Appendix F

GEI Standard Operating Procedures

U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION I

LOW STRESS (low flow) PURGING AND SAMPLING PROCEDURE FOR THE COLLECTION OF GROUND WATER SAMPLES FROM MONITORING WELLS

July 30, 1996
Revision 2

U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION I

LOW STRESS (low flow) PURGING AND SAMPLING PROCEDURE FOR THE COLLECTION OF GROUND WATER SAMPLES FROM MONITORING WELLS

I. SCOPE & APPLICATION

This standard operating procedure (SOP) provides a general framework for collecting ground water samples that are indicative of mobile organic and inorganic loads at ambient flow conditions (both the dissolved fraction and the fraction associated with mobile particulates). The SOP emphasizes the need to minimize stress by low water-level drawdowns, and low pumping rates (usually less than 1 liter/min) in order to collect samples with minimal alterations to water chemistry. This SOP is aimed primarily at sampling monitoring wells that can accept a submersible pump and have a screen, or open interval length of 10 feet or less (this is the most common situation). However, this procedure is flexible and can be used in a variety of well construction and ground-water yield situations. Samples thus obtained are suitable for analyses of ground water contaminants (volatile and semi-volatile organic analytes, pesticides, PCBs, metals and other inorganics), or other naturally occurring analytes.

This procedure does not address the collection of samples from wells containing light or dense non-aqueous phase liquids (LNAPLs and DNAPLs). For this the reader may wish to check: Cohen, R.M. and J.W. Mercer, 1993, DNAPL Site Evaluation; C.K. Smoley (CRC Press), Boca Raton, Florida and U.S. Environmental Protection Agency, 1992, RCRA Ground-Water Monitoring: Draft Technical Guidance; Washington, DC (EPA/530-R-93-001).

The screen, or open interval of the monitoring well should be optimally located (both laterally and vertically) to intercept existing contaminant plume(s) or along flowpaths of potential contaminant releases. It is presumed that the analytes of interest move (or potentially move) primarily through the more permeable zones within the screen, or open interval.

Proper well construction and development cannot be overemphasized, since the use of installation techniques that are appropriate to the hydrogeologic setting often prevents "problem well" situations from occurring. It is also recommended that as part of development or redevelopment the well should be tested to determine the appropriate pumping rate to obtain stabilization of field indicator parameters with minimal drawdown in shortest amount of time. With this information field crews can then conduct purging and sampling in a more expeditious manner.

The mid-point of the saturated screen length (which should not exceed 10 feet) is used by convention as the location of the pump intake. However, significant chemical or permeability contrast(s) within the screen may require additional field work to determine the optimum vertical location(s) for the intake, and appropriate pumping rate(s) for purging and sampling more localized target zone(s). Primary flow zones (high(er) permealability and/or high(er) chemical concentrations) should be identified in wells with screen lengths longer than 10 feet, or in wells with open boreholes in bedrock. Targeting these zones for water sampling will help insure that the low stress procedure will not underestimate contaminant concentrations. The Sampling and Analysis Plan must provide clear instructions on how the pump intake depth(s) will be selected, and reason(s) for the depth(s) selected.

Stabilization of indicator field parameters is used to indicate that conditions are suitable for sampling to begin. Achievement of turbidity levels of less than 5 NTU and stable drawdowns of less than 0.3 feet, while desirable, are not mandatory. Sample collection may still take place provided the remaining criteria in this procedure are met. If after 4 hours of purging indicator field parameters have not stabilized, one of 3 optional courses of action may be taken: a) continue purging until stabilization is achieved, b) discontinue purging, do not collect any samples, and record in log book that stabilization could not be achieved (documentation must describe attempts to achieve stabilization) c) discontinue purging, collect samples and provide full explanation of attempts to achieve stabilization (note: there is a risk that the analytical data obtained, especially metals and strongly hydrophobic organic analytes, may not meet the sampling objectives).

Changes to this SOP should be proposed and discussed when the site Sampling and Analysis Plan is submitted for approval. Subsequent requests for modifications of an approved plan must include adequate technical justification for proposed changes. All changes and modifications must be approved before implementation in field.

II. EQUIPMENT

A. Extraction device

Adjustable rate, submersible pumps are preferred (for example, centrifugal or bladder pump constructed of stainless steel or Teflon).

Adjustable rate, peristaltic pumps (suction) may be used with caution. Note that EPA guidance states: "Suction pumps are not recommended because they may cause degassing, pH modification, and loss of volatile compounds" (EPA/540/P-87/001, 1987, page 8.5-11). *

The use of inertial pumps is discouraged. These devices frequently cause greater disturbance during purging and sampling and are less easily controlled than the pumps listed above. This can lead to sampling results that are adversely affected by purging and sampling operations, and a higher degree of data variability.

B. Tubing

Teflon or Teflon lined polyethylene tubing are preferred when sampling is to include VOCs, SVOCs, pesticides, PCBs and inorganics.

PVC, polypropylene or polyethylene tubing may be used when collecting samples for inorganics analyses. However, these materials should be used with caution when sampling for organics. If these materials are used, the equipment blank (which includes the tubing) data must show that these materials do not add contaminants to the sample.

Stainless steel tubing may be used when sampling for VOCs, SVOCs, pesticides, and PCBs. However, it should be used with caution when sampling for metals.

The use of 1/4 inch or 3/8 inch (inner diameter) tubing is preferred. This will help ensure the tubing remains liquid filled when operating at very low pumping rates.

Pharmaceutical grade (Pharmed) tubing should be used for the section around the rotor head of a peristaltic pump, to minimize gaseous diffusion.

C. Water level measuring device(s), capable of measuring to 0.01 foot accuracy (electronic "tape", pressure transducer). Recording pressure transducers, mounted above the pump, are especially helpful in tracking water levels during pumping operations, but their use must include check measurements with a water level "tape" at the start and end of each record.

D. Flow measurement supplies (e.g., graduated cylinder and stop watch).

E. Interface probe, if needed.

F. Power source (generator, nitrogen tank, etc.). If a gasoline generator is used, it must be located downwind and at least 30 feet from the well so that the exhaust fumes do not contaminate the samples.

G. Indicator field parameter monitoring instruments - pH, Eh, dissolved oxygen (DO), turbidity, specific conductance, and temperature. Use of a flow-through-cell is required when measuring all listed parameters, except turbidity. Standards to perform field calibration of instruments. Analytical methods are listed in 40 CFR 136, 40 CFR 141, and SW-846. For Eh measurements, follow manufacturer's instructions.

H. Decontamination supplies (for example, non-phosphate detergent, distilled/deionized water, isopropyl alcohol, etc.).

I. Logbook(s), and other forms (for example, well purging forms).

J. Sample Bottles.

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

L. Sample tags or labels.

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

N. Well keys.

O. Site specific Sample and Analysis Plan/Quality Assurance Project Plan.

P. PID or FID instrument (if appropriate) to detect VOCs for health and safety purposes, and provide qualitative field evaluations.

III. PRELIMINARY SITE ACTIVITIES

Check well for security damage or evidence of tampering, record pertinent observations.

Lay out sheet of clean polyethylene for monitoring and sampling equipment.

Remove well cap and immediately measure VOCs at the rim of the well with a PID or FID instrument and record the reading in the field logbook.

If the well casing does not have a reference point (usually a V-cut or indelible mark in the well casing), make one. Describe its location and record the date of the mark in the logbook.

A synoptic water level measurement round should be performed (in the shortest possible time) before any purging and sampling activities begin. It is recommended that water level depth (to 0.01 ft.) and total well depth (to 0.1 ft.) be measured the day before, in order to allow for re-settlement of any particulates in the water column. If measurement of total well depth is not made the day before, it should not be measured until after sampling of the well is complete. All measurements must be taken from the established referenced point. Care should be taken to minimize water column disturbance.

Check newly constructed wells for the presence of LNAPLs or DNAPLs before the initial sampling round. If none are encountered, subsequent check measurements with an interface probe are usually not needed unless analytical data or field head space information signal a worsening situation. Note: procedures for collection of LNAPL and DNAPL samples are not addressed in this SOP.

IV. PURGING AND SAMPLING PROCEDURE

Sampling wells in order of increasing chemical concentrations (known or anticipated) is preferred.

1. Install Pump

Lower pump, safety cable, tubing and electrical lines slowly (to minimize disturbance) into the well to the midpoint of the zone to be sampled. The Sampling and Analysis Plan should specify the sampling depth, or provide criteria for selection of intake depth for each well (see Section I). If possible keep the pump intake at least two feet above the bottom of the well, to minimize mobilization of particulates present in the bottom of the well. Collection of turbid free water samples may be especially difficult if there is two feet or less of standing water in the well.

2. Measure Water Level

Before starting pump, measure water level. If recording pressure transducer is used-initialize starting condition.

3. Purge Well

3a. Initial Low Stress Sampling Event

Start the pump at its lowest speed setting and slowly increase the speed until discharge occurs. Check water level. Adjust pump speed until there is little or no water level drawdown (less than 0.3 feet). If the minimal drawdown that can be achieved exceeds 0.3 feet but remains stable, continue purging until indicator field parameters stabilize.

Monitor and record water level and pumping rate every three to five minutes (or as appropriate) during purging. Record any pumping rate adjustments (both time and flow rate). Pumping rates should, as needed, be reduced to the minimum capabilities of the pump (for example, 0.1 - 0.4 l/min) to ensure stabilization of indicator parameters. Adjustments are best made in the first fifteen minutes of pumping in order to help minimize purging time. During pump start-up, drawdown may exceed the 0.3 feet target and then "recover" as pump flow adjustments are made. Purge volume calculations should utilize stabilized drawdown value, not the initial drawdown. Do not allow the water level to fall to the intake level (if the static water level is above the well screen, avoid lowering the water level into the screen). The final purge volume must be greater than the stabilized drawdown volume plus the extraction tubing volume.

Wells with low recharge rates may require the use of special pumps capable of attaining very low pumping rates (bladder, peristaltic), and/or the use of dedicated equipment. If the recharge rate of the well is lower than extraction rate capabilities of currently manufactured pumps and the well is essentially dewatered during purging, then the well should be sampled as soon as the water level has recovered sufficiently to collect the appropriate volume needed for all anticipated samples (ideally the intake should not be moved during this recovery period). Samples may then be collected even though the indicator field parameters have not stabilized.

3b. Subsequent Low Stress Sampling Events

After synoptic water level measurement round, check intake depth and drawdown information from previous sampling event(s) for each well. Duplicate, to the extent practicable, the intake depth and extraction rate (use final pump dial setting information) from previous event(s). Perform purging operations as above.

4. Monitor Indicator Field Parameters

During well purging, monitor indicator field parameters (turbidity, temperature, specific conductance, pH, Eh, DO) every three to five minutes (or less frequently, if appropriate). Note: during the early phase of purging emphasis should be put on minimizing and stabilizing pumping stress, and recording those adjustments. Purging is considered complete and sampling may begin when all the above indicator field parameters have stabilized. Stabilization is considered to be achieved when three consecutive readings, taken at three (3) to five (5) minute intervals, are within the following limits:

turbidity (10% for values greater than 1 NTU),
DO (10%),
specific conductance (3%),
temperature (3%),
pH (± 0.1 unit),
ORP/Eh (± 10 millivolts).

All measurements, except turbidity, must be obtained using a flow-through-cell. Transparent flow-through-cells are preferred, because they allow field personnel to watch for particulate build-up within the cell. This build-up may affect indicator field parameter values measured within the cell and may also cause an underestimation of turbidity values measured after the cell. If the cell needs to be cleaned during purging operations, continue pumping and disconnect cell for cleaning, then reconnect after cleaning and continue monitoring activities.

The flow-through-cell must be designed in a way that prevents air bubble entrapment in the cell. When the pump is turned off or cycling on/off (when using a bladder pump), water in the cell must not drain out. Monitoring probes must be submerged in water at all times. If two flow-through-cells are used in series, the one containing the dissolved oxygen probe should come first (this parameter is most susceptible to error if air leaks into the system).

5. Collect Water Samples

Water samples for laboratory analyses must be collected before water has passed through the flow-through-cell (use a by-pass assembly or disconnect cell to obtain sample).

VOC samples should be collected first and directly into pre-preserved sample containers. Fill all sample containers by allowing the pump discharge to flow gently down the inside of the container with minimal turbulence.

During purging and sampling, the tubing should remain filled with water so as to minimize possible changes in water chemistry upon contact with the atmosphere. It is recommended that 1/4 inch or 3/8 inch (inside diameter) tubing be used to help insure that the sample tubing remains water filled. If the pump tubing is not completely filled to the sampling point, use one of the following procedures to collect samples: (1) add clamp, connector (Teflon or stainless steel) or valve to constrict sampling end of tubing; (2) insert small diameter Teflon tubing into water filled portion of pump tubing allowing the end to protrude beyond the end of the pump tubing, collect sample from small diameter tubing; (3) collect non-VOC samples first, then increase flow rate slightly until the water completely fills the tubing, collect sample and record new drawdown, flow rate and new indicator field parameter values.

Add preservative, as required by analytical methods, to samples immediately after they are collected if the sample containers are not pre-preserved. Check analytical methods (e.g. EPA SW-846, water supply, etc.) for additional information on preservation. Check pH for all samples requiring pH adjustment to assure proper pH value. For VOC samples, this will require that a test sample be collected during purging to determine the amount of preservative that needs to be added to the sample containers prior to sampling.

If determination of filtered metal concentrations is a sampling objective, collect filtered water samples using the same low flow procedures. The use of an in-line filter is required, and the filter size (0.45 um is commonly used) should be based on the sampling objective. Pre-rinse the filter with approximately 25 - 50 ml of ground water prior to sample collection. Preserve filtered water sample immediately. Note: filtered water samples are not an acceptable substitute for unfiltered samples when the monitoring objective is to obtain chemical concentrations of total mobile contaminants in ground water for human health risk calculations.

Label each sample as collected. Samples requiring cooling (volatile organics, cyanide, etc.) will be placed into a cooler with ice or refrigerant for delivery to the laboratory. Metal samples after acidification to a pH less than 2 do not need to be cooled.

6. Post Sampling Activities

If recording pressure transducer is used, remeasure water level with tape.

After collection of the samples, the pump tubing may either be dedicated to the well for resampling (by hanging the tubing inside the well), decontaminated, or properly discarded.

Before securing the well, measure and record the well depth (to 0.1 ft.), if not measured the day before purging began. Note: measurement of total well depth is optional after the initial low stress sampling event. However, it is recommended if the well has a "silting" problem or if confirmation of well identity is needed.

Secure the well.

V. DECONTAMINATION

Decontaminate sampling equipment prior to use in the first well and following sampling of each subsequent well. Pumps will not be removed between purging and sampling operations. The pump and tubing (including support cable and electrical wires which are in contact with the well) will be decontaminated by one of the procedures listed below.

<u>Procedure 1</u>

The decontaminating solutions can be pumped from either buckets or short PVC casing sections through the pump or the pump can be disassembled and flushed with the decontaminating solutions. It is recommended that detergent and isopropyl alcohol be used sparingly in the decontamination process and water flushing steps be extended to ensure that any sediment trapped in the pump is removed. The pump exterior and electrical wires must be rinsed with the decontaminating solutions, as well. The procedure is as follows:

Flush the equipment/pump with potable water.

Flush with non-phosphate detergent solution. If the solution is recycled, the solution must be changed periodically.

Flush with potable or distilled/deionized water to remove all of the detergent solution. If the water is recycled, the water must be changed periodically.

Flush with isopropyl alcohol (pesticide grade). If equipment blank data from the previous sampling event show that the level of contaminants is insignificant, then this step may be skipped.

Flush with distilled/deionized water. The final water rinse must not be recycled.

<u>Procedure 2</u>

Steam clean the outside of the submersible pump.

Pump hot potable water from the steam cleaner through the inside of the pump. This can be accomplished by placing the pump inside a three or four inch diameter PVC pipe with end cap. Hot water from the steam cleaner jet will be directed inside the PVC pipe and the pump exterior will be cleaned. The hot water from the steam cleaner will then be pumped from the PVC pipe through the pump and collected into another container. Note: additives or solutions should not be added to the steam cleaner.

Pump non-phosphate detergent solution through the inside of the pump. If the solution is recycled, the solution must be changed periodically.

Pump potable water through the inside of the pump to remove all of the detergent solution. If the solution is recycled, the solution must be changed periodically.

Pump distilled/deionized water through the pump. The final water rinse must not be recycled.

VI. FIELD QUALITY CONTROL

Quality control samples are required to verify that the sample collection and handling process has not compromised the quality of the ground water samples. All field quality control samples must be prepared the same as regular investigation samples with regard to sample volume, containers, and preservation. The following quality control samples shall be collected for each batch of samples (a batch may not exceed 20 samples). Trip blanks are required for the VOC samples at a frequency of one set per VOC sample cooler.

Field duplicate.

Matrix spike.

Matrix spike duplicate.

Equipment blank.

Trip blank (VOCs).

Temperature blank (one per sample cooler).

Equipment blank shall include the pump and the pump's tubing. If tubing is dedicated to the well, the equipment blank will only include the pump in subsequent sampling rounds.

Collect samples in order from wells with lowest contaminant concentration to highest concentration. Collect equipment blanks after sampling from contaminated wells and not after background wells.

Field duplicates are collected to determine precision of sampling procedure. For this procedure, collect duplicate for each analyte group in consecutive order (VOC original, VOC duplicate, SVOC original, SVOC duplicate, etc.).

If split samples are to be collected, collect split for each analyte group in consecutive order (VOC original, VOC split, etc.). Split sample should be as identical as possible to original sample.

All monitoring instrumentation shall be operated in accordance with EPA analytical methods and manufacturer's operating instructions. EPA analytical methods are listed in 40 CFR 136, 40 CFR 141, and SW-846 with exception of Eh, for which the manufacturer's instructions are to be followed. Instruments shall be calibrated at the beginning of each day. If a measurement falls outside the calibration range, the instrument should be re-calibrated so that all measurements fall within the calibration range. At the end of each day, check calibration to verify that instruments remained in calibration. Temperature measuring equipment, thermometers and thermistors, need not be calibrated to the above frequency. They should be checked for accuracy prior to field use according to EPA Methods and the manufacturer's instructions.

VII. FIELD LOGBOOK

A field log shall be kept to document all ground water field monitoring activities (see attached example matrix), and record all of the following:

Well identification.

Well depth, and measurement technique.

Static water level depth, date, time and measurement technique.

Presence and thickness of immiscible liquid (NAPL) layers and detection method.

Pumping rate, drawdown, indicator parameters values, and clock time, at the appropriate time intervals; calculated or measured total volume pumped.

Well sampling sequence and time of each sample collection.

Types of sample bottles used and sample identification numbers.

Preservatives used.

Parameters requested for analysis.

Field observations during sampling event.

Name of sample collector(s).

Weather conditions.

QA/QC data for field instruments.

Any problems encountered should be highlighted.

Description of all sampling equipment used, including trade names, model number, diameters, material composition, etc.

VIII. DATA REPORT

Data reports are to include laboratory analytical results, QA/QC information, and whatever field logbook information is needed to allow for a full evaluation of data useability.

EXAMPLE (Mini[illegible] Requirements)

Well PURGING-FIELD WATER QUALITY MEASUREMENTS FORM

Location (Site/Facility Name)______________________
Well Number______________ Date______________
Field Personnel______________________
Sampling Organization______________________
Identify MP______________________

Depth to (below MP) ________ top / ________ bottom of screen
Pump Intake at (ft. below MP)______________
Purging Device; (pump type)______________

Clock Time 24 HR	Water Depth below MP ft	Pump Dial[1]	Purge Rate ml/min	Cum. Volume Purged liters	Temp. °C	Spec. Cond.[2] µS/cm	pH	ORP/ Eh[3] mv	DO mg/L	Turb- idity NTU	Comments

1. Pump dial setting (for example: hertz, cycles/min, etc).
2. µSiemens per cm(same as µmhos/cm)at 25°C.
3. Oxidation reduction potential (stand in for Eh).

RE-001

Field Notebook

FIELD NOTEBOOK

Objective

The field notebook is intended to serve as a record of significant field activities performed or observed by GEI. The field notebook will serve as a factual basis for preparing field observation reports, if required, and reports to clients and regulatory agencies.

Procedure

1. Use a separate all-weather bound notebook for each site/location/project number.

2. Write neatly using black or blue ink (or note if field conditions [i.e., cold or wet weather] require use of pencil).

3. Write the project name, project number, and book number (i.e., 1 of 3) on the front cover. On the inside cover, identify the project name, project number, and "Return Book to" GEI's address.

4. Number all of the pages of the field book starting with the first entry.

5. Record activities as they occur.

6. Neatly cross out mistakes using a single line and initial them. Erasures are not permitted.

7. Sign or initial and date the bottom of every page with an entry. Cross out unused portions of a page.

8. Record the following information upon each arrival at the site:

   a) Date/time/weather/project number
   b) GEI personnel
   c) Purpose of visit/daily objectives

9. Record conversations with: [Recommendation - If possible, record telephone numbers of individual contacts for the site in the field notebook.]

   a) Contractors
   b) Clients
   c) Visitors (include complete names, titles, and affiliations whenever possible).
   d) GEI office staff
   e) Landowners (site or abutters)
   f) Note time of arrival and departure of individuals visiting the site.

10. Examples of the field information to be recorded include time of occurrences.

    a) General site work activities
    b) Subcontractor's progress

c) Type and quantity of monitoring well construction materials used
d) Use of field data sheets (i.e., boring logs, monitoring well sampling logs, etc.)
e) Ambient air monitoring data
f) Locations of sampling points
g) Surveying data (including sketches with north arrows)
h) Changes in weather
i) Rationale for critical field decisions
j) Recommendations made to the client representative and GEI Project Manager

11. Record the following information upon departure.

a) Include a site sketch of conditions at the end of the day.
b) Time
c) Summarize work completed/work remaining
d) Place a diagonal line though and sign portions of pages not used or skipped.

Precautions

- Only record facts. Do not record opinions.
- Do not fail to record an observation because it does not appear to be relevant at that time.
- Identify conditions or events which could affect/impede your ability to observe conditions.
- Do not use spiral notebooks because pages can be easily removed.

References

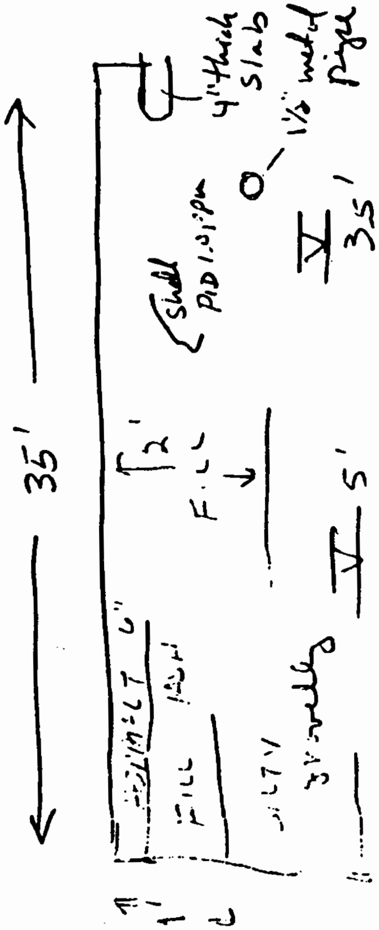
1. *ASFE Model Daily Field Report* (1991), ASFE, Inc.

Attachment

Example Field Notebook

OPERATOR: RALPH
Backhoe: John Deere 310D
PSC Philip Services

START TP-9 1310 PID - 0.0



FILL = ASH, BRICK, REFRACTORY, TIMBER PIECES, metal bars, glass, black silt, fly ash, clam shells, wire, bottles

Groundwater has no sheen or sign of LNAPL.

Soil sample taken from side wall just outside the slab at 2 ft. depth

PID #5 Used on TP-9

Misc. Notes

TP-9 Closed up between 1515 & 1550

GP-15 moved from Work Plan to a location on the holder pad

location 54' ⊥ to front fence
76.5' from NE corner of bldg

– refusal at 15 ft.

1640 – removed Mini RAMS from test pits – one beeped on way to field office

All field activity closed at 1715

MONDAY 2/22/99

Jeff & John arrive at 7:50
everyone on site except Geoprobe

0830–0930 Backhoe scoring + remove asphalt from TP-2

RE-002

Field Observation Report

RE-002

Field Observation Report

FIELD OBSERVATION REPORT

Objective

A Field Observation Report is required to accurately summarize the activities, observations, and decisions made during the day's field work. The daily field observation report may serve as a permanent record of the day's activity for the Project Manager (PM), in-house consultant (IHC), and client.

Procedure

At the close of the day's field work, a Field Observation Report must be prepared by the individual responsible for the field notebook. This report must be completed before leaving work for the day. Contents of the report should include, at a minimum, the following information.

1. A record of person(s) present at the site, time of arrival, departure times (e.g., GEI, contractor(s), client, etc.).

2. A record of the daily objective(s) and the activities performed (e.g., drilled five borings in the overburden).

3. A summary of deviation(s) from the field plan or objectives.

4. A summary of field decision(s) made, who made it/them, and the basis for such decision(s).

5. A diagram, sketch, and/or map showing the location and extent of the work or other significant observation(s) made during the day.

6. Any recommendations that may result from field observations and any actions that resulted from those recommendations.

7. A summary listing and field sketch showing location(s) of field activity.

8. Submit a draft report to the PM/IHC for review and editing related to the clarity and conciseness of the report. Complete any editorial changes, sign, date, and submit the report to PM/IHC for approval/signature. Field Observation Reports should be written neatly. They need not be typed unless specifically requested by the PM.

Precautions:

- Not all projects require daily field observation reports.

- The Field Observation Report should be based solely upon factual information, not opinions. Any speculation should be clearly noted in the report as such.

- The Field Observation Report should never be released to anyone other than the PM/IHC prior to review and sign-off unless explicitly authorized by the PM/IHC.

References

1. *GEI Technical Manual*, dated July 1987

Attachment

Example Field Observation Report

FIELD OBSERVATION REPORT

Date	01/18/92
Report No.	8
Project No.	99709
Page	1 of 4

PROJECT ABC Industries Building Demolition

CLIENT Checkmore Development

CONTRACTOR Demolition Brothers

TIME OF ARRIVAL 0915 DEPARTURE 1545

WEATHER Sunny, 25 F

PERSONS CONTACTED/AFFILIATION

Tom Tuttle/ Demolition Inc.
Joe Robinson/ Checkmore Development
Gary Bark / Checkmore Development
Fran Garman / Checkmore Development

GEI REPRESENTATIVES

Reporter: Gerry E. Inline

OBSERVATIONS

1. Purpose of Site Visit: The purpose of the site visit was to observe the excavation of No. 2 fuel oil contaminated soil from beneath and adjacent to the southwest corner of the former ABC Industries (ABC) building and to collect confirmatory soil samples from the bottom and sidewalls of the excavation for DEP-certified laboratory testing.

   On March 5, 1991, a release of No. 2 fuel oil was observed upon removal of an underground storage tank (UST) for the ABC. Contaminated soil beneath and adjacent to southwest corner of the ABC was left in place during the initial clean up in the spring of 1991. The ABC was demolished during December 1991 and January 1992 to allow for the construction of Parking Deck D5.

   The figure on page 5 shows the location of the former UST, the ABC building and the limits of contaminated soil removed in the spring of 1993.

2. Demolition of ABC: Wreckem Inc. demolished and removed the majority of the ABC building before I arrived on site. The basement wall and footing in the southwest corner of the building (in the vicinity of the contaminated soil) was left in place.

3. Removal of Concrete Floor Slab: Demolition Inc. removed the floor slab in the southwest corner of the ABC building. Concrete which was oil stained was stockpiled on plastic.

FIELD OBSERVATION REPORT

PROJECT ABC Building Demolition

CLIENT Checkmore Development Company

CONTRACTOR Demolition Brothers, Inc.

Date 01/18/92

Report No. 8

Project No. 93295

4. Excavation and Stockpiling of Soil: Demolition Brothers excavated soil with a Komatsu excavator and stockpiled the soil on site, north of the Mall building adjacent to Thurber Construction's field trailer.

I collected samples of the excavated soil for jar headspace screening for volatile organic compounds (VOCs). I screened the samples using Massachusetts Department of Environmental Protection's (DEP) Jar Headspace Method (DEP Policy #WSC-400-89, Attachment I) using an organic vapor meter (OVM). Demolition Bros. stockpiled the excavated soil on plastic in three separate stockpiles based on the following criteria:

Stockpile 1: VOC levels greater than 100 parts per million (ppm) and/or visible oil staining.

Stockpile 2: VOC levels between 50 and 100 ppm without visible oil staining.

Stockpile 3: VOC levels less than 50 ppm without visible oil staining.

The table on Page 3 shows the results of the jar headspace screening. The figure on Page 6 shows the excavation limits and the soil sample locations.

Form 4.3.1-18 JUL 88

GEI Consultants, Inc.

By Gerry E. [signature] App'd ____

FIELD OBSERVATION REPORT

PROJECT ABC Industries Building Demolition

CLIENT Checkmore Development Company

CONTRACTOR Demolition Brothers, Inc.

Date 01/18/92

Report No. 8

Project No. 99709

Sample Location Number[1]	Sample Number	OVM Reading[2] (ppm)	Comments
1	99709-14N-45E-161[3]	0	
2	99709-0N-29E-160.5	19	
3	99709-4N-35E-159	352	
4	99709-3S-35E-157	475	
5	99709-10N-27E-158	406	
6	99709-3N-34E-156.5	16	at groundwater table
7	99709-15N-31E-158	91	
8	99709-13N-36E-156.5	28	at groundwater table
9	99709-12N-40E-158	389	
10	99709-3S-55E-161	86	adjacent to concrete floor slab
11	99709-10N-35E-157	67	
12	99709-10N-35E-156.5	37	at groundwater table Tested for TPH[4]

Notes:

1. Sample locations shown on page 4.
2. DEP Jar Headspace Method #WSC-400-89, Attachment I.
3. Sample No. 99709-14N-45E-161 is 24 ft. north and 55 ft. east of the center of Parking Deck D footing D16/17 at elevation 161.
4. Sample delivered to a DEP-certified laboratory for TPH testing.

Φ GEI Consultants, Inc.

By Terry E. [signature] App'd ____________

FIELD OBSERVATION REPORT

PROJECT ABC Industries Building Demolition

CLIENT Checkmore Development Company

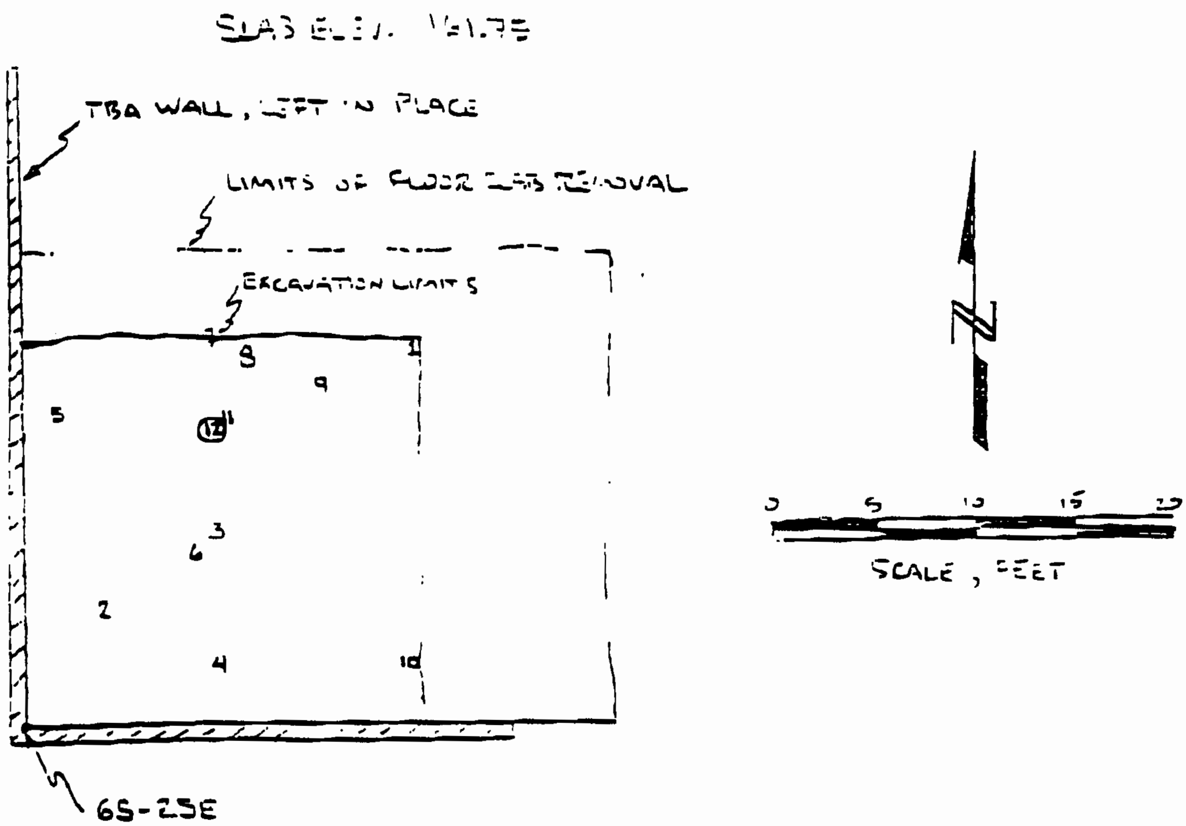
CONTRACTOR Demoltion Brothers, Inc.

Date 01/18/94

Report No. 8

Project No. 99709

EXCAVATION & SAMPLE LOCATION PLAN



LEGEND:

(hatched line)	WALL.
(solid line)	LIMITS OF EXCAVATION.
(dashed line)	LIMITS OF FLOOR SLAB REMOVAL.
1	LOCATION OF SOIL SAMPLE NO. 1.
(12)	LOCATION OF CONFIRMATORY SOIL SAMPLE NO. 12.

GEI Consultants, Inc.

By Gerry E. Inline App'd

RE-003

Boring/Rock Coring Logs

BORING/ROCK CORING LOGS

Objective

To prepare and record a succinct, accurate representation of subsurface conditions, drilling and soil sampling activities, monitoring well installation details, and borehole abandonment procedures. A completed boring log should contain sufficient information to facilitate the preparation of geologic cross sections, to identify possible contaminant sources or pathways observed, and to offer readers a thorough account of drilling and borehole abandonment procedures.

Procedures

1. Prior to beginning drilling activities, complete the header of the boring log to the extent possible. Record the names of the driller and assistant and the types of drilling equipment used for each boring/rock core.

2. Complete the log concurrently with drilling procedures (i.e., do not let the driller work faster than your ability to accurately represent the subsurface conditions).

3. Record the conventional geotechnical parameters during Standard Penetration Testing as per ASTM-D1586, including blowcounts of the hammer per 6-inch increment, total penetration of the split-spoon sampler, and length of the entire sample recovered (see *Split-Spoon Sampling*, SOP SA-001). Record the weight of the hammer, size of the split-spoon sampler, and distance of the hammer fall.

4. Record the depth at which casing or augers are seated and the sizes of the equipment. Be certain to include sizes and seating depths of telescoped casing.

5. Record the time at which each sample is retrieved from the borehole.

6. Record the results of any headspace tests performed on samples collected from discrete depths and also the type of field PID used and GEI's equipment number (i.e., Thermo Environmental Instruments, Inc. OVM; GEI OVM #4).

7. Summarize procedures used to decontaminate sampling equipment between sampling depths or locations. Reference the SOP if applicable.

8. Provide soil descriptions in accordance with *Soil Classification*, SOP RE-004. Record approximate percentage of each constituent and list in order of predominance.

9. In the appropriate column, record all observations with regard to environmental conditions, including staining, odors, foreign material, and presence of free product.

10. Record the color of each soil sample in the appropriate column. Include descriptions of mottled soil and other distinguishing soil color conditions.

11. Information regarding rock coring procedures, including the length of the core run, recovered core length, rock quality designation, and fracture zones should be recorded on the separate rock core log. Provide rock descriptions, including rock type, hardness, grain size, structure, weathering, and color. Separate rock core logs should be completed for each core run.

12. Record relevant drilling observations such as advance rate, water levels, drilling difficulties, changes in drilling method or equipment, amounts and types of any drilling fluids, running sands, and borehole stability.

13. Record the procedures and material used to abandon or seal each borehole upon completion. If the borehole is completed as a monitoring well, record the well construction details in accordance with SOP SS-004, Monitoring Well Installation.

14. Prepare all logs in pen.

Precautions

- A separate Field Observation Report (FOR) should be completed after each day of drilling (see SOP RE-002).

- Keep boring logs and rock core logs focused on actual observations. Record only factual information on the logs.

- The boring logs should be returned to GEI from the field in a legible form that can be used in a report directly or allow secretaries or technicians to prepare typed logs in the same format if required for specific projects.

Attachments

Example Boring Log
Example Rock Core Log

BORING MW2-05-20

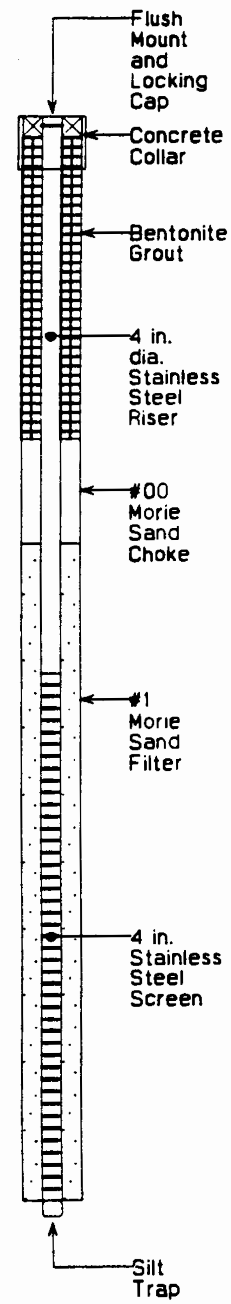
T: Pleasantville MGP Site
JECT NO.: 2007-09-02-02
I.J. PERMIT NO.: NA
OCATION: Corner of shop at alley
JATE STARTED: 9/11/1996
DATE COMPLETED: 9/11/1996
DRILLING CONTRACTOR: Uni-tech Drilling
RILLER: Butch
NSPECTOR: Paul Maywood
DRILLING METHOD: 4 1/4" HSA
SAMPLING METHOD: None

GROUND ELEVATION: 28.41
INNER CASING ELEVATION: 28.14
DATUM: NGVD of 1929
OUTER CASING: NA
RISER PIPE: From 0 to 10.5 ft.
WELL SCREEN: NA
ANNULAR FILL:
BENTONITE GROUT: From 0 to 6 ft.
#00 MORIE SAND CHOKE: From 6 to 8 ft.
#1 MORIE SAND FILTER: From 8 to 20.5 ft.

'LIT OON MPLE DEPTH (ft)	BLOWS PER 6 in.	PER CENT RECOVERY	FID (ppm)	PID (ppm)	DEPTH (ft. BGS)	SOIL DESCRIPTION color, density, SOIL, admixture, moisture, other notes, ORIGIN	VISUAL IMPACTS	ODOR	SAMPLE ANALYSIS	LITHOLOGY	USCS CODE	DEPTH (ft. BGS)
0-2	5,6 6,6	80	NT	0	0	Asphalt and light orange brown medium to fine sand FILL with trace to little gravel, slightly moist, no odor	None	None				0
2-4	6,7 6,7	80	NT	0		coarsening to medium sand FILL, no odor	None	None			FL	
4-6	8,14 20,21	75	NT	0	5	Light yellow brown to light orange brown medium to coarse SAND with some fine gravel, no odor or visual impact	None	None			SP GP	5
6-8	10,19 24,24	75	NT	0		Light yellow brown medium to fine SAND with thin ornge brown bands	None	None				
8-10	12,18 28,30	60	NT	0		thinly banded and cross-bedded	None	None			SP	
10-12	12,19 24,28	70	NT	0	10	laminated, no cross-bedding	None	None				10
12-14	20,24 37,33	85	NT	0		thin gravel and coarse sand 12.9-13, moist to wet by 14, no odor	None	None			SP GP	
14-16	22,28 32,38	65	NT	0	15	Medium to fine SAND with trace fine gravel, saturated, no odor	None	None				15
16-18	41,34 37,42	65	NT	0		very light gray	None	None			SP	
18-20	18,22 25,32	70	NT	0		light olive gray, poorly sorted, small dark red brown medium sand inclusion 19-19.1	None	None				
20.5	augered				20	Light gray to light brown or light orange brown fine SAND, loose, no odor						20

End of boring at 20.5 ft.

WELL CONSTRUCTION



RE-004

Soil Classification

SOIL CLASSIFICATION

Objective

Soil classification is necessary to classify soil samples collected in the field in a consistent manner. This information may be used by geologists, scientists, engineers, contractors, developers, and other design professionals.

Procedure

1. If the soil sample is being collected during drilling activities, complete the header of the attached boring log prior to beginning drilling activities. Complete the log concurrently with drilling procedures.

2. Soil samples should be described according to the American Society of Testing Materials (ASTM) Standard Practice for Description and Identification of Soils (Visual-Manual Procedure) D2488-90 (see attached charts).

3. Record the location of the sampling point (include sketch if appropriate).

4. Record vertical measurements for each sample from original ground surface.

5. Identify and record the recovery and the type of soil in terms of the major and minor constituents (i.e., sand, gravel, silt, clay) and choose the group name and Unified Soil Classification Symbol according to the attached charts.

6. Record sample structure (i.e., laminated, stratified, homogeneous) lenses/layers of different soils. Note cementation, desiccation cracks, and mineralogy.

7. Estimate and record the percentage of each constituent and list in order of predominance.

8. Record maximum particle size.

9. Record plasticity and dilatancy for fine-grained soils.

10. Record odor, presence of iron or other staining, and presence of organic matter, shells, debris, or other unusual characteristics of the sample. Be specific in type of odor (i.e., tar vs gasoline vs. fuel oil, etc) and visual impacts (i.e., sheen vs DNAPL vs stain).

11. Record color of sample.

12. Record local or geologic name if known (i.e., Boston Blue Clay or glacial till).

13. If a soil split-spoon sample contains more than one soil type (for example, the upper portion is silty sand and the lower portion is clay), all soil types should be classified and samples should be jarred separately.

14. Record sampler type, blow counts, etc.

15. Record field screening instrument readings.

Precautions

- Certain projects/clients will require the use of other classification systems. Other classification systems should not be used unless specifically required by the client in the project contract.

- Some soil characteristics, such as plasticity and dilatancy, are difficult to identify in the field during extremely cold or wet weather. The field classification should be verified in the office after the samples have returned to room temperature if samples were collected during extreme weather conditions.

- The ASTM Standard Test Method for Classification Soils for Engineering Purposes, D2487-90, should be used in conjunction with the Visual-Manual Method if exactness in soil classification is required.

- Note: The SOP for VOC Field Screening, TE-001, may be required.

References

1. *Annual Book of ASTM Standards* (1993), Section 4, v. 4.08 Soil and Rock; Building Stones; Geosynthetics, D2488-90, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure), American Society of Testing Materials (ASTM).

Attachments

Example Boring Log
Visual/Manual Descriptions of Fine- and Coarse-Grained Soils
Boring Log and Well Construction Data Entry Forms

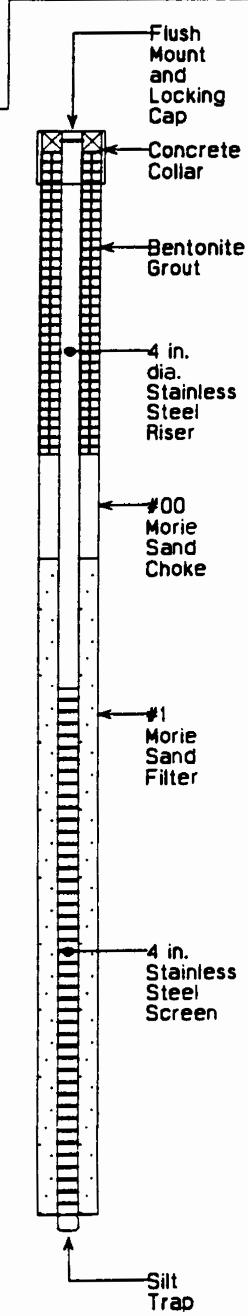
BORING MW2-05-20

CT: Pleasantville MGP Site
ECT NO.: 2007-09-02-02
..J. PERMIT NO.: NA
.OCATION: Corner of shop at alley
DATE STARTED: 9/11/1996
DATE COMPLETED: 9/11/1996
DRILLING CONTRACTOR: Uni-tech Drilling
DRILLER: Butch
INSPECTOR: Paul Maywood
DRILLING METHOD: 4 1/4" HSA
SAMPLING METHOD: None

GROUND ELEVATION: 28.41
INNER CASING ELEVATION: 28.14
DATUM: NGVD of 1929
OUTER CASING: NA
RISER PIPE: From 0 to 10.5 ft.
WELL SCREEN: NA
ANNULAR FILL:
BENTONITE GROUT: From 0 to 6 ft.
#00 MORIE SAND CHOKE: From 6 to 8 ft.
#1 MORIE SAND FILTER: From 8 to 20.5 ft.

SPLIT SPOON SAMPLE DEPTH (ft)	BLOWS PER 6 in.	PER CENT RECOVERY	FID (ppm)	PID (ppm)	DEPTH (ft. BGS)	SOIL DESCRIPTION: color, density, SOIL, admixture, moisture, other notes, ORIGIN	VISUAL IMPACTS	ODOR	SAMPLE ANALYSIS	USCS CODE	DEPTH (ft. BGS)
0-2	5,6 6,6	80	NT	0	0	Asphalt and light orange brown medium to fine sand FILL with trace to little gravel, slightly moist, no odor	None	None		FL	0
2-4	6,7 6,7	80	NT	0		coarsening to medium sand FILL, no odor	None	None		FL	
4-6	8,14 20,21	75	NT	0	5	Light yellow brown to light orange brown medium to coarse SAND with some fine gravel, no odor or visual impact	None	None		SP GP	5
6-8	10,19 24,24	75	NT	0		Light yellow brown medium to fine SAND with thin ornge brown bands	None	None		SP	
8-10	12,18 28,30	60	NT	0		thinly banded and cross-bedded	None	None		SP	
10-12	12,19 24,28	70	NT	0	10	laminated, no cross-bedding	None	None		SP	10
12-14	20,24 37,33	85	NT	0		thin gravel and coarse sand 12.9-13, moist to wet by 14, no odor	None	None		SP GP	
14-16	22,28 32,38	65	NT	0	15	Medium to fine SAND with trace fine gravel, saturated, no odor	None	None		SP	15
16-18	41,34 37,42	65	NT	0		very light gray	None	None		SP	
18-20	18,22 25,32	70	NT	0		light olive gray, poorly sorted, small dark red brown medium sand inclusion 19-19.1	None	None		SP	
20-20.5	augered				20	Light gray to light brown or light orange brown fine SAND, loose, no odor					20
						End of boring at 20.5 ft.					

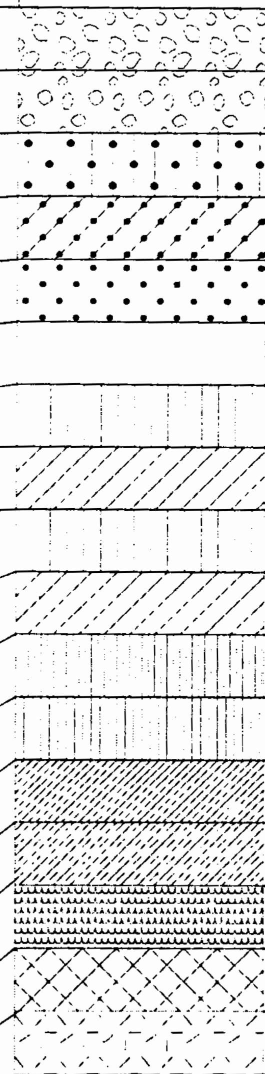
WELL CONSTRUCTION



ASTM Standard Designation
Unified Soils Classification

Typical Descriptions	Letter Symbols	Fill Pattern Number
Well-Graded Gravels, Gravel-Sand Mixtures, Little or No Fines.	GW	25
Poorly-Graded Gravels, Gravel-Sand Mixtures, Little or No Fines.	GP	26
Silty-Gravels, Gravel-Sand-Silt Mixtures.	GM	3
Clayey-Gravels, Gravel-Sand-Clay Mixtures.	GC	4
Well-Graded Sands, Gravelly Sands, Little or No Fines.	SW	2
Poorly-Graded Sands, Gravelly Sands, Little or No Fines.	SP	6
Silty Sands, Sandy Silt Mixtures.	SM	9
Clayey Sands, Sand and Clay Mixtures.	SC	10
Inorganic Silts and Very Fine Sands, Rock Flour, Silty or Clayey Fine Sands or Clayey Silts with Slight Plasticity.	ML	11 14
Inorganic Clays of Low to Medium Plasticity, Gravelly Clays, Sandy Clays, Silty Clays, Lean Clays.	CL	18
Organic Silts and Organic Silty Clays of Low Plasticity.	OL	13
Inorganic Silts, Micaceous or Diatomaceous Fine Sand or Silty Soils.	MH	16
Inorganic Clays of High Plasticity, Fat Clays.	CH	19
Organic Clays of Medium to High Plasticity, Organic Silts.	OH	20
Peat, Humus, Swamp Soils with High Organic Contents.	PT	74
Fill Material.	FL	57
Bedrock.	BR	

Fill Patterns



Boring Log and Well Construction
Data Entry Forms

Well/Boring ID: ________

Head Information			
Project:		Drilling Method:	
Project No:		Sampling Method:	
Location:		Ground Elevation (ft):	
Date Started:		Datum:	
Date Completed:		Water Table Elevation:	
Drilling Contractor:		Weather:	
Driller:		Inspector:	
Boring/Well Depth (ft):		Checked by:	

Well Construction Information

Name/Fill Pattern	Item	Description (as it would appear on the final form)	Depth Range (depth from surface) Sample: 0-1.5
Cover (33c)	Guard (top)		
Seal (74f)	Backfill		
Case (1c)	Riser (PVC)		
Case (7w)	Screen (PVC)		
Seal (71f)	Grout		
Seal (68f)	Bentonite		
Seal (8f)	Sand Pack		
Case (24)	Sediment Trap (bottom)		
Oseal (71f)	Concrete pad		
Ocase (21)	St. Steel outer casing		
	Others (specify)		

NOTE: Additional copies of these forms can be obtained by printing WordPerfect file ``BORLOG.WPD'' which is located in drive/directory AES\DATA:TECH\TEMPLATE\GT3.

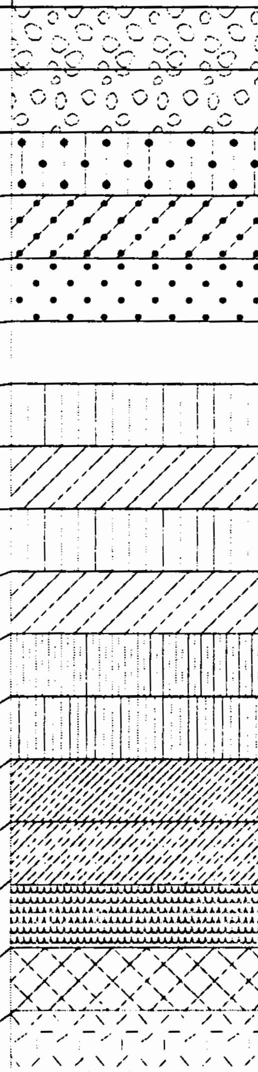
Soil Description

Initial Depth	Color, SOIL TYPE, moisture content, ORIGIN, other notes	Fill Pattern Number

Depth Range Information															Depth Information			
Split-Spoon Interval	Blow Count/ 6 inch interval				Visual Contamination				Olfactory (optional)				Sample Analysis	Recovery (%)	HNU (ppm)	LEL (%)	Other
					None	Stain	Sheen	Heavy	None	Slight	Moderate	Strong					
0.0-2.0	*13*	*30*	*1*	*50*	*0.0-1.5*	*1.5-3.0*			*0.0-1.0*		*1.0-3.0*						
2.0-4.0	*25*	*15*	*2*	*3*				*3.0-8.0*				*3.0-9.0*	*3.5-4.5*				

ASTM Standard Designation
Unified Soils Classification

Typical Descriptions	Letter Symbols	Fill Patterns	Fill Pattern Number
Well-Graded Gravels, Gravel-Sand Mixtures, Little or No Fines.	GW		25
Poorly-Graded Gravels, Gravel-Sand Mixtures, Little or No Fines.	GP		26
Silty-Gravels, Gravel-Sand-Silt Mixtures.	GM		3
Clayey-Gravels, Gravel-Sand-Clay Mixtures.	GC		4
Well-Graded Sands, Gravelly Sands, Little or No Fines.	SW		2
Poorly-Graded Sands, Gravelly Sands, Little or No Fines.	SP		6
Silty Sands, Sandy Silt Mixtures.	SM		9
Clayey Sands, Sand and Clay Mixtures.	SC		10
Inorganic Silts and Very Fine Sands, Rock Flour, Silty or Clayey Fine Sands or Clayey Silts with Slight Plasticity.	ML		11
Inorganic Clays of Low to Medium Plasticity, Gravelly Clays, Sandy Clays, Silty Clays, Lean Clays.	CL		14
Organic Silts and Organic Silty Clays of Low Plasticity.	OL		18
Inorganic Silts, Micaceous or Diatomaceous Fine Sand or Silty Soils.	MH		13
Inorganic Clays of High Plasticity, Fat Clays.	CH		16
Organic Clays of Medium to High Plasticity, Organic Silts.	OH		19
Peat, Humus, Swamp Soils with High Organic Contents.	PT		20
Fill Material.	FL		74
Bedrock.	BR		57



RE-006

Investigation-Derived Waste Management

INVESTIGATION DERIVED WASTE (IDW) MANAGEMENT

Objective

The objective of this SOP is to provide guidelines for the proper management of IDW resulting from site investigation activities. This SOP addresses IDW generated during field tasks typically performed for environmental site investigations. The intent of this SOP is to provide a set of guidelines for proper assessment and handling of these IDWs.

Procedures

1. Determine the suspected contamination type and impacted media anticipated, based on previous investigations, current analytical data, and/or site history.

2. Consider the following issues when selecting IDW management option(s):

   a) anticipated volume of IDW to be generated during on-site activities
   b) potential contaminants and their concentrations
   c) location of the nearest populations and the likelihood and/or degree of site access
   d) potential exposures to workers
   e) potential for environmental impacts
   f) community concerns
   g) potential storage areas
   h) regulatory constraints
   i) potential on-site treatment options

3. Review IDW Management Options summarized in Table 1 for each media suspected of contamination.

4. Select IDW Management Option(s) prior to the commencement of field activities that will generate waste materials.

5. Include the selected IDW Management Option(s) in the Field Plan.

In addition to the issues considered above for the selection of IDW management strategies/disposal options, more specific considerations/guidelines include:

Test Pit Excavation

A. Segregate contaminated soil from uncontaminated soil using visual and/or field screening methods.

B. Use appropriate barrier (two layers of 6-ml plastic sheeting) for temporary stockpiling of contaminated soil adjacent to test pit.

C. Backfilling of test pits with contaminated soil.

D. For situations where returning contaminated soil to the test pit is deemed protective by the project manager, backfill soil in the same order as the soil was excavated from the test pit.

Boring/Monitoring Well Installation

A. For auger borings, segregate contaminated soil (determined by visual and/or field screening methods) from uncontaminated soil during drilling. Segregate residual contaminated soil from split-spoon sampling.

B. Auger cuttings or sediment generated by drive and wash may be spread around the ground surface at the boring location if deemed appropriate by the project manager. IDW may be placed in an appropriate area or container pending characterization and appropriate disposal. (A useful rule of thumb is to assume generation of one 55-gallon drum of cuttings for each 20 feet drilled with 7-¼-inch-I.D. augers).

C. Segregate contaminated drilling fluid from uncontaminated fluid for rotary wash borings.

D. Drilling fluid management options include pouring the drilling fluid on the ground in the Area of Concern (AOC) or containerizing the fluid in drums or tanks.

Water Development/Sampling

A. Contaminated groundwater removed from wells by pumping or bailing for the purpose of well development and sampling may be poured on the ground in the AOC or containerized in drums or tanks at the project manager's discretion.

Decontamination Fluids

A. Decontamination fluids may only be poured on the ground in the vicinity of the well in situations deemed protective by the project manager. Alternatively, the fluids may be containerized in drums or tanks.

Disposable Personal Protective Equipment

A. Disposable PPE must be managed like any other IDW. It should only be removed from the site with the project manager's approval, and may be disposed of as ordinary rubbish only if it has not come into contact with hazardous materials.

Precautions

- The preferred IDW management option is to return the IDW to its source.
- The IDW selected must be in accordance with state/federal regulations.
- Our clients are responsible for the disposal of IDW, should disposal be necessary.

References

1. *Guide to Management of Investigation - Derived Wastes* (April 1992), United States Environmental Protection Agency, Publication 9345.3-03FS.

2. *Standard References for Monitoring Wells*, Massachusetts Department of Environmental Protection, Publication No. WSC-310-91.

Attachment

Table 1: Summary of IDW Management Options

RE-007

Chain-of-Custody

CHAIN-OF-CUSTODY

Objective

To provide a record of the custody of any environmental field sample from time of collection to delivery to the laboratory. This form can be used as a legal document to guarantee that samples were not mishandled and that they were delivered to the laboratory within the time frame necessary to start analysis. A sample is under custody if:

a) it is in GEI's possession; or
b) it is in GEI's view after being in GEI's possession; or
c) it was in GEI's possession and then it was locked up to prevent tampering; or
d) it is in a designated secure area. GEI facilities are designated secure areas.

Procedures:

1. Following sample collection, the sample container is labeled with the sample ID, the date and time (military time) of sample collection, and the sampler's initials (see Sample Handling SOP No. SA-005). Sample custody begins at this time.

2. Record the above information in the Field Notebook (See Field Notebook SOP No. RE-001).

3. Place the sample into a cooler with ice.

4. Complete the Chain-of-Custody (COC) form as described below and as illustrated in the attached example. A COC form must accompany each shipment/delivery of samples to the laboratory. Laboratory COC forms may be substituted for the attached form as long as the laboratory form contains the same information, at a minimum, as the attached form.

    - Record the project name and number and the sampler's name(s).

    - For each sample, enter the sample identification number, date and time (military time) collected, whether the sample is a grab or composite sample and the number of sample containers. Record the type of analysis requested and the preservative (if appropriate) in the vertical boxes. The attached form illustrates the correct entry for the following example samples:

        - composite surface soil sample SS-1 collected at 10:20 am on 2-11-96 to be analyzed for VOCs, BNs, metals, and cyanide; and

        - grab groundwater sample GW-1 collected at 10:25 am on 2-11-96 to be analyzed for VOCs, BNs, metals, and cyanide.

5. When samples are ready to be relinquished, complete the bottom of the form with date and time (military time) and signatures of relinquisher and receiver of samples as indicated. The sample collector is always the first signature while the analytical laboratory is the final signature. Theoretically, all individuals handling the samples between collection and laboratory should

sign the form; however, if a common carrier (i.e., Federal Express, UPS) is used for shipping, GEI must identify the carrier in the 'Received by' box on the COC. If the sampler hand delivers the samples to the laboratory, the received box must be signed by the laboratory.

6. The forms are in triplicate (white, yellow, and pink copies). The pink copy should be retained by the sampling personnel and provided to the project manager for proper filing. The white and yellow copies should accompany the samples to the laboratory.

7. Prior to sample shipment, the COC must be placed inside the cooler (in a ziplock bag or other watertight package), and the cooler must be sealed with a signed COC seal.

Precautions

- If some samples on the COC prepared in the field are not being sent to the laboratory, you should prepare a new COC for the laboratory samples. The field COC should be marked "sample sent to laboratory" in the remarks section associated with each sample sent, initialed, and dated.

- The field notebook must document all GEI personnel who had custody of any or all of the samples on the COC. If the sampler will not be responsible for shipping the samples to the laboratory, the samples must be relinquished to the shipper and the COC signed and dated by the sampler and the shipper, even if both people are GEI personnel.

References

1. *NEIC Policies and Procedures Manual* (October 1979), U.S. EPA (EPA-330/9-78-001-R).

Attachment

GEI Consultants, Inc., Atlantic Environmental Division Chain-of-Custody Record

GEI CONSULTANTS, INC., ATLANTIC ENVIRONMENTAL DIVISION
188 Norwich Avenue, P.O. Box 297, Colchester, CT 06415
PHONE: (860) 537-0751 FAX: (860) 537-6347

№ 3475

CHAIN OF CUSTODY RECORD

PROJECT NAME: ______________________

PROJECT NUMBER: ______________________

SAMPLE NO.	DATE	TIME	GRAB	COMP	NO. OF CONT.	SAMPLE MATRIX	ANALYSIS PRSV.	PRSV.	PRSV.	PRSV.	PRSV.	PRSV.	PRSV.	PRSV.	PRSV.	PRSV.	COMMENTS

Relinquished by:	Date/Time	Received by:	Relinquished by:	Date/Time	Received by:
Relinquished by:	Date/Time	Received by:	Relinquished by:	Date/Time	Received for Laboratory by:
Method of Shipment:	Shipping Waybill No.:	Remarks:			

SAMPLED BY: ______________ (Print Name) ______________ Signature

______________ (Print Name) ______________ Signature

SA-001

Split-Spoon Sampling

SPLIT-SPOON SAMPLING

Objective

The objective of this SOP is to standardize the collection of soil samples obtained during the installation of exploratory overburden soil borings. Consult the project-specific field sampling plan or work plan for variations to the sampling procedures stated below.

Procedure

1. Select the size (length and diameter) of split-spoon sampler based on the amount of soil that is needed for characterization. The ASTM standard for N-values is 1⅜-inch I.D. Specify spoon size and basket type to driller prior to mobilization to the site.

2. Select a soft or stiff basket for the spoon (a softer basket works better for loose or soft material).

3. Clear all subsurface and overhead utilities prior to sampling. Record the confirmation number from the locating service in the field log. Record all conversations with utility representatives regarding clearing of utilities in field log.

4. At the designated soil elevation interval, direct drillers to put sampler (split-spoon) down the hole. Ensure that the drill string is not allowed to free fall to the bottom of the hole. Have the drillers use a slide plate to lower the drill string to the bottom of the hole.

5. Prior to hammering the split spoon to collect the sample, verify that the split-spoon is no more than 6 inches above the top of the desired sample depth. If the split spoon is more than 6 inches above the top of the desired sample depth, clean out the hole prior to sampling. Record all depth measurements relative to ground surface.

6. Follow Soil Boring SOP (SS-002) for advancing the split spoon. Record the number of blows to advance the spoon. Record hammer weight. It should be 140 lbs.

7. After the split spoon has been removed, open the split spoon by unscrewing the nose/shoe (holds basket) and gently pull apart the spoon using hands so as not to disturb the sample. Sometimes it may be necessary to tap the spoon with a hammer to enable the spoon to split open. Note any material in the nose (shoe) of the spoon.

8. Immediately collect a sample for VOCs (if required by the site-specific field sampling plan) by collecting soil from the entire length of the split spoon, unless otherwise specified. When the most impacted interval (based on field instrument screening) is sampled for laboratory analysis, screen the spoon with the field instrument first (step 9 below), then collect the soil sample for VOC analysis from the appropriate interval.

9. Screen the soil sample for VOCs (see SOP TE-001, *VOC Field Screening*) or other constituents as indicated in the site-specific field sampling plan.

10. Log the lithology of the sample in accordance with SOP RE-004, *Soil Classification*. Record features (strata change, contamination, etc.) of the spoon on field boring log. Measure the recovery (amount of material in the spoon) in the spoon and in the nose (shoe). Measure and record strata differences in the spoon.

11. Collect sample for laboratory analysis in the following manner.

    a) Use clean sampling equipment. Decontaminate all sampling equipment (in accordance with SOP SA-007, *Equipment Decontamination,* or site-specific quality assurance plan) prior to obtaining samples.

    b) Put on a clean pair of protective gloves, generally disposable vinyl gloves.

    c) If using drive and wash techniques, clean fluid from surface of sample with a stainless-steel spatula. Collect soil from the center of the spoon - away from the sidewalls if recovery allows.

    d) Place samples in laboratory-prepared glassware in accordance with the *Sample Handling* SOP (SA-005). Avoid having headspace (especially for VOC samples) and wipe soil from threads to ensure a good seal.

    e) Collect material from the entire length of the spoon rather than taking the entire sample from one point unless otherwise specified in the project field sampling or work plan.

    f) If distinct horizons exist, either geologic or chemical, collect a sample from each horizon if required in the project plan.

    g) Store samples on ice or refrigerate from the time of collection until delivery at the laboratory.

12. Collect Driller Jar Soil Samples in the following manner.

    a) Save a representative sample of the soil and place it in a driller's jar. Project Manager may require saving of entire sample for grain size/classification purposes.

    b) **Label jars even if they contain no sample material.** What does this mean? - label an empty jar for intervals in which there is no recovery? Label jars with project #, boring #, sample #, sample depth, blow counts, and recovery.

13. Decontaminate the spoon using the *Equipment Decontamination* SOP (SA-007) or project-specific work plan/quality assurance project plan decontamination procedures.

Precautions

At all times, follow safety procedures as defined in the site-specific Health and Safety Plan.

Be aware of the length of the drill string, the sample depth, and the required stickup of the drill string to ensure accurate sample interval measurement.

If drilling with hollow-stem augers, the removal of the drill string from the hole, prior to attaching the split-spoon sampler, may cause soils to be sucked up into the augers (blow-in/running sands). Upon recovery, determine what is blow-in. In general, blow-in is more unconsolidated than the rest of the sample and lacks stratification (do not include blow-in for recovery or sample collection).

If soils are loose sands or soft clay, the drill string and the sampler may advance slightly under its own weight, giving a false depth for soil collection.

Never sample more than two spoons consecutively unless material is tight. Do not let the split-spoon penetrate more than it can hold.

- In many instances groundwater will fill the auger and the split spoon will travel through the water before being pushed into a deeper zone. There is no guarantee that soils in the split spoon will not be contaminated with standing water in the auger. To ensure that a sample is not contaminated, the drilling procedure may have to be modified to seal off the upper zone from the lower zone using casing and then washing the interior of the casing clean.

References

1. *Standard Method for Penetration Test and Split-Barrel Sampling of Soils* (1984), American Society for Testing and Materials (ASTM) D1586-84.

2. *Field Sampling Procedures Manual* (May 1992), New Jersey Department of Environmental Protection and Energy.

3. *Standard Reference for Monitoring Wells* (April 1991), Commonwealth of Massachusetts Department of Environmental Protection, WSC-310-91.

SA-005

Sample Handling

SAMPLE HANDLING

Objective

Sampling handling involves the collection and shipping of environmental samples to a laboratory for chemical analysis. The overall objective of sample handling is to ensure that:

- samples are properly labeled and documented;
- samples are properly preserved;
- samples are properly packaged; and
- samples are properly transported to laboratories.

Procedure

1. Prior to mobilizing to the field, select a shipper or arrange for a courier for sample delivery to the laboratory. If using a shipper (i.e., Federal Express, UPS) determine the time constraints for pickup requests, the location and hours of the nearest shipping office, and any size/weight restrictions.

2. Label all laboratory glassware with waterproof ink prior to collecting samples. The label should have an adhesive and be placed on the jar or bottle, not on the cap.

3. Record the following information on the label and in the field notebook (See Field Notebook SOP RE-001): project number, sample identification (i.e., MW201 or SS-2), date and time (military time) of collection, sampler's initials, and preservative, if present.

4. If sample jars are not prepreserved, add preservative as appropriate.

5. At each sampling location, samples must be collected in order of volatility, most volatile first. Samples collected for volatile analysis must be placed in sample containers immediately upon retrieval of the sample.

6. Aqueous samples for volatile analysis must be collected without air bubbles. Soil samples for volatile analysis should be compacted to eliminate as much headspace as possible. Other laboratory glassware should also be filled when possible. Care must be taken to avoid getting soils on the threads of sample jars, which can cause a faulty seal.

7. If compositing of samples is performed in the field, specify basis for composite (i.e., volume, weight, spoon recovery, etc.) and record procedure for compositing sample in the field book.

8. Once samples have been collected, place samples in a cooler with ice or a blue pack and start the chain-of-custody form (see *Chain-of-Custody* SOP RE-007).

9. For shipping, individually wrap each sample bottle with "bubble packing" or suitable packing material and place the wrapped bottles in the cooler with sufficient packing material between samples to avoid breakage.

10. Place a layer of packing material above and below the sample bottles. Place blue ice packs or ice bags on top of the packing material. Fill the remaining space in the cooler with packing material to eliminate the possibility of vertical movement of samples.

11. Place the completed and signed chain-of-custody form in a plastic bag and place on top of the packing material in the cooler.

12. Fill out the appropriate shipping or courier forms and attach to the top of the cooler. If necessary, place the proper shipping labels on the cooler. Have the courier sign the chain-of-custody form (or write pickup by FEDEX, UPS, etc. with date and time). Place a custody seal on the cooler.

13. A copy of the waybills must be kept by the field supervisor to trace shipments if necessary.

Precautions

- At all times, follow safety procedures as defined in the site-specific Health and Safety Plan.
- Field personnel must be aware of analyses which have short holding times and schedule sampling events and shipping accordingly. Shipment of samples for analyses with short holding times must be planned in advance. Refer to the project work plan, quality assurance project plan, or state/federal regulations for holding time and preservative information.
- In general, glassware for aqueous samples contains preservatives, i.e., HNO_3, HCl, etc.. When collecting the sample, take care not to overfill the container, thus flushing the preservative out of the bottle.
- Never composite samples for VOCs in the field. Collect individual aliquots and direct the laboratory to perform compositing.
- Collection of aqueous samples should not be performed over the opening of a monitoring well. Preservatives from overfilling, a marker pen or other objects could fall into the well.
- If the recharge volume for a monitoring well is low, completely fill all volatile vials and then collect the minimum sample volume required for each remaining analysis.
- During subsurface soil sampling, if the recovery from the split-spoon sample is inadequate, if appropriate, resample the bottom of the borehole to obtain proper sample volume.
- Laboratories will homogenize and test the contents of the sample container, unless directed otherwise. Samples should not contain rocks, twigs, leaves, etc. unless these materials are of interest.

References

1. *Manual of Ground-Water Quality Sampling Procedures* (September 1981), U.S. EPA Office of Research and Development (EPA-600/2-81-160).

2. *Soil Sampling Quality Assurance User's Guide* (March 1984), U.S. EPA Office of Research and Development Environmental Monitoring Systems Laboratory, Cooperative Agreement CR 810550-01 (EPA-600/4-84-043).

3. *Standard References for Monitoring Wells* (January 1991), Massachusetts Department of Environmental Protection, DEP Publication # WSC-310-91.

SA-006

Field Quality Control Samples

FIELD QUALITY CONTROL SAMPLES

Objective

Field quality control (QC) samples are used to monitor the reproducibility and representativeness of the field activities. The QC samples are handled, transported, and analyzed in the same manner as the associated field samples. QC samples may include trip blanks, field blanks, and field duplicates.

Procedures

1. Trip blanks are used to monitor possible sources of contamination from transport, storage, inadequate bottle cleaning, or laboratory methodologies.

   a) Trip blanks are sample containers filled at the laboratory with analyte-free water, are transported to and from the site, and are not opened until time of analysis.

   b) The trip blanks are stored with the sample containers prior to and after field activities and remain with the collected samples until analyzed.

   c) Generally, one trip blank per VOC shipment AND when sample shipment is by Fed Ex or other large carrier.

2. Field blanks, also called equipment blanks, are used to monitor the adequacy of decontamination procedures and possible sources of contamination from inadequate bottle cleaning or laboratory methodologies.

   a) Field blanks are samples collected by pouring laboratory supplied or distilled or deionized water through a decontaminated piece of field equipment.

   b) The water is then collected in a sample bottle(s) and stored with the associated field samples and submitted for analysis.

   c) Generally collected at a frequency of 1/20 samples and when nondedicated sampling equipment is used. Check project-specific work plan and/or quality assurance project plan for required frequency.

3. Field duplicates are used to evaluate the precision and representativeness of the sampling procedures.

   a) Field duplicates are two samples collected from the same location using the same procedures. Both samples are submitted to the laboratory as individual samples with different sample identification.

   b) Field duplicates from groundwater sampling are collected by alternating filling sample containers from the same sampling device. Volatile samples must be collected from the same bailer.

c) Soil or sediment field duplicates are collected by homogenizing the sample for all analyses except volatiles. The homogenized sample is then divided into two equal portions and placed in separate sample containers. Field duplicates for volatile analysis are collected at two adjacent sampling locations.

d) Each sample is assigned a different sample identification.

e) Generally collected at frequency of 1/20 samples. Check project-specific work plan and/or quality assurance project plan for required frequency.

4. All field QC samples should be labeled in the field and submitted "blind" to the laboratory.

Precautions

- At all times, follow safety procedures as defined in the site-specific Health and Safety Plan.
- Trip blanks must never be opened in the field.
- Trip blanks are usually for VOCs only because less volatile compounds are not likely to cross-contaminate other samples by simply being in close proximity.
- Water of documented quality must be used during the collection of field blanks.
- Field duplicates must have different sample identifications.

References

1. *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods* (November 1986), U.S. Environmental Protection Agency Department of Solid Waste, Washington, D.C.

SA-007

Equipment Decontamination

EQUIPMENT DECONTAMINATION

Objective

The objective of this Standard Operating Procedure is to provide standard methods for the decontamination and cleaning of non-dedicated sampling equipment in order to minmize the cross-contamination of samples.

Procedures

1. Inspect equipment for cleanliness prior to moving onto a site and prior to relocating to each new sampling location. All contractor-provided equipment (augers, rods, spoons, backhoe buckets) shall be decontaminated by steam cleaning **prior to coming on site.**

2. Equipment decontamination is a sequential procedure consisting of the following general steps: alconox-solution wash; potable water rinse; methanol wash, and three distilled-water rinses.

3. Alconox solution is a mixture of approximately 1 cup of Alconox per 1 gallon of potable water. Alconox solution wash requires scrubbing the equipment with a brush soaked in alconox solution and removing any visible contamination or dirt from the equipment.

4. Before advancing each boring, drilling equipment (including augers, casing, rods, and washtub) must be decontaminated by steam cleaning.

5. Split-spoon samplers must be decontaminated prior to collecting each sample. The split-spoon decontamination procedure includes: a gross wash and scrub in a bucket of alconox solution; potable water rinse; methanol wash, and three distilled-water rinses.

6. Pumps and tubing used for sample collection and well development must be decontaminated by flushing with a minimum of one gallon of potable water; then flushing with a minimum of one pint of methanol and rinsing twice with distilled water.

7. For pumps and tubing, perform a final rinse of the sampling equipment with the water being sampled.

Precautions

- Do not store the deionized/distilled water in polyethylene bottles, use Nalgene, glass, or Teflon. Polyethylene may leach phthalates.

- Do not attempt to decontaminate string or rope; replace it.

- Due to eye and skin absorption hazards, safety glasses and gloves must be worn when handling decontamination solvents.

- The decontamination procedure may require modification based on site specific conditions and methods used should not interfere with the site-specific chemical analyses. The procedure may also require modification based on state regulations.

- Steam cleaning with potable water is an acceptable decontamination method for drilling equipment (i.e., augers).

- If sampling for metals, the decontamination procedure requires modification to include rinsing with a 1:1 nitric acid and rinsing with deionized water in place of distilled water.

- Dedicated equipment need not be decontaminated beyond initial decontamination prior to field use.

References

1. *Standard References for Monitoring Wells* (1991), Massachusetts DEP, Boston, DEP Publication #WSC-310-91.

SS-002

Overburden Soil Boring Drilling: Hollow-Stem Augers

OVERBURDEN SOIL BORING DRILLING: HOLLOW-STEM AUGERS

Objective

The objective of this SOP is to standardize the drilling of overburden soil borings for environmental investigations. This SOP addresses the use of hollow-stem augers to drill the soil boring.

Procedure

1. Contact the Owner to determine the locations of underground utilities/obstructions. Verify with the contractor that the utility clearance service of the particular state you're working in has been contacted. Ask the subcontractor to provide you with the utility clearance authorization number and the time of clearance to proceed, and record the number in the field notebook.

2. Inspect the drilling rig to make sure it is clean and that the down-hole equipment has been steam-cleaned. Check that the steam-cleaner is working properly (i.e., that steam is being produced). Measure and record lengths of all down-hole drilling equipment, including the drilling heads and miscellaneous rods and attachments. Record all observations and measurements in the field notebook.

3. If a surface soil-sample is desired, collect this sample with a split-spoon sampler prior to setting the first flight of augers up over the borehole. For all soil samples, use a 140-lb hammer to drive the sampler, unless conditions necessitate using a 300-lb hammer (see SOPs SA-001, *Split-Spoon Sampling*, and RE-004, *Soil Classification,* for details). Count and record the number of blow counts per 6-inch increments (confirm blow counts with driller if necessary).

4. Decontaminate the split-spoon sampler after each use (see *Equipment Decontamination,* SOP SA-007) or use another decontaminated split-spoon sampler.

5. Direct the drillers to drill the borehole to the top of the next sampling interval. Remove the auger cutting bit/plug and insert the split-spoon sampler into the interior of the augers (the drillers are responsible for this activity). Measure the stick-up of the rods attached to the sampler to ensure that the nose of the spoon is in virgin soils below the augers.

6. Watch for signs of a soil strata change at depth during drilling (i.e., change in blow counts, change in soil color, soil wetness, soil contamination, bouncing of the drill rig, etc.). If important to the investigation, stop drilling and collect a soil sample.

7. Follow steps 4-7 until the borehole has been drilled to the desired depth. If bedrock confirmation is required and refusal is encountered, a 5-foot core of the rock (at a minimum) is required to verify the bedrock surface.

8. If a monitoring well is not installed in the soil boring, fill the boring with either cement/bentonite grout or properly-tamped and hydrated bentonite. Do not backfill the boring with drill cuttings.

9. Complete boring log and, if necessary, well installation logs (SOP RE-003, *Boring/Rock Coring Logs*).

10. Record boring locations on a site map and in a field notebook sketch. Measure each location from on-site reference points in the field notebook so that enough information can be obtained to recreate the location.

Precautions

- At all times, follow safety procedures as defined in the site-specific Health and Safety Plan.
- In areas of significant soil contamination, hollow-stem augers may cross-contaminate upper soil layers as contaminated cuttings move up the auger flights. The potential also exists for contaminated augers to carry contamination to deeper soil strata.
- If *in situ* borehole permeability tests are to be performed prior to installation of the monitoring well, the hollow-stem auger method is not appropriate due to water loss at the auger junctions.
- If significant unanticipated contamination is encountered during drilling, stop drilling to confer with the project manager and evaluate health and safety conditions. If the borehole is to be advanced below the contaminated strata, use telescoping techniques (see *Borehole Telescoping Techniques* SOP) to avoid cross-contaminating underlying geologic strata.
- When drilling below the groundwater table in fine to medium sands, the potential exists for the phenomenon of "running sands" or "blow in" to occur. Frequent measurements inside the hollow-stem augers after the drill bit/plug is removed will indicate if running sands are present. If sands start to flow into the auger, pour clean water into the augers and keep the augers filled during sampling.
- If necessary, arrange for the storage of contaminated soil cuttings and water in drums or other appropriate containers in a secure place at the site. Containers should be labeled.
- Plan the drilling program to drill borings from the least- to most-contaminated areas. Be prepared in advance and know where alternative drilling locations are in the event that problems are encountered at each planned soil boring location. Alternative locations will need to have utility clearance.

References

1. *Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers* (October 1990), American Society for Testing and Materials [ASTM] D5092-90.

2. Nielsen, D.M. (1993), "Correct Well Design Improves Monitoring," *Environmental Protection*, July, pp. 38-49.

3. *Standard References for Monitoring Wells* (April 1991), Commonwealth of Massachusetts Department of Environmental Protection, WSC-310-91.

SS-004

Monitoring Well Installation

MONITORING WELL INSTALLATION

Objective

The objective of this SOP is to standardize the installation of shallow overburden monitoring wells for environmental investigations. This SOP addresses the installation of monitoring wells screened across the groundwater table and assumes the monitoring wells will be constructed of flush-joint PVC pipe; the screened section will have factory-slotted openings. Well dimensions (well diameter, screen length, and screen slot-diameters) will be specified in the Work Plan.

Procedure

1. Using a weighted tape, measure and record the depth of the completed soil boring before beginning the well installation.

2. Measure the depth to groundwater in the borehole over a 10 to 15-minute period to ensure that the groundwater elevation has approximately stabilized. Compare the saturated soil depth estimated from split-spoon samples to the measured water level in the borehole. If drilling water has been used during boring advancement, pump the water out of the borehole to the static water depth (based on examination of the soil samples) and monitor the recovery of groundwater until the level has stabilized.

3. Choose the monitoring well screen and riser lengths so that the slotted section of the screen intersects the groundwater table. If the borehole is deeper than the desired well depth, then fill the base of the borehole with bentonite.

4. Install a plug just below the lowest slotted section of the screen.

5. Place at least 12 inches of clean uniformly-graded medium quartz filter sand pack into the base of the borehole. Measure and record the depth of the boring. Temporarily cover the top of the riser pipe and lower the complete well plus riser into the borehole, with the base resting on the sand pack.

6. Add adequate sand to surround the area around the slotted section. The filter sand should extend at least 2 feet above the top of the slotted section.

7. Remove the drilling casing/augers from the borehole slowly, at a maximum of 2-foot intervals. As the drillers pour or use tamping rods to place the filter sand in the borehole, take frequent measurements of the depth-to-sand. Do not let the sand "bridge" in the annular space. Continue to observe the water level in the borehole.

8. Place at least 1 foot of bentonite seal (chips or balls or slurry) above the filter pack. If the seal is above the water table, use at least 5 gallons of potable water to hydrate the bentonite.

9. If necessary, pump bentonite-cement grout into the annular space to the ground surface. Grout should be mixed in approximately the following proportions: 7.5 gallons water to one 94-lb. bag

of cement to 2-4 lbs of pulverized bentonite. The grout must be mixed using the pump on the rig to ensure proper mixing. The protective casing should be set in the grout before it sets.

10. The protective surface casing will be either a flush-mounted roadbox or a steel guardpipe. The base of either type of casing must extend at least 1 foot into the grout below the ground surface (below the frost line) whenever possible.

11. Cut the monitoring well riser flat and place a mark or "V"-notch or an arrow on the casing with an indelible marker at one point for surveying and groundwater measurements. Cut the well riser so that the top of the well is 3 to 6 inches below the top of the protective casing.

12. Set bentonite-cement grout in the annular space between the protective casing and the borehole up to the ground surface. Slope the concrete radially away from the protective casing at the ground surface to promote surface water runoff. In areas of high traffic or areas of parking lots and/or roadways where plowing occurs, set the roadbox FLUSH with the ground surface to avoid damage to the well.

13. If the well is installed in a high-traffic area with a guardpipe, additional protection such as steel pole bumpers around the guardpipe may be necessary.

14. Place a locking cap on the well pipe. Either drill a hole in the well cap or cut a slit in the top of the well pipe to prevent pressure from building up in the well.

15. Label the protective well casing with a paint pen and tape out the location to nearby landmarks so that the well may be located in the future (enter this information in the field notebook). If possible, place a brightly colored stake or other identifier adjacent to the well.

16. Develop the well (see SOP SS-005, *Monitoring Well Development*).

Precautions

- At all times, follow safety procedures as defined in the site-specific Health and Safety Plan.

- Site-specific conditions must be evaluated to determine appropriate materials/slot sizes and screen lengths.

- The water table will fluctuate seasonally and from year-to-year. Try and estimate the maximum high and low elevations of the water table from the current water table elevation and the season. Place the 10-foot screen so that at least 2 feet of the screen will extend above the top of the screen when water is at its highest. If very substantial fluctuations in the groundwater table are expected, a 15-foot screen is acceptable.

- Do not screen across different hydrostratigraphic units if possible (for example, outwash sands and till) unless specified in the Work Plan or approved by the Project Manager.

- If the formation is composed of a material that is uniformly coarser than the filter sand, than the grain size of the filter sand must be increased. Consideration should also be given to changing the slot size on the well screen. Differences in average grain size should generally not be greater than a factor of two to four times.

- Do not use borehole/auger cuttings for backfill during monitoring well installation. If the cuttings are suspected to contain contamination which was identified during drilling, do not use cuttings for filter pack materials.

- Do not screen across a confining (e.g., silt or clay) layer. Backfill all confining layers with hydrated bentonite or grout.

References

1. *Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers* (October 1990), American Society for Testing and Materials [ASTM] D5092-90.

2. Nielsen, D.M. (1993), "Correct Well Design Improves Monitoring," *Environmental Protection,* July, pp. 38-49.

3. *Standard References for Monitoring Wells* (April 1991), Commonwealth of Massachusetts Department of Environmental Protection, WSC-310-91.

SS-005

Monitoring Well Development

MONITORING WELL DEVELOPMENT

Objective

The objective of this SOP is to standardize the development of monitoring wells for environmental investigations. The purposes of developing a monitoring well are to remove fluids introduced during drilling and to maximize the movement of water into the well by reducing the fines which may be trapped in the sand pack around the screen, in order to reduce siltation during sampling.

Procedure

1. Decontaminate all development equipment prior to use (see SOP SA-007, *Equipment Decontamination*).

2. Calculate or estimate the amount of water introduced to the borehole during drilling. At a minimum, this is the amount of water that must be removed during development. In addition, compute the volume of water in the monitoring well.

3. Place a 12-volt submersible pump (or grundfos pump) attached to a power source into the borehole or use a manual sampling device such as a bailer or waterra pump. Collect a sample of the standing water in the borehole and record the physical properties (color, turbidity, etc.). Then, at a minimum, remove the greater of the following two amounts of groundwater:

   a) ten well volumes; or
   b) the amount of water introduced during drilling.

4. Pump the ground water into a 5-gallon pail so that the volumetric flow rate and water volume from the pump or bailer can be calculated.

5. Monitor the groundwater level in the well as the water is being pumped to determine if the pumping rate is sufficient to create a drawdown in the well. The "over-pumping" development method requires that the well be developed/stressed at a faster rate than the well would normally be pumped or bailed for sample collection.

6. Collect groundwater samples every few well volumes during the pumping and record the physical properties (color, turbidity, etc.) (see respective SOPs).

7. Once half the desired volume of water has been pumped, request that the drillers attach surge blocks on a rod into the well. This surge block apparatus may be operated by hand or may be attached to the drill stem on the drill rig. It is operated by the driller. Slowly move the surge block up and down in the upper portion of the well. Start at a slow pace and progress to a faster surging action further down the well screen.

8. During surging, remove the surge block periodically to pump more water from the well to remove accumulated fines.

9. Monitor the turbidity and color of the water during this procedure. The well is considered fully developed when ~~all of~~ the following criteria have been met:

   a) the volume of water introduced during drilling has been removed; and
   b) the water removed from the well is <u>relatively</u> free of fine-grained materials.

10. Record the final amount of water removed and the physical properties (color, turbidity) of the well water.

Precautions

- At all times, follow safety procedures as defined in the site-specific Health and Safety Plan.
- Always remove groundwater with fines from the well <u>before</u> surging, as these fines may be forced into the well screen otherwise by the surging action.
- If the groundwater in the monitoring well is contaminated, the water removed during well development will need to placed in a properly labeled drum (see SOP RE-006, *Investigation-Derived Waste Management*).
- If the soils around the well screen are composed of fine-grained silts and clays, over-pumping and mechanical surging is not recommended since these more vigorous techniques can cause mixing of the fines into the filter pack. To develop these wells, use of a bailer is recommended.

References

1. *Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers* (October 1990), American Society for Testing and Materials [ASTM] D5092-90.

2. Nielsen, D.M. (1993), "Correct Well Design Improves Monitoring," *Environmental Protection,* July, pp. 38-49.

3. "The Methods & Mechanics of Well Development, Part 2 of 5," *National Drillers Buyers Guide,* March 1993, p. 17.

4. *Standard References for Monitoring Wells* (April 1991), Commonwealth of Massachusetts Department of Environmental Protection, WSC-310-91.

SS-006

Test Pit Excavation

TEST PIT EXCAVATION

Objective

The test pit is used to characterize geologic strata and collect representative soil samples from these strata.

Procedure

1. Have contractors steam clean equipment before beginning field activities.

2. Contact the owner to determine the location of underground utilities. Verify with the contractor that local/regional utility clearance service has been contacted. Ask the subcontractor to provide you with the local/regional utility clearance service authorization number and record it in the field notebook. Mark out/stake out the approximate excavation extent. Clearance may require marking of subsurface explorations prior to contacting utility clearance service.

3. Excavate the designated area using a backhoe to the dimensions indicated in the Work Plan. Place excavated material that has suspected and/or visible contamination on a plastic liner away from the excavation.

4. During excavation, monitor ambient air for VOCs or other contaminants of concern. Record readings in field notebook (see SOP RE-001, *Field Notebook*).

5. Describe sidewall strata, test pit dimensions, and soil classifications on test pit log (see SOP RE-004, *Soil Classification*). Record the presence and size of existing obstructions and any existing foundations. Take photographs of excavation sidewalls.

6. Label sample bottles (see SOP SA-005, *Sample Handling*).

7. Collect soil samples from the test pit sidewalls and bottom at designated depths, at strata changes, or based upon field screening using equipment (backhoe bucket, stainless-steel remote sampler, etc.) designated in the field plan. Do not enter a test pit unless side slopes satisfy OSHA regulations and other health and safety concerns have been addressed.

8. Transfer sample to the appropriate glassware with a decontaminated stainless-steel trowel or spatula (see SOP SA-007, *Equipment Decontamination*).

9. Store samples on ice in a cooler (see SOP SA-005, *Sample Handling,* and SOP RE-007, *Chain-of-Custody*).

10. Screen soil samples for VOCs or other contaminants of concern. Record results in field notebook.

11. Backfill excavation as soon as possible with material designated in the Work Plan. Segregate contaminated soil as necessary (see SOP RE-006, *Investigation-Derived Waste Management*). Properly identify segregated material and secure as designated in the Work Plan.

12. Measure the dimensions of the excavation. Record in the field notebook.

13. Sketch the dimension and location of the test pit relative to a site reference point. Record in the field notebook. Note the sample locations by number on a cross-section sketch and plan view sketch.

Precautions

- At all times, follow safety procedures as defined in the site-specific Health and Safety Plan.

- NEVER CLIMB INTO THE EXCAVATION TO COLLECT A SOIL SAMPLE unless the excavation is shored or the sidewalls are sloped in accordance with OSHA regulations and all proper personal protective safety precautions have been considered and implemented.

- Terminate excavation if flow of groundwater into the excavation adversely affects the stability of the excavation (i.e., slumping). Note the depth to groundwater in the field notebook .

- Terminate the excavation if drums, tanks, or other potential sources of contamination are observed. Record visible drum markings, labels, and any other pertinent information on the test pit log and in the field notebook. Photograph drums and materials.

- Do not leave an open excavation unattended without isolating it from passersby and vehicular traffic.

References

1. *Earth Manual* (1968), United States Department of the Interior, Bureau of Reclamation, United States Government Printing Office, Washington, D.C., pp. 134-139.

2. *OSHA Standards for Excavations*, Department of Labor, Federal Register, 29 CFR Part 1926, 1989.

TE-001

VOC Field Screening

VOC FIELD SCREENING

Objective

The objective of field screening of soils is to obtain a site-specific measure of the relative concentrations of VOCs present in soil at a site. This information can be used: 1) to segregate soil based on degree of contamination, 2) to identify samples for quantitative analysis of VOCs, or 3) as a qualitative method to evaluate the presence or absence of VOCs in soil. A photoionization (PID) or flame ionization detector (FID) may be used.

Procedure

1. Prior to a sampling event, the instrument must be calibrated to the appropriate standard and have an appropriate detector for the contaminants expected to be encountered at the site. The type of standard and detector used should be recorded in the field notebook.

2. Record background readings of atmospheric conditions in the work area while walking across the work area. The highest meter response should be recorded.

3. Half-fill a clean, glass jar with the sample to be analyzed using a clean trowel or soil spatula. Quickly cover the open top with one or two sheets of clean aluminum foil and screw on the cap to tightly seal the jar. Each jar should be labeled to indicate the location and depth from which the sample was collected.

4. Allow headspace development for at least 10 minuted. Vigorously shake the jar for 15 seconds, both at the beginning and end of the headspace development period. When ambient temperatures are below 50°F, headspace development should occur, if possible, within a heated van or building.

5. After headspace development, remove the screw cap and expose the foil seal. Quickly puncture the foil seal with the instrument's sampling probe to a point about one-half of the headspace depth.

6. Following probe insertion through the foil seal, record the highest meter response as the jar headspace concentration. Maximum response should occur between 2 and 5 seconds after probe insertion.

Precautions

- At all times, follow safety procedures as defined in the site-specific Health and Safety Plan.

- The various instruments may work poorly in the rain and below freezing temperatures. Under such conditions, it should be operated from within a heated vehicle or building.

- Care must be taken to prevent water or soil particles from entering the tip of the instrument probe. If this occurs, the tip should be removed and cleaned/dried before further use.

- While establishing background conditions and performing jar headspace screening, care should be taken to avoid extraneous VOC sources such as vehicle emissions which are not site related.
- Erratic meter response may occur at high organic vapor concentrations or conditions of elevated headspace moisture.
- Caution must be exercised when interpreting VOC headspace screening data. Results are dependent on site conditions. Screening results may differ by orders of magnitude from analytical testing results.
- Note that states may have specific procedures for field monitoring.

References

1. *Management Procedures for Excavated Soils Contaminated with Virgin Petroleum Oils* (August 1990), Massachusetts Department of Environmental Protection, Policy #WSC-400-89.

TE-002

Environmental Surveying

ENVIRONMENTAL SURVEYING

Objective

Field surveying tasks performed by GEI personnel during environmental investigations generally consist of determining approximate locations and accurate elevations of borings and monitoring wells. This information is used for topographical surveys, groundwater contour drawings, site location drawings, and analyses.

Procedure

1. The following equipment is needed for basic surveying.

   a) engineer's level or transit (the instrument)
   b) surveyor's rod and rod level
   c) 150-foot or 300-foot tape
   d) field notebook

2. All points to be surveyed should be examined in order to determine access and the most effective point(s) to set up the level or transit and establish turning points.

3. A benchmark (point of known elevation or a reference elevation) should be determined. The benchmark selected should be a permanent object with a small likelihood of being disturbed. Examples are a substantial metal or concrete post founded firmly in the ground, a spike driven into a telephone pole, a defined corner of the masonry of a bridge or building, or a water hydrant. A geodetic survey monument (brass disc) is generally preferable for use as an initial benchmark if one is available nearby.

4. The instrument should be set up in a location where the benchmark is visible to the instrument operator.

5. The tripod supporting the instrument must be set in a stable position and the level or transit leveled.

6. Use the leveling screws to adjust the instrument until it is level on all axes. If the instrument cannot be leveled properly, repeat the operation from the beginning. If a transit is being used, also level the telescope. To confirm successful leveling, rotate the level or transit 90° and recheck the level bubble. Repeat this until the level or transit has been rotated 360°.

7. The instrument operator should set up the notebook with the headings shown in Figure 1 and enter information as indicated by the *Field Notebook* SOP. Include the elevation and a careful description of the benchmark for the survey in the field notebook. In addition, a detailed sketch should be prepared showing all survey points in relation to general site features.

8. The rod is held on the initial benchmark, taking care to keep the rod plum, and the levelman finds the backsight reading. This reading is recorded in the backsight column (BS). The backsight reading is added to the elevation of the benchmark to determine the height of the instrument (HI).

9. The instrument is now aimed at the rod which is held on the first turning point and determines the foresight reading. This is recorded in the foresight column (FS). This reading subtracted from the HI gives the elevation of the turning point (TP).

10. The instrument can now move forward and set up at a new location to permit the determination of the elevation of additional points. The instrument must be re-leveled as described in Steps 5 and 6. The rod remains at the turning point until the instrument is ready, at which time the rod is held plum to be read using the relocated instrument. This BS reading is recorded in the BS column. It is added to the elevation of the turning point to determine the new HI.

11. The rod can now be moved to establish another turning point. A new FS is determined, and the process is repeated until the elevations of all required points are determined.

12. When the elevations of all desired points have been determined, a check should be performed by resurveying the original benchmark or surveying another point of known elevation (closing the level loop). The degree of error should not be greater than 0.05 foot for typical environmental work at GEI.

13. When measuring the elevations of monitoring wells, the elevation of the ground surface, the protective casing, and the highest point of the PVC riser should all be measured. A permanent mark should be made on the PVC riser at the measurement point to serve as a reference for conducting water level measurements.

14. To locate monitoring wells or borings on a plan, the distance between the point and a minimum of two established points shown on the plan should be measured and recorded using a 150-foot or 300-foot tape measure. This will allow for locating the desired point by "swinging arcs." To the extent practicable the two established points should be perpendicular to one another as measured from the point to be located. Alternatively, stadia distances may be measured using the instrument and rod. The distance from the center of the instrument to the rod is found by sighting through the instrument onto the rod and multiplying the stadia interval or reading (the interval between the apparent locations of the bottom and top stadia hairs of the instrument on the rod) by 100.

Sta	BS	HI	FS	Elevation	
Benchmark	9.42	922.64		913.22	Spike in telephone pole #10
B405 (T.P.)	6.34	927.51	1.47	921.17	Boring $405
B406 (T.P.)	10.15	934.75	2.91	924.60	Boring #406
Benchmark			21.53	913.22	Spike in telephone pole #10
					913.22 -913.22 0.00 check

Precautions

- At all times, follow safety procedures as defined in the site-specific Health & Safety Plan.
- The instrument must be level when measurements are made.
- The rod must be kept plum. Under windy conditions, this can be facilitated through the use of a rod level.
- The backsight and foresight distances should be equalized insofar as field conditions permit. Sight distances should be limited to 300 feet.
- Computations should be checked in the field for accuracy.
- Care must be taken that the proper crosshair is read at all times. The center horizontal crosshair is read to determine elevation differences, while the outer crosshairs are read to determine stadia distance.
- When taping off locations, the tape must be held taut and level.
- If surveying conditions are difficult or a large number of turning points are required, it may be prudent to subcontract surveying work to a licensed land surveyor.
- The instrument should be handled carefully at all times and should be professionally cleaned and calibrated once a year.

References

1. Rayner, William Horace and Milton O. Schmidt, *Fundamentals of Surveying* (1963).
2. Davis, Raymond E., et al., *Surveying Theory and Practice* (1981), New York: McGraw-Hill Company.

TE-004

pH/Temperature

pH/TEMPERATURE

Objective

The objective of this Standard Operating Procedure is to provide standard methods for determining the pH and temperature of liquids using a combination pH/temperature meter.

Procedure

1. Calibrate the meter according to the equipment manufacturer's instructions at the beginning of each day of use. Calibration for pH shall be performed using at least two buffer solutions from various ranges. Solutions chosen should be similar in pH to the expected level of the samples or liquids tested (pH 7 and 4 buffer solution preferred in most cases for ground or surface water measurements).

2. Calibration is checked every two hours or every five monitoring locations (whichever occurs first) and at the end of the day be measuring the two calibration solutions used. The reading and times are recorded. If the readings are outside ±0.2 pH units, the meter must be recalibrated.

3. Immediately prior to testing a sample decontaminate testing beaker or container and probe assembly with one rinse with sample solution. Do not use methanol to rinse the probe. Methanol rinses could damage the probe.

4. Gently shake the probe and beaker to remove excess solution. Visually inspect the bottom of the probe to ensure that liquid or sediment is not trapped between outer casing and probe.

5. Pour sample into testing container and insert both temperature and pH probe. Stir sample for 30 seconds using both probes. Let the probes equilibrate in the sample solution for another 30 seconds. Measure and record the temperature. Measure and record pH reading after the reading has stabilized or after 60 seconds, whichever is sooner. A reading has stabilized if pH units have not changed ±0.1 pH units during a five second period.

6. Record pH to the nearest 0.1 unit and temperature to the nearest whole number.

Precautions

- At all times, follow safety procedures as defined in the site-specific Health and Safety Plan.

- Only coatings and particulates may affect the response of the probe; more thorough cleaning with alconox and distilled water and gently wiping the probe surface may be required to clean the surface of the probe.

- Temperature affects both the response of the instrument to pH and the actual pH of the sample. The automatic temperature compensation (ATC) function compensates for the variation in the response of the meter only. Therefore, the pH must always be reported with temperature.

- The probe is a fragile thin glass bulb surrounded on three sides by a plastic casing. Care must be taken in handling the probe to avoid breakage.

- Buffer solutions should not be used past their expiration date.

References

1. *Standard Methods for the Examination of Water and Wastewater*, 18th Edition, Method 4500-H. American Public Health Association (1992).

TE-005

Specific Conductance

SPECIFIC CONDUCTANCE

Objective

The objective of this Standard Operating Procedure is to provide standard methods for determining the conductivity of waters using a field conductivity meter.

Procedures

1. Calibrate the meter according to equipment manufacturer's instructions at the beginning of each day of use. Calibration shall be performed using a standard KCL solution of 0.20 mS/cm (200 uS/cm, S=mho).

2. Record the make, model, and GEI identification number of the instrument in the field notebook.

3. Calibration is checked at the beginning of the day immediately prior to sampling, after five sampling locations or two hours (whichever occurs first), and at the end of the day. If the readings are outside +/- 0.02 mS/cm, the meter must be recalibrated. Initial calibration should be conducted under the same conditions (i.e., temperature, location) as field testing.

4. Immediately prior to testing a sample, decontaminate testing beaker or container and probe assembly with one methanol rinse, two distilled water rinses, and one sample solution rinse.

5. Gently shake the probe and beaker to remove excess solution.

6. Pour sample into the testing container and insert probe. Stir sample with the probe for approximately 10 seconds. Let the probe equilibrate in the sample solution for another 5 seconds. Measure conductivity and record in field notebook.

7. Record conductivity to the nearest whole number.

Precautions

- At all times, follow safety procedures as defined in the site-specific Health and Safety Plan.

- Oily coatings and particulates may affect the probe's response; more thorough cleaning using a weak alconox solution and double distilled water rinse and gently wiping the probe surface may be required to clean the surface of the probe.

- In contaminated example (stained, conductance >750 μmhos/cm), rinse probe with clean water immediately after measuring sample to minimize fouling of probe.

- Calibration solutions should not be used past their expiration date and must be discarded after three months of use.

- Temperature is internally compensated to 25 °C in the range of 0 °C to 50 °C. This may be meter specific.

References

1. *Standard Methods for the Examination of Water and Wastewater*, 18th Edition, Method 2510. American Public Health Association (1992).

STANDARD OPERATING PROCEDURE FOR RISING HEAD SLUG TESTS

1. INTRODUCTION

Rising and falling head slug tests can be performed on selected monitoring wells to evaluate the hydraulic conductivity of the aquifer. In general, the approximate horizontal hydraulic conductivity of a given aquifer zone may be determined by adding or removing a known volume (slug) to or from the well, and observing and recording the subsequent rate of water level fall or rise within the well. The resulting data can be used to determine the hydraulic conductivity of the aquifer test zone via a number of analytical solution methods.

Both types of variable-head slug tests, the falling head test (slug injection) and rising head test (slug withdrawal), can be conducted. The falling head test is typically not applicable to "water table" wells (i.e., where the static water table is below the top of the screen), since the escape of water from the well to the unsaturated well pack after adding the slug to the well leads to an overestimation of the hydraulic conductivity (Bouwer, 1989). Therefore, only rising head tests should be conducted at "water table" wells. This procedure describes the methods to be employed when conducting a rising head test.

The testing apparatus and measurement techniques for the rising head test are described below.

A slug bar of known volume will be used to alter the water levels in the wells.

Due to the relatively rapid recovery of water levels in permeable soils subsequent to the insertion or removal of the slug bar, a computerized pressure transducer that is capable of recording pressure changes (which represent water levels) over small time increments will be used. This will allow for frequent and accurate measurements during the critical early part of the test. Further, the pressure transducer is capable of taking measurements on a logarithmic scale, which is amenable to post-test data processing.

2. PROCEDURE

Rising head tests are conducted as follows.

- The static water level (i.e., depth to water) in the well to be tested will be measured and recorded using an electronic water level indicator. All measurements taken during the test will be recorded in the field log book.

- The pressure transducer will be installed in the well a minimum of 5 feet below the deepest point of insertion of the slug bar. Where the well is not deep enough to allow this, the transducer will be installed as far below the deepest point of insertion of the slug bar as possible. The transducer will be allowed to thermally equilibrate for 15 to 30 minutes (to allow instrumentation wiring to expand/ contract) before measurements are taken.

- The slug bar will be fully submerged into the water column of the well.
- The water level in the well will be allowed to return to static condition after both the slug and transducer have been inserted. The transducer will be calibrated to read 100.00 feet at static conditions.
- When the water level in the well has returned to static condition, the transducer will be started using logarithmically-spaced data recording intervals, and the slug bar will be rapidly removed from the water column and well.
- The transducer will continue to record water levels until the water level has recovered to within 15 percent of the original static water level relative to the initial test displacement (85 percent recovery), or until an elapsed time of one hour.
- Data stored in the transducer will be transferred to and stored on a portable computer for analysis.

The Hvorslev (1951) or Bouwer and Rice (1989) methods of slug test analysis will be used to analyze the test data and, as appropriate, to estimate hydraulic conductivities. The data will be presented graphically, and the results and pertinent variables used as part of the analytical solutions will be summarized on the test results.

3. REFERENCES

Hvorslev, M.J., "Time Lag and Soil Permeability In Ground-water Observations," *U.S. Army Corps of Engrs. Waterways Experiment Station Bulletin No. 36,* 1951.

Bouwer, H., "The Bouwer and Rice Slug Test – An Update," *Ground Water,* vol. 27(3), 304, 1989.