and between drilling locations. The drilling equipment will be decontaminated at the designated decontamination pad. Decontamination fluids generated on the pad will be collected in the decontamination pad sump. The decontamination fluids will then be pumped into containers for storage and disposal.

### *2.1.7 Investigation Derived Waste (IDW) – Liquid*

Water collected from well development, purging and equipment decontamination processes will be collected into either 55-gallon drums or a large polyethylene tank to be temporarily stored at the NYSDEC approved central staging area. The drums or tank will be properly labeled. At the completion of this investigation, the generated liquids will be sampled for disposal purposes. **Table 3** specifies the analytical requirements for the disposal of liquid IDW.

If the IDW analysis determines that the analytes do not exceed the guidance values for protection of class GA water (source of drinking water (groundwater)) set forth in Division of Water

Technical and Operational Guidance Series (1.1.1) (NYSDEC, June 1998) the IDW liquid will be released on-site. If the analysis values exceed the guidance values, off-site disposal will be necessary and Shaw will contract with an appropriate transport and disposal firm.

#### *2.1.8 IDW – Solid*

Soils generated during the installation of soil borings and soil sampling activities will be stored in 55 gallon drums or a single roll-off container staged in a central area. The drums or roll-off container will be properly labeled. At the completion of the well installation and soil sampling activities, a singe composite sample will be collected from the solid IDW to characterize this waste for disposal. **Table 3** specifies the analytical requirements for the disposal of the solid IDW.

If the IDW analysis determines that the analytes do not exceed the soil cleanup objectives to protect groundwater quality set forth in NYSDEC Technical and Administrative Guidance Memorandum: Determination of Soil Cleanup Objectives and Cleanup Levels (TAGM 4046) (NYSDEC, January 24, 1994) the solid IDW will be released on-site. If the analysis values exceed the guidance values, off-site disposal will be necessary and Shaw will contract with an appropriate transport and disposal firm.

### *2.2 Soil Gas Survey*

Twenty soil gas points will be installed at the locations shown on **Figure 3.** Points will be installed to a maximum depth of 2.5 feet below ground surface (bgs) by 'slam bar' or equivalent method (Geoprobe). During the installation of these soil gas points, continuous air monitoring of the breathing space will be conducted with a PID (11.7 eV). Following the installation of a point, a clean vapor extraction rod will be placed into the hole and driven another six inches into the ground. The PID nozzle will be placed in the extraction rod for approximately 60 seconds. Peak concentrations will be recorded in the field notebook. All equipment will be removed from the location and the point will be backfilled and the area return to previous conditions.

At three selected locations, air samples will be collected over one hour in appropriately sized Summa canisters for laboratory analysis. Collected air samples will be analyzed for the following constituents:

- VOCs via EPA Method TO-15.

Immediately following collection, labeled analytical samples will be placed in an appropriate sized container, reducing the sample's exposure to light and excess heat and the appropriate entry will be made in the field notebook and COC.

## 2.2 Surface Soil Samples

Nine surface soil sampling locations are depicted on **Figure 4.** Sampling locations were chosen based on historical activities at the Site. Samples will be collected from the 0- to 2-inch soil interval. Samples will be collected in the appropriate containers using clean stainless steel spoons and tools. All selected soil intervals will be analyzed for the following constituents:

- SVOCs via EPA Method 8270, and
- Total Metals via EPA Methods 6010/7471.

Of the nine surface soil samples, three locations will be additionally analyzed for the following constituents:

- Pesticides and PCBs via EPA Methods 8081/8082.

Immediately following collection, labeled analytical samples will be placed in a cooler and chilled to 4°C and the appropriate entry will be made in the field notebook and COC.

## 2.3 Soil Borings

Shaw personnel will oversee the installation of seven soil borings to approximately 30 feet below grade. Three of these borings will be converted to piezometers upon completion. Borings will be located in areas of concern to identify any potential source areas. Borings will be installed using a Geoprobe rig using direct push technology to continuously collect samples. All recovered soil intervals will be screened using a PID. Soils will be visually identified and logged by a Shaw geologist. Soil cuttings, which are assumed to be non-hazardous based upon existing laboratory analytical data, will be containerized and transported to an on-site staging area for subsequent characterization and disposal as described in **Section 2.1.8**.

### *2.3.1 Subsurface Soil Sampling Procedures*

Soil borings will be advanced using direct push technology and 1.5-inch sampling tubes. Continuous 1.5-inch (diameter) by 48-inch (length) split spoon samples will be collected at each boring location from grade to 30 feet bgs.

The Shaw geologist will describe and log the extracted subsurface soils with respected to their geologic features and properties. Specific information that must be logged includes:

1. A description of the soil using the Unified Soil Classification System (USCS) and modified Burmeister System;
2. PID readings over each one foot interval.

At the completion of each soil boring, the Shaw geologist will select one soil interval for laboratory analysis. Selection of the sampled interval will be based on PID head space readings, visual observations and vertical location in relation to the water table. All samples will be analyzed for the following constituents:

- VOCs via EPA Method 8260,
- SVOCs via EPA Method 8270,
- Total Organic Carbon via EPA Method 9060, and
- Total Metals via EPA Methods 6010/7471.

Of the sampled soil intervals, the three intervals exhibiting the overall highest PID reading will be additionally analyzed for the following constituents:

- Pesticides and PCBs via EPA Methods 8081/8082.

### *2.3.2 Piezometer Installation*

Three previously selected locations (**Figure 5**) will be completed as piezometers for determination of groundwater flow direction. Following the completion of these soil borings, the boring will be filled with bentonite chips to bring the bottom elevation of the boring to 20 feet below grade.

Piezometers will be constructed of 1 inch diameter PVC well riser and screen. Well screens will be 10 feet in length. Only new undamaged well riser and screen will be used. A PVC well end cap and a bottom cap will be installed on each monitoring well. The PVC riser will extend to approximately 2 feet above grade.

Casing and screen sections will be flush-jointed and internally threaded. Joints will be completed so that the threads are buried within the riser walls. No couplings, chemicals, glues or solvents will be used in peizometer construction.

After setting the well screen and riser within the augers, a sand pack of fine sand will be installed within the borehole annulus from the bottom of the borehole to approximately two feet above the top of the screen. Bentonite chips and native material will be installed within the annular space above the sand pack.

### 2.3.3 Survey of New Piezometers

The new sampling locations will be professionally surveyed following installation of the piezometers. The new locations will be accurately located on a map in relation to existing well locations. The piezometers will be measured for location, top of PVC and ground surface elevations.

## 2.4 Monitoring Well Installation Procedure

Monitoring wells will be advanced to a depth of at least 20 feet bgs with 4.25 inch inside diameter (ID) by 8 inch outside diameter (OD) hollow stem augers. Continuous sampling during drilling will not be necessary because monitoring well locations will be drilled on top of previously advanced soil borings.

The construction of monitoring well MW-2D will differ due to the additional installation depth. Continuous sampling at this location will begin at 30 feet bgs to refusal at bedrock. The well will be installed at the bedrock interface.

Monitoring well installation will proceed in accordance with the specification provided below. The well screen, riser, gravel pack material and bentonite will be installed through the hollow stem of the augers. The auger will be removed as the well installation proceeds. The monitoring wells will only be acceptable provided that the screened zone and bentonite seal have been installed properly.

Monitoring wells will be constructed of 2-inch PVC well riser and screen. Well screens will be 10 feet in length. Only new undamaged well riser and screen will be used. A PVC well cap or 'gripper' cap and a bottom cap will be installed on each monitoring well. The PVC riser will extend to grade.

Casing and screen sections will be flush-jointed and internally threaded. Joints will be completed so that the threads are buried within the riser walls. No couplings, chemicals, glues or solvents will be used in well construction.

After setting the well screen and riser within the augers, a sand pack of fine sand will be installed within the borehole annulus from the bottom of the borehole to approximately two feet above the top of the screen. The sand pack will be emplaced slowly to prevent 'bridging' of the sand within the hole. The driller, to ensure proper installation, will measure the depth to the sand pack. A 0.5-foot thick layer of fine sand (Morie 00 or equivalent) will be emplaced in the annulus on top of the gravel pack.

A cement/bentonite grout slurry will be installed by tremie pipe within the annular space above the find sand layer. During installation, the tremie pipe will be withdrawn from the annular space as the slurry is emplaced. The hollow stem auger will also be withdrawn as the grout is added to the borehole to grade level.

The well will then be finished with a protective flush-mounted road box.

### 2.4.1 Monitoring Well Development

Following installation, the monitoring wells will be developed using a submersible pump and mechanical surging. Alternative methods may be used at the discretion of the NYSDEC and the Shaw geologist. The newly installed monitoring wells will be developed for the purpose of removing fine materials from the sand pack and restoring normal hydraulic conditions in the screened interval.

During well development, the discharge water will be monitored every 15 minutes for the following parameters:

- Turbidity,
- Specific conductivity,
- pH, and
- Temperature.

Water produced during development will be containerized and transported to an on-site staging area for subsequent characterization and disposal as described in **Section 2.1.7**. Development will continue until a turbidity measurement of 50 Nephelometric Turbidity Units (NTU) or less is achieved. If this is not practical, due to a naturally high content of fine materials in the formation, well development will continue for at least one hour. The stabilization of field parameters will be used as an indication of when the development is nearing completion.

Efforts will be made to produce water for sampling that is as clear and sediment free as possible. Field parameters will be recorded in a field notebook. Wells will not be sampled for a minimum of two weeks following the completion of development.

### *2.4.2 Survey of New Monitoring Wells*

The new monitoring well locations will be professionally surveyed following installation and development. The new wells will be accurately located on a map in relation to existing well locations. Each new well will be measured for top of PVC, top of casing and ground surface elevations. If significant damage is observed on existing wells, those locations will also be measured for top of PVC, top of casing and ground surface elevations.

### *2.4.3 Groundwater Quality Assessment*

Groundwater samples will be collected from all existing and accessible well locations (four temporary wells and two water supply wells) and the four newly installed monitoring wells to assess groundwater quality. A minimum of two weeks will be required after installation and development for the new wells before they may be sampled. The existing wells were last sampled in the fall of 2001.

Prior to sampling, a round of synoptic water levels will be taken for all wells during a single day. Water level measurements will be collected in the following manner:

1. Decontaminate the electronic water level indicator with deionized water,

2. Remove locking well cap (note time of day, date, etc.),
3. Remove inner well casing cap and collect a PID reading at the well head,
4. Record PID reading in the field notebook,
5. Lower water level indicator tape into the well until the water surface is encountered,
6. Measure distance from the water surface to the reference measuring point on the well casing and record in field notebook (noting if measurement is taken from top of steel casing, top of PVC riser, from ground surface or some other position),
7. Measure total depth of well and record in field notebook (noting where the measurement is referenced), and
8. Remove the tape, close and lock the well.

Three to five well volumes will then be purged from each well. The following field measurements will be collected prior to purging, after each purged volume, and prior to sampling:

- Specific Conductivity,
- PH,
- Temperature,
- Oxidation/Reduction Potential, and
- Dissolved Oxygen.

Purge water will be containerized and transported to an on-site staging area for subsequent characterization and disposal as described in **Section 2.1.7**. Stabilization of the measured field parameters within +/- 10 percent from successive purge volumes will indicate when groundwater in the well is at equilibrium with the aquifer. Samples will be collected within three hours of purging using a disposable polyethylene or Teflon bailer suspended on new nylon twine. Groundwater samples will be collected in the following manner:

1. Samplers will don new sampling gloves at each well prior to sampling,
2. Visually examine the exterior of the monitoring well for signs of damage or tampering and record in field notebook,
3. Unlock well cap, removed inner well casing cap and collect a PID reading at the well head,
4. Record PID reading in field notebook,

5. Measure the static water level in the well with a decontaminated electronic water level indicator,
6. Calculate the volume of water in the well according to the calculation provide on the Monitoring Well Sampling Log,
7. Purge three to five well volumes of water from the well using a submersible pump at a pumping rate of one gallon per minute or less (purge water will be discharged to a small hand dug trench near each well),
8. Measure and record time, specific conductivity, pH, temperature, turbidity, oxidation reduction potential and dissolved oxygen prior to purging and after each well volume,
9. Obtain sample from well with a pre-cleaned, disposable polyethylene or Teflon bailer suspended on new nylon twine,
10. Sample for VOCs first by slowly lowering the bailer to avoid degassing, then collect other organic and inorganic samples by pouring directly into pre-preserved sample bottle from the bailer,
11. Place the analytical samples in cooler with bagged ice and chill to 4°C,
12. Replace and lock well cap, and
13. Record entire event in field notebook.

Groundwater samples will be analyzed for the following constituents:

- VOCs via EPA Method 8260,
- SVOCs via EPA Method 8270,
- Total Metals via EPA Methods 6010/7471, and
- Pesticides and PCBs via EPA Methods 8081/8082.

## 2.5 Dye Testing

Dye tests will be performed on all located sumps, drains and catch basins at the Site (**Figure 7**). A biodegradable, non-toxic dye and water solution will be added to all identified drainage structures on the Site. Approximately 10 gallons of the pre-mixed dye solution will be introduced at individual locations. The drainage system will be monitored from a downgradient location. Once the dye solution has cleared the monitoring station, testing will begin at the next selected location.

If the dye solution does not appear at the anticipated down gradient location, another 10 gallons will be added to the structure and efforts will be made to locate the discharge point. This process will be repeated until the discharge point is located or 50 gallons of dye solution has been introduced into the system.

## 2.6 Sediment Samples

Five sediment sampling locations are depicted on **Figure 8.** Sampling locations were chosen based on historical activities at the Site and river current. Sediment samples will be collected at specified locations along the bank and dam at the specified locations. Sediment samples will be obtained from a boat/barge through the use of 'trap' sediment samplers. Samples will be collected in the appropriate containers using clean stainless steel spoons and tools. Sediment samples will be analyzed for the following constituents:

- VOCs via EPA Method 8260,
- SVOCs via EPA Method 8270
- Pesticides and PCBs via EPA Methods 8081/8082, and
- Total Metals via EPA Methods 6010/7471.

Immediately following collection, labeled analytical samples will be placed in a cooler and chilled to 4°C and the appropriate entry will be made in the field notebook and COC.

# 3.0 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

This section describes the QA/QC requirements for field activities at the Luster-Coate site.

## 3.1 Field Instrument Calibration

Field instrument calibration and/or calibration checks will be performed in accordance with the instrument manufacturer's specifications. Instruments will be calibrated and/or checked on a daily basis in the field prior to use. The Shaw employee performing the calibration will record the procedure in their field notebook. The employee will record the name of the instrument, the serial number, the date, the results of the calibration and the identification of the calibration standards.

## 3.2 QA/QC Sample Collection

QA/QC sample collection will occur as described in the following sections. At least five percent (one out of every 20 samples) of the total number of collected samples will be analyzed for QA/QC methods. **Table 1** identifies the number of QA/QC samples required during this PSA.

## 3.3 Equipment Blanks

Equipment blanks will be collected to evaluate potential cross contamination of samples due to repeated use of the same sampling equipment. Equipment blanks will be performed on the following pieces of sampling equipment:

- Bowls, spoons and pans used to collect soil samples,
- Split spoon sampling devices used to collect soil samples during drilling operations, and
- Bailers used to collect groundwater during monitoring well sampling.

Equipment blanks will be collected using the following procedures:

1. Decontaminate the sampling device using procedures outline in **Section 2.1.6** of this plan,
2. Pour distilled/deionized water over the sampling equipment and collect the rinse water in the appropriate pre-preserved sample bottles, and

3. Label the bottles (example: Equipment Blank 1 – matrix, EB-1 – matrix) and record the event in the field notebook.

### 3.4 Trip Blanks

A trip blank is an aliquot of deionized water that is sealed in a 40-ml sample bottle, which is provided to the sampling team by the analytical laboratory. The trip blank is used to determine whether cross contamination occurs between aqueous samples during shipment. The blanks are analyzed for VOCs only. The sealed trip blank bottles will be placed in the cooler containing the day's aqueous VOC samples. The trip blank will remain with those samples during the sampling event and shipment to the laboratory.

### 3.5 Duplicate Samples

Duplicate samples will be analyzed to check the laboratory reproducibility of analytical data. Duplicate samples must be taken from the identical matrix as the original sample. Duplicate samples will be labeled in a manner so as not to reveal the connection to the original sample (example: Duplicate 1 – matrix, Dup 1 – matrix). Time of duplicate sampling will not be included with the sample identification and COC. Location and time of collection of each duplicate sample will be recorded in the sampler's field notebook and on the sampler's copy of the COC.

### 3.6 Matrix Spike/Matrix Spike Duplicate (MS/MSD)

To ensure that the analytical laboratory has sufficient volume to perform MS/MSD analysis, triple sample volume must be submitted. At the selected sample location, three sample sets will be collected, one for sample analysis, one for matrix spike analysis and one for matrix spike duplicate analysis. These samples must be obtained from identical matrices. The sample set will be labeled in a manner that identifies the sample location (example: MW-5, MW-5 MS, MW-5 MSD).

# *Tables*

**Table 1**
**Anticipated Samples**
**Luster-Coate Metallizing Corporation Preliminary Site Assessment**
**Churchville, New York**

**SOIL/GAS**

| Analytical Method | Surface Soil Samples | MS | MSD | Blind Duplicate | Equipment Blank | Total Samples |
|---|---|---|---|---|---|---|
| TO-15 | 3 | conducted through laboratory QC | | 1 | 0 | 4 |

**SURFACE SOIL**

| Analytical Method | Surface Soil Samples | MS | MSD | Blind Duplicate | Equipment Blank | Total Samples |
|---|---|---|---|---|---|---|
| 6010/7471 | 9 | 1 | 1 | 1 | 1 | 13 |
| 8270 | 9 | 1 | 1 | 1 | 1 | 13 |
| 8081/8082 | 3 | 1 | 1 | 1 | 1 | 7 |

**SEDIMENT**

| Analytical Method | Surface Soil Samples | MS | MSD | Blind Duplicate | Equipment Blank | Total Samples |
|---|---|---|---|---|---|---|
| 8260 | 5 | 1 | 1 | 1 | 1 | 9 |
| 6010/7471 | 5 | 1 | 1 | 1 | 1 | 9 |
| 8270 | 5 | 1 | 1 | 1 | 1 | 9 |
| 8081/8082 | 5 | 1 | 1 | 1 | 1 | 9 |

**SUBSURFACE SOIL**

| Analytical Method | Soil Samples | MS | MSD | Blind Duplicate | Equipment Blank | Total Samples |
|---|---|---|---|---|---|---|
| 8260 | 7 | 1 | 1 | 1 | 1 | 11 |
| 6010/7471 | 7 | 1 | 1 | 1 | 1 | 11 |
| 8270 | 7 | 1 | 1 | 1 | 1 | 11 |
| 8081/8082 | 3 | 1 | 1 | 1 | 1 | 7 |
| 9060 | 7 | 1 | 1 | 1 | 1 | 11 |

**GROUNDWATER**

| Analytical Method | Groundwater Samples | MS | MSD | Blind Duplicate | Equipment Blank | Total Samples |
|---|---|---|---|---|---|---|
| 8260 | 10 | 1 | 1 | 1 | 1 | 14 |
| 6010/7471 | 10 | 1 | 1 | 1 | 1 | 14 |
| 8270 | 10 | 1 | 1 | 1 | 1 | 14 |
| 8081/8082 | 10 | 1 | 1 | 1 | 1 | 14 |
| DO | Taken in field | | | | | |
| Redox | Taken in field | | | | | |

**Table 1**
**Anticipated Samples**
**Luster-Coate Metallizing Corporation Preliminary Site Assessment**
**Churchville, New York**

| IDW SAMPLES | | |
|---|---|---|
| Analytical Method | Composite Soil | Total Samples |
| TCLP VOC | 1 | 1 |
| TCLP SVOC | 1 | 1 |
| TCLP Metals | 1 | 1 |
| TPH | 1 | 1 |
| 8082 | 1 | 1 |
| pH, Fishpoint, Reactive Cyanide and Sulfide | 1 | 1 |
| Analytical Method | Water Samples | Total Samples |
| TCLP VOC | 1 | 1 |
| TCLP SVOC | 1 | 1 |
| TCLP Metals | 1 | 1 |
| TPH | 1 | 1 |
| 8082 | 1 | 1 |
| pH, Fishpoint, Reactive Cyanide and Sulfide | 1 | 1 |

| Total Numbers | |
|---|---|
| Analytical Method | Total Samples |
| TO 15 | 4 |
| 8260 | 34 |
| 6010/7471 | 47 |
| 8270 | 47 |
| 8081/8082 | 39 |
| 9060 | 11 |
| TCLP VOC | 2 |
| TCLP SVOC | 2 |
| TCLP Metals | 2 |
| TPH | 2 |
| pH, Fishpoint, Reactive Cyanide and Sulfide | 2 |

**Table 2A**
**Surface Soil and Sediment Sample Collection and Analytical Protocols**
**Luster-Coate Metallizing Corporation Preliminary Site Assessment**
**Churchville, New York**

## Soil/Gas

| Analysis | USEPA Method | Sample Preservation | Holding Time | Container Type | Volume Required |
|---|---|---|---|---|---|
| Volatile Organic Compound (full 8260 list) | TO-15 | none | 7 days | Suma Canister | based on container size |

## Surface Soil

| Analysis | USEPA Method | Sample Preservation | Holding Time | Container Type | Volume Required |
|---|---|---|---|---|---|
| Semi-Volatile Organic Compound | 8270 | 4°C | 7 days extraction / 40 days analysis | 1 L Amber Glass | 1 Liter |
| Total Metals | 6010 / 7471 | HNO3 to pH <2 | 180 days Hg - 28 days | 8 oz Plastic | 200 mL |
| Pesticides and PCBs | 8081 / 8082 | 4°C | 7 days extraction / 40 days analysis | 1 L Amber Glass | 1 Liter |

## Sediment

| Analysis | USEPA Method | Sample Preservation | Holding Time | Container Type | Volume Required |
|---|---|---|---|---|---|
| Volatile Organic Compounds | 8260 | 4°C and zero headspace | 14 days | 2 oz Glass | 2 oz |
| Semi-Volatile Organic Compound | 8270 | 4°C | 7 days extraction / 40 days analysis | 4 oz Amber Glass | 4 oz |
| Total Metals | 6010 / 7471 | 4°C | 180 days Hg - 28 days | 8 oz Glass | 400 grams |
| Pesticides and PCBs | 8081 / 8082 | 4°C | 7 days extraction / 40 days analysis | 8 oz CWM | 60 grams |

**Table 2B**
**Subsurface Soil and Groundwater Sample Collection and Analytical Protocols**
**Luster-Coate Metallizing Corporation Preliminary Site Assessment**
**Churchville, New York**

## Soil

| Analysis | USEPA Method | Sample Preservation | Holding Time | Container Type | Volume Required |
|---|---|---|---|---|---|
| Volatile Organic Compounds | 8260 | HCl to pH <2 and zero headspace | 14 days | 40 mL glass vial | 120 mL |
| Semi-Volatile Organic Compound | 8270 | 4°C | 14 days | 4 oz Amber Glass | 4 oz |
| Total Metals | 6010 / 7471 | 4°C | 180 days<br>Hg - 28 days | 8 oz Glass | 400 grams |
| Pesticides and PCBs | 8081 / 8082 | 4°C | 14 days | 4 oz Amber Glass | 60 grams |
| Total Organic Carbon | 9060 | 4°C | 28 days | Plastic/Glass | 100 mL |

## Groundwater

| Analysis | USEPA Method | Sample Preservation | Holding Time | Container Type | Volume Required |
|---|---|---|---|---|---|
| Volatile Organic Compounds | 8260 | HCl to pH <2 and zero headspace | 14 days | 40 mL glass vial | 120 mL |
| Semi-Volatile Organic Compound | 8270 | 4°C | 7 days extraction / 40 days analysis | 1 L Amber Glass | 1 Liter |
| Total Metals | 6010 / 7471 | $HNO_3$ to pH <2 | 180 days<br>Hg - 28 days | 8 oz Plastic | 200 mL |
| Pesticides and PCBs | 8081 / 8082 | 4°C | 7 days extraction / 40 days analysis | 1 L Amber Glass | 1 Liter |

**Table 3**
**Analytical Protocols for the Disposal of Investigation Derived Waste (IDW)**
**Luster-Coate Metallizing Corporation Preliminary Site Assessment**
**Churchville, New York**

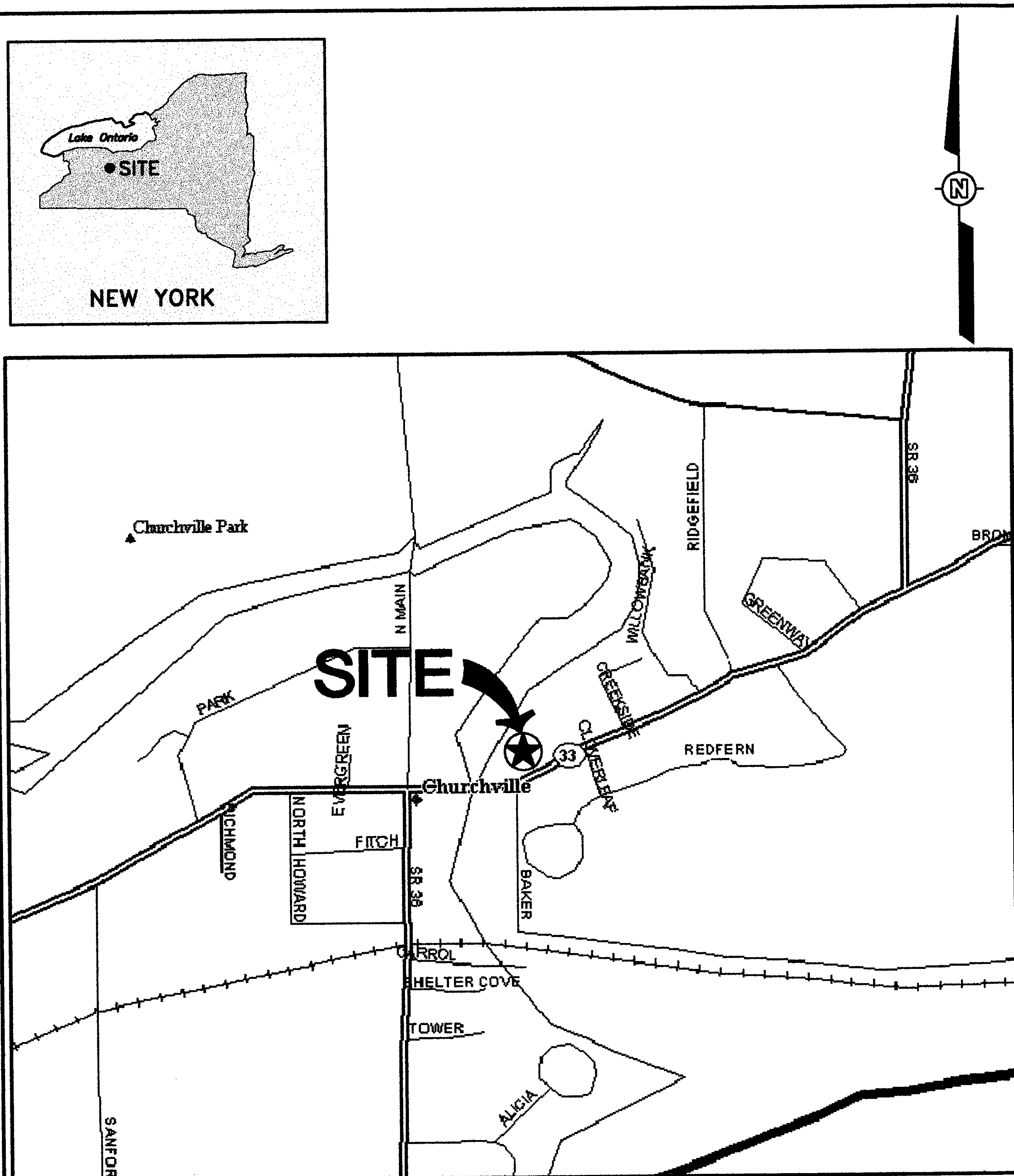
## IDW - Soil

| Analysis | USEPA Method | Sample Preservation | Holding Time | Container Type | Volume Required |
|---|---|---|---|---|---|
| TCLP Volatile Organic Compounds | 1311 / 8260B | 4°C | 14 days | 4 oz CWM | 300 grams |
| TCLP Semi-Volatile Organic Compound | 1311 / 8270C | 4°C | 14 days | 8 oz CWM | 300 grams |
| TCLP Total Metals | 1311 / 6010 / 7470 | 4°C | 180 days<br>Hg - 28 days | 8 oz CWM | 300 grams |
| pH, Flashpoint, Reactive Cyanide and Sulfide | SW 9040B / SW 1010 / SW 7.3.3.2 rev 3 / SW 7.3.4.2 rev 3 | 4°C | 7 days | 8 oz CWM | 300 grams |
| Total Petroleum Hydrocarbons | 418.1 | 4°C | 28 days | 4 oz CWM | 20 grams |
| PCBs | 8082 | 4°C | 7 days extraction / 40 days analysis | 8 oz CWM | 30 grams |

## IDW - Water

| Analysis | USEPA Method | Sample Preservation | Holding Time | Container Type | Volume Required |
|---|---|---|---|---|---|
| TCLP Volatile Organic Compounds | 1311 / 8260B | HCl to pH <2 | 14 days | 40 mL Glass Vial | 5 mL |
| TCLP Semi-Volatile Organic Compound | 1311 / 8270C | 4°C | 14 days | 1 L Amber Glass | 1 Liter |
| TCLP Total Metals | 1311 / 6010 / 7470 | 4°C | 180 days<br>Hg - 28 days | 500 mL Plastic | 200 mL |
| pH, Flashpoint, Reactive Cyanide and Sulfide | SW 9040B / SW 1010 / SW 7.3.3.2 rev 3 / SW 7.3.4.2 rev 3 | 4°C | 7 days | 1 L Amber Glass | 250 mL each |
| Total Petroleum Hydrocarbons | 418.1 | H2SO4 | 28 days | 1 L Amber Glass | 1 Liter |
| PCBs | 8082 | 4°C | 7 days extraction / 40 days analysis | 1 L Amber Glass | 1 Liter |

# *Figures*




NOT TO SCALE

**REFERENCE:**

MAP FROM DELORME'S MAP EXPERT, FREEPORT, MAINE.

Shaw Environmental, Inc.

NEW YORK STATE
DEPARTMENT OF ENVIRONMENTAL CONSERVATION

FIGURE 1
SITE LOCATION MAP
LUSTER-COATE METALLIZING CORP.
32 EAST BUFFALO STREET
CHURCHVILLE, NEW YORK 14428

| OFFICE | DATE | DESIGNED BY | DRAWN BY | CHECKED BY | APPROVED BY | DRAWING NUMBER |
|---|---|---|---|---|---|---|
| ALBANY, NY | 07/16/04 | NA | S. SHKOLNIK | | | 109220A1 |

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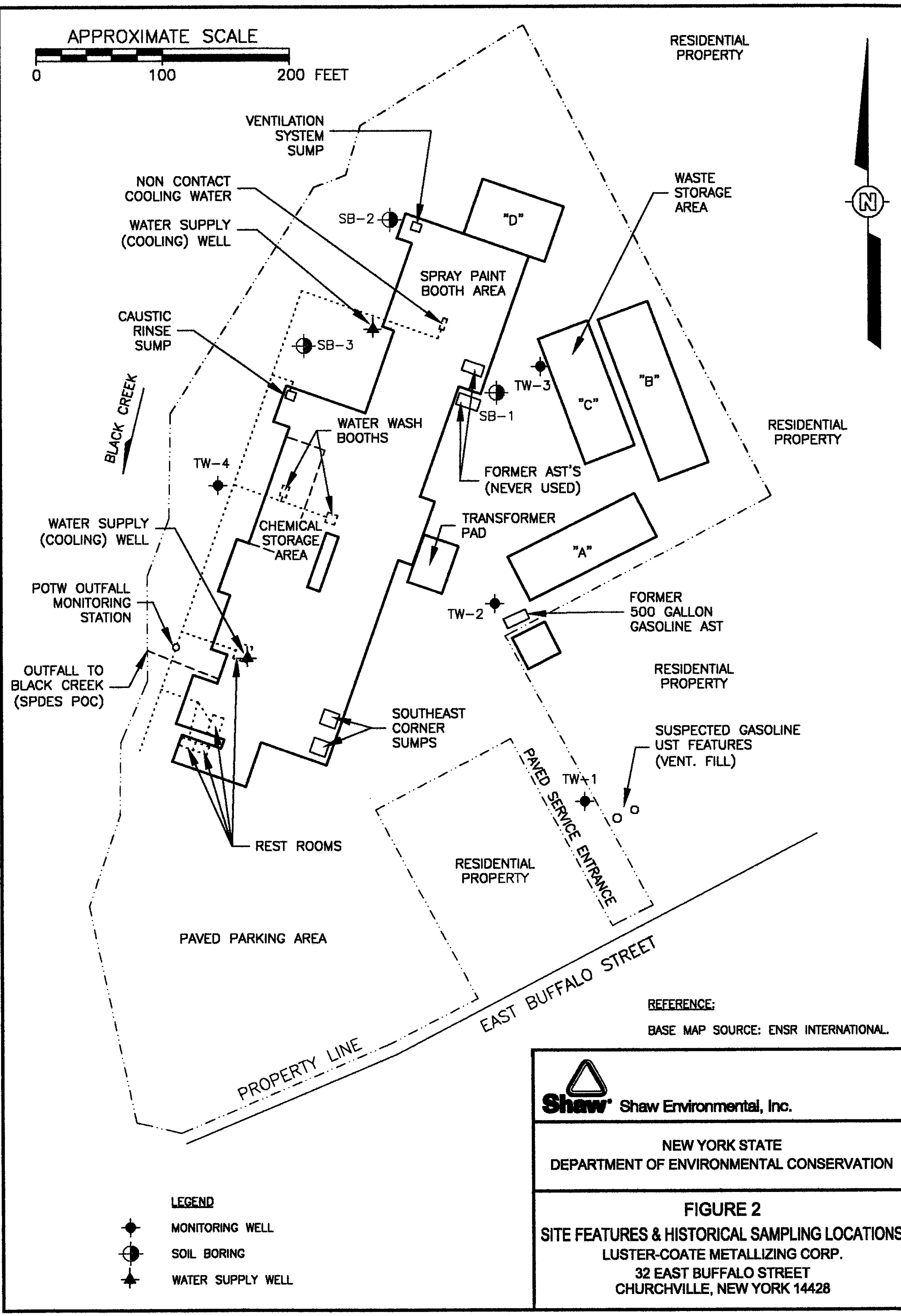
Plot Date/Time: 09/29/04 10:10am Image: CHURCHVI
Plotted by: Samuil.Shkolnik




| OFFICE | DATE | DESIGNED BY | DRAWN BY | CHECKED BY | APPROVED BY | DRAWING NUMBER |
|---|---|---|---|---|---|---|
| ALBANY, NY | 08/11/04 | NA | S. SHKOLNIK | KLH | DS | 109220A10 |

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NEW YORK STATE
DEPARTMENT OF ENVIRONMENTAL CONSERVATION

**FIGURE 2**

**SITE FEATURES & HISTORICAL SAMPLING LOCATIONS**

LUSTER-COATE METALLIZING CORP.
32 EAST BUFFALO STREET
CHURCHVILLE, NEW YORK 14428

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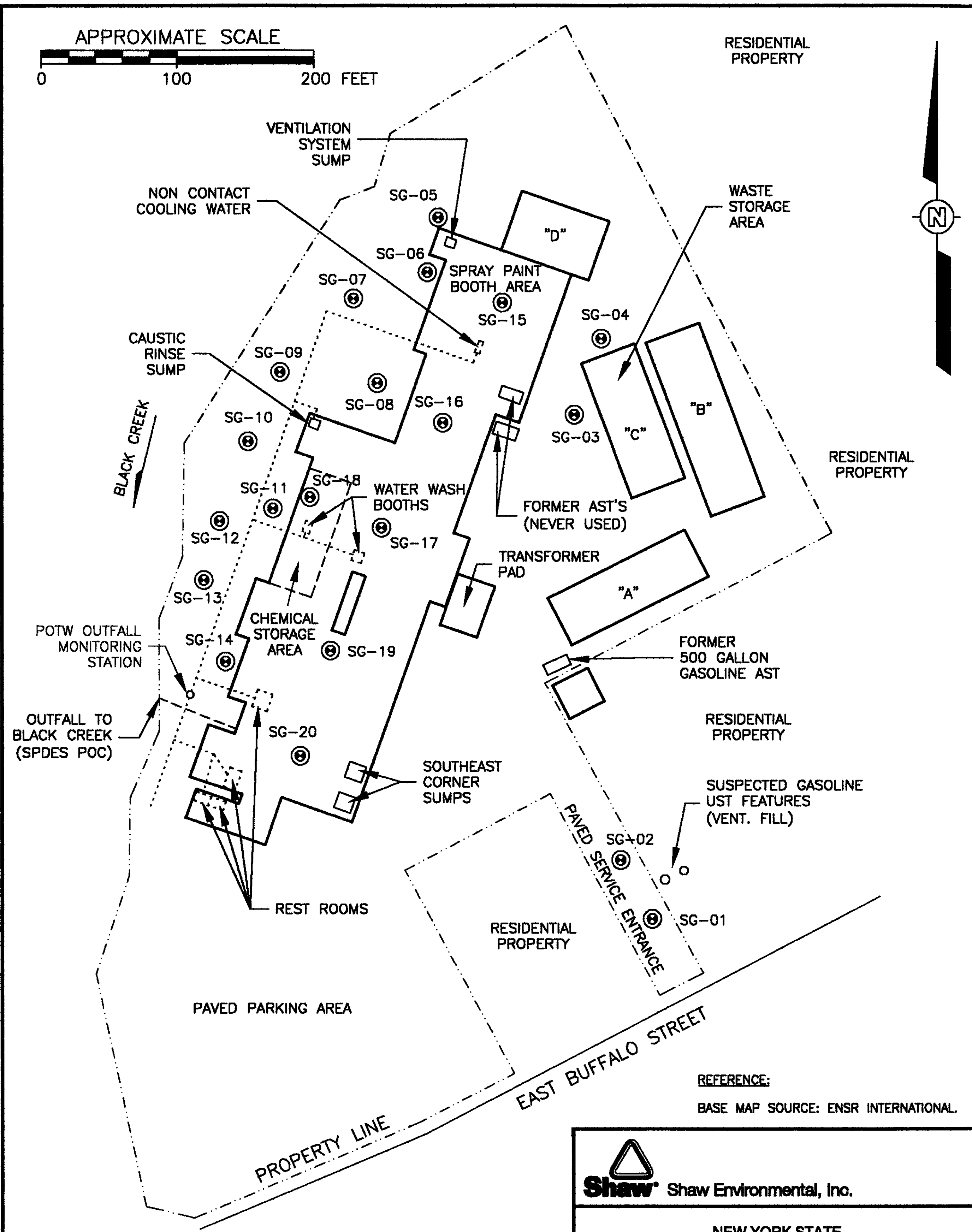
Plotted by: Samuil.Shkolnik




REFERENCE:

BASE MAP SOURCE: ENSR INTERNATIONAL.

Shaw Environmental, Inc.

NEW YORK STATE
DEPARTMENT OF ENVIRONMENTAL CONSERVATION

**FIGURE 3**

**PROPOSED SOIL GAS SAMPLING LOCATIONS**

**LUSTER-COATE METALLIZING CORP.**
**32 EAST BUFFALO STREET**
**CHURCHVILLE, NEW YORK 14428**

LEGEND

⊛ PROPOSED SOIL GAS SAMPLING LOCATION

| OFFICE | DATE | DESIGNED BY | DRAWN BY | CHECKED BY | APPROVED BY | DRAWING NUMBER |
|---|---|---|---|---|---|---|
| ALBANY, NY | 08/12/04 | D. SERVETAS | S. SHKOLNIK | KLH | DS | 109220A11 |

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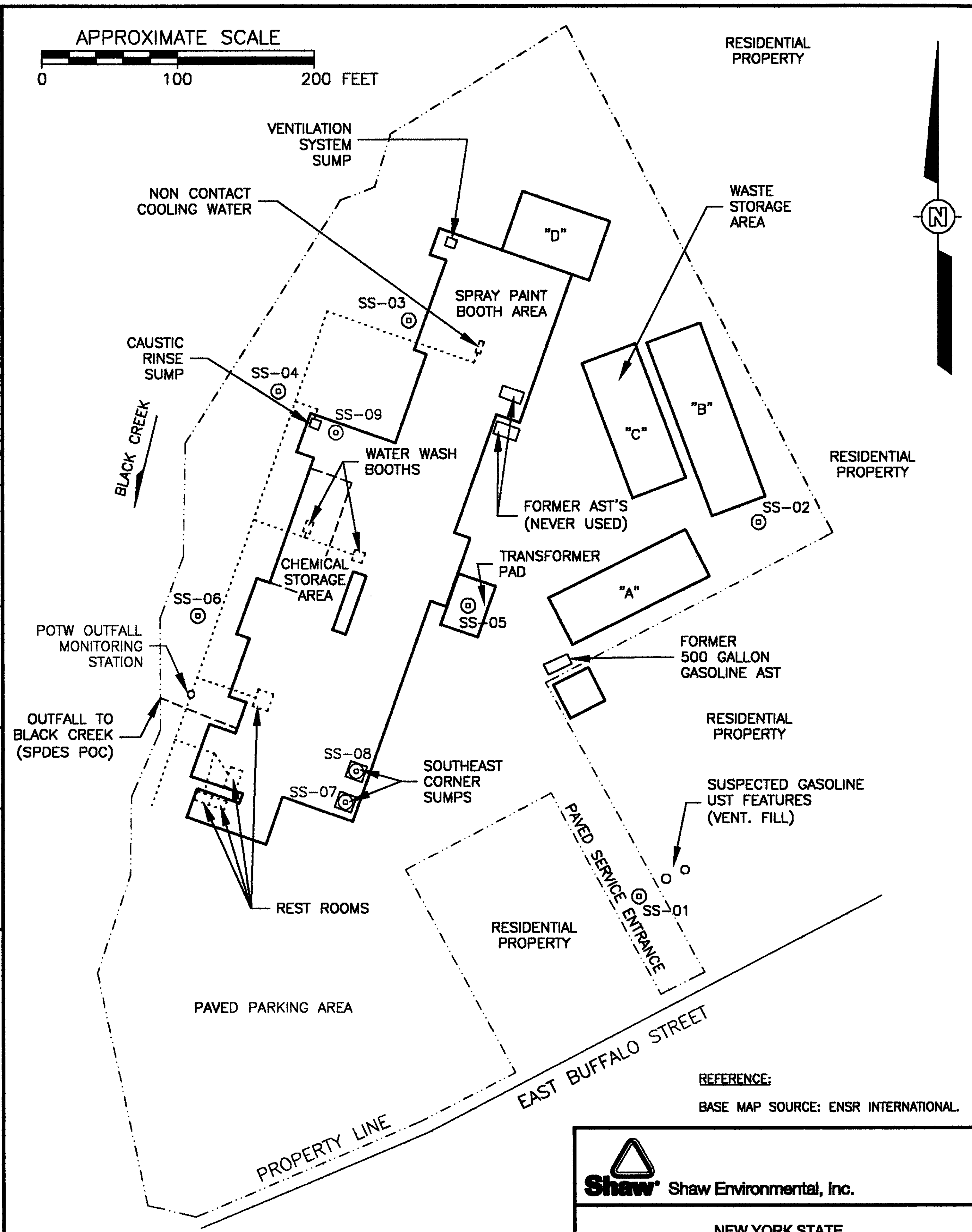


REFERENCE:

BASE MAP SOURCE: ENSR INTERNATIONAL.

LEGEND

◎ PROPOSED SURFACE SOIL SAMPLING LOCATION

Shaw Shaw Environmental, Inc.

NEW YORK STATE
DEPARTMENT OF ENVIRONMENTAL CONSERVATION

**FIGURE 4**

**PROPOSED SURFACE SOIL SAMPLING LOCATIONS**

LUSTER-COATE METALLIZING CORP.
32 EAST BUFFALO STREET
CHURCHVILLE, NEW YORK 14428

| OFFICE | DATE | DESIGNED BY | DRAWN BY | CHECKED BY | APPROVED BY | DRAWING NUMBER |
|---|---|---|---|---|---|---|
| ALBANY, NY | 08/12/04 | D. SERVETAS | S. SHKOLNIK | | DS | 109220A12 |

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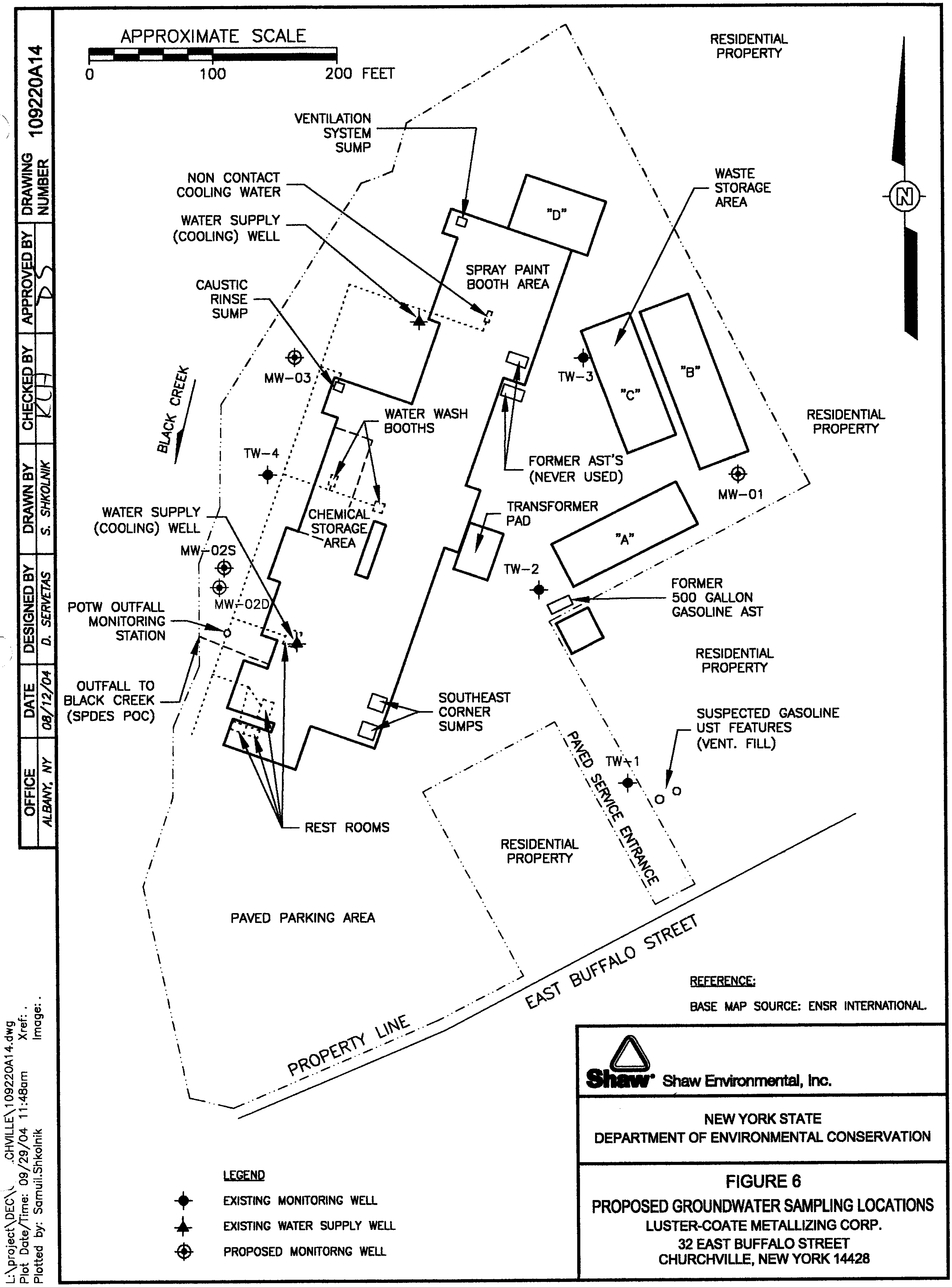
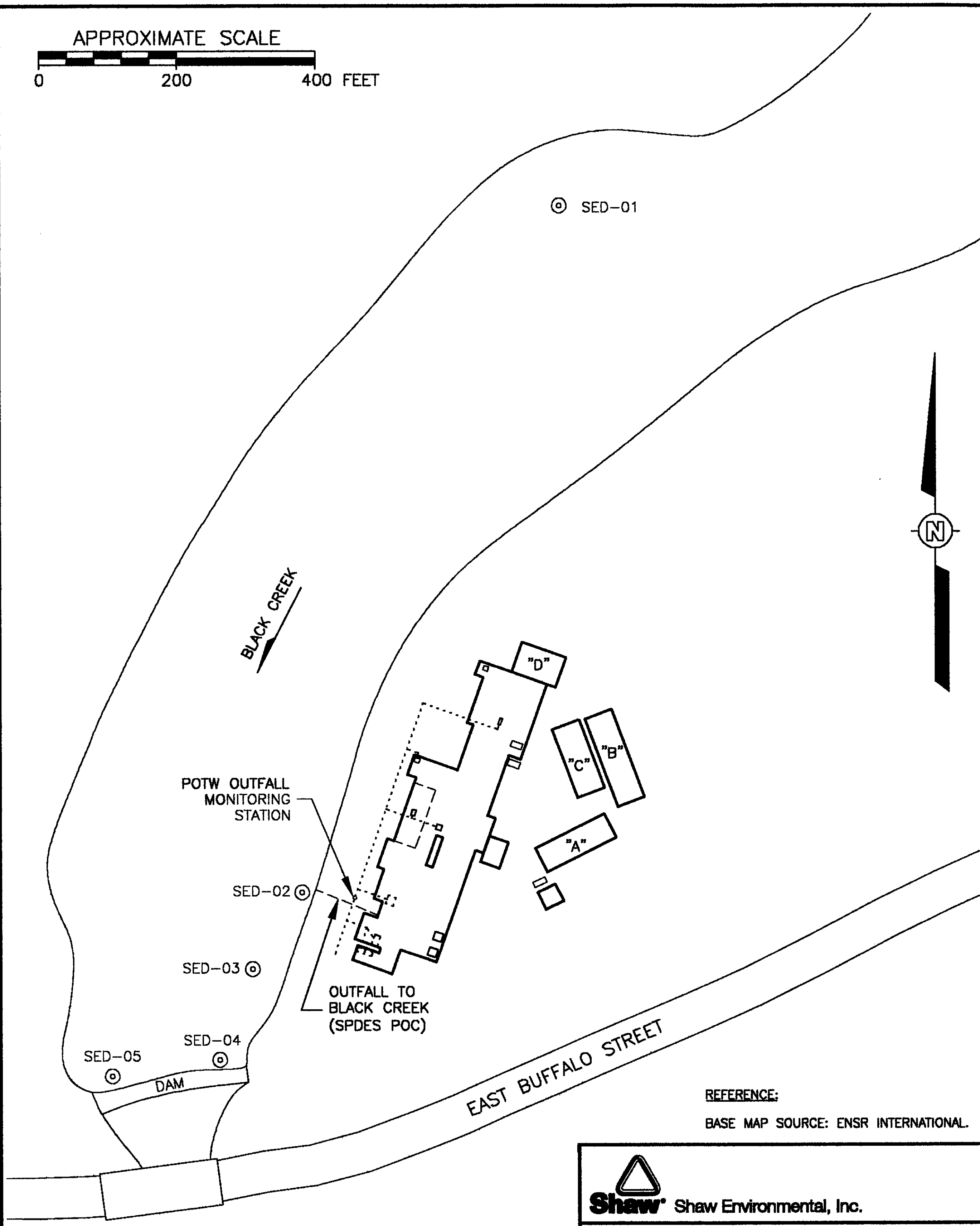
Plotted by: Samuil.Shkolnik




Shaw Environmental, Inc.

NEW YORK STATE
DEPARTMENT OF ENVIRONMENTAL CONSERVATION

FIGURE 6
PROPOSED GROUNDWATER SAMPLING LOCATIONS
LUSTER-COATE METALLIZING CORP.
32 EAST BUFFALO STREET
CHURCHVILLE, NEW YORK 14428




| OFFICE | DATE | DESIGNED BY | DRAWN BY | CHECKED BY | APPROVED BY | DRAWING NUMBER |
|---|---|---|---|---|---|---|
| ALBANY, NY | 08/13/04 | D. SERVETAS | S. SHKOLNIK | KH | DS | 109220A16 |

REFERENCE:

BASE MAP SOURCE: ENSR INTERNATIONAL.

Shaw Environmental, Inc.

NEW YORK STATE
DEPARTMENT OF ENVIRONMENTAL CONSERVATION

**FIGURE 8**

**PROPOSED SEDIMENT SAMPLING LOCATIONS**

LUSTER-COATE METALLIZING CORP.
32 EAST BUFFALO STREET
CHURCHVILLE, NEW YORK 14428

LEGEND

⊙ PROPOSED SEDIMENT SAMPLING LOCATION

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Plot Date/Time: 09/29/04 11:49am Image: .
Plotted by: Samuil.Shkolnik

# *APPENDIX A*

## *SHAW STANDARD OPERATING PROCEDURES*

# STANDARD OPERATING PROCEDURE

**Subject: Shipping and Packaging of Non Hazardous Samples**

## 1. PURPOSE

The purpose of this procedure is to provide general instructions in the packaging and shipping of non-hazardous samples. The primary use of this procedure is for the transportation of samples collected on site to be sent off site for physical, chemical, and/or radiological analysis.

## 2. SCOPE

This procedure applies to the shipping and packing of all non-hazardous samples. Non-hazardous samples are those that do not meet any hazard class definitions found in 49 CFR 107-178, including materials designated as Class 9 materials and materials that represent Reportable Quantities (hazardous substances).

In general most soil, air, and aqueous samples do not meet any of DOT's hazardous materials definitions. However, samples for which screening has shown a potential hazard sufficient to meet a DOT definition or that are derived from a source known or suspected to meet a DOT definition must be packaged and shipped in accordance with the applicable DOT and/or IATA requirements. Refer to Shaw E & I SOP T-FS-013.

## 3. REFERENCES

- U.S. Army Corps of Engineers, 2001, *Requirements for the Preparation of Sampling and Analysis Plans*, EM200-1-3, Washington, D.C.
- U.S. Department of Transportation Regulations, 49 CFR Parts 108-178
- International Air Transport Association (IATA), *Dangerous Goods Regulations*, current edition.

## 4. DEFINITIONS

- **Cooler/Shipping Container**—Any hard-sided insulated container meeting DOT's or IATA's general packaging requirements.
- **Bubble Wrap**—Plastic sheeting with entrained air bubbles for protective packaging purposes.

## 5. RESPONSIBILITIES

### 5.1 Procedure Responsibility

The Field Sampling Discipline Lead is responsible for maintenance, management, and revision of this procedure. Questions, comments, or suggestions regarding this technical SOP should be sent to the Field Sampling Discipline Lead.

### 5.2 Project Responsibility

Shaw employees performing this task, or any portion thereof, are responsible for meeting the requirements of this procedure. Shaw employees conducting technical review of task performance are also responsible for following appropriate portions of this SOP.

For those projects where the activities of this SOP are conducted, the Project Manager, or designee, is responsible for ensuring that those activities are conducted in accordance with this and other appropriate procedures. Project participants are responsible for documenting information in sufficient detail to provide objective documentation (i.e. checkprints, calculations, reports, etc.) that the requirements of this SOP have been met. Such documentation shall be retained as project records.

## 6. PROCEDURE

### 6.1 Packaging

- Use tape and seal off the cooler drain on the inside and outside to prevent leakage.
- Place packing material on the bottom on the shipping container (cooler) to provide a soft impact surface.
- Place a 55-gallon or equivalent plastic bag into the cooler (to minimize possibility of leakage during transit).
- Starting with the largest glass containers, wrap each container with sufficient bubble wrap to ensure the best chance to prevent breakage of the container.
- Pack the largest glass containers in bottom of the cooler, placing packing material between each of the containers to avoid breakage from bumping.
- Double-bag the ice (chips or cubes) in gallon or quart freezer zip-lock plastic bags and wedge the ice bags between the sample bottles.
- Add bagged ice across the top of the samples.
- When sufficiently full, seal the inner protective plastic bag, and place additional packing material on top of the bag to minimize shifting of containers during shipment.
- Tape a gallon zip-lock bag to the inside of the cooler lid, place the completed chain of custody document inside, and seal it shut.
- Tape the shipping container (cooler) shut using packing tape, duct tape, or other tear-resistant adhesive strips. Taping should be performed to ensure the lid cannot open during transport.
- Place a custody seal on two separate portions of the cooler, to provide evidence that the lid has not been opened prior to receipt by the intended recipient.

### 6.2 Labeling

- A "This Side Up" arrow must be adhered to all sides of the cooler.
- The name and address of the receiver and the shipper must be on the top of the cooler.
- The airbill must be attached to the top of the cooler.

### 6.3 Shipping Documentation

- A Cooler Shipment Checklist (Attachment 1) should be completed and kept in the project file.

## 7. ATTACHMENTS

- **Attachment 1**—Shaw E & I Cooler Shipment Checklist

## 8. FORMS

None.

# SAMPLE SHIPMENT CHECKLIST

Shaw™
Shaw E & I, Inc.

Project Name ____________________ Project Number ____________

Address ____________________ Date ________ Time ________

City, State, Zip ____________________ Fax No. ____________

Site Contact No. ____________________

| SAMPLE CHECKLIST | YES | NO | COMMENTS |
|---|---|---|---|
| SAMPLE LIDS ARE TIGHT AND CUSTODY SEALS IN PLACE? | ☐ | ☐ | |
| ARE ALL SAMPLE NUMBERS, DATES, TIMES AND OTHER LABEL INFORMATION LEGIBLE AND COMPLETE? | ☐ | ☐ | |
| HAVE ALL SAMPLE NUMBERS, DATES, TIMES AND OTHER SAMPLING DATA BEEN LOGGED INTO THE SAMPLE LOG BOOK? | ☐ | ☐ | |
| DO SAMPLE NUMBERS AND SAMPLE DESCRIPTIONS ON THE LABELS MATCH THOSE ON THE COC? | ☐ | ☐ | |
| HAVE THE SAMPLES BEEN PROPERLY PRESERVED? | ☐ | ☐ | |
| HAVE THE CHAIN OF CUSTODIES BEEN FILLED OUT COMPLETELY AND CORRECTLY? | ☐ | ☐ | |
| DOES THE ANALYTICAL SPECIFIED ON THE COC MATCH THE ANALYTICAL SPECIFIED IN THE SCOPE OF WORK? | ☐ | ☐ | |
| HAVE THE COC'S BEEN PROPERLY SIGNED IN THE TRANSFER SECTION? | ☐ | ☐ | |

| PACKAGING CHECKLIST | YES | NO | COMMENTS |
|---|---|---|---|
| HAS EACH SAMPLE BEEN PLACED INTO AN INDIVIDUAL PLASTIC BAG? | ☐ | ☐ | |
| HAS THE DRAIN PLUG OF THE COOLER BEEN TAPED CLOSED WITH WATER PROFF TAPE FROM THE INSIDE? | ☐ | ☐ | |
| HAVE ALL THE SAMPLES BEEN PLACED INTO THE COOLER IN AN UPRIGHT POSITION? | ☐ | ☐ | |
| IS THERE ADEQUATE SPACING OF SAMPLES SO THAT THEY WILL NOT TOUCH DURING SHIPMENT? | ☐ | ☐ | |
| HAVE AN ADEQUATE NUMBER OF BLUE ICE PACKS OR WATER ICE BEEN PLACED AROUND AND ON TOP OF THE SAMPLE? | ☐ | ☐ | |
| HAS FRESH BLUE ICE OR WATER ICE BEEN ADDED TO THE COOLER THE DAY OF THE SHIPMENT? | ☐ | ☐ | |
| HAS THE COOLER BEEN FILLED WITH ADDITIONAL CUSHIONING MATERIAL? | ☐ | ☐ | |
| HAS THE COC BEEN PLACE IN A ZIPLOCK BAG AND TAPED TO THE INSIDE OF THE LID OF THE COOLER? | ☐ | ☐ | |
| HAVE CUSTODY SEALS BEEN PLACED ONTO THE LID? | ☐ | ☐ | |
| HAS THE COOLER BEEN LABELED "THIS SIDE UP"? | ☐ | ☐ | |
| IF REQUIRED, HAS THE COOLER BEEN LABELED WITH THE DOT PROPER SHIPPING NAME, UN NUMBER AND LABEL? | ☐ | ☐ | |
| HAS THE LABORATORY PERFORMING THE ANALYSES BEEN NOTIFIED OF THE SHIPMENT OF SAMPLES? | ☐ | ☐ | |

PROBLEMS/RESOLUTIONS: ________________________________________

________________________________________

________________________________________

PREPARED BY: ____________________ SIGNATURE ____________________

# STANDARD OPERATING PROCEDURE

**Subject: Decontamination of Contact Sampling Equipment**

## 1. PURPOSE

This procedure defines the Shaw E & I standard that must be implemented for decontamination of contact sampling equipment. Contact sampling equipment is equipment that comes in direct contact with the sample or portion of sample that will undergo chemical analyses or physical testing. This SOP is intended to provide minimum guidelines and general procedures for decontaminating contact sampling equipment used during field sampling activities. The benefits of its use include the following:

- Minimizing the spread of contaminants within a study area and from site to site
- Reducing the potential for worker exposure by means of contact with contaminated sampling equipment
- Improved data quality and reliability

## 2. SCOPE

This procedure applies to all instances where non-disposable direct contact sampling equipment is utilized for sample collection. This procedure is not intended to address decontamination of peristaltic or other sampling pumps and tubing. The steps outlined in this procedure must be executed between each distinct sample data point.

## 3. REFERENCES

- U.S. Environmental Protection Agency, Region 4, 2001, *Environmental Investigations Standard Operating Procedures and Quality Assurance Manual,* 980 College Station Road, Athens, Georgia. November.
- US Army Corp of Engineers, Washington, D.C., 2001, Requirements for the Preparation of Sampling and Analysis Plans (EM-200-1-3), February.

## 4. DEFINITIONS

- **Soap**—A standard brand of phosphate-free laboratory detergent, such as Liquinox®.
- **Organic Desorbing Agent**—A solvent used for removing organic compounds. The specific solvent would depend upon the type of organic compound to be removed. See Attachment 1 for recommendations.
- **Inorganic Desorbing Agent**—An acid solution for use in removing trace metal compounds. The specific acid solution would depend upon the type of inorganic compound to be removed. See Attachment 1 for recommendations.
- **Tap water**—Water obtained from any municipal water treatment system. An untreated potable water supply can be used as a substitute for tap water if the water does not contain the constituents of concern.

- **Analyte-free water (deionized water)**—Water that has been treated by passing through a standard deionizing resin column, and for organics either distillation or activated carbon units. At a minimum, the finished water should contain no detectable heavy metals or other inorganic compounds, and/or no detectable organic compounds (i.e., at or above analytical detection limits). Analyte-free water obtained by other methods is acceptable, as long as it meets the above analytical criteria.

Other solvents may be substituted for a particular purpose if required. For example, removal of concentrated waste materials may require the use of either pesticide-grade hexane or petroleum ether. After the waste material is removed, the equipment must be subjected to the standard cleaning procedure. Because these solvents are not miscible with water, the equipment must be completely dry prior to use.

## 5. RESPONSIBILITIES

### 5.1 Procedure Responsibility

The Field Sampling Discipline Lead is responsible for maintenance, management, and revision of this procedure. Questions, comments, or suggestions regarding this technical SOP should be sent to the Field Sampling Discipline Lead.

### 5.2 Project Responsibility

Shaw employees performing this task, or any portion thereof, are responsible for meeting the requirements of this procedure. Shaw employees conducting technical review of task performance are also responsible for following appropriate portions of this SOP.

For those projects where the activities of this SOP are conducted, the Project Manager, or designee, is responsible for ensuring that those activities are conducted in accordance with this and other appropriate procedures. Project participants are responsible for documenting information in sufficient detail to provide objective documentation (i.e. checkprints, calculations, reports, etc.) that the requirements of this SOP have been met. Such documentation shall be retained as project records.

## 6. PROCEDURE

### 6.1 Health and Safety

Minimum Health and Safety Procedures should be implemented based on the site-specific decontamination protocol that is designed. Health and Safety procedures should take into consideration the potential use of either dangerous solvents or corrosive liquids.

### 6.2 Implementation

A decontamination area should be established. A separate tub needs to be available for each of the first four steps. Each type of water and soap solution can be placed in hand-held sprayers made of an inert material. The analyte-free water needs to be placed in a container that will be free of any compounds of concern. Special containers will be needed if solvents or acid solutions are used. For example, an acid solution cannot be placed in a sprayer that has any metal parts that will come in contact with the acid solution.

The minimum steps for decontamination are as follows:

1. Remove particulate matter and other surface debris using appropriate tools such as a brush or hand-held sprayer filled with tap water.

2. Scrub the surfaces of the contact sampling equipment using tap water and soap solution and a second brush made of inert material.

3. Rinse contact sampling equipment thoroughly with tap water.

4. Rinse contact sampling equipment thoroughly with analyte-free water (not necessary if sampling for disposal profiling purposes).

5. Place contact sampling equipment on a clean surface appropriate for the compounds of concern and allow to air dry.

It is Shaw E & I policy to containerize all decontamination fluids. This policy will be followed unless an the client specifically directs an alternate procedure in writing.

The use of solvents and/or acid solutions will be dependent on the site-specific conditions. A site with a high probability of high concentrations of compounds or with waste material present will require additional decontamination procedures. Attachment 1 provides some guidance for additional decontamination procedures.

## 7. ATTACHMENTS

- **Attachment 1**—Recommended Decontamination Procedures.

## 8. FORMS

None.

## ATTACHMENT 1
## RECOMMENDED DECONTAMINATION PROCEDURES

| Compound | Detergent Wash | Tap Water | Inorganic Desorbing Agent | Tap Water | Organic Desorbing Agent[1] | Deionized Water | Air Dry |
|---|---|---|---|---|---|---|---|
| **Organics** | | | | | | | |
| Volatile Organic Compounds | ✓ | ✓ | | | Methanol Purge & Trap grade | ✓ | ✓ |
| Base Neutrals/Acid Extractables/PCBs/Pesticides | ✓ | ✓ | | | Hexane | ✓ | ✓ |
| Organic Bases[2] | ✓ | ✓ | 1% nitric acid | ✓ | Isopropyl Alcohol | ✓ | ✓ |
| Organic Acids[3] | ✓ | ✓ | 1% nitric acid | | Isopropyl Alcohol | ✓ | ✓ |
| **Inorganics** | | | | | | | |
| Trace Metals and Radio Isotopes | ✓ | ✓ | 10% Nitric acid -Trace metals grade | ✓ | | ✓ | ✓ |
| Cations/Anions | ✓ | ✓ | | | | ✓ | ✓ |
| Acidic Compounds | ✓ | ✓ | | | | ✓ | ✓ |
| Basic Compounds (caustic) | ✓ | ✓ | 1% nitric acid | ✓ | | ✓ | ✓ |

1 – All organic solvents must be Pesticide Grade or better. The selection of appropriate solvent rinses should first consider if a *known or suspected* contaminant requires removal from sampling equipment. Secondly, identify whether the subsequent analytical protocol would be impacted by the proposed solvent or an impurity thereof (e.g., residual acetone present in isopropyl alcohol would be measured with certain volatile organics analysis).
2 - Organic bases include amines, hydrazines.
3 - Organic acids include phenols, thiols, nitro and sulfonic compounds.

Adapted from: Appendix E, Requirements for the Preparation of Sampling and Analysis Plans (EM-200-1-3), February 2001. US Army Corp of Engineers, Washington, D.C.

# STANDARD OPERATING PROCEDURE

**Subject: Trowel/Spoon Surface Soil Sampling**

## 1. PURPOSE

The purpose of this document is to provide the methods and procedure for sampling of surface soils using trowels or spoons. Trowels or spoons can be used when matrices are composed of relatively soft and non-cemented formations and to depths of up to 12 inches into the ground surface, dependent on site conditions. Samples for VOC analysis should not be collected via trowel or spoon method. However, a trowel or spoon may be utilized to penetrate to and expose the undisturbed material at the desired depth for sampling by more applicable methods.

## 2. SCOPE

This procedure is applicable to all Shaw E & I projects where surface soil samples will be collected via trowel or spoon methods.

## 3. REFERENCES

- U.S. Army Corps of Engineers, 2001, *Requirements for the Preparation of Sampling and Analysis Plans*, Appendix C, SectionC.6, EM200-1-3, Washington, D.C.

## 4. DEFINITIONS

- **Trowel**—A sample collection device with a curved and pointed metal blade attached to a handle. All trace environmental samples should be collected using stainless steel blades.
- **Spoon**—A sample collection device with a round metal blade attached to a handle.
- **Surface Soil**—Soil that is removed from the surface no greater than 6 inches below grade after removing vegetation, rocks, twigs, etc.
- **Weathered Soil**—The top ⅛ to ¼ inch of soil impacted by heat from sun, rain or foot traffic that could evaporate, dilute, or otherwise deposit contaminants from an adjacent location, thereby misrepresenting the actual soil characteristic.

## 5. RESPONSIBILITIES

### 5.1 Procedure Responsibility

The Field Sampling Discipline Lead is responsible for maintenance, management, and revision of this procedure. Questions, comments, or suggestions regarding this technical SOP should be directed to the Field Sampling Discipline Lead.

### 5.2 Project Responsibility

Shaw employees performing this task, or any portion thereof, are responsible for meeting the requirements of this procedure. Shaw employees conducting technical review of task performance are also responsible for following appropriate portions of this SOP.

For those projects where the activities of this SOP are conducted, the Project Manager, or designee, is responsible for ensuring that those activities are conducted in accordance with this and other appropriate procedures. Project participants are responsible for documenting information in sufficient detail to provide objective documentation (i.e. checkprints, calculations, reports, etc.) that the requirements of this SOP have been met. Such documentation shall be retained as project records.

## 6. PROCEDURE

### 6.1 Equipment

- Decontaminated trowel or spoon, stainless steel construction for trace environmental sampling. If samples will be collected at depth (0-6 inches) the trowel or spoon will require decontamination prior to collection of the targeted-depth sample. Alternatively, a different trowel or spoon can be used to remove the material to the targeted depth and the sample collected using a clean dedicated trowel or spoon.
- Engineers rule or stiff measuring tape
- Decontaminated stainless steel mixing bowl

### 6.2 Sampling

1. Don a pair of clean gloves.
2. If desired, place plastic sheeting around the targeted location to keep sampled material in place. Use a knife to cut an access hole for the sample location.
3. Remove any surficial debris (e.g. vegetation, rocks, twigs) from the sample location and surrounding area until the soil is exposed. Once exposed the soil surface is designated as "at grade", or 0 inches.
4. Use a trowel to scrape and remove the top 1/8 to 1/4 inch of weathered soil. (A spoon can be interchanged with trowel).
5. If collecting a sample for VOC analysis, collect the sample first following more applicable methods.
6. With a new trowel, place the point of the blade on the ground. While holding the handle of the trowel partially rotate the blade in a clockwise/counter-clockwise motion while pushing at a downward angle until the blade is inserted to the required depth or the blade is nearly covered. Be certain that the trowel is not inserted to a depth where the soil will touch the handle or other non-stainless steel portion of the trowel or the sampler's hand.
7. With a prying motion lift up the trowel with soil on the blade and place soil into the stainless steel mixing bowl.
8. Repeat 6 and 7 until the required depth of soil is placed into the mixing bowl.
9. Measure the depth of the sample location with a rule or tape to verify the sampling depth and record in the field logbook.
10. Homogenize the non-VOC sample and transfer the sample directly into the sample container(s). Cap the sample container(s), label, complete documentation, and place into the sample cooler.

## 7. ATTACHMENTS

None.

## 8. FORMS

None.

# STANDARD OPERATING PROCEDURE

**Subject:** **Sampling of in-process Piles**

## 1. PURPOSE

The purpose of this procedure is to provide a simple and statistically sound method for sampling of small (<500cy) in-process stockpiles on project sites for characterization purposes where state and/or other regulatory or project-specific requirements are not pre-determined. These stockpiles may be the result of soil excavation/segregation, treatment of residual production, or debris segregation.

## 2. SCOPE

This procedure applies to the sampling of in-process stockpiles of less than 500cy in volume where the intent is to determine a *gross average* and UCL for a specific property or parameter set for comparison to decision levels. Examples include determining disposal profiles, overburden reuse determination, treated material confirmation, and backfill usability.

This procedure is *not intended* to provide spatial distribution data of legacy stockpiles or to be used where stockpiles exceed 500cy in volume. In these cases, project/task-specific sampling and analysis designs should be developed based upon the project/task required goals and objectives.

## 3. REFERENCES

- U.S. Environmental Protection Agency, 2002, *RCRA Waste Sampling Draft Technical Guidance, Planning, Implementation, Assessment*, EPA/530-D-02-002, August.
- U.S. Environmental Protection Agency, 1994, *Waste Pile Sampling*, EPA/ERT SOP 2017.
- American Society for Testing and Materials, *Standard Guide for Sampling of Waste Piles*, ASTM D6009.

## 4. DEFINITIONS

- **Stockpile**—Solid material placed into a conical, pyramid, rectangular, windrow, or other elongated shape with sloped sides. Stockpiles may be generated as a result of a treatment process, soil excavation, debris segregation, or other tasks.
- **Composite Sample**—A sample created by the mixing of several discrete samples into one sample representative of the average characteristics of the entity sampled.

## 5. RESPONSIBILITIES

### 5.1 Procedure Responsibility

The Field Sampling Discipline Lead is responsible for maintenance, management, and revision of this procedure. Questions, comments, or suggestions regarding this technical SOP should be directed to the Field Sampling Discipline Lead.

### 5.2 Project Responsibility

Shaw employees performing this task, or any portion thereof, are responsible for meeting the requirements of this procedure. Shaw employees conducting technical review of task performance are also responsible for following appropriate portions of this SOP.

For those projects where the activities of this SOP are conducted, the Project Manager, or designee, is responsible for ensuring that those activities are conducted in accordance with this and other appropriate procedures. Project participants are responsible for documenting information in sufficient detail to provide objective documentation (i.e. checkprints, calculations, reports, etc.) that the requirements of this SOP have been met. Such documentation shall be retained as project records.

## 6. PROCEDURE

**Safety Note:** *Soil and treated residual stockpiles may contain unstable materials and could collapse or engulf personnel without warning. In addition, slopes can be steep and if wetted could be become hazardous. Personnel should not climb onto any stockpile unless the site ECP determines that is safe to do so. Whenever possible, in-process stockpiles should be sampled in locations accessible from waist to chest high without scaling the pile or with heavy equipment assistance.*

*Debris piles should not be scaled under any circumstances and* ***must*** *be sampled either with long-reach implements or heavy equipment assistance.*

### 6.1 Determine Sample Locations

The procedure for determining sample locations is based upon the collection and compositing of six grab samples from the pile itself. The locations are chosen on a systematic or systematic random design depending upon the pile volume. If VOCs are a concern, including for TCLP, additional grab samples are collected and submitted without compositing for analysis.

1. Determine the stockpile volume. Although the number of grab samples does not vary with volume, the sampling design used to determine grab locations is volume dependent. Therefore, a gross estimate of the pile volume is required. This can be obtained from discussions with operations personnel or based on knowledge of the "batch" size.

   If an operational estimate is not available or plausible, a simple and conservative estimate for typical piles can be obtained by first determining the closest geometric shape(s) of its base, measuring the height/length, and calculating as follows:

   - Conical (typical) pile: V= 1/3 A*H

     Where:

     A= area of base

   - Elongated (windrow): V= A*L

     Where:

     A=area of pile face
     L= length of pile/windrow

2. Determine the number and distance between the measured location points, using Table 1 below.

**Table 1**
**Grab Sample Location Determination**

| Pile Volume (estimated) | Number of Equidistant Points | Number of Selected Locations |
|---|---|---|
| Up to 100cy | 6 | 6 with 3 for VOC (if needed) |
| 100-200cy | 12 | 6 with 3 for VOC (if needed) |
| 200-300cy | 18 | 6 with 3 for VOC (if needed) |
| 300-400cy | 21 | 6 with 3 for VOC (if needed) |
| 400-500cy | 24 | 6 with 3 for VOC (if needed) |
| >500cy | SOP not applicable | SOP not applicable |

3. Starting at a randomly selected point, measure and mark with a flag or stake the required locations from Table 1 along the pile perimeter. If the pile is larger than 100cy, label each marked location assigning a unique number to each one.

4. Referring to Table 1, determine the sample locations for sampling. For piles greater than 100cy use a random number generator to determine the locations to be sampled. This can also be done using a "draw" from numbered slips of paper.

## 6.2 Collect Sample

1. At each selected grab sample location, collect a sample from material approximately waist high. Each sample should be collected from material at least 2 feet into the pile by using a shovel or trowel to first remove the upper crust layer or using a trier to collect the sample and not containerizing the upper 2 feet. Place the material from each grab into a mixing container.

2. If collecting a sample for VOCs, at the selected location obtain the material from the exposed material immediately after removing the upper crust using appropriate methods. VOC samples should not be mixed or composited in the field.

3. If an excavator or other assistance is being used, direct the operator to scoop into the pile at least 2-3 feet and collect the "grab" for each location by collecting material from the upper foot of the bucket contents in three randomly selected spots. Collect VOC samples first.

4. If collecting debris samples, place a piece of each type of waste at the selected sample location into the mixing container. Debris pieces should also be cut or reduced to a manageable size (1-2 inches square) before being mixed. Some debris may be light, and larger volumes may need to be sampled and submitted in order to provide adequate sample mass. This is especially true of PPE and other low-mass waste materials.

5. Once the material from all six sample locations has been obtained, mix and homogenize the composite and place the material into appropriate labeled sample containers. The VOC samples should always remain discrete. In some cases, the laboratory may be instructed to create a VOC-lab composite by combining medium/high level extracts or even combining 5g core sampler aliquots into a TCLP/VOC-(ZHE) test.

## 7. ATTACHMENTS

None

## 8. FORMS

None

# STANDARD OPERATING PROCEDURE

**Subject: Water Level Measurement**

## 1. PURPOSE

The purpose of this procedure is to provide the methods and procedures for measurement of groundwater well water levels and for conducting LNAPL measurements. Well water levels can either be determined as part of the well purging/sampling effort or be independently determined to provide information on site hydrology.

## 2. SCOPE

This procedure is applicable to all Shaw E & I projects where groundwater level measurements are taken.

## 3. REFERENCES

- American Society of Testing and Materials, D4750-87 (Reapproved 2001), *Standard Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well)*, West Conshohocken, PA.
- U.S. Department of the Interior, 1977 (updated 1984), *National Handbook of Recommended Methods for Water-Data Acquisition*, Chapter 2, Reston, VA.

## 4. DEFINITIONS

- **Measuring Tape**—Steel or plastic tape with graduations to 0.01 feet. The tape shall not stretch more than 0.05 feet under normal use.
- **Electronic Measuring Device**—Commercial probe and cable designed to register a signal when the probe contacts water. The cable must have graduations to 0.01 feet.

## 5. RESPONSIBILITIES

### 5.1 Procedure Responsibility

The Field Sampling Discipline Lead is responsible for maintenance, management, and revision of this procedure. Questions, comments, or suggestions regarding this technical SOP should be sent to the Field Sampling Discipline Lead.

### 5.2 Project Responsibility

Shaw E & I employees performing this task, or any portion thereof, are responsible for meeting the requirements of this procedure. Shaw E & I employees conducting technical review of task performance are also responsible for following appropriate portions of this SOP.

For those projects where the activities of this SOP are conducted, the Project Manager, or designee, is responsible for ensuring that those activities are conducted in accordance with this and other appropriate procedures. Project participants are responsible for documenting information in sufficient detail to provide objective documentation (i.e. checkprints, calculations, reports, etc.) that the requirements of this SOP have been met. Such documentation shall be retained as project records.

## 6. PROCEDURE

Two techniques are discussed below: the measuring-tape method and the electronic method.

### 6.1 Equipment

The following equipment should be used when measuring groundwater levels:

- Decontaminated, weighted tape with graduations to 0.01 feet. The weight should be sufficient to ensure plumbness of the tape, but slender enough so as not to raise the water level significantly when submerged in the water.
- Decontaminated, commercial electronic water-level measuring device.
- Engineer's rule, graduated to 0.01 feet.
- Oil/water interface probe and meter.

### 6.2 Weighted Steel Tape

The following procedure should be used when measuring groundwater levels with a measuring tape:

1. Unlock the well cover and remove the cap.
2. Locate the reference point on the riser pipe.
3. Don a pair of clean gloves.
4. Slowly lower the weighted tape down the well until the bottom is reached, indicated by a bump and sudden slack in the line.
5. Straighten the tape out, removing the slack, and measure the distance at the reference point.
6. Record the reading at the reference point as Depth to Bottom (DTB).
7. Withdraw the tape from the well and record the reading at the wet/dry interface as Depth to Water (DTW).
8. The difference between the two measurements is the depth of the water column (DWC).
9. Dry and decontaminate the wetted portion of the tape.

### 6.3 Electronic Measurement

The following procedure should be used when measuring groundwater levels with an electronic water-level measuring device:

1. Check for proper instrument response by inserting the probe in water. Fix or replace the instrument as needed.
2. Unlock the well cover and remove the cap.
3. Locate the reference point on the riser pipe.
4. Don a pair of clean gloves.

5. Slowly lower the probe down the well until the signal indicates that the water has been contacted.
6. Record the reading at the reference point as DTW.
7. Withdraw the probe and repeat steps 5 & 6. Duplicate measurements should agree within 0.02 feet. If not, continue with measurements until 0.02 feet precision is achieved.
8. Lower the probe until the bottom of the well is reached, as indicated by slack in the line.
9. Pull slightly to remove the slack, measure at the reference point, and record as DTB.
10. Determine the water column length as (DTB-DTW) and record as DWC.
11. Remove the probe from the well and decontaminate it.

### 6.4 Light Non-Aqueous Phase Liquids

Oil or other light non-aqueous phase liquids (LNAPL) may be floating on the water in selected wells. If so, measure the LNAPL level and the water level using an oil/water interface probe as follows:

1. Check for proper instrument response by inserting the probe in water. Instruments typically indicate LNAPL with a steady indicator light and tone, while water is indicated by an intermittent light and tone.
2. Unlock the well cover and remove the cap.
3. Locate the reference point on the riser pipe.
4. Don a pair of clean gloves.
5. Slowly lower the oil/water interface probe down the well until the signal indicates that LNAPL has been contacted (typically a steady indicator light and tone).
6. Record the reading at the reference point as DTNAPL.
7. Continue lowering the probe until the signal indicates that water has been contacted (typically an intermittent light and tone).
8. Record the reading at the reference point as DTW.
9. Determine the depth of LNAPL as (DTW-DTNAPL) and record it.
10. Withdraw the probe and repeat steps 5 & 6. Duplicate measurements should agree within 0.02 feet. If not, continue with measurements until 0.02 feet precision is achieved.
11. Lower the probe until the bottom of the well is reached, as indicated by slack in the line.
12. Pull slightly to remove the slack, measure at the reference point, and record as DTB.
13. Determine the water column length as (DTB-DTW) and record as DWC.
14. Remove the probe from the well and decontaminate it.

## 7. ATTACHMENTS

None.

## 8. FORMS

None.

# STANDARD OPERATING PROCEDURE

## Subject: Sampling of Aqueous Liquids via Bailer

### 1. PURPOSE

The purpose of this procedure is to provide the methods and techniques to be utilized when sampling aqueous liquids using bailer methods. This procedure does not apply to the use of depth-integrated modified bailer systems such as the Kemmerer Sampler. Bailers should not be utilized when sampling for trace levels of VOCs in wells containing high solids loads or wells that have been purged using micro techniques.

### 2. SCOPE

This procedure is applicable to all Shaw E & I projects where samples will be collected using a bailer. These may include groundwater wells, water treatment pools, frac tanks, and other containers.

It is not applicable to direct push groundwater sampling. See Shaw E & I SOP T-GS-009 for possible direct push groundwater sampling methods.

### 3. REFERENCES

- U.S. Army Corps of Engineers, 2001, *Requirements for the Preparation of Sampling and Analysis Plans*, Appendix C, Section C.2, EM200-1-3, Washington, D.C.
- American Society of Testing and Materials, D6634-01, *Standard Guide for Selection of Purging and Sampling Devices for Ground-Water Monitoring Wells*, West Conshohocken, PA.
- American Society of Testing and Materials, D4448-01, *Standard Guide for Sampling Ground-Water Monitoring Wells*, West Conshohocken, PA.

### 4. DEFINITIONS

- **Bailer**—A device used to collect aqueous liquid samples typically consisting of a long tube with a check valve system attached to a rope or cable. The bailer is lowered into the liquid, and once the desired depth is reached, the check valve is set by causing an upward motion. Bailers are constructed of stainless steel, polyethylene plastic, or Teflon™. Those made of polyethylene and Teflon™ can be considered disposable and utilized for one-time use.
- **Single check valve bailer**—The most commonly used type of bailer, it is a tubular bailer with a bottom check valve that allows water to enter the bailer while it is lowered. The weight of the water in the bailer closes the check valve upon retrieval.
- **Top-filling bailer**—A tubular bailer that is only open on the top. The bailer is lowered beneath the water surface and water enters the top of the bailer. This type of bailer should not be used for environmental sampling. However, it is a very effective well purging device.
- **VOC sampling device/attachment**—A detachable spigot usually constructed of polyethylene or Teflon™ that can be attached to the bottom of a bailer to regulate the flow while emptying the device, preventing agitation of the liquid as it exits.

## 5. RESPONSIBILITIES

### 5.1 Procedure Responsibility

The Field Sampling Discipline Lead is responsible for maintenance, management, and revision of this procedure. Questions, comments, or suggestions regarding this technical SOP should be sent to the Field Sampling Discipline Lead.

### 5.2 Project Responsibility

Shaw E & I employees performing this task, or any portion thereof, are responsible for meeting the requirements of this procedure and utilizing materials of a construction specified in the project plans or applicable to the contaminants of concern and other aspects of the sampling effort. These may include well diameter, well construction materials, depth to water, and the presence of DNAPL or LNAPL contaminants. Shaw E & I employees conducting technical review of task performance are also responsible for following appropriate portions of this SOP.

For those projects where the activities of this SOP are conducted, the Project Manager or designee is responsible for ensuring that those activities are conducted in accordance with this and other appropriate procedures. Project participants are responsible for documenting information in sufficient detail to provide objective documentation (i.e. checkprints, calculations, reports, etc.) that the requirements of this SOP have been met. Such documentation shall be retained as project records.

## 6. PROCEDURE

### 6.1 Equipment

The following equipment should be used for sampling aqueous liquids using bailer methods:

- Dedicated bailer; construction depending upon contaminants of concern and intended data use per the project plan. Disposable bailers should be utilized for one sample location only.
- Dedicated polyethylene/Teflon™-coated string or Teflon™-coated steel cable for lowering and raising the bailer.
- Tripod with mechanical winch for lowering and raising the bailer (typically only for deep or large-diameter wells).
- Plastic sheeting.

### 6.2 Sampling

The following procedure should be used when sampling aqueous liquids using bailer methods:

1. Don a pair of clean gloves.
2. Securely attach the required amount of string or cable to the bailer.
3. Spread a new piece of plastic sheeting around the well so as to keep the bailer rope from contacting the ground. This step is not necessary if sampling treatment pools or storage tanks.
4. If required, unlock the well cover and remove the cap.
5. If sampling a well, measure the static water level and total well depth as described in SOP T-FS-108.

6. Purge the well as detailed in SOP T-FS-110 using a separate bailer or other device. **Do not purge and sample with the same bailer.** The project planning documents should specify a well purging endpoint, which may include either of the following:
   - A selected number of well volumes
   - Water property stabilization as indicated by pH, conductivity, turbidity, or temperature measurements, etc.
7. Collect the sample immediately after purging, if applicable, by slowly lowering the bailer to the desired sampling depth and stopping briefly.
8. Set the check valve by pulling upward on the string/cable and then slowly raise the bailer to the surface.
9. Wipe the bailer body with a paper towel or tissue to prevent liquid from the outside from entering the sample containers.
10. If using one, attach the VOC device to the bottom of the bailer.
11. Transfer the groundwater sample immediately to the sample bottles.
    - Fill VOA vials first by opening the VOC device spigot and allowing the liquid to slowly fill the container without agitation and to a meniscus slightly above the top of the vial.
    - Cap and check all VOA vials for entrained air by slowly tipping and observing for bubbles. If any are present, discard the sample and collect again as above.
    - If not using a VOC attachment, the liquid can be collected by pushing up on the check valve or pouring from the top of the bailer.
12. Continue lowering and retrieving the bailer as needed to fill all required sample bottles.
13. Add preservatives to the samples as needed, and place the sample bottles on ice.
14. Note that most sample bottles come with preservatives already added. If such is the case, do not overfill the bottles.
15. Replace the well cap, if required, and lock the cover.
16. Record the sampling information.
17. Dispose of or decontaminate the bailer and string/rope as required in the project plan

## 7. ATTACHMENTS

None.

## 8. FORMS

None.

# STANDARD OPERATING PROCEDURE

**Subject:** **Well Purging and Sampling Preparation**

## 1. PURPOSE

This procedure is intended to provide the methods to be used for preparing groundwater wells for sampling. Preparation includes accessing the well, screening for VOCs (if required), measuring depth and water column height, determining the well volume, and purging the stagnant groundwater from the monitoring well. This procedure presents methods for purging using both bailer and pump techniques

## 2. SCOPE

This procedure is applicable to all Shaw E & I projects where groundwater samples will be collected from a monitoring well and where no project/program-specific procedure is in place. Unless specifically directed in project/program plans, well purging will be considered complete when 3 to 5 well volumes have been removed from the well and/or the well water quality parameters (pH, specific conductivity, temperature, dissolved oxygen) collected during purging have stabilized for three consecutive readings.

## 3. REFERENCES


- U.S. Army Corps of Engineers, 2001, *Requirements for the Preparation of Sampling and Analysis Plans*, Appendix C, Section C.2, EM200-1-3, Washington, D.C.
- American Society for Testing and Materials, D6634-01, *Standard Guide for Selection of Purging and Sampling Devices for Ground-Water Monitoring Wells*, West Conshohocken, PA.
- American Society for Testing and Materials, D4448-01, *Standard Guide for Sampling Ground-Water Monitoring Wells*, West Conshohocken, PA.


## 4. DEFINITIONS

- **Bailer**—A device used to collect water typically consisting of a long tube with a check valve system attached to a rope or cable. The bailer is lowered into the water, and once the desired depth is reached, the check valve is set by causing an upward motion on the bailer. Bailers are constructed of stainless steel, polyethylene plastic, or Teflon™. Bailers made of polyethylene and Teflon™ may be considered disposable.
- **Pump**—An electric, compressed air, or inert gas driven device that raises liquids by means of pressure or suction. The types of pumps used for well purging should be chosen based on the well size and depth, the type of contaminants, and the specific factors affecting the overall performance of the sampling effort. Pump types that may be used include centrifugal, peristaltic, centrifugal submersible, gas displacement, and bladder pumps.
- **Well Purging**—The action of removing stagnant groundwater using mechanical means from a monitoring well. Well purging is performed prior to collecting groundwater samples from a well for purposes of attaining representative samples from the groundwater zone where the monitoring well is screened.

## 5. RESPONSIBILITIES

### 5.1 Procedure Responsibility

The Field Sampling Discipline Lead is responsible for maintenance, management, and revision of this procedure. Questions, comments, or suggestions regarding this technical SOP should be directed to the Field Sampling Discipline Lead.

### 5.2 Project Responsibility

Shaw employees performing this task, or any portion thereof, are responsible for meeting the requirements of this procedure and utilizing materials of a construction specified in the project plans or applicable to the contaminants of concern and other aspects of the sampling effort. These aspects may include well diameter, well construction materials, depth to water, and the presence of DNAPL or LNAPL contaminants. Shaw employees conducting technical review of task performance are also responsible for following appropriate portions of this SOP.

For those projects where the activities of this SOP are conducted, the Project Manager, or designee, is responsible for ensuring that those activities are conducted in accordance with this and other appropriate procedures. Project participants are responsible for documenting information in sufficient detail to provide objective documentation (i.e. checkprints, calculations, reports, etc.) that the requirements of this SOP have been met. Such documentation shall be retained as project records.

## 6. PROCEDURE

### 6.1 Considerations

When planning for the well sampling task, the following variables should be reviewed to determine which well purging method to use:

- **Recharge capacity of each well:** The recharge capacity of a well will determine how fast the well should be purged. The purge rate should be the same as the recharge rate of the groundwater zone to prevent drawing the water table down and creating a cascading effect of groundwater entering the well along the well screen. If recharge rates are greater than 0.5 gallons per minute, bailers or pumps may be used to remove water from the well. Wells with slow recharge rates (<0.5gpm) may need to be sampled using other methods such as low-flow or micro-purge techniques that do not agitate the well and therefore do not require full purging.
- **Well construction details, including well depth, diameter, screened interval, screen size, material of construction, and depth to water table:** The diameter and well depth will determine the size of the pump or bailer that will be required to remove water. The screen opening size will limit the rate at which water can be removed from the well due to high flow rates through the screen creating turbulent flow.
- **Groundwater quality, including type and concentration of chemical compounds present:** Choose a device that is constructed of materials compatible with the chemicals in the groundwater. Chemical contaminants can also dictate the rate at which the water can be removed from the well. Whenever possible, wells that contain VOCs should be purged using low-flow purging methods to prevent volatilization.
- **Presence of LNAPL or DNAPL:** If LNAPL or DNAPL are present, it is not recommended that the well be purged, due to the potential for creating a contaminated smear zone.

## 6.2 Equipment

The following equipment is recommended for use in conducting well purging:

- Bailers and line
- Pump and discharge hose/line
- Water level indicator
- Swabbing materials
- pH meter–if desired
- Specific conductance meter–if desired
- Temperature meter or gauge–if desired
- Nephelometer-turbidity–if desired
- Dissolved Oxygen meter–if desired
- Photoionization detector (PID)
- Drums or tanks to contain the purge water
- Field log book or sheets
- Calculator
- Plastic sheeting to spread around sampling area

## 6.3 Pre-Purging

To prevent cross contamination of other wells on-site, upgradient and background wells should be sampled first. The procedure for pre-purging is as follows:

- Prepare the area surrounding the well by placing plastic sheeting on the ground surface to prevent potential cross-contamination of the purging and sampling implements.
- Place and secure the drum, tank, or suitable purge-water container in close proximity to the well for the collection and storage of purge water. *Purge water must be containerized and disposed of in the manner specified in the project/program plan or as the client directs.* ***Never*** *return purge water to the well.* If in doubt or where requirements are not specified, handle all purge water as waste and dispose of it accordingly.
- If screening for organics, measure and record the background organic vapors in the ambient air using a PID in accordance with manufacturer recommendations.
- Open the well casing, remove the well cap, and immediately measure and record the organic vapor levels from the head space within the well casing using a PID, if required, in accordance with manufacturer recommendations.
- Measure the depth to the static water level and the depth to the bottom of the well using the water level indicator in accordance with Shaw E & I SOP T-FS-108, *Water Level Measurements.*
- Calculate the volume of water within the well casing and screen as follows:

$$V = [\pi(di/2)^2\ (TD-H)]\ (7.48)$$

Where:

V = volume of groundwater in the casing, gallons

di = inside diameter of casing, feet

TD = total well depth, feet

H = depth to the static water level, feet

Alternatively, for typical well casing diameters, the Volume can be determined as follows:

V = CF x (TD-H)

Where:

V = volume of groundwater in casing, gallons

CF = Casing Factor, gallons per linear foot-from table below

| Well Diameter (inches) | Casing Factor (CF) (gallons/foot) |
|---|---|
| 2 | 0.16 |
| 4 | 0.65 |
| 6 | 1.47 |
| 8 | 2.61 |
| 10 | 4.08 |
| 12 | 5.88 |

## 6.4 Well Purging by Bailing

*The well must not be bailed dry; water should be purged from the well at the same rate as it recharges to prevent loss of contaminants through degassing and to prevent agitation, which may release false levels of fine-grained particles or sediments to the groundwater zone. Water level measurements may be performed to verify that water levels remain constant during bailing.*

The procedure for well purging by bailing is as follows:

- Attach new bailer line to a clean bailer or new disposable bailer using several slipknots. Attach the other end of the bailer line to the protective casing or your wrist using several slipknots, allowing sufficient length to remove the water from the well screen area.
- Slowly lower the bailer down the well to avoid agitating the water and begin bailing groundwater by allowing water to pass through the bailer check valve into the bailer. Remove the filled bailer and empty the water into the purge-water container.
- If water quality parameters are not being used to determine stabilization, remove 5 well volumes from the well and then sample using a freshly decontaminated reusable or unused disposable bailer. **Do not sample with the same bailer used to purge.**
- If water quality parameters are being used to determine stabilization, two well volumes should be removed and the water quality parameters measured and recorded as the last bailer amount is removed from the well. This should be done by filling measurement containers with water directly from the bailer and taking readings.

- Continue purging until 3 to 5 well volumes have been removed from the well and three consecutive water quality parameter reading sets yield results within 10 percent of each other.
- Once stabilization has been achieved, collect the sample using a freshly decontaminated reusable or unused disposable bailer. **Do not sample with the same bailer used to purge.**

### 6.5 Well Purging Using a Pump

*The well must not be pumped dry; water should be purged from the well at the same rate as it recharges to prevent loss of contaminants through degassing and to prevent agitation, which may release false levels of fine-grained particles or sediments to the groundwater zone. Water level measurements may be performed to verify that water levels remain constant during pumping.*

The procedure for well purging using a pump is as follows:

- Review and understand the proper operating and maintenance instruction for each type of pump that is used prior to placing the pump in the well. Each pump type has specific procedures for operation.
- Assemble the pump and discharge line in accordance with manufacturer instructions. Ensure the pump discharge line is long enough so that the pump intake can be located within the well screen area and the discharge end can reach the purge water container.
- Lower the pump into the well until it is submerged and at the desired pumping depth.
- Start the pump and begin monitoring discharge rates and volume collected.
- If water quality parameters are not being used to determine stabilization, remove 5 well volumes from the well and then sample using the appropriate method.
- If water quality parameters are being used to determine stabilization, remove 2 well volumes and measure and record the water quality parameters at regular intervals as the purging continues. This can be accomplished either by using in-line direct-reading instruments or by collecting the pump discharge into appropriate measurement containers.
- Continue purging until 3 to 5 well volumes have been removed from the well and three consecutive water quality parameter reading sets yield results within 10 percent of each other.
- Once the stabilization has been achieved, collect the sample using a method applicable to the well and contaminants of concern.

## 7. ATTACHMENTS

None.

## 8. FORMS

None.

# STANDARD OPERATING PROCEDURE

**Subject:** **Low Flow/Micro-Purge Well Sampling**

## 1. PURPOSE

This procedure is intended to provide methods for low-flow sampling of groundwater from monitoring wells. Low-flow or micro-purge sampling is a method of collecting samples from a well that does not require the removal of large volumes of water from the well and therefore does not overly agitate the water and suspended particles or potentially aspirate VOCs. The method entails the removal of water directly from the screened interval without disturbing any stagnant water above the screen by pumping the well at low enough flow rates to maintain minimal drawdown of the water column followed by in-line sample collection. Typical flow rates for low-flow sampling range from 0.1 L/min to 0.5 L/min depending on site characteristics.

## 2. SCOPE

This procedure is applicable to all Shaw E & I projects where groundwater samples will be collected from a monitoring well using low-flow or micro-purge methods and where no project/program-specific procedure is in use.

## 3. REFERENCES

- U.S. Army Corps of Engineers, 2001, *Requirements for the Preparation of Sampling and Analysis Plans*, Appendix C, Section C.2, EM200-1-3, Washington, D.C.
- American Society for Testing and Materials, D6771-02, *Standard practice for Low-Flow Purging and Sampling for Wells and Devices Used for Ground-Water Quality Investigations*, West Conshohocken, PA.
- American Society for Testing and Materials, D4448-01, *Standard Guide for Sampling Ground-Water Monitoring Wells*, West Conshohocken, PA .
- U.S. Environmental Protection Agency Region 1, 1996, *Low Stress (Low Flow) Purging and Sampling Procedure for the Collection of Ground Water Samples from Monitoring Wells*, SOP GW0001, Revision 2, July 30.

## 4. DEFINITIONS

- **Low Flow**—Refers to the velocity that is imparted during pumping to the formation adjacent to the well screen, not necessarily the flow rate of the water discharged by the pump at the surface.
- **Micro-purge**—Another term for low-flow sampling referred to as such due to the fact that pre-sampling groundwater removal (purging) is performed at flow rates 2-3 orders of magnitude less than typical bailer or pump methods.
- **Pump**—An electric, compressed air, or inert gas driven device that raises liquids by means of pressure or suction. The types of pumps used for well purging should be chosen based on the well size and depth, the type of contaminants, and the specific factors affecting the overall performance of the sampling effort. Low flow/micro-purge sampling is performed using specially constructed pumps, usually of centrifugal, peristaltic, or centrifugal submersible design, with low draw rates (<1.0L/min).

- **Well Purging**—The action of removing groundwater using mechanical means from a monitoring well prior to collecting groundwater samples. Purging removes the stagnant groundwater from the column allowing the groundwater surrounding the well screen to enter the collection zone.

## 5. RESPONSIBILITIES

### 5.1 Procedure Responsibility

The Field Sampling Discipline Lead is responsible for maintenance, management, and revision of this procedure. Questions, comments, or suggestions regarding this technical SOP should be directed to the Field Sampling Discipline Lead.

### 5.2 Project Responsibility

Shaw employees performing this task, or any portion thereof, are responsible for meeting the requirements of this procedure and utilizing materials of a construction specified in the project plans or applicable to the contaminants of concern and other aspects of the sampling effort. These aspects may include well diameter, well construction materials, depth to water, and the presence of DNAPL or LNAPL contaminants. Shaw employees conducting technical review of task performance are also responsible for following appropriate portions of this SOP.

For those projects where the activities of this SOP are conducted, the Project Manager, or designee, is responsible for ensuring that those activities are conducted in accordance with this and other appropriate procedures. Project participants are responsible for documenting information in sufficient detail to provide objective documentation (i.e. checkprints, calculations, reports, etc.) that the requirements of this SOP have been met. Such documentation shall be retained as project records.

## 6. PROCEDURE

Low-flow/micro-purge sampling involves removing water directly from the screened interval without disturbing any stagnant water above the screen or without lowering the water table. Since it is not based upon the removal of well volumes, it requires in-line monitoring of water quality parameters (pH, specific conductivity, temperature, dissolved oxygen, redox potential) to determine when the groundwater sample zone has stabilized. The sample is then collected using the same pump directly from the discharge tubing.

### 6.1 Considerations

The following variables should be reviewed in planning for low-flow purging and sampling:

- **Recharge capacity of each well:** The recharge capacity of a well will determine how fast the well should be purged. The purge rate should be no greater than the recharge rate of the groundwater zone to prevent water table drawdown.
- **Well construction details, including well depth, diameter, screened interval, screen size, material of construction, and depth to water table:** The diameter and well depth will determine the size of the pump and the location from which the pump will operate. Peristaltic and suction draw pumps are only viable at depths of less than 25 feet. The pump intake should be placed within the well screen.

- **Pump:** Low-flow purging and sampling can be used in any well that can be pumped at a constant rate of not more than 1.0 L/min. Continuous discharge and cycle discharge pumps with adjustable flow rate controls should be used to avoid causing continuous drawdown. Whenever possible, dedicated pumps should be installed to avoid disturbing the water column.

- **Groundwater quality, including type and concentration of chemical compounds present:** Low-flow methods can be used for all types of aqueous-phase contamination, including VOCs, SVOCs, metals, pesticides, PCBs, radionuclides, and micrbiological constituents. Pump parts and tubing should be made of materials that are compatible with the analytes of interest.

## 6.2 Equipment

The following equipment is recommended for use in conducting well purging:

- Pump and discharge hose/line, constructed of compatible materials, capable of <1.0L/min draw rates
- Water level indicator
- Swabbing materials
- Flow-through Water Quality Meter (pH, specific conductance, temperature, optional Dissolved Oxygen, Redox potential)–calibrated
- Nephelometer–calibrated (if required)
- Photoionization Detector (PID)–calibrated (if screening for VOCs is required)
- Drums or tanks to contain the purge water
- Field log book
- Calculator
- Plastic sheeting
- Sample containers and preservatives
- Ice and Ziploc-type bags

## 6.3 Pre-Sampling

To prevent cross contamination of other wells on-site, upgradient and background wells should be performed first. The procedure for pre-sampling is as follows:

- Prepare the area surrounding the well by placing plastic sheeting on the ground surface to prevent potential cross-contamination of the pump and discharge hose or sample equipment and materials.

- Place and secure the drum, tank, or suitable purge water container in close proximity to the well for the collection and storage of purge water. *Purge water must be containerized and disposed of in the manner specified in the project/program plan or as the client directs.* ***Never** return purge water to the well.* If in doubt or where requirements are not specified, handle all purge water as waste and dispose of it accordingly.

- If performing VOC screening, measure and record the background organic vapors in the ambient air using a PID, in accordance with manufacturer recommendations.

- Open the well casing, remove the well cap, and immediately measure and record the organic vapor levels from the head space within the well casing using a PID, in accordance with manufacturer recommendations.
- Measure the depth to the static water level using the water level indicator in accordance with Shaw E & I SOP T-SF-108, *Water Level Measurements*.

## 6.4 Well Purging

The procedure for well purging is as follows:

- Review and understand the proper operating and maintenance instruction for each type of pump that is used prior to placing the pump in the well. Each pump type has specific operating procedures.
- Some wells may include a dedicated pump that is already placed in the well along the well screen. If this is the case, review well construction data to verify the proper placement of the pump intake. Inspect the location where the discharge line and pump support cable exit the well to determine that they are in the proper position (markings should be present at the well head to show this).
- Assemble the pump and discharge line in accordance with manufacturer instructions. Ensure the pump discharge line is long enough so that the pump intake can be located within the well screen area and the discharge end can reach the purge water container.
- Slowly lower the pump into the well until it is submerged and at the desired pumping depth.
- Connect the pump discharge to the flow-through water quality meter system in accordance with the manufacturer's procedure.
- Start the pump and begin monitoring discharge rates and volume collected. Adjust flows if necessary to remain in a range of 0.1 to 0.5L/min without exceeding the well discharge rate.
- Monitor and record the pH, conductivity, temperature, dissolved oxygen, redox potential, and turbidity at set intervals (2 to 10 minutes).
- Collect the sample following the procedure below when all water monitored water quality parameters are stable, as indicated by three consecutive readings differing by less than 10 percent.

## 6.5 Sample Collection

The procedure for sample collection is as follows:

- Prepare the sample bottles and preservatives required for the sampling.
- Don a pair of clean gloves.
- Collect the sample immediately after purging through the pump discharge line.
  - Fill VOA vials first (reduce the flow rate of the pump discharge) allowing the liquid to slowly fill the container without agitation and obtain a meniscus slightly above the top of the vial.
  - Cap and check all VOA vials for entrained air by slowly tipping and observing for bubbles. If any are present, discard the sample and collect again as above.
- Continue filling all required sample bottles.

- Add preservatives to the samples as needed, and place the sample bottles on ice. Note that most sample bottles come with preservatives already added. If such is the case, do not overfill the bottles.
- Replace the well cap, if required, and lock the cover.
- Record the sampling information.
- Secure the area by removing equipment and materials, properly dispose of plastic sheeting and other disposable sampling materials, and close the purge water container(s).
- Decontaminate the pumping equipment and sampling equipment. The pumping equipment should not be decontaminated if it is dedicated to the well.

## 7. ATTACHMENTS

None.

## 8. FORMS

None.

# STANDARD OPERATING PROCEDURE

**Subject: Sampling of Drums and Other Containers**

## 1. PURPOSE

This procedure is intended to provide general guidance for sampling of drums and other small containers for all analyses including characterization or compatibility (HazCat) analysis. The procedure also presents container handling and safety requirements and reiterates Shaw policies with regards to safe container handling.

## 2. SCOPE

This procedure is applicable to all Shaw E & I instances where drums or other containers of less than 120-gallon capacity require sampling either for specific analysis or characterization purposes. This procedure also presents important safety information and Shaw policies concerning the opening of drums/containers.

## 3. REFERENCES

- Cassis, Jo, et al., 1985, *Guidance Document for Cleanup of Surface Tank and Drum Sites*, Prepared for Office of Emergency and Remedial Response, USEPA, Washington, D.C. under Contract No. 68-01-6930.
- U.S. Environmental Protection Agency, 2002, *RCRA Waste Sampling Draft Technical Guidance, Planning, Implementation, Assessment*, EPA/530-D-02-002, August.
- U.S. Environmental Protection Agency, 1994, *Drum Sampling*; EPA/ERT SOP 2009.
- U.S. Environmental Protection Agency, 1986, *Drum Handling Practices at Hazardous Waste Sites*, EPA/600/2-86/013.

## 4. DEFINITIONS

- **Drum**—A container constructed of metal, plastic, glass, or fiber designed to hold material. The size of the container can be as small as an ampoule found on laboratories shelves to as large as 120-gallon capacity.
- **Drum Type A**—A drum or other container in which the contents are reasonably known and for which a qualified chemist or other hazardous material-experienced individual has determined that no hazard from shock sensitivity, air reactivity, or hazardous reactions is probable. These drums may be opened by hand unless damaged or visibly bulging. Determination may be made based upon visual inspection of drum/container condition, legible labeling, site information/records, or process/use knowledge that is supported by other information. Examples include staged IDW, waste oils, and other unused/waste products that do not degrade into shock-sensitive compounds. Type A Drums must also be constructed of typical materials and not of nickel stainless steel, aluminum, center bung, or other special designs usually used to hold highly reactive materials. *All drums removed from landfills or dump sites must be treated as Drum Type B containers and accessed remotely.*
- **Drum Type B**—A drum that poses a potential risk of injury to the sampler from shock sensitivity, air reactivity, flammability, toxicity, or rapid polymerization. Included in this category are drum/containers with visible crystals along the sides or tops, those constructed

of non-typical materials or design (nickel stainless steel, aluminum, or center bung), non-IDW drums that are bulging, containers with too much damage to allow for safe hand-opening, and **all** unknowns from sites where there is not assurance of non-hazardous content. *In addition, it is Shaw policy that all drums removed from landfills or dump sites must be treated as Drum Type B containers and accessed remotely and in Level B PPE unless a clear determination can be made to handle them otherwise.*

**Equipment**

- **Dosimeter**—A portable, transistorized survey meter that can be used for radiation monitoring purposes and/or contamination measurements. *All drums in landfills, in dump sites, or from sites where there is a potential that radioactive materials may have been used must be screened with a dosimeter.*
- **Drum Thief**—A thin-walled borosilicate glass tube used to collect liquid samples from drums and containers.
- **LEL (Lower Explosive Limit)**—An air monitoring device that can test the surrounding air for sufficient oxygen content for life support and/or the presence of combustible gases or vapors which may pose a potential flammability hazard. The lower explosive limit is defined as the minimum concentration of a particular combustible gas in the air that can be ignited. The upper explosive limit is defined as the maximum concentration that can be ignited.
- **Toxic Gas Meter**—A portable warning device used for detecting specific toxic gases found in the surrounding air (i.e., $H_2S$, HCl, Cl, HCN, and $COCl_2$).
- **PID (Photoionization Detector)**—A portable air-monitoring instrument used to detect organic vapors. The PID does not distinguish between different types of vapors or tell if more than one vapor is present.

**Special Types of Containers**

- **Laboratory Packs**—Such drums are commonly used for disposal of expired chemicals and process samples from laboratories, hospitals, and similar institutions. Bottles in the lab pack may contain incompatible materials and may not be packed in absorbent material. They may contain radioisotopes; shock-sensitive material; or highly volatile, highly corrosive, or very toxic exotic chemicals. Lab packs have been the primary ignition sources for fires at some hazardous waste sites.
- **Exotic Metal Drums**—Very expensive drums (aluminum, nickel, stainless steel, or other unusual metals) that usually contain an extremely dangerous material.
- **Polyethylene or PVC-lined Drums**—Often contain strong acids or bases. If the lining is punctured, the substance usually corrodes the steel, resulting in a significant leak or spill and possible explosive gas (hydrogen) generation.
- **Single-Walled Drums Used as a Pressure Vessel**—These drums have fittings for both product filling and placement of an inert gas, such as nitrogen. Such drums may contain reactive, flammable, or explosive substances.

## 5. RESPONSIBILITIES

### 5.1 Procedure Responsibility

The Field Sampling Discipline Lead is responsible for maintenance, management, and revision of this procedure. Questions, comments, or suggestions regarding this technical SOP should be directed to the Field Sampling Discipline Lead.

### 5.2 Project Responsibility

Shaw employees performing this task, or any portion thereof, are responsible for meeting the requirements of this procedure. Shaw employees conducting technical review of task performance are also responsible for following appropriate portions of this SOP.

For those projects where the activities of this SOP are conducted, the Project Manager, or designee, is responsible for ensuring that those activities are conducted in accordance with this and other appropriate procedures. Project participants are responsible for documenting information in sufficient detail to provide objective documentation (i.e., checkprints, calculations, reports, etc.) that the requirements of this SOP have been met. Such documentation shall be retained as project records.

## 6. PROCEDURE

*Safety note: Drums and other containers can pose a potential threat to the employee's health and the environment. It is extremely important that all safety precautions outlined in an approved project HASP are understood and followed.* ***At no time shall Shaw E & I employees open an unknown and potentially hazardous or Type B drum/container by hand.*** *All monitoring devices shall be intrinsically safe and all tools shall be non-sparking. To protect against possible toxic gas/vapor exposure, all drums/containers should be accessed and sampled in Level B PPE unless the site responsible person (SSHO or chemist) deems otherwise based upon clear and unquestionable information. All unknowns where there is not assurance of the absence of toxic gas or vapors from cyanide, sulfide, or strongly corrosive acids* ***must*** *be opened and sampled using Level B PPE.*

### 6.1 Evaluate and Log Drum/Container

- Verify that all screening instruments are operational and have been calibrated before proceeding.
- If the sampling is being performed for purposes of compatibility or HazCat analysis, obtain a blank Drum/Container log or, if using a touch pad-based drum logging system, advance to a blank entry.
- If the drum/container is being sampled for other purposes, use the standard project sampling logging convention.
- Assign a number to the drum/container *before* beginning the visual evaluation. This will ensure that all drums/containers are accounted for.
- Complete the header and visual observation sections of the Drum/Container log. Be sure to note any markings, the manufacturer trade names, the drum condition, and NFPA information on the drum/container. Do not complete the Volume section until after the drum has been opened. Also, if on a staging area, notate the location of the drum/container on the log; draw a map if necessary.
- If using a dosimeter, perform the radiation survey on the drum first. If the activity is above the limits of the HASP, do not continue unless your PPE is sufficient to proceed.

### 6.2 Open and/or Sample Drum/Container

- Type B drums that have been remotely opened via a backhoe-attached brass punch will most likely be staged for sampling. Drums/containers may sometimes be logged, opened remotely and sampled as they are unearthed from landfills and dump sites and then placed into over-packs with or without their lids in place. Type A drums/containers can be opened using a bung wrench, non-sparking crow-bar-type implement, or even a brass punch and hammer combination. Type B containers not opened via backhoe are usually opened using drum/container-attachable remote punch apparatus or, in the case of small containers, drill-based cap removal or drilling systems.

- If the drum/container is not in direct contact with the ground surface, make sure it is grounded before proceeding. Static electricity could potentially ignite any flammable contents.
- If the drum/container was previously opened, remove the lid of the over-pack container or other covering from the top of the drum.
- If opening the drum manually or with a single-container remote-opening system, proceed to open the drum/container.
- Use a PID (if weather permits), LEL meter, and/or toxic gas meter to collect air monitoring readings from the drum/container. Record the results on the Drum/Container Log.
- If the drum is empty (<2 inches of content for a 55-gallon drum), note it on the Drum/Container Log and proceed to the next drum/container.
- Insert the drum thief almost to the bottom of the drum or until a solid layer is encountered. About 1 foot of tubing should extend above the drum. Allow the waste in the drum to reach its natural level in the tube. Cap the top of the sampling tube using a thumb or forefinger. Carefully remove the capped tube from the drum and insert the uncapped end in the sample container. Release thumb or forefinger from tube and allow the glass thief to drain completely into the sample container. Repeat as necessary until the required sample volume has been collected.
- Close the sample container cover tightly, wipe off with a paper towel, and place a label on the sample container. Replace the overpack lid or place a plastic cover over the drum/container.
- Place the used sampling tube, along with paper towels or waste rags (used to wipe up any spills), into an empty metal barrel marked "sampling waste" for subsequent disposal. Alternatively, break the drum thief in half inside the drum/container and leave it in the drum. *Make sure the top of the thief does not extend above the drum cover or serious eye/hand injury may occur to others.*
- Solids in drums are sampled by use of tongue depressors or disposable scoops. All reasonable efforts shall be made to obtain the sample to a depth of 12 inches or refusal. It is sometimes necessary to sample the material with the use of a trier. Nonexpendable sampling tools must be decontaminated between drums. Sometimes, the material must first be broken up with a non-sparking hammer or hammer and chisel, or, for rubber-like solids, a piece may need to be cut off with a knife.
- In some instances, a solid may form on top of a liquid. When the solid is broken up this may reveal the liquid layer. The solid and liquid should be collected.
- Every effort must be made to collect all phases of the drum contents. *If a layer is not accessible or cannot be sampled it **must** be noted on the Drum/Container Log.* Drums may contain air- or water-reactive solids that are covered with inert materials such as phosphorous under water or metallic sodium under light hydrocarbon fuels. *Misclassification of such drums can and has resulted in serious repercussions during future handling efforts.*
- After sampling is complete, the container should be resealed to prevent the escape of vapors and possible reactions from rainwater, air, etc. The resealing method depends on the opening methods used and may include replacing the lid and retaining ring, placing the drum in an over-pack when it cannot be resealed by any other method, and/or placing polyethylene sheeting over the drum in a manner that prevents rainwater from entering the drum.

- Samples should be documented, packaged, and shipped in accordance with the project plans and Shaw SOPs. *Samples with known hazards evident from the field data must be shipped in accordance with Shaw SOP T-FS-013.* Remember to keep the total weight of samples, cooler, and ice below 60 pounds.

## 6.3 Drum/Container Log Completion–HazCat/Compatibility Projects

For projects where samples are being collected to characterize the container contents for segregation and/or disposal (HazCat or compatibility analysis), the field data gathered during the sampling activities is imperative to the process and must be recorded on a Drum/Container Sampling Log. The following information is needed for the form:

- Drum Number—Use either straight numeric or a site standard convention. Do **not** identify/number drums by items such as date or locations. This information should be cross-reference to drum numbers elsewhere.
- Project Number—Assigned by Shaw E & I to each project.
- Page x of y—If the drum log is accompanied by Material Safety Data Sheets (MSDSs) or other information, then the total number of pages is required. Commonly, will be page 1 of 1.
- Project Location—Generally the client company's name and/or street address of the facility or site.
- Project Contact—The Shaw E & I employee responsible for overseeing the sampling operation. This person should be the individual to whom questions are to be directed or verbal results given for review (i.e., project chemist, or site supervisor).
- Phone—Site phone or number of the supporting Shaw E & I office.
- Logger—Name of individual responsible for filling in the sampling portion of the Drum Inventory Log.
- Sampler—Name of individual(s) responsible for obtaining the sample.
- Weather—Weather conditions during sampling (e.g., temperature and/or precipitation).
- Date—Date when sample is collected.
- Time—Time when sample is collected.
- Drum Type—Place an "x" in the box or boxes that best describe the drum type and materials of construction.
- Lid Type—Place an "x" in the box that describes the type of closure on the container.
- Drum Condition—Place an "x" in the box indicating the integrity of the drum. "Meets DOT specifications" means the drum can be shipped according to U.S. Department of Transportation (DOT) regulations.
- Drum Size—Place an "x" in the box indicating the volume of the drum when full. If the drum is over-packed, the inner drum volume should be indicated, not the size of the over-pack.
- Drum Contents—Place an "x" in the box indicating the volume of waste contained in the drum.
- Overpacked—Place an "x" in the "yes" box if the container was overpacked, along with an "x" in the box that states the type of overpack utilized.

- Layers—Designate the layer as top, middle, or bottom for a multi-layered sample. If only one layer exists, complete only the line associated with the top layer, "T."
- Physical State—Place an "x" in the box indicating the actual physical state of each layer.
- Color—Write in the standard color description for each layer of the sample. **The only acceptable color descriptions are as follows:**
  - blue (blu) white (wht) black (blk)
  - red (red) cream (crm) orange (org)
  - pink (pnk) yellow (yel) gray (gry)
  - colorless (cls) purple (pup) tan (tan)
  - green (grn) brown (brn) green-blue (g-bl)
- Clarity—Add an "x" in the box indicating the clarity of each layer of the sample.
- Layer Thickness—Record the estimated thickness of each layer in inches.
- pH—Record the pH measurement in standard units (SU), 0 to 14, or designate "N/A" if no measurement was obtained. Measurements should be made by pH test strips.
- PID—Record the results for vapor analysis by photoionization detector (PID) or designate "N/A" if no measurement was obtained. The PID scale reads in ppm (0 to 2,000).
- Dosimeter—Record the results of the field radiation survey in this space or designate "N/A" if no measurement was obtained. The dosimeter's scale units are in millirems per hour (mr/hr or mrem/hr).
- Other—Use this space to record additional analysis that may take place or designate "N/A" if no other measurements were taken. The information should include the equipment used, the parameter being measured, and its concentration. Example: Drager tube - HCN - 5 ppm.
- DOT Haz—Hazard category from placards or stencils on drum. Example: Corrosive Liquid.
- UN/NA—Space for any UN or NA numbers that are stenciled or written on the drum. These numbers are always prefixed by either UN or NA.
- MFG Name—Record the name, address, and telephone number of the company producing or distributing the chemical/product. If the space provided is inadequate, indicate that the information continues on the back of the log, and do so.
- Chemical Name—Record the chemical compound, key ingredient, trade name, and/or chemical name of the contents on the label or stenciled on the drum. Indicate whether the information was printed on a label or stenciled or handwritten on the drum. If the space provided is inadequate, indicate that the information continues on the back of the log, and do so.
- Additional Information—This space is for additional information or comments for which no specific space is designated. It can provide unusual comments or indicate problems such as contents too hard to sample, drum color, or colored crystals formed on the drum. If the space provided is inadequate, indicate that the information continues on the back of the log.

The Drum/Container Log acts as its own Chain of Custody for projects where an on-site laboratory is being utilized. On these projects, the samples should be transferred along with the log, and the log should be signed and transferred to the on-site laboratory staff. This transfer is not necessary whenever the sampling personnel are also the on-site laboratory staff, as occurs on small projects.

For projects where the samples will be shipped to an off-site laboratory for HazCat, copies of the Drum/Container Logs must be included with the Chain of Custody documentation. The samples should be transferred via Shaw's standard Chain of Custody form.

## 7. ATTACHMENTS

None.

## 8. FORMS

- Drum Container Sampling Log

# STANDARD OPERATING PROCEDURE

**Subject: Sediment Sampling using a Core Sampler**

## 1. PURPOSE

The purpose of this document is to provide the methods and procedures for collecting sediment samples using sediment/gravity core samplers. These samplers are usually used to collect intact sediment cores in shallow waters. However, they can be mounted onto deep-water drill rigs or similar systems.

## 2. SCOPE

This procedure is applicable to all Shaw E & I projects where sediment core samples will be collected.

## 3. REFERENCES

- U.S. Army Corps of Engineers, 2001, *Requirements for the Preparation of Sampling and Analysis Plans,* Appendix C, Section C.6, EM200-1-3, Washington, D.C.
- Wildlife Supply Company (WILDCO) web-site at http://www.wildco.com/

## 4. DEFINITIONS

- **Sediment/Gravity Core Sampler**—A sampling device consisting of a hollow metal tube with a tapered nose-piece collar and a check valve system. The check valve allows water to flow through the sampler body on descent and prevents wash-out of the sample as it is retrieved. The tube is divided lengthwise and accepts a brass or plastic insert sleeve that actually holds the sample. The sampler can be attached to an extension handle and/or drive hammer.

## 5. RESPONSIBILITIES

### 5.1 Procedure Responsibility

The Field Sampling Discipline Lead is responsible for maintenance, management, and revision of this procedure. Questions, comments, or suggestions regarding this technical SOP should be directed to the Field Sampling Discipline Lead.

### 5.2 Project Responsibility

Shaw employees performing this task, or any portion thereof, are responsible for meeting the requirements of this procedure. Shaw employees conducting technical review of task performance are also responsible for following appropriate portions of this SOP.

For those projects where the activities of this SOP are conducted, the Project Manager, or designee, is responsible for ensuring that those activities are conducted in accordance with this and other appropriate procedures. Project participants are responsible for documenting information in sufficient detail to provide objective documentation (i.e. checkprints, calculations, reports, etc.) that the requirements of this SOP have been met. Such documentation shall be retained as project records.

## 6. PROCEDURE

*Safety Notes: Always use proper life-saving equipment when sampling from a boat or barge. Consult the project HASP for requirements.*

### 6.1 Equipment

The following equipment is used for collecting sediment samples with a core sampler:

- Decontaminated commercial sediment/gravity corer with extension handle(s), stainless steel construction for trace environmental sampling
- Brass or plastic sleeves—consult project plan
- Drive hammer, if required
- Plastic sheeting to keep emptying area clean
- Carpenter's chalk or duct/electrical tape
- Plastic or metal shallow pan to empty sampler into

### 6.2 Sampling Procedure

The procedure for collecting sediment samples with a core sampler is as follows:

- Don a pair of clean gloves.
- Place plastic sheeting around the area where the sampler will be emptied to keep sampled material in place.
- Assemble the sampler by placing an insert sleeve into the tube and attaching the nose-piece and top collar (usually done with screw threads)
- Attach to an extension or drive hammer system with sufficient length to reach the bottom plus 2 to 3X the sampler length. Mark the extension at the point equal to the water depth plus the length of the corer tube and nose-piece above the bottom of the corer.
- Slowly lower the sampler until the bottom is felt.
- Make sure that the handle/extension is straight up and push down in a straight direction to force the sampler into the bottom sediment. If using a drive hammer, be sure that the system is straight during each drive.
- Continue to push/drive the sampler until the mark of the extension is at water level indicating that the entire sampler has been driven into the sediment.
- Withdraw the sampler by pulling straight up. It may be necessary to twist slightly while pulling.
- Retrieve the sampler from the water and place the corer body into the shallow pan.
- Disassemble the sampler and retrieve the sleeve. Place Teflon™ tape over each end and cap. Label the ends Top and Bottom (T/B).
- Clean and dry the sleeve; then attach a completed sample label, document the sample, and place it into an appropriate container.
- Decontaminate the sampler

## 7. ATTACHMENTS

None.

## 8. FORMS

None.

# STANDARD OPERATING PROCEDURE

**Subject: Jar Headspace Screening**

## 1. PURPOSE

The purpose of this procedure is to provide the basic methods and guidance for volatile organic compound (VOC) screening of environmental samples using jar headspace techniques. Jar headspace analytical screening can be used to provide field data regarding the presence or absence of VOC vapors in environmental samples.

Field screening for VOC compounds can be useful for such environmental characterization purposes as discovery of site VOC contamination; selection of field samples to submit to a laboratory for analyses; selection of surface soil sampling locations; selection of boring locations; placement of groundwater monitoring wells; soil cutting (from drilling operations) screening for disposal characterization purposes; and purge water (from well purging/sampling tasks) screening for disposal characterization purposes.

## 2. SCOPE

This SOP is applicable to all Shaw E & I projects where VOC screening by the jar headspace method is employed. This procedure serves as general guidance on the proper methods for conducting jar headspace analytical screening. Users should always consult state-specific, program-specific, or project-specific requirements to ensure compliance with requirements when performing the activities of this SOP.

## 3. REFERENCES

- Massachusetts Department of Environmental Protection, *Interim Remediation Waste Management Policy for Petroleum Contaminated Soils*, #WCS-94-400.

## 4. DEFINITIONS

- **Flame Ionization Detector (FID)**—An organic compound detector based upon the ionization in a flame of compounds containing carbon-hydrogen bonds. The FID is a gross screening tool that detects the total organic content of the introduced sample. Its response is lower to halogenated compounds, and it will not respond to compounds lacking a carbon-hydrogen bond.
- **Ionization Potential (IP)**—The amount of energy required to remove an electron from the outer shell of a molecule or atom. The resultant molecule or atom will be a positively charged cation.
- **Photo Ionization Detector (PID)**—An organic compound detection system based upon the ionization of compounds via UV-radiation. A PID will respond only to those compounds with IP values less than or equal to the output of the UV-lamp. As such it is an indicator of aromatic and conjugated organic compounds. PID response is lower for halogenated compounds. PID systems are available with either a 10.2 or 11.7ev lamp.

## 5. RESPONSIBILITIES

### 5.1. Procedure Responsibility

The Field Sampling Discipline Lead is responsible for maintenance, management, and revision of this procedure. Questions, comments, or suggestions regarding this technical SOP should be directed to the Field Sampling Discipline Lead.

### 5.2. Project Responsibility

Shaw E & I employees performing this task, or any portion thereof, are responsible for meeting the requirements of this procedure. Shaw E & I employees conducting technical review of task performance are also responsible for following appropriate portions of this SOP.

For those projects where the activities of this SOP are conducted, the Project Manager, or designee, is responsible for ensuring that those activities are conducted in accordance with this and other appropriate procedures. Project participants are responsible for recording information in sufficient detail to provide objective documentation (i.e., checkprints, calculations, reports, etc.) that the requirements of this SOP have been met. Such documentation shall be retained as project records.

## 6. PROCEDURE

### 6.1. Equipment

The equipment to be used for jar headspace screening includes the following:

- Field logbook(s)
- Volatile organic compound vapor meter (PID or FID)
- Field Data Forms - See Section 8
- Indelible markers
- Wide-mouth glass jars (16-oz preferred, 8 oz minimum size)
- Stainless steel laboratory spoons
- Aluminum foil

### 6.2. Field Gas Chromatography

If field GC is being employed, the following additional equipment will be required:

- Gas Chromatograph system
- Calibration standards and materials
- Gas-tight syringes

### 6.3. Procedure Steps

- Calibrate field screening equipment in accordance with the manufacturer's instructions and/or project-specific requirements.
- Obtain a soil sample from the sampling device (split spoon, spatula, shovel, etc.) <u>immediately</u> after removal from the ground. Groundwater samples can be collected from the inside of auger

flights using a disposable bailer. In order to reduce loss of the volatiles, take care to minimize handling of the sample and exposure to the air during transfer to the jar.

- Half-fill a clean glass jar with the sample to be analyzed. Quickly cover each open top with one or two sheets of clean aluminum foil and subsequently apply screw caps to tightly seal the jars. Sixteen-ounce (approximately 500 mL) soil or "mason" type jars are preferred. Do not use jars with less than 8 oz. (approximately 250 mL) total capacity.
- Allow sealed jar to sit for at least 10 minutes. Vigorously shake jars for 15 seconds at the beginning of the headspace development period. Where ambient temperatures are below 32°F (0°C), sample bottles should be placed within a heated vehicle or building for the prescribed period to allow the volatilization process to occur.
- Remove screw/lid and expose foil seal. Puncture foil seal with instrument sampling probe into the jar. Keep probe tip sufficiently above the media surface to avoid uptake of water droplets or soil particulates into the sample probe.
- As an alternative collection method or when using a field GC, use a gas-tight syringe to withdraw a measured volume of the headspace and inject into the probe inlet or calibrated GC.
- Following probe insertion through the foil seal and/or sample injection into the probe, the maximum (non-GC) instrument response should occur between 2 and 5 seconds. Record the highest meter response as the jar headspace concentration in the field log book or sheet. For GC analysis, determine and record the response/concentration of the target compound(s)
- Perform Duplicate QC and evaluate in accordance with the project plans
- Dispose of all wastes, including screened samples, in accordance with the project plans

## 7. ATTACHMENTS

- Attachment 1, Ionization Potentials for Common Volatile Contaminants

## 8. FORMS

- Jar Headspace Screening Results Log

## Attachment 1
## Ionization Potentials for Common Volatile Contaminants

| Analyte | IP (eV) | Analyte type |
|---|---|---|
| Acetone | 9.69 | AAK |
| Acrolein | 10.10 | AAK |
| Allyl alcohol | 9.67 | SDO |
| Benzene | 9.245 | AC |
| Bromochloromethane (I.S.) | 10.77 | AH |
| Bromoform | 10.51 | AH |
| Bromomethane | 10.53 | AH |
| n-Butanol | 10.04 | AAETS |
| 2-Butanone (MEK) | 9.53 | AAK |
| Carbon disulfide | 10.08 | AAETS |
| Carbon tetrachloride | 11.47 | AH |
| Chlorobenzene | 9.07 | AC |
| Chlorodibromomethane | 10.59 | AH |
| Chloroethane | 10.98 | AH |
| Chloroform | 11.42 | AH |
| Chloromethane | 11.28 | AH |
| 1,2-Dibromoethane | 10.19 | AH |
| Dibromomethane | 10.49 | AH |
| 1,2-Dichlorobenzene | 9.07 | AH |
| 1,3-Dichlorobenzene | 9.12 | AH |
| 1,4-Dichlorobenzene | 8.94 | AH |
| Dichlorodifluoromethane | 12.31 | AH |
| 1,2-Dichloroethane | 11.12 | AH |
| trans-1,2-Dichloroethene | 9.66 | AH |
| 1,2-Dichloropropane | 10.87 | AH |
| Diethyl ether | 9.53 | AAETS |
| Ethanol | 10.48 | AAETS |
| Ethyl acetate | 10.11 | AAE |
| Ethyl benzene | 8.76 | AC |
| Ethylene oxide | 10.565 | MM |
| 2-Hexanone | 9.34 | AAK |
| Iodomethane | 9.54 | AH |
| Isopropylbenzene | 8.69 | AH |
| Methane | 12.98 | PC |
| Methanol | 10.85 | AAETS |
| Methylene chloride (DCM) | 11.35 | AH |
| 4-Methyl-2-pentanone (MIBK) | 9.30 | AAK |
| Naphthalene | 8.12 | AC |
| Nitrobenzene | 9.92 | AC |
| Pyridine | 9.32 | HM |
| Styrene | 8.47 | AC |

| Analyte | IP (eV) | Analyte type |
|---|---|---|
| Tetrachloroethene | 9.32 | SDO |
| Toluene | 8.82 | AC |
| Trichloroethene | 9.45 | SDO |
| Trichlorofluoromethane | 11.77 | AH |
| Vinyl acetate | 9.19 | SDO |
| Vinyl chloride | 9.995 | SDO |
| o-Xylene | 8.56 | AC |
| m-Xylene | 8.56 | AC |
| p-Xylene | 8.445 | AC |

*PC = Paraffins and Cycloparaffins*
*AH = Alkyl Halides*
*AAETS = Aliphatic Alcohol, Ether, Thiol, and Sulfides*
*AAK = Aliphatic Aldehydes and Ketones*
*AAE = Aliphatic Acids and Esters*
*SDO = Some Derivatives of Olefins*
*HM = Heterocyclic Molecules*
*AC = Aromatic Compounds*
*MM = Miscellaneous Molecules*

# SOP T-GS-001
# Standards for Conducting Subsurface Soil Sampling While Drilling

Prepared By: ______________________ Date: ______________

J.C. Isham, RG, CEG, CHG
Sr. Hydrogeologist

Authorized By: ______________________ Date: ______________

John E. Sciacca, R.G.
Discipline Lead

# STANDARD OPERATING PROCEDURE

**Subject:** **Subsurface Soil Sampling While Drilling**

## 1. PURPOSE

This procedure provides the standard practice for subsurface soil sampling while drilling. The procedure includes the minimum recommended steps and quality checks that employees and subcontractors are to follow when performing the subject task.

This procedure may also contain guidance for other recommended or suggested practice that is based upon collective professional experience. Recommended practice goes beyond the minimum requirements of the procedure, and should be implemented when appropriate.

## 2. SCOPE

Geosciences Standard Operating Procedure (SOP) T-GS-001 describes standards for collecting subsurface soil samples while drilling, and defines how such sampling will be conducted and documented for projects executed by Shaw Environmental & Infrastructure Inc. This standard is specific to sampling activities that are intended for the collection of soil samples for chemical analysis. Proper collection procedures are necessary to assure the quality and integrity of all subsurface soil samples.

This SOP addresses technical requirements and required documentation. Responsibilities of individuals performing the work are also detailed. Additional project-specific requirements for subsurface soil sampling while drilling may be developed, as necessary, to supplement this procedure and to address project-specific conditions and/or objectives. This standard does not address subsurface soil sampling using direct-push techniques. Such sampling is covered under another SOP.

## 3. REFERENCES

Soil sampling should follow accepted industry practices while drilling. These are as defined by the latest version of the following ASTM Standards:

| | |
|---|---|
| ASTM D 1586-99 | Standard Method for Penetration Test and Split- Barrel Sampling of Soils. |
| ASTM D 1587-00 | Standard Practice for Thin-Walled Tube Sampling of Soils. |
| ASTM D 3550-01 | Standard Practice for Thick Wall Ring-Lined Split Barrel Sampling of Soils. |
| ASTM D 6169-98 | Selection of Soil and Rock Sampling Devices Used with Drill Rigs for Environmental Investigations. |

## 4. DEFINITIONS

The following definitions are applicable to the collection of subsurface soil samples while drilling, and are used in this SOP.

- **Borehole**—Any hole drilled into the subsurface for the purpose of identifying lithology, collecting soil samples, and/or installing monitoring wells.

- **Split-Spoon Sampler**—A steel tube, split in half lengthwise, with the halves held together by threaded collars at either end of the tube. This device can be driven into resistant (semiconsolidated) materials using a drive weight or drilling jars mounted to the drilling rig. A standard split-spoon sampler (used for performing standard penetration tests, ASTM D-1586) is 2 inches in outside diameter and 1⅜ inches in inside diameter. This standard spoon typically is available in two common lengths, providing either 20-inch or 26-inch internal longitudinal clearance for obtaining 18-inch or 24-inch long samples, respectively. Six-inch long sleeves (tubes) of brass, stainless steel, or plastic are commonly placed inside the sampler to collect and retain soil samples. A 5-foot long split-spoon sampler is available. A modified split-spoon sampler is also commonly used. The modified design is similar to the standard split-spoon, except the outside diameter varies from 2 to 3½ inches, and the inside diameter varies from 1½ to 3 inches (ASTM D 3550). The 2½-inch outside diameter sampler is referred to as the California Sampler.
- **Shelby Tube Sampler**—A thin-walled metal tube used to recover relatively undisturbed samples. These tubes are available in various sizes, ranging from 2 to 6 inches in outside diameter and from 18 to 54 inches in length (ASTM D 1587). A stationary piston device is included in the sampler to reduce sampling disturbance and to increase sample recovery. It has been found to be advantageous to collect Shelby tube samples from soft soil with the use of a hydraulically operated sampler (ASTM D 6519), often referred to as the Osterberg sampler. It has also been found to be advantageous to collect Shelby tube samples from hard soil with the use of a core barrel sampler, such as the Pitcher and Dennison samplers.
- **Drilling Jars**—A set pair of linked, heat-treated steel bars. The jars may be attached to a wireline sampling string incorporating a split spoon or other impact sampler. The jars are used to drive the sampler into the soil ahead of the bottom of the borehole, such as in cable tool drilling.

## 5. RESPONSIBILITIES

### 5.1 Procedure Responsibility

The Geosciences Discipline Lead is responsible for the development, maintenance, and revision of this procedure. Any questions, comments, or suggestions regarding this technical SOP should be sent to the Geosciences Discipline Lead. The Geosciences Discipline Lead's location and associated contact information can be found on the Insider.

### 5.2 Project Responsibility

Employees conducting subsurface soil sampling while drilling, or any portion thereof, are responsible for meeting the requirements of this procedure. Employees conducting technical review or oversight of such efforts are also responsible for following appropriate portions of this SOP.

For those projects where subsurface soil sampling while drilling is conducted, the Project Manager, or designee, is responsible for ensuring that sampling activities are conducted in accordance with this and other appropriate procedures. Project participants are responsible for documenting information in sufficient detail to provide objective documentation (i.e. forms, calculations, reports, etc.) that the requirements of this SOP have been met. Such documentation shall be retained as project records.

## 6. PROCEDURES (TECHNICAL REQUIREMENTS AND STANDARDS)

This section addresses the process and procedures involved with subsurface soil sampling while drilling. Proper subsurface soil sampling procedures are necessary to ensure the quality and integrity of the samples.

The details within this SOP should be used in conjunction with project-specific work plans. The project work plans will generally provide the following information:

- Sample collection objectives
- Anticipated locations of soil borings and target horizons or depths of soil samples to be collected
- Numbers and volumes of samples to be collected
- Types of chemical analyses to be conducted for the samples
- Specific quality control (QC) procedures and sampling required
- Any additional subsurface soil boring sampling requirements or procedures beyond those covered in this SOP, as necessary

There are many different methods that may be used for subsurface soil sample collection during drilling. Refer to ASTM D 6169-98 for guidance for the selection of soil sampling devices used with drill rigs. This SOP focuses on the two most common methods of soil sample collection: split-spoon sampling and Shelby tube sampling. At a minimum, the basic procedures outlined below for these two subsurface soil sampling methods will be followed.

## 6.1 General Sampling Considerations

The two subsurface soil sampling methods covered in this SOP, split-spoon and Shelby tube, are commonly used in conjunction with hollow stem auger, air rotary, and dual tube percussion drilling methods. Split-spoon or Shelby tube sampling may also be conducted when drilling with mud rotary methods; however, when using this drilling method the samples are not generally used for chemical analyses. This is because the samples may become invaded or chemically altered when they are tripped through the drilling mud during sample retrieval. In addition, loose unconsolidated soils may also literally wash out of the samplers when they are tripped through the mud column.

The procedures described in this SOP should be used in conjunction with the SOP for the specific drilling method used at the site. The drilling method SOPs are listed on the Insider. Included in these drilling method SOPs are specific drilling requirements related to subsurface soil sampling. These also include, but are not limited to, site clearance, site preparation, and health and safety requirements. Consequently, this SOP, the SOP for the specific drilling method to be used at the site, and the project work plans, should be reviewed together before the initiation of drilling and sampling.

## 6.2 Split-Spoon Sampling

Split-spoon samples for chemical analysis are usually obtained in brass, plastic, or stainless steel sleeves. The types, dimensions, and number of sleeves to be used, along with the length and type of sampler, should be stated in the project work plans. The split-spoon sampler, lined with the appropriate sleeves, is connected to the drill rod string or a wireline sampling string and is driven by a drive hammer (140 or 340 pound, depending on the size of the sampler) or drilling jars into the undisturbed soil ahead of the bottom of the borehole. The project-specific procedure for collecting and preserving samples from the split-spoon sampler should be outlined in the project work plans. The basic standard procedure for split-spoon sampling is described in the following text.

6.2.1 Calibrate all field analytical and health and safety monitoring equipment according to the instrument manufacturer's specifications. Calibration results must be recorded on the appropriate form(s) as specified by the project work plan or health and safety plan. Instruments that cannot be calibrated according to the manufacturer's specifications must be removed from service and tagged.

6.2.2 Wear the appropriate personal protective equipment as specified in the project work plan or health and safety plan. Personal protection will typically include the following, at a minimum: hard hat, safety glasses, gloves, steel-toed boots, hearing protection, and coveralls.

**6.2.3** Between each sampling location and prior to each sampling run, decontaminate the sampler, sleeves, and other sampling equipment according to applicable Shaw- and/or project-specific procedures.

**6.2.4** Drill or advance the borehole to the desired depth or target horizon where the sampling run is to begin. During drilling, monitor vapors in the breathing zone according to the project work plan and health and safety plan.

**6.2.5** When the desired sampling depth or target horizon is reached, remove the drill bit or plug from inside the drive casing or augers. Check the bottom depth with a tape to measure for the presence of "flowing sands" or slough inside the auger, casing, or borehole.

**6.2.6** Insert the sleeves into the split-spoon sampler, connect the halves, and screw together the rear threaded collar and front drive shoe. Attach the split-spoon sampler to the bottom end of the drill rod string or wireline sampling string. Set up and attach the specified-weight hammer, if used.

**6.2.7** Drive the sampler into the soil at the bottom of the borehole. Record the type of sampler assembly and hammer weight on the appropriate form(s) (an example Visual Classification of Soil Form [i.e., field log] is included in Section 8), as specified in the project work plans. To minimize off-gassing of the volatiles, the sampler should not be driven until the sampling team is ready to process the sample.

**6.2.8** When conducting penetration testing, observe and record on the appropriate form the number of hammer blows as described in appropriate Shaw- and/or project-specific procedures.

**6.2.9** Pull the drill rod or wireline sampling string up from the bottom of the borehole and remove the sampler.

**6.2.10** Remove the drive shoe and rear collar from the sampler and open the split barrel.

**6.2.11** Remove the sleeves one at a time, starting with the sleeve adjoining the drive shoe. Observe and record the amount of sample recovery on the appropriate form per applicable Shaw procedures. Any observed field problems associated with the sampling attempt (e.g., refusal) or lack of recovery should be noted on the appropriate form. Log the sample in accordance with applicable Shaw and/or project-specific requirements.

**6.2.12** Select the sleeve(s) to be submitted for laboratory analysis. Sample sleeve selection should be based on five factors: (1) judgment that the sample represents relatively undisturbed intact material, not slough; (2) proximity to the drive shoe; (3) minimal exposure to air; (4) lithology; and (5) obvious evidence of contamination. The project work plans should specify which sample sleeves will be submitted for specific analyses and confirm the selection factor(s).

**6.2.13** Place Teflon™ film over each end of sleeves to be submitted for chemical analysis, and seal each end with plastic end caps. Do not use any type of tape to seal the cap, because tape causes a toluene interference. All samples should be individually stored in resealable plastic bags. Note: Additional project-specific sample preparation steps or modifications may be required as stated in the project work plans.

**6.2.14** Appropriately label and number each sleeve to be submitted for analysis. The label will be filled out using waterproof ink and may contain the following information:

- Project number
- Boring number
- Sample number
- Bottom depth of sleeve
- Date and time of sample collection
- Parameters of analysis

- Sampler's initials

**6.2.15** Document the sampling event on the appropriate form(s), as specified in the project work plans. The information listed on the form should, at a minimum, include the following:

- Project name and number
- Date and time of the sampling event
- Drilling and sampling methods used – specify sample type
- Sample number
- Sample location
- Boring number
- Sample depth interval
- Sample description (type of matrix)
- Weather conditions
- Unusual events
- Signature or initials of the sampler

**6.2.16** Appropriately preserve, package, handle, and ship the sample in accordance with applicable Shaw and/or project-specific procedures. The samples shall also be maintained under custody. Samples stored on site will be subject to the provisions of applicable Shaw procedures and/or project work plans. However, all reasonable attempts should be made to ship samples on the date they are collected.

**6.2.17** One of the sample sleeves may also be utilized for lithologic logging. This sleeve may not then be retained for chemical analysis, as soil must be removed from the sleeve to effectively describe the soils/lithology and compile the lithologic log.

**6.2.18** Where headspace organic vapor screening is required by the project work plans, remove the soil from one of the remaining sleeves and place in a seam-sealing, polyethylene bag. Place the bag in the sunlight (warm) for at least five minutes, then using an organic vapor probe (portable photoionization detector, flame ionization detector, or other appropriate instrument), monitor the soil headspace for organic vapors. Record the reading on the appropriate form(s) specified in the project work plans.

**6.2.19** Repeat this sampling procedure at the intervals specified in the project work plans, and/or at suspected significant lithology changes until the bottom of the borehole is reached and/or the last sample is collected.

## 6.3 Thin-Walled or Shelby Tube Sampling

A thin-walled tube, or Shelby tube sampler may be used to collect relatively undisturbed soil samples. The project-specific procedure for collecting soil samples using a Shelby tube sampler should be outlined in the project work plans. The basic or standard procedure for Shelby tube sampling is described in the following text.

**6.3.1** Calibrate all field analytical and health and safety monitoring equipment as discussed in Section 6.2.1.

**6.3.2** Wear the appropriate personal protective equipment as described in Section 6.2.2.

**6.3.3** Between each sampling location and prior to each sampling run, decontaminate the sampler and other sampling equipment according to applicable Shaw- and/or project-specific procedures.

**6.3.4** Drill or advance the borehole to the desired depth or target horizon where the sampling run is to begin. While drilling, monitor the breathing zone according to the project work plans and health and safety plan.

**6.3.5** Once the desired sampling depth or target horizon is reached, connect the sampling tube to the drill rod string and advance the tube to the bottom of the boring. Then push the tube about 2 to 2.5 feet into the soil with a continuous, rapid motion without impact or twisting. If Osterberg, Pitcher, or Dennison samplers are used, follow the manufacturers instructions for advancement of the sampler.

**6.3.6** Pull the drill rod string up from the bottom of the borehole and remove the sampling tube from the string. Observe and record the amount of sample recovery and any associated problems as discussed in Section 6.2.11.

**6.3.7** Place Teflon™ film over each end of the tube if it is to be submitted for chemical analysis and seal the ends with plastic end caps. With a waterproof marker, write a "T" for top on the leading end and a "B" for bottom on the trailing end of the tube. Note: Additional project-specific sample preparation steps or modifications may be required, as stated in the project work plans.

**6.3.8** Appropriately label and number the tube as described in Section 6.2.14.

**6.3.9** Document the sampling event on the appropriate form(s), as discussed in Section 6.2.15.

**6.3.10** Appropriately preserve, package, handle, and ship the sample in accordance with applicable Shaw- and/or project-specific procedures. The samples shall also be maintained under custody. Samples stored on site will be subject to the provisions of applicable Shaw procedures and/or project work plans. However, all reasonable attempts should be made to ship samples on the date they are collected.

**6.3.11** Repeat this sampling procedure at the intervals specified in the project work plans until the bottom of the borehole is reached and/or the last sample is collected.

Records generated as a result of this SOP will be controlled and maintained in the project record files.

## 7. ATTACHMENTS

None.

## 8. FORMS

Example Visual Classification of Soils Form (Field Log)

Shaw™ Shaw E & I, Inc.

EXAMPLE

# VISUAL CLASSIFICATION OF SOILS

| PROJECT NUMBER: | PROJECT NAME: | |
|---|---|---|
| BORING NUMBER: | COORDINATES: | DATE: |
| ELEVATION: | GWL: Depth Date/Time | DATE STARTED: |
| ENGINEER/GEOLOGIST: | Depth Date/Time | DATE COMPLETED: |
| DRILLING METHODS: | | PAGE: OF |

| DEPTH ( ) | SAMPLE TYPE & NO. | BLOWS ON SAMPLER PER ( ) | RECOVERY ( ) | DESCRIPTION | USCS SYMBOL | MEASURED CONSISTENCY (TSF) | WELL CONSTRUCTION | REMARKS |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |

NOTES:

Drilling Contractor: ____________________

Drilling Equipment: ____________________

Driller: ____________________

____________________

1651-8-02

# SOP T-GS-008

# Standards for Conducting Soil Gas Surveys

Prepared By: ______________________ Date: ______________
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Senior Hydrogeologist

Authorized By: ______________________ Date: ______________
John E. Sciacca, R.G.
Geosciences Discipline Lead

# STANDARD OPERATING PROCEDURE

**Subject:** **Standards for Conducting Soil Gas Surveys**

## 1. PURPOSE

This procedure provides the Shaw standard practice for soil gas surveys. The procedure includes minimum required steps and quality checks employees and subcontractors are to follow when performing the subject task.

This procedure may also contain guidance for recommended or suggested practice that is based upon collective professional experience. Recommended practice goes beyond the minimum requirements of the procedure, and should be implemented when appropriate.

## 2. SCOPE

Geosciences Standard Operating Procedure (SOP) T-GS-008 describes standards for performing soil gas surveys for use in the environmental industry, and how such work will be conducted and documented for projects executed by Shaw Environmental & Infrastructure, Inc. (Shaw E & I). The SOP addresses technical requirements and required documentation. Responsibilities of individuals performing the work are also detailed. Additional project-specific requirements for soil gas surveys may be developed, as necessary, to supplement this procedure and address project-specific conditions and/or objectives.

The SOP also provides details of materials, equipment, and selected methods commonly used to perform soil gas surveys. Soil gas surveys are used to assess soil gas for the presence of volitile organic compound (VOC) vapors.

## 3. REFERENCES (STANDARD INDUSTRY PRACTICES)

Soil gas surveys should follow accepted industry practices. These industry practices are presented in the latest version of the following ASTM Standard:

ASTM D 5314 – 92 Standard Guide for Soil Gas Monitoring in the Vadose Zone (Reapproved 2001)

Additional reference materials, which are useful for conducting soil gas surveys, are listed In Attachment 1.

## 4. DEFINITIONS

The following definitions are applicable to conducting soil gas surveys.

- **Soil Gas**—Vadose Zone atmosphere within soil textural voids and pore spaces.
- **Soil Gas Survey**—For the purpose of this SOP, a measurement of the volatile organic compounds present in subsurface soil gas resulting from environmental contamination.
- **Vadose Zone**—The hydrogeologic region extending from the soil surface to the top of the principal water table. The unsaturated subsurface soil zone above the water table.

## 5. RESPONSIBILITIES

### 5.1. Procedure Responsibility

The Geosciences Discipline Lead is responsible for the development, maintenance, and revision of this procedure. Any questions, comments, or suggestions regarding this technical SOP should be sent to the Geosciences Discipline Lead. The Geosciences Discipline Lead's location and associated contact information can be found on the Insider.

### 5.2. Project Responsibility

Employees conducting soil gas surveys are responsible for meeting the requirements of this procedure. Employees conducting technical review or oversight of soil gas surveys are also responsible for following appropriate portions of this SOP.

For those projects where soil gas surveys are conducted, the Project Manager, or designee, is responsible for ensuring that survey activities are conducted in accordance with this and other appropriate procedures. Project participants are responsible for recording information in sufficient detail to provide objective documentation (i.e., work plans, calculations, reports, etc.) that the requirements of this SOP have been met. Such documentation shall be retained as project records.

## 6. PROCEDURES (TECHNICAL REQUIREMENTS AND STANDARDS)

The purpose of soil gas surveys is to screen for the presence of VOC vapors in unsaturated subsurface soils. Soil gas surveys should be employed at locations where VOCs are known or suspected to exist.

Soil gas surveys for VOC compounds can be useful for such environmental characterization purposes as the following:

- Discovery of the extent of site VOC contamination
- Estimate of the source and extent of groundwater plumes
- Selection of surface soil sampling locations
- Selection of soil boring locations
- Placement of groundwater monitoring wells
- Screening for soil disposal characterization purposes

In most instances, soil gas survey results are rapidly available, allowing for real-time modifications and decision making during fieldwork.

A soil gas survey is a sampling procedure used to directly measure the volatile chemical composition of the vodose zone soil atmosphere. Soil gas sampling is frequently used as an indirect indicator of contamination occurring in and below a sampling horizon. Soil gas monitoring is used as a method to indicate the presence, composition, and origin of volatile contaminants in and below the vadose zone. A soil gas survey is commonly used as a reconnaissance tool for determining the best location for other monitoring devices such as soil borings and monitoring wells.

A soil gas survey is very effective as a rapid and relatively inexpensive method of detecting volatile contaminants in the soil atmosphere. Soil gas measurements can be used to both determine the presence or absence of a volatile contaminant in the subsurface and to determine relative concentrations. Volatile organic contaminant vapors diffuse through unsaturated soils to the surface, achieving equilibrium with other soil gases. Their equilibrium concentration will be a function of their source concentration (separate phase product, soils contamination, and groundwater contamination), their volatility, quantity of organic carbon present in the surrounding matrix, soil moisture, and the distance of travel. Once the soil gas concentration over or near a contaminant source has equilibrated, the composition is fairly stable as the only active exchange of soil gas with the atmosphere occurs in the top 12 to 18 in. of soil. Thus sampling of the soil gas below this depth can provide useful information about subsurface contamination.

A soil gas survey is a simple procedure that can provide a qualitative indication of the presence and delineation of volatile subsurface contaminants.

***Note:*** *It is highly recommended that ASTM D 5314 – 92, Standard Guide for Soil Gas Monitoring in the Vadose Zone (Reapproved 2001) be read and understood prior to developing site-specific soil gas survey procedures and work plans, conducting field data collection, and interpreting the results of the survey.*

## 6.1. Methodology

Soil gas surveys are generally used to indicate the presence and horizontal and vertical delineation of volatile contaminants in subsurface, unsaturated soils. It is a qualitative survey method, not quantitative. The quantity of data (vertical and horizontal) is important in that an individual soil gas reading is not useful by itself, but becomes a reliable indicator when supported by surrounding readings. The more data generated, the more reliable the delineation will be. In a soil gas survey the concentrations of specific compounds may not be as important (depending on survey objectives) as the relative levels of a general class of contaminant (e.g., petroleum hydrocarbons, chlorinated organics, etc.). One should therefore choose the simplest sampling method that provides adequate confirmation of the type of contaminant being monitored. Both active and passive approaches to soil gas surveys are available.

### 6.1.1. Overview of Methods

**Methods for Conducting Soil Gas Surveys:** There are six general methods for conducting soil gas surveys. Methods 1, 2 and 4 are explained in detail, in Attachment 2 of this document, as they are the methods most commonly used for conducting soil gas surveys.

Method 5 is commonly used for monitoring soil headspace in samples collected during drilling.

1. <u>Collection of soil gas using a WHOLE-AIR ACTIVE APPROACH:</u>
   - Involves the forced movement of bulk soil atmosphere from the sampling horizon to a collection or analyzing device through a hollow sampling probe
   - Sample can be analyzed at the point of recovery and/or collected in a bag or canister for analysis elsewhere
   - Best where contaminant concentrations are expected to be high and the vadose zone is highly permeable to vapor
2. <u>Collection of soil gas using a SORBED CONTAMINANTS ACTIVE APPROACH:</u>
   - Involves the forced movement of bulk soil atmosphere from the sampling horizon through a hollow sample collection probe to a collection device designed to extract and trap sample stream contaminants by adsorption
   - Well suited to sites where soil is highly permeable to vapor and where contaminant concentrations may be lower than required for successful whole-air surveys
   - Contaminant trapping is accomplished by use of an adsorbent collection medium such as charcoal or Tenax™

3. <u>Collection of soil gas using a WHOLE-AIR PASSIVE APPROACH:</u>

   - Involves the entry of bulk atmosphere or soil atmosphere components from a near-surface sampling horizon to a collection or containment device through a flux chamber (hollow probe placed into the subsurface that is sealed a the above ground end) or similar apparatus
   - Useful to some very specific applications such as monitoring soil contaminant emissions from soil or water to assess the health hazard risk to the general public

4. <u>Collection of soil gas using a SORBED CONTAMINANTS PASSIVE APPROACH:</u>

   - Involves the passive movement of contaminants in soil to a sorbent collection device over time
   - Best suited where contaminant concentrations and soil permeability are low
   - Samplers are placed into shallow holes, backfilled and left in place for two to ten days
   - Charcoal or Gore-tex™ is generally used as the adsorbent

5. <u>Collection of soil samples for subsequent HEADSPACE ATMOSPHERE OR EXTRACTION SAMPLING:</u>

   - Examines contaminants that are present in a headspace atmosphere above a contained soil sample generally using a Photo Ionization Detector (PID)
   - Can be a relatively poor method for determining many of the more volatile contaminants due to sample loss during handling and temperature variations affecting volatility, so is therefore limited in value

6. <u>Collection of SOIL PORE LIQUID HEADSPACE GAS APPROACH:</u>

   - Uses a suction lysimeter or other device, installed in the vadose zone, to sample soil pore liquid
   - Soil vapor that collects in the soil pore liquid sampling device is extracted and analyzed
   - Limited by the expense and complexity of installing the sampling devices

**Methods of Soil Penetration:** Soil gas samples can be obtained using the following methods of penetration.

- <u>Shallow driven points</u> (less than 3 ft.) advanced into the subsurface using a slam bar and small diameter (less than 1 in.) drive probe; can drive 30 or more points per day; good for contamination above about 30 ft. depth; must pre-drill through sealed surfaces such as concrete
- <u>Hydraulically driven points</u> using ½- to 2-inch diameter probes; can be advanced to a depth of 30 to 60 feet below ground surface; slow method (10 to 15 points per day); good for deep contamination or complex geology; can cause a "skin" of fine grained material that blocks soil vapor readings
- <u>Drilled hole</u> collection point using conventional drilling methods to penetrate to the to the sample collection depth; slow method (6 to 15 points per day); eliminates skin problem; can be used as a permanent monitoring point; soil gas samples can be collected using sorbent trap, bags, or canister

**Methods to Extract Soil Gas:** The following sampling methods are used to retrieve/extract soil gas samples.

- Syringe samples are collected directly from sample collection equipment and subsurface penetrating equipment using syringes. The sample within the syringe is immediately analyzed in the field using a PID, FID, field Gas Chromatography (GC), field GC/Mass Spectrometer (GC/MS), or detector tubes. This is a relatively rapid method for whole air sampling (field use only) that requires pumping soil gas to the surface. Syringe volume (i.e., aliquot) is a function of collection equipment and analytical instrumentation.
- Direct injection samples are directly conveyed from sample collection and subsurface penetrating equipment into analytical instruments such as a PID, FID, field GC, field GC/MS, or detector tubes. This is a relatively rapid method for whole air sampling (field use only) that requires pumping soil gas to the surface. Some instruments, like the PID and FID, have pumps in them that may be sufficient for obtaining and analyzing whole air soil gas.
- Bag samples are very useful for samples having moderate to high VOC concentrations. Bag samples may be analyzed using any instrument, especially field or laboratory-based GC and GC/MS. Sample holding time is limited to approximately 1 to 3 days. Collection of bag samples requires a pump. Bags are filled directly, whereby sample passes through the pump into the bag, or indirectly, whereby the bag is filled using a sample bag vacuum chamber.
- Pre-evacuated Canisters are very useful for samples having low to high VOC concentrations. Sample holding time is approximately 14 days. Canister samples should only be analyzed by qualified personnel. Canister samples are most often analyzed using field or laboratory-based GC and GC/MS. No sample collection pump is required because the canisters are pre-evacuated to negative 25 to 30 pounds per square inch (psi). Due to the inherent sophistication of canisters, a slightly higher standard of care is required when collecting samples with them compared to collecting samples using syringes and bags.
- Collector tubes are sorbant traps consisting of materials like charcoal, Tenax ™, and Petrex™. Collector tubes are very useful for samples having low concentrations. Sample holding times are as long as 30 days depending on contaminants. The method is relatively slow. Laboratory analysis is required for collector tube samples.

### 6.1.2. Limitations

The following limitations apply to soil gas surveys for the environmental investigation industry:

- A soil gas survey is only applicable to volatile contaminants
- Any barrier that interferes with vapor migration such as perched water, clay or made-made structures can lead to a low or false negative reading
- Soil gas readings taken within 24 to 48 hours of heavy precipitation can produce drastically reduced or non-existent readings
- Biodegradation can reduce the vapor levels of many hydrocarbons, including BTEX compounds
- The deeper the contamination relative to the soil gas sample point, the more the impact of biodegradability is likely to be
- Soil gas surveys are qualitative at best, do not provide repeatable quantitative information over time, and data must be confirmed by soil and groundwater sampling

### 6.1.3. Survey Design Considerations

The success in applying the soil gas sampling technique selected is controlled in part by the methodology in applying that sampling technique. The selected methodology should be guided by the project objectives, by the subsurface lithology and stratigraphy, and by the perceived spatial and temporal array of the potential sampling targets. In order to design a successful soil gas survey, the following considerations must be taken into account. The objectives and design considerations and information should be listed and descried in a soil gas sampling plan as part of the project-specific work plans.

**Development of a sampling grid:**

The following are basic considerations for development of a sample grid:

- Sample collection points should be distributed over the geographical area of interest
- The selection of the grid size is strongly dependent on the relationship between project confidence level requirements and cost
- Small survey targets and complex vadose zone geology require decreased spacing between sample collection locations
- Overly large grid cell spacing results in inadequate, over-interpreted data
- Grid arrays can be designed as regularly spaced, predetermined locations or they can be irregularly spaced and continually field modified as analytical data is generated

The sample grid, or grid development methodology should be described in the project work plans.

**Contaminant profiling:**

Contaminant profiling consists of sampling at closely spaced intervals in a linear array both vertically and horizontally. The following are basic considerations for the profiling:

- Results are commonly displayed as contaminant concentration versus distance on *X, Y, Z* plots
- Concentration data are commonly displayed logarithmically
- Horizontal profile intervals (i.e., spacing between samples) may range from about 25 to 100 feet
- Vertical profile intervals should, in part, be based on soil lithology and stratigraphy
- Useful as a corroborative tool to support other monitoring methods

**Multiple depth sampling:**

The following are basic considerations for multiple depth sampling:

- Allows assessment of changes in soil gas contaminant fractions with depth
- Some sampling systems can recover soil gas samples as probes are advanced deeper into the vadose zone
- Practice is helpful in determining the optimum sampling depth for a particular site or to demonstrate the presence or absence of soil atmosphere contamination in a certain horizon
- Cross-contamination in sampling may be unavoidable, so quality control is limited

**Time variant methodologies:**

Considerations regarding time variant methodologies are as follows:

- Consists of monitoring soil gas contaminant concentrations in the vadose zone over time
- Can help monitor the effectiveness of remedial air-injection or suction systems as well as the migration of contaminants from a source such as an underground storage tank
- Proper maintenance of long-term monitoring systems is essential

**Field Quality Assurance/Quality Control (QA/QC) (See also Attachment 3):**

Field QA/QC is essential for establishing support for any interpretation of the sample data. The following are basic issues for appropriate implementation of QA/QC for the survey:

- QA/QC requirements are dependent upon the data quality objectives defined in the planning phase of the survey and presented in the project work plans
- Persons collecting field data should not be changed during a soil gas survey
- Field personnel should closely follow a predetermined sampling procedure specified in the project work plans. (Note: Example procedures are presented in Appendix 2). Deviations from predetermined sampling procedures must be recorded in the field notes
- An adequate equipment decontamination procedure must be used and specified in the project work plans
- Bias of soil gas data (i.e., consistently lower-than-actual or higher-than-actual concentrations related to the measurement process) can occur for a number of reasons (malfunction of the field instrument, subsurface barriers to vapor diffusion, etc.) and must be considered in data evaluation

QA/QC samples must be collected to support the integrity of the soil gas survey, the type and magnitude of which depends upon the purpose of the soil gas survey and the specified requirements for data quality. At a minimum, the following QA/QC samples should be taken when collecting soil gas samples for laboratory or field GC analysis (variations of these sampling techniques can be used to check field equipment when taking only field readings):

- **Field blanks**: samples of ambient air or nitrogen recovered from the sampling system to determine sample contamination by ambient air or to test for contamination of the sampling system; collect at least one field blank for each ten soil samples or one per sample batch
- **Travel blanks**: a sample of ambient air or carrier gas not containing contamination , handled in the same manner as those containers holding samples, to audit sample integrity during handling and transport; include one travel blank in each batch of samples
- **Sample container blanks**: obtained by sampling the contents of a clean container to ensure that residual contaminants are not present in the container prior to sampling; should be collected and analyzed prior to each use of a sample container
- **Sample probe blanks**: carrier gas or atmospheric air drawn through the sampling device and recovered in the same manner as soil gas to check for the presence of sample train contaminants; should be collected and analyzed prior to each use of a probe and/or other components of the sampling system
- **Field replicates**: separate soil gas samples collected from the sample site into multiple containers, can be used to estimate the precision of sampling and analysis; collect at least 10% of the total number of soil gas samples

- **Sample spiking**: the addition of a known quantity of a known compound or mixture to the soil gas sample to provide internal checks of analytical quality; generally done in the lab, not recommended in the field

A documentation audit should be completed at the conclusion of each working day or at the conclusion of sample collection, and should include evidence of an equipment inventory, sample inventory including QA/QC samples, review of field notes and chain-of-custody (COC) documentation. COC documentation is mandatory when samples are transmitted to an off-site laboratory.

**Sample handling and transport:**

The period of sample handling and transport represents the greatest opportunity for loss or gain of contaminants from or to sample containers. Therefore, appropriate handling and transport protocols must be identified and followed. The following are considerations for sample handling and transport:

- Minimize the time between sample collection and analysis: pre-arrange analysis with the selected laboratory when samples are analyzed off site
- Protect samples from exposure to light and excess heat and exercise precautions against leaks
- Select materials for soil gas sampling, transfer and containment that will not impact sample integrity(e.g., Teflon™, stainless steel, Tygon™, and Tedlar™); avoid porous rubbers and plastics and corrosive metals
- Problems of sample handling and transport are minimized by integration of the sampling and analytical system (i.e., by feeding the sample stream directly into the intake port of the analyzer when doing field analysis)
- Cross contamination is a concern with integral systems; when recovering samples by syringe, syringes must be either disposed of after each sample collection (if plastic) or decontaminated between each sample collection (if glass); syringe samples should be injected into the analyzer immediately upon sample collection
- Hand pumps and mechanical pumps can contribute to sample contamination, and should only be installed behind the analyzer or container in the sample train
- If samples are to be transported to an off-site laboratory, they must be properly packaged to avoid damage to sample containers; take care to keep samples from becoming overly warm or agitated during transport
- Archiving (i.e., storing) of soil gas samples should not be done due to the likelihood of degradation of stored samples.

Sample handling and transport for the soil gas survey should follow appropriate Shaw E & I technical SOPs and/or project-specific requirements/procedures.

**Analysis of samples:**

The following are issues/considerations regarding soil gas sample analysis:

- Soil gas analysis procedures are based upon pre-existing protocol established for the analysis of contaminants in ambient air
- Soil gas surveying as a field screening technique can be effective without the use of highly sophisticated analytical techniques
- Portable field instruments (PIDs, FIDs and infrared detectors) are the most commonly used analyzers when performing an soil gas survey as a field screening technique; limitations of these instruments include measurement capabilities for relatively low concentrations only,

limited selectivity, inability to separate contaminant compounds, and limited accuracy regarding the use of field monitoring instruments)

- Use of a field GC or GC/MS provides much greater analytical capabilities than portable field instruments but may not be warranted for a field screening survey
- Detector tubes (e.g. Draeger Tubes) can be used for field analysis, particularly if compound-specific detection is required; they are relatively inexpensive and provide immediate results, but are restricted to applications with few interfering compounds

Specific sample analysis requirements and methods should be specified in the project work plans.

### 6.1.4. Field Implementation

Field implementation of the soil gas survey should follow methods and detailed procedures specified in the project work plans and applicable Shaw E & I technical SOPs. The methods and procedures in the work plans should address site-specific conditions and factors.

It is not possible for this SOP to present a detailed specific soil gas survey procedure that would be applicable given the variety of available methods and techniques and the wide range of specific conditions for sites across the country. Therefore, example soil gas survey procedures are included in Attachment 2. The example procedures may be customized or supplemented to address site- or project-specific conditions and requirements.

Field implementation of the soil gas survey should be supervised by the Project Geologist/Hydrogeologist, or designee. The Project Geologist/Hydrogeologist is the individual responsible for overall technical oversight of the soil gas survey, including the determination of data needs and ensuring that adequate quantity and quality of data are collected. The Project Geologist/Hydrogeologist should preferably be a senior geologist/hydrogeologist who has significant experience in planning, conducting and interpreting the results of soil gas surveys.

The following should be conducted at the completion of the field phase of the soil gas survey:

- All documentation should be completed according to applicable Shaw E & I technical SOPs and/or project-specific requirements
- Any and all boreholes from the survey should be backfilled/abandoned according to applicable Shaw E & I technical SOPs and/or the project work plans
- The site should be cleaned, the ground washed as necessary, and the site conditions restored according to the project work plans
- All excess soil and sampling materials should be properly contained, labeled and managed in compliance with the project work plans and/or other applicable requirements

### 6.1.5. Interpretation of Results

Interpretation of soil gas survey results allows one to determine the presence and distribution of VOC vapors in the subsurface. Areas where subsurface contamination is most likely to exist can be identified as can areas where soils appear to be relatively "clean". Point sources may be identified as well as the general direction of contaminant distribution. A soil gas survey does not however, provide the same level of quantification (or confidence) as obtained from soil sampling for laboratory analysis, nor does it indicate the vertical extent of contamination. Soil gas surveys results can be used to develop a sampling plan for more definitive soil and groundwater testing.

The following are important points or considerations in the interpretation of soil gas survey results:

- Soil gas data interpretation is an iterative process including the examination of the raw data, selection of appropriate and useful data displays, an establishment of correlation of the data set to other vadose zone monitoring data and ground truth.

- Soil gas data cannot be consistently interpreted in a manner that establishes direct correlation between contaminants in a soil gas horizon and contaminants in other horizons; however, the detection of contaminants in soil gas does suggest the existence of a contaminant source, and increase in contaminant concentration can suggest close proximity to the source.

- It is the responsibility of the interpreter to examine soil gas data with in the context of other site characteristics, and provide an interpretation based upon sound judgment and thorough yet practical data treatment.

- Soil gas data are normally interpreted as raw data; the application of correction factors is not recommended.

- Statistical treatment of soil gas monitoring data allows the interpreter to estimate the amount of variation noted in the survey data due to errors. It can also be of use to define anomalous data subpopulations when the boundaries of a contaminated area are not clearly defined or if the existence of multiple populations of data (i.e., contaminated and uncontaminated) within a single data set is in doubt.

- Soil gas data from survey profiles displayed on an *X, Y, Z* plots can be used to examine the overall context for soil gas measurement data potentially indicating contamination; the profile can illustrate spatially significant groupings of data populations.

- Soil gas data obtained by sampling at a single depth should be mapped to suggest the lateral extent of subsurface contamination. Map suites of soil gas data obtained from multiple depths can sometimes aid in determining the depth to the contaminant source.

- Three-dimensional plotting of the soil gas data may help in data interpretation.

- Other vadose and saturated zone monitoring methods should be used to corroborate data obtained from a soil gas survey.

Upon completion of collection and analysis of all soil gas samples, the following process may be used to prepare and evaluate the data as part of a mapping effort:

- Plot all survey points and associated vapor concentrations onto a site map.

- Draw interpreted vapor iso-concentration contour lines on the map.

- Identify the areas that show the highest vapor concentrations (for evaluation of relation to groundwater plumes, the interpreted upgradient and downgradient directions may also be plotted).

- Use the areas identified from the above plot along with other information gathered during pre-subsurface assessment to decide the locations of subsurface exploration points (boreholes, wells, test pits, etc.). Further investigation of areas where soil vapors are highest may be warranted, and if groundwater wells will be installed, place wells both upgradient and downgradient of the anticipated contaminant plume.

### 6.1.6. Reporting

A soil gas survey report should be compiled to document the survey and present the interpretation of results. The report should focus upon addressing and meeting the objectives of the survey as described in the project work plans. All reports should discuss data related to the QA/QC objectives and should include data comparability, representativeness, bias, precision accuracy, completeness and analytical detection limits wherever possible. A general discussion of the reliability of results and analytical detection limits is warranted. Soil gas survey reports should include the following elements:

- The objectives and purpose of the soil gas study and the rationale for the selection of a particular monitoring/sampling technique

- A discussion of the sample array in three dimensions, sampling method employed and analytical scheme chosen
- A discussion on the impact of vadose zone (hydrogeologic) properties on survey design
- The characteristics of a contaminant source or spill, if known, and a list of the chemical compounds known or suspected to have been used at the site
- Any unique characteristics of the site or the study that could provide a meaningful context in which to interpret the soil gas data
- A site plan showing sample locations, physical features, iso-concentration contours of specific compounds or groups and any other necessary information to guarantee map clarity
- Cross sections showing changes in contaminant concentration with depth or concentration profiles of more than one contaminant through several sample locations, if possible
- A discussion regarding the physical structures at the site that impacted the location of sampling points and possibly the migration of soil gas (e.g., concrete pads, buried pipelines, etc.)
- An evaluation of the impact of the regional and local hydrogeologic conditions within the survey area on the results of the survey
- A detailed description of the type of soil gas survey conducted, including selection of method, sampling array, background sampling, decontamination procedure, field and/or laboratory analytical methods, and QA/QC procedures
- Any unusual conditions that occurred during the survey (e.g., rainfall events, changes in atmospheric conditions such as cold or warm front passage, visual observation of contamination at sampling points, etc.)
- If the subject site is contaminated, a discussion of soil gas characterization of uncontaminated or non-anomalous contiguous property
- Data collected during field sampling and field or laboratory analysis, compiled in tabular form; this data should include sampling and analysis dates, soil/rock description at each sampling point, depth and diameter of sampling point, quantity of soil gas purged prior to sampling, quantity of sample extracted, and tabulation of QA/QC samples recovered
- A discussion of the results of QA/QC efforts, establishing performance within limits set prior to the survey; systematic errors or bias can be detected in this review
- A discussion of the results of the mapping process described at the end of Section 6.1.5
- Wherever possible, a discussion that correlates soil gas data subsurface soil samples and groundwater samples
- Conclusions drawn from the results, and recommendations, if appropriate

## 6.2. Technical Review

All soil gas survey work plans, results, and reports should undergo technical review. The technical reviewer should be an experienced senior geologist or earth scientist. At a minimum, the technical reviewer should be a person capable of planning, conducting and evaluating soil gas survey programs. The technical reviewer should not have developed or conducted the work to be reviewed. Individuals needing assistance in finding qualified technical reviewers may consult internal Shaw technical listings for experts in soil gas surveys, or may possibly use an expert outside of Shaw E & I, if necessary.

The technical review, at a minimum, should consider and evaluate the following items:

- Purpose and scope of the soil gas survey
- Site use and operational history
- Nature and extent of spills, if known
- Site lithology and stratigraphy
- Depth to groundwater
- Existing site environmental data
- Expected results of the soil gas survey
- Contaminants of interest at the site
- Selected soil gas survey method (active or passive, whole air or sorbed)
- Sample area and sample point spacing
- Vertical sampling profile
- Sampling methodology
- Ambient temperatures expected during the sampling
- Selected analytical method/s
- QA/QC procedures
- Equipment decontamination procedures
- Survey data mapping and reports
- Conclusions and recommendations

The soil gas survey report(s) should be reviewed relative to the bulleted items in Section 6.1.6. In addition, the report review should consider/check the following:

- The data generated should be of adequate quality and useable for the purposes of the survey.
- All analysis techniques and evaluations of the data should have followed sound, established practices.
- All maps and work products generated should have followed appropriate standards or requirements and be technically supportable.
- The interpretations and conclusions generated in the report should also be technically supportable.

Any issues raised during the technical review should be resolved between the reviewer and staff preparing the work plan, conducting the survey, or compiling the report before external (i.e., outside of Shaw E & I) submission of the work plan or results. The technical review comments and issues, and corresponding resolution should be documented and filed with the project records. Such records should be maintained until project closeout.

## 7. ATTACHMENTS

- Attachment 1, Additional References Relevant to Soil Gas Surveys
- Attachment 2, Example Soil Gas Survey Procedures
- Attachment 3, Analytical Methods and QA/QC

## 8. FORMS

None.

# Attachment 1

## Additional References Relevant to Soil Gas Surveys

The following are additional references relevant to planning, conducting and evaluating soil gas surveys.

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# Attachment 2

## Example Soil Gas Survey Procedures

The following soil gas survey procedures are provided as example or basic procedures. They may be used for planning soil gas surveys. However, site-specific conditions and specific survey requirements will dictate the specific field data collection and analytical procedures to be employed. The procedures may be supplemented or customized to address the project/site-specific conditions, equipment, methodologies and quality control requirements.

**Pre-Soil Gas Survey Activities (Applicable to All Example Procedures)**

Inspection of the area slated for the soil gas survey is performed prior to field mobilization and as part of the planning task. Site access issues (e.g. physical and/or time restrictions), ground cover (e.g., paved and/or unpaved), the presence of power supplies, and the presence of subsurface utilities should all be evaluated as part of the planning process.

Upon mobilization to the site, the following activities should be performed and recorded in a Field Logbook (unless otherwise directed in the project work plans) immediately prior to conducting the site soil gas survey:

1. Create a sampling grid (or pattern) for site areas suspected of containing contamination; the sampling points should be located according to the project work plan. Spacing may be closer in areas where sources of contamination are known to exist. If possible, reference the grid to one or more site landmarks or unique features on the grid drawing. The orientation of the grid to compass "north" should also be established and recorded.
2. A unique numbering system should be used for the sampling points. One system that is recommended is to start sample point one at the northwest corner of the grid. Numbers would then increase from west to east across the first row and proceed from the northernmost row to the southernmost row (i.e., numbers would increase in a direction similar to the direction words are read on a page).
3. Use a steel measuring tape to layout the sampling grid (or pattern). Clear each sampling point of loose debris and mark the sampling grid using stakes with orange flags for dirt or grass areas and fluorescent paint or wax pencil for asphalt or concrete covered locations.
4. Draw the sampling grid layout with numbering system in the Field Logbook.
5. Create a results table in Field Logbook.
6. Assemble soil gas sampling equipment.
7. Calibrate equipment according to manufacturer's specifications and/or project-specific requirements/procedures.

**Example Procedure 1 - Whole-Air Active Approach**

The following procedure can be employed for the active collection of soil gas samples, at small sites, from shallow penetration holes (three feet or less). Analysis of samples can be by direct reading using a field meter (e.g., PID, FID, etc.) or by collecting vapor samples into sample bags for laboratory analysis.

1. Bring the following equipment to the site to perform the soil gas survey:
   - Site plan and engineering scale for plotting sample locations

- Tape measure or trundle wheel
- Cable locating device
- Impact drill (and generator if needed) if concrete must be penetrated
- Slam bar or impact hammer
- One or more clean stainless steel vapor extraction rods
- Field vapor monitoring instrument(s) (PID, FID, portable GC and/or detector tubes)
- Syringes, sample bags or a sample pump if needed
- Cooler
- Caulking gun and silicon rubber-based caulk (if sample points penetrate concrete)
- Triple rinse decontamination equipment

2. As with any subsurface investigation, locate underground utilities prior to beginning ground penetration. It would also be prudent to use an underground cable locating device to use as a double check at each monitoring point location.
3. Begin in an area suspected of containing the highest concentrations of subsurface VOCs. The distance and direction of subsequent sampling locations will be based on consideration of the values measured at the previous locations.
4. Decontaminate all equipment, including rods and other sampling equipment, according to applicable Shaw E & I technical SOPs and/or the project work plans.
5. Once all underground utility locations are satisfactorily located, use the impact drill to penetrate any overlying sealed surface such as concrete.
6. Use the slam bar or impact driver to drive a ½ in. hole to a depth of 18 to 24 in.
7. Place a clean vapor extraction rod into the hole and drive it to the desired depth into virgin soil.
8. If a sample pump is used, purge approximately one volume of air from the rod. Using the pump, extract a vapor sample into a syringe or into an air bag. A syringe sample can be injected directly into a portable GC or into an appropriate detector tube for analysis; a bag sample can be placed in a cooler for subsequent shipment to a laboratory. Bag samples should be kept in a closed cooler without ice that is kept out of out of direct sunlight.

   If an FID or PID is used, use the instrument sample probe to draw air directly from the vapor extraction rod into the instrument and record the peak concentration that occurs as vapor is being drawn in.

   If bag samples are collected for laboratory analysis, field readings must also be taken using a field instrument to help determine the best sampling locations.
9. When sampling is finished, withdraw the probe, wipe it with a clean, dry cloth, and decontaminate it appropriately. The probe should be allowed to dry before taking the next sample (a propane torch may be used to dry the probe quickly).
10. Using the tape measure or trundle wheel, measure the location of the sampling point and plot it along with the field reading on the site plan. As each point is plotted, observe any trends in the distribution of contaminant concentrations to determine the location of each subsequent sampling point.

11. Abandon the borehole as specified in the project work plans. When sampling has been performed through concrete or other sealed surfaces, the probe holes should be sealed with a durable, quick drying caulk, preferably of a color similar to the surface (particularly on active facilities where the presence of numerous open drill holes would not be acceptable). Squeeze a plug of caulk fully into the top several inches of the drill hole.

12. Move to the next location and repeat the above procedure. The survey is successfully completed when all areas showing significant vapor concentrations have been delineated out to where the vapor concentrations are very low or not detectable. This is not always possible if contamination extends to areas that are inaccessible (such as beneath structures or off site).

**Example Procedure 2 - Whole-Air Active Approach**

The following procedure can be employed for the active collection of soil gas samples, at small or large sites, from shallow penetration and deep holes, and either by direct reading using a field meter or by collecting vapor samples into sample bags for off-site or field laboratory analysis.

**General Equipment and Material Requirements**

The following equipment & materials should be brought to the site to perform the soil gas survey:

- Soil Gas Survey Plan – (Field Sampling Plan [FSP])
- Personal Protective Equipment (PPE)
- Field Logbook(s)
- VOC vapor meter (PID or FID)
- Calibration gas for VOC vapor meter
- On/off valves
- Drill
- Drill bits, 1/2", 5/8", 11/16", and 3/4"
- 5/8" diameter pipe probes (drivable or passive)
- Generator - for power tools and/or non-battery operated vacuum pump
- 16" Needle valve
- Stainless steel union tee, 3/16"
- Stainless steel reducer, 3/16" to 1/8"
- Gray silicone rubber septa, 1/4" diameter
- Vacuum extraction pump (to 25" Hg) that does not contribute to blank contamination
- Retractable probes
- Sampling tips
- Air piezometer
- Detector tubes
- Zero Air compressed gas tank
- Hand auger

- Slide hammer, pneumatic hammer, and/or electric hammer (depending on the type(s) of sampling media anticipated). Direct push (hydraulic) sampling equipment may also be used.
- Teflon tubing
- Compass
- "Rocktite", plumber's putty, or rubber stopper - to create surface seal for soil gas probe
- Field Data Forms
- Decontamination supplies
- Indelible markers
- Stakes with orange flags
- Fluorescent paint or wax pencils
- Trash containers
- Construction gloves
- Paper towels
- Aluminum foil
- Plastic garbage bags
- Storage containers (e.g. DOT approved 55 gallon drums) for storage and disposal of contaminants and contaminated soils

If a field GC is being employed, include the following:

- Field GC
- Calibration standards
- 40 ml glass sample bottles with Teflon lined lids
- Air-tight sampling syringes, 1 ml and 5 ml

**Procedure**

1. Locate underground utilities prior to beginning ground penetration as in number 2 of Example Procedure 1.
2. Lay out the sampling grid for the area to be surveyed.
3. If the surface is concrete or asphalt, first make a hole in the concrete using a 3/4" drill with a masonry bit. The bit size should be 1/8" larger than the pipe probe diameter; e.g., if a 5/8" pipe probe is being used, drill the hole with a 3/4" bit.
4. Decontaminate all equipment according to applicable Shaw E & I technical SOPs and/or the project work plans.
5. The next step is to advance the sampling (pipe) probe into the subsurface soils. The first option is to use a manual driver such as a bucket auger or slide hammer. While inexpensive, it can be time-consuming and labor-intensive. Manual driving may be impossible in hard-packed soil, gravel, or soil with sufficient amount of stones. The second option is to use an electrical hammer. This is an attractive option if driving the probe to deeper depths or penetrating pavement. A

portable generator or electrical outlet (if available) is required for operation. The third option is to use a hydraulic (i.e., direct push) unit. These are typically mounted in a field vehicle and can typically reach depths of 20 feet. Units equipped with percussion capability are even more effective and those with a rotary function can drill through concrete.

6. Attach a shielded sampling tip to the end of the pipe probe. This tip will typically have Teflon tubing attached that passes right through the pipe probe.

7. Drive the pipe probe with attached tip to a depth of about one foot or to depth specified in the project work plans. If deeper sampling points are desired, push the probe further into the soil using a slide hammer, pneumatic hammer, or electric hammer or hydraulic unit. Use extension shafts for deeper depths. A permanent position marking should be made every six inches along the lengths of the pipe probe and extension shafts so that the depth of sample collection can be recorded.

   Pipe probe sampling depths as well as observations concerning the nature of the sampling surface must be recorded in the Field Logbook.

8. Make a seal at the surface using Rocktite™, plumber's putty or a rubber stopper to keep surface air from short circuiting the system.

9. Test soil gas using field screening equipment (PID or FID) as follows:

   - Zero the PID or FID by operating the equipment in a background area, typically on or near the site perimeter at an upwind location.

   - The well volume should be evacuated prior to sampling. To sample soil gas, connect the PID or FID sample tubing to the tee arm of a stainless steel tee. The tee sidearm has a reducer fitting attached and sized so that the PID or FID probe fits snugly into it. Insert the meter probe directly into the sidearm tubing. Allow the equipment to draw in the soil gas for several seconds prior to taking a reading. Continue to take readings while drawing soil gas through the sampling system. The maximum instrument response should be recorded. Record instrument response in the Field Logbook and other appropriate forms as specified in the project work plans.

     Instrumentation with digital (LED/LCD) displays may not be able to discern maximum headspace response unless equipped with a "maximum hold" feature or strip-chart recorder. The sampler must clear the maximum response value prior to each sample screening event. Record the highest meter response as the soil gas concentration in the Field Logbook or form.

10. For collection and analysis of soil gas vapors by field GC using a stainless steel tee with septum, proceed as follows:

    - Connect one end of the stainless steel tee to the pipe probe and the end directly opposite to a vacuum pump.

    - Screw a stainless steel nut containing a 1/4" gray silicone rubber septum onto the reducer end of the tee arm.

    - Turn on pump and flush the soil gas through the main manifold for one to two minutes (for blanks, use zero air as the gas source; for calibration standards, use commercially prepared standard mixtures, the concentrations of which bracket the range of interest).

    - Insert syringe needle through septum and into tee so that the tip of the needle is in the flow path of the soil gas.

    - Open syringe valve and draw plunger to about two-thirds of maximum capacity; depress plunger. Perform this step several times to flush syringe and reduce the likelihood of carryover. Finally, draw plunger to past the one ml mark, close the syringe valve, and withdraw needle. Change septum every 20 injections to avoid the possibility of leaks.

To Analyze Sample:

- Analyze two calibration standards that bracket the concentration range of interest.
- Analyze blank sample, as required.
- Depress syringe plunger slightly so that the plunger head is even with the 1 ml mark of the syringe.
- With GC in the "ready to inject" status, insert the syringe needle with sample completely into the GC injection port. Simultaneously depress the syringe plunger and push the GC start or go button. For blanks, the same procedure should be followed using background air. Record instrument response in Field Logbook and other appropriate forms as specified in the project work plans.

11. Disconnect and remove all surface sampling equipment. Extract/remove the probe pipe from the subsurface.
12. Abandon the borehole as specified in the project work plans. When sampling has been performed through concrete or other sealed surfaces, the probe holes should be sealed with a durable, quick drying caulk, preferably of a color similar to the surface (particularly on active facilities where the presence of numerous open drill holes would not be acceptable). Squeeze a plug of caulk fully into the top several inches of the drill hole.
13. Move to the next location and repeat the above procedure.

**Procedure 3 - Sorbed Contaminants Approach**

Presented below are two procedures that can be used for the collection of gas samples using the sorbed contaminants approach. The Petrex™ method is a passive collection approach and requires the burial of sample collection devices. Tenax™ Tube sampling is an active approach which uses an air sampling pump to draw vapors from a pre-drilled hole into a sample collection device located at the surface.

**Petrex™ Sampling**

Petrex™ sampling is accomplished by burying a series of sampling bottles containing an activated charcoal sample collector.

Basic sampling procedure:

1. Bury the sample collectors on 50 to 100 ft. centers in a grid pattern extending from the spill source area, each at a depth of 12 inches.
2. Leave the collectors in the ground for 3 to 7 days, as prescribed in the project work plans.
3. After the prescribed burial period, recover the charcoal collectors, seal them and ship them to a laboratory for analysis.
4. Have the laboratory analyze the samples using Curie effect mass spectrometry which provides both a mass spec "fingerprint" of the contaminant and a relative concentration (ion flux).

**Tenax™ Tube Sampling by Vacuum Pump**

Collection of an accurately known volume of air is critical to the integrity of the results. For this reason, great care should be taken when setting up each piece of sampling equipment.

Basic sampling procedure:

1. Connect a ¼" swagelok fitting with urethane tubing from the top of the rotameter to a Gilian vacuum pump.

2. Connect a swagelok fitting with urethane tubing to the bottom of the rotameter.

3. Insert a "dummy" Tenax™ tube into the universal tube holder by placing the Tenax™ tube into one end of the holder, then gently align the other end of the Tenax™ tube with the inlet hole on the cap of the tube holder. Gently twist down the cap to get an airtight seal between the Tenax™ tube and holder.

   **Note**: Twisting the cap down too hard will result in a broken Tenax™ tube.

4. Check the system for leaks by turning on the vacuum pump; the ball in the flowmeter indicates flow throughout the system. Place your finger over the open end of the tube holder. The ball in the flowmeter will slowly drop to the bottom of the flowmeter to indicate no flow. If the ball does not slowly drop, this indicates leaks in the system. Reassemble the sampling configuration piece by piece, originating from the vacuum pump. After attachment of each piece of equipment, turn on the vacuum to check for leaks. Repeat this process until you're assured of no leaks.

   **Note**: The importance of assembling a leak-proof system is critical. A leaky system will result in erroneous analytical results.

5. To collect an air sample, the "dummy" Tenax™ tube is removed from the tube holder and a treated Tenax™ tube is **carefully** inserted into the tube holder for sample collection.

   **Note**: Polyethylene gloves must be worn when handling the Tenax™ tubes. Cross contamination of hydrocarbon on your hands, clothing, or immediate sampling area will result in erroneous results. When removing the Tenax™ tube from the storage container, keep the container inverted to minimize loss of helium.

6. Start the pump, verify air flow, and record the following parameters on the appropriate form:

   - Project/project number: required for project identification and billing
   - Site: project site location
   - Sampling location: be as specific as possible, e.g., vapor monitoring well in west site of cafeteria
   - Sampling time required: flow rates recorded during sampling are generally consistent. The desired air sample volume is 1 liter, therefore, it is necessary to calculate the time required to collect a 1 liter sample by the flow rate Q, the sampling time requirement can be calculated:

     Example:

     If the flow rate recorded = 52.0 cc/min.

     and the sample volume desired = 1 Liter

     then the sampling time is: (1 Liter/52.0 cc/min.) x (1000 cc./Liter) = 20 min

   - Ambient air temperature (°C): this value can be obtained from either a hand carried thermometer or the local weather station
   - Barometric pressure (mm Hg): This value can be obtained from either a hand carried barometer or the local weather station
   - Relative humidity (%): This value can be obtained from either a hand carried relative humidity gauge or the local weather station

- Dry gas meter reading: This value will be calculated by the laboratory staff

**Note**: It is very important to document activities or chemicals that may affect the results of your air sampling.

7. Record the following information on the appropriate form for proper analysis:
   - Instrument model no., e.g., Hi Flow Sampler Model Hfs 113A up
   - Pump serial no.: e.g., S/N 7126
   - Date(s) sampled
   - Time period sampled
   - Operator: your name
   - Calibrated by: your name
   - Tenax™ tube no.: number indicated on the side of the tube
   - Sample number: in chronological order from sample no. 1 through sample no. *n*. These numbers must be consistent with chain of custody form
   - Rotameter reading: this value can be obtained directly from the F &P Lab Crest Flowrator meter during actual sampling
   - Flow rate Q (mL/min): this value can be obtained from the calibration curve supplied with the F&P Lab Crest Flowrator meter

   **Note**: The rotameter reading and flow rates should be recorded at least 4 times during sampling. Be sure the calibration curve is consistent with: (a) the air curve; and (b) the float ball, (e.g., sapphire, black grass, etc.).

8. At the end of the sampling duration, remove the Tenax™ tube from the tube holder and carefully insert into the storage and transport container. Label the storage container with the appropriate sample identification number.
9. Rewrap the storage containers with Tenax™ tubes in bubble pack and place tubes in a cooler on ice for transport. (See "Tenax™ Tube Packaging Procedure")
10. Complete a Chain-of-Custody form according to applicable Shaw E & I technical SOPs and/or project-specific requirements. Place it in a plastic bag and then into the cooler with the Tenax™ tubes.
11. Samples should be transported immediately to the laboratory for analysis. All samples should be pre-scheduled for analysis with the lab to accommodate desired turnaround time.

    Package the samples as follows:
    - Use a cooler which can easily hold the tubes, wrapped in bubble pack, in a lengthwise manner.
    - Place a layer of ice in a plastic bag on the bottom of the cooler. Follow this with a layer of bubble pack.
    - Place the bag of tubes, containing the charcoal pack, which has been wrapped in bubble pack, in the cooler.
    - Place another layer of bubble pack on top of the tubes.

- Add two "ice-packs."
- The cooler should be sealed securely and shipped overnight.

The only exception to the above procedure occurs when shipping syringes. These should be sent at room temperature after being securely packed in a cardboard box.

# Attachment 3

## Analytical Equipment and Quality Assurance/Quality Control

The following text provides information on some of the analytical equipment used and basic QA/QC issues for soil gas surveys.

**Soil Gas Screening Using a Photoionization Detector (PID)**

A PID operates on the principle that VOCs, when subjected to a sufficient energy level of photoionizing energy will eject photons, which can be detected by special instrumentation. Each compound requires a specific level of energy (Photoionization Activation Energy), which must be reached before this effect (and therefore, the compound) can be detected. When using a PID meter at sites with unknown volatile chemicals of concern, PID instruments must be operated with a minimum 10.6 eV (+/-) lamp source (11.7 eV is recommended if available). For sites with known chemicals of concern, standard tables can be used to determine the minimum lamp energy required in your screening instrument.

**Note:** certain compounds, such as methane, cannot be detected by the commercially available field instruments (11.7 eV is currently the maximum). PIDs are also more sensitive to low temperatures and the presence of moisture than a flame ionization detector (FID). If wet field conditions are anticipated, the use of a FID should be considered.

Operation, maintenance, and calibration of the PID should be performed in accordance with the manufacturer's specifications and/or project-specific requirements.

**Soil Gas Screening Using a Flame Ionization Detector (FID)**

An FID will react to all VOCs. FIDs will also detect the presence of methane gas, which cannot be seen by field PIDs (methane has a photoionization activation energy level of 12.6 eV which is greater than the energy level field PIDs can generate). Methane gas is commonly present at landfills and in areas with active microbial activity such as wetlands.

To distinguish between a FID response to "target" VOCs and methane, an activated charcoal filter must be placed over the sampling port so that the air sample is drawn through it. Activated charcoal will adsorb VOCs but will not adsorb methane. A FID response which is still present when a charcoal filter is employed is an indication that methane rather than VOCs is present.

Operation, maintenance, and calibration of the FID shall be performed in accordance with the manufacturer's specifications and/or project-specific requirements.

**Soil Gas Screening Using a Field Gas Chromatograph (GC)**

Field GCs are slower and more costly to operate than the readily available PID and FID meters, but under the right conditions may provide "real-time" analysis which can substitute for the slower and more costly laboratory analysis. The data quality objectives of the project must be considered to determine if the additional time and expense of field GC operation can be justified for your project.

It is important to note that most field GCs employ a PID energy source to detect VOCs. When employing a PID GC, the PID technology listed above applies.

**Quality Assurance/Quality Control**

Emphasis should be placed on thoroughly decontaminating sample collection equipment prior to use, and making sure that there is no cross-contamination or sampling equipment components that may introduce contamination. Sample containers will typically be decontaminated and verified by the manufacturer or supplier before arriving at the job site.

One duplicate sample should be collected for every ten soil gas samples collected. Soil gas survey screening data should be recorded and compared; generally, duplicate sample values should be consistent to plus or minus 20 percent.

Every 10 samples, perform three successive measurements of a single sample as a check on single sample reproducibility.

Since the intent of soil gas surveying is for screening purposes, and since significant matrix effects are not anticipated, no matrix spikes need to be performed.

**Blanks**

If PID or FID field screening equipment is being used, collect an equipment blank as follows:

- Connect zero air source (99.9999% pure) with needle valve attached to sampling manifold (without the pump) with sidearm tee
- Make sure needle valve is closed; slowly open zero gas supply valve
- Flush sampling manifold with zero air for about 5 minutes
- To sample zero air, insert the PID or FID sample tubing into the sidearm tubing
- Allow the equipment to draw in the gas for several seconds prior to taking a reading. The maximum instrument response should be recorded. Record instrument response in the Field Logbook Table and Soil Gas Screening Results Log.

If portable GC analysis is being performed, collect an equipment blank by passing zero air through the pipe probe manifold and into a Tedlar bag or glass bomb, as follows:

- Connect zero air source with needle valve attached to Tedlar bag or glass bomb
- Make sure needle valve is closed; slowly open zero gas supply valve
- Purge with zero air for at least 5 minutes
- Collect the blank sample in the Tedlar bag or glass bomb. Isolate sample container by closing valve connection to sample collection device

**Calibrations**

If field screening equipment is being used, calibrate the equipment in accordance with manufacturer's instructions. PID and FID field instruments should be operated and calibrated to yield "total organic vapors" in ppm (v/v) as benzene unless the user is screening for a specific compound of concern. In the latter case, the instrument can be calibrated for representative response to the target compound.

If a portable GC is being used, it must be calibrated with at least two standard concentrations that bracket the expected concentration range of the sample analytes. If the sample concentration exceeds the calibration range, the results should be considered as "estimated". Alternatively, the sample may be diluted to bring the concentration into the calibration range, or a higher concentration standard may be employed. The instrument calibration shall be checked/adjusted no less than once every 10 analyses, or daily, whichever occurs sooner. Calibration results should be saved by taping into the Field Notebook or placing in a separate binder.

# SOP T-GS-014

# Standards for Drilling Equipment, Development Equipment, Heavy Equipment, and Well Material Decontamination

Prepared By: ______________________ Date: ______________

Neil Hey
Sr. Geologist

Authorized By: ______________________ Date: ______________

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Discipline Lead

# STANDARD OPERATING PROCEDURE

**Subject:** **Drilling Equipment, Development Equipment, Heavy Equipment, and Well Material Decontamination**

## 1. PURPOSE

This procedure provides the standard practice for decontamination of drilling equipment, well development equipment, heavy equipment, and well construction materials. The procedure includes the minimum required steps and quality checks that employees and subcontractors are to follow when performing the subject tasks.

This procedure may also contain guidance for recommended or suggested practice that is based upon collective professional experience. Recommended practice goes beyond the minimum requirements of the procedure, and should be implemented when appropriate.

## 2. SCOPE

Geosciences Standard Operating Procedure (SOP) T-GS-014 describes standards for decontamination of drilling equipment, development equipment, heavy equipment, and well construction materials. The SOP also describes how such decontamination will be conducted and documented for projects executed by Shaw Environmental & Infrastructure, Inc. (Shaw E & I). This standard is specific to decontamination of non-sample-contacting equipment and well materials used during work activities at potentially contaminated sites. Proper decontamination is necessary to minimize the spread of contaminants within a project site and from site to site, to reduce the potential for worker exposure by means of contact with contaminated equipment, and to improve sample data quality and reliability.

This SOP addresses technical requirements and required documentation. Responsibilities of individuals performing the work are also detailed. Additional project-specific requirements for drilling equipment, development equipment, heavy equipment, and well material decontamination may be developed, as necessary, to supplement this procedure and address project-specific conditions and/or objectives.

This standard is applicable only at sites where chemical (organic and inorganic) wastes are a concern and is not intended for use at radioactive or mixed (chemical and radioactive) waste sites. This procedure is not intended to address decontamination of sample-contacting equipment. Decontamination of sample-contacting equipment is covered under other Shaw E & I technical SOPs.

## 3. REFERENCES (STANDARD INDUSTRY PRACTICES)

Decontamination procedures for non-sample-contacting equipment and well materials should follow accepted industry practices. These are included in the latest version of the following American Society for Testing and Materials (ASTM) standard:

| | |
|---|---|
| ASTM D 5088-90[a] | Standard Practice for Decontamination of Field Equipment Used at Nonradioactive Waste Sites |

[a] Current edition approved June 29, 1990.

Additional reference materials, which are useful for planning and conducting non-sample-contacting equipment and well material decontamination, include the following:


- Driscoll, Fletcher G. 1986, *Groundwater and Wells*, Johnson Filtration Systems, Inc., St. Paul Minnesota.
- U.S. Army Corp of Engineers, 1998, "General Equipment Decontamination Procedures, Chapter 9," *Removal of Underground Storage Tanks (EM-1110-1-4006)*, Washington D.C., September 30.
- U.S. Environmental Protection Agency, 1987, *EPA Compendium of Superfund Field Operations Methods*, EPA 540/P-87/001a, OSWER 9355.0-14.


## 4. DEFINITIONS

The following definitions are applicable to conducting decontamination of drilling equipment, development equipment, heavy equipment, and well materials, and are used in this SOP.

- **Control Rinse Water**—Water used for equipment washing and rinsing having a known chemistry. This can include treated potable water dispensed from any municipal water system (tap water). An untreated potable water supply may be used as a substitute for tap water if the water does not contain any chemicals of concern.
- **Decontamination**—The process of removing or reducing to a known level, undesirable physical or chemical constituents, or both, from non-sample-contacting equipment and well materials.
- **Non-Phosphate Detergent**—A standard brand of phosphate-free, laboratory-grade detergent such as "Alconox" or "Liquinox."
- **Non-Sample-Contacting Equipment**—Related equipment associated with the field or sampling effort, that does not directly contact soil or water samples, but does contact potentially contaminated media. Such equipment can include, but is not limited to, augers, drilling rods, drill bits, drill pipe, well development pumps, bailers, surge blocks, geophysical tools, excavation machinery, etc.
- **Sample-Contacting Equipment**—Equipment that comes in direct contact with a sample or portion of a sample that will undergo chemical analyses or physical testing. Such equipment can include, but is not limited to, bailers, split spoon samplers, soil gas sampling probes, etc.

## 5. RESPONSIBILITIES

### 5.1. Procedure Responsibility

The Geosciences Discipline Lead is responsible for the development, maintenance, and revision of this procedure. Any questions, comments or suggestions regarding this technical SOP should be sent to the Geosciences Discipline Lead. The Geosciences Discipline Lead's location and associated contact information can be found on the Insider.

### 5.2. Project Responsibility

Shaw E & I employees conducting this type of decontamination, or any portion thereof, are responsible for meeting the requirements of this SOP. Shaw E & I employees conducting field technical review of decontamination plans and field efforts are also responsible for following the appropriate portions of this SOP. This SOP and project work plans should be reviewed prior to implementing the decontamination activities at the project site.

For those projects where non-sample contacting equipment and well materials decontamination are conducted, the Project Manager, or designee, is responsible for ensuring that decontamination activities are conducted in accordance with this and other appropriate procedures. Project participants are responsible for documenting information in sufficient detail to provide objective documentation that the requirements of this SOP have been met. Such documentation shall be retained as project records.

## 6. PROCEDURE

This section provides the basic procedures to be followed for decontamination of drilling equipment, development equipment, heavy equipment, and well materials. Project-specific work plans will provide specific information regarding the following:

- Types of equipment requiring decontamination under this SOP
- Location of the decontamination station
- Types and/or specifications for materials to be used in the fabrication of the decontamination station
- Types of materials and additional details on the procedures to be used in the decontamination process

All personnel associated with either the fabrication of the decontamination station or the decontamination of the non-sample-contacting equipment or well materials must read this SOP, other appropriate Shaw E & I SOPs, and the project work plans prior to implementation of related decontamination activities. Information and requirements for the decontamination of any and all sample-contacting equipment is presented in other Shaw E & I technical SOPs.

Collection of equipment rinsate or wipe samples during or after decontamination activities may be required. Such requirements, including timing and frequency of sampling will be specified in the project work plans. Procedures for collection and handling of the samples may be found in applicable Shaw E & I technical SOPs and the project work plans.

### 6.1. Health and Safety

Health and safety procedures should be implemented based on the site-specific decontamination protocol. Health and safety procedures should take into consideration the potential use of dangerous high-pressure washers. Personnel conducting non-sample-contacting equipment and well material decontamination should understand and comply with all applicable Shaw E & I and project-specific health and safety requirements/procedures.

### 6.2. Decontamination Facility

A decontamination station will be set up in an area designated exclusively for decontamination of drilling equipment, development equipment, heavy equipment, and/or well materials. The location of the station should be specified in the project work plans. All decontamination activities will be conducted within the station.

At a minimum, the station will be constructed such that all rinsates, liquid spray, soil, debris, and other decontamination wastes are fully contained and may be collected for appropriate waste management and disposal. The station may be as simple as a bermed, impermeable polyethylene sheeting, of sufficient thickness (so as not to be punctured), with an impermeable sump for collecting rinse water. More sophisticated designs involving self-contained metal decontamination pads in combination with bermed polyethylene sheeting may also be used, depending on project-specific requirements. These requirements along with specific equipment and construction specifications for the decontamination station should be provided in the project work plans.

## 6.3. Decontamination of Down-hole Drilling and Development Equipment

All down-hole drilling and development equipment (including but not limited to drill pipe, drive casing, drill rods, bits, tools, bailers, surge blocks, etc.) will be thoroughly decontaminated before mobilization onto each site and between each boring or well at a project site. Procedures for decontamination of down-hole pumps are detailed in Section 6.4. Decontamination will be performed in accordance with this SOP and the project work plans.

The minimum basic steps for drilling and development equipment decontamination are as follows:

- Appropriate personal protective equipment (as specified in the project work plans) must be worn by all personnel performing decontamination, in order to limit worker exposure.
- Initially, scrape or brush any caked drill cuttings, soil, or other material from the equipment. Containerize the scrapings for appropriate disposal.
- Thoroughly spray and wash the equipment with heated control rinse water (potable water) using a high-pressure washer or steam cleaner. Alternatively, hand-wash the equipment with a non-phosphate detergent solution using a brush.
- Rinse the washed equipment with potable water.
- Place the decontaminated equipment (such as drill pipe, drive casing, bits, tools, bailers, surge block, etc.) onto clean plastic sheeting or drying racks to prevent contact with contaminated soil or water and allow it to air dry. If the equipment is not used immediately, cover it or wrap it in clean plastic sheeting to minimize airborne contamination.
- Document the decontamination activities on the appropriate form(s), as specified in the project work plans.

## 6.4. Decontamination of Pumps Used for Well Development and Purging

All down-hole pumps used for well development or non-dedicated pumps used for purging prior to well sampling shall be decontaminated between each well. Decontamination will be performed in accordance with this SOP and the project work plans.

The minimum basic steps for non-dedicated pump decontamination are as follows:

- Appropriate personal protective equipment (as specified in the project work plans) will be worn by all personnel performing decontamination, in order to limit worker exposure.
- Submerge the pump and associated hose, piping, or tubing in a clean wash basin filled with a non-phosphate detergent solution.
- Operate the pump for a minimum of ten minutes; recycle the detergent solution through the pump and hose, piping, or tubing back into the wash basin.
- Clean all exterior surfaces of both the pump and hose, piping, or tubing with a brush and clean cloth.
- Submerge the pump and hose, piping, or tubing in a clean rinse basin filled with control rinse water (potable water).
- Operate the pump for a minimum of 10 minutes; discharge the rinse water through the pump and hose, piping, or tubing directly into the appropriate container. The discharged rinse water at the end of the 10 minute time period should be checked and not show visible evidence of remaining non-phosphate detergent solution.

- Place the decontaminated pump and associated materials onto clean plastic sheeting or drying racks to prevent contact with contaminated soil or water and allow it to air dry. If the pump is not used immediately, cover it or wrap it in plastic sheeting to minimize airborne contamination.
- Document the decontamination activities on the appropriate form(s), as specified in the project work plans.

### 6.5. Decontamination of Heavy Equipment

Heavy equipment (e.g., drill rigs, development rigs, backhoes, and other non-sample-contacting equipment) will be decontaminated between drilling or excavation/construction sites and prior to entering or leaving an exclusion zone. Decontamination will be performed in accordance with the project work plans.

The minimum basic steps for heavy equipment decontamination are as follows:

- Appropriate personal protective equipment (as specified in the project work plans) will be worn by all personnel performing decontamination, in order to limit worker exposure.
- Equipment caked with drill cuttings, soil, or other material will be initially scraped or brushed. The scrapings will be containerized and appropriately disposed of.
- Thoroughly spray and wash the equipment with heated control rinse water (potable water) using a high-pressure washer or steam cleaner.
- Rinse the washed equipment with potable water.
- During the decontamination effort, fluid systems (e.g., hydraulic fluid lines, air lines, brake lines, etc.) should be routinely inspected for any leaks or problems, which may potentially result in an inadvertent release at the site, thereby contributing to the volume of waste or contamination. Any identified problems should be repaired immediately and documented on the appropriate form(s).
- Document the decontamination activities on the appropriate form(s), as specified in the project work plans.
- Between boreholes or excavations at the same project site, the back-end of the drill rigs or backhoes should be washed with potable water until surfaces are visibly free of soil buildup or drilling fluids.

### 6.6. Decontamination of Well Materials

Well materials (including, but not limited to, well casing, well screens, centralizers, end caps, etc.) shall be decontaminated prior to use in constructing a well. Decontamination will be performed in accordance with this SOP and the project work plans. If factory-sealed and cleaned materials are used, no decontamination will be necessary, provided that certification of decontamination is submitted with the materials.

The minimum basic steps for well material decontamination are as follows:

- Appropriate personal protective equipment (as specified in the project work plans) will be worn by all personnel performing decontamination, in accordance with the work plans.
- Thoroughly spray and wash the materials with heated control rinse water (potable water) using a high-pressure washer or steam cleaner.
- Rinse the washed equipment with potable water.

- Place the decontaminated materials onto clean plastic sheeting or drying racks to prevent contact with contaminated soil or water and allow it to air dry. If the materials are not used immediately, cover them or wrap them in plastic sheeting to minimize airborne contamination.
- Document the decontamination activities on the appropriate form(s), as specified in the project work plans.

## 7. ATTACHMENTS

None.

## 8. FORMS

None.

# SOP T-GS-017
# Standards for Conducting Hollow Stem Auger Drilling

Prepared By: ______________________ Date: ______________
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# STANDARD OPERATING PROCEDURE

**Subject:** **Standards for Conducting Hollow Stem Auger Drilling**

## 1. PURPOSE

This procedure provides the standard practice for hollow stem auger drilling. This procedure includes the minimum required steps and quality checks that employees and subcontractors are to follow when performing the subject task.

This procedure may also contain guidance for recommended or suggested practice that is based upon collective professional experience. Recommended practice goes beyond the minimum requirements of the procedure, and should be implemented when appropriate.

## 2. SCOPE

Geosciences Standard Operating Procedure (SOP) T-GS-017 describes standards for hollow stem auger drilling, and discusses how such drilling activities will be conducted for projects executed by Shaw Environmental & Infrastructure, Inc. (Shaw E & I). The SOP addresses technical requirements and required documentation. Responsibilities of individuals performing the work are also detailed. Additional project-specific requirements for hollow stem auger drilling may be developed, as necessary, to supplement this procedure and address project-specific conditions and/or objectives.

## 3. REFERENCES (STANDARD INDUSTRY PRACTICES)

Hollow stem auger drilling activities should follow accepted industry practices. These industry practices are as presented in the latest version of the following ASTM Standards:

| | |
|---|---|
| ASTM D 5784-95[1] | Standard Guide for Use of Hollow Stem Augers for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices |
| ASTM D 6286-98[2] | Standard Guide for Selection of Drilling Methods for Environmental Site Characterization |

[1] Current edition approved October 10, 1995, reapproved 2000
[2] Current edition approved August 10, 1998.

Additional reference materials, which are useful for planning and conducting hollow stem auger drilling, include the following:


- Aller, Linda, B.W. Truman, G. Hackett, R.J. Petty, J.H. Lehr, H. Sedoris, D.M. Nelson, J.E. Denne, 1989, *Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells*, National Water Well Association, Dublin, Ohio.
- Driscoll, Fletcher G., 1986, *Groundwater and Wells*, Johnson Division, St. Paul, Minnesota.
- Shuter, Eugene, W.E. Teasdale, 1989, "Application of Drilling, Coring and Sampling Techniques to Test Holes and Wells," *Techniques of Water Resource Investigations*, U.S. Geological Survey, Book 2 Chapter F1.
- U.S. Environmental Protection Agency (EPA), 1986, *RCRA Ground-Water Monitoring Technical Enforcement Guidance Document*, OSWER-9950.1.

## 4. DEFINITIONS

The following definitions are applicable to hollow stem auger drilling and this SOP.

- **Cleanout depth**—The depth to which the end (bit or core barrel cutting end) of the drill string has reached after an interval of cutting. The cleanout depth (or drilled depth as it is referred to after clean-out of any sloughed material in the bottom of the borehole) is usually recorded to the nearest 0.1 feet (0.03 m).
- **Drawworks**—A power-driven winch, or several winches, usually equipped with a clutch and brake system(s) for hoisting or lowering a drill string or sampling device.
- **Drill hole, Boring, or Borehole**—A cylindrical hole advanced into the subsurface by mechanical means (e.g., drilling).
- **Drill string**—The complete hollow stem auger assembly under rotation including augers, bit, sample barrel or core barrel, and/or removable center plug. The total length of the auger assembly is used to determine drilling depth by referencing the position of the top of the auger assembly to a fixed datum near the ground surface.
- **Hoisting line or Drilling line**—Wire rope used on the drawworks to hoist and lower loose augers, the removable center plug, sampling rods and sample barrel, or the downhole sampling hammer assembly.
- **Hollow Stem Auger Drilling**—A drilling method using rotating auger flights (typically in 5-foot joints) with a bit on the bottom of the lead flight (sometimes called the "lead auger"). The flights consist of a hollow pipe and an outer spiral plate, which when rotated, forces soil cuttings upward along the borehole wall to the surface. The auger string is advanced by rotation, with downward pressure exerted by the rig, forcing the bit to cut the soil at the bottom and direct cuttings to the augers. Hollow stem augers typically range from 6 to 14 inches in diameter.

  A retractable plug with a pilot bit is placed at the bottom of the auger string to prevent cuttings from entering the hollow stem. When the plug is retracted, a sampler may be sent through the hollow center to sample soil at the bottom of the borehole without requiring the augers to be removed. A wireline sampler may also be attached to the inside of the lead auger for coring as the borehole is advanced.

  The hollow stem auger method is commonly used for drilling and sampling of soil borings, collection of soil gas and screening-level water samples, and installation of some smaller diameter wells for environmental projects. The well casing string may be placed through the hollow stem.

  This drilling method has advantages over other drilling techniques in certain circumstances, and disadvantages in others. This method is highly suitable for unconsolidated and consolidated fine-grained soils. Hollow-stem auger drilling can achieve the most rapid rates of penetration in soft, sticky, clay-dominated soils. However, coarse and consolidated gravels and hard bedrock may be too dense for adequate drill penetration. Soil cuttings are typically disaggregated and remolded, making bedding, fabric, and soil property determination difficult.

  Although hollow stem auger methods allow for the collection of driven soil samples and soil cores, these types of soil samples may be more efficiently collected using direct push methods. Hollow stem auger soil sampling methods are typically utilized when soil borings and monitoring wells are required at the same location, or when the depth or soil types limit the effectiveness or practicality of direct push methods.

  The most reliable method for logging of soils during hollow stem auger drilling is to collect relatively intact samples through the hollow stem. An advantage of the hollow stem auger method is that soil samples can be readily obtained from the bottom of the hole without requiring the removal of the auger string (unlike with air or mud rotary methods).

The hollow stem auger method may be used to install monitoring wells (limited by diameter), as it allows good depth control and the auger can be progressively pulled as well construction materials are added to the borehole. The methodology may also be used to drill out monitoring wells for abandonment.

Another advantage of the hollow stem auger method is that air or mud are not required as circulating media. Therefore, there is limited to no potential for flushing of soil samples collected for chemical analyses, and a reduction in volumes of investigation-derived wastes requiring costly handling and management procedures. Auger-type rigs can be significantly smaller than other types of rigs, making them suitable for some jobs with significant space constraints, including overhead clearance.

One limitation of the hollow stem auger method is a typical maximum drilling depth of 100 to 200 feet (may be less depending on soil conditions). Another limitation is that the method tends to smear clays along the borehole wall, creating a "skin" that has to be removed through well development.

- **Mast**—A load-bearing structure on a drilling rig used for supporting the rotation head, pulldown hydraulics, hoisting lines, and so forth. It must be constructed to safely carry the expected loads encountered in drilling and completion of wells of the diameter and depth for which the rig manufacturer specifies the equipment. To allow for contingencies, it is recommended that the rated capacity of the mast should be at least twice the anticipated weight load or normal pulling load.

## 5. RESPONSIBILITIES

### 5.1. Procedure Responsibility

The Geosciences Discipline Lead is responsible for the development, maintenance, and revision of this procedure. Any questions, comments, or suggestions regarding this technical SOP should be sent to the Geosciences Discipline Lead. The Geosciences Discipline Lead's location and associated contact information can be found on the Insider.

### 5.2. Project Responsibility

Employees planning or supervising hollow stem auger drilling are responsible for meeting the requirements of this procedure. Employees conducting technical review or oversight of hollow stem auger drilling activities are also responsible for following appropriate portions of this SOP.

For those projects where hollow stem auger drilling methods are conducted, the Project Manager, or designee, is responsible for ensuring that the drilling activities are conducted in accordance with this and other applicable procedures. Project participants are responsible for recording information in sufficient detail to provide objective documentation (i.e. field notes, logs, forms, reports, etc.) that the requirements of this SOP have been met. Such documentation should be retained as project records.

## 6. PROCEDURES (TECHNICAL REQUIREMENTS AND STANDARDS)

This section contains basic requirements and procedures for hollow stem auger drilling. As stated above, the hollow stem auger method is commonly used for soil sampling and monitoring well installation on environmental projects.

The selection and implementation of hollow stem auger drilling techniques must incorporate site-specific conditions and requirements. Consequently, the project-specific work plans should identify the following:

- The purpose of each borehole (e.g., to install a monitoring well, to collect soil samples, to conduct soil vapor sampling, etc.)
- Specific methodology for drilling, including equipment to be utilized and cuttings/fluid containment requirements
- Specific locations, depths, and diameters of boreholes
- Type of sampling and/or logging of boreholes to be conducted
- Details of mobilization/demobilization and decontamination of equipment
- Appropriate health and safety guidelines and personnel protective equipment requirements
- Additional procedures or requirements beyond those covered in this SOP

## 6.1. Basic Equipment Requirements and Considerations

Basic equipment requirements and considerations are as follows:

- Rigs should be of sufficient horsepower, torque, and hoisting capacity to drill boreholes of anticipated diameter to anticipated maximum depths, as specified in the project work plans. Each rig should be equipped with a pump capable of injecting water and/or grout.
- Drill rigs should preferably be self-propelled or capable of accessing anticipated site field conditions.
- Rigs used for hollow stem auger drilling should have a sampling drive hammer system attached to the mast assembly. Mechanical or automatic hammer systems are preferable; however, downhole hammers and free-falling hammers controlled with a heavy hemp rope and a "Cat-Head" are acceptable and also used. The use of retrofitted drilling rigs with anything but a manufacturer-supplied sampling drive hammer assembly should not be allowed. A rig that requires personnel to climb onto the mast to attach or detach the hammer is unacceptable for safety reasons.
- Monitoring, extraction, or injection wells may be constructed through the interior portion of the hollow stem augers. A minimum clearance of 2 inches between the outer wall of the well casing and the borehole wall is preferred (greater annular clearance usually results in fewer well construction difficulties).
- Only Teflon™-based thread compound may be used to lubricate auger bolts or threaded portions of the drill string assembly. No other compound may be used unless otherwise directed in the project work plans. Such directed use in the project work plans should take into account applicable regulatory agency requirements and/or approval.
- Drill bit teeth and associated hard facing on the auger flights should be in good or "near new" condition. Proper types of bits, augers, and sampling string apparatus are to be available at the sizes and lengths needed to properly drill the desired diameters in the formation(s) to be encountered.
- During drilling, no additives (except water) may be added to the borehole and interior portion of the auger string without appropriate regulatory approval and/or concurrence with project-specific requirements. Only "clean" water may be added to the borehole and interior portion of the auger string, and only after discussion with and approval by the rig geologist. The rig geologist is

responsible for ensuring that drilling and sampling activities are conducted in a manner that is consistent with applicable Shaw E & I policies and procedures, regulatory agency requirements, and project-specific requirements/procedures.

## 6.2. Health and Safety Requirements

Prior to initiating drilling activities, applicable Shaw E & I and project-specific safety requirements must be reviewed by Shaw E & I site personnel and subcontractors. This review is conducted to familiarize these individuals with specific hazards associated with the site and drilling activities, as well as with health and safety procedures associated with the operation and maintenance of drilling equipment. Such information may be found in the project health and safety plan and other applicable Shaw E & I policies and procedures, including HS316 "Drill Rig Operations." Additional health and safety requirements are presented in the following text.

- Tailgate Safety Meetings should be held in the manner and frequency stated in the project health and safety plan. All Shaw E & I and subcontractor personnel at the site should have appropriate training and qualifications, as specified by the project health and safety plan. Documentation should be kept readily available in the project files on site.
- During drilling, all personnel within the exclusion zone should pay close attention to all rig operations. Rotating drilling tools can catch or snag loose clothing causing serious injury. Sampling hammers can often create pinch points and/or crush hazards. Improper handling of augers can also create potential pinch points (hands and feet), crush hazards, and back strain.
- Clear communication signals must be established with the drilling crew, since verbal communication may not be heard during the drilling process. Hearing protection is usually mandatory around drill rigs.
- The entire crew should be aware of the need to inform the rig geologist when any unforeseen hazard arises or when anyone is approaching the exclusion zone.

## 6.3. Drilling Site Mobilization

Basic site preparation and mobilization requirements and procedures are as follows:

- All drilling and sampling equipment should be decontaminated before drilling as specified in applicable Shaw E & I technical SOPs and/or project-specific requirements/procedures.
- The driller and the rig geologist should inspect the drilling equipment for proper maintenance and appropriate decontamination. All clutches, brakes, winches, and drive heads should be in proper working order. All cables and hydraulic hoses should be in good condition. All auger connections, associated auger bolts, sampling rod joints, and plug rod joints should be in good condition with no significantly worn threads, cracked or worn joint connections, or other signs of excessive wear.
- Any excessive leakage of fluids from the rig should be immediately repaired and appropriate portions of the rig decontaminated again before it is allowed to remobilize to the site.
- The logistics of drilling, logging, sampling, cuttings/fluid containment, and/or well construction should be determined before mobilizing. The site should be prepared in accordance with the project work plans.
- Before mobilization, the Site Superintendent and the rig geologist should assess the drilling site. This assessment should identify potential hazards (e.g., slip/trip/fall, overhead, soft or sloping ground, etc.) and determine how drilling operations may impact the environment (e.g., dust, debris, noise). Potential hazards should be evaluated and corrected, or the borehole location changed or shifted in accordance with the project work plans.

- The Site Superintendent, or designee, should ensure that all identifiable underground and overhead utilities around the drilling location have been marked and properly noted. The borehole location should be properly cleared as per the project work plans. At a minimum, copies of the site clearance documents should be kept on-site in a common accessible location.

- Overhead obstructions such as trees, tall shrubs, and building overhangs should be evaluated and avoided for safety reasons, as they can impair the proper function of drill mast components. .

- Once site preparation is completed, the rig is mobilized to the site and positioned over the identified borehole location. The rig should then be leveled with a set of hydraulic pads at the front and rear of the equipment. Once the rig is leveled, the mast should be raised slowly and carefully to prevent tipping or damaging the rig and to avoid hitting any obstructions or hazards.

- Appropriate barriers and markers should be in place prior to drilling, as per the project health and safety plan. Visqueen (plastic) may be required beneath the rig and around the auger area. When plastic is placed in the general vicinity of the rotating augers, extra precaution may be necessary to make sure that the plastic does not pose a safety hazard or unwarranted distraction or nuisance to the drill crew.

- Appropriate containment for cuttings and other investigation-derived waste should be set up on site prior to the commencement of drilling.

### 6.2 Basic Drilling Requirements and Procedures

Basic hollow stem auger drilling requirements and procedures are as follows:

- Immediately prior to drilling, all safety sampling and monitoring equipment will be calibrated as per manufacturer's specifications and appropriate project-specific requirements/procedures. The rig geologist should inform the driller of the appropriate equipment (e.g., cookie cutter, etc.) to be used for penetrating the specific surface cover (e.g., asphalt, concrete, cement, etc.) at the drilling location.

- In the event of breaking ground where a shallow subsurface hazard may exist (e.g., unidentifiable utility, trapped vapors, etc.), the driller should be informed of the potential hazard. Drilling of the surface hole should commence slowly to allow continuous visual inspection and, if necessary, probing. The shallow portion of the hole may be hand excavated, or hand augered, to the anticipated maximum depth of any suspected obstructions. Specific requirements for such subsurface hazard clearance should be contained in the project work plans.

- Once the surface cover is removed, and the subsurface hazard clearance completed (if required), hollow stem auger drilling of the borehole may commence.

- During hollow stem auger drilling operations, as the borehole is advanced, the rig geologist will generally do the following:

  - Observe and monitor rig operations
  - Conduct all health and safety monitoring and sampling, and supervise health and safety compliance
  - Prepare a boring log from cuttings or soil samples as per applicable Shaw E & I technical SOPs and project-specific requirements
  - Document drilling progress and other appropriate observations on appropriate forms
  - Supervise the collection and preparation of any soil, soil vapor, or groundwater samples

The rig geologist should not leave the drill site whenever drilling operations are conducted and the borehole is being advanced. A Shaw E & I employee should be present at all times when subcontract personnel are on the project site.

- As drilling progresses, the rig geologist should observe and be in frequent communication with the driller regarding drilling operations. Conditions noted should include relative rates of penetration (as indicated by fast or slow drilling), rotation speeds, chattering and bucking of the rig, hard or sticky drilling, drilling refusal, etc. These conditions, including penetration rates, should be recorded on the appropriate logs and forms as per applicable Shaw E & I technical SOPs and/or the project work plans. Drilling should not be allowed to progress faster than the rig geologist can adequately observe conditions, compile logs, and supervise safety and sampling activities.

  The rig geologist should also observe the fitting and placement of auger connections, as well as the make-up and tightening of drill rods for the center plug, and/or sampling string. Any observed drilling problems and causes, including significant down time, should be recorded on the appropriate forms.

  Cutting and fluid containment during drilling should be observed and supervised by the rig geologist as per the project work plans.

- The rig geologist should continue to oversee or conduct appropriate health and safety sampling and monitoring during drilling. If any potentially unsafe conditions are evident from drilling observations or health and safety monitoring, the rig geologist may suspend drilling operations at any time and take appropriate actions, in accordance with the project health and safety plan. In the event of a suspension of drilling activities, the following actions are required:

  – The Site Superintendent must be informed of the situation

  – Appropriate corrective action must be implemented before drilling may continue

  – The observed problem, suspension, and corrective action must be entered on the appropriate forms

- During drilling, the rig geologist will compile a boring log in accordance with applicable Shaw E & I technical SOPs. The boring log should include the following:

  – Borehole location

  – Name of the drilling company and driller

  – Dates and times of drilling events, including when drilling began, the total depth and when it was reached, intermediate milestones, and any changes in equipment (e.g., over ream auger sizes, etc.)

  – Relative drilling rate(s) and presence of drill chatter (these parameters may aid in confirming lithologic boundaries)

  – Lithologic data and descriptions from cuttings or soil samples including depths, frequency, and quality

  – Sampling depths and recovery of soil samples

  – Premature total depth due to refusal and the cause of refusal (if known)

  – Any other observed drilling conditions such as observed groundwater levels, zones of hard or soft drilling, flowing sands etc.

- The rig geologist will also enter pertinent information on the appropriate forms (in addition to the boring log), as required in the project work plans. This information includes but is not limited to the following:
  - The dates and times of drilling events including when drilling began, the total depth and when it was reached, intermediate milestones, and any changes in equipment (e.g., over ream auger sizes, etc.)
  - The dates, times, and causes of any significant down time
  - Premature total depth due to refusal and the cause of refusal
- Subsurface soil sampling with a drive sampler can be done at discrete intervals while drilling with hollow stem auger methods. Though sample breaks are commonly made at five foot intervals (when new flights are added to the auger string), drive sampling can be conducted at any depth interval. The sampling depths or intervals should be specified in the project work plans. Driven samples typically require the removal of the drive head and extraction of the center plug to allow the insertion of a sampling string. The sampler is advanced (driven or pushed) beyond the bit to obtain a relatively undisturbed sample. Drive sampling conducted during hollow stem auger drilling should follow requirements in appropriate Shaw E & I technical SOPs and/or the project work plans.
- Soil organic vapor (SOV) sampling may be conducted in the vadose zone at discrete intervals during hollow stem auger drilling. This is done by stopping at the desired depth and driving a sample probe through the hollow stem into the soil ahead of the bit, and then collecting a vapor sample. The sampling should be supervised by the rig geologist following applicable Shaw E & I technical SOPs and/or project-specific requirements/procedures.
- Direct push groundwater samples can be obtained at discrete intervals during hollow stem auger drilling. This is done by stopping at the selected interval or zone and advancing a direct push sampler beyond the lead auger to retrieve a water sample. The direct push groundwater sampling should be supervised by the rig geologist following applicable Shaw E & I technical SOPs and/or project-specific requirements/procedures.
- If the borehole is to be abandoned once drilling is completed, the abandonment should follow procedures outlined in applicable Shaw E & I technical SOPs and the project work plans. The abandonment will be supervised by the rig geologist.
- Hollow stem auger boreholes may be used for monitoring, extraction, or injection well installation. If a monitoring, extraction, or injection well is to be installed in the borehole, installation should follow appropriate Shaw E & I technical SOPs and project-specific requirements/procedures. The well installation will be supervised by the rig geologist. In the process of constructing a well, the auger string should be extracted from the borehole using the rig's hydraulics, or hoisting line; providing a vertical lift with as little rotation of the auger string as possible. Rotation of the auger string while constructing wells should be minimized in order to avoid damaging or lifting the well casing.

## 6.4. Demobilization

After drilling, sampling, and well installation or borehole abandonment is completed, the augers and rods are laid down, the mast is lowered, and the rig is moved off of the location. Demobilization/site restoration will be supervised by the rig geologist or appropriate designee. Additional demobilization requirements/procedures are as follows:

- All debris generated by the drilling operation should be removed and appropriately disposed of.
- The site should be cleaned, the ground washed as necessary, and the site conditions restored as specified by the project work plans.

- All abandoned borings should be topped off and completed as specified in the project work plans. All wells should also have their surface completions finished in accordance with the project work plans.
- Any hazards remaining as a result of drilling activities should be identified, and appropriate barriers and markers should be put in place, in accordance with the project health and safety plan.
- All soil cuttings, drilling fluids, and decontamination fluids should be properly contained, clearly labeled, and maintained, in compliance with the project work plans and/or other applicable local, state, and federal requirements and regulations.

## 6.5. Technical Review

All hollow stem auger drilling specifications, procedures, and results (e.g., reports, forms, etc.) should undergo technical review. It is recommended that the technical reviewer also provide review/oversight of the actual field implementation of the hollow stem auger drilling activities. This should include aiding in troubleshooting drilling problems. The technical reviewer should be an experienced senior geologist or hydrogeologist. At a minimum, the technical reviewer should be a person capable of planning and supervising hollow stem auger drilling and associated sampling and well installation programs. Individuals needing assistance in finding qualified technical reviewers may consult internal Shaw technical listings for experts in drilling or hollow stem auger drilling.

Any issues raised during the technical review shall be resolved between the reviewer and the staff planning, conducting, or preparing results of hollow stem auger drilling activities as follows:

- Comments/issues raised relative to planning and developing detailed procedures for hollow stem auger drilling should be resolved before mobilization and drilling commences
- Comments/issues raised relative to results of drilling activities should be resolved before external (i.e., outside of Shaw E & I) use or submission of the results.

The technical review comments and issues, and corresponding resolution, shall be documented and filed with the project records. The records should be maintained until project close-out.

# 7. ATTACHMENTS

None.

# 8. FORMS

None.

# SOP T-GS-021
# Standards for Conducting Direct Push Drilling and Soil Sampling

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# STANDARD OPERATING PROCEDURE

**Subject:** **Standards for Conducting Direct Push Drilling and Soil Sampling**

## 1. PURPOSE

This procedure provides the standard practice for direct push drilling and soil sampling. The procedure provides the minimum required steps and quality checks that employees and subcontractors are to follow when performing the subject task.

This procedure may also contain guidance for recommended or suggested practice that is based upon collective professional experience. Recommended or suggested practice goes beyond the minimum requirements of the procedure and should be implemented when appropriate.

## 2. SCOPE AND RELATED STANDARDS

Geosciences Standard Operating Procedure (SOP) T-GS-021 describes standards for direct push drilling and soil sampling, and discusses how such drilling and sampling will be conducted and documented for projects executed by Shaw Environmental & Infrastrucure Inc. (Shaw E & I). Responsibilities of individuals performing the work are also detailed. Additional project-specific requirements for direct push drilling and soil sampling may be developed, as necessary, to supplement this procedure and to address project-specific conditions and/or objectives.

This SOP covers requirements for collection of soil and unconsolidated materials by direct push methods primarily for laboratory or other testing and for lithologic description or analysis (logging). It describes basic equipment and procedures and addresses aspects of the process where quality must be maintained. It does not address procedures for specific brands of equipment, or for uncommon purposes of boring or sampling. Other types of soil and rock sampling while drilling are addressed in other Shaw E & I technical SOPs.

## 3. REFERENCES (STANDARD INDUSTRY PRACTICES)

The methodology for direct push drilling and soil sampling should follow industry standard practices. The following references are relevant and useful for planning and conducting direct push drilling and soil sampling:

| | |
|---|---|
| ASTM D 6282-98 | Direct Push Soil Sampling for Environmental Site Characterizations |
| ASTM D 6286-98 | Standard Guide for Selection of Drilling Methods for Environmental Site Characterization |

## 4. DEFINITIONS

The following definitions are applicable to direct push drilling and soil sampling and this SOP.

- **Direct push drilling**—The creation of a boring by the displacement of soil without cutting or grinding and without the production of mechanically-altered soil (cuttings) at the ground surface. In direct push drilling, soil is displaced, primarily laterally, as a pipe or rod is forced vertically downward, creating a cylindric space (i.e. a boring). Energy to create the boring may be generated from constant pressure (e.g., hydraulically-powered), vibration, or other means.
- **Slough**—Slough is soil or other earth material that has been dislodged from its original location within the boring and displaced elsewhere within the boring (usually to the bottom). The creation

and sampling of slough should be avoided, because slough has disturbed properties and is typically of uncertain origin with respect to depth. The presence of slough also impedes proper abandonment of borings.

- **Conductor Casing**—Conductor casing is drill pipe that is extended down into the ground as a boring is advanced, to prevent sidewall material from falling into the borehole and covering the in-place soil material that constitutes the bottom of the boring. Conductor casing is usually removed when a borehole is being abandoned.

- **Sample**—A mass of soil or earthen material that has been removed from the boring from a known depth, has had little internal disturbance, and may be considered representative of the in-situ earthen material from a known depth and representative with respect to the intended tests or properties of interest.

## 5. RESPONSIBILITIES

### 5.1 Procedure Responsibility

The Geosciences Discipline Lead is responsible for the development, maintenance, and revision of this procedure. Any questions, comments, or suggestions regarding this technical SOP should be sent to the Geosciences Discipline Lead. The Geosciences Discipline Lead's location and associated contact information can be found on the Insider.

### 5.2 Project Responsibility

Employees planning or conduction direct push drilling and soil sampling, or any portion thereof, are responsible for meeting the requirements of this procedure. Employees conducting technical review or oversight of direct push drilling and soil sampling are also responsible for following appropriate portions of this SOP.

For those projects where direct push drilling and soil sampling activities are conducted, the project manager or designee is responsible for ensuring that drilling and sampling activities are conducted in accordance with this and other appropriate procedures. Project participants are responsible for recording information in sufficient detail to provide objective documentation (i.e., field notes, logs, forms, reports, etc.) that the requirements of this SOP have been met. Such documentation shall be retained as project records.

## 6. PROCEDURES (TECHNICAL REQUIREMENTS)

This section addresses basic requirements and procedures involved with direct push drilling and soil sampling. This section includes information on selection of methods and equipment, planning and preparation requirements, health and safety requirements, drilling and sampling procedures, and key practices for ensuring quality.

Proper drilling and subsurface soil sampling procedures are necessary to ensure the quality and integrity of the samples. The details within this SOP should be used in conjunction with project-specific work plans. The project work plans should generally provide the following information:

- Specific direct push drilling and soil sampling methodologies and equipment to be employed
- Sample collection objectives
- Anticipated locations and total depths of soil borings and target horizons or depths of soil samples to be collected
- Numbers and volumes of samples to be collected

- Types of chemical analyses to be conducted for the samples
- Specific quality control (QC) procedures and sampling requirements
- Detailed direct push drilling and subsurface soil sampling requirements or procedures based upon site-specific conditions and project-specific objectives/requirements

## 6.1 Selection of Methods and Equipment

The practice of direct push drilling and soil sampling involves numerous variations in methodology and types of equipment. There are few industry-wide standards for direct push drilling and soil boring. Key aspects of the variations in direct push drilling and sampling are as follows:

- **The use of single-wall or dual-wall sampling systems**. Single-wall systems generally provide lower-quality sampling and higher rates of production than dual-wall systems. Single-wall systems can typically be advanced with lower energy sources (i.e., to greater depth) than dual-wall systems because they have smaller area and hence encounter less sidewall friction and tip resistance during advance.
- **Open-hole or cased boring. This SOP recommends that borings always be advanced through or with a conductor casing.**
- **Open-barrel or closed (sealed)-barrel sampler**. Open-barrel samplers are open at the bottom at all times, and may fill with slough, lose sample material as they are retrieved, or contribute or be subject to cross-contamination. Closed-barrel samplers are closed at the bottom until being mechanically opened at a target depth. Closed-barrel samplers reduce the potential for sampling of slough or cross-contamination of the sample.
- **Liner or inner-barrel material**. Inner barrel/sampler tubes should be selected based on the need to see or access samples for lithologic evaluation and the need to perform chemical or other analytical testing. Use of lexan or other see-through materials can be beneficial in identifying soil type or visual indications of contamination (such as petroleum saturation). Some liners, such as lexan, can be quickly cut to select certain sample intervals for testing, and the sample may be retained, shipped and stored directly in the liner. Liners or sample barrel material should generally not be made of materials that include any of the chemical species that are sought during analysis.
- **Energy source for making the boring**. Energy sources may be static or dynamic, and may include vibratory or sonic systems, hydraulic systems, percussion (hammer) systems, or even rotational systems.
- **Energy source for removing the sampler**. Energy sources may be static or dynamic, and are generally one of the following: hydraulically-lifted rod systems, winch and wire rope systems, or percussive systems (backpounding). This SOP recommends against backpounding as a means of removing samplers, as it tends to disturb samples.
- **Use of checkball or open-top tubes for collection of soil**. Checkball systems prevent fluids that are within the sampling barrel, above the sample, from flowing down into the barrel as the sampler is retrieved. Checkball systems are mostly used when sampling granular soils beneath the water table, to minimize the potential for water to dislodge or alter sample material as the barrel is retrieved.
- **Use of catchers or retainers**. Catchers are used to help retain loose soils within the sampling barrel as it is retrieved. Catchers are most commonly used when sampling granular soils beneath the water table, with variable success.

## 6.2 Planning and Preparation

Planning for direct push drilling and soil sampling activities involves the following:

- Identifying drilling and sample collection objectives and exact methodologies and equipment to be used for sample collection.
- Identifying specific drilling and sampling locations, targeted depths, and specific identification numbers of soil samples to be collected.
- Identifying numbers and volumes of samples to be collected.
- Specifying types of chemical analyses to be conducted for the samples.
- Listing specific quality control (QC) procedures and sampling requirements.
- Describing any detailed project-specific sampling requirements or procedures beyond those covered in this SOP, as necessary.
- Listing expected soil types, hydrostratigraphy, and/or formations to be encountered (if known).
- Identifying and listing all pertinent health and safety issues and requirements, including those contained in the project-specific health and safety plan(s), relative to work activities (including site utility clearance).
- Compiling main subcontractor requirements for direct push drilling and soil sampling and generating of the statement of work to procure subcontractor services.

All of the above information and items should be compiled as part of a sampling plan contained within the project work plans. This plan includes detailed, project-specific direct push drilling and soil sampling procedures beyond the basic procedures and requirements in this SOP.

Preparation for direct push drilling and soil sampling activities includes the following:

- Securing all necessary site access, permitting, and plan approvals.
- Procuring the appropriate direct push drilling and sampling subcontractor.
- Completing all necessary underground utility clearance activities at each of the sampling locations; each location should be cleared according to requirements in appropriate Shaw E & I technical SOPs and the project work plans.
- Briefing the rig geologist, subcontractor personnel, and other site personnel on specific information necessary for effective implementation of the sampling effort (e.g., sampling objectives, locations and depths, project-specific sampling requirements and procedures, pertinent health and safety requirements, etc.).
- Verifying that job personnel have proper health and safety training.

The project manager, or designee, is responsible for appropriately briefing field personnel, as described above.

## 6.3 Health and Safety Requirements

Prior to initiating drilling and sampling activities, applicable Shaw E & I and project-specific safety requirements must be reviewed by Shaw E & I site personnel and subcontractors. This review is conducted to familiarize these individuals with specific hazards associated with the site and drilling activities, as well as with health and safety procedures associated with the operation and maintenance of drilling equipment. Such information may be found in the project health and safety plan and other applicable Shaw E & I policies and procedures, such as HS316 "Drilling Operations." Additional health and safety requirements include the following:

- Tailgate Safety Meetings should be held in the manner and frequency stated in the project health and safety plan. All Shaw E & I and subcontractor personnel at the site should have appropriate training and qualifications as per the project health and safety plan. Documentation should be kept readily available in the project files on site.
- During drilling, all personnel within the exclusion zone should pay close attention to all rig operations. Pushed or driven drill tools can catch or snag loose clothing, causing serious injury.
- Clear communication signals must be established with the drilling crew, since verbal communication may not be heard during the drilling process.
- The entire crew should be made aware to inform the rig geologist when any unforeseen hazard arises or when anyone is approaching the exclusion zone.

### 6.4 Drilling and Sampling Requirements/Procedures

This SOP cannot present a single, detailed and specific procedure that is applicable to all methods and equipment that are available (Section 6.1) or to the specific sampling objectives of a specific project. An example procedure for direct push drilling and soil sample collection is shown in Attachment 1 (Section 7). The example procedure may be supplemented or customized to provide project-specific requirements and procedures.

Sample quality is easily compromised by poorly selected or haphazard drilling and sampling technique. Common problems and suggested solutions include the following:

- Generation of excess slough. Excess sloughing occurs when conductor casing is not used, when soil materials fall out of the sample barrel as it is retrieved, and when soil at or near the ground surface falls into the boring. Slough is excess when the amount that is present hinders the collection of sufficient representative sample volume or mass for the required testing or lithologic analysis.
- Collection of slough for testing or logging. This occurs when a large volume of slough is present in the boring bottom at the time the sampler is emplaced and driven into soil. Because slough is disturbed and from unknown depth, it is unsuitable for logging or testing.
- Disturbance (negatively-biasing) of samples for analysis of Volatile Organic Compounds (VOCs). The act of driving a sampling tube into soil causes compression and some heating of the soil, and can create macroscopic void space, i.e., a microannulus between the soil and sampling tube. Heating, compression of soil, and creation of void space contribute to the migration of gaseous fluids as well as the partitioning of VOCs, such as gasoline or solvent vapors. Although some heating, compression, and formation of microannular space are unavoidable, care should be taken to minimize these phenomena to the extent that is reasonably possible. Some sampling devices and methods are more suitable for analysis of samples for VOCs than others.
- Improper abandonment of borings. Excess slough or caving (the dislodgement and falling of a significant volume of sidewall material) hinders the proper abandonment of a boring. Where this occurs, the borehole should be cleaned out prior to grouting. A tremmie pipe should be used to conduct grout to the bottom of the borehole if a conductor casing is not in place prior to and during grouting.

Additional key practices that will ensure the quality of the samples collected and proper/efficient abandonment of the borings, include the following:

- Drill with a Conductor Casing. Various equipment, systems, and methods exist for direct push drilling and soil sampling. Some systems are open-hole (i.e., do not use conductor casing), hence borings made with these systems are at high risk for slough-related difficulties in logging, sampling, and abandonment. Most systems have provisions for driving down a conductor casing, to keep the boring open and relatively free of slough when the sampler or a plug or drive-point is not present at the bottom of the casing system. **This SOP recommends the use of a method of direct push drilling that integrally includes the advancement of conductor casing as the boring is made**, and further recommends that the conductor casing remain in place during sampling and into the abandonment process.

- Measure the Boring Depth. A weighted tape should be used to verify the depth of the boring within the conductor casing. Measurement should be made with reference to the ground surface. It is important to measure depth at the start of sampling intervals and at total depth (TD) of the boring.
- Clean-Out Excessive Slough. If slough is present, it should be removed by forcing a sampler into it and retrieving and emptying the sampler of slough.
- Identify Slough and Avoid Sampling it or Logging It as In Situ Material. Slough is generally easy to identify based on jumbled internal textures, lighter density, macroscopic and unmineralized void spaces, greater softness and malleability, and decreased cohesion, as compared to in situ material that has not been dislodged prior to the sampling process.
- Grout Through a Conductor Casing. Grouting through a conductor casing prevents any significant accumulation of slough in the boring and ensures that grout will be the predominant material in the borehole, thereby minimizing any potential for vertical migration of fluids in the filled borespace. This minimizes potential liability.

### 6.5 Documentation

Accurate documentation of the boring, sampling, and abandonment activities is important for interpreting sample results, interpreting boring conditions and lithologic information, and conceptually reconstructing events. Appropriate forms (including boring logs) should be completed as per appropriate Shaw E & I technical SOPs and project-specific requirements/procedures.

### 6.6 Technical Review

All direct push drilling and soil sampling specifications, procedures, and results (e.g., reports, forms, etc.) should undergo technical review. It is recommended that the technical reviewer also provide review/oversight of the actual field implementation of direct push drilling and soil sampling activities. This should include aiding in troubleshooting drilling and sampling problems. The technical reviewer should be an experienced senior geologist or hydrogeologist. At a minimum, the technical reviewer should be a person capable of planning and supervising direct push drilling and associated sampling and well installation programs. Individuals needing assistance in finding qualified technical reviewers may consult internal Shaw technical listings for experts in drilling or direct push drilling and sampling.

Any issues raised during the technical review shall be resolved between the reviewer and the staff planning, conducting, or preparing results of direct push drilling and soil sampling activities, as follows:

- Comments/issues raised relative to planning and developing detailed procedures for direct push drilling and soil sampling should be resolved before mobilization and drilling commences.
- Comments/issues raised relative to the results of drilling and sampling activities should be resolved before external (i.e., outside of Shaw E & I) use or submission of the results.

The technical review comments and issues, and corresponding resolution, shall be documented and filed with the project records. Such records should be maintained until project closeout.

## 7. ATTACHMENTS

- Attachment 1, Example Direct Push Drilling and Soil Sampling Procedure.

## 8. FORMS

None.

## Attachment 1

### Example Direct Push Drilling and Soil Sampling Procedure

The following procedure is provided as an example. It should be customized based on project/site-specific equipment, methodology, and sampling and quality control requirements. This procedure is written for a direct push drilling rig that uses a small diameter conductor casing with a three-foot long inner wireline sample barrel (with a three-foot long acrylic liner) connected to the bottom of the casing. The casing and associated sample barrel are driven, pushed, or vibrated into the ground in three-foot increments. Soil samples are collected into the acrylic sample tubes as the conductor casing and sample barrel are advanced into the formation. The samples inside the liner and sample barrel are then retrieved with a wireline, leaving the conductor casing in place. Soil samples are thus continuously collected until the total depth of the boring is reached. The example procedure consists of the following:

1. Decontaminate the direct push sampling rig and associated sampling equipment before mobilizing to the first sample location, in accordance with applicable Shaw E & I technical SOPs and/or project-specific requirements/procedures.

2. Inspect the direct push rig to make sure the equipment is properly maintained, adequately decontaminated, and determined capable of achieving the objectives for drilling (equipment advancement), sample collection, and abandonment of the boring (to be done by the driller and rig geologist).

3. Calibrate all field analytical and health and safety monitoring equipment according to the instrument manufacturer's specifications and/or project work plans. Calibration results must be recorded on the appropriate form(s) as specified by the project work plans or health and safety plan.

4. Wear the appropriate personal protective equipment, as specified in the project work plans or health and safety plan. Personal protection will typically include, at a minimum, a hard hat, safety glasses, gloves, steel-toed boots, hearing protection, and coveralls.

5. Remove the surface cover (e.g., concrete, asphalt, etc.) at the drilling/sampling location according to the project work plans.

6. Once the direct push rig is sited at the sampling location, make sure the location is reasonably free of underground utilities, as per the project work plans. Manually probe or excavate near-surface soils (as required) as an additional step to avoid underground utilities or structures.

7. Learn the drilling equipment heights and dimensions necessary to independently determine the boring or sampler depth while observing the work (to be done by the rig geologist). Such information includes lengths of rods, casing, barrels, and other in-ground equipment; the length of strokes or advances; and the height from ground surface to "full down" stroke of the direct push rig.

8. Between each sampling location and prior to each sampling run, decontaminate the sampling equipment according to applicable Shaw E & I technical SOPs and/or project-specific procedures.

9. Inform the driller of the expected total depth, the first and expected additional sampling depths, the likelihood of encountering groundwater or NAPL, and any contingency or opportunistic decisions that are anticipated (such as contingency-sampling or increased total depth).

10. Record the type of sampler assembly on the appropriate form(s) as specified in appropriate Shaw E & I technical SOPs or the project work plans. To minimize off-gassing of volatiles, the sampler should not be advanced/pushed until the sampling team is ready to process the sample.

11. Commence drilling and sample collection by advancing the conductor casing and associated sample barrel (with liner) for the first three-foot increment.

12. Pull the wireline sampling string up from the bottom of the borehole and remove the sample barrel. Make sure that each sample barrel is retrieved as quickly and smoothly as possible. Record the depth interval for each sample drive as the sample barrel is being retrieved.

13. Remove the acrylic liner containing the soil sample from the sample barrel.

14. Observe and record the amount of sample recovery on the appropriate form(s), according to applicable Shaw E & I procedures and/or the project work plans. Any observed field problems associated with the sampling attempt (e.g., refusal) or lack of recovery should be noted on the appropriate form.

15. Select the appropriate portion of the liner containing the sample to be cut and be submitted for laboratory analysis. Such selection should be based on the following factors: (1) judgment that the sample represents relatively undisturbed intact material, not slough; (2) volume/length of sample required for analysis; (3) minimal exposure to air; (4) lithology; and (5) obvious evidence of contamination. The project work plans should specify the volume/length of sample to be submitted for specific analyses and confirm the selection factor(s).

16. Place Teflon™ film over each end of the liner containing the samples to be submitted for chemical analysis and seal each end with plastic end caps. Do not use any type of tape to seal the cap, because tape causes a toluene interference. All samples should be individually stored in resealable plastic bags. Note: Additional project-specific sample preparation steps or modifications may be required as stated in the project work plans.

17. Appropriately label and number each sample to be submitted for analysis as per applicable Shaw E & I technical SOPs and the project work plans. The label will be filled out using waterproof ink and may contain, at a minimum, the following information:

    - Project number
    - Boring number
    - Sample number
    - Bottom depth of sleeve
    - Date and time of sample collection
    - Parameters of analysis
    - Sampler's initials

18. Document the sampling event on the appropriate form(s), as specified in the project work plans. The information listed on the form(s) should, at a minimum, include the following:

    - Project name and number
    - Date and time of the sampling event
    - Sampling methods used – specify sample type
    - Sample number
    - Sample location
    - Sample depth interval
    - Sample description (type of matrix)
    - Weather conditions

- Unusual events, including lack of water or insufficient water volume in sampler
- Signature or initials of sampler

19. Appropriately preserve, package, handle, and ship the sample in accordance with applicable Shaw E & I technical SOPs and/or project-specific procedures. The samples shall also be maintained under custody. Samples stored on site will be subject to the provisions of applicable Shaw E & I procedures and/or project requirements. All reasonable attempts should be made to ship samples on the date they are collected.

20. Cut/split the remaining acrylic liner to expose the remaining soils for logging. The descriptions of the soil and preparation of a boring log should follow applicable Shaw E & I technical SOPs and project-specific requirements/procedures. The soil boring log should include the following information:

    - Borehole location
    - Name of the drilling company and driller
    - Dates and times when drilling began and when it was completed
    - Lithologic data and descriptions from soil samples
    - Sampling depths and recovery of soil samples

21. Continue to advance the borehole in three-foot increments and collect soil samples to the total depth. As the borehole is advanced, the rig geologist will generally do the following:

    - Observe and monitor rig operations
    - Conduct all health and safety monitoring and sampling and supervise health and safety compliance
    - Prepare a boring log from cuttings or soil samples as per applicable Shaw E & I technical SOPs and project-specific requirements
    - Document drilling progress and other appropriate observations on appropriate forms
    - Supervise the collection and preparation of any soil, soil vapor, or groundwater samples

    The rig geologist should not leave the drill site while drilling operations are being conducted and the borehole is being advanced.

22. As drilling progresses, the rig geologist should observe and be in frequent communication with the driller regarding drilling operations. Conditions noted should include relative rates of penetration, flowing sands, drilling refusal, changes in equipment, etc. These conditions should be recorded on the appropriate logs and forms as per applicable Shaw E & I technical SOPs and/or the project work plans. Drilling should not be allowed to progress faster than the rig geologist can adequately observe conditions, compile logs, and supervise safety and sampling activities.

23. The rig geologist should also observe the make-up and tightening of connections as additional conductor casing joints are added to the drill string. Any observed drilling problems and causes, including significant down time, should be recorded on the appropriate forms.

24. Cuttings (i.e., left over soil samples) and fluid containment during drilling should be observed and supervised by the rig geologist as per the project work plans.

25. Periodically measure the boring depth with a weighted tape to verify its depth. If it cannot be directly measured, then count rods or pipe lengths that have been inserted into the ground or take other action to verify depth (in a manner that is independent of asking the driller the boring depth).

26. If the borehole is to be abandoned once drilling and sampling is completed, follow procedures outlined in applicable Shaw E & I technical SOPs and the project work plans. The abandonment will be supervised by the rig geologist. If the borehole contains slough, the slough should be removed prior to abandonment.

27. If a monitoring well is to be installed in the borehole, follow appropriate Shaw E & I technical SOPs and project-specific requirements/procedures. The well installation will be supervised by the rig geologist.

28. After drilling, sampling, and well installation or borehole abandonment is completed, lay the conductor casing down and move the rig off of the location. The rig geologist or appropriate designee will supervise demobilization/site restoration. Additional demobilization requirements/procedures are as follows:

    - All debris generated by the drilling operation should be removed and appropriately disposed of.

    - The site should be cleaned, the ground washed as necessary, and the site conditions restored as per the project work plans.

    - All abandoned borings should be topped off and completed as per the project work plans. All wells should also have their surface completions finished as per the project work plans.

    - Any hazards remaining as a result of drilling activities should be identified and appropriate barriers and markers put in place, as per the project health and safety plan.

    - All soil cuttings and fluids should be properly contained, clearly labeled, and maintained in compliance with the project work plans and/or other applicable requirements.

29. Complete all appropriate forms and documentation as required in the project work plans.

# SOP T-GS-025

# Standards for Soils Logging

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Authorized By: ______________________ Date: ______________
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# STANDARD OPERATING PROCEDURE

**Subject: Standards for Soils Logging**

## 1. PURPOSE

This procedure provides the standard practice for soils logging (the description of soils). The procedure includes the minimum required steps and quality checks that employees and subcontractors are to follow when performing the subject task.

This procedure may also contain guidance for other recommended or suggested practice that is based upon collective professional experience. Recommended practice goes beyond the minimum requirements of the procedure, and should be implemented when appropriate.

## 2. SCOPE

Geosciences Standard Operating Procedure (SOP) T-GS-025 describes standards for the description and field classification of engineering soils by visual-manual methods for projects executed by Shaw Environmental & Infrastructure, Inc., (Shaw E & I). It applies to soils logging for generation of boring logs, trench logs and any other type of descriptive soil log generated by visual observation and manual tests performed in the field. This procedure does not cover all of the requirements or standards for generation and completion of boring logs. (Standards for boring log generation can be found in Shaw E & I technical SOP T-GS-027.) This SOP does not include nor cover the use of laboratory or field geotechnical tests to identify/classify and describe soils, although descriptions may be augmented by data from such tests, when available.

The SOP addresses technical requirements and required documentation. Responsibilities of individuals performing the work are also detailed. Additional project-specific requirements for of soils logging may be developed, as necessary, to supplement this procedure and address project-specific conditions and/or objectives.

## 3. REFERENCES

The description and classification of soil should follow accepted industry practices. These are presented in the latest version of the following American Society for Testing and Materials (ASTM) Standards:

| | |
|---|---|
| ASTM D 653-02a | Standard Terminology Relating to Soil, Rock, and Contained Fluids |
| ASTM D 2487-00 | Standard Test Method for Classification of Soils for Engineering Purposes |
| ASTM D 2488-00 | Standard Practice for Description and Identification of Soils (Visual-Manual Procedure) |

Additional reference materials that are useful for planning and conducting soils logging include the following:

- United States Army, 1997, *Field Manual (FM) 5-410, Military Soils Engineering,* Revised, June 1997. Available on line at: http://www.adtdl.army.mil/cgi-bin/atdl.dll/fm/5-410/toc.htm
- United States Bureau of Reclamation (USBR), 1998, *Engineering Geology Field Manual, Second Edition*. Available on line at: http://www.usbr.gov/pmts/geology/fieldman.htm

- United Stated Department of Agriculture (USDA), 1993, *Soil Survey Manual, Soil Conservation Service*. Available on line at: http://soils.usda.gov/procedures/ssm/main.htm
- American Geological Institute, AGI Data Sheets
- US Army Corps of Engineers, 1953, *The Unified Soil Classification System; US Army Technical Memorandum, No.3-357.*
- Compton, Robert R., 1962, *Manual of Field Geology*, John Wiley and Sons Inc.
- US Department of the Interior, 1974, *Earth Manual*, a Water Resources Technical Publication.


## 4. DEFINITIONS

The following definitions are applicable to the logging of soils and this SOP.

- **Clay**—Soil passing a No. 200 (75 µm) sieve that can be made to exhibit plasticity (putty-like properties) within a range of water contents, and that exhibits considerable strength when air-dry. For classification, a clay is a fine-grained soil, or fine-grained portion of a soil, with a plasticity index equal to or greater than 4.
- **Coarse Grained Soils**—Soils composed of greater than 50% sand and gravel or larger sized particles.
- **Fine Grained Soils**—Soils composed of 50% or more silt and clay sized particles.
- **Gravel**—Particles of rock that will pass through a 3-inch (75mm) sieve and be retained on a No. 4 (4.75-mm) sieve.
- **Sand**—Particles of rock that will pass a No. 4 (4.75-mm) sieve and be retained on a No. 200 (75-µm) sieve.
- **Silt**—Soil passing a No. 200 (75-µm) sieve that is nonplastic or very slightly plastic and that exhibits little or no strength when air dry. For classification, a silt is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index less than 4.
- **Soil**—All unconsolidated materials above bedrock.
- **Standard Penetration Test**—ASTM D 1586 method for the collection of soil samples.
- **USCS**—Unified Soil Classification System.

## 5. RESPONSIBILITIES

### 5.1. Procedure Responsibility

The Geosciences Discipline Lead is responsible for the development, maintenance, and revision of this procedure. Any questions, comments, or suggestions regarding this technical SOP should be sent to the Geosciences Discipline Lead. The Geosciences Discipline Lead's location and associated contact information can be found on the Insider.

### 5.2. Project Responsibility

Employees planning or conducting soils logging are responsible for meeting the requirements of this procedure. Employees conducting technical review or oversight of such efforts are also responsible for following appropriate portions of this SOP.

For those projects where soils logging is conducted, the Project Manager, or designee, is responsible for ensuring that logging activities are conducted in accordance with this and other appropriate procedures. Project participants are responsible for recording information in sufficient detail to provide objective documentation (i.e., logs, forms, reports, etc.) that the requirements of this SOP have been met. Such documentation shall be retained as project records.

## 6. PROCEDURES (TECHNICAL REQUIREMENTS)

This section addresses the process and procedures necessary for the preparation of soil descriptions based on the field classification of soils by visual-manual methods. Objective, quantitative and accurate observations are necessary to insure the quality and scientific integrity of soil descriptions. The guidance contained within this SOP should be used in conjunction with project-specific work plans to prepare soil descriptions.

All personnel required to log soil for Shaw Technical Services should follow the guidelines presented in this SOP unless project, contract or client requirements specify otherwise. The guidance provided in this SOP is based primarily on the procedures contained in the most recent version of American Society for Testing and Materials (ASTM) D 2488, *"Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)"*. The logging/description of rock is discussed in Shaw E & I technical SOP T-GS-026, *"Standards for Rock Logging"*. Preparation of boring logs should follow Shaw E & I technical SOP T-GS-027, *"Standards for Generation of Boring Logs"* and/or the project work plans. Personnel involved in describing soil and preparing soil boring logs should be familiar with these documents.

Field soil descriptions prepared for soils collected from boreholes may be recorded on the Visual Classification of Soils form (Section 8) unless project, contract or client requirements specify otherwise. Descriptions will focus on making and recording objective, concise, quantitative and accurate observations. The field geologist conducting the logging should refrain from providing subjective, interpretative, diagnostic, or genetic comments and observations until the soil is completely and accurately described following the guidance contained in this SOP.

### 6.1. Soils Description

The standard method for classification of soil is the Unified Classification System (USCS). This system and classification method is presented in ASTM D 2488-00 *"Standard Practice for Description and Identification of Soils (Visual Manual Procedure)"*. When classifying soils using this method, a representative soil sample is obtained. The soil sample is then attributed to one of two broad groups; 1) fine-grained soils, or 2) coarse-grained soils. Fine-grained soils are composed of 50% or more silt and clay sized particles. Coarse-grained soils are composed of greater than 50 % sands and gravels. Flow charts for determining the USCS symbol and associated name are provided on Figures 1a, 1b and 2 in ASTM D 2488-00. A summary chart of the groups and USCS symbols is provided in Attachment 1. The soil description for each group should be prepared to contain the information and follow the sequence provided below.

#### 6.1.1. *Fine Grained Soils* (Silts and Clays) Description Format

The standard description format for a fine-grained soil is as follows:

**SOIL GROUP NAME;** color; moisture state; consistency; plasticity; percentage of fines; percentage and size range of coarse fraction; maximum particle size; evidence of contamination (visual/olfactory); other terms (see below).

### 6.1.2. *Coarse Grained Soils* (Sands and Gravels) Description Format

The standard description format for a coarse-grained soil is as follows:

Grading term, **SOIL GROUP NAME;** color; moisture state; density; percentage and size range of coarse fraction; maximum particle size; angularity; shape; percentage and plasticity of fines; evidence of contamination (visual/olfactory); other terms (see below).

### 6.1.3. Other Terms to Include in Description:

Additional information useful for describing the characteristics of a soil includes:

- Hardness of coarse sand and larger particles
- Surface coating on coarse-grained particles
- Bedding and other soil structures
- Organic soil, or presence of organic material
- Cement, caliche
- HCl reaction
- Mineralogy/petrology of grains/clasts
- Debris; metal, concrete, plastic, etc.
- Evidence of fill
- Evidence of disturbance

## 6.2. Descriptive Terms (Explanation and Use)

A brief explanation and use of the above descriptive terms are provided in the following text. Specific criteria and field methods used to assign the proper term in a soil sample description are provided in ASTM D 2488-00 and other references listed above. These terms should be included in the descriptions of the soil units.

- **Soil Group Name:** The primary criterion used to assign the soil group name is the percentage of each soil particle size fraction. The soil group name will be assigned based on the percentage and size range distribution of soil particles using Figures 1a, 1b and 2 in ASTM D 2488-00 and/or the classification chart in Attachment 1. Following determination of the soil group name, the Unified Soil Classification System (USCS) group symbol should be assigned to the soil unit. The group name and USCS group symbol for fine grained soils will also need to be determined following the procedure in Section 14 of ASTM D 2488-00.
- **Grading term:** (Coarse-grained soils): Gradation is the proportion by mass of a soil distributed in a specified particle-size range. Coarse-grained soils are described as poorly graded or well graded. Note that grading is the opposite of sorting; a well graded soil is poorly sorted and vice versa. Grading is described in Sections 15.3.1 and 15.3.2 of ASTM D 2488-00.
- **Color:** Color is an especially important property in identifying organic soils and is often important in identifying other types of soils. Within a given locality, color may also be useful in identifying materials of similar geologic units. Color should be described for moist samples. Note in the description if the color represents a dry condition. If the sample contains layers or patches of varying colors, (i.e., mottled) this should be noted, and representative colors should be described.

The Munsell Soil Color System should be used for consistent color descriptions and identification. This is because a given color will often be given different names by different people conducting the logging. A given color may also appear differently to people when next to other colors.

- **Moisture state:** Describe as dry, moist, or wet according to the following:
  - Dry Absence of moisture, dusty, dry to touch
  - Moist Damp but no visible water
  - Wet Visible free water, usually soil is below the water table.
- **Density (Coarse grained soils):** Describe density (degree of firmness) for coarse-grained soils as very loose, loose, medium dense, dense, or very dense, as indicated by the criteria in below. This observation is inappropriate for fine-grained soils. Terminology is as follows:

| Density | Standard Penetration Resistance (SPT) |
|---|---|
| Very loose | 0 – 4 |
| Loose | 5 – 10 |
| Medium dense | 11 – 30 |
| Dense | 31 – 50 |
| Very dense | > 50 |

- **Consistency (Fine grained soils):** Describe consistency (degree of firmness) for intact fine-grained soils as very soft, soft, firm, hard, or very hard, as indicated by the criteria in below. This characteristic should not be used for soils with significant amounts of gravel. Classification is as follows:

| Consistency | Thumb/Thumbnail Test | Standard Penetration Resistance (SPT) |
|---|---|---|
| Very soft | Thumb penetration > 1in. (25 mm) | < 2 |
| Soft | Thumb penetration ≈ 1 in. (25 mm) | 2 – 4 |
| Firm | Thumb penetration ≈ ¼ in. (5 mm) | 5 – 15 |
| Hard | Thumb will not indent, but thumbnail will | 16 - 30 |
| Very hard | Thumbnail will not indent. | > 30 |

- **Plasticity (Fine grained soils):** Describe as nonplastic, low, medium or high. To determine plasticity, shape into an elongated thread about one-eighth inch in diameter. Describe plasticity based on the following:

- **Nonplastic:** A 1/8-inch thread cannot be rolled at any water content.
- **Low:** The thread can barely be rolled and a lump cannot be formed when drier than the plastic limit.
- **Medium:** The thread is easy to roll and little time is needed to reach the plastic limit. The thread cannot be re-rolled when the plastic limit is reached and the lump crumbles when drier than the plastic limit.
- **High:** It takes a considerable amount of time to reach the plastic limit when rolling the sample. The thread can be re-rolled several times once the plastic limit is reached and the lump can be formed without crumbing when drier than the plastic limit.

- **Percentage of fines:** Estimate (to the nearest 5%), the percentage of silt and clay sized particles combined, or the percentage of silt and clay individually to the nearest 10%.
- **Percentage of coarse fraction:** Estimate (to the nearest 5%), the percentage of sand and gravel sized particles.
- **Size range of coarse fraction:** Describe the size range as fine sand, medium sand, coarse sand, fine gravel, coarse gravel, cobble or boulder size.
- **Maximum particle size or dimension:** Describe the maximum particle size of the course fraction.
- **Angularity:** Angularity is a description for coarse-grained materials only. The angularity of the coarse sand, gravel, cobbles, and boulders, are described as angular, subangular, subrounded, or rounded as indicated by the criteria below. A range of angularity may be stated, as such: sub-rounded to rounded. The criteria are:
  - **Angular** – Particles have sharp edges and relatively planar sides with unpolished surfaces.
  - **Subangular** – Particles are similar to angular description but have rounded edges.
  - **Subrounded** – Particles have nearly planar sides but well-rounded corners and edges.
  - **Rounded** – Particles have smoothly curved sides and no edges.
- **Shape:** Describe the shape of the gravel, cobbles, and boulders as "flat", "elongated" or "flat and elongated" if they meet the criteria below. Indicate the fraction of the particles that have the shape, such as: one-third of gravel particles are flat, note any unusually shaped particles.

  The particle shape is classified/described as follows, where length, width, and thickness refer to the greatest, intermediate, and least dimensions of a particle, respectively:
  - **Flat** – Particles with width/thickness ratio>3
  - **Elongated** – Particles with length/width ratio>3
  - **Flat and elongated** – Particles meet criteria for both flat and elongated.
- **Evidence of contamination (visual/olfactory):** Describe any visual signs (i.e., staining) or odors which may indicate contamination is present.
- **Other Terms:** (see below).

## 6.3. Other Terms

Other geologic observations should be included to describe soils. These other observations and terms are just as important as the descriptive terms in Section 6.2. These other terms need to be carefully considered, observed and included in the soil descriptions, as applicable. Such terms include the following:

- **Hardness:** Indicate the hardness of coarse sand or larger particles as hard, or state what happens when the particles are hit by a hammer; (e.g., "gravel-size particle fractures with considerable hammer blow", "some gravel-size particles crumble with hammer blow"). Hard particles are those that do not fracture or crumble when struck with a hammer. Remember that the larger the particle, the harder the blow required to fracture it. A good practice is to describe the particle size and the method that was used to determine the hardness.
- **Surface coating:** On coarse-grained particles.
- **Bedding**: Describe thickness, orientation, and/or grading.
- **Soil Structure:** Describe as stratified, laminated, fissured, slickensided, blocky, lenses, homogeneous. The descriptors presented are for soils only; they are not synonymous with descriptions for rock.
  - **Stratified** – Alternating layers of varying material or color; note thickness
  - **Laminated**[1] - Alternating layers of varying material or color with layers less than 6 mm thick; note thickness.
  - **Fissured**[1] – Breaks along definite planes with little resistance to fracturing.
  - **Slickensided**[1] – Fracture planes appear polished or glossy, sometimes striated.
  - **Blocky**[1] – Cohesive soil that can be broken down into small angular lumps which resist further breakdown.
  - **Lenses** – Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay; note thicknesses.
  - **Homogeneous** – Same color and textural or structural appearance throughout.

  [1]Do not use for coarse grained soils with the exception of fine sands, which can be laminated.
- **Organic soil:** Note the presence and type of organic particles; change in color upon exposure to air or odor.
- **Cementation:** Describe the cementation of intact soils as weak, moderate, or strong as indicated by the criteria below:
  - **Weak** – Crumbles or breaks with handling or little finger pressure
  - **Moderate** – Crumbles or breaks with considerable finger pressure
  - **Strong** – Will not crumble or break with finger pressure.
- **HCl reaction:** Calcium carbonate is a common cementing agent in soils. The reaction with dilute hydrochloric acid is useful in determining the presence and abundance of calcium carbonate. Describe the reaction with HCl as none, weak, or strong, as indicated by the criteria below:
  - **None** –No visible reaction

- **Weak** – Some reaction, with bubbles forming slowly
- **Strong** – Violent reaction, with bubbles forming immediately.

- **Mineralogy/petrology:** of grains/clasts: Describe the specific minerals (e.g., mica, gypsum, etc.) and/or lithologies of clasts and relative percentages.
- **Evidence of fill:** Describe debris such as metal, concrete, plastic, etc.
- **Evidence of disturbance:** Describe visual evidence and degree of disturbance. Classify as natural (biological, tectonic, etc.) or man made e.g., construction.
- **Sedimentary structures:** Describe sedimentary structures or lack of structures in soil samples (includes root tubes).

### 6.4. Boring Log Preparation

Soil descriptions prepared following the guidance in this SOP should be recorded on a boring log according to the provisions and requirements of Shaw E & I technical SOP T-GS-027, *"Standards for Generation of Boring Logs"*. The soil descriptions should be recorded on the log in waterproof and smear-proof blue or black ink. Additional information may also be included on the log to supplement the soil descriptions as described in SOP T-GS-027. An example Visual Classification of Soils field log form is included in this SOP (Section 8).

### 6.5. Technical Review

All soil descriptions (logging results) should undergo technical review and approval before internal or external (i.e., outside of Shaw E & I) distribution. The technical reviewer should be an experienced senior geologist or hydrogeologist and capable of the logging and describing soils following the requirements of this procedure. For logging/soil descriptions prepared for a site in a state that requires review and approval of such work products by a registered or licensed geologist, the individual conducting the technical review should hold appropriate registration or licensing in that state.

The technical reviewer should be given appropriate information on the geology of the site, the scope of associated site activities, any and all assumptions used in the logging and any other important information regarding site conditions or issues affecting soil descriptions. The technical reviewer must also be given sufficient time to conduct a sound and thorough review.

Certain states require the logging of soils and generation of boring logs under the supervision of a registered or licensed geologist. For sites and projects in such states, an appropriately registered or licensed geologist should be identified during the planning/preparation phase of the project. The registered/licensed geologist will meet with the field geologist(s) that will be conducting the soils logging. The registered/licensed geologist will brief the field geologist(s) regarding applicable requirements for soils logging and boring log generation, including the requirements in this SOP and Shaw E & I technical SOP T-GS-027 *"Standards for Generation of Boring Logs."* The registered/licensed geologist may also observe/review the logging conducted by the field geologist(s) at the site during drilling and logging operations.

Any issues raised during the technical review should be resolved between the reviewer and employees generating the soil descriptions before internal distribution or external submission of the boring logs containing the descriptions. The technical review comments and issues and corresponding resolution should be documented and filed with the project records. Such records should be maintained until project closeout.

## 7. ATTACHMENTS

- Attachment 1, ASTM Soil Classification & USCS Group Symbols

## 8. FORMS

- Example Visual Classification of Soils form

# Attachment 1

## ASTM Soil Classification & USCS Group Symbols

| | | | | | Group Symbol | | | | Group Name |
|---|---|---|---|---|---|---|---|---|---|
| >50% Sand & Gravel | GRAVEL % gravel > % sand | ≤5% fines | Well-graded | | GW | <15% sand | | | Well-graded GRAVEL |
| | | | | | | ≥15% sand | | | Well-graded GRAVEL with Sand |
| | | | Poorly-graded | | GP | <15% sand | | | Poorly graded GRAVEL |
| | | | | | | ≥15% sand | | | Poorly graded GRAVEL with Sand |
| | | 10% fines | Well-graded | fines - ML or MH | GW-GM | <15% sand | | | Well-graded GRAVEL with Silt |
| | | | | | | ≥15% sand | | | Well-graded GRAVEL with Silt and Sand |
| | | | | fines - CL or CH | GW-GC | <15% sand | | | Well-graded GRAVEL with Clay |
| | | | | | | ≥15% sand | | | Well-graded GRAVEL with Clay and Sand |
| | | | Poorly-graded | fines - ML or MH | GP-GM | <15% sand | | | Poorly graded GRAVEL with Silt |
| | | | | | | ≥15% sand | | | Poorly graded GRAVEL with Silt and Sand |
| | | | | fines - CL or CH | GP-GC | <15% sand | | | Poorly graded GRAVEL with Clay |
| | | | | | | ≥15% sand | | | Poorly graded GRAVEL with Clay and Sand |
| | | ≥15% fines | | fines - ML or MH | GM | <15% sand | | | Silty GRAVEL |
| | | | | | | ≥15% sand | | | Silty GRAVEL with Sand |
| | | | | fines - CL or CH | GC | <15% sand | | | Clayey GRAVEL |
| | | | | | | ≥15% sand | | | Clayey GRAVEL with Sand |
| | SAND % sand > % gravel | ≤5% fines | Well-graded | | SW | <15% gravel | | | Well-graded SAND |
| | | | | | | ≥15% gravel | | | Well-graded SAND with Gravel |
| | | | Poorly-graded | | SP | <15% gravel | | | Poorly graded SAND |
| | | | | | | ≥15% gravel | | | Poorly graded SAND with Gravel |
| | | 10% fines | Well-graded | fines - ML or MH | SW-SM | <15% gravel | | | Well-graded SAND with Silt |
| | | | | | | ≥15% gravel | | | Well-graded SAND with Silt and Gravel |
| | | | | fines - CL or CH | SW-SC | <15% gravel | | | Well-graded SAND with Clay |
| | | | | | | ≥15% gravel | | | Well-graded SAND with Clay and Gravel |
| | | | Poorly-graded | fines - ML or MH | SP-SM | <15% gravel | | | Poorly graded SAND with Silt |
| | | | | | | ≥15% gravel | | | Poorly graded SAND with Silt and Gravel |
| | | | | fines - CL or CH | SP-SC | <15% gravel | | | Poorly graded SAND with Clay |
| | | | | | | ≥15% gravel | | | Poorly graded SAND with Clay and Gravel |
| | | ≥15% fines | | fines - ML or MH | SM | <15% gravel | | | Silty SAND |
| | | | | | | ≥15% gravel | | | Silty SAND with Gravel |
| | | | | fines - CL or CH | SC | <15% gravel | | | Clayey SAND |
| | | | | | | ≥15% gravel | | | Clayey SAND with Gravel |
| 50% or More Fines | Low-Plasticity Clay | | | | CL | <30% sand & gravel | <15% Sand and Gravel | | Lean CLAY |
| | | | | | | | 15-25% sand & gravel | % sand ≥ % gravel | Lean CLAY with Sand |
| | | | | | | | | % sand < % gravel | Lean CLAY with Gravel |
| | | | | | | ≥30% sand & gravel | % sand ≥ % of gravel | < 15% gravel | Sandy lean CLAY |
| | | | | | | | | ≥ 15% gravel | Sandy lean CLAY with Gravel |
| | | | | | | | % sand < % gravel | < 15% sand | Gravelly lean CLAY |
| | | | | | | | | ≥ 15% sand | Gravelly lean CLAY with Sand |
| | Low-Permeability Silt | | | | ML | <30% sand & gravel | 15% sand & gravel | | SILT |
| | | | | | | | 15-25% sand & gravel | % sand ≥ % gravel | SILT with Sand |
| | | | | | | | | % sand < % gravel | SILT with Gravel |
| | | | | | | ≥30% sand & gravel | % sand ≥ % of gravel | < 15% gravel | Sandy SILT |
| | | | | | | | | ≥ 15% gravel | Sandy SILT with Gravel |
| | | | | | | | % sand < % gravel | < 15% sand | Gravelly Silt |
| | | | | | | | | ≥ 15% sand | Gravelly Silt with Sand |
| | Plastic Clay | | | | CH | <30% sand & gravel | < 15% sand & gravel | | Fat CLAY |
| | | | | | | | 15-25% sand & gravel | % sand ≥ % gravel | Fat CLAY with Sand |
| | | | | | | | | % sand < % gravel | Fat CLAY with Gravel |
| | | | | | | ≥30% sand & gravel | % sand ≥ % of gravel | < 15% gravel | Sandy fat CLAY |
| | | | | | | | | ≥ 15% gravel | Sandy fat CLAY with Gravel |
| | | | | | | | % sand < % gravel | < 15% sand | Gravelly fat CLAY |
| | | | | | | | | ≥ 15% sand | Gravelly fat CLAY with Sand |
| | Plastic Silt | | | | MH | <30% sand & gravel | < 15% sand & gravel | | Elastic SILT |
| | | | | | | | 15-25% sand & gravel | % sand > % gravel | Elastic SILT with Sand |
| | | | | | | | | % sand < % gravel | Elastic SILT with Gravel |
| | | | | | | ≥30% sand & gravel | % sand ≥ % of gravel | < 15% gravel | Sandy elastic SILT |
| | | | | | | | | ≥ 15% gravel | Sandy elastic SILT with Gravel |
| | | | | | | | % sand < % gravel | < 15% sand | Gravelly elastic SILT |
| | | | | | | | | ≥ 15% sand | Gravelly elastic SILT with Sand |
| | Organics (Peat or Bay Mud) | | | | OL/OH | <30% sand & gravel | < 15% sand & gravel | | Organic SOIL |
| | | | | | | | 15-25% sand & gravel | % sand ≥ % gravel | Organic SOIL with Sand |
| | | | | | | | | % sand < % gravel | Organic SOIL with Gravel |
| | | | | | | ≥30% sand & gravel | % sand ≥ % of gravel | < 15% gravel | Sandy Organic SOIL |
| | | | | | | | | ≥ 15% gravel | Sandy Organic SOIL with Gravel |
| | | | | | | | % sand < % gravel | < 15% sand | Gravelly Organic SOIL |
| | | | | | | | | ≥ 15% sand | Gravelly Organic SOIL with Sand |

Shaw™ Shaw E & I, Inc.

# EXAMPLE
# VISUAL CLASSIFICATION OF SOILS

| | | |
|---|---|---|
| PROJECT NUMBER: | PROJECT NAME: | |
| BORING NUMBER: | COORDINATES: | DATE: |
| ELEVATION: | GWL: Depth Date/Time | DATE STARTED: |
| ENGINEER/GEOLOGIST: | Depth Date/Time | DATE COMPLETED: |
| DRILLING METHODS: | | PAGE: OF |

| DEPTH ( ) | SAMPLE TYPE & NO. | BLOWS ON SAMPLER PER ( ) | RECOVERY ( ) | DESCRIPTION | USCS SYMBOL | MEASURED CONSISTENCY (TSF) | WELL CONSTRUCTION | REMARKS |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |

NOTES:

Drilling Contractor: ____________________

Drilling Equipment: ____________________

Driller: ____________________

____________________

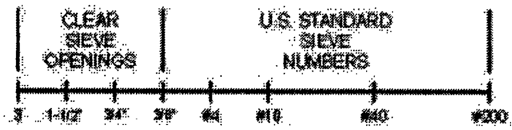
## CONSISTENCY OF COHESIVE SOILS

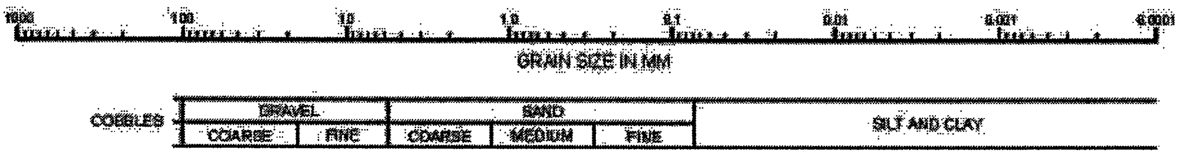
| CONSISTENCY | UNCONFINED COMPRESSIVE STRENGTH (TONS PER SQUARE FOOT) |
|---|---|
| VERY SOFT | LESS THAN 0.25 |
| SOFT | 0.25 to 0.50 |
| FIRM | 0.50 to 2.0 |
| HARD | 2.0 to 4.0 |
| VERY HARD | MORE THAN 4.0 |

## DENSITY OF GRANULAR SOILS

| DENSITY | STANDARD PENETRATION RESISTANCE (1) |
|---|---|
| VERY LOOSE | 0-4 |
| LOOSE | 5-10 |
| MEDIUM DENSE | 11-30 |
| DENSE | 31-50 |
| VERY DENSE | OVER 50 |

(1) STANDARD PENETRATION RESISTANCE IS THE NUMBER OF BLOWS REQUIRED TO DRIVE A 2-INCH O.D. SPLIT BARREL SAMPLER 12 INCHES USING A 140-POUND HAMMER FALLING FREELY THROUGH 30 INCHES. THE SAMPLER IS DRIVEN 18 INCHES AND THE NUMBER OF BLOWS RECORDED FOR EACH 6-INCH INTERVAL. THE SUMMATION OF THE FINAL TWO INTERVALS IS THE STANDARD PENETRATION RESISTANCE.




USCS CLASSIFICATION FOR SOILS

## COARSE-GRAINED SOILS

| | | |
|---|---|---|
| CLEAN GRAVELS (LITTLE OR NO FINES) | GW | WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES |
| | GP | POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES |
| GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES) | GM | SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES |
| | GC | CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES |
| CLEAN SANDS (LITTLE OR NO FINES) | SW | WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES |
| | SP | POORLY-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES |
| SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES) | SM | SILTY SANDS, SAND-SILT MIXTURES |
| | SC | CLAYEY SANDS, SAND-CLAY MIXTURES |

## FINE-GRAINED/HIGHLY ORGANIC SOILS

| | | |
|---|---|---|
| SILTS AND CLAYS LIQUID LIMIT (LESS THAN 50) | ML | INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY |
| | CL | INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS SILTY CLAYS, LEAN CLAYS |
| | OL | ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY |
| SILTS AND CLAYS LIQUID LIMIT (GREATER THAN 50) | MH | INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS |
| | CH | INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS |
| | OH | ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS |
| HIGHLY ORGANIC SOILS | PT | PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS |

# SOP T-GS-031
# Standards for Design and Installation of Groundwater Monitoring Wells

Prepared By: ______________________ Date: ______________
Dan Wynne, R.G., C.E.G., C.H.G.
Senior Technical Consultant

Authorized By: ______________________ Date: ______________
John E. Sciacca, R.G.
Geosciences Discipline Lead

# STANDARD OPERATING PROCEDURE

**Subject: Standards for Design and Installation of Groundwater Monitoring Wells**

## 1. PURPOSE

This procedure provides the standard practice for groundwater monitoring well design and installation. The procedure provides the minimum required steps and quality checks that employees and subcontractors are to follow when performing the subject task.

This procedure may also contain guidance for recommended or suggested practice that is based upon collective professional experience. Recommended or suggested practice goes beyond the minimum requirements of the procedure and should be implemented when appropriate.

## 2. SCOPE AND RELATED STANDARDS

Geosciences Standard Operating Procedure (SOP) T-GS-031 describes standards for the design and installation of groundwater monitoring wells, and how such design and installation will be conducted and documented for projects executed by Shaw Environmental & Infrastrucure Inc. (Shaw E & I). Responsibilities of individuals performing the work are also detailed. Additional project-specific requirements for monitoring well design and installation may be developed, as necessary, to supplement this procedure and address project-specific conditions and/or objectives.

This SOP covers requirements for basic monitoring well design and installation. The following types of well design and installations are <u>not</u> covered specifically in this SOP:

- Any well that is not primarily intended for groundwater monitoring.
- Wells with multiple screen interval completions.
- Multiple wells or casings within a single boring.
- Instrumented wells (e.g. wells with inclinometers).
- Driven wells.

Individuals needing assistance in the design and installation of monitoring wells and/or these other types of wells/completions may consult internal Shaw E & I technical listings for experts or may contact the Geoscience Discipline Lead (see Section 5.1).

## 3. REFERENCES (STANDARD INDUSTRY PRACTICES)

The design and installation of groundwater monitoring wells should follow industry standard practices. These are discussed in the latest version of the following ASTM Standards:

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| ASTM D 5092-02 | Design and Installation of Groundwater Monitoring Wells in Aquifers |
| ASTM D 5787-95 | Practice for Monitoring Well Protection |

The following references are also useful for the planning, design, and installation of groundwater monitoring wells:

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|---|---|
| ASTM D 6286-98 | Selection of Drilling Methods for Environmental Site Characterization |

ASTM F 480-02 — Standard Specification for Thermoplastic Well Casing Pipe and Couplings Made in Standard Dimension Ratios (SDRs), SCH 40 and SCH 80.

Smith, S. A., 1995, *Monitoring and Remediation Wells: Problem Prevention, Maintenance and Rehabilitation,* CRC Press.

U. S. Army Corps of Engineers, 1998, *Monitoring Well Design, Installation and Documentation at Hazardous, Toxic and Radioactive Waste Sites, Engineer Manual EM 1110-1-4000*, November 1. http://www.usace.army.mil/inet/usace-docs/eng-manuals/em1110-1-4000/.

## 4. DEFINITIONS

The following definitions are applicable to monitoring well design and installation and this SOP.

- **Monitoring Well**—An engineered structure made for the purposes of accurately recording the depth to free water within the ground and for the repeated collection of liquid samples that are representative of the conditions of the groundwater within the vicinity of the screened portion of the well.
- **Installation**—The construction of a groundwater monitoring well within the ground.
- **Water Table**—The surface or level in the saturated zone at which the hydraulic pressure is equal to atmospheric pressure.
- **Well Casing String (System)**—Monitoring well components consisting of blank casing (riser), well screen, well sump (optional) and top and bottom caps that are connected together and placed in the well boring for construction of the well.

## 5. RESPONSIBILITIES

### 5.1 Procedure Responsibility

The Geosciences Discipline Lead is responsible for the development, maintenance, and revision of this procedure. Any questions, comments, or suggestions regarding this technical SOP should be sent to the Geosciences Discipline Lead. The Geosciences Discipline Lead's location and associated contact information can be found on the Insider.

### 5.2 Project Responsibility

Employees designing or installing groundwater monitoring wells, or any portion thereof, are responsible for meeting the requirements of this procedure. Employees conducting technical review or oversight of monitoring well design or installation are also responsible for following appropriate portions of this SOP.

For those projects where groundwater monitoring well design and installation are conducted, the Project Manager, or designee, is responsible for ensuring that design and installation activities are conducted in accordance with this and other appropriate procedures. Project participants are responsible for recording information in sufficient detail to provide objective documentation (e.g., field notes, completion diagrams, reports, etc.) that the requirements of this SOP have been met. Such documentation shall be retained as project records.

## 6. PROCEDURES

Groundwater monitoring wells are constructed to facilitate reliable, repeatable, representative and cost-effective sampling of groundwater with minimal disturbance of the aquifer. The degree of representativeness of samples depends upon both the well installation and the sampling procedures. Poor well design or construction may result in samples that are unrepresentative of the groundwater quality of the strata or formation in which the wells are screened. Well sampling procedures are addressed in other Shaw E & I technical SOPs.

This SOP presents procedures for monitoring well design and installation that will facilitate collection of representative samples and be protective of the environment, in manners consistent with accepted practice and with most regulatory requirements.

## 6.1 Planning

The planning phase for monitoring well design and installation is an important function and includes the following:

- Identifying and addressing conceptual design issues/parameters (see Section 6.1.1)
- Selecting drilling and well construction methods to be used
- Identifying key approvals necessary for site access and installation of monitoring wells
- Listing key Health and Safety requirements
- Identifying and listing key requirements of subcontractor(s) used for well installation

All planning, design and installation of monitoring wells shall meet applicable federal, state or local agency regulations/requirements. Additional program/project-specific requirement may also need to be addressed. Design elements and specifications, drilling methods, health and safety requirements, and detailed site- or project-specific installation procedures should be described in the project-specific work plans.

### 6.1.1 Conceptual Design

The expected stratigraphic interval for completion, approximate total depth of the well and the expected drilling conditions need to be known/developed. This is necessary in order to compile the design for the well(s) (see Section 6.2), select methods for the drilling and construction of a well, and compile appropriate site-specific installation procedures.

The following are critical issues that must be identified and addressed during conceptual design:

- Monitoring and sampling objectives for the well(s) (e.g., collect groundwater samples, monitor position of the water table, measure thickness of non-aqueous phase liquid (NAPL), collect NAPL samples, etc.)
- Specific hydrostrapigraphic interval or zone targeted for monitoring (e.g., base of unconfined unit A, top of confined aquifer B, first water-bearing fractured interval in unit X, water table in unconfined unit C, etc.)
- Any expectations for other future uses of the well(s) (e.g., groundwater extraction, NAPL [product] recovery, fluid injection for remediation, etc.).
- Expected top and bottom depths of the targeted zone (screen interval) of monitoring and total depth of the well(s).
- The type(s) of sampling that are to be performed in the well.
- Contaminant and groundwater chemistry and relation to composition of well materials.
- Current and expected use of the drill site area during the lifetime of the well.
- Expected long-term range or fluctuation in the position of the water table, or water level in the well(s).
- Expected grain size gradations of the zone that is to be filter-packed.

- Expectations for the presence of light or dense NAPL.
- Rough diameter of well casing and screen to be installed.
- "Drillability" of the geologic formations and/or type of drilling method(s) appropriate for penetrating formations to be encountered and installing the well(s) (see Section 6.1.2).
- Need for telescoped casing, including shallow permanent casing.
- Requirements for collecting formation fluid, cuttings or intact formation samples as the well boring is advanced (drilled).
- Requirements for geophysical logging of the wellbore or completed well.

Additional project-specific critical issues may also need to be identified and addressed, and should be described in the project work plans.

### 6.1.2 Selection of Drilling and Well Construction Methods

The drilling method(s) to be used for constructing the monitoring well will need to be identified. Primary criteria for selecting a drilling method are:

- Ability to drill and maintain a stable wellbore of the desired diameter and depth in the geologic formations at the site and effectively construct the well, as anticipated.
- Ability to avoid more complex constructions such as telescoped casings (deep wells) and shallow permanent casings to prevent communication between water-bearing zones.
- Minimizing formation damage or introduction of drilling fluids into the formation.
- Cost and time factors (budget) for the drilling method and site conditions.
- Flexibility of a drilling method to adapt to unexpected but possible different subsurface conditions or lithology, such as a perched aquifer or bedrock where only alluvium was anticipated.
- Surface access requirements, impacts and limitations for drilling and sampling equipment (e.g., wildlife areas, archaeology site, buildings, etc.).
- Minimizing and controlling the generation of cutting or fluid wastes produced during the drilling.
- Ability to efficiently and reliably collect samples and data during the drilling process.

The selected drilling method(s) should be specified in the project work plans.

### 6.1.3 Approvals

Specific approvals for well installation need to be identified and can include notifications, permits, legal access and right-of-entry, and contacting and cooperating with inspection authorities.

Typical or basic pre-work approvals include some or all of the following:

- Permit for Drilling and/or Well Construction. A permit for drilling and/or installation of the well(s) may be required from a government agency (and sometimes also from a client agency) that has appropriate jurisdiction. Fees or accounts for payments of fees for oversite are often required by many jurisdictions.
- Project work plans. Review and approval of various work plans (containing design specifications and procedures for installing monitoring wells) by a regulatory agency and the client, are often required.
- Request/notification for underground utilities. In nearly every state it is a legal requirement to notify a third-party consortium for the identification and marking of known underground utility

structures and features. There may also be client-specific requirements for underground utility identification and clearance.

- Legal Authority to Enter/Construct. Rights of entry and rights to construct must be in hand for any property that is not owned by the Client and under contract.
- Requirements for inspections before, during or after well installation may exist. Regulatory agencies in urbanized areas and on more sophisticated or larger projects commonly retain and exercise the right to inspect work.

The approvals need to be appropriately planned for and executed in order to effect timely and efficient installation of the monitoring wells.

### 6.1.4 Health & Safety

All applicable Shaw E & I and project-specific health and safety requirements for drilling and well installation shall be identified and adhered to at a minimum. The Client, regulatory agencies, property owner or site operator, may have additional requirements that must be identified and addressed. All requirements must be listed and described in the project health and safety plan.

### 6.1.5 Subcontractors & Personnel

Requirements for the subcontractor that is drilling and installing the monitoring well(s) must be identified. The requirements are compiled into a statement of work to procure subcontractor services once the design of the monitoring well(s) is completed.

The drilling subcontractor typically must possess one or more licenses pertaining to its qualifications to perform the type of work, and authority to work in the city or state. This can include a contractor's license, issued by the state, and other specialized licenses, such as for drilling and installation of water wells, to demonstrate expertise and responsibility. Such license requirement should be listed in the project work plans.

## 6.2 Design Process and Considerations

Monitoring wells may be designed after the approximate completion interval and total depth, drilling conditions, method of drilling, sampling requirements, and relevant understanding of contaminant and groundwater chemistry are known. Additional site- or project-specific conditions may also need to be known. Certain special design or installation conditions require additional evaluation and consideration. Some conditions potentially requiring special design or installation considerations are listed in Attachment 1. The following text discusses the components that need to be evaluated and specified for the monitoring well design. The specific design components and parameters for the well(s) should be described in the project work plans.

### 6.2.1 Borehole and Casing Diameters

The borehole diameter must be sufficiently wide to construct the well and the well casing string must be sufficiently wide for use after completion. The borehole diameter should be at least 4 inches greater than the nominal casing diameter. For deep borings it may be prudent for the boring diameter to be 6 inches greater than the nominal casing diameter. For drilling methods that involve constructing the well within temporary casing (i.e., hollow-stem auger or temporarily driven drill casing), it is common for the boring diameter to be 6 to 7 inches greater than the nominal well casing diameter (i.e., 10 to 12 –inch diameter boreholes). The borehole diameter needs to be sufficiently wide such that all the well construction materials may be placed without obstruction.

The well casing should have an interior diameter sufficient to allow passage of all equipment that might plausibly be used within the casing during the lifetime of the well. Monitoring wells are commonly 2 or 4-inch nominal diameter for depths to about 200 feet, and often 6-inch diameter for greater depths.

It is common to select an inside casing diameter that is 1 inch greater than the diameter of any equipment expected to be used within the well casing for shallower wells, and 2 inches greater for deeper wells.

Many monitoring wells are installed in boreholes made by direct push drilling methods. For these wells the casing strings are relatively small diameter, generally <2 inches. The borehole diameters using direct push methods are also relatively small, generally <3 inches. Viable monitoring wells can be constructed using these methods; however, due to the relatively narrow annular space, a pre-pack may be used for the filter pack (see Section 6.2.8).

### 6.2.2 Length and Position of Well Screen

Only factory-manufactured well screen should be used. Screens are commonly available in lengths of 5, 10, and 20 feet, and sometimes 2.5 feet. Pieces may be joined for greater lengths.

Most monitoring well screens are designed to be 5 or 10 feet long and many regulatory agencies specify these lengths in their guidance or regulations. The reason for short screen lengths is that well screens and associated filter packs are analogous to elevator shafts within buildings: contaminants and other materials may migrate up and down within them with ease. In addition, there may be stratification of dissolved phase contaminants in the formation that may be diluted during purging and sampling across a long screen interval.

There are a few site-specific situations where well screens of 20 feet or more may be suitable or necessary. Such situations could include: where the expected range in water levels is 20 feet or more, and the well needs to screen across the water table; or where the target formation is more than 20 feet thick, the contaminant plume is believed to be of great thickness, there is little or no vertical groundwater gradient within the target formation and no potential for a NAPL. In general, the length of screen (and associated length of filter pack) selected for the well should be based upon site-specific objectives, requirements, and conditions, should be designed to meet monitoring/sampling objectives and should not contribute to enhanced vertical transport of contaminants.

The position or depth of the well screen relative to the water table, or specific target horizon or fracture/stratigraphic interval must be clearly known. Such information should be specified in the project work plans.

### 6.2.3 Length of Filter Pack

The filter pack should not extend more than 2 to 3 feet above the top of the well screen and no more than 1 to 2 feet below the bottom cap or sump. This is because filter packs typically have much higher vertical permeability than the adjoining native formation, and hence will facilitate the preferential vertical flow of groundwater or contaminants. Excess length of filter packs facilitates the vertical spread of contamination as well as the collection of samples that "average" (i.e., dilute) across a greater thickness of aquifer than anticipated.

A transition (or secondary) pack may be placed over the primary filter pack. The transition pack is a finer gradation material than the primary pack, and is designed to retard the infiltration of the overlying bentonite and/or cement seal into the primary filter pack. It is appropriately used where the primary filter pack is a coarse gradation with a high potential for the infiltration of the overlying seal material.

### 6.2.4 Lengths of Seals

A bentonite seal should be placed directly over the uppermost filter pack. It should be 2 to 3 feet thick. A cement annular seal should extend from the top of the bentonite seal to the surface. In deeper wells the seal may be over one-hundred feet thick.

The lengths and positions of the bentonite and cement seals may have to be adjusted if the water table is shallow (i.e., <6 feet deep). At times, a thicker bentonite seal may also be prudent when there are uncertainties in the borehole condition. Information on the composition of the seals is provided in Sections 6.2.10 and 6.2.11.

### 6.2.5 Shallow Permanent Casing

The use of a permanent (larger diameter) shallow casing may be necessary to isolate the wellbore and well casing string (Section 6.2.6) and prevent communication between water-bearing zones. Such casings are commonly steel pipe of large diameter. The inside diameter of such casing should be at least 4 inches more than the exterior well casing diameter, to provide an adequate width for filling with a cement seal. This may require a very large initial boring for the shallow casing, and may necessitate a different drilling method. The use of a shallow casing in well construction will typically double the total cost of well construction.

Permanent shallow casings may be appropriate where:

- The shallow or overlying aquifer or zone is highly contaminated and the deeper aquifer or zone of completion may have much lower or no contamination.
- The monitoring well will be screened/filter packed in a zone that has distinct contaminant or natural chemistry from that of an overlying zone of saturation.
- The monitoring well will be screened/filter packed in a zone that has different total head from an overlying zone of saturation, indicating that advection would occur between the two zones via the wellbore.
- Either the screened/filter pack zone or an overlying zone of saturation is an important resource for drinking water supply.
- A NAPL is suspected to exist above the zone that is to be screened/filter packed.

At times, a temporary drive casing may be used in drilling and constructing a well in place of a permanent shallow casing. The use of a permanent shallow casing or temporary drive casing in the installation of the well should be based upon site-specific objectives and conditions, and specified in the project work plans.

### 6.2.6 Well Casing String

This section discusses each component of the well casing string. The components include blank casing (riser), well screen, sump (optional), and top and bottom caps.

<u>Blank Casing or Riser</u>

Blank well casing (or riser) is attached to the top of the well screen and extends from the screen up to, or just above, the ground surface. Blank casing is made from the following materials:

- <u>PVC</u>. Any PVC well pipe/screen should be manufactured to ASTM F-480 standards. Schedule (SCH) 40 or SCH 80 are typically used; SCH 80 is typically used for total depths greater than roughly 100 feet. Use of SCH 40 PVC at depths roughly greater than 100 to 150 feet; or in environments rich in ketones, esters or certain aromatic hydrocarbons, may be problematic.
- <u>Stainless Steel</u>. Stainless steel (SS) is commonly used for wells with high concentrations of solvents or other organic compounds. Type 304 is the most commonly used grade and 316 is less commonly used, but more resistant to corrosion/chemical reaction. Use in saline or reducing waters may cause corrosion or leaching of metals.
- <u>PTFE (Teflon)</u>. PTFE is very expensive. It's surface is slippery, and it may slip during installation, and it may be difficult for seal material to bond to it. It has higher chemical resistance and lower leachability than PVC or SS.
- <u>Reinforced Fiberglass</u>. Outside surface is slippery and is brittle, easy to crack if not handled with care. Usually used for monitoring specific remediation applications/techniques.

ABS plastic and low carbon steel pipe are other materials that are sometimes used for blank well casing.

Well casing material should be selected based upon the following factors:

- The expected total well depth and expected depth of water during construction. For wells deeper than roughly 100 feet, the selection of casing material must consider the potential for the casing to collapse or tear apart as it is being hung in the well bore.
- The natural and contaminant groundwater chemistry. Saline waters and pH<7 are conditions which will likely degrade stainless steel or other metal well casings. Certain chemical products, or high dissolved concentrations, of non-polarizing organic compounds may cause swelling or even dissolution of PVC, or dissolution of some plasticizers.
- The cost of the well casing material. Well casing materials vary in cost as follows: most affordable – PVC; moderately affordable – steel; most expensive – PTFE (Teflon).

Casing connections should be flush treaded. O-rings of known chemistry and compatible with the water chemistry and sampling objectives may be used to ensure a tight seal. Glued or solvent welded connections are not acceptable as the glues or solvents can alter the chemistry of the groundwater samples. Connections held together with slip couplings and sheet metal screws are also not acceptable. The screws can easily fail and can also damage sampling equipment.

<u>Well Screen</u>

Well screens are composed of the same materials as the blank casing and should be factory-manufactured. For monitoring wells the dominant criterion for selection of the screen should be sizing to exclude approximately 90% of the filter or sand pack particles. Sizing and selection of well screen and filter pack is covered in Shaw E & I technical SOP T-GS-033, *"Standards for Filter Pack and Well Screen Slot Size Selection"*.

Common screen types are slotted (milled) or wire-wrap. Slotted (milled) screen has the least open area (typically 2-6%) and is the least expensive. The most common widths of the cut slots used are 0.010 and 0.020-inch. Wire-wrap screen typically has 5-15% open area and comes in various grades of spacing between the wraps. Teflon and fiberglass screens are usually only available as slotted screen.

Well screens do not have to be of the same material as the blank casing. For example, a well could be constructed of SCH 80 PVC blank casing and 304 stainless well screen. If different materials are used, care should be taken to ensure the screen and blank casing can be securely connected, and that the use of dissimilar metals does not create problems with corrosion/cathodic reaction at the connection. Individuals needing help in designing well casing string configurations should find a senior geologist/hydrogeologist with monitoring well design and installation experience.

<u>Well Sump (Foot)</u>

A well sump consists of a short piece (i.e., one to three feet) of blank well casing with a bottom cap that is attached to the bottom of the screen section. A sump is used when dense non-aqueous phase liquid (DNAPL) is expected to enter the well (and is to be sampled and/or removed from the well), or a significant amount of sediment may enter the well over time.

The use of a foot or sump results in the expenditure of more resources during installation, development and well purging. It is a practice that carried over from the installation of water supply wells, and is generally of little benefit for monitoring wells. The use of a sump may not be practical where the bottom of the well screen is to be set at the top of a lower confining unit. Consequently, the current trend is to avoid the use of sumps in monitoring wells.

<u>Top and Bottom Caps</u>

The well screen or sump should have a firmly attached bottom cap. The top cap is usually either a slip cap that is placed over the top of the blank casing, or a rubber (expansion) gasket cap that is used to seal the top of the casing. The purpose of the top cap is to prevent entry of surface water into the well casing.

### 6.2.7 Centralizers

Centralizers are concentric devices that are designed to keep the well casing centered within the borehole, and to build a well that has an adequate annular space around the sides of the well casing. Centralizers are generally not used for wells less than 20 feet total depth and are typically not used when constructing a well through hollow stem augers or when using direct push drilling methods. The augers maintain space between the well casing string and borehole wall as the well is constructed.

Drillers generally have to use extra care in installing wells with centralizers. This is because the centralizers may become dislodged during installation of the casing string, hinder emplacement of filter pack or seal material with a tremie pipe, or hinder measuring the depths of filter pack or seal material. Any installation of centralizers should be closely supervised.

Centralizers, if used, are typically placed at intervals of every 20 feet for SCH 40 PVC casings. They may be placed at intervals of every 40 feet for steel or other more rigid casings. Centralizers are also placed at just above the top of the well screen and for certain wells, at the bottom of the screen or sump. The exact spacing to be used should be based on well- and site-specific conditions and specified in the project work plans. Metal centralizers will interface with electrical geophysical logs run inside PVC well casing.

### 6.2.8 Filter Pack

Filter packs may either be artificial (emplaced engineered material, including pre-packs) or natural (in-place geologic formation). Artificial packs are used most commonly and should be considered the default approach. Natural sand packs are not recommended and should generally only be used when installation of an artificial pack is not feasible (due to subsurface conditions).

Engineered (Artificial) Filter Pack. Engineered filter packs should consist of chemically inert rounded particles of a defined size distribution. Clean-washed and bagged graded silica sands are usually used for this purpose. Selection of filter pack size should follow appropriate Shaw E & I technical SOPs and/or project-specific requirements.

Pre-Pack. Pre-pack and channel-pack are integral systems of interior casing, filter pack, centralizers and exterior casing. They are commonly used for small diameter (i.e., one-inch casing diameter) wells and may be preferable for larger diameters wells where heaving or caving formation is prevalent. Filter pack gradations and screen opening sizes can be designed or selected from several off-the-shelf products.

Natural Sand Pack. Use of a natural pack may be appropriate if the following criteria are met: an engineered filter pack cannot be installed; and the natural formation in the vicinity of the proposed well screen is well characterized, homogeneous, composed predominantly of grains that will not enter the well screen, sufficiently permeable, and loose enough that it will collapse around the well screen. The use of a natural sand pack will usually require prior regulatory agency and client approval. Such approval should be documented, as required for the project, and maintained as project records.

### 6.2.9 Transition (Secondary) Filter Pack

A transition (or secondary) sand pack may be placed above the primary filter pack. This transition pack may be used where the filter pack is sufficiently coarse-grained and graded such that there is potential for the bentonite seal to migrate significantly in to it. Such migration may result in bentonite entering the well screen. An optional upper transition filter pack may also be placed between the bentonite seal and the cement seal. Transition sand packs are typically 2 to 3 feet thick and composed of a more finely graded engineered silica sand than the primary filter pack.

### 6.2.10 Bentonite Seal

The bentonite seal serves to separate the sanitary seal from the filter pack and provide extra protection against any migration of fluid up or down the wellbore from the screen/filter pack interval. It is typically 2-3 feet thick and may be composed of bentonite chips or pellets that are emplaced and then hydrated in-place, or it may be composed of a mechanically-mixed bentonite powder-water slurry that is tremmied into place. More information about the bentonite seal is provided in Section 6.4.1.

### 6.2.11 Cement Annular Seal

The cement seal constitutes the bulk of the annular fill in a deep well. Its primary purpose is to prevent fluids from migrating up or down the wellbore above the filter pack. To do this it must have low permeability, fill the entire annular space and not shrink.

The seal is composed of a grout mixture of Portland cement and water, with or without a bentonite additive. An admixture of about 5% bentonite powder, added to a cement-water slurry, is used to minimize shrinkage of the seal after it has been emplaced and is setting. Some regulatory agencies have guidance, requirements or specifications for using or not using bentonite in the grout. Such guidance and/or requirements need to be known and incorporated into the well design.

The use of quick-setting or other additives is not recommended as they can affect the chemistry of the groundwater samples. At times such additives may be necessary in highly permeable formation, but should only be used <u>after</u> appropriate regulatory approval. Such approval should be documented in the project files. Proper mixing and installation are important. The seal material should be mechanically mixed. It should be emplaced into the borehole in a way that prevents contact with the boring sidewall until it is in-place, so that it does not pull sidewall material with it as it falls. This helps to prevent voids or bridging of the cement. Additional information on the composition and mixing of the cement seal is presented in ASTM D 5787.

Cement generates heat as it sets. It is possible for deformation or failure of thermoplastic (i.e., PVC or ABS) well casing to occur from the heat generated during setting of the cement seal. This problem is exacerbated by more-rapidly-setting cements and thicker annular spaces. At times, the thickness of the annular space is greater than designed, for example if the formation washes out during drilling or cleaning of the wellbore. In such cases the potential for softening and sagging of the well casing is great as the cement sets. If this occurs the well must be abandoned and replaced. Changing the design of the well may also be necessary.

### 6.2.12 Above-Grade or Flush-Mount Surface Completion

Selection of an above-grade or flush-mount surface completion is largely determined by the likelihood of vehicle traffic at the site surface, or other client/property owner requirements (e.g., visual aesthetics, etc.). Flush-mount completions are default practice where there is vehicle traffic, the ground surface is stable and flooding is not anticipated. Above-grade completions are commonly used in areas of little or no vehicle traffic, where the ground surface is unstable (loose or muddy), where high grasses are present or where a likelihood of standing water exists. There may be strict regulatory requirements for the design and construction of surface completions. Such requirements must be identified and incorporated into the well design.

The following are the primary design criteria for every surface completion:

- Preventing hazard to/from vehicles.
- Preventing damage to the well.
- Preventing inflow of surface waters.
- Preventing unauthorized access and/or tampering. (requires some form of locking or securing the well head)
- Ease of use.
- Client/property owner requirements.

The exact type and components of the surface completion to be used should be described in the project work plans.

**Above-Grade Completions**

The primary components of an above-grade completion are the surface pad, protective casing, locking lid, drain hole, and bollards. Information on each of these components is provided in the following text.

Surface Pad. The surface pad is a concrete pad that both stabilizes the protective casing, provides a firm surface for workers, and directs surface waters away from the well casing. The protective pad should be at least two feet by two feet and at least 4 inches thick; however, it is recommended that it be somewhat larger and at least 6 inches thick. The surface pad should have a slight slope away from the protective casing to drain water away from the well.

Protective Casing. The protective casing should be weather and tamper-resistant, capable of keeping rainfall from reaching the well casing and resistant to opening without use of significant force. It is set around and over the well casing, extending from at least 6 inches above the well casing to at least 2 feet below grade (~30 inches below top of surface pad). There should be cement all the way around the protective casing, to its full depth.

Lid. The protective casing should have a locking, hinged lid that will protect the wellhead from rain, tampering, animals and ultraviolet damage.

Drain hole. A small hole should be drilled through the protective casing, a short distance above the top of the surface pad (higher if flooding is anticipated).

Bollards. Bollards (a.k.a. bumpers, traffic guards) are emplaced around the protective casing to hinder the destruction of well from vehicles. Bollards are often made of six-foot long, 4 to 6-inch diameter iron (black) pipe, filled with concrete. Bollards should be painted in a weather-resistant and highly-visible color paint.

Bollards should be set to a depth of at least 30 inches. They should be placed in an oversized, slough-free borehole or excavation that is filled with concrete. The borehole or excavation for the bollard should be at least 6 inches greater diameter than the bollard. Bollards are typically placed 3 to 6 feet from a well, usually 4 per well. At times, the bollards are embedded in the surface pad.

Bollards are easily knocked over when the momentum (speed and/or weight) of an impacting vehicle is great. For wells that are deeper or otherwise significantly expensive to replace, more robust bollards may be made as follows:

- Use a wider-diameter, thicker walled pipe for the bollard.
- Use a longer pipe. Bury it more deeply yet maintain enough height that any portion of a vehicle will strike the bollard before striking the protective well casing.
- Bury the pipe in a wider excavation. A wider and heavier concrete base is more difficult to dislodge than a narrow, shallow and light base.
- Space the bollards further out from the well. This may require use of 6 or more bollards.

Bollards should not be placed as to completely prevent a development, workover or sampling rig from accessing the well.

**Flush-Mount Completions**

Flush-mount completions are constructed for monitoring wells that need to be secured from damage when driven over by vehicles, constructed in locations that have very low likelihood of flooding, and need to be resistant to entry of rainfall or sheetflow. A locking protective street box or vault is the main component of the flush-mount completion. The box needs to have the following characteristics:

- Have sufficient strength to not break, crack, significantly sag or permanently deform when the greatest expectable vehicle wheel weight is upon it.

- Have a lid that is snuggly fitting and securely bolted to the frame.
- Have minimal potential for rainfall or sheetflow to enter it.

The box should be set slightly above surface grade and placed in concrete. The concrete should completely surround the box and be sloped from the top edge of the box to surface grade. The top of the blank well casing should be positioned inside the box to provide sufficient clearance to install a top cap on the casing.

### 6.3 Monitoring Well Installation

The basic process for monitoring well installation consists of: drilling and preparing the well boring or borehole, (includes setting permanent shallow protective casing [if required] and drilling borehole to total depth [TD]); decontaminating the well material (as necessary); connecting the components of the well casing string; carefully placing the well casing string in the borehole; placing/setting the annular materials (filter pack, transition pack [optional], bentonite seal and cement seal); and constructing the surface completion. The procedures for installation (construction) of a monitoring well depend upon a variety of site-specific conditions and factors discussed in Sections 6.1 and 6.2.

Detailed site-specific procedures for monitoring well installation should be developed and described in the project work plans and be based on the site-specific conditions and factors. Drilling of the borehole for the well should also follow applicable Shaw E & I technical SOPs and project-specific requirements/procedures. An example, or basic monitoring well installation procedure is included as Attachment 2. It is not possible for this SOP to present a detailed, specific procedure that would be applicable to the wide range of well designs, and drilling and installation methods available or applicable to specific conditions for a particular project. The example procedure may be customized and supplemented to address site- or project-specific conditions and requirements. Monitoring well installation should be supervised by the rig geologist.

### 6.4 Documentation

Accurate documentation is important to show the monitoring well was installed appropriately and to help ensure the usability of monitoring and sampling results from the well. Appropriate forms should be completed as per applicable Shaw E & I technical SOPs and project-specific requirements/procedures. Such forms can consist of a well construction form and a boring log. An example well construction form is included with this SOP (see Section 8). Basic requirements for generation of boring logs are presented in Shaw E & I technical SOP T-GS-027, *"Standards for Generation of Boring Logs"*.

Additional aspects of work may be addressed on separate appropriate forms. Such items to be entered on the appropriate forms include the following:

- Observations or measurements pertaining to health and safety
- Times of starting and completion of tasks and any significant down time
- Any problems or issues related to installing a particular well
- Exact counts (footages, weights, bags, piece numbers, etc.) of materials, as required for payment purposes.

In addition, the regulatory agencies may have specific documentation requirements for monitoring well installations. These requirements should be known and planned for in advance to ensure timely and effective compliance.

## 6.5 Acceptance

Shaw E & I or client QC programs may have specific requirements for the acceptance of a monitoring well. These requirements may include submittals of documentation (see above discussion) and/or field tests. The following are examples of field QC tests.

<u>Straightness of Well Casing</u>

A well casing must be sufficiently straight that any instrument/equipment used within the casing can freely pass through it. As many instruments/equipment have lengths of 3 feet, 10 feet, or even more, a casing that is not straight can cause an instrument or equipment to become stuck or prevent it from passing the area of constriction. Methods to help ensure a straight casing are to drill a straight boring (if possible) and, once the boring is complete, to hang or suspend the casing (using slips, etc.) while constructing the well.

<u>Sediment Content or Turbidity</u>

A client or over site agency may have a maximum measured turbidity allowed for water samples produced from a monitoring well. They may refuse to accept a well that does not adequately clean up of sediment and turbidity during development. Careful design and construction of the well help ensure that the initial sedimentation rate and turbidity within the well can be reduced to acceptable limits during subsequent development of the well.

At times monitoring wells are required to be designed and installed in fine-grained non-aquifer units. In such cases the required maximum turbidity standards may not be achieved even with careful design and well installation practices.

## 6.6 Technical Review

All monitoring well design and installation specifications, procedures, and results (e.g., reports, forms, etc.) should undergo technical review. It is recommended that the technical reviewer also provide review/oversight of the actual field implementation of monitoring well installation activities. This should include aid in troubleshooting drilling and installation problems. The technical reviewer should be an experienced senior geologist or hydrogeologist. At a minimum, the technical reviewer should be a person capable of planning and supervising monitoring well installation programs. Individuals needing assistance in finding qualified technical reviewers may consult internal Shaw E & I technical listings for experts in well design and installation.

Any issues raised during the technical review shall be resolved between the reviewer and staff planning, conducting or preparing results of monitoring well installation activities as follows:

- Comments/issues raised relative to planning, design and developing detailed procedures for monitoring installation should be resolved before mobilization and drilling/well installation commences; and
- Comments/issues raised relative to results of well installation activities should be resolved before external (i.e., outside of Shaw E & I) use or submission of the results.

The technical review comments and issues, and corresponding resolution should be documented and filed with the project records. Such records should be maintained until project closeout.

# 7. ATTACHMENTS

- Attachment 1, Conditions Potentially Requiring Special Design or Installation Considerations
- Attachment 2, Example Monitoring Well Installation Procedure

## 8. FORMS

- Example Monitoring Well Construction Form.

## Attachment 1

## Conditions Potentially Requiring Special Design or Installation

*Installation over 100 feet total depth* – potential for casing failure during installation of well. Careful selection of casing materials and drilling techniques; careful handling of well materials during installation recommended.

*Installation in waters with polar organic chemicals at concentrations > approximately 25% of solubility limit* – potential for damage to PVC casing, screen and components. Literature research and possibly using material other than PVC is recommended.

*Installation in reducing waters or waters with hydrogen sulfide* – potential for corrosion of steel casing components and leaching of metals such as Ni and Cr into well waters. Use of non-metal casing may be recommended.

*Drilling through a confining zone between two saturated zones* – high potential for advective flow of contaminated water through borehole. Use of a conductor casing or temporary drive casing may be required.

*Extremely unstable formation/flowing sands* – necessitates careful consideration and implementation of drilling and installation techniques, including use of mud rotary drilling methods and/or temporary drive casing. Use of water to flood hollow stem augers to construct wells in flowing sands is another technique. However, there may be issues with possible chemicals in the water supply used. May also require prior regulatory acceptance/concurrence and some agencies may not allow use of this technique.

*Installation at the water table* – careful review of range in depth to water is recommended. Recommend for well screen that is high enough and low enough to capture all expectable depths of water.

*Installation through uncased borehole* – a high potential exists for dislodging of loose sidewall materials during installation, and of bridging of sand or seal materials, or entrainment of sloughed sidewall materials. Use of a tremmie pipe is recommended for installing filter pack and seals.

*Expected use includes active recovery of liquids* – the well screen and filter pack should be more carefully designed to ensure adequate flow of liquids into the well casing.

*Monitoring for radionuclides* – certain well construction materials (such as bentonite) contain naturally-occurring radioactive components. Discussion of construction materials with geoscience leads at Shaw's U.S. Dept. of Energy Project Offices are recommended.

## Attachment 2

## Example Monitoring Well Installation Procedure

The following monitoring well installation procedure is provided as an example or basic procedure. It should be customized based on project/site-specific conditions, equipment, methodologies and quality control requirements. This procedure is written for a generic 2- or 4- inch diameter monitoring well installed inside a mud rotary boring or inside hollow stem augers or temporary drive casing. The rig geologist should supervise drilling of the well boring and installation of the monitoring well. The example procedure consists of the following:

1. The well boring should be drilled to the desired total depth using the methods and procedures specified in applicable Shaw E & I technical SOPs and the project work plans. This includes generation of a boring log by the rig geologist during the advancement of the boring.

2. After the borehole has been successfully drilled to the target total depth, remove drill cuttings prior to constructing the well. Additional conditioning of the borehole may be required depending upon observed conditions. Review logs and notes with the driller for any zones or depths exhibiting drilling problems that may affect the well installation. Make sure the proposed screen depths will be placed in the proper stratigraphic interval. Identify and plan any other necessary actions mutually agreed upon by the rig geologist, project geologist, and the driller to ensure or aid in effective installation of the well.

3. Remove the drill pipe and bit if using rotary techniques, or remove the center bit boring if using the hollow-stem auger technique. The well construction materials will then be installed inside the open borehole or through the center of the drive casing or augers.

4. Measure the total depth of the completed boring using a weighted sounding line. The borehole depth is checked to assure that formation material has not heaved to fill the borehole. If heaving has taken place, options for cleaning, redrilling, or installation in the open section of the boring should be discussed with project geologist and driller.

5. In the event that the hole was drilled beyond the desired depth, sealant (usually bentonite or as specified in the project work plans) may be added to the bottom of the boring to raise the bottom of the hole to the desired depth. The bentonite should be added gradually to prevent bridging. Bentonite addition should stop when its level has reached approximately six inches to one foot below the desired base of the well casing string. The bentonite plug should be allowed to hydrate for at least one hour before installation of a filter pack or other well materials.

6. Calculate volumes of filter pack, bentonite pellets/slurry, and cement grout required, based on borehole and well casing dimensions.

7. Place a layer of filter pack (six inches to one foot or as specified in the project work plans) at the bottom of the borehole. The filter pack will be installed through the center of the drive casing/augers. Filter pack will be added slowly while withdrawing the drive casing/augers. Measure and record the depth to the top of the layer.

8. Thoroughly decontaminate the blank casing, well screen, sump (optional), and top and bottom caps to be installed in the well according to applicable Shaw E & I technical SOPs and/or the project work plans.

9. Inspect the blank casing, well screen, sump, top and bottom caps and any other well construction materials prior to installation to assure that no damage has occurred during shipment and decontamination activities.

10. Connect the well casing string together. Make sure the top cap is securely positioned on the blank casing to prevent unwanted material from entering the well during construction activities. Carefully lower the well string through the open borehole, drive casing, or inside of the augers

until the well string is at the desired depth. The well string should be suspended by the installation rig and should not rest on the bottom of the boring. The casing string should be vertical and centrally positioned in the borehole. Stainless steel centralizers should be used if necessary and feasible. In the event the well string was dropped, lowered abruptly, or for any other reason suspected of being damaged during placement, the string should be removed from the boring and inspected.

In certain instances, the well string may rise after being placed in the borehole due to heaving sands. If this occurs, the driller must not place any drilling equipment (drill pipe, hammers, etc.) to prevent the casing from rising. The rig geologist should note the amount of rise. The rig geologist should then consult with the project geologist for an appropriate course of action.

11. Record the following information on the appropriate forms according to this SOP and/or the project work plans: length of well screen, total depth of well boring, depth from ground surface to top of grout or bentonite plug in bottom of borehole (if present), depth to base of well string and depth to top and bottom of well screen.

12. When using the mud rotary drilling technique, tremie the filter pack into the annular space around the screen. Clean, potable water may be used to assist with the filter pack tremie operation. For all other drilling techniques, the filter pack may be allowed to free-fall or be tremied according to the project work plans. If using drive casing or augers, the drive casing or augers should be pulled slowly during filter pack installation in increments of roughly 0.5 to 1 foot so that the filter pack can fill the annular space between the well screen and borehole wall.

13. Filter pack settlement should be monitored by initially measuring the sand level (before beginning to withdraw the drive casing/augers). In addition, depth soundings using a weighted tape should be taken repeatedly to continually monitor the level of the sand. The top of the well casing should also be monitored to detect any movement due to settlement or upward lifting from drive casing/auger removal. If the top of the well casing moves upwards at any time during the well installation process, the driller should not be allowed to set drilling equipment (downhole hammers, drill pipe, etc.) on the top of the casing to prevent further movement.

14. Filter pack should be added until its height is approximately two to three feet above the top of the screen (unless otherwise specified in the project work plans), and verification of its placement (by sounding) should be conducted. The filter pack may then be gently surged or swabbed in order to settle the pack material and reduce the possibility of bridging.

15. The height of the filter pack should then be re-sounded and additional filter pack placed as necessary. Once the placement of the filter pack is completed, the depth to the top of the pack is measured and recorded on the appropriate forms according to the project work plans. The total volume of filter pack used should be recorded and compared to the pre-installation calculated volume. If the actual volume used is less than the calculated volume the project geologist should be consulted to help determine if bridging of the sand pack occurred.

16. A two- to three-foot thick (unless otherwise specified in the project work plans) bentonite seal is then installed on top of the filter pack. If pellets or chips are used, they should be added gradually to avoid bridging. Repeated depth soundings will be taken using a weighted tape to ascertain the top of the bentonite seal. The seal should be allowed to hydrate for at least one hour, or as specified in the project work plans, before proceeding with the grouting operation.

17. After hydration of the bentonite seal, cement grout is placed in the annular space. The grout may be pumped through a tremie pipe and filled from the top of the bentonite seal upward. The bottom of the tremie pipe should be maintained below the top of the grout to prevent free fall and bridging. When using drive casing or hollow-stem auger techniques, the drive casing/augers should be raised in incremental intervals, keeping the bottom of the drive casing/augers below the top of the grout. Grouting will cease when the grout level has risen to within approximately one to two feet of the ground surface, depending on the surface completion type (flush mount versus aboveground). The grout levels should be checked for settlement after a time period specified in

the project work plans. If settling has occurred, the grout should be topped off to the original level.

18. For above-grade completions, the protective steel casing should be centered over the well casing (riser) and inserted into the grouted annulus. The bottom of the protective casing should be set at a depth of 2 feet below grade. Prior to installation, a 2-inch deep temporary spacer shall be placed between the PVC well cap and the bottom of the protective casing cover to keep the protective casing from settling onto the well cap.

19. After the protective casing has set, concrete surface pad (2-feet by 2-feet by 4-inches thick) is constructed at ground surface around the protective steel casing. The concrete is sloped away from the protective casing to promote surface drainage from the well.

20. Four steel bollards will be embedded to a depth of approximately 30 inches below surface grade. The posts will be installed in concrete filled postholes spaced equally around the well at a distance of approximately 3 feet from the protective steel casing.

21. After the surface pad has set, a drainage hole may be drilled into the protective casing if required by the project work plans. The drainage hole is positioned approximately two inches above ground surface, just above the top of the surface pad.

22. For flush-mount completions, a street box or vault is set and cemented in position. The street box or vault will be centered over the well casing (riser). The top of the street box or vault will be positioned slightly above grade and the cement sloped to grade to promote surface drainage away from the well

23. A minimum of 24 hours after final grouting should elapse before installation of the concrete pad and steel guard posts for above-grade completions, or street boxes or vaults for flush-mount completions.

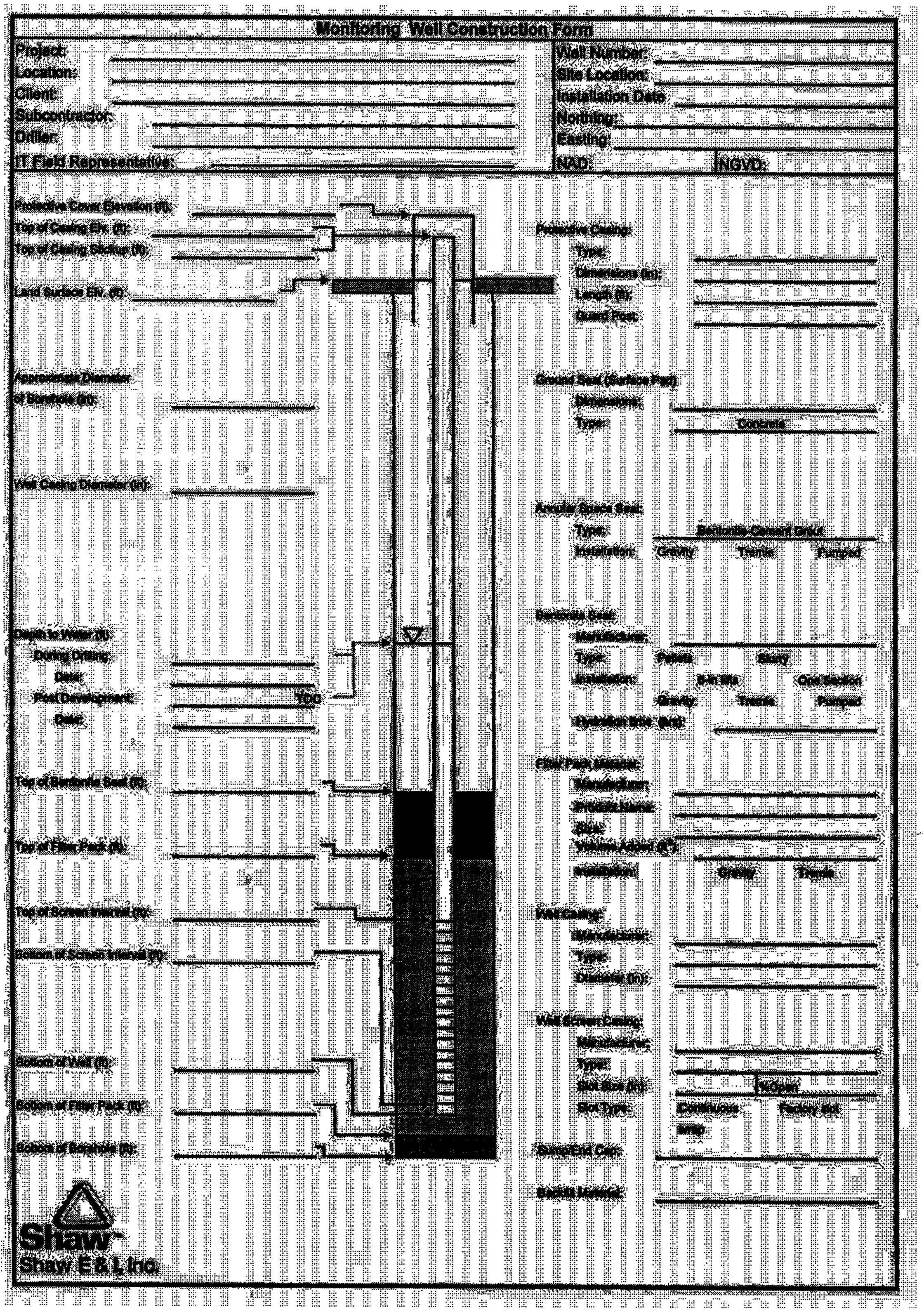
24. The well head will be labeled to identify, at a minimum, the well number, depth, and date of installation. A reference or measuring point for measuring water levels may also be placed or marked at the well head.

25. Following well completion and demobilization of the rig, the well site should be cleared of all debris and trash and restored to a neat and clean appearance according to the project work plans. All investigation-derived waste generated at the well site should be appropriately contained and managed according to the project work plans.

26. All measurement should be recorded and all appropriate documentation completed according to this SOP and/or project-specific requirements.

27. The well head may be surveyed after completion according to applicable Shaw E & I technical SOPs and/or project-specific requirements.

## Example Monitoring Well Construction Form



# SOP T-GS-033

# Standards for Filter Pack and Well Screen Selection

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# STANDARD OPERATING PROCEDURE

**Subject: Standards for Filter Pack and Well Screen Selection**

## 1. PURPOSE

This procedure provides the technical standards to be used in determining appropriate filter pack and well screens for monitoring, extraction and injection wells. The procedure includes the minimum required steps and quality checks that employees and subcontractors are to follow when performing the subject task.

This procedure may also contain guidance for recommended or suggested practice that is based upon collective professional experience. Recommended practice goes beyond the minimum requirements of the procedure, and should be implemented when appropriate.

## 2. SCOPE

Geosciences Standard Operating Procedure (SOP) T-GS-033 describes standards for filter pack and well screen selection, and describes how such work will be conducted and documented for projects executed by Shaw Environmental and Infrastructure, Inc. (Shaw E & I). The SOP addresses technical requirements and required documentation. Responsibilities of individuals performing the work are also detailed. Additional project-specific requirements for filter pack and well screen selection may be developed, as necessary, to supplement this procedure and address project-specific conditions and/or requirements.

This scope does not address filter pack or screen slot design for wells in bedrock or well-consolidated formations, or use for recovery of nonaqueous phase liquids (NAPLs).

## 3. REFERENCES (STANDARD INDUSTRY PRACTICES)

Filter pack and well screen selection should follow accepted industry practices. These practices are presented in the latest version of the following ASTM Standard:

ASTM D 5092 - 02 Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers.

Additional references, which are useful for filter pack and screen selection, include the following:


- Driscoll, F.G., 1986, *Groundwater and Wells*, second edition, U.S. Filter/Johnson Screens, St. Paul, Minnesota.
- Gass, Tyler E., 1988, "Monitoring: Well Filter Pack and Screen Slot Selection: A Reassessment of Design Parameters", *Water Well Journal*, National Water Well Association, June, pp. 30-32.
- Nielsen, David M., editor, 1991, *Practical Handbook of Ground-Water Monitoring*, Lewis Publishers, Chelsea, Michigan, 717 pp.


## 4. DEFINITIONS

The following definitions are applicable to filter pack and well screen selection and this SOP.

- **Annular Space**—The space (annulus) between the casing and screen and the borehole wall.

- **Bentonite**—Bentonite is composed of the clay mineral montmorillonite that has the ability to adsorb large amounts of water and, in doing so, swell. Bentonite may be powdered, granular, palletized or chipped sodium montmorillonite furnished in sacks or buckets from a commercial source and should be free of impurities which adversely impact the water quality in the well. Pellets consist of roughly spherical or disk shaped units of compressed bentonite powdered. Chips are large, irregularly shaped, and coarse granular units of bentonite free of additives. Granules consist of coarse particles of unaltered bentonite, typically smaller than 0.2 in (50mm).
- **Borehole**—A cylindrical hole advanced into the subsurface by mechanical means (e.g., drilling).
- **Casing**—Pipe, made from various materials, inserted into a borehole to eliminate caving.
- **Entrance Velocity**—The industry recommended groundwater velocity passing through the total screen length to minimize friction losses, incrustation, and corrosion. This value is a function of the screen open area, length, and groundwater flow rates and is generally 0.1 ft/sec for extraction wells and 0.05 ft/sec for injection wells.
- **Extraction Well**—A well designed and built for continuous, or semi-continuous, extraction of groundwater. Well efficiency is a primary concern in the design and construction of extraction wells.
- **Grout**—Material consisting of cement, or a cement-bentonite mixture.
- **Hydraulic Communication**—The migration of fluids from one geologic zone to another, especially along a well casing, grout plug, or through backfill material.
- **Injection Well**—A well designed and built to facilitate the infiltration or injection of water into the subsurface. Well efficiency under a variety of poor-performance and operational-difficulty scenarios should be considered during design and construction of injection wells.
- **Monitoring Well**—A well designed and built mainly for groundwater sample collection and groundwater elevation measurements.
- **Neat Cement**—Cement that has no additives to modify its setting time or rheological properties.
- **Perforation**—A slot or hole made in a well casing, and sometimes the annular cement seal, to allow for communication of fluids between the well, the annular space and the formation.
- **Piezometer**—A nonpumping, small diameter well with a short screen length designed and built mainly for discrete groundwater elevation measurements.
- **Primary Filter or Sand Pack**—A clean, well rounded, silica sand or sand and gravel mixture of selected grain size and gradation that is installed in the annular space between the borehole wall and the well screen, (extending an appropriate distance above the screen), for the purpose of retaining and stabilizing the particles from the adjacent strata. A term used in place of gravel pack.
- **Screen Open Area**—The area per foot open by the screen slots to allow water to enter the screen. Most screen manufacturers provide tables that show this area per foot for each size of screen and for various widths of slot openings.
- **Secondary Filter or Sand Pack or Transition Sand**—A clean, well rounded, uniformly graded, silica sand that is placed in the annulus between the primary filter pack and the over-lying bentonite seal or between the seal and overlying grout backfill, or both, to prevent movement of bentonite seal or grout, or both into the primary filter or sand pack.
- **Tremie Pipe**—A small diameter pipe inserted in a well boring for controlled delivery of filter pack and sealing material to specific depths during well construction.

- **Well Efficiency**—The theoretical drawdown (or buildup) related to the actual drawdown (or buildup) in a pumping (or injection) well. Also defined as the ratio of the drawdown (buildup) in the aquifer/formation at the radius of the well to the drawdown (buildup) inside the well during pumping (injection). Design and construction factors have a direct bearing on the efficiency of the extraction or injection well.

- **Well Screen**—A tubular device with slots, holes, or louvers, attached to the well casing and serves as the intake portion of a well. The screen allows groundwater to enter the well, and helps, along with the filter pack, to prevent or limit the entrance of sediment into the well.

## 5. RESPONSIBILITIES

### 5.1. Procedure Responsibility

The Geosciences Discipline Lead is responsible for the development, maintenance, and revision of this procedure. Any questions, comments, or suggestions regarding this technical SOP should be sent to the Geosciences Discipline Lead. The Geosciences Discipline Lead's location and associated contact information can be found on the Insider.

### 5.2. Project Responsibility

Employees conducting filter pack and well screen selection are responsible for meeting the requirements of this procedure. Employees conducting technical review or oversight of filter pack and well screen selection activities are also responsible for following appropriate portions of this SOP.

For those projects where filter pack and well screen selection are conducted, the Project Manager, or designee, is responsible for ensuring that such activities are implemented and documented in accordance with this and any other appropriate procedures. Project participants are responsible for recording information in sufficient detail to provide objective documentation (i.e., forms, drawings, plans, reports, etc.) that the requirements of this SOP have been met. Such documentation shall be retained as project records.

## 6. PROCEDURES (TECHNICAL REQUIREMENTS)

This SOP addresses design considerations pertaining to filter pack and well screen selection for several types of groundwater wells. These include monitoring wells, extraction wells, and injection wells. It is intended to provide guidance in situations where formation properties such as transmissivity, permeability, grain size, cementedness and homogeneity/heterogeneity are not well known and filter pack and/or screen slot size must be determined during or after the drilling of a wellbore or pilot borehole. **In situations where formation properties are confidently known, it is common and acceptable practice for project documents to specify filter pack and well screen type and size, based on familiarity with the geologic formation and/or experience with similar-type wells within the same geologic formation near or in the site area.**

For effective selection of filter pack and well screen, the project-specific work plans should identify the following:

- The purpose of the well, expected screen depth/target stratigraphic interval and desired flow rate
- The chemistry of formation water
- The homogeneity/heterogeneity, cementedness, permeability and grain-size distribution of the formation in which the well is to be screened
- Any other project-specific requirements that may affect inter pack and well screen types and sizes

Additional information on monitoring and extraction/injection well design requirements can be found in Shaw E & I SOPs T-GS-031, *Standards for Design and Installation of Groundwater Monitoring Wells* and T-GS-032, *Standards for Design and Installation of Groundwater Extraction and Injection Wells*, respectively. The requirements of these SOPs should also be understood in the selection and design of filter pack and well screens.

## 6.1. Methodology and Requirements

Details of well design requirements are provided in Chapter 13 of Driscoll, 1986 and other Shaw E & I technical SOPs. Well screens and filter packs should be designed to maximize open area and transmitting capacity while minimizing entrance velocities. Well screen and filter pack design is presented in Chapter 12 and 13 of Driscoll, 1986. Driscoll (1986, pp. 395-405), and Nielsen and Schalla (in Nielsen, 1991; pp. 309) address various issues related to well screen selection, types, open areas and entrance velocities.

The following text presents the basic methods and requirements for filter pack and well screen selection. Such methods and requirements were derived, in part, from the above references and standards.

### 6.1.1. Well Screen Selection

Regardless of the type of well being constructed, several parameters must be considered during the screen selection process. The screen strength must be adequate to withstand not only the stresses of installation, but also other forces that may be applied during well completion, development and use. For deeper wells, forces that tend to pull the casing and screen apart must be exceeded by the tensile strength of the material and the collapse resistance must be greater than the external hydrostatic forces.

Screen durability, especially important in corrosive environments must be considered. Optimization of this parameter will extend the life of the well. The following are generalizations that should be considered during the screen selection process. The presence of bicarbonate tends to retard corrosion; however, at higher concentrations it may promote encrustation. Sulfate and nitrate are neutral and chloride accelerates corrosion. Concentrations of carbon dioxide of over 50 mg/liter are usually corrosive. Water containing hydrogen sulphide should be checked for the presence of sulphate-reducing bacteria which are highly detrimental to well screens. Acidic water may be severely corrosive, but the corrosion is usually uniform, rather than pitting. Consequently, well life may be greater than normally expected.

Material selection is of particular importance in monitoring wells. The use of stainless steel, versus PVC or other materials such as fiberglass or iron must be weighed against the chemical nature of the parameters/contaminants being monitored. Regulatory restrictions may also dictate the type of material being considered.

Individuals needing assistance in selecting well screens may search the literature or consult internal Shaw E & I technical listings for experts in monitoring or extraction/injection well design and installation.

### 6.1.2. Well Screen Slot Size (Width) Determination

An optimal well screen slot size will allow maximum transmission of water and prevent pass- through of filter pack material, if used. The well screen should have the largest possible aperture size consistent with retaining the filter pack or formation material in the annular portion of the well. Unless prior information is available, well screen slot openings for either method may be selected from evaluation of sieve analysis data from samples collected from the targeted screen interval of the well. For fine-grained formations the smallest slot size of 0.010-inch should be used.

Gass (1988) presents simple rules-of-thumb for common well situations. Driscoll (1986. pp. 435-438) and Nielsen and Schalla (in Nielsen, 1991; pp. 284-287) address the selection of slot size for wells constructed with naturally developed rather than artificial filter packs.

A design procedure for the selection of screen slot size for monitoring wells is explained in ASTM D 5092 (2002). Driscoll (1986. pp. 434-438) and Nielsen and Schalla (in Nielsen. 1991; pp. 290-293) describe a similar procedure for all wells. The procedure requires knowledge of the grain size distribution of the filter pack and is summarized on Attachment 1 – Basic Guidelines for Screen Slot Width Design.

ASTM D 5092 (2002) recommends the slot size and arrangement should retain at least 90% and preferably 99% of the filter pack for monitoring wells. Similarly, EPA recommends that the screen slot size for monitoring wells should retain from 90 to 100% of the filter pack material or from 50 to 100% of the formation material in naturally packed wells.

### 6.1.3. Well Screen Open Area and Screen Length

Well screen open area is the percentage of the slotted portion of a screen that is open, along the length of the screen. Common screen types are slotted (milled) or wire-wrap. Slotted screen has the least open area (typically 2-6%). Wire wrap screen typically has 5-15% open area and comes in various grades of spacing between wraps. Percentage open areas of well screens are usually available from well screen manufacturers. While field slotting, (or in some cases down hole slotting) is possible, the EPA requires that screens for monitoring wells be slotted at the mill.

Assuring adequate open area is important in extraction wells, high-flow wells or other wells where efficiency is important such as injection wells. A rule-of-thumb is that for pumping wells, the well-screen should have a percentage open area equal or greater than the effective porosity of the adjacent natural formation. However, references cited in Nielsen and Schalla (in Nielsen, 1991; pp. 309) indicate that open areas in excess of 8 or 10 % are as functional as open areas of 30 % or more.

In tight formations, such as silts, the flow of water into or out of a well is typically limited by the transmissivity of the formation adjoining the filter pack. In more permeable units such as sands, the potential exists that water may be able to flow through the formation and the filter pack faster than it can efficiently flow into or out of the well screen. In such situations it is important to maximize open area and ensure that water can enter the well at a sufficiently low velocity to maintain optimal flow. If open area is insufficient, water may enter the well too quickly and entrance velocities may be so high that turbulent flow occurs. This can lead to friction losses in the screen openings and may cause mineral precipitation, encrustation or corrosion, diminishing well performance. Attachment 2 (Basic Guidelines for Selection of Well Screen Open Area) outlines the determination of minimum percentage open area for a well screen.

Screen length should be optimized based upon the purpose of the well. In certain cases, the screened interval will be sized to cover only the zones with the highest hydraulic conductivities. Driscoll (1986. pp 432-436) provides recommendations for screen lengths in extraction wells. Screen lengths for monitoring wells are usually kept to a minimum length appropriate for characterizing a plume, thus minimizing the effects of dilution and potential enhanced vertical transport. In some cases where primarily hydraulic information is sought, piezometers may be installed as points or with screens specifically tailored to optimize the data collection.

Because clogging of screens, (attributed to high entrance velocities and caking of entrained sediments), is a major issue in injection wells, screen lengths are usually approximately twice as long as in an extraction well discharging the same volume. An additional screen length concern for injection wells, particularly in consolidated rock aquifers, is hydrofracturing due to pressure build-up. While beyond the scope of this SOP, the effects of this process should be addressed during the project planning stage.

### 6.1.4. Filter Pack Design

The primary function of an installed filter pack is to increase permeability immediately surrounding a well casing, and minimize the migration of formation materials into a well. Some situations that may require the use of a filter pack include: the natural formation is poorly sorted, or is uniformly sorted fine sands, silt or clay; the natural formation is poorly cemented; or the diameter of the borehole is much greater than the diameter of the screen. The convention/basic requirement for monitoring wells in granular unconsolidated formations is the use of a filter pack (unless technically or economically impractical). To properly design a filter pack the gross distribution of formation grain sizes must be known, with particular attention to finer lithologies within the interval to be filter-packed. This is usually done through careful logging and sieve analysis of a sample that is representative of the finer lithology encountered in the interval to be filter-packed.

In some circumstances, a filter pack may be unnecessary. Often wells in competent rock do not require screens and thus do not require a filter pack. In other cases such as for extraction/injection wells in permeable coarse sand-gravel formations, the formation may be developed to behave as a filter pack without the introduction of engineered materials. Driscoll (1986, pp. 439), Nielsen and Schalla (in Nielsen, 1991; pp. 282-284) and ASTM (2002, p. 6) address such circumstances.

Sieve analyses are typically performed on formation samples that are collected intact from the well bore or pilot boring and then disaggregated and dried prior to sieving. Sieve analyses should be performed on samples that represent the finest-grained formation encountered in the anticipated filter pack intervals. This is because one purpose of a filter pack is to minimize the migration of formation fines into a well. More than one sieve analysis may be required if markedly different grain-size lithologies are encountered in the proposed screen interval. Sieve analyses may be performed for each well to be installed, or may be performed on representative samples of each lithologic type encountered during installation of a well group.

Sieve analyses may be performed in the field if equipment and trained personnel are available and QC requirements can be satisfied. Efficient sieving in the field may be hindered by the effort required to fully disaggregate and dry samples prior to sieving.

In some cases sieve analyses are not practical. Examples of environments where sieve analyses are not practical are for samples collected from overbank or floodplain deposits where sediments are interbedded with clays, silts and very fine sand.

Filter packs should be selected to exclude 85% to 99% (weight) of formational material from the well without severely reducing the yield of the well. ASTM D 5092 (2002), Driscoll (1986, pp. 438-443 and 722) and Nielsen and Schalla (in Nielsen, 1991; pp. 287-294) describe the selection of filter pack size from sieve analysis. Attachment 1 – Basic Procedure for Filter Pack Design, also summarizes the design and selection of filter pack material.

Filter pack material should be composed of inert, cleanly washed, contaminant free, well-rounded material. Engineered materials of uniform shape and size are ideal. These can include industrial grade glass or beads. Quartz sand or well-washed, bagged river sands that meet such characteristics are often commercially available at low cost. Such materials should be composed entirely of quartzose mineral grains if possible. Commercially available washed pea gravel may be acceptable for use in gravel aquifers; however, if used in monitoring wells, it must be inert and not coated with chemically active oxide materials.

For fine-grained formations noted above in Section 6.0, an example of a commercially available fine grained sand pack is one within a nominal sieve size of 16 by 30 which should be used against a screen slot size of 0.010-inch.

Filter pack material should be installed in a manner that prevents bridging and particle-size segregation. Allowing the filter pack to free-fall into the annular space is only appropriate for very shallow wells using materials of uniform grain size. In all other cases, the filter material should be tremied into place.

In certain instances, such as where formation stability and sloughing is a problem during well construction, pre-packed screens may be considered. In these situations care must be taken to protect the screen from down-hole damage during the installation phase to protect the integrity of the well. The filter packing material should meet the same requirements stated above.

## 6.2. Technical Review

The results of the filter pack and screen selection should be presented as part of the well design in the project work plans. The filter pack and well screen design and supporting documentation (e.g., graphs, sieve analysis results, calculations, etc.) used to select the filter pack and well screens should undergo technical review. The technical reviewer should be an experienced senior geologist or hydrogeologist. At a minimum, the technical reviewer should be a person capable of planning and conducting filter pack and well screen selection. The technical reviewer should not have developed or conducted the particular filter pack and well screen selection activity to be reviewed. Individuals needing assistance in finding qualified technical reviewers may consult internal Shaw technical listings for experts in monitoring or extraction/injection well design/installation, or may possibly use an expert outside of Shaw, if necessary.

Any issues raised during the technical review should be resolved between the reviewer and staff planning and/or conducting the filter pack and well screen selection before execution of the work or external (i.e., outside of Shaw E & I) submission of the results. The technical review comments and issues, and corresponding resolution should be documented and filed with the project records. Such records should be maintained until project closeout.

## 7. ATTACHMENTS

- Attachment 1, Basic Guidelines for Screen Slot Width Design
- Attachment 2, Basic Guidelines for Selection of Well Screen Open Area
- Attachment 3, Basic Procedure for Filter Pack Design

## 8. FORMS

None.

# Attachment 1

# Basic Guidelines for Screen Slot Width Design

The following are basic guidelines for well screen slot width selection/design:

- Determine the 85%-retained, 90%-retained and 99%-retained grain sizes for the filter pack.
- The casing slot width should be somewhere between the 85%-retained and the 99%- retained filter-pack sizes. In general, a filler casing slot (i.e., approximates the 99%- retained size) will result in less turbidity and sand in the well, but will also restrict the inflow of water and result in an inefficient well.
- If the well is to be extensively developed or high well efficiency is important, then a slot width that approximates the 85%-retained or 90%-retained size may be appropriate.
- If the well is to produce sediment-free water without extensive development, and well efficiency is not important, a slot width closer to the 99%-retained size may be appropriate.
- Wider slots are less prone to corrosion or fouling. Narrower slots become more easily fouled, generally correspond to lower percentages of open area, and generally contribute to well inefficiency.

# Attachment 2

# Basic Guidelines for Selection of Well Screen Open Area

For wells where efficiency is relatively unimportant and extensive pumping is not anticipated, the percentage open area of the well screen is generally unimportant.

For wells that are to be pumped extensively, or where well efficiency is important, a high percentage open area is generally important. A rule of thumb for such situations is that the percentage open area in a well screen should equal or exceed the effective porosity of the adjacent formation.

Information pertaining to the percentage or total open area per linear unit (i.e., per column-foot) of a diameter and type of well screen is available from well screen manufacturers.

To test whether open area is sufficient to prevent turbulent flow, do the following:

- Determine the open area per foot of well screen-column (expressed as square feet ($ft^2$)per column-foot of well screen). [Either look-up from manufacturer's information, or determine the total casing area per column-foot and multiply it by the open area].
- Estimate the flow of water into the well and the screen length over which it will occur. Consider expected drawdown and well inefficiency when estimating the length of screen through which flow will occur.
- Calculate the expected flow of water into the well, as cubic feet per second per lineal foot of well-column ($ft^3$/sec, per foot of well column).
- Divide the flow of water into the well ($ft^3$/sec per foot of well-column) by the open area of the well screen ($ft^2$/foot of well-column) to get the expected entrance velocity.
- Compare the expected entrance velocity to target velocity of 0.1 ft/sec for extraction wells. Injection wells should have an entrance velocity of less than 0.5 ft/sec. An entrance velocity in excess of 0.1 ft/sec will cause turbulent flow and may cause casing pitting and corrosion and greater well inefficiency.

If the estimated entrance velocity is too high, consider one of the following:

- Use of a wider diameter well screen. Open area generally increases by almost the ratio of the squares of the casing diameters.
- Use of another style of well screen (for example, continuous-wrapped wire screens have open areas greater than slotted screens).
- Whether the expected flow of water into the well may be slowed down without compromising the use of the well. This might require use of a different pump in an extraction well, or might be unacceptable for a well is designed to control the migration of a contaminant plume via pumping and hydraulic capture.

# Attachment 3

# Basic Guidelines for Filter Pack Design

1. Perform a sieve analysis on a representative sample from either each major lithology, or only the finest lithology, within the interval to be filter-packed.

2. Determine the grain-size at which 30% of the formation material passes to a finer sieve (30% passing, or D30). This is the same grain-size for which 70% of the formation material is retained.

3. Multiply the formation D30 by a number between 4 and 6 (i.e., 5) if the formation is uniform and fine, and a number between 6 and 10 (i.e., 8) if it is coarse and/or heterogeneous. This number is the ideal filter pack-D30. Plot it on a cumulative grain-size distribution chart.

4. Draw a vertical line and several different steep lines throughout the ideal filter pack-D30. The lines should have steepness that vary between 1 and 2.5, where steepness is the Uniformity Ratio, defined as the ratio of the 60%-passing to the 10%-passing (D60/D10) [This is the same as the ratio of the 40%-retained to the 90%-retained]. Altogether, the lines represent the range of ideal filter pack gradations.

   A filter pack composed of uniform particles, such as glass beads, has a Uniformity Coefficient of approximately 1 and falls best when emplaced into a well. Graded materials (such as most commercially-available. clean-washed. bagged sands) tend to segregate during placement.

5. Compare the range of ideal filter pack gradations with local, commercially available, clean-washed, inert materials and select one such material that has a grain-size distribution that approximates the ideal filter pack range. In some cases where commercially available sand sizes are not available, filter pack material may require specially blended mixtures.

# SOP T-GS-037

# Standards for Conducting Well Development


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# STANDARD OPERATING PROCEDURE

**Subject:** **Standards for Conducting Well Development**

## 1. PURPOSE

This procedure provides the standard practice for development of monitoring, extraction and injection wells completed primarily in granular formations. The procedure includes the minimum required steps and quality checks that all employees and subcontractors are to follow when performing the subject task.

This procedure may also contain guidance for recommended or suggested practice that is based upon collective professional experience. Recommended practice goes beyond the minimum requirements of the procedure, and should be implemented when appropriate.

## 2. SCOPE

Geosciences Standard Operating Procedure (SOP) T-GS-037 describes standards for well development, and how such development activities will be conducted for projects executed by Shaw Environmental and Infrastructure, Inc. (Shaw E & I). The SOP addresses technical requirements and required documentation. Responsibilities of individuals performing the work are also detailed. Additional project-specific requirements for well development may be prepared, as necessary, to supplement this procedure and address project-specific conditions and/or objectives.

## 3. REFERENCES (STANDARD INDUSTRY PRACTICES)

Well development should follow accepted industry practices. These industry practices are presented in the latest version of the following ASTM Standards:

| | |
|---|---|
| ASTM D 5521-94 | Standard Guide for Development of Ground-Water Monitoring Wells in Granular Aquifers |
| ASTM D 5092-02 | Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers. |
| ASTM D 6724-01 | Standard Guide for Installation of Direct Push Ground Water Monitoring Wells |
| ASTM D 6725-01 | Standard Guide for Installation of Direct Push Ground Water Monitoring Wells |

Additional reference materials, which will be useful for planning and conducting well development, include the following:

- Aller, Linda, B.W. Truman, G. Hackett, R.J. Petty, J.H. Lehr, H. Sedoris, D.M. Nelson, J.E. Denne, 1989, *Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells*, National Water Well Association, Dublin, Ohio.
- Driscoll, Fletcher G. 1986, *Groundwater and Wells*, Johnson Division, St. Paul, Minnesota.
- Izraell, Ruth, D. Yeskis, M. Collins, K. Davies, B. Zavala, 1992, *Monitoring Well Development Guidelines for Superfund Project Managers*, U.S. EPA Groundwater Forum, Office of Solid Waste and Emergency Response, April 1992.

- U.S. Environmental Protection Agency, 1986, RCRA Ground-Water Monitoring Technical Enforcement Guidance Document, OSWER-9950.1.

Additional reference materials on well development may be found in regulatory or other governmental links on the Internet.

## 4. DEFINITIONS

The following definitions are applicable to well development and this SOP.

- **Airlift Pumping**—A method of well development for groundwater production wells. It utilizes an airlift pump consisting of two pipes, with one (the air line) inside the other (the eductor pipe) used to withdraw water from a well. The lower ends of the pipes are submerged, and compressed air is delivered through the inner pipe to form a mixture of air and water. This mixture rises in the outer (eductor) pipe to the surface because the specific gravity of this mixture is less than that of the water column. This method of pumping is not usually recommended by regulatory agencies for development of monitoring wells due to the fact that volatile organics may be stripped from the groundwater, or the introduction of air can change formation and groundwater chemistry.
- **Backwashing**—The reversal of water flow (due to the addition of water to a well) that causes water to move through the well screen, sand pack and into the formation to loosen bridges and facilitate the removal of fine grained materials. Only formation water and a pump without a check valve are used for this process. Water is first discharged from the well and then the pump is shut down. The corresponding water column in the eductor line then flows back down through the pump and into the well causing the flow reversal.
- **Bailer**—A cylindrical steel, stainless steel, Schedule 40 Polyvinyl Chloride (PVC) or Teflon container with a valve at the bottom, and sometimes open at the top, for admission of fluid and sediment. The bailer is attached to a wire line or string and used in recovering and removing water, cuttings, mud, sand or debris from the bottom of a well.
- **Bailing**—A technique whereby a bailer is lowered to the bottom of a well and then raised to recover and remove water, cuttings, mud, sand or debris from the well.
- **Eductor Pipe**—The pipe used to transport water discharged to the surface from a pump (during pumping or air lifting).
- **Hydraulic Jetting**—A well development method that employs a jetting tool with nozzles and a high-pressure pump to force water outwardly through the well screen, the filter pack and into the adjacent formation to dislodge fine sediment and sand bridges, and rehabilitate formation damage from drilling.
- **Overpumping**—Pumping at rates generally greater than those used during sampling, well purging, or general groundwater extraction. Commonly combined with backwashing or surging of the well as part of development.
- **Suction Bailer (Also referred to as a Double Bailer or Moran Bailer or Sand Pump)**—A suction bailer is a specially built bailer that can remove sediment or other foreign objects from the bottom of a monitoring or extraction well. The upward and downward movement of the bailer may also help to surge the well. A suction bailer is one of the tools used by a well development subcontractor.
- **Surge Block**—A plunger like tool consisting of leather or rubber discs sandwiched between steel or wooden discs that may be solid or valved (vented surge block) that is used in well development. (See "Surging" below.)

- **Surging**—A well development technique using a number of different types of equipment or methods to create a strong inward and outward movement of water through the well screen, sand pack, and into the formation.
- **Turbidity**—The state, condition, or quality of opaqueness or reduced clarity of a fluid due to the presence of suspended matter. Also, a measure of the ability of suspended material to disturb or diminish the penetration of light through a fluid; commonly measured as nephelometric turbidity units (NTUs).
- **Washing**—The addition of water to a well to conduct development. This is usually done for wells with the water level in the middle of the well screen interval. That is, part of the sand pack and formation is not saturated. The water is added to develop the unsaturated portion of the well screen, sand pack and adjoining formation. Potable water from a domestic water supply is commonly used; however, most regulatory agencies do not like the use of this technique for monitoring wells. Any water added to the well must be of known and acceptable chemistry. The effects of the wash water to the formation groundwater chemistry must also be ascertained.

  Well water may also be used to wash the well cap and inside of the casing (above the static water level) of sediment from the development process. This application of washing is usually acceptable to the regulatory community.
- **Well Development**—The use of any number of mechanical techniques to remove fine grained materials, drilling fluids, and sand bridges from the well screen, sand pack and adjacent formation to provide sediment-free representative groundwater samples, enhance well yields and help restore natural hydraulic conditions in the formation.

## 5. RESPONSIBILITIES

### 5.1. Procedure Responsibility

The Geosciences Discipline Lead is responsible for the development, maintenance, and revision of this procedure. Any questions, comments or suggestions regarding this technical SOP should be sent to the Geosciences Discipline Lead.

### 5.2. Project Responsibility

Employees conducting well development are responsible for meeting the requirements of this procedure. Employees conducting field technical review of well development activities are also responsible for the following appropriate portions of this SOP.

For those projects where well development methods are conducted, the Project Manager, or designee, is responsible for ensuring that well development activities are conducted in accordance with this and other appropriate procedures. Project participants are responsible for recording information in sufficient detail to provide objective documentation (i.e., field notes, reports, etc.) that the requirements of this SOP have been met. Such documentation shall be retained as project records.

## 6. PROCEDURES (TECHNICAL REQUIREMENTS AND STANDARDS)

This section presents information on basic considerations and methods, planning and preparation, basic procedures and requirements, and technical review requirements for well development.

### 6.1. Basic Considerations and Methods

Well development is conducted to help restore natural hydraulic conditions in the formation, enhance well yields and provide sediment-free water samples from the wells that are representative of groundwater in the formation. The development process involves use of one or a combination of mechanical methods to 1) recover fluids introduced into the formation and sand pack during drilling; 2) remove fine grained materials and sand bridges from the sand pack and adjacent formation; 3) remove the "skin" from the borehole wall; and 4) help repair damage to the formation from drilling.

Well development should be conducted on all newly installed wells, after a specified period of time (e.g., a minimum of 48 hours and not more than seven days after sealing the annular space of the well). State or local regulatory agencies may specify the time period and individuals planning well development activities should be aware of such requirements relative to their specific site(s). Monitoring wells may also be redeveloped after they have not been used for a period of time, show evidence of sediment buildup in the bottom of the well, or start yielding turbid water samples. Extraction/injection wells may also be redeveloped to restore or improve yield and specific capacity, and after rehabilitation efforts. The remainder of this text will focus upon development of newly installed wells or redevelopment of wells that have not undergone rehabilitation efforts.

Many well development methods are currently in use within the industry. These include surging, bailing, pumping, overpumping, airlifting, washing, backwashing, and jetting. Descriptions and information on these methods are provided in Driscoll (1986) and ASTM D 5521-94. Some combination of methods are specifically planned and implemented for development of wells relative to specific construction parameters and subsurface conditions at a particular site. For instance, monitoring wells can be developed by: surging and pumping; surging and bailing; bailing, pumping and backwashing, etc. The focus of developing monitoring wells is towards providing representative groundwater samples, though some monitoring wells are used for slug and specify capacity testing. The combination of development methods selected reflects the main objective.

The focus of extraction/injection well development is generally towards restoring the natural hydraulic conditions in the formation and enhancing well yields. Many extraction/injection wells are installed using mud rotary methods. Consequently, development of such wells tends to commonly be a multi-staged process utilizing several different and "aggressive" methods. These methods and operations are utilized to clean the filter pack, breakdown the mud cake, and repair the formation at the filter pack/formation interface. Polyphosphates and/or surfactants may be used to remove drilling mud from the well. Example combinations of methods for extraction/injection well developed include: airlifting, jetting and mechanical surging; jetting, pumping and overpumping; bailing, mechanical surging and pumping, etc.

The specific combination used should include a method that imparts a surge or flow of water from the well out thorough the sand pack, into the formation and back through the sand pack into the well. This surge or flow is necessary to remove fines and drilling fluids, and break up sand bridges in the sand pack and formation.

The exact combination of development methods to be used for wells at a site depends on a variety of project- or site-specific factors that include, but are not limited to, the following:

- Development objectives
- Intended use and type of the well
- Well construction parameters
- Drilling methods used, including type of drilling fluids and volume of fluid loss
- Regulatory requirements
- Type(s) of contaminants present, or potentially present, including non-aqueous phase liquids(NAPL)
- Type and composition of formation at the well completion interval
- Water level position inside the well

- Other previous well development issues or problems occurring at the site
- Types and relative costs of methods available by local subcontractors

Certain special well construction and site conditions may require additional evaluation and consideration for the planning and implementation of well development activities. Some conditions potentially requiring special planning and implementation considerations are listed in Attachment 1.

Individuals planning and selecting appropriate development methods/combinations for their particular wells should consider and evaluate the above information. They should look at methods and techniques used for previous similar wells (completed in the same formations) on site or near the site area. They may also seek the aid of an experienced senior geologist or hydrogeologist. Individuals needing assistance in finding qualified technical assistance may consult internal Shaw technical listings for experts in well development.

## 6.2. Planning and Preparation

Planning and preparation for well development activities involves the following:

- Identifying specific well development objectives and development methods to be used (including possible limitations to the development methodologies)
- Determining specific well(s) to be developed, locations of the wells, specific identification numbers and securing construction details on the wells
- Securing construction details and information on the expected condition of each of the wells to be developed
- Listing known or assumed hydrogeologic conditions for each well, e.g., high yield, low yield, potential for presence of non-aqueous phase liquid (NAPL)
- Identifying and listing exact equipment to be used (simple or complex)
- Determining type, duration and frequency of field parameter measurements to be made during development
- Identifying and listing exact criteria to be used to determine when a well has been sufficiently developed
- Describing the estimated duration(s) of the development effort per well
- Specifying water and sediment handling and disposal requirements
- Identifying site access and restrictions on equipment layout
- Determining and listing expected hardcopy and electronic work products to be generated from the development activities
- Listing all pertinent Health and Safety issues and requirements, including those contained in the project-specific Health and Safety Plan(s), relative to work activities
- Identifying applicable requirements of this and other applicable SOPs and pertinent project-specific requirements for the well development effort
- Determining and describing detailed project-specific procedures for the well development effort

- Identifying all main subcontractor requirements for well development to be compiled into subsequent Statement of Work to procure subcontractor services
- Procuring the appropriate well development subcontractor

The above information is necessary for effective implementation of the well development effort and should be presented in the project work plans, especially the detailed project-specific development procedures.

Prior to initiating well development activities in the field, site personnel and subcontractors should be briefed on the above information in the work plans and project or corporate health and safety requirements. This is done to familiarize personnel with specific objectives, requirements procedures and hazards associated with the site as well as health and safety procedures associated with the field operation. The project manager, or designee, is responsible for ensuring that the briefing is conducted.

### 6.3. Basic Procedures and Requirements

This text describes the basic method or process for conducting well development. It is not possible to write a single specific procedure for well development applicable to the wide range of sites encountered methods available. Attachments 2 and 3 provide example general procedures for monitoring well and extraction/injection well development, respectively. These example procedures should be modified or customized, as appropriate, to address specific site conditions and requirements. These detailed project-specific procedures should be presented in the project work plans.

The basic process for monitoring well development is as follows.

- Decontaminate the development rig and all development equipment, including pumps, bailers, riser pipes, etc. in accordance with appropriate Shaw E & I technical SOPs and/or project-specific requirements/procedures.
- Calibrate all field measuring and testing equipment (e.g. pH, temperature, conductivity, turbidity, dissolved oxygen meters, etc.) according to the instrument manufacturer's specifications, and appropriate Shaw E & I technical SOPs and/or project-specific requirements.
- Access the wellhead according to the project work plans; visually inspect the well to ensure that it is undamaged, properly labeled, and secured. Any observed problems with the well head should be noted on the appropriate forms and reported to the Site Superintendent.
- Unlock the well and obtain a depth to water level measurement according applicable to Shaw E & I technical SOPs or project-specific procedures/requirements. Sound the total well depth and compare that value with that shown on the well completion diagram or form. In addition, observe and record any unusual conditions such as possible obstructions or tight-spots as the well tape is lowered or removed from the well. (Do not insert bailers, pumps or surge blocks into the well if obstructions, parting of the casing or other damage to the well are suspected. Instead, report the conditions to the Site Superintendent and Project Manager and obtain approval to continue or cease well development activities, as appropriate.)
- Calculate the volume of water in the well (well volume). The equation for the calculation is shown on the Example Well Development Record (Section 8).
- Collect an initial sample of the well water and measure and record field parameters on the appropriate forms according to the project work plans.
- Compare the measured total well depth to the well construction diagram. If sand or sediment is present inside the well, it should be first removed. This is usually done by bailing; however, airlifting may also be used for extraction/injection wells. (Note: during the initial lowering of the

bailer into the well, direct the subcontractor to lower the bailer slowly, and not drop the bailer to the bottom of the well. Failure to do this may cause the bailer to break or dislodge the well bottom cap or sump, resulting in costly repair/replacement of the well).

- Periodically measure the depth to water and check to see that the well recovers sufficiently during and immediately after sediment removal.
- Begin developing by applying the development method or combination of methods as specified in the project work plans. Begin gently at first and then progress as appropriate and specified.
- While development progresses, take periodic water level measurements (as specified in the project work plans) (at least one every 5 to 10 minutes) to determine if drawdown is occurring and record the measurements on the appropriate forms.
- While development progresses, measure the water discharge and calculate the rate at which water is being removed from the well. Record the volume, time and rate on the appropriate forms. Record any observations made regarding general well yield and/or recovery.
- While developing, periodically collect water directly from the pump, eductor pipe or bailer discharge and measure for specified parameters. The time intervals for collection and measurement (e.g., every 15 minutes, etc.) should be listed in the project work plans. The parameters measured usually include: temperature, pH, conductivity, and turbidity. Dissolved oxygen (DO) and oxidation/reduction potential (ORP) are optional parameters that may also be measured. All measurements and associated times should be recorded on the appropriate form(s).
- Development should continue until a predetermined set of conditions are met. The exact conditions and criteria should be specified in the project work plans. These can include the following:
    - The well water appears clear and sediment free to the unaided eye
    - The sediment thickness remaining in the well is less than 1 percent of the screen length
    - A predetermined number of well volumes (previously calculated) of water, usually from three to five, have been removed from the well
    - The final turbidity goal (usually 5 or 10 NTUs) has been attained
    - The measured indicator parameters have stabilized. Stabilization is defined where three or more readings are within tolerances specified in the project work plans. Example tolerances and indicator parameters include: 0.1 units for pH; 1 degree F or less for temperature; and, 10 percent or less for conductivity.
    - Review of measured parameters may also be conducted to determine if drilling fluids have been sufficiently removed from the formation.
    - Sand production during pumping is less than or equal to a specified value (e.g., 3 parts per million [ppm])

Termination of development prior to the required water removal and stabilized parameters will require the concurrence with the Project Geologist/Hydrogeologist. The Project Geologist/Hydrogeologist is responsible for ensuring that development activities are appropriately planned and implemented. The individual selected as the Project Geologist/Hydorgeologist should be a senior professional with experience in planning, implementing, and evaluating well development programs.

- Once development is considered complete, obtain a final water level and turbidity measurement and record on the appropriate form(s). Collect a 1-pint sample of the well water for storage and photographing.

- Remove all equipment form the well and decontaminate appropriately for storage or development of another well according to the project work plans.
- Complete documentation of the well development event on the appropriate form(s). At a minimum, the following information should be recorded:
  - Project name/client name
  - Project number
  - Well I.D. number
  - Location
  - Start and end dates
  - Developer/subcontractor
  - Well diameter
  - Total depth of well as installed and at time of development
  - Top and bottom depth of screen/sand pack
  - Static water level
  - Development method(s)
  - Equipment used; decontamination method and calibration method
  - Record of water levels, volumes removed, measured parameters, measurement times and any observations.
- Collect and appropriately transport and dispose of water removed from the well in accordance with the project work plans and regulatory requirements.
- Allow the well to recover for a time period specified in the project work plans (generally 24 to 48 hours - check for local and/or regulatory requirements) prior to sampling.

### 6.4. Technical Review

All well development procedures, data analysis, and results (e.g., reports, etc.) should undergo technical review. It is recommended that the technical reviewer also provide review/oversight of the actual field implementation of well development activities. The technical reviewer should be an experienced senior geologist or hydrogeologist. At a minimum, the technical reviewer should be a person capable of planning, conducting, and evaluating well development activities and results. Individuals needing assistance in finding qualified technical reviewers may consult internal Shaw technical listings for experts in well development.

Any issues raised during the technical review should be resolved between the reviewer and staff conducting the well development activities before external (i.e., outside of Shaw) use or submission of the results. The technical review comments and issues, and corresponding resolution, shall be documented and filed with the project records. Such records should be maintained until project closeout.

## 7. ATTACHMENTS

- Attachment 1, Conditions Potentially Requiring Special Well Development Considerations

- Attachment 2, Example Monitoring Well Development Procedure
- Attachment 3, Example Extraction/Injection Well Development Procedure

**8. FORMS**

- Example Well Development Record

**ATTACHMENT 1**
**Conditions Potentially Requiring Special Well Development Considerations**

*Wells completed in fine-grain-dominated formation materials (i.e., in units dominated by clay, silt or fine sand); not in an aquifer* – For some of these formations, no well design or development technique can reduce the turbidity of the water, or improve the well efficiency or hydraulic conductivity of the formation. Aggressive development of such wells can actually damage the wells or substantially increase the turbidity of the water. Suitable objectives and methods will need to be compiled for the development effort and possibly discussed with the client and regulatory agencies beforehand. Development of such wells should be conducted and progress carefully.

*Wells with a minimal height of water column (e.g., less than 2 feet) inside the well screen* – Such wells should not be surged. Can develop with bailing and pumping, but may need to develop again in stages; that is, come back in the wet season when the water level may be higher. May develop by bailing (to remove sediment) and pumping. Could also develop by washing; however, any water added to the well must be of acceptable and known chemistry. The effect of such water on the formation groundwater chemistry must also be ascertained. Such use will also likely require prior regulatory approval. All water added to the well should be removed; this is not always possible.

*Damaged wells* – Damaged or obstructed wells should never be developed or redeveloped. Such wells first need to be repaired or replaced.

*Use of surge blocks in PVC wells/well screens* – The use of surge blocks in such wells has a high potential to collapse or damage of PVC well screens. A vented surge block may help. The development subcontractor should use the surge block carefully in a slow and gentle manner when starting to surge a well. When sediment is first removed from the well by bailing, pumping or airlifting it is important to monitor the water level to see if the well recharges sufficiently. A well that does not recharge sufficiently has a sediment-blocked screen or sand pack; this will result in collapsing of the screen during surging if the blockage isn't removed first.

*Small diameter wells (i.e. < 2-inches in diameter)* – Such wells are commonly installed using direct-push methods and usually cannot be developed with a surge block. They are commonly developed by bailing and pumping. Because many of these wells are installed in fine-grain-dominated formations, development should be conducted carefully and initially at low discharge rates.

*Use of long or heavy bailers with power winch systems* – Long stainless steel bailers are commonly used by development subcontractors with power winch systems. At times the subcontractor lowers the bailer too quickly and the bailer hits and dislodges the bottom cap or well sump. The subcontractor must be instructed to first carefully lower the bailer to the bottom of the well and mark the cable appropriately. Thereafter the subcontractor must lower the bailer carefully, noting when the bailer is approaching the bottom of the well and slowing the winch down appropriately.

## ATTACHMENT 2
## Example Monitoring Well Development Procedure

This text provides an example monitoring well development procedure by bailing, pumping and back-washing. Other projects and sites may have different conditions and requirements, and use different development methods. This example procedure may therefore be modified or customized, as appropriate, to address specific site conditions, requirements and methods.

The example procedure is as follows:

1. Development will be performed no less than 2 days and not more than 7 days after well installation is complete.
2. Decontaminate the development rig and all downhole equipment (e.g., pumps, bailers, surge blocks, pumps, riser pipes, etc.) in accordance with the project work plans. This includes steam cleaning with unchlorinated water from an approved source followed by thorough rinsing with 100-PPM unchlorinated, organic-free water.
3. Inspect the equipment to ensure that it is in good working order. Repair or replace damaged or malfunctioning equipment and decontaminate appropriately.
4. Calibrate and test all measuring and testing equipment prior to use according to manufacturer's specifications and appropriate project-specific requirements and procedures.
5. Access the well head according to the project work plans; visually inspect the well to ensure that it is undamaged, properly labeled, and secured. Any observed problems with the well head should be noted on the appropriate forms and reported to the Site Superintendent.
6. Unlock the well and obtain a depth to water level measurement according to applicable Shaw E & I technical SOPs or project-specific procedures/requirements. Then sound the total well depth and record the measurements on the appropriate forms specified in the project work plans. (If LNAPL or DNAPL is expected, use an interface probe for monitoring according to applicable Shaw E & I technical SOPs.)

   In addition, observe and record any unusual conditions such as possible obstructions or tight-spots as the well tape is lowered or removed from the well. (Do not insert bailers, pumps, or surge blocks into the well if obstructions, parting of the casing or other damage to the well are suspected. Instead, report the conditions to the Site Superintendent and obtain approval to continue or cease well development activities, as appropriate.)
7. Calculate the volume of water in the well (well volume). (The equation for the calculation is shown on the Example Well Development Record [Section 8]).
8. Slowly lower a bailer into the well to mid-screen and collect a water sample. Empty the sample into a vessel and measure and record field parameters on the appropriate forms according to the project work plans and as discussed below.
9. Compare the measured total well depth to the well construction diagram. If sand or sediment is present inside the well, they should be first removed by bailing. After the bailer is initially placed on the bottom of the well, check to make sure that the subcontractor marks the wire line as to the total depth of the well. Bail the sediment from the bottom of the well.
10. Periodically measure the depth to water and check to see that the well recovers sufficiently during and immediately after sediment removal via bailing.
11. Once sediment removal is complete, measure the water level. Allow sufficient equalization of the water level to commence pumping.

12. Lower a decontaminated electric-powered submersible pump (without check valve) into the well and pump the well.

13. Periodically during pumping, the well will be backwashed by turning the power of the pump off and allowing the water in the pump pipe to flow back into the well. (This creates a surging action of water into the screen, sandpack and formation.) Additionally, the pump will be periodically lifted up and down inside the well screen while the pump is operating. Water will not be added to the well to aid in development, nor will any type of airlift techniques be used.

14. While developing, periodically collect water directly from the pump eductor pipe or bailer discharge every 15 minutes and measure for the following parameters: temperature, pH, conductivity, turbidity, dissolved oxygen (DO) and oxidation/reduction potential (ORP). Record all measurements and associated times on the appropriate form(s).

15. Rinse the cap and all internal components of the well casing above the water table with well water to remove all traces of soil/sediment/cuttings. Washing will be conducted before and/or during development.

16. Development will proceed until the following conditions are met:

    - The well water is clear to the unaided eye.
    - The measured turbidity is ≤ 5 NTU.
    - The sediment thickness remaining in the well is less than 1 percent of the screen length (the depth to the water/sediment interface will be measured with a weighted tape and the percentage of sediment height to screen length will be calculated).
    - At least three well volumes (including the saturated filter material in the annulus), plus the volume of water/drilling fluid lost during the drilling process has been removed form the well.
    - The pH, temperature and conductivity of the development water have stabilized. Stabilization is defined as successive readings in which the pH has changed ≤ 0.1 pH units, temperature has changed ≤ 1 degree F or less, and conductivity has changed by less than 10%.

17. Once development is considered complete, obtain a final water level and turbidity measurement and record on the appropriate form(s). Collect a 1-pint sample of the well water; label the jar with the well number and development date. Agitate the sample and immediately photograph with a 35-millimeter camera in a backlit setting so that the clarity of the water is visible. Prepare the sample for storage according to the project work plans.

18. Remove all equipment from the well; if the equipment is to be stored, decontaminate appropriately according to the project work plans.

19. Cap and secure the wellhead.

20. Complete documentation of the well development event on the appropriate form(s). At a minimum the following information should be recorded:

    - Project name/client name
    - Project number
    - Well I.D. number
    - Location
    - Date of well installation.
    - Start and end dates of development

- Developer/subcontractor
- Well diameter
- Height of well casing above ground surface
- Quantity of water lost during drilling
- Total depth of well as installed and at time of development
- Top and bottom depth of screen/sand pack
- Static water Level
- Development method(s); description of pumping technique
- Type and size/capacity of pump used.
- Equipment used, decontamination method and calibration method
- Record of water levels, volumes removed, measured parameters and measurement times
- Any observations including physical character of removed water and changes in clarity, color, particulates, and odor during development.

21. Collect and appropriately transport and dispose of water removed from the well in accordance with the project work plans and regulatory requirements.
22. Allow the well to recover at least 48 hours prior to sampling.

## ATTACHMENT 3
## Example Extraction/Injection Well Development Procedure

This text provides an example extraction/injection well development procedure by airlifting, jetting, pumping and overpumping. Other projects and sites may have different conditions and requirements, and use different development methods. This example procedure may therefore be modified or customized, as appropriate, to address specific site conditions, requirements and methods. Extraction and injection well development is a multi-staged process whereby different operations and techniques are utilized to clean the filter pack, breakdown the mud cake, and repair the formation at the filter pack/formation interface.

During extraction/injection well development, chemical additives may need to be used, with prior regulatory agency approval, to assist in breaking down mud cake built up during mud rotary drilling. Drilling mud can be a polymer mud (e.g. Polygel), a bentonite-based mud, or a combination of both (e.g. Quikgel). An example of an additive for the dispersal of polymer drill mud is sodium hypochlorite (which will release free chlorine into the well). An example of an additive to disperse bentonite mud or other clays is by the addition of polyphosphates. Polyphosphates should be added in accordance with the manufacturer's specifications. Whenever using chemical additives, care must be used to remove all chemical additives. Over-pumping of the well is recommended to remove the chemical additives.

The example procedure is as follows:

1. Development will be performed no less than 2 days and not more than 7 days after well installation is complete.

2. Decontaminate the development rig and all downhole equipment (e.g., pumps, bailers, jetting tools, riser pipes, etc.) in accordance with applicable Shaw E & I technical SOPs and project-specific requirements/procedures. This includes steam cleaning with unchlorinated water from an approved source followed by thorough rinsing with 100-ppm unchlorinated, organic-free water.

3. Inspect the equipment to ensure that it is in good working order. Repair or deplace any damaged or malfunctioning equipment and decontaminate appropriately.

4. Calibrate and test all measuring and testing equipment prior to use according to manufacturer's specifications and appropriate project-specific requirements and procedures.

5. Access the well head according to the project work plans; visually inspect the well to ensure that it is undamaged, properly labeled, and secured. Any observed problems with the well head should be noted on the appropriate forms and reported to the Site Superintendent.

6. Unlock the well and obtain a depth to water level measurement according to applicable Shaw E & I technical SOPs or project-specific procedures/requirements. Then sound the total well depth and compare that value with that shown on the well completion diagram or form. In addition, observe and record any unusual conditions such as possible obstructions or tight-spots as the well tape is lowered or removed from the well. (Do not insert bailers, pumps, jetting tools or surge blocks into the well if obstructions, parting of the casing or other damage to the well are suspected. Instead, report the conditions to the Site Superintendent and obtain approval to continue or cease well development activities, as appropriate.)

7. Obtain a water level depth measurement and sound the bottom of the well. (If LNAPL or DNAPL is expected, use an interface probe for monitoring according to applicable Shaw E & I technical SOPs.)

8. Calculate the volume of water in the well (well volume). (The equation for the calculation is shown on the Example Well Development Record [Section 8]).

9. Collect an initial sample of the well water and measure and record field parameters on the appropriate forms according to the project work plans and as discussed below.

10. Compare the measured total well depth to the well construction diagram. If sand or sediment is present inside the well, they should be first removed by airlifting. (Note: if the air supply is from an air compressor and the well will be sampled for petroleum hydrocarbons, an appropriate filter will need to be placed between the airline and the compressor.) Periodically measure the depth to water and check to see that the well recovers sufficiently during and immediately after sediment removal via airlifting.

11. Periodically measure the depth to water and check to see that the well recovers sufficiently during and immediately after sediment removal.

12. Once sediment removal is complete, the entire screen shall be jetted with water using a jetting tool (see page 516 of Driscoll [1986]). The jetting velocity shall be between 150 and 300 feet per second, or pressure not to exceed screen manufacturer's recommendations. The Sediment should then be removed form the bottom of the well via airlifting. Two cycles of jetting should be required.

13. Mechanically surge the entire length of the well screen with an approved appropriate-sized surge block to remove sediment from the filter pack. The surging should start slowly at first in the blank casing just above the screen, then get progressively stronger to be effective.

14. The surging shall proceed in 10-foot intervals from just above the top of the screen working down. Each 10-foot section should be surged for 10 minutes. The rate of ascent and descent of the surge block within the 10-foot section should be increased to about 3 feet per second, or as directed. The section of screen shall then be isolated with a shell-catcher, or other device, and pumped at a predetermined rate (the rate will be increased up to the maximum allowable rate) until the return water is clear. The surging shall be repeated until the working section pumps clear after surging. This process shall be continued down the entire length of the well's screened interval. Depending upon the amount of material pulled through the screen into the well, airlifting should be incorporated at any point in this stage of well development to remove sediment and prevent the surge block form becoming sand-locked.

15. Following jetting and surging, a submersible pump will be installed approximately 10 feet below the expected maximum drawdown. The well will be pumped at progressively higher rates until the discharge water is visually clear and sediment free. The pumping rate will be stepped up from the design flow rate to a maximum flow rate of approximately 2 to 5 times higher.

16. While developing, periodically collect water directly from the pump eductor pipe discharge every 15 minutes and measure for the following parameters: temperature, pH, conductivity, turbidity, dissolved oxygen (DO) and oxidation/reduction potential (ORP). Record all measurements and associated times on the appropriate form(s).

17. Rinse the cap and all internal components of the well casing above the water table with well water to remove all traces of soil/sediment/cuttings. Washing will be conducted before and/or during development.

18. Development will proceed until the following conditions are met:

    - The well water is clear to the unaided eye.
    - The sediment thickness remaining in the well is less than 1 percent of the screen length (the depth to the water/sediment interface will be measured with a weighted tape and the percentage of sediment height to screen length will be calculated).
    - At least five well volumes (including the saturated filter material in the annulus), plus the volume of water/drilling fluid lost during the drilling process has been removed form the well.

- The measured turbidity is ≤ 10 NTU.
- The pH, temperature and conductivity of the development water have stabilized. Stabilization is defined as successive readings in which the pH has changed ≤ 0.1 pH units, temperature has changed ≤ 1 degree F or less, and conductivity has changed by less than 10%.
- Sand production during pumping is less than 3 ppm.

19. Once development is considered complete, obtain a final water level and turbidity measurement and record on the appropriate form(s). Collect a 1-pint sample of the well water; label the jar with the number and development date. Agitate the sample and immediately photograph with 35-millimeter camera in a backlit setting so that the clarity of the water is visible. Prepare the sample for storage according to the project work plans.
20. Remove all equipment form the well and decontaminate appropriately for storage according to the project work plans.
21. Cap and secure the wellhead.
22. Complete documentation of the well development event on the appropriate form(s). At a minimum the following information should be recorded:

- Project name/client name
- Project number
- Well I.D. number
- Location
- Date of well installation.
- Start and end dates of development
- Developer/subcontractor
- Well diameter
- Height of well casing above ground surface
- Quantity of water lost during drilling and fluid purging
- Total depth of well as installed and at time of development
- Top and bottom depth of screen/sand pack
- Static water Level
- Development method(s); description of surging, jetting and pumping technique
- Type and size/capacity of pump used.
- Equipment, decontamination and calibration methods used
- Record of water levels, volumes removed, measured parameters and measurement times
- Any observations including physical character of removed water and changes in clarity, color, particulates, and odor during development.

23. Collect and appropriately transport and dispose of water removed from the well in accordance with the project work plans and regulatory requirements.

24. Allow the well to recover at least 24 hours prior to sampling.

# EXAMPLE
# WELL DEVELOPMENT RECORD

**Project Name:** ______________________________

Location: ____________________ Well/Piez. No.: ____________________

Personnel: ____________________ Date Installed: ____________________

Date (Start/End): ____________________ Csg. Diameter (I.D.): ____________________

Method of Development: ____________ Total Depth (ft. TOC): ____________________

❑ Surging ❑ Bailing ❑ Pumping ❑ Other (State Method) __________

❑ Original Development ❑ Redevelopment Development Date: __________

Depth to water before developing well: ______________________________

| | | | | Volume (V) | | Purge Factor | | Volume To Purge |
|---|---|---|---|---|---|---|---|---|
| Height of Water Column: ________ | feet ________ | = | | ________ | gal.* | ________ | = | ________ |

$$V = (B * r_c^2 * L_c * 7.48)+(B*(r_w-r_c)^2*L_s*ø_s*7.48)= \_\_\_\_\_\_ \text{ gallons}$$

Depth purging from: __________ feet Time purging begins: ____________________

Weather: ____________________ Screened Interval (ft. BGL): ____________________

Equipment Nos.: pH Meter__________ EC Meter__________ Turbidity Meter__________

Equipment decontaminated prior to development Y ________ N ________

Describe ______________________________

| Date | Time | Water Level (ft. TOC) | Volume Removed (gal.) | Temp (C) | pH | EC | Turbidity | D.O. | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
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- Water levels – Reported to the nearest 0.01 foot.
- pH – Reading rounded to 0.1 pH units
- Electrical conductivity – Reported to the nearest 10% mhos/cm or
- µmho/cm @25 C or in mS/cm of instrument set range
- Water temperature – Reported to the nearest 0.1 C
- D.O. report in 0.1 mg/L
- Turbidity report in NTV nearest whole #

Where:
B=3.14
$ø_s$=porosity of the sand pack
$r_c$ =radius of the well casing and screen in feet
$L_c$=length of water column inside the casing and screen in feet
$r_w$ =radius of the well bore in feet
$L_s$ =length of saturated portion of the sand pack in feet
7.48 gallons/cubic foot=conversion from cubic feet to gallons