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MEMORANDUM

Disclaimer – Please note, Conestoga-Rovers & Associates (CRA) changed its name to GHD Limited on July 1, 2015. This document was originally submitted under the CRA name prior to this date. However, in the interest of continuity, the CRA name will remain on this document after July 1, 2015.

TO:	Peter Ramanauskas (U.S. EPA)	REF. NO.:	013968
FROM:	FOR P.G. Bill Steinmann (CRA)/aj/755	DATE:	March 30, 2016
C.C.:	Gerald O'Callaghan (IDEM), Cheryl Hiatt (GM), Ed Peterson (GM), Stephen Song (Ramboll-ENVIRON), Francis Ramacciotti (Ramboll-ENVIRON), Jim McGuigan (GHD), Katie Kamm (GHD), Paul Gallaway (GHD)		
RE:	**Unsampled Areas Soil Sampling Work Plan – Revision 3 GM CET Bedford Facility Bedford, Indiana**		

This memorandum presents proposed surface soil sampling throughout areas of the GM CET Bedford Facility (Facility) that were determined to not be in an Area of Interest (AOI) (Current Conditions Report, CRA, 2001) and therefore have received limited to no sampling completed under the RCRA Facility Investigation (RFI). This sampling is being completed to identify whether there are remaining Facility areas that may require specific work restrictions or health and safety protocols to be employed by maintenance or construction workers in the event of future work activities or that may need additional corrective measures.

The proposed soil sampling will be conducted utilizing Incremental Sampling Methodology (ISM). These methods and proposed sampling locations are presented below.

Methodology

ISM is a specialized type of composite sampling with specific structure and requirements that stand apart from common compositing practices. ISM is designed to provide more precise and less biased estimates of the mean concentration of analytes in soil by addressing specific sampling errors. Consequently, ISM can result in better performance in terms of decision error reduction than other sampling methodologies. A defined Decision Unit (DU) is first subdivided or gridded-off into cells or subareas based on the desired number of increments (an increment is the sample spacing) to be obtained. That is, the number of cells is equivalent to the number of increments within a DU. An increment represents a fixed position from which a portion of the sample is collected. The number of increments is determined based on expected variability of the chemical of concern and media. Because of the widely varying shapes and sizes of these areas, the number of increments will vary somewhat, depending on size and shape of the DU. Using a systematic-random design, a random position is established for a given cell, and then the same position is repeated in all of the remaining cells in the DU. These are presented on the attached figures for each DU.

Placement of markers (e.g., pin flags and posts) at the corners and/or edges of each DU will be surveyed to assist with a visual delineation of the subareas (or cells) where increments are to be collected. Individual cells will then be measured and marked prior to sampling. A trial run with no sample collection may be performed within the DU to quickly establish the distance between increment collection points to ensure the desired number of increments is achieved.

ISM Sampling Plan

Three replicate samples will be collected per DU. At each increment location within a single DU, approximately the upper 4 inches of surface soil will be collected. Each increment will be treated as a separate sample and will be collected and placed into a sample container (that is, all increments will be combined into one ISM sample for the initial sampling, one for the duplicate, and one for the triplicate for a total of three replicate samples per DU).

The ISM samples will be stored on ice and shipped overnight to the laboratory for analysis of polychlorinated biphenyls (PCBs). Once at the analytical laboratory, the samples will be prepared by the laboratory by thoroughly combining all of the increments of each ISM replicate sample, as per guidelines described in the Interstate Technology Regulatory Council[1] (ITRC) document. The laboratory and field SOPs are attached to this Work Plan in Attachments 1 and 2, respectively.

- A defined DU will first be subdivided or gridded-off into uniform cells or subareas based on the number of increments or cells intended for that DU.
- If additional DUs are defined during the sampling phase in the field, random sampling within the grid design may be used in the field. A random position will be designated and sampled in each cell. A random starting point or random position for each cell will be obtained with dice. The process will be repeated for replicate samples: i.e., a new random position will be established for the single collection point to be repeated in all of the cells, or for each cell, depending on the sampling design.

For each DU, a Global Positioning System (GPS) device will be used to delineate the DU. Depending on the size of the DU and terrain features, placement of markers (e.g., pin flags and posts) at the corners and/or edges will be used with a visual delineation of the cells or subareas where increments are to be collected. A square-shaped DU with 30 increments could be divided into five rows, with six increments collected from each row in a systematic random fashion, with an initial random starting point. For more rectangular-shaped DUs, fewer rows will be used with more increments per row collected. Row lengths and increments per row may be modified as needed for odd-shaped DUs. A trial run with no sample collection will be performed to quickly establish the distance between increment collection points to achieve the desired number of increments, while using the flags as guides that were positioned within or around the DU. Field modifications may be required depending upon a number of factors (e.g., safety,

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1 ITRC (Interstate Technology & Regulatory Council). 2012. Incremental Sampling Methodology. ISM-1. Washington, D.C.: Interstate Technology & Regulatory Council, Incremental Sampling Methodology Team. www.itrcweb.org.

heterogeneity, structures blocking locations, etc.). A final drawing showing actual increment locations within each DU will be prepared for each DU, following completion of the sampling.

A two-person team will be used; one person collecting the increments and the other holding the sample container and labeling the container (e.g., clean polyethylene bag) and keeping track of the number of increments. Flags may be used to mark DU boundaries and to aid in visualizing the travel paths and/or to mark the actual increment locations. The ISM sampler will start in one corner or end of the DU and collect an increment at the predetermined positions. For the systematic random sampling design, the location of the first increment will be determined randomly, and subsequent increments will be collected in the same relative location within each grid, resulting in a serpentine collection pattern ending at the opposite corner or end of the DU from where sampling was started (see Attachment 2 for further detail).

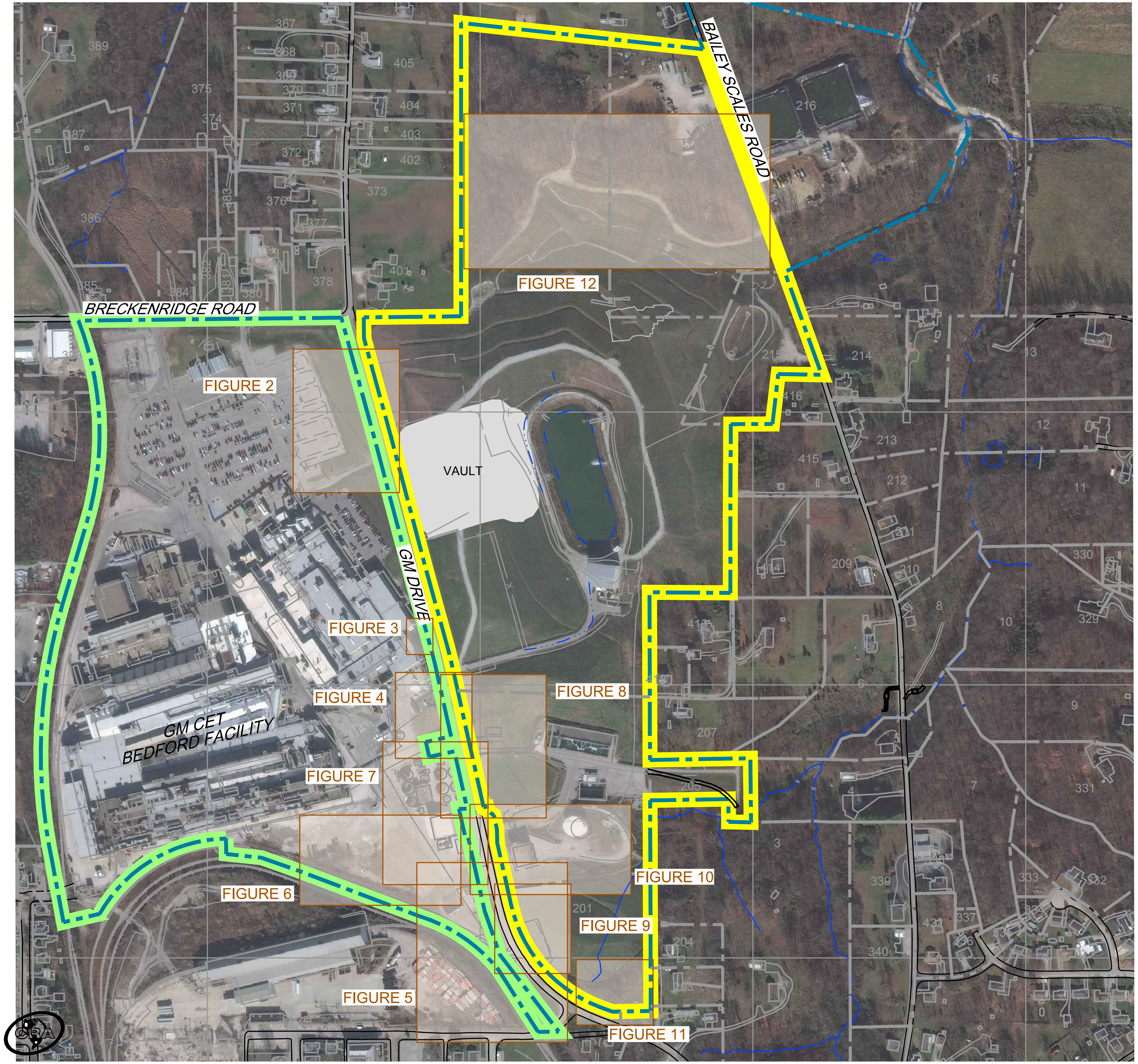
Proposed Sampling Locations

- Figure 1 presents an overall view of the Facility and the locations of each unsampled area where surface soil samples will be collected and provides a key-map for the detailed sampling plans. Each DU has been identified through West Plant and East Plant areas.
- Figures 2 through 6 present unsampled areas within the West Plant Area where ISM will be utilized. Each of these DUs will result in the collection of three replicate samples of the individual increments per DU.
    - Figure 2 presents WP01, WP02, and WP03. This area of the West Plant has been sampled sporadically in the past. This area has been separated into 3 DUs due to the size. The spacing of the increments was determined to be representative of each DU.
    - Figure 3 presents WP04, located to the west of GM Drive, north of the WWTP. Some of this area may be covered with rip-rap and/or asphalt. Surface samples will be collected from non-covered areas.
    - Figure 4 presents DU WP05. This DU was chosen due to analytical data that was reported in the lawn area north of this DU next to the administration building. The area and spacing of the increments was chosen to be representative of this relatively smaller area.
    - Figure 5 presents DUs WP06 and WP07. This is a grassy area located along the property boundary where the CRA trailers are located and where future Plant activities could occur. Because of the shape of this DU and mixed surfaces (grassy and gravel areas), the spacing and number of increments were chosen to fit the area.
    - Figure 6 presents DUs WP08 and WP09 and is located within and to the east of AOI 1. A number of samples have been collected within AOI 1. These DUs are designed to further collect samples within the grassy lawn area. Because the area was fairly large, it was divided into two DUs in order to obtain two separate samples. The grid density was kept the same for each DU.
- Figure 7 presents the unsampled area within the Facility's process water wastewater treatment plant in the West Plant Area.
    - Figure 7 presents WP10, which is located within the WWTP. Due to the density of activities that occur in this DU and the multitude of structures, the sample locations were located in areas that could be accessed by Plant personnel working around the wastewater processes.
- Figures 8 and 9 present the unsampled road ditch area along the east side of GM Drive within the southern portion of the East Plant Area where mowing or weed cutting might occur.

    - Figure 8 presents DU EP01. This is an elongated DU that is located just outside of the current East Plant cap in a drainage ditch west of the cap. It would be affected by personnel cutting weeds. Due to the shape and the small narrow area, twelve sets of samples (investigative, duplicate, and triplicate) were selected to represent any potential PCB concentrations.
    - Figure 9 presents DU EP02. This area is also elongated in a drainage ditch along the east side of GM Drive. This DU is also located to the west of the Parcel 201 engineered cap in a grassy area with limited sampling. The size of the DU was dictated by the road to the west and the cap to the east on GM property.
- Figures 10 and 11 present ISM grids within the unsampled areas of AOI 8 located within the southern portion of the East Plant Area. The ISM grids located to the north (Figure 10) of the million-gallon above ground storage tank (AST) and the area south of the AST (Figure 11) will consist of 60 increments for each of the replicate samples. The area south and west of the Sludge Building (Figure 11) will consist of 64 individual increments for each replicate sample due to the shape of the DU.
    - Figure 10 shows DUs EP03, EP04, EP05, EP06, EP12, EP13, EP14, and EP15 in the area of the Plant's process water treatment and sludge building. There is a riprap apron around the west and south side of the building. The areas to the north and east of the sludge building are gravel covered. These are areas of the plant where some limited soil sampling had been previously conducted. The shapes and density of the increments were chosen to be representative of each DU. This is an area where there are more Plant personnel than other more remote areas. It does include a contained area for the large million gallon storage tank.
    - Figure 11 presents DUs EP07 and EP08. This area is located south of the current engineered cap at Parcel 201. Because this is a larger area that has not been sampled and is an area where Plant personnel would maintain the grass, two DUs were chosen as representative. This area also includes a portion of the Plant property that has been encroached by the residence to the south. The density of the increments is consistent with other DUs; however, some increment locations may not be accessible due to property use (e.g., buildings).
- Figure 12 presents DUs EP09, EP10, and EP11, which are located to the north of the engineered cap in the East Plant Area. These are located in an area that has been sporadically sampled in the past where Facility personnel have access. Because of the size of this area, three DUs are proposed with a similar density of increments in each to represent potential PCB concentration. This area is predominately treed.

Data Analysis

For each DU where ISM will be utilized, the mean result of the replicate samples will be compared to risk-based PCB screening criterion utilized for the remainder of the Facility. The IDEM screening limit for PCBs at this time is 10 mg/kg PCBs, based on changes to the U.S. EPA's criterion, and would be the screening criterion used for this sampling. Any corrective measures that might be in addition to the Interim Measures already performed would be evaluated and proposed in the Corrective Measures Proposal.



0 200 400ft

LEGEND

- EXISTING BUILDINGS
- FENCE LINE
- RAILROAD TRACKS
- DIRT ROADS
- ROADS / PAVED AREAS
- APPROXIMATE SURFACE WATER LOCATION
- APPROXIMATE PARCEL BOUNDARY
- APPROXIMATE GM PROPERTY BOUNDARY
- EAST PLANT AREA
- WEST PLANT AREA

NOTES:

1. GM PROPERTY BOUNDARY SURVEY BY BLEDSOE RIGGERT GUERRETTAZ RECEIVED OCTOBER 2007. ADJACENT PROPERTY BOUNDARY LOCATIONS APPROXIMATED FROM THE LAWRENCE COUNTY SURVEY PLATS. ADJOINING PROPERTY LINES MAY NOT ACCURATELY REPRESENT THE TRUE PROPERTY BOUNDARIES

2. ALL LOCATIONS WILL BE COLLECTED TO THE EXTENT THAT THERE ARE NO INTERFERING STRUCTURES OR SURFACES ETC.

SOURCES: BASE MAP COMPLETED BY AIR-LAND SURVEYS, FLINT, MI. APRIL 2001 AND CRA SURVEYS 2002 TO 2009. NOVEMBER 20, 2013 IMAGE © 2015 - TerraServer®

figure 1

KEY PLAN
UNSAMPLED AREAS WORK PLAN
GM CET BEDFORD FACILITY
Bedford, Indiana

13968-00(MEMO755)GN-WA015 MAR 30/2015

SOURCES: BASE MAP COMPLETED BY AIR-LAND SURVEYS, FLINT, MI. APRIL 2001 AND CRA SURVEYS 2002 TO 2009. NOVEMBER 20, 2013 IMAGE © 2015 - TerraServer®

LEGEND

PLANT BOUNDARY

MW-X143Y245S MONITORING WELL LOCATION

INITIAL SAMPLE LOCATION

DUPLICATE SAMPLE LOCATION

TRIPLICATE SAMPLE LOCATION

NOTE: ALL LOCATIONS WILL BE COLLECTED TO THE EXTENT THAT THERE ARE NO INTERFERING STRUCTURES OR SURFACES ETC.

figure 2

WEST PLANT - UNSAMPLED AREA 1 OF 6
UNSAMPLED AREAS WORK PLAN
GM CET BEDFORD FACILITY
Bedford, Indiana

13968-00(MEMO755)GN-WA016 MAR 30/2015

SOURCES: BASE MAP COMPLETED BY AIR-LAND SURVEYS, FLINT, MI. APRIL 2001 AND CRA SURVEYS 2002 TO 2009. NOVEMBER 20, 2013 IMAGE © 2015 - TerraServer®

LEGEND
- PLANT BOUNDARY
- INITIAL SAMPLE LOCATION
- DUPLICATE SAMPLE LOCATION
- TRIPLICATE SAMPLE LOCATION

NOTE: ALL LOCATIONS WILL BE COLLECTED TO THE EXTENT THAT THERE ARE NO INTERFERING STRUCTURES OR SURFACES ETC.

figure 3

WEST PLANT - UNSAMPLED AREA 2 OF 6
UNSAMPLED AREAS WORK PLAN
GM CET BEDFORD FACILITY
Bedford, Indiana

CRA

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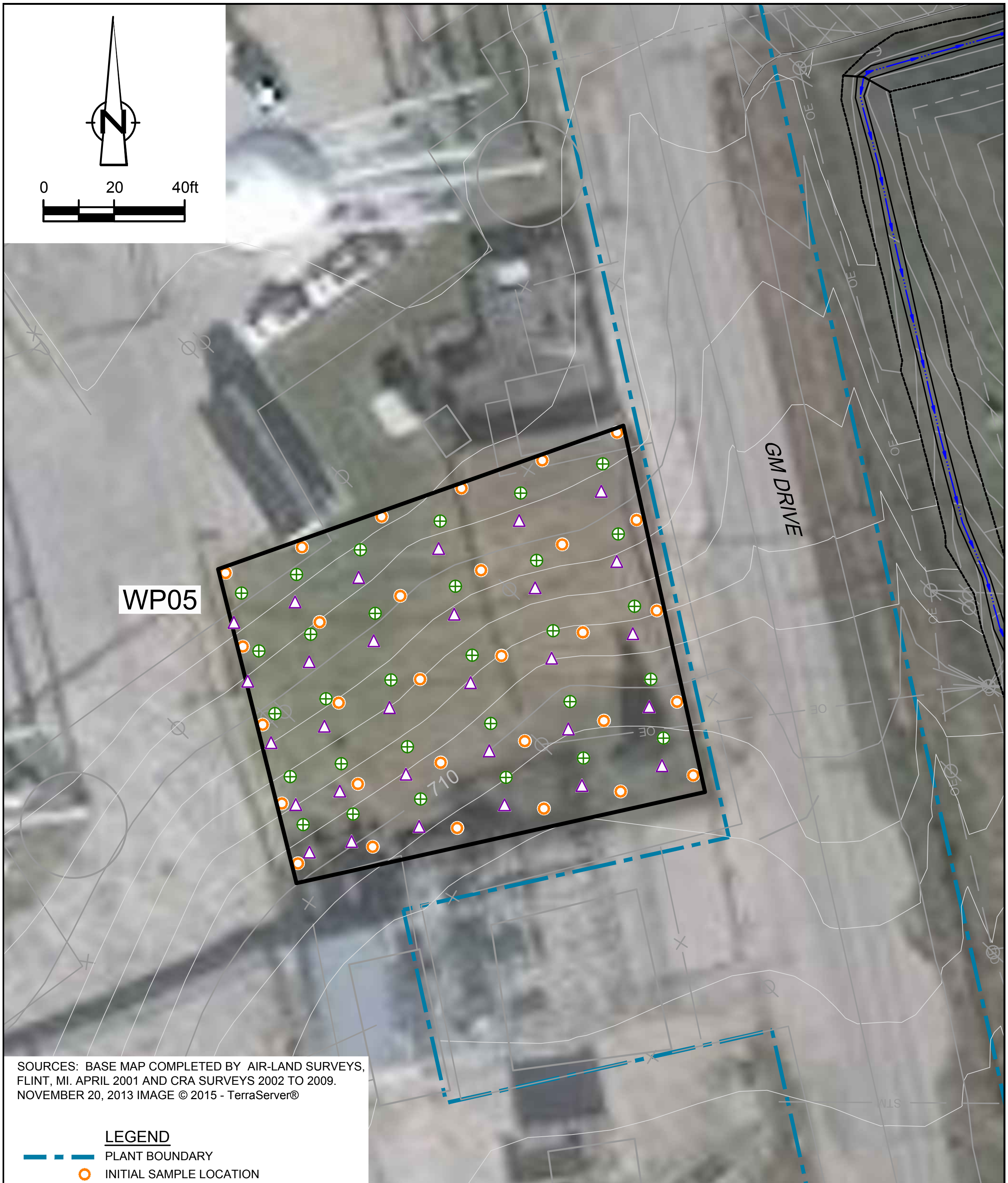


SOURCES: BASE MAP COMPLETED BY AIR-LAND SURVEYS, FLINT, MI. APRIL 2001 AND CRA SURVEYS 2002 TO 2009. NOVEMBER 20, 2013 IMAGE © 2015 - TerraServer®

LEGEND

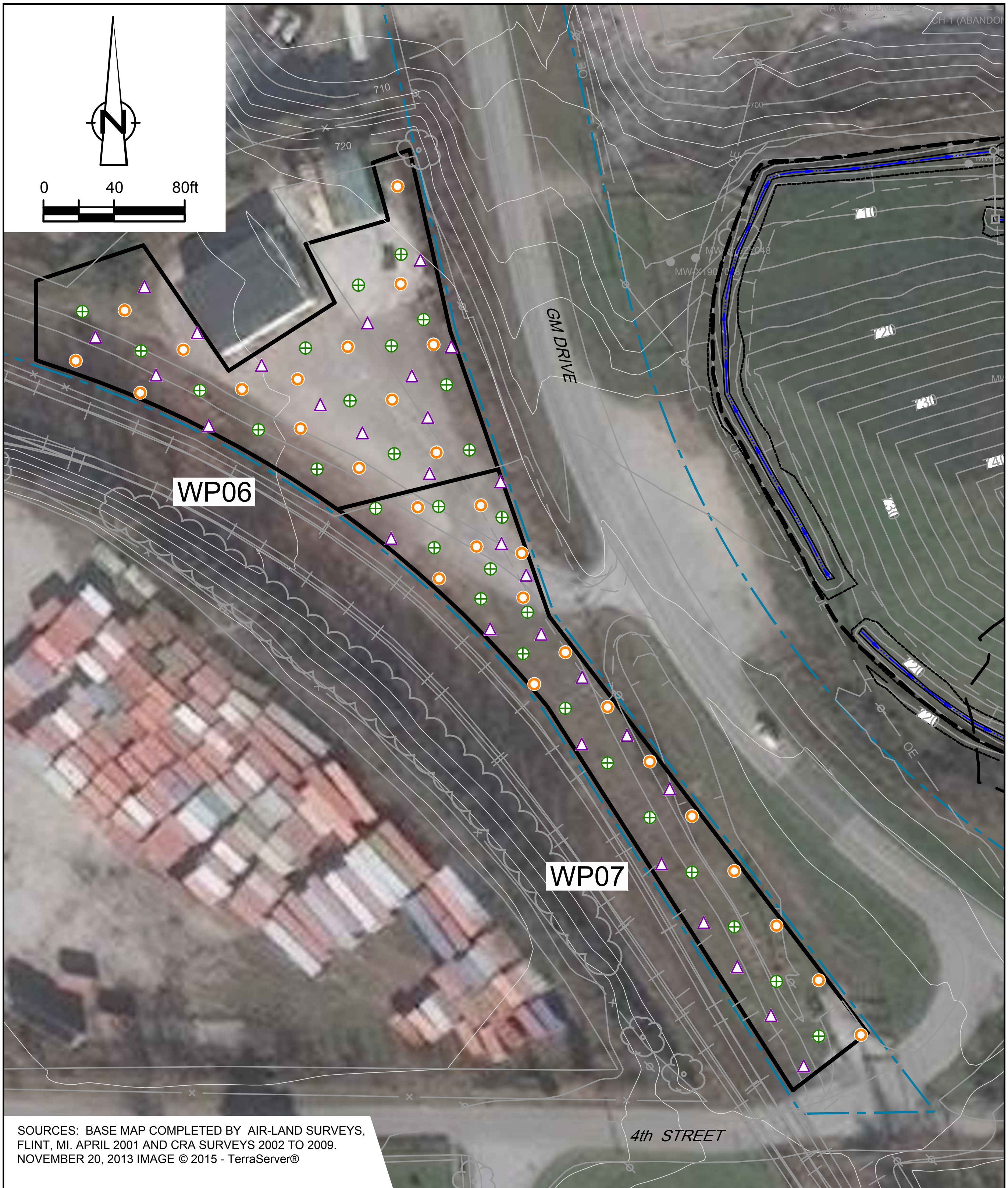
- PLANT BOUNDARY
- INITIAL SAMPLE LOCATION
- DUPLICATE SAMPLE LOCATION
- TRIPLICATE SAMPLE LOCATION

NOTE: ALL LOCATIONS WILL BE COLLECTED TO THE EXTENT THAT THERE ARE NO INTERFERING STRUCTURES OR SURFACES ETC.

figure 4

WEST PLANT - UNSAMPLED AREA 3 OF 6
UNSAMPLED AREAS WORK PLAN
GM CET BEDFORD FACILITY
Bedford, Indiana

13968-00(MEMO755)GN-WA016 MAR 30/2015



SOURCES: BASE MAP COMPLETED BY AIR-LAND SURVEYS, FLINT, MI. APRIL 2001 AND CRA SURVEYS 2002 TO 2009. NOVEMBER 20, 2013 IMAGE © 2015 - TerraServer®

LEGEND
- PLANT BOUNDARY
- INITIAL SAMPLE LOCATION
- DUPLICATE SAMPLE LOCATION
- TRIPLICATE SAMPLE LOCATION

NOTE: ALL LOCATIONS WILL BE COLLECTED TO THE EXTENT THAT THERE ARE NO INTERFERING STRUCTURES OR SURFACES ETC.

figure 5

WEST PLANT - UNSAMPLED AREA 4 OF 6
UNSAMPLED AREAS WORK PLAN
GM CET BEDFORD FACILITY
Bedford, Indiana

13968-00(MEMO755)GN-WA016 MAR 30/2015

SOURCES: BASE MAP COMPLETED BY AIR-LAND SURVEYS, FLINT, MI. APRIL 2001 AND CRA SURVEYS 2002 TO 2009. NOVEMBER 20, 2013 IMAGE © 2015 - TerraServer®

LEGEND

- PLANT BOUNDARY
- MW-X169Y058S MONITORING WELL LOCATION
- INITIAL SAMPLE LOCATION
- DUPLICATE SAMPLE LOCATION
- TRIPLICATE SAMPLE LOCATION

NOTE: ALL LOCATIONS WILL BE COLLECTED TO THE EXTENT THAT THERE ARE NO INTERFERING STRUCTURES OR SURFACES ETC.

CRA

figure 6

WEST PLANT - UNSAMPLED AREA 5 OF 6
UNSAMPLED AREAS WORK PLAN
GM CET BEDFORD FACILITY
Bedford, Indiana

13968-00(MEMO755)GN-WA016 MAR 30/2015

LEGEND
PLANT BOUNDARY
MW-X169Y058S MONITORING WELL LOCATION
INITIAL SAMPLE LOCATION
DUPLICATE SAMPLE LOCATION
TRIPLICATE SAMPLE LOCATION

NOTE: NOT A GRIDABLE AREA DUE TO UTILITIES

SOURCES: BASE MAP COMPLETED BY AIR-LAND SURVEYS, FLINT, MI. APRIL 2001 AND CRA SURVEYS 2002 TO 2009. NOVEMBER 20, 2013 IMAGE © 2015 - TerraServer®

NOTE: ALL LOCATIONS WILL BE COLLECTED TO THE EXTENT THAT THERE ARE NO INTERFERING STRUCTURES OR SURFACES ETC.

figure 7

WEST PLANT - UNSAMPLED AREA 6 OF 6
UNSAMPLED AREAS WORK PLAN
GM CET BEDFORD FACILITY
Bedford, Indiana

13968-00(MEMO755)GN-WA017 MAR 30/2015

SOURCES: BASE MAP COMPLETED BY AIR-LAND SURVEYS, FLINT, MI. APRIL 2001 AND CRA SURVEYS 2002 TO 2009. NOVEMBER 20, 2013 IMAGE © 2015 - TerraServer®

LEGEND
- PLANT BOUNDARY
- EAST PLANT COVER LIMIT
- CH-7 MONITORING WELL LOCATION
- INITIAL SAMPLE LOCATION
- DUPLICATE SAMPLE LOCATION
- TRIPLICATE SAMPLE LOCATION

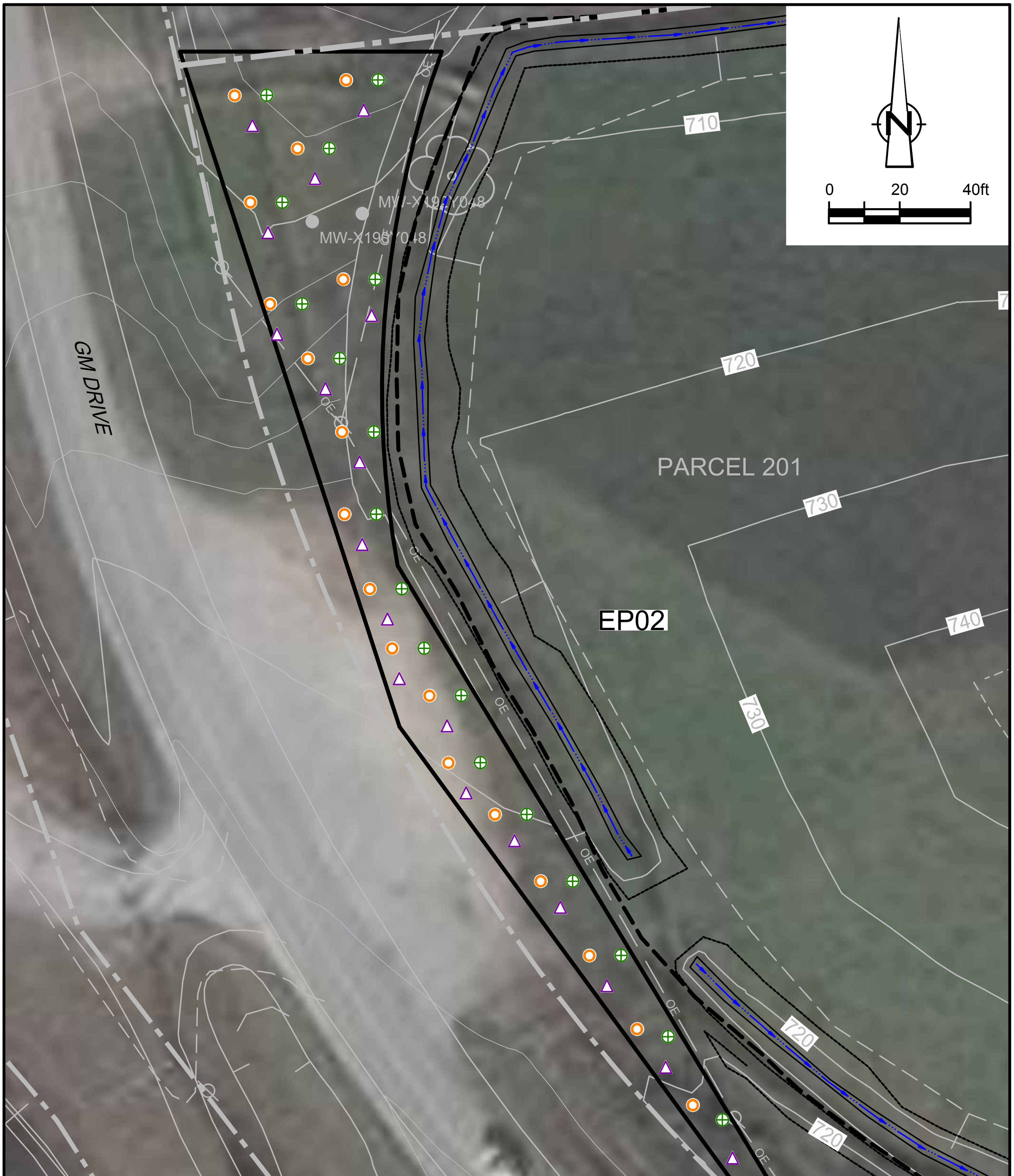
NOTE: ALL LOCATIONS WILL BE COLLECTED TO THE EXTENT THAT THERE ARE NO INTERFERING STRUCTURES OR SURFACES ETC.

CRA

figure 8

EAST PLANT - UNSAMPLED AREA 1 OF 5
UNSAMPLED AREAS WORK PLAN
GM CET BEDFORD FACILITY
Bedford, Indiana

13968-00(MEMO755)GN-WA017 MAR 30/2015



LEGEND

PLANT BOUNDARY

EAST PLANT COVER LIMIT

MW-X190Y048 MONITORING WELL LOCATION

INITIAL SAMPLE LOCATION

DUPLICATE SAMPLE LOCATION

TRIPLICATE SAMPLE LOCATION

NOTE: ALL LOCATIONS WILL BE COLLECTED TO THE EXTENT THAT THERE ARE NO INTERFERING STRUCTURES OR SURFACES ETC.

figure 9

EAST PLANT - UNSAMPLED AREA 2 OF 5
UNSAMPLED AREAS WORK PLAN
GM CET BEDFORD FACILITY
Bedford, Indiana

SOURCES: BASE MAP COMPLETED BY AIR-LAND SURVEYS, FLINT, MI. APRIL 2001 AND CRA SURVEYS 2002 TO 2009.
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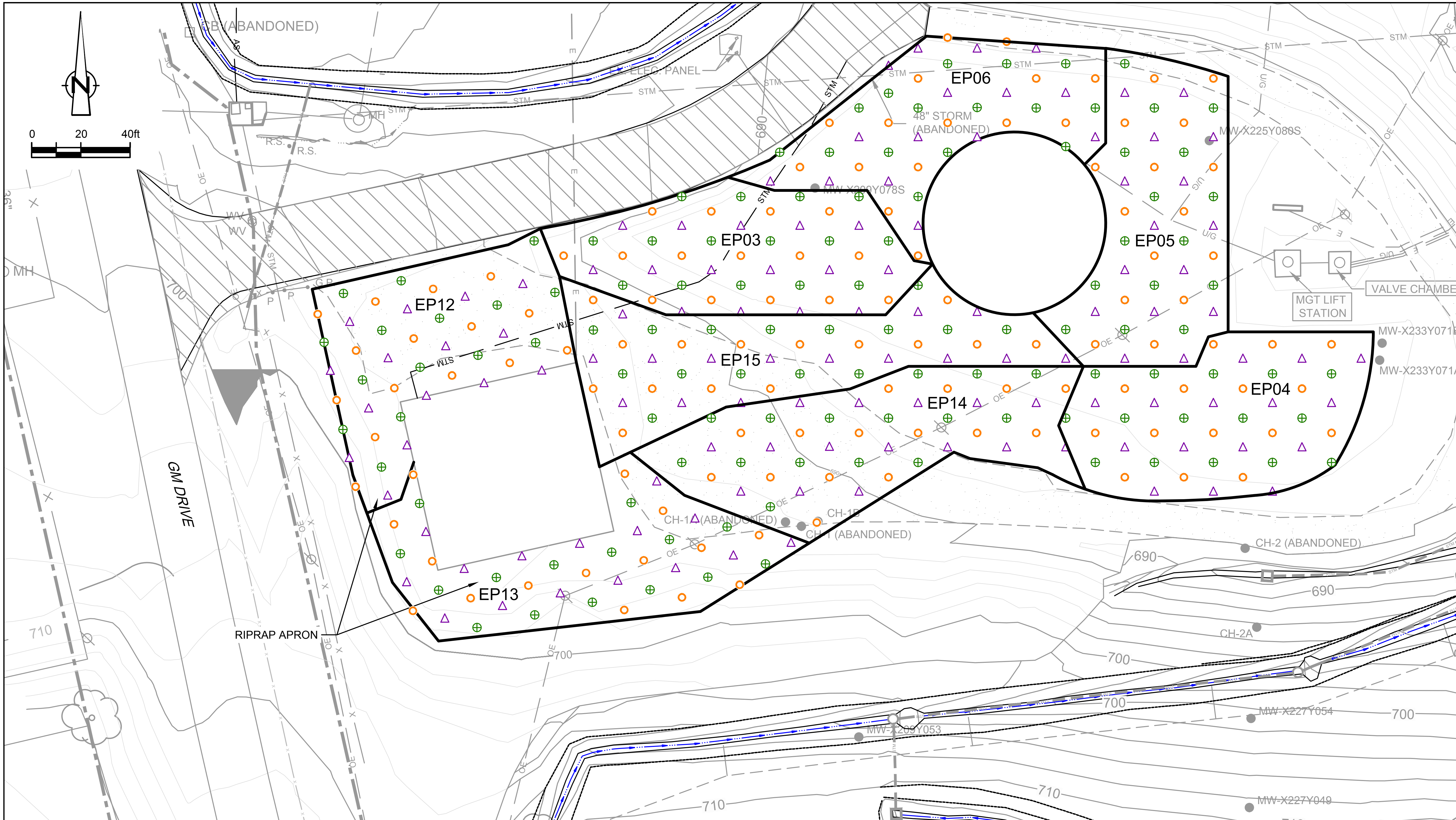


SOURCES: BASE MAP COMPLETED BY AIR-LAND SURVEYS, FLINT, MI. APRIL 2001 AND CRA SURVEYS 2002 TO 2009. NOVEMBER 20, 2013 IMAGE © 2015 - TerraServer®

LEGEND

- PLANT BOUNDARY
- MW-X209Y053 MONITORING WELL LOCATION
- INITIAL SAMPLE LOCATION
- DUPLICATE SAMPLE LOCATION
- TRIPLICATE SAMPLE LOCATION

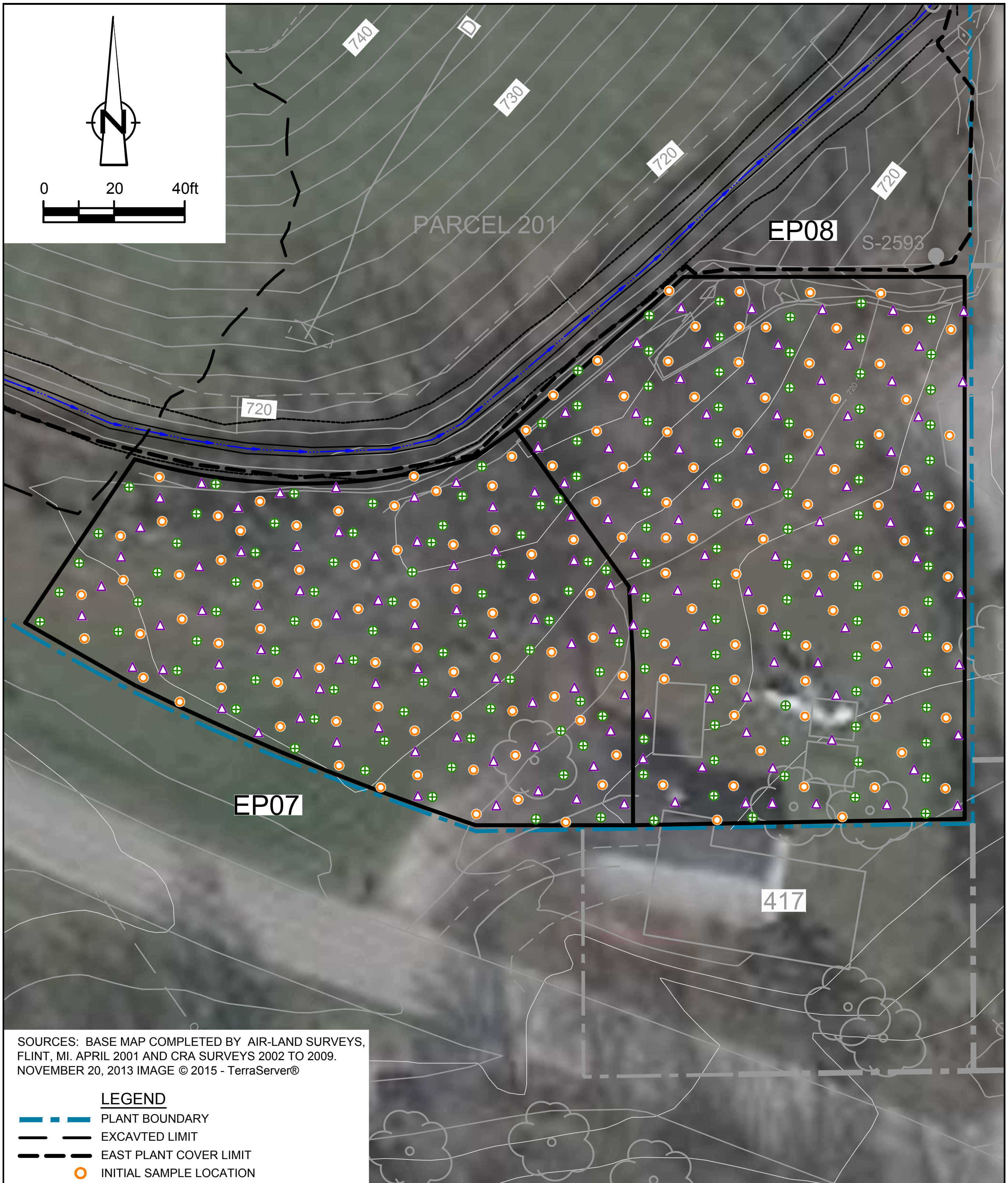
NOTE: ALL LOCATIONS WILL BE COLLECTED TO THE EXTENT THAT THERE ARE NO INTERFERING STRUCTURES OR SURFACES ETC.

figure 10

EAST PLANT - UNSAMPLED AREA 3 OF 5
UNSAMPLED AREAS WORK PLAN
GM CET BEDFORD FACILITY
Bedford, Indiana

CRA

13968-00(MEMO755)GN-WA019 OCT 19/2015



SOURCES: BASE MAP COMPLETED BY AIR-LAND SURVEYS, FLINT, MI. APRIL 2001 AND CRA SURVEYS 2002 TO 2009. NOVEMBER 20, 2013 IMAGE © 2015 - TerraServer®

LEGEND

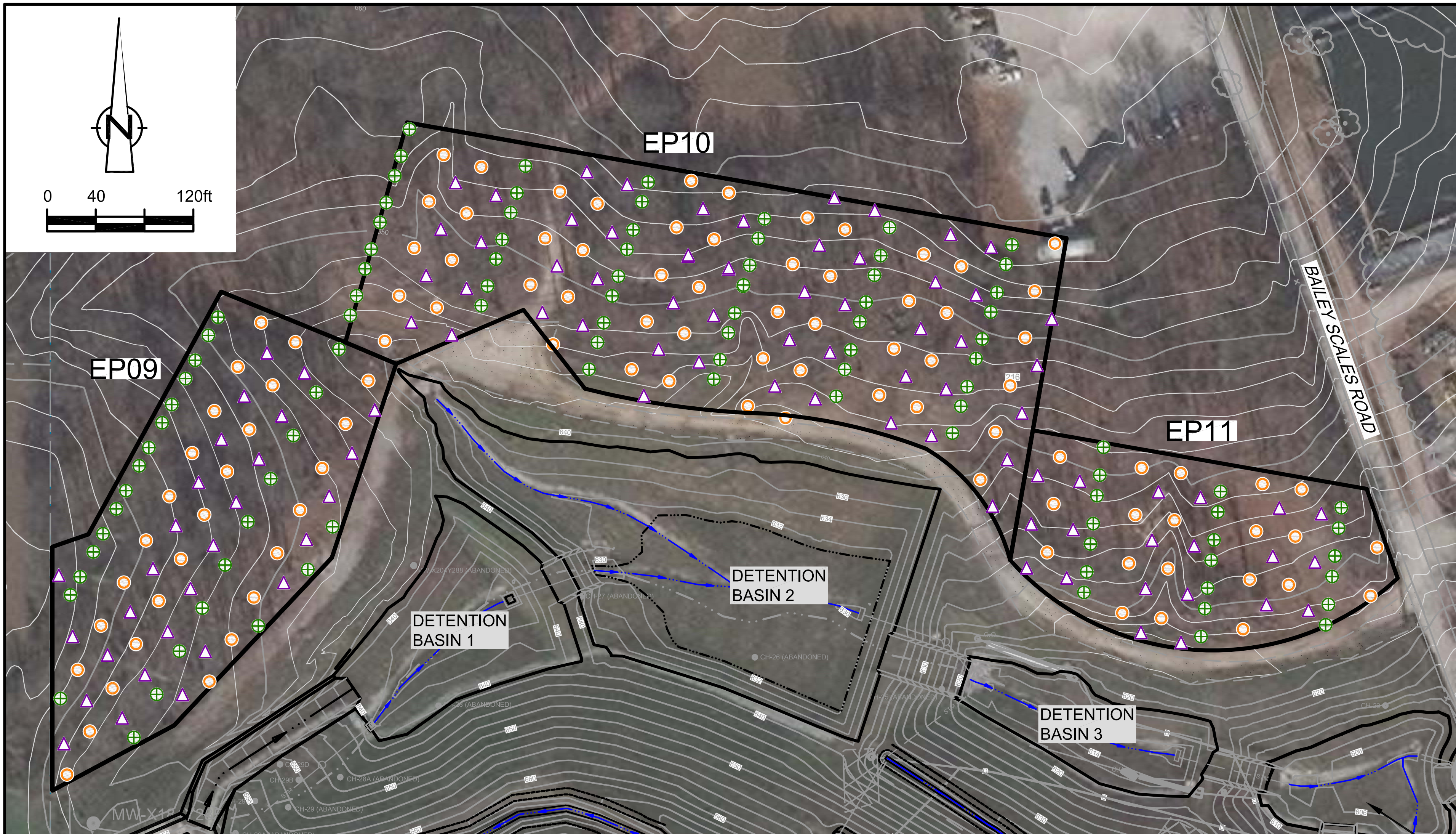
- PLANT BOUNDARY
- EXCAVTED LIMIT
- EAST PLANT COVER LIMIT
- INITIAL SAMPLE LOCATION
- DUPLICATE SAMPLE LOCATION
- TRIPLICATE SAMPLE LOCATION

NOTE: ALL LOCATIONS WILL BE COLLECTED TO THE EXTENT THAT THERE ARE NO INTERFERING STRUCTURES OR SURFACES ETC.

figure 11

EAST PLANT - UNSAMPLED AREA 4 OF 5
UNSAMPLED AREAS WORK PLAN
GM CET BEDFORD FACILITY
Bedford, Indiana

13968-00(MEMO755)GN-WA016 MAR 30/2015



LEGEND

PLANT BOUNDARY

MW-X261Y356D MONITORING WELL LOCATION

INITIAL SAMPLE LOCATION

DUPLICATE SAMPLE LOCATION

TRIPLICATE SAMPLE LOCATION

NOTE: ALL LOCATIONS WILL BE COLLECTED TO THE EXTENT THAT THERE ARE NO INTERFERING STRUCTURES OR SURFACES ETC.

SOURCES: BASE MAP COMPLETED BY AIR-LAND SURVEYS, FLINT, MI. APRIL 2001 AND CRA SURVEYS 2002 TO 2009. NOVEMBER 20, 2013 IMAGE © 2015 - TerraServer®

figure 12

EAST PLANT - UNSAMPLED AREA 5 OF 5
UNSAMPLED AREAS WORK PLAN
GM CET BEDFORD FACILITY
Bedford, Indiana

13968-00(MEMO755)GN-WA016 MAR 30/2015

Attachment 1

Title: SUBSAMPLING

[Method: ASTM D6323-12]

Approvals (Signature/Date):

Technology Specialist	12/03/14 Date	Health & Safety Coordinator	12/08/14 Date
Quality Assurance Manager	01/22/15 Date	Technical Director	01/15/15 Date

This SOP was previously identified as SOP No. NC-OP-046, Rev 0, dated 11/27/14

Facility Distribution No. ___________ Distributed To:_______________________

The controlled copies of this SOP are the PDF copy that is posted to the laboratory's SOP Directory and, where applicable, the copy that is printed and placed in the General Chemistry SOP binder. Printed or electronic copies distributed outside of the facility are considered uncontrolled.

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1. SCOPE AND APPLICATION

1.1. These mixing, subsampling, and splitting techniques are applicable to a wide range of soil, sediment, tissue, water, and waste samples. Care must be taken to match the appropriate technique with the matrix, target analytes and quality objectives.

1.2. The goal of all mixing, subsampling, and splitting techniques is to obtain representative splits or subsamples for preparation and analysis. Particle size reduction and processing can be beneficial in obtaining representative subsamples and specific processes for particle size reduction and processing can be found in the soil processing SOP (NC-OP-044) and non-soil processing SOP (NC-OP-045).

1.3. This document accurately reflects current laboratory Standard Operating Procedures (SOP) as of the date above. All facility SOPs are maintained and updated as necessary.

1.4. **NOTE:** If foreign or quarantined solids are received, refer to SOP NC-SM-019 Canton Foreign Soils, current revision, and contact your Environmental Health and Safety Coordinator for proper handling instructions.

2. SUMMARY OF METHOD

2.1. All samples should be mixed and subsampled appropriately for the test and analytes of interest.

2.2. Solid sample mixing procedures include in-jar mixing, horizontal surface mixing, and mortar and pestle.

2.3. Solid sample subsampling procedures include alternate scoop, one-dimensional slabcake, two-dimensional slabcake, and cone and quarter methods.

2.4. Liquid sample subsampling procedures include centrifuge, pipettes, coliwasa devices, and multiphase procedures.

3. DEFINITIONS

3.1. Refer to the glossary in the TestAmerica Canton Quality Assurance Manual (QAM), current version.

3.2. Mix: To thoroughly blend the sample and reduce the analyte concentration differences between different parts of the overall sample. It is most effective when the particle size and density differences within the sample are small.

3.3. Incremental Sampling Methodology: A structured composite sampling and processing protocol that reduces data variability and provides a reasonably unbiased estimate of the mean contaminant concentrations in an area/volume of soil targeted for sampling. ISM provides representative samples of specific soil areas/volumes defined as decision units (DUs) by collecting numerous increments of soil (typically 30-100 increments) that are combined, processed, and subsampled according to specific protocols.

3.4. Grinding: A generic term for soil disaggregation or milling.

3.5. Disaggregation: The act of breaking the soil clumps into individual small particles but keeping the small pebbles and hard crystalline particles intact.

3.6. Milling: Complete particle size reduction of all soil components including hard crystalline materials to a defined maximum particle size (e.g. <250 µm or <75 µm).

3.7. Sample: For laboratory technicians, the sample is all the material delivered to the laboratory in a container collected by the field crew.

3.8. Subsample: The small representative amount removed from a field sample selected for final analysis. This is also referred to in some SOPs as the aliquot.

3.9. Representative subsample: A subsample taken in such a way that each particle had an equal chance of being selected. The most representative subsample is one that most closely resembles the true value of the material sampled or contains the least amount of error.

4. INTERFERENCES

4.1. Method interferences may be caused by contaminants in solvents, reagents, glassware, and other processing apparatus that lead to discrete artifacts. All of these materials must be routinely demonstrated to be free from interferences under conditions of the analysis by running laboratory method blanks as described in the Quality Control section of each analytical SOP. Specific selection of reagents may be required to avoid introduction of contaminants.

4.2. Metallic components of particle size reduction equipment can contribute some metal content to the solid samples. Hence carbon steel components are usually preferable to stainless steel when necessary to minimize contamination from chromium, nickel and molybdenum. Some contamination from iron is common.

5. SAFETY

5.1. Employees must abide by the policies and procedures in the Corporate Environmental Health and Safety Manual, the Facility Addendum to the Corporate EH&S Manual, and this document.

5.2. Eye protection that protects against splash, laboratory coat, and appropriate gloves must be worn while samples, standards, solvents, and reagents are being handled. Cut-resistant gloves must be worn doing any other task that presents a strong possibility of getting cut. Disposable gloves that have been contaminated will be removed and discarded; other gloves will be cleaned immediately.

5.3. Exposure to chemicals must be maintained **as low as reasonably achievable**; therefore, unless they are known to be non-hazardous, all samples must be opened, transferred and prepared in a fume hood, or under other means of mechanical ventilation where possible. All samples with stickers that read "Caution/Use Hood!" **must** be opened in the hood. Contact the EH&S Coordinator if this is not possible. Solvent and waste containers will be kept closed unless transfers are being made.

5.4. The following is a list of the materials used in this method, which have a serious or significant hazard rating. NOTE: This list does not include all materials used in the method. The table contains a summary of the primary hazards listed in the Safety Data Sheet (SDS) for each of the materials listed in the table. A complete list of materials used in the method can be found in the Reagents and Standards section. Employees must review the information in the SDS for each material before using it for the first time or when there are major changes to the SDS.

Material (1)	**Hazards**	**Exposure Limit (2)**	**Signs and symptoms of exposure**
Methanol	Flammable Poison Irritant	200 ppm-TWA	A slight irritant to the mucous membranes. Toxic effects exerted upon nervous system, particularly the optic nerve. Overexposure may include headache, drowsiness and dizziness. Methanol is a defatting agent and may cause skin to become dry and cracked. Skin absorption can occur: symptoms may be parallel to inhalation exposure. Irritant to the eyes.
Acetone	Flammable	1000 ppm-TWA	Inhalation of vapors irritates the respiratory tract. May cause coughing, dizziness, dullness, and headache.
1 – Always add acid to water to prevent violent reactions.			
2 – Exposure limit refers to the OSHA regulatory exposure limit.			

5.5. All work must be stopped in the event of a known or potential compromise to the health and safety of a TestAmerica associate. The situation must be reported **immediately** to the EH&S Coordinator and the Laboratory Supervisor.

5.6. When operating the electric chopper or grinder, be sure to keep all aqueous liquids clear to prevent the risk of electrical shock from any spills.

5.7. Avoid inhalation of sample dust. Work in a ventilation hood when necessary to avoid accidental dust inhalation. Wear a dust mask or respirator if the ventilation hood does not provide sufficient dust protection.

5.8. If there is any malfunction in the equipment. De-energize and tag out.

5.9. All noise levels are below OSHA limits.

5.10. Only trained personnel are permitted to use crushing equipment. A list of trained personnel will be maintained with EH&S and QA.

6. EQUIPMENT AND SUPPLIES

6.1. Butcher Paper

6.2. Plastic wrap

6.3. Aluminum foil

6.4. 8 oz. Glass jars with lids

6.5. Top-loading balance.

6.6. Appropriate containers for each subsample

7. REAGENTS AND STANDARDS

7.1. Deionized water: Reagent water must be produced by a Millipore DI system or equivalent. Reagent water must be free of the analytes of interest as demonstrated through the analysis of preparation blanks.

7.2. Methanol: VOC grade

7.3. Acetone: Pesticide grade

8. SAMPLE COLLECTION, PRESERVATION, AND STORAGE

8.1. Not applicable to this procedure. Sample collection, preservation, and storage are dependent on the requested test method and analytes.

9. QUALITY CONTROL

9.1. Equipment processing blanks might be applicable for some particle size reduction or selection techniques. There is no single blank matrix that is suitable for all analytes, equipment or processes. The blank matrix should be chosen by the client/data user based on the advantages and limitations described below in Section 9. If no blank matrix is selected by the client, reagent water should be used as the default when possible, as noted in Section 9.2.

9.2. Reagent water (or organic solvents) may be used to rinse the equipment surfaces. This liquid is then analyzed for the target analytes. This process is good at monitoring residue on equipment surfaces from previously processed samples. It does not evaluate the potential contribution of the equipment surface material to a solid sample.

9.3. Sand may be run through processing equipment and then analyzed to monitor for both sample carryover residue and contamination from equipment surface erosion. This process is most applicable for organic analytes. Sand always contains metals. These metals concentrations might be too high for suitable blank demonstrations. Also, the sand material is frequently more abrasive than soil and can over estimate sample contamination due to erosion of the equipment surfaces.

9.4. Teflon boiling chips can be suitable to monitor the cleanliness of processing equipment surfaces. This option is between reagent water and sand regarding abrasion of the equipment surfaces. This material is generally non-detect at parts per billion concentrations for most organic and inorganic analytes. The Teflon material does not mimic the behavior of soil in the subsequent sample extraction or digestion procedures.

9.5. Reprocess half of a field sample and look for differing analyte concentrations between the single and double processed sample aliquots. The occurrence of significantly elevated analyte concentrations in the double processed sample can be a good indication of carryover or contamination due to equipment surface erosion. This is most applicable for monitoring metals contamination in soil grinders.

10. CALIBRATION AND STANDARDIZATION

10.1. Not applicable to this procedure.

11. PROCEDURE

11.1. One-time procedural variations are allowed only if deemed necessary in the professional judgment of QA, operations supervisor, or designee to accommodate variation in sample matrix, chemistry, sample size, or other parameters. Any variation in procedure shall be completely documented using a Nonconformance Memo.

11.2. Any unauthorized deviations from this procedure must also be documented as a nonconformance with a cause and corrective action described.

11.3. Sample Preparation

11.3.1. The following sections describe a variety of procedures. Additional procedures for sample preparation are available in the Soil and Non-Soil Processing SOPs. The client/data user must select the procedure that is most appropriate for the sample matrix, analytes, and quality objectives. The selection of the procedure(s) can be made by the client in consultation with the appropriate TestAmerica representatives during project planning. There is no single default procedure that can be used in the absence of client selection.

11.3.2. Solid Sample Mixing Procedures

11.3.2.1. In jar mixing

11.3.2.1.1. The flowable sample is thoroughly stirred in the sample jar using a wooden blade.

11.3.2.2. Horizontal surface mixing

11.3.2.2.1. The sample is transferred to an aluminum tray or onto a sheet of paper and mixed with a wooden blade.

11.3.3. Solid Sample Subsampling Procedures

11.3.3.1. Multiple increments from a jar

11.3.3.1.1. Select 5-10 small sample increments from various locations within the sample container to make the entire subaliquot. The increments must come from all general areas of the container--top, sides, center, and bottom.

11.3.3.2. Two dimensional slabcake

11.3.3.2.1. Spread the sample to a consistent depth on a clean flat area covered with an appropriate disposable cover (butcher paper, aluminum tray or foil or plastic depending on the analytes of interest).

11.3.3.2.2. Select 30 or more small increments spread evenly over the sample area or as dictated by client data quality objectives. The increments must be collected with a blunt end spatula or scoop to evenly collect from the top middle and bottom of the slabcake. A coring device of suitable material can also be used if the sample is sufficiently cohesive (e.g. moist soil).

11.3.3.2.3. If the sample has noxious odors or produces dust, the sample spreading and increment collecting should be performed in a hood or large flat bag of appropriate material. The analyst must be protected from potential inhalation hazards from the sample.

11.3.3.3. Alternate scoop

11.3.3.3.1. Wet or dry solid samples can be divided into two or more smaller aliquots. Determine the number of sub-aliquots, and prepare that many empty containers.

11.3.3.3.2. Scoops of the mixed laboratory sample are either placed in the analytical vessel or discarded.

11.3.3.3.3. Three scoops are discarded for every scoop saved. Randomly select an aliquot and place in the first container. Place the next three aliquots in the second container. Repeat as needed for additional aliquot containers.

11.3.3.3.4. Repeat the aliquoting cycle until the original sample is consumed.

11.3.3.3.5. The alternate scoop technique can also be used to subaliquot discrete samples that are to be homogenized into one composite sample.

11.3.3.3.5.1. Determine approximately the ratio of aliquot to discard scoops required to consume the sample and achieve the aliquot size required for homogenization. For example, if a 50 g aliquot is desired from a 250 g sample, a ratio of one scoop used to four scoops discarded will be used.

11.3.3.3.5.2. For each discrete sample, set up two empty containers of appropriate volume.

11.3.3.3.5.3. Stir each discrete sample in its container, or if necessary homogenize on a sheet of butcher paper and return to the jar.

11.3.3.3.5.4. Place one of the empty containers on a balance and tare it. Place one scoop of sample from the top of the discrete sample jar into this container. This will be the portion used for a homogenized composite later.

11.3.3.3.5.5. Into the second jar, place the three or more (as determined in Section 11.3.3.3.5.1) scoops to be discarded.

11.3.3.3.5.6. Repeat Sections 11.3.3.3.5.4 and 11.3.3.3.5.5 until the sample has been consumed and the desired weight of the subaliquot is in the tared container. Record the weight of the sub-aliquot.

11.3.3.3.5.7. Repeat this process for all of the discrete samples that will be used for the composite, using approximately equal weights of each discrete sample.

11.3.3.3.5.8. After all discrete samples have been sub-aliquoted using the alternate scoop procedure, combine them on a sheet of butcher paper and homogenize. Pour the homogenized sample volume into the labeled sample jar for the composite sample.

11.3.3.4. One dimensional slabcake

11.3.3.4.1. This process is intended to produce large sub-samples from very large dry flowable solid samples, such as those collected using \incremental sampling methodology, dried and then chopped using the process described in Section 1.1.1See Reference 16.1.7.

11.3.3.4.2. Pour the dry soil sample into a long thin pile onto a clean horizontal surface. The pour height should not exceed 20 cm to minimize the formation of a dust cloud.

11.3.3.4.3. Ensure that the sample container makes at least 20 passes back and forth over the “line of sample”.

11.3.3.4.4. Using a rectangular flat-bottomed scoop, remove an increment from the “line of sample”. Ensure that a complete cross cut of the sample line includes the entire depth of that increment. Combine increments as needed to produce the needed sub-sample size.

11.3.3.5. Cone and quarter (for dry flowable samples)

11.3.3.5.1. Pour the sample into a cone on a clean flat area covered with an appropriate disposable cover (butcher paper, aluminum foil, or plastic depending on the analytes of interest).

11.3.3.5.2. Cut the cone in half in two directions to form four quadrants.

11.3.3.5.3. Return opposite quadrants to the original sample container.

11.3.3.5.4. Repeat the process in Sections 11.3.3.5.1 through 11.3.3.5.3 until the needed aliquot size has been obtained.

11.3.4. Liquid Sample Mixing Procedures

11.3.4.1. Closed container shaking

11.3.4.1.1. All liquid samples should be mixed by shaking in the original closed sample container unless a multiple layer sub-aliquoting procedure is used. This applies to emulsifiable layers such as oil and water and suspendable particulates in water. The sample must remain mixed long enough to pour out a representative aliquot. Samples that show noticeable separation in under a minute should be sub-aliquoted using an appropriate technique as described below.

11.3.4.1.2. The shaking process must be vigorous enough to mix and distribute analytes associated with different layers, particulates, or inside container walls.

11.3.5. Liquid Sample Subsampling Procedures

11.3.5.1. Pour

11.3.5.1.1. Samples that are well mixed can be sub-aliquoted by pouring an appropriate volume off the top of the sample.

11.3.5.2. Layer Subsampling

11.3.5.2.1. Some liquid samples with multiple layers separate too quickly to pour a representative sub-aliquot off the top. In some instances it is best to separate the layers and handle them as individual samples. In other instances representative aliquots of each layer must be collected and processed as a single sub-sample.

11.3.5.2.2. Unless directed otherwise, record the phase ratios (or volumes) of the layers.

11.3.5.2.3. Gravity or Centrifuge Settling

11.3.5.2.3.1. Allow the sample layers to separate based on density. Centrifugation can be used to accelerate the process if simple gravity settling is not fast enough.

11.3.5.2.4. Separatory Funnel

11.3.5.2.4.1. Gently pour the sample into a separatory funnel. Allow time for additional layer separation as needed.

11.3.5.2.4.2. Drain the layers out into separate containers one at a time.

11.3.5.2.4.3. Some oils stick to the separatory funnel sides so the draining process must be slow enough to avoid remixing the layers.

11.3.5.2.5. Pipette

11.3.5.2.5.1. Use a pipette of appropriate size to collect a sub-aliquot of a sample layer of interest and transfer to an empty container.

11.3.5.2.5.2. If the entire sample is to be separated, pipette almost all the top layer into a new container. Draw the small volume of the top layer into the pipette along with a small portion of the second layer. Allow the two layers to separate in the pipette (like a separatory funnel). Dispense the bottom layer back into original sample container with the bulk of the bottom layer. Next dispense the remaining top layer into the container that holds the top layer.

11.3.5.2.5.3. Repeat as needed for each layer of interest.

11.3.5.2.6. Coliwasa

11.3.5.2.6.1. A coliwasa is a “coring device” designed for liquid multi-layer samples. It is a long tube with a short valve at the bottom. When designed and used properly it collects representative aliquots of each layer with each sub-aliquoting immersion.

11.3.5.2.6.2. The volume collected is determined by the diameter of the coliwasa and the height of the sample. The larger the tube diameter or taller the sample height, the larger the volume of sample collected.

11.3.5.2.6.3. Place the foot of the valve and its control rod in the multi-layer sample. Slowly slide the coliwasa tube over the control rod and close the ground glass seal of the valve at the bottom.

11.3.5.2.6.4. Lift the coliwasa by the control rod to keep the valve sealed.

11.3.5.2.6.5. Place the coliwasa over the new sample aliquot container. Grasp the top of the coliwasa tube and slowly lower the control rod a few millimeters to open the foot valve and drain the sample into the container.

11.3.5.2.6.6. Repeat Sections 11.3.5.2.6.3 through 11.3.5.2.6.5 until sufficient sample aliquot has been collected.

11.3.6. Multiphase Sample Mixing Procedures

11.3.6.1. All liquid samples should be mixed by shaking unless a multiple layer subaliquoting procedure is used. This applies to emulsifiable layers such as oil and water and suspendable particulates in water. The sample must remain mixed long enough to pour out a representative aliquot. Samples that show noticeable separation in under a minute should be subaliquoted using an appropriate technique as described below.

11.3.6.2. Closed container shaking

11.3.6.2.1. The shaking process must be vigorous enough to mix and distribute analytes associated with different layers, particulates, or inside container walls.

11.3.6.3. Open container stirring

11.3.6.3.1. The sample is stirred or swirled to mix.

11.3.6.4. Wet Sediments

11.3.6.4.1. Aqueous samples for non-volatile compound analysis may contain settleable materials. If the settleable materials are to be included as part of the laboratory sample, and they will remain suspended, or can easily be re-suspended and will remain so during the subsampling operation, the sample should be handled as a liquid sample. These samples should be gently swirled for 15 seconds or slowly inverted six times to reduce heterogeneity.

11.3.6.4.2. If the liquid portion only is to be used, the settleable material must be allowed to sink to the bottom before withdrawing the subsample.

11.3.6.4.3. If the settleable material will not remain suspended and is to be included in the analysis, the sample should be treated as a multilayered sample.

11.3.7. Multi-phase Sample Subsampling Procedures

11.3.7.1. Multi-layered samples may include liquid/liquid layers, liquid/solid samples, or solid/solid samples.

11.3.7.2. If the liquid portion of a sludge sample can be re-mixed with the solid portion and will re-separate over time, the sample should be handled as a solid sample.

11.3.7.3. If the solid portion will remain suspended or can easily be re-suspended, the sample should be treated as a liquid sample. Mixing may occur by inverting the container or with slight shaking

11.3.7.4. Layer Separating

11.3.7.4.1. Gravity/Centrifuge – The solid/liquid phase separation may be achieved by gently centrifuging the unopened container or by allowing it to sit undisturbed until the solid portion is settled.

11.3.7.4.2. Pipette – For liquid/liquid layers, separate the layers using a pipette. Each layer may be either transferred into another container or directly into the analytical vessel. Each separated portion is then handled as a homogeneous liquid sample.

11.3.7.4.3. Filter/Decant – For liquid/solid layers, the liquid subsample may be obtained by filtering or decanting the liquid portion from the solid portion. The liquid portion is then handled as a homogeneous liquid sample. The solid portion is handled as a solid laboratory sample.

11.4. Sample Analysis

11.4.1. Not applicable to this procedure

11.5. Analytical Documentation

11.5.1. Record all analytical information in LIMS, including any corrective actions or modifications to the method.

11.5.2. Record all standards and reagents in the LIMS reagents module. All standards and reagents are assigned a unique number for identification.

12. DATA ANALYSIS AND CALCULATIONS

12.1. Not applicable to this procedure.

13. METHOD PERFORMANCE

13.1. The Group/Team Leader has the responsibility to ensure this procedure is performed by an associate who has been properly trained in its use and has the required experience.

14. POLLUTION PREVENTION

14.1. It is TestAmerica's policy to evaluate each method and look for opportunities to minimize waste generated (i.e., examine recycling options, ordering chemicals based on quantity needed, preparation of reagents based on anticipated usage, and reagent stability). Employees must abide by the policies in Section 13 of the Corporate Environmental Health and Safety Manual (CW-E-M-001) for "Waste management and Pollution Prevention".

15. WASTE MANAGEMENT

15.1. All waste will be disposed of in accordance with Federal, State and Local regulations. Where reasonably feasible, technological changes have been implemented to minimize the potential for pollution of the environment. Employees will abide by this method and the policies in Section 13 of the Corporate Environmental Health and Safety Manual (CW-E-M-001) for "Waste Management and Pollution Prevention".

15.2. Waste Streams Produced by the Method

15.2.1. Used wood spatulas, aluminum sheets, butcher paper; discard in solid waste.

15.3. Laboratory personnel assigned to perform hazardous waste disposal procedures must have a working knowledge of the established procedures and practices of TestAmerica. They must have training on the hazardous waste disposal practices upon initial assignment to these tasks, followed by annual refresher training.

16. REFERENCES

16.1. References

16.1.1. U.S. EPA, 2000. TRW Recommendations for Sampling and Analysis of Soil at Lead (Pb) Sites. EPA-540-F-00-010. OSWER 9285.7-38. April. Available on-line at: http://www.epa.gov/superfund/programs/lead/products/sssiev.pdf

16.1.2. U.S. EPA, 2003. TRW Recommendations for Performing Human Health Risk Analysis on Small Arms Shooting Ranges. OSWER 9285.7-37. March. Available on-line at: http://www.epa.gov/superfund/programs/lead/products/firing.pdf

16.1.3. U.S. EPA, 2003. Superfund Lead-Contaminated Residential Sites handbook. OSWER 9285.7-50. August. Available on-line at: http://www.epa.gov/superfund/programs/lead/products/handbook.pdf

16.1.4. Michigan DEQ SOP #213 Revision #1, Nov. 9, 2004, Soil Fractions Preparation for Lead Analysis (Creating Total, Fine and Coarse Soil Samples). Available on-line at: http://www.deq.state.mi.us/documents/deq-rrd-OpMemo_2_SoilFractionsPrepForLead.pdf

16.1.5. ASTM D 6323-12, Laboratory Subsampling of Media Related to Waste Management Activities, 2012

16.1.6. TestAmerica Canton Quality Assurance Manual (QAM), current version

16.1.7. TestAmerica Corporate Environmental Health and Safety Manual, CW-E-M-001, and TestAmerica Canton Facility Addendum and Contingency Plan, current version

16.1.8. Corporate Quality Management Plan (CQMP), current version

16.1.10 Revision History

Historical File:		Revision 1: 05/19/99		Revision 7: 06/10/09
		Revision 2: 02/23/04		Revision 8: 09/13/10
		Revision 3: 05/24/04		Revision 9: 09/28/11
		Revision 4: 10/13/06		
		Revision 5: 11/06/06		
		Revision 6: 05/28/08		

16.2. Associated SOPs and Policies, current version

16.2.1. QA Policy, QA-003

16.2.2. Glassware Washing, NC-QA-014

17. MISCELLANEOUS (TABLES, APPENDICES, ETC.)

17.1. Reporting limits

17.1.1. Not applicable to this procedure

17.2. Method deviations – None

Attachment 2

PART C

FIELD METHOD GUIDELINES

MARCH 2011
REF. NO. 17300 (2) PART C
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Revision 0, March 14, 2011, 2001

FIELD METHOD GUIDELINES

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- 6.8 TERRESTRIAL/INVERTEBRATES COLLECTION
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- 6.10 SAMPLE HANDLING AND SHIPPING
- 6.11 INCREMENTAL SOIL SAMPLING

FMG 7.0 AIR SAMPLING
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- 7.2 VOLATILE ORGANIC COMPOUNDS (VOCs)

FMG 8.0 FIELD INSTRUMENTS – USE/CALIBRATION

FMG 9.0 EQUIPMENT DECONTAMINATION

FMG 10.0 WASTE CHARACTERIZATION

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INTERIOR AND EXTERIOR INSPECTIONS

INTRODUCTION

Environmental investigations are performed at GM Remediation Team sites for a variety of reasons, such as RCRA Remedial Facility Investigations, CERCLA Remedial Investigations/Feasibility Studies, Phase I Environmental Site Assessments, or other site-specific or regulatory reasons. These projects involve investigations of various levels of detail; however, in all cases it is advisable, and often required, to perform a formal site-wide visual inspection prior to planning or initiating any other field work. Site inspections provide valuable site information, identify and document conditions of environmental concern, and help to focus an investigation on the appropriate issues.

This FMG has been prepared to serve as a guideline for performing both interior and exterior environmental site inspections, at sites of any size, whether owned, leased, or otherwise occupied by GM. The FMG provides a checklist of items to be investigated and observed. All items listed may not be applicable for a given site. In addition, a particular site may have elements that are not on this checklist but should be evaluated. It is up to the individual performing the inspection to consider as many aspects of the site, its history of activity, and current conditions as possible to facilitate meaningful results.

Note: Although this FMG deals with the specifics of performing an inspection, it should be done in conjunction with additional site research, including but not limited to:

- Interviews with key site personnel.
- Review of available site information.
- Historic data sources, such as fire insurance maps and aerial photos.
- Requests for information from governmental agencies or other sources.

In addition, although this FMG draws from the requirements in the ASTM Phase I Environmental Site Assessment Standard (see References), it does not replicate all aspects of the Standard; as such, is not to be considered a substitute for an ASTM Assessment or to be used in lieu of an ASTM Phase I Environmental Site Assessment.

PROCEDURES REFERENCED

- FMG 1.4 - Data Recording - Field Books/Digital Recording.
- FMG 8.0 - Field Instruments – Use/Calibration.

PROCEDURAL GUIDELINES

Prior to Performing the Inspection:

1. If the property is not owned by GM, and if required, obtain an access agreement or other form of written permission to enter the site.
2. Determine if a site-specific Health and Safety Plan (HASP) is required or has been developed. If so, follow the requirements of the HASP, especially with regard to areas of the site where oil or hazardous substances may be present. There may also be site-specific safety requirements that must be followed; check with site personnel regarding this. *Do not enter any site location that may be considered a Confined Space, as defined by OSHA Title 29, Part 1910.146*.
3. Contact the identified key site personnel who will provide access to all areas of the site. Make inquiries with the site personnel regarding available relevant site information. Such information may include, but is not limited to: site, building construction, or utility drawings; previous environmental site reports; environmental audits; permits; tank registrations; Material Safety Data Sheets; Community Right-to-Know plans; safety plans; hydrogeologic or geotechnical reports; or hazardous waste generator reports.
4. Review all available information in light of the planned site inspection and list specific site locations to investigate.
5. Assemble items listed in the "Equipment And Materials" section below.

Inspection Procedure

1. Inspect the site using the FMG checklist below or other appropriate checklist.
2. If a reasonably accurate drawing of the facility is available, mark the locations of key features observed in the inspection on the drawing. Locate the features accurately by measuring distances from existing features. If no drawing is available, record the measurements systematically in a field book, describing in detail existing features from which the measurements were taken. Also record accurate dimensions of the features being described.

3. Record observations for all relevant site features in a field book or pre-printed checklist. Be thorough in your observations, keeping in mind the potential environmental effects any given feature or object may have had on the site.
4. Be cognizant of site features that may not be on the checklist but may have environmental significance.
5. Accurately record the content and other pertinent information of labels on containers of suspect substances.
6. If subsurface structures are present, such as catch basins, sumps, floor drains, etc., that contain standing liquid or debris, they can act as collection or dispersion points for subsurface contaminants. Obtain a reading of the vapors in the structure with a PID or other VOC-detection device, and record the readings.
7. Provide a written general description of the site. Include at a minimum:
   - Approximate lot size;
   - Grading (level, sloped, terraced, etc.);
   - Building sizes and types;
   - Paved, grass, wooded areas, wetlands, etc.;
   - Site drainage features; and
   - Bedrock outcrops.
8. Make notes of observations of the following areas on the site. This checklist is not intended to be all-encompassing and may need to be supplemented with other items as appropriate for the site. Record all observations as they pertain to potential environmental issues, making note of visual or olfactory evidence or instrument readings that may indicate the current presence or potential past presence or release of hazardous substances or petroleum products:

<u>Features Potentially Found in Interior or Exterior Areas</u>

a. Raw material/waste storage areas.
b. Loading/unloading areas and compactor locations.
c. Hydraulic lifts, ramps, or pits.
d. Drums or other containers of hazardous substances, or petroleum products, or unknown substances.
e. Aboveground storage tanks.
f. Underground storage tanks.
g. Tank fill locations.
h. Underground utilities.
i. Accumulation of oil or other standing liquid.

j. Stains or corrosion.

k. Electric transformers or capacitors.

l. Emergency generators.

m. Potential asbestos-containing materials. (Note: testing is required to confirm the presence of asbestos-containing materials; samples must be obtained by a certified asbestos technician.)

n. Potential lead-based paint. (Note: testing is required to confirm the presence of lead in paint.)

Features Typically Found in Interior Areas

a. Basements and crawl spaces.

b. Concrete, dirt, or gravel floors.

c. Process areas.

d. Floor drains or sumps.

e. Hydraulic elevators.

Features Typically Found in Exterior Areas

a. Septic tanks/leaching fields.

b. Sanitary/storm/process wastewater sewers.

c. Wastewater treatment facilities.

d. Catch basins, drains, manholes.

e. Solid waste/areas of waste or soil filling.

f. Pits/ponds/lagoons.

g. Overhead utilities.

h. Stained soil or pavement.

i. Stressed vegetation.

j. Pavement cuts or patches.

k. Wells – potable water supply, groundwater monitoring, irrigation, injection.

EQUIPMENT/MATERIALS

- Site drawings and other background information.
- Copy of written access permission (if required).
- A copy of this FMG or a site-specific checklist of items for observation.

- Field book, ball point pen.
- Flashlight.
- Tape measure.
- Camera (if allowed on site).
- Photoionization detector (PID) or other VOC monitoring instrument.
- Lead-paint testing instrument (if required).

REFERENCES

American Society for Testing and Materials, 2000, Standard Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process, Standard No. E1527-00.

Occupational Health and Safety Administration (OSHA), 29 CFR 1910.146, "Permit-Required Confined Spaces".

REMEDIATION TEAM	FIELD METHOD GUIDELINE NO.: FMG 1.2
REAL ESTATE & FACILITIES	EFFECTIVE DATE: MARCH 14, 2011
GENERAL MOTORS	
REVISION NO.: 0	REVISION DATE:

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FMG 1.2-01 SOIL VAPOR SAMPLING LOG

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SOIL-GAS SURVEY (PASSIVE AND ACTIVE)

INTRODUCTION

This procedure describes protocols for conducting passive and active soil-gas surveys. Soil-gas surveys are used to detect volatile organic compounds (VOCs), such as industrial solvents, BTEX, Stoddard, and associated hydrocarbons and motor fuels, in soil and groundwater. The procedures can be modified to detect mercury or radon gas, if necessary. The typical purpose of conducting a soil-gas survey is to identify soil "hot spots" and to track or map contaminant plumes in the groundwater, thereby limiting the number of exploratory soil borings and monitoring wells.

Conducting a soil-gas survey is appropriate for evaluating the integrity of tanks, pipes, and equipment foundations, for plume mapping, as a screening tool for sites being evaluated for real-estate transactions, and as a means to assess the progress of remediation over time. Soil-gas surveys are generally inappropriate for detecting water-soluble VOCs such as ketones, alcohols, and MTBE, many but not all semi-volatile organic compounds, any mineral-oil-based or water-soluble cutting oils, lubricating oils, greases, pesticides, or PCBs.

An **active** soil-gas survey consists of extracting representative "whole-air" samples of the actual soil gas into airtight sample bags or vessels (e.g., Tedlar® bags) and screening the samples on a gas chromatograph (GC). Active surveys may involve submitting the samples for laboratory analysis or using a portable, on-site GC to screen the samples immediately upon collection. This capacity is useful in situations where real-time data is a high priority.

A **passive** soil-gas survey consists of using passive, adsorptive soil-gas screening modules (e.g., Gore-Sorber™, Emflux®, etc.) which are installed in the ground for a fixed time period and retrieved in accordance with the manufacturer's recommendations. In passive surveys, no actual soil gas is removed from the ground. Instead, the sensor modules are installed in the ground and left for a period of 1 to 2 weeks during which time they adsorb VOCs from the soil gas. The modules are then retrieved and submitted for laboratory analysis. Passive surveys are more sensitive because they integrate the sampling over a period of time. They facilitate detection on sites with low soil permeability and they can "smooth" weather-related fluctuations in soil gas availability.

Soil gas survey methods continue to evolve over the years. There are currently a number of methods on the market; passive methods such as Emflux® and Gore-Sorber™ and active methods such as Geoprobe® sampling systems. In specific cases, it may be desirable to collect and screen soil-vapor samples in a manner consistent with a previous survey conducted on the site so as to facilitate data comparison. Alternatively, it may be desirable to employ a method that offers greater sensitivity, better detection of a specific target analyte, depth-profiling capability, or lower cost. Therefore, the practitioner is advised to consider which method will most effectively meet the project goals, allowing for developments in methods over time and site-specific conditions.

This FMG, in general terms, provides a generic protocol for performing passive soil-gas screening. Specific methodologies associated with methods such as the Gore-Sorber™ and Emflux® systems have also been incorporated into this FMG, based on their successful usage. These methods are patented, flexible, cost-effective, relatively simple to deploy, sensitive to a wide range of VOCs, give mass-spectral detection of target VOCs and unknowns, and give reproducible results over time.

PROCEDURES REFERENCED

- FMG 1.3 - Utility Clearance.
- FMG 6.10 - Sample Handling and Shipping.
- FMG 8.0 - Field Instruments – Use/Calibration.
- FMG 9.0 - Equipment Decontamination.

PROCEDURAL GUIDELINES

Generic procedures which apply to both passive or active soil vapor surveys are discussed in the following paragraphs, followed by discussion of specific procedures for passive and active screening.

All appropriate project plans should be consulted prior to performing the soil gas survey. Allowances should be made for all site access considerations, safety and personal protection considerations, gathering all necessary equipment, etc.

First, perform an underground utility check of private and/or public utilities for the area to be covered. If exact survey locations are predetermined then there is only the need to locate and mark out the specific locations.

If a generalized survey spanning a wider area is to be performed then a sampling grid must be established and the locations marked out across the survey area. Depending on the size of the coverage area a 25- to 75-foot sample spacing is usually sufficient to provide meaningful contouring of the sample results. Stagger the sample points along adjacent gridlines to provide optimal coverage with the fewest number of samples. Use transect lines of samples for covering large areas or for surveys where complete grids are unfeasible or unnecessary.

Passive Soil-Vapor Screening Survey

Passive soil vapor systems operate on the premise of adsorption of contaminants by small adsorptive modules composed of proprietary, patented, or highly-specialized materials which are unique to the manufacturer. These materials generally repel water in the subsurface but allow free passage of organic vapors which adsorb onto the modules.

A probe hole is advanced with a small diameter slide-hammer (slam-bar) probe or other rod-type probe to a shallow depth (typically 2 to 4 feet) into the soil. Pilot holes would need to be advanced through concrete, asphalt, or other solid surface seals, if present. The probe hammer or bar is manually driven probe to its full depth into the soils to form a pilot hole and then removed. A total organic vapor reading is then taken from down inside the open probe hole using a PID or FID organic vapor detector, or an equivalent instrument. Record the reading on Form FMG 1.2-01 - Soil Vapor Sampling Log.

The modules are emplaced in the soil borehole in accordance with the manufacturer's recommendations. The holes are then usually sealed off from the atmosphere with a cork, hydrated bentonite granules, or other non-VOC-containing sealant and the modules are allowed to remain in place for a fixed period of time, as specified by the manufacturer's requirements. Volatile organic constituents, if present within the soil-vapor, are passively adsorbed onto the modules.

Records will be kept regarding sample name and location, module serial number, time of installation, installation depth, and organic vapor reading on the forms provided.

After the appropriate length of time the adsorptive portion of the module is then retrieved and sent to the manufacturer. The manufacturer then forwards the modules to an internal, or external, qualified laboratory for contaminant analysis and quantification by thermal desorption/gas chromatography/mass spectrometry (TD/GC/MS), or equivalent methods. These methods also typically provide for quality assurance/quality control (QA/QC) samples in the form of blank samples that are submitted for analysis but, instead of being emplaced in the subsurface as a field sample would, are subjected only to surface atmospheric exposures. This evaluates the effects of environmental cross-contamination during handling, transportation, and pre-deployment.

The manufacturers can typically provide the results of the survey, allowing the Project Manager to interpret and plot the data as desired. Alternatively, the manufacturer may also contour and plot the data using its own evaluative tools. In such cases the manufacturer may require a site plan be sent to them with the sample locations and module serial numbers labeled. The manufacturer will plot the data on the map provided and prepare a concentration results map, with input from the Project Manager who reviews the data and selects the VOC compounds to be depicted on the final concentration contour map. Either scenario may be implemented.

Active Soil Gas Screening Survey

Apply the same pre-survey procedures to the active soil vapor survey. For conducting an active soil-gas survey, a decontaminated steel probe is advanced using any applicable method to create a probe hole (power hammer, slam-bar, contracted Geoprobe® system, etc.). A length of clean, flexible tubing (typically polyethylene plastic, Teflon, or Tygon) is inserted into the probe hole and sealed around the probe hole at the ground surface using hydrated bentonite clay to prevent short-circuiting of atmospheric air down into the hole. Soil-vapor is drawn up through the probe using a small vacuum pump or an evacuation chamber sampler (e.g., SKC's Vac-U-Chamber, Pelican® case, or equivalent) and directly injected into a sample bag or vessel (e.g., Tedlar® bag) which is connected to the down-probe line using Teflon and Tygon tubing at the surface.

An alternative method for this procedure entails using a steel tube that is perforated near the tip which remains down the probe hole and is similarly sealed at the surface. The vapor sample is then drawn through this tube, as opposed to placing temporary plastic tubing into the hole and drawing the vapor through it. This also requires various related fittings and locking ends to properly join the metal and plastic tubes.

In addition, this procedure can either be performed manually (utilizing manual installation of the appropriate steel sampling tubes, etc.) or can be performed using a Geoprobe® system operated by a contractor who is experienced in this procedure. This method operates on the same basic principals as if performed manually, only it is operated using a single, fully-functional, self-contained unit that performs all aspects of the procedure.

The initial soil-gas sample drawn from the sample probe will also first be screened using a PID or FID organic vapor detector meter (or equivalent) to obtain an initial estimate of VOC vapor concentrations, and the number will be recorded on the field sampling log.

The initial sample serves to purge the small amount of atmospheric air present in the sampling tube when it is installed and to equilibrate the sampling vessel with the soil-vapor (for this reason this initial sample will not be screened for VOCs by GC). The initial sample also serves to reduce the effects of any potential cross-contamination. A second sample is obtained using the same methods as above and submitted for GC screening. Any sample vessels collected shall be labeled with the date, time, and location of the sample. The sample vessel will be placed in a room-temperature cooler or other sturdy container for physical protection and analyzed using a GC within a maximum holding time of 24 hours.

Sampling, collection, and screening procedures are expected to be carried out by personnel with sufficient experience; accordingly, this FMG does not cover the details of their use. Screening of samples using a portable or laboratory GC will only be performed by personnel with extensive experience in GC operation. Alternatively, the samples may be submitted to a contract laboratory for analysis of volatile organics by an appropriate GC/MS method such as USEPA 8260 or others, as specified in the project Work Plan.

Common target VOCs for field screening during soil-gas surveys include:

- Vinyl Chloride.
- Methylene Chloride.
- Trichloroethene (TCE).
- Tetrachloroethene (PCE).
- 1,1,1-Trichloroethane (1,1,1-TCA).
- 1,1-Dichloroethene (1,1-DCE).
- trans-1,2-Dichloroethene (t-1,2-DCE).
- cis-1,2-Dichloroethene (c-1,2-DCE).
- BTEX compounds.
- Stoddard solvent.
- Site-specific test fuels.

The list of target analytes for field screening may be expanded to include additional or site-specific target compounds, as necessary.

A number of conditions exist with respect to the on-site or in-house GC screening analysis process which require an advanced level of experience to guarantee quality data. As such, only an experienced operator should be responsible for data analysis.

EQUIPMENT/MATERIALS

For All Soil Gas Surveys:

- Site base map to scale.
- Site utility interference maps.
- 100- or 300-foot measuring tape.
- Water-based, non-VOC-containing marker paint.
- Slide hammer probe (slam bar), heavy duty, or equivalent, or
- Powered percussion drill or hammer and bits/tips.
- Electric extension cord.

- Ground-fault interrupter.
- Portable generator (if needed).
- Passive adsorbent modules.
- Corks, strings, insert or retrieval devices, and miscellaneous supplies.
- PID or FID organic vapor detector meter, or equivalent.
- Clipboard and pen.
- Sampling log.
- Insulated cooler (for sample retrieval).
- Personal protective materials.
- Decontamination equipment.
- Scissors.
- Broom and dustpan.
- Portland cement (or fast-setting cement), trowel, and can and stir stick.

Include for Active Soil Vapor Survey:

- Perforated stainless steel sampling tubes, with fittings.
- various length and diameter tubing (e.g., Tygon, Teflon, etc.).
- Sample vessels (e.g., Tedlar® bags).
- Evacuation chamber (allows direct filling of air sample bags using negative pressure).
- Hydrated granular bentonite clay.

REFERENCES

The Gore-Sorber® Screening Survey Guide to Passive Soil Gas Surveys, ©1995 W.L. Gore & Associates, Inc., Elkton, Maryland 21922.

Gore-Sorber® Screening Survey Options; Gore options A2 (BTEX, fuel hydrocarbons, and TPH); A10 (17 chlorinated solvents); A1 (25 Standard Target VOCs/SVOCs); A4 (32 Target VOCs/SVOCs); A6 (Target VOCs/SVOCs and Explosives).

Geoprobe Systems® Equipment and Tools Catalog: Hydraulic Probing Machines, Mobile Laboratories, Small Diameter Sampling Tools, current edition, Corporate Headquarters: Salina, KS 67401, 913-825-1842.

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FMG 1.3-01 PROPERTY ACCESS/UTILITY CLEARANCE RECORDS

FMG 1.3–02 UTILITY CLEARANCE CHECKLIST (ACTIVE FACILITIES)

UTILITY CLEARANCE

INTRODUCTION

Invasive field investigation activities such as drilling, soil gas surveys, test excavation or remedial construction activities require location of underground utilities prior to initiating work. Such clearance is sound practice in that it minimizes the potential for damage to underground facilities and more importantly, is protective of the health and safety of personnel. Under no circumstances will invasive activities be allowed to proceed without obtaining proper utility clearance by the appropriate public agencies and/or private entities. **This clearance requirement applies to all work on both public and private property, whether located in a dense urban area or a seemingly out-of-the-way rural location.**

The responsibility of obtaining this clearance lies with the Consultant or Contractor performing the work.

In most states such utility clearance is required by law, and obtaining clearance includes contacting a public or private central clearance agency via a "one-call telephone service and providing them with proposed exploration location information. This is discussed in more detail herein. It is important to note that public utility agencies may not, and usually don't have information regarding utility locations on private property. As such, utility clearance on GM plant property must be cleared using available site drawings, and written approval must be obtained from plant personnel with appropriate knowledge of existing utilities. In the event the utility clearance is required for an active facility, the Facility Area Manager (FAM) will be the single source of contact for utility clearances.

PROCEDURES REFERENCED

- FMG 1.1 - Interior and Exterior Inspections.
- FMG 1.2 - Soil-Gas Surveys (Passive and Active).
- FMG 2.0 - Subsurface Investigations.
- FMG 4.1 - EM Survey.

PROCEDURAL GUIDELINES

- Before marking any proposed exploration or underground construction locations, it is critical that all readily available information on underground utilities and structures be obtained. This includes publicly available information as well as information in the possession of private landowners. Any drawings obtained must be reviewed in detail for information pertaining to underground utilities. The FAM will be the single point of contact for utility clearances at active facilities. At active facilities Form FMG 1.3-02 - Utility Clearance Checklist (Active Facilities) will be completed.
- Using the information obtained, the site should be viewed in detail for physical evidence of buried lines or structures, including pavement cuts and patches, variation in or lack of vegetation, variations in grading, etc. (Care must also be taken to avoid overhead utilities as well.) Presence of surface elements of buried utilities should be documented, such as manholes, gas or water service valves, catch basins, monuments, or other evidence.
- Overhead utility lines must be taken into account when choosing exploration and excavation locations. Most states require a minimum of 10 feet of clearance between equipment and energized wires. Such separation requirements may also be voltage-based and may vary depending on state or municipality regulations.
- In evaluating clearance from overhead lines, the same restrictions may apply to "drops", or wires on a utility pole connecting overhead and underground lines.
- Using the information obtained and observations made, proposed exploration or construction locations should be marked in the field. Marking locations can be accomplished using spray paint on the ground, stakes, or other means. **All markings of proposed locations should be made in white**, in accordance with the generally accepted universal color code for facilities identification (AWMA 4/99):
  - White: Proposed Excavation or Drilling Location.
  - Pink: Temporary Survey Markings.
  - Red: Electrical Power Lines, Cables, Conduit, and Lighting Cables.
  - Yellow: Gas, Oil, Steam, Petroleum, or Gaseous Materials.
  - Orange: Communication, Alarm or Signal Lines, Cables, or Conduits.
  - Blue: Potable Water.
  - Purple: Reclaimed Water, Irrigation, and Slurry Lines.
  - Green: Sewers and Drain Lines.
- In order to effectively evaluate the proposed locations with these entities, detailed, accurate measurements between the proposed locations and existing surface features should be obtained. Such features can be buildings, street intersections, utility poles, guardrails, etc.

- Obtaining the utility clearance generally involves two entities:
  - The designated "one-call" underground facilities protection organization for the area; and
  - The landowner.

  Both entities must be contacted and the proposed locations evaluated in light of information available for existing underground facilities. The detailed measurement information described above will be required by the "one call" agency. The owners of the applicable, participating, underground utilities are obligated mark their respective facilities at the site in the colors described above. Utility stake-out activities will typically not commence for approximately 72 hours after the initial request is made.

- The public and private utility entities generally only mark the locations of their respective underground facilities within public rights-of-way. Determination of the locations of these facilities on private property will be the responsibility of the project Consultant or Contractor. If available information does not contain sufficient detail to locate underground facilities with a reasonable amount of confidence, alternate measures may be appropriate, as described below. In some cases, the memory of a long-time employee of a facility on private property may be the best or only source of information. It is incumbent on the Consultant or Contractor to exercise caution and use good judgement when faced with uncertainty.

> *Note: It is important to note that not all utilities are participants in the "one-call" agency or process. As such, inquiries must be made with the "one-call" agency to determine which entities do not participate, so they can be contacted independently.*
>
> *Most utility stake-outs have a limited time period for which they remain valid, typically 2 to 3 weeks. It is critical that this time period be taken into account to prevent expiration of clearance prior to completion of the invasive activities, and the need to repeat the stake-out process.*

- Care must be exercised to document receipt of notice from the involved agencies of the presence or absence of utilities in the vicinity of the proposed locations. FMG 1.3-01 - Property Access/Utility Clearance Data Sheet can be used to record contacts made and responses received from each entity.

  Most agencies will generally provide a telephone or fax communication indicating the lack of facilities in the project area. **If contact is not made by all of the agencies identified by the "one-call" process, do not assume that such utilities are not present. Re-contact the "one-call" agency to determine the status.**

- For complicated sites with multiple proposed locations and multiple utilities, it is advisable to arrange an on-site meeting with utility representatives. This will minimize the potential for miscommunication amongst the involved parties.

- Completion of the utility stake out process is not a guarantee that underground facilities will not be encountered in excavations or boreholes; in fact, most "one-call" agencies and individual utilities do not offer guarantees, nor do they accept liability for damage that might occur. Accordingly, it is advisable that any invasive activities proceed with extreme caution in the upper 4 to 5 feet in the event the clearance has failed to identified an existing facility. This may necessitate hand-excavation or probing to confirm potential presence of shallow utilities. If uncertainty exists for any given utility, extra activities can be initiated to solve utility clearance concerns. These options include:

- Hand digging, augering or probing to expose or reveal shallow utilities and confirm presence and location. In northern climates this may require advancing to below frost line, typically at least 4 feet.
- Screening the proposed work areas with utility locating devices, and/or hiring a utility locating service to perform this task. The private utility locating service is a growing industry that has formed a national organization. The National Utility Locate Contractors Association (NULCA) can be reached at 715-635-6004.

EQUIPMENT/MATERIALS

- White spray paint.
- Wooden stakes, painted white or containing white flagging.
- Color-code key.
- Available drawings.
- Form FMG 1.3-01 - Property Access/Utility Clearance Data Sheet and Form FMG 1.3-02 - Utility Clearance Checklist (Active Facilities).

REFERENCES

American Public Works Association, April 1999, Uniform Color Code (http://www.apwa.net/).

PROPERTY ACCESS/UTILITY CLEARANCE DATA SHEET

PROJECT NAME: ______________________ PROJECT NUMBER: __________

GENERAL MOTORS REPRESENTATIVE: ______________________

__________________ __________________ PHONE: __________

ON-SITE PROPERTY ACCESS APPROVAL ______________________ (OWNER OR AUTHORIZED AGENT SIGNATURE)

OFF-SITE PROPERTY ACCESS APPROVAL (if applicable) ______________________ (OWNER OR AUTHORIZED AGENT SIGNATURE)

UTILITY CLEARANCE APPROVAL ______________________ (OWNER OR AUTHORIZED AGENT SIGNATURE)

CONTRACTOR VERIFICATION APPROVAL ______________________ (OWNER OR AUTHORIZED AGENT SIGNATURE)

UTILITIES (INDICATE THAT LOCATION/UTILITY PRESENCE WAS CHECKED) *												
Borehole/ Excavation Location	Date (m/d/y)	Telephone	Water	Storm Sewer	Sanitary Sewer	Process Sewer	Gas	Electrical	Cable	Overhead Utilities	Other	Comments/Warnings

Additional Comments:

____

____

____

White: Field Office
Yellow: Field File
Pink: Owner/Client/Agent

* Note as appropriate, Contractor, Client or Owner, or Agent to sign, indicating no utilities are at the selected borehole/excavation locations.

UTILITY CLEARANCE CHECKLIST (ACTIVE FACILITIES)

Prior to excavating or penetrating (i.e., soil boring, wells, Geoprobe, etc.) soil on General Motors (GM) property, it is necessary to check for underground utilities that may be routed through the area in question. The following process is recommended:

1. Process is intended only for locating utilities on GM property.
2. Utilities of concern include, but are not limited to, the following:
   - storm and sanitary sewers, drain tiles, gas, electric, telephone, city water, steam, condensate, process waste, and other process piping.
3. Underground structures such as foundations, tunnels, etc. also require location and identification.
4. Review all site utility, mechanical, electrical, and foundation drawings for the area in question.
5. Interview site personnel familiar with the area; the Facilities Manager should be contacted at the minimum.
6. Visually inspect area in question, with a representative from the GM property, assigned by the Facilities Manager.
7. Look for disruptions in pavement or flooring indicating a trench.
8. Look for manholes, pipe risers, catch basins, fire hydrants, post indicator valves, etc. (PIVs and hydrants are located above a pipe, but don't assume it is the main line. Most often they are above a lateral line.)
9. Check adjacent buildings or structures for locations of utilities entering the ground. In buildings look for services adjacent to machines.
10. Compare the drawings with observations in the field.
11. A pipe and cable locator device should be used to help verify physical location of utilities shown on drawings.
12. Call the following if uncertain of the location of a public utility. They will have maps of storm, sanitary, water, etc. They will also mark the utility's location:
    - local electric, gas, or telephone companies, contract service, municipal or city water departments and/or engineering departments.
13. Evaluate safety needs and develop a safe operating procedure (SOP).
14. Dig a test pit when utility location cannot be absolutely determined.
15. Identify the utility(s) and mark location.
16. Update record drawings when discrepancy identified in the field.

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DATA RECORDING – FIELD BOOKS/DIGITAL RECORDING

INTRODUCTION

This procedure describes protocol for documenting standard investigation activities in the field. Field data serves as the cornerstone for an environmental project, not only for site characterization but for additional phases of investigation or remedial design. Inaccurate or incomplete field data may create significant problems and additional project costs. In addition, recorded field data becomes a legal record of project work, and should be approached with that in mind. Producing legally defensible data includes proper and appropriate recording of field data as it is obtained in a manner that will preserve it for future use.

This procedure provides guidelines for accurate, thorough collection and preservation of written and electronic field data.

PROCEDURES REFERENCED

- FMG 8.0 - Field Instruments – Use/Calibration.

PROCEDURAL GUIDELINES

Typical field data to be recorded generally includes, but is not limited to, the following:

- General field observations.
- Numeric field measurements and instrument readings.
- Quantity estimates.
- Sample locations and corresponding sample numbers.
- Relevant comments and details pertaining to the samples collected.
- Documentation of activities, procedures, and progress achieved.
- Contractor pay item quantities.
- Weather conditions.
- A listing of personnel involved in site-related activities.

- A log of conversations, site meetings, and other communications.
- Field decisions made and pertinent information associated with the decisions.

Written Field Data

Written field data is generally recorded on one of two media: a standardized, pre-printed field log form, or a bound field log book. In general, use of a field log form is preferable as it prompts field personnel to make appropriate observations and record data in a standardized format. This promotes completeness and consistency from one person to the next. Most of the General Motors (GM) FMGs include standardized field log forms.

In the absence of an appropriate pre-printed form, the data should be recorded in an organized and structured manner in a dedicated project field log book. Log books must be hard-cover, bound so that pages cannot be added or removed, and should be made from high-grade 50 percent rag paper with a water-resistant surface.

The following are guidelines for use of field log forms and log books:

1. Information must be factual and complete. Do not abbreviate.
2. All entries will be made in black indelible ink with a ballpoint pen and will be written legibly. Do not use "rollerball" or felt tip-style pens, since the water-soluble ink can run or smear in the presence of moisture.
3. All pages in a log book must be consecutively numbered. Field log forms should also be consecutively numbered.
4. Each day's work must start a new log book page.
5. At the end of each day, the current log book page must be signed and dated by the field personnel making the entries.
6. When using field log forms, they must also be signed and dated.
7. Make data entries immediately upon obtaining the data. Do not make temporary notes in other locations for later transfer to log forms or log books; this only increases the potential for error or loss of data.
8. Entry errors are to be crossed out with a single line, dated, and initialed by the person making the correction.
9. Do not leave blanks on log forms, if no entry is applicable for a given data field, indicate so with "NA" or a dash ("--").
10. At the earliest practical time, photocopies of log forms and log book pages should be made and placed in the project file as a backup in the event the book or forms are lost or damaged.
11. Log books should be dedicated to one project only, i.e., do not record data from multiple projects in one log book.

Electronic Data

Electronic data recording is widely used in environmental investigation and remediation projects. In general, it involves electronic measurement of field information through the use of monitoring instruments, sensors, gauges, and equipment controls. The following is a list of guidelines for proper recording and management of electronic field data:

1. Field data management should follow requirements of a project-specific data management plan (DMP), if one exists.
2. Use only instruments that have been calibrated in accordance with manufacturer's recommendations.
3. Usage of instruments, controls, and computers for the purpose of obtaining field data should only be performed by personnel properly trained and experienced in the use of the equipment and software.
4. Use only fully licensed software on PCs and laptops. Software piracy, even if unintentional, is a felony and exposes GM, its contractors, and their employees to severe criminal and financial penalties.
5. Loss of electronic files may mean loss of irreplaceable data. Every effort should be made to back up electronic files obtained in the field as soon as practical. A backup file placed on a disk and kept in a separate location from the original will minimize the potential for loss.
6. Electronic files, once transferred from field instruments or laptops to office computers, should be protected if possible to prevent unwanted or inadvertent manipulation or modification of data. Several levels of protection are usually available for spreadsheets, including making a file "read-only" or assigning a password to access the file.
7. Protect floppy disks from exposure to moisture, excessive heat or cold, magnetic fields, or other potentially damaging conditions.
8. Remote monitoring is often used to obtain stored electronic data from site environmental systems. A thorough discussion of this type of electronic field data recording is beyond the scope of this FMG. Such on-site systems are generally capable of storing a limited amount of data as a comma-delimited or spreadsheet file. Users must remotely access the monitoring equipment files via modem or other access, and download the data. In order to minimize the potential for loss of data, access and downloading of data should be performed frequently enough to insure the data storage capacity of the remote equipment is not exceeded.

EQUIPMENT/MATERIALS

- Five by seven-inch National 407 Field Book, with high-grade 50 percent rag paper with water-resistant surface, hard-cover, or equivalent.
- Appropriate field log forms.
- Indelible ball point pen (do not use "rollerball" or felt-tip style pens).
- Straight edge.
- Pocket calculator.
- Laptop computer (if required).

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DRILLING TECHNIQUES

INTRODUCTION

This section will provide a brief description of common methods for conducting subsurface investigations. It should be noted that every drilling technology has its limitations.

PROCEDURES REFERENCED

- FMG 2.3 - Soil Borings.
- FMG 2.4 - Bedrock Coring.
- FMG 2.6 - Soil Classification.
- FMG 2.7 - Rock Classification.
- FMG 3.2 - Overburden Wells.
- FMG 3.3 - Top of Bedrock Wells.
- FMG 3.4 - Deep Bedrock Wells.
- FMG 3.6 - Piezometers.

PROCEDURAL GUIDELINES

It is important that the drilling method or methods used minimize disturbance of subsurface materials and not contaminate the subsurface and groundwater. The actual drilling method would be dependent upon site-specific geologic conditions. It is important to note that the drilling equipment selected be decontaminated before and between borehole locations to prevent cross contamination (see FMG 9.0 - Equipment Decontamination). Where possible drilling methods that minimize waste generation (soil cuttings), and wastewater generation (decontamination water), should be selected for GM Remediation Team investigation/remedial tasks.

In other settings it may be desirable to dictate drilling procedures that minimize turbidity/maximize the ability to achieve sediment-free groundwater. Generally, rotosonic techniques or rotary spun casing techniques achieve these objectives, or oversizing the borehole/sand pack may be considered, as well.

Rotosonic Drilling

This method consists of a combination of rotation with high frequency vibration to advance a core barrel to a desired depth. Once the vibration is stopped, the core barrel is retrieved, and the sample is vibrated or hydraulically extracted into plastic sleeves or sample trays. Monitoring wells shall be installed through the outer casing with minimal formation disturbance and mixing of formation materials. Rotosonic drilling generally requires less time than more traditional methods and minimizes soil mixing and soil disturbance (preferred for well locations where low turbidity is an important objective). Continuous, relatively undisturbed samples can be obtained through virtually any formation. Conventional sampling tools can be employed as attachments (i.e., hydropunch, split spoon, Shelby tube, etc.). No mud, air, water, or other circulating medium is required. The rotosonic method can drill easily through formations such as rock, sand, clay, or glacial till. The main limitation of this method is the availability of equipment, the large area required (i.e., drill units are quite large), and costs.

Direct-Push (Geoprobe™)

Direct-push refers to the sampler being "pushed" into the soil material without the use of drilling to remove the soil. This method relies on the amount of the drill weight combined with percussion for advancement of the tool string. Discrete soil samples are continuously obtained as well groundwater and vapor samples can also be collected utilizing this method. Subsurface investigations typically probe to depths of 30 feet or more, depths will vary based on site-specific geology.

Direct-push method is widely used for UST investigations and property investigations. This method is used extensively for initial site screening activities to delineate vertical and horizontal plume presence and can significantly reduce investigative costs.

This method is becoming more popular due to the limited cuttings that are produced during the sampling process and the sampling process speed.

The use of the Geoprobe™ 6600 also allows for the installation of 2-inch diameter monitoring wells in that the 4 1/4-inch hollow-stem auger method can be utilized.

Rotary Method

This method consists of a drill rod attached to a drill bit (soils: tricone, drag; rock: button studded, diamond studded) that rotates and cuts through the soils and rock. The cuttings produced are forced to the surface between the borehole wall and the drill rod by drilling fluids which generally consist of water, drilling mud, or air. The drilling fluids not only force the cuttings to the surface but also keep the drilling bit cool. Using rotary methods for well installations can be difficult as it usually requires several steps to complete the installation. First, the borehole is drilled; then temporarily cased; then the well is installed; and then the temporary casing is removed. In some cases, the borehole may remain open without installing a casing but this will only occur in limited instances (i.e., cohesive soils).

i) Water Rotary

When using water rotary, the potable water supply shall be analyzed for contaminants of concern. Water rotary is the preferred rotary method since the potable water is the only fluid introduced into the borehole during drilling. However, the use of water as a fluid is generally only successful when drilling in cohesive soils. The use of potable water (only) also reduces well development time, when compared to mud rotary.

ii) Air Rotary (typically used in rock)

When using air rotary, the air compressor must have an in-line oil filter system assembly to filter the oil mixed with the air coming from the compressor. This will help eliminate contaminant introduction into the formation. The oil filter system shall be regularly inspected. Air compressors not having an in-line oil filter system are not acceptable for air rotary drilling. A cyclone velocity dissipater or similar air containment system shall also be used to funnel the cuttings to one location rather than letting the cuttings blow uncontrolled out of the borehole. Air rotary may not be an acceptable method for well installation where certain contaminants are present in the formation. Alternatively, it may be necessary to provide treatment for the air being exhausted from the borehole during the installation process.

iii) Mud Rotary

Mud rotary is the least preferred rotary method because contamination can be introduced into the borehole from the constituents in the drilling mud (i.e., Ohio, Michigan). The drilling muds are generally non-toxic and do not introduce contaminants into the borehole, however, it is possible for mud to commonly infiltrate and affect water quality by sorbing metals and polar organic compounds (Aller et al., 1991). Chemical composition and priority pollutants analysis may be obtained from the manufacturer. Mud rotary shall utilize only potable water and pure (no additives) bentonite drilling muds. The viscosity of the drilling mud shall be kept as low as possible in order to expedite well development. Proper well development is essential to ensure the removal of all the drilling mud and to return the formation to its previously undisturbed state.

<u>Hollow-Stem Auger</u>

The hollow-stem continuous-flight auger is among the most frequently used in the drilling of monitoring wells (overburden wells) or for placement of overburden casings for bedrock wells.

The primary advantages of hollow-stem augering are that:

- Generally, no additional drilling fluids are introduced into the formation.

- Representative geologic soil samples can be easily obtained using split-spoon samples in conjunction with the hollow-stem augers.
- Monitoring wells can be installed through the augers eliminating the need for temporary borehole casings.

Disadvantages of hollow-stem augering are:

- Creates problems for select parameters.
- Large volumes of cuttings are typically generated.
- Decontamination is fairly time consuming/labor intensive.
- Relatively slow when compared to direct-push methods (soil sampling tasks).

Installing monitoring wells through hollow-stem augers is a relatively simple process although precautions need to be taken to ensure that the well is properly backfilled. This can be particularly problematic in cases where flowing sand is present.

Hollow-stem augers are available with inside diameters of 2.5, 3.25, 4.0, 4.25, 6.25, 8.25, and 10.25 inches. The most commonly used are 4.25 inches for 2-inch (5 cm) monitoring wells and 6.25 inches for 4-inch (10 cm) monitoring wells. Boreholes can usually be drilled with hollow-stem augers to depths up to 100 feet (30 m) in unconsolidated clays, silts, and sands. Removing augers in flowing sand conditions while installing monitoring wells may be difficult since the augers have to be removed without being rotated. A bottom plug or pilot bit assembly should be utilized to keep out soils and/or water that have a tendency to plug the bottom of the augers during drilling. If flowing sands are encountered, potable water (analyzed once for contaminants of concern) may be poured into the augers to equalize the pressure to keep the formation materials and water from coming up into the auger once the bottom plug is removed.

<u>Dual-Wall Reverse Circulation Air Method of Drilling</u>

This method consists of two concentric strings of drill pipe (an outer casing and a slightly smaller inner casing). The outer drill pipe is advanced using rotary drilling with a donut-shaped bit attached to the dual casing string cuts an area only the width of the two casings and annulus between. Compressed air is continually forced down the annulus between the inner casing carrying the drill cuttings and groundwater. At the surface, the inner casing is connected to a cyclone hopper where the drill cuttings and groundwater fall out the bottom of the hopper, and air is disbursed out the top. The dual wall provides a fully cased borehole in which to install a monitoring well. The only soil or groundwater materials exposed at any time are those at the drill bit. Therefore, the potential for carrying contamination from one stratum to another is minimal. Depth-specific groundwater samples can be collected during drilling; however, since the groundwater is aerated, analysis for volatile compounds may not be valid.

Well Points

In some limited cases, well points (sand points) are driven into place without the use of augers. This method provides no information on the geologic condition (other than the difficulty of driving which may be related to formation density). Well points are most often used simply to provide dewatering of a geologic unit prior to excavation in the area. Well points are also used in monitoring shallow hydrogeologic conditions such as in stream beds.

REFERENCES

Numerous publications are available describing current monitoring well design and construction procedures.

Driscoll, F.G., 1986. Groundwater and Wells, 2nd Edition. Johnson Division.

EPA/625/6-90/0166 (July 1991), Handbook Ground Water Volume II: Methodology.

Freeze, R.A. and Cherry, J.A., 1979. Groundwater. Prentice Hall, Inc.

National Water Well Association, 1989. Handbook of Suggested Practices for the Design and Installation of Groundwater Monitoring Wells.

Environmental Protection Agency (1986), RCRA Groundwater Monitoring Technical Enforcement Guidance Document, OSWER-9950.1.

In addition, the following ASTM publications apply:

ASTM D5474	Guide for Selection of Data Elements for Ground-Water Investigations
ASTM D5787	Practice for Monitoring Well Protection
ASTM D5521	Guide for Development of Ground-Water Monitoring Wells in Granular Aquifers
ASTM D5978	Guide for Maintenance and Rehabilitation of Ground-Water Monitoring Wells
ASTM D5299	Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes and Other Devices for Environmental Activities
ASTM D5092	Standard Practice for Design and Installation of Ground Water Monitoring Wells in an Aquifer.

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SOIL BORINGS

INTRODUCTION

The following presents a description of the methods generally employed for the installation of boreholes and the collection of subsurface soil samples. Boreholes are typically installed to define geologic conditions for hydrogeologic and geotechnical evaluation; to allow the installation of monitoring wells and piezometers; and to allow the collection of subsurface soil samples (generally above the water table) for chemical analysis.

Several manual methods are available for the collection of shallow subsurface soil samples (e.g., hand augers, post-hole augers, vibratory hammers). However, the most common methods used by GM to advance boreholes are rotosonic drilling techniques, hollow-stem augers (HSA), or the use of a direct-push equipment. Rotosonic drilling and direct-push techniques are preferred boring approaches at GM Facilities. FMG 2.2 - Drilling Techniques, provides insight into the advantages/disadvantages of these drilling methods.

PROCEDURES REFERENCED

- FMG 1.3 - Utility Clearance.
- FMG 2.2 - Drilling Techniques.
- FMG 2.6 - Soil Classification.
- FMG 2.7 - Rock Classification.
- FMG 6.1 - Soil.

PROCEDURAL GUIDELINES

The following activities must be undertaken prior to undertaking a borehole installation and subsurface soil sampling program.

i) Assemble all equipment and supplies required per the Work Plan.

ii) Obtain a site plan and any previous stratigraphic logs. Determine the exact number and location of boreholes to be installed and the depths of samples for chemical analysis.

iii) Contact the analytical group to arrange/determine:

- Laboratory;
- Glassware/sample jars;
- Cooler;
- Shipping details;
- Start date; and
- Expected duration.

iv) Establish borehole locations in field using available landmark or by surveying methods if necessary.

v) Arrange for utility clearance of franchised utilities and site utilities.

vi) Determine notification needs with the Project Manager. Have the regulatory groups, landowner, GM Facility personnel, and laboratory been informed of the sampling event?

vii) Determine the methods for handling and disposal of drill cuttings, wash waters, and spent decontamination fluids.

Once the prior planning and preparation activities are completed, the borehole installation and subsurface soil sampling program can proceed. The typical series of events which takes place is:

- Locating and marking of borehole locations (if not already completed).
- Equipment decontamination.
- Final visual examination of proposed drilling area for utility conflicts/final hand auger or post-hole check to verify utility absence.
- Advancement of borehole and collection of the soil sample.
- Field screening of soil sample.
- Description of soil sample. (Form FMG 2.6-01 - Stratigraphy Log - Overburden (Page 1/Page 2) will be used to record data.)
- Sample preparation and packaging.
- Abandonment of boreholes.
- Surveying of borehole locations and elevations.
- Field note completion and review.

i) <u>Locating and Marking of Boreholes/Final Visual Check</u>

The proposed borehole locations marked on the site plan are located in the field and staked. On most sites, this will likely be done several days in advance of the drill rig arriving on site. Unless boreholes are to be installed on a fixed grid, the proposed locations are usually strategically placed to assess site conditions.

Once the final location for the proposed boring has been selected and utility clearances are complete, one last visual check of the immediate area should be performed before drilling proceeds. This last visual check should confirm the locations of any adjacent utilities (subsurface or overhead) and verification of adequate clearance. If gravity sewers or conduits exist in the area, any access manholes or chambers should be opened and the conduit/sewer alignments confirmed. Do not enter manholes unless confined space procedures are followed.

ii) Borehole Advancement

If possible, it is prudent to use a hand auger or post-hole digging equipment to a sufficient depth to verify the absence of buried utilities and pipelines. This procedure should clear the area to the full diameter of the drilling equipment which will follow.

If it is necessary to relocate any proposed borehole due to terrain, utilities, access, etc., the Project Manager must be notified and an alternate location will be selected.

Prior to use and between each borehole location at an environmental site, the drilling and sampling equipment must be decontaminated. All decontamination must be conducted in accordance with the project-specific plans or the methods presented in FMG 9.0 - Equipment Decontamination.

The clean augers/tooling are covered with clean plastic sheeting to prevent contact with foreign materials. For geotechnical, geologic, or hydrogeologic studies where contaminants will not be present, it is sufficient to clean the drilling equipment simply by removing the excess soils.

Collection of soil samples is one of the most important considerations in selecting drilling methods. Therefore, the need for reviewing drilling techniques (FMG 2.2 - Drilling Techniques) and the Site objectives must first be considered. Soil Classification will be completed in accordance with FMG 2.6 - Soil Classification. Sections iii) and iv) describe borehole soil sampling procedures using direct-push tooling and HSA/split-spoon sampling (Standard Penetration Testing - SPT), respectively.

iii) Direct-Push/Macro-Core™ Soil Sampler

The operation of the direct-push/Macro-Core™ Soil Sampler (or equivalent) consists of "pushing" the sampler into the subsurface and then retrieving it using a direct-push soil probing machine. The collected soil core is contained within an internal soil liner (acetate, polyethylene, or teflon) and removed from the sampler once returned to the ground surface. Sampler length is variable depending on equipment available (2 feet, 4 feet, 5 feet). Once the soil liner has been removed and the outer sampler decontaminated, a new liner is inserted and the sampler reassembled. The clean sampler is then driven back down the same hole to collect the next soil sample.

The Macro-Core™ sampler can be used in either the open-tube or closed-point sampling mode. The open-core sample mode is most commonly used in stable soil conditions. In unstable soils, the piston rod point system prevents collapsed soil from entering the sampler as it is advanced back down the hole. Once at the sample depth, the piston rod is unthreaded and released. The sampler is then driven into the subsurface to fill the sampler with soil, the piston point rides on top of the soil, as it enters the sampler.

Once recovered the soil liner with collected soils is opened (cut lengthwise) and examined to collect soil screening information, soil logging information, and soils for chemical analysis.

iv) Standard Penetration Testing (SPT) Sampling and Testing Procedure

This method is used to obtain representative samples of subsurface soil materials and to determine a measure of the in situ relative density of the subsurface soils. The test methods described below must be followed to obtain accurate SPT values. The split spoon is typically driven in advance of an HSA string which allows collection of the disturbed but representative sample.

SPT sampling is performed by using a split barrel sampler in accordance with ASTM D1586. The split barrel sampler, or split spoon, consists of an 18- or 24-inch long, 2-inch outside diameter tube, which comes apart length wise into two halves. The split spoon is typically driven in advance of an HSA string which allows collection of the disturbed but representative soil sample.

Once the borehole is advanced to the target depth and the borehole cleaned of cuttings, representative soil samples are collected in the following manner:

- The split-spoon sampler should be inspected to ensure it is properly cleaned and decontaminated. The driving shoe (tip) should be relatively sharp and free of severe dents and distortions.
- The cleaned split-spoon sampler is attached to the drill rods and lowered into the borehole. Do not allow the sampler to drop onto the soil.
- After the sampler has been lowered to the bottom of the hole, it is given a single blow to seat it and make sure that it is in undisturbed soil. If there still appear to be excessive cuttings in the bottom of the borehole, remove the sampler from the borehole and remove the cuttings.
- Mark the drill rods in three or four successive 6-inch (0.15 m) increments, depending on sampler length, so that the advance of the sampler under the impact of the hammer can be easily observed for each 6-inch (0.15 m) increment.

The sampler is then driven continuously for either 18 or 24 inches (0.45 or 0.60 m) by use of a 140-pound (63.5 kg) hammer. The hammer may be lifted and dropped by either the cathead and rope method, or by using a trip, automatic, or semi-automatic drop system. The hammer should free-fall a distance of 30 inches (±1 inches) (760 mm, ±25 mm) per blow. Measure the drop at least daily to ensure that the drop is correct. To ensure a free-falling hammer, no more than 2 1/4 turns of the rope may be wound around the cathead (see ASTM D1586). The number of blows applied in each 6-inch (0.15 m) increment is counted until one of the following occurs:

- A total of 50 blows have been applied during any one of the 6-inch (0.15 m) increments described above;
- A total of 100 blows have been applied;
- There is no advancement of the sampler during the application of ten successive blows of the hammer (i.e., the spoon is "bouncing" on a stone or bedrock); or
- The sampler has advanced the complete 18 or 24 inches (0.45 or 0.60 m) without the limiting blow counts occurring as described above.

In some cases where the limiting number of blow counts has been exceeded, the Consultant may direct the driller to attempt to drive the sampler more if collection of a greater sample length is essential.

On the field form, record the number of blows required to drive each 6-inch (0.15 m) increment of penetration. The first 6 inches is considered to be a seating drive. The sum of the number of blows required for the second and third 6 inches (0.15 m) of penetration is termed the "standard penetration resistance" or the "N-value".

Note: If the borehole has sloughed and there is caved material in the bottom, the split spoon may push through this under its own weight, but now the spoon is partially "pre-filled". When the spoon is driven the 18 or 24 inches representing its supposedly empty length, the spoon fills completely before the end of the drive interval. Two problems arise:

1. *the top part of the sample is not representative of the in-place soil at that depth; and*
2. *the SPT value will be artificially higher toward the bottom of the drive interval since the spoon was packed full. These conditions should be noted on the field log.*

The sampler is then removed from the borehole and unthreaded from the drill rods. The open shoe (cutting end) and head of the sampler are partially unthreaded by the drill crew and the sampler is transferred to the geologist/engineer work surface.

Note: A table made out of two sawhorses and a piece of plywood is appropriate, or a drum, both covered with plastic sheeting.

The open shoe and head are removed by hand, and the sampler is tapped so that the tube separates.

Note: Handle each split spoon with clean disposable gloves if environmental issues are being investigated.

Measure and record the length of sample recovered making sure to discount any sloughed material that is present on top of the sample core.

Caution must be used when conducting SPT sampling below the groundwater table, particularly in sand or silt soils. These soils tend to heave or "blow back" up the borehole due to the difference in hydraulic pressures between the inside of the HSA and the undisturbed soil. To equalize the hydraulic pressure, the inside of the HSA must be filled with water or drilling mud. The drilling fluid level within the boring or HSAs needs to be maintained at or above the in situ groundwater level at all times during drilling, removal of drill rods, and sampling. Since heave or blow back is not always obvious to the driller, it is essential that the water level in the borehole always be maintained at or above the groundwater level.

Heaving conditions and the use of water or mud should be noted on the field logs.

SPT sampling below the water table in sands and silt occasionally results in low SPT values being obtained due to the heaving effect disturbing the soil especially if the water level in the hole has not been maintained at the in situ water level. Suspect low N values should be noted on the field logs. If it is critical to have accurate N values below the water table, other methods can be employed, such as conducting a dynamic cone penetration test. This quick and easy test involves attaching a cone shaped tip to the end of the drill rods, and driving the tip into the ground similar to the SPT method, except that the borehole is not pre-augered. Cones may be driven 20 to 40 feet through a formation without augering. Blow counts are recorded for each foot (0.3 m) of advancement.

A variation of split barrel sampling involves the use of a longer barrel in conjunction with HSAs. The sampling barrel is installed inside the auger with a swivel attachment to limit rotation of the barrel. After completion of a 5-foot auger penetration, the auger is left in place and the barrel retrieved from the borehole. The sampler should be handled and the sample retrieved in the same way as described above for SPT sampling.

Thin-Walled Samplers (Shelby Tubes)

Thin-walled samplers are used to collect relatively undisturbed samples (as compared to split-spoon samples) of soft to stiff clayey soils. Shelby tubes are commonly used. The Shelby Tube has an outside diameter of 2 or 3 inches and is 3 feet long. These undisturbed samples are used for certain laboratory tests of structural properties (consolidation, hydraulic conductivity, shear strength) or other tests that might be influenced by sample disturbance. Procedures for conducting thin-walled tube sampling are provided in ASTM D1587, and are briefly described below.

- The soil deposit being sampled must be cohesive in nature, and relatively free of sand, gravel, and cobble materials, as contact with these materials will damage the sampler.
- Clean out the borehole to the sampling elevation using whatever method is preferred that will ensure the material to be sampled is not disturbed. If groundwater is encountered, maintain the liquid level in the borehole at or above groundwater level during the sampling operation.
- Bottom discharge bits are not permitted. Side discharge bits may be used, with caution. Jetting through an open-tube sampler to clean out the borehole to sampling elevation is not permitted. Remove loose material from the center of a casing or HSA as carefully as possible to avoid disturbance of the material to be sampled.
- Place the sample tube so that its bottom rests on the bottom of the hole. Advance the sampler into the formation without rotation by a continuous and relatively rapid motion; usually hydraulic pressure is applied to the top of the drill rods.
- Determine the length of advance by the resistance and condition of the formation, but the length shall never exceed 5 to 10 diameters of the tube in sands and 10 to 15 diameters of the tube in clays.
- In no case should the length of advance be greater than the sample-tube length minus an allowance for the sampler head and a minimum of 3 inches for cuttings.
- The tube may be rotated to shear the bottom of the sample 2 to 3 minutes after pressing in, and prior to retrieval to ensure the sample does not slide out of the tube. Lift the weight of the rods off of the tube prior to rotating.
- Withdraw the sampler from the formation as carefully as possible in order to minimize disturbance of the sample.
- Package and transport the sample in accordance with FMG 6.10 - Sample Handling and Shipping.

On occasion it maybe required to extract the sample from the tube in the field.

- A sample extruder, which consists of a clamp arrangement to hold the tube and a hydraulic ram to push the sample through the tube, is usually mounted on the side of the rig. To prevent cross-contamination, be certain that the extruder is field cleaned between each sample.
- The sample is then extruded into a carrying tray; these are often made from a piece of 4-inch or 6-inch diameter PVC pipe cut lengthwise. Be certain that the carrying tray is field cleaned between each sample. The sample is carried to the work station to describe the sample, trim the potentially cross contaminated exterior, and place it in the appropriate container.
- The Shelby tube may then be thoroughly field cleaned and decontaminated for reuse. Since they are thin-walled, the tubes are easily damaged, crimped, or otherwise distorted during handling or pushing. The Shelby tube should be inspected before use and any which are significantly damaged should be rejected.

v) <u>Borehole Completion</u>

At the completion of the soil boring, once the soil/groundwater samples have been collected, the borehole annulus is then abandoned. Borehole abandonment options are identified in FMG 2.5 - Borehole Abandonment/Sealing. Each boring will be surveyed to establish vertical/horizontal information; field ties (i.e., swing ties) will also be collected to document the boring location. Once completed, a stratigraphic log will be prepared for reporting purposes.

EQUIPMENT/MATERIALS

- Drilling equipment.
- Form 2.6-01 - Stratigraphy Log - Overburden (Page 1/Page 2).
- Tape measure.

REFERENCES

ASTM D420-93 - Guide to Site Characterization for Engineering, Design, and Construction Purposes.

ASTM D1452-80 - Practice for Soil Investigation and Sampling by Auger Borings.

ASTM D1586-84 - Test Method for Penetration Test and Split-Barrel Sampling of Soils.

ASTM D1587-94 - Practice for Thin-Walled Tube Geotechnical Sampling of Soils.

ASTM D2488-93 - Practice for Description and Identification of Soils (Visual-Manual Procedure).

EPA OSWER-9950.1,1986. RCRA Ground-Water Monitoring Technical Enforcement Guidance Document.

National Water Well Association, Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells. 1989.

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REAL ESTATE & FACILITIES	EFFECTIVE DATE: MARCH 14, 2011
GENERAL MOTORS	
REVISION NO.: 0	REVISION DATE:

BEDROCK CORING

INTRODUCTION

The following procedures describes the methodology for bedrock coring.

PROCEDURES REFERENCED

- FMG 2.7 - Rock Classification.

PROCEDURAL GUIDELINES

- Prior to initiating coring activities, ensure that the overburden portion of the hole is isolated from the bedrock portion of the hole using an overburden casing routed in place.
- Coring must be performed utilizing an approved coring method and size, and performed with wire line coring techniques.
- Potable water or air can be utilized as circulating medium.
- If required, all rock cuttings produced will be properly contained and disposed of in accordance with the Work Plan requirements.
- All coring activities shall be performed following procedures outlined in ASTM D2113.
- Upon completion of the coring activities the core hole shall be flushed to remove all residual rock cuttings from the bottom of the corehole.
- All bedrock core runs should be completed without interruption so penetration rates can be determined.
- Upon completion of bedrock coring activities, the corehole shall be flushed to remove all residual bedrock cuttings and measured to confirm final depth.

EQUIPMENT/MATERIALS

- Drilling equipment.
- Appropriate coring equipment.

- Form FMG 2.7-01 - Bedrock Stratigraphic Log.
- Tape measure.
- Hand lense.
- Camera.
- Work Plan.
- Health and Safety Plan.

REFERENCES

American Society for Testing and Materials (1991) Standard D2113-8307 "Standard Practice for Diamond Core Drilling for Site Investigations" Annual Book of ASTM Standards, Section 4, Volume 04.08.

American Society for Testing and Material (1991) Standard D5434-93 "Standard Guide for Field Logging of Subsurface Exploration of Soil and Rock" Annual Book of ASTM Standards, Section 4, Volume 04.09.

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BOREHOLE ABANDONMENT/SEALING

INTRODUCTION

The following procedure describes common techniques for the abandonment/sealing of overburden boreholes. Borehole completion may have been performed by a rotosonic drilling technique, direct push sampling device, hollow-stem augering/split-spoon sampling, solid-stem augering, or other soil sample collection techniques. The method of borehole abandonment selected for a program will be dependent on a number of factors such as: depth to groundwater, presence of contamination (and degree of contamination i.e., light or dense non-aqueous phase liquids - NAPL), confining layer presence and/or physical setting (i.e., open field/vacant land, vs. facility setting). The Work Plan guiding these activities (soil boring/boring closure) will dictate which method of borehole abandonment/seating is required. Rotosonic drilling methods are often preferred for soil boring activities on GM Remediation Team sites where appropriate. The borehole abandonment/sealing techniques reviewed in the following consist of:

- Soil cutting backfill;
- Bentonite chip backfill; or
- Cement/bentonite grout backfill using tremie techniques.

Boreholes need to be abandoned and sealed properly to prevent surface water entry to the groundwater regime, to eliminate any physical hazard, and to prevent/protect groundwater movement from one aquifer to another.

PROCEDURES REFERENCED

- FMG 2.3 - Soil Borings.

PROCEDURAL GUIDELINES

Soil Cutting Backfill

Typically employed when working above groundwater table and at shallow depths (maximum depth 2 feet).

- The final depth of borehole will be measured and recorded.
- Cuttings are dropped into borehole after sample equipment is removed.
- Drill rod and/or probe rodding is used to compact/compress cuttings to allow return of all cuttings back into borehole.
- Mound final surface of cuttings above ground surface to allow settlement and promote surface water runoff away from boring. Final restoration will be completed in accordance with needs of the GM Facilities representative and /or the GM Remediation Team Project Manager.
- Borehole abandonment will be documented in field records/notes.

Bentonite Chip Backfill

Typically employed when working above or just into the groundwater table.

- Excess cuttings have been drummed for disposal or excess cuttings have been spread at ground surface.
- The depth of the borehole will be measured and recorded.
- Bentonite chips will be dropped into borehole as hollow-stem augers are removed, or after the boring equipment has been removed from the borehole (solid-stem auger, probing tools, split-spoon samplers).
- Sufficient water will be needed to hydrate bentonite chips as they are placed.
- The bentonite chip backfill will be extended to within 1 foot of ground surface, the final borehole space will be backfilled with native soil and mounded slightly to allow settlement and promote surface water runoff away from the boring. Alternatively, the borehole cuttings may be mixed with bentonite to complete the abandonment/sealing task. Final restoration will be completed in accordance with needs of the GM Facilities representative and/or the GM Remediation Team Project Manager.
- Borehole abandonment will be documented in field records/notes.

Cement/Bentonite Grout Backfill

Typically employed when working below the groundwater table, or in an area where a confining layer exists and the potential for groundwater/NAPL movement along a preferential pathway (i.e., former borehole) must be eliminated.

- The final depth of borehole will be measured and recorded.
- The volume of grout required will be calculated from the above measurements.

- A grout mix of one bag (94 pounds) of Portland cement and 3 pounds of bentonite with approximately 7.5 gallons of clean water will be prepared.
- Using a tremie tube placed at the base of the borehole the grout will be pumped until observed at the required elevation. The tremie tube will be raised as the grout level rises (positive displacement technique).
- The bentonite/grout backfill will be extended to within 1 foot of ground surface, the final borehole space will be backfilled with native soil and mounded slightly to allow settlement and promote surface water runoff away from boring. Final restoration will be completed in accordance with the GM Facility representative and/or the GM Remediation Team Project Manager.
- Borehole abandonment will be documented, noting depth of borehole, volume of grout used and mix ratio.
- Groundwater displaced from the borehole may or may not require containment depending on borehole setting and/or water quality.

Note: *At the completion of borehole abandonment/sealing activities (regardless of methodology employed) it is necessary to check for surface settlement a few days after work completion to determine if the borehole area requires "topping off".*

Final Restoration

The area around the borehole and the borehole surface shall be restored as directed by the GM Facility representative (e.g., asphalt, concrete, vegetation). Time for borehole settlement may be permitted, then final restoration performed; or alternatively final restoration may be required immediately in active interior work areas.

Cleanup

The area around the borehole shall be completely cleaned up of any investigation related materials (litter, etc.).

EQUIPMENT/MATERIALS

- Grout pump/mixing equipment.
- Form FMG 2.6-01 - Stratigraphic Log (Overburden) (Page 1/Page 2).

REFERENCES

ASTM D5299 "Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes and Other Devices for Environmental Activities.

United States Environmental Protection Agency (1992) "Guide to Management of Investigation-Derived Wastes", Quick Reference Fact Sheet.

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SOIL CLASSIFICATION

INTRODUCTION

The stratigraphic log is a factual description of the soil at the borehole location and is relied upon to interpret the soil characteristics, and their influence and significance in the subsurface environment. The accuracy of the stratigraphic log is to be verified by the person responsible for interpreting subsurface conditions. An accurate description of the soil stratigraphy is essential for a reasonable understanding of the subsurface conditions. Confirmation of the field description by examination of representative soil samples by the project geologist, hydrogeologist, or geotechnical engineer (whenever practicable) is recommended.

The ability to describe and classify soil correctly is a skill that is learned from a person with experience and by systematic training and comparison of laboratory results to field descriptions.

It is GM Remediation Team's Policy to log soils according to the Unified Soil Classification System (USCS) described in the following.

PROCEDURES REFERENCED

- FMG 2.1 - Test Pits.
- FMG 2.3 - Soil Borings.

PROCEDURAL GUIDELINES

Several methods for classifying and describing soils or unconsolidated sediments are in relatively widespread use. The Unified Soil Classification System (USCS) is the most common. With the USCS, a soil is first classified according to whether it is predominantly coarse grained or fine grained.

The description of fill soil is similar to that of natural undisturbed soil except that it is identified as fill and not classified by USCS group, relative density, or consistency. Those logging soils must attempt to distinguish between soils that have been placed (i.e., fill) and not naturally present; or soils that have been naturally present but disturbed (i.e., disturbed native).

It is necessary to identify and group soil samples consistently to determine the subsurface pattern or changes and non-conformities in soil stratigraphy in the field at the time of drilling. The stratigraphy in each borehole during drilling is to be compared to the stratigraphy found at the previously completed boreholes to ensure that pattern or changes in soil stratigraphy are noted and that consistent terminology is used.

Visual examination, physical observations and manual tests (adapted from ASTM D2488, visual-manual procedures) are used to classify and group soil samples in the field and are summarized in this subsection. ASTM D2488 should be reviewed for detailed explanations of the procedures. Visual-manual procedures used for soil identification and classification include:

- Visual determination of grain size, soil gradation, and percentage fines.
- Dry strength, dilatancy, toughness, and plasticity (thread or ribbon test) tests for identification of inorganic fine grained soil (e.g., CL, CH, ML, or MH).
- Soil compressive strength and consistency estimates based on thumb indent and pocket penetrometer (preferred) methods.

The three main soil divisions are: coarse grained soil (e.g., sand and gravel), fine grained soil (e.g., silt and clay), and soil with high natural organic matter content (e.g., peat and marl).

Coarse Grained Soil

The USCS group symbols for coarse grained soil are primarily based on grain or particle size, grain size distribution (gradation), and percent fines (silt and clay content).

Coarse grained soils are then further subdivided according to the predominance of sand and gravel. Course grained soil is made up of more than 50 percent, by weight, sand size, or larger (75 μm diameter, No. 200 sieve size or larger). It is noted that there are other definitions for coarse grained or coarse textured soil and for sand size such as soil having greater than 70 percent particles equal to or greater than 50 μm diameter.

Descriptions for grain size distribution of soil include; poorly graded (i.e., soil having a uniform grain size, SP and GP) and well graded (i.e., poorly sorted; having wide range of particle sizes with substantial intermediate sizes, SW and GW).

Coarse grained soils are further classified based on the percentage of silt and clay it contains (fines content). Coarse grained soils containing greater than 12 percent fines is commonly described as dirty. This description arises from the soil particles that adhere when the soil is rubbed between the hands or adhere to the sides of the jar after shaking or rolling the soil in the jar. The jar shake test which results in segregation of the sand and gravel particles is also used as a visual aid in determining gravel and sand percentages.

Examples of the group symbol, name, and adjectives used to describe the primary, secondary, and minor components of soil are; GW - Sandy Gravel (e.g., 70 percent gravel and 30 percent sand) or Sandy Gravel trace silt (less than 10 percent silt), and SP - Sand, uniform.

Relative density is an important parameter in establishing the engineering properties and behavior of coarse grained soil. Relative density of non-cohesive (granular) soil is determined from standard penetration test (SPT) blow counts (N values) (after ASTM Method D1586).

The SPT gives a reliable indication of relative density in sand and fine gravel. N values in coarse grained soil are influenced by a number of factors that can result in overestimates of relative density (e.g., in coarse gravel and dilatent silty fine sand) and can be conservative and underestimate the relative density (e.g., sand below the groundwater table and uniform coarse sand). These effects will be assessed by the project geotechnical engineer, if required, and need not be taken into account by field personnel.

Other dynamic methods, such as modified SPT and cone penetration tests, are used on occasion to supplement or replace the SPT method for certain site-specific conditions. The details of all modifications to the SPT or substitute methods should be recorded as they are required to interpret test results and correlate to relative density.

Fine Grained Soil

A soil is fine grained if it is made up of half or more of clay and silt (i.e., fines greater than 50 percent by weight passing the 75 μm (No. 200) sieve size). A description of visual-manual field methods and criteria (after ASTM D2488) that are used to further characterize and group fine grained soil (e.g., CL, CH, ML, or MH) including dry strength, dilatancy, toughness, and plasticity (thread or ribbon test) follows. Fine grained soils are subdivided on a basis of the liquid limit and the degree of plasticity.

The accurate identification of silts and clays can be aided by the use of some single field tests. Clay is sticky, will smear readily, and can be rolled into a thin thread even when the moisture content is low. When it is dry clay forms hard lumps. Silt on the other hand, has a low dry strength, can be rolled into threads only at high moisture content, and a wet silt sample will puddle when it is tapped.

Criteria for Describing Dry Strength

Description	***Criteria***
None	The dry specimen crumbles into powder with mere pressure of handling.
Low	The dry specimen crumbles into powder with some finger pressure.
Medium	The dry specimen breaks into pieces or crumbles with considerable finger pressure.

High	The dry specimen crumbles into powder with finger pressure. Specimen will break into pieces between thumb and a hard surface.
Very High	The dry specimen cannot be broken between the thumb and a hard surface.

<u>Criteria for Describing Dilatency</u>

Description	***Criteria***
None	No visible change in small wetted specimen when rapidly shaken in palm of hand.
Slow	Water appears slowly on the surface of the specimen during shaking and does not disappear or disappears slowly upon squeezing.
Rapid	Water appears quickly on the surface of the specimen during shaking and disappears quickly upon squeezing or stretching.

<u>Criteria for Describing Toughness</u>

Description	***Criteria***
Low	Only slight pressure is required to roll the thread near the plastic limit. The thread and the lump are weak and soft.
Medium	Medium pressure is required to roll the thread to near the plastic limit. The thread and the lump have medium stiffness.
High	Considerable pressure is required to roll the thread to near the plastic limit. The thread and the lump have very high stiffness.

<u>Criteria for Describing Plasticity</u>

Description	***Criteria***
Nonplastic	A 1/8-inch (3 mm) thread cannot be rolled at any water content.
Low	The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit.
Medium	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be re-rolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit.
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be re-rolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit.

Examples of group symbol identification based on visual-manual procedures and criteria for describing fine grained soil are:

Group Symbol	*Dry Strength Plasticity*	*Dilatency*	*Toughness*
ML	None to low Slight	Slow to rapid	Low or thread cannot be formed
CL	Medium to high Low	None to slow	Medium
MH	Low to medium Low	None to slow	Low to medium
CH	High to very high High	None	High

A requirement for positive classification by USCS group symbols (as described in Test Method ASTM D2487) is laboratory determination of particle size characteristics, liquid limit and plasticity index. The need for this type of testing will be determined by the project geologist, hydrogeologist, or geotechnical engineer.

Examples of name terminology that accompanies the group symbols are ML - Sandy Silt (e.g., 30 percent sand) and CL - Lean Clay with sand (e.g., 15 to 29 percent sand).

The correlation between N value and consistency for clays is rather unreliable. It is preferable to determine consistency using more appropriate static test methods, particularly for very soft to stiff clay soil. N value estimates of consistency are more reasonable for hard clay.

Unconfined compressive strength (Su) may be estimated in the field from the pocket penetrometer test method. To obtain a pocket penetrometer estimate of consistency and compressive strength, the soil core is cut perpendicular to the core length, the length of core (minimum 4 inches) is held in the hand and a moderate confining pressure is applied to the core (not sufficient to deform the core); the penetrometer piston tip is slowly inserted into the perpendicular face of the core until the penetrometer indents into the soil core to the mark indicated on the tip of the penetrometer piston; the penetrometer estimate of soil compressive strength (Su) is the direct reading of the value mark on the graduated shaft (in tons per square foot or other unit of pressure as indicated) indicated by the shaft ring marker, or in some models, by the graduated piston reading at the shaft body. To obtain an average estimate, this procedure is completed several times on both ends and mid cross-section of the core. For Shelby tube (or thin wall sampler) samples the pocket penetrometer tip is applied to the exposed bottom of the sample at several locations.

Estimates of compressive strength for clay soil of very soft to stiff consistency are better established by in situ shear vane tests or other static test methods.

The description of consistency (or strength) is an important element in determining the engineering properties and strength characteristics of fine grained cohesive soil. Consistency terms (e.g., soft, hard) are based on the unconfined compressive strength (Su) and shear strength or cohesion (cu) of the soil.

The ease and pattern of soil vapor and groundwater movement in the subsurface is influenced by the natural structure of the soil. Soil structure, for the most part, depends on the deposition method and, to a lesser extent, climate.

Visual Appearance/Other Features

Those logging soils should also note the presence, depth and components of fill soils (if evident), and note the distinction between disturbed native soils (i.e., excavation likely performed) vs. undisturbed native soils.

Other features such as root presence/structure, and soil fractures should also be recorded. Soil fractures should be described noting fracture orientation (i.e., horizontal/vertical), length/aperture and appearance of soil infilling, oxidation and/or weathering (if present).

Field Sample Screening

Upon the collection of soil samples, the soil is screened with a photoionization detector (PID) for the presence of organic vapor. This is accomplished by running the PID across the soil sample. Record the highest reading and sustained readings.

Note: The PID measurement must be done upwind of the excavating equipment or any running engines so that exhaust fumes will not affect the measurements.

Another method of field screening is head space measurements. This consists of placing a portion of the soil sample in a sealable glass jar, placing aluminum foil over the jar top, and tightening the lid. Alternatively, plastic sealable bags maybe utilized for field screen in lieu of glass containers. The jar should only be partially filled. Shake the jar and set aside for at least 30 minutes. After the sample has equilibrated, the lid of the jar can be opened; the foil is punctured with the PID probe and the air (headspace) above the soil sample is monitored. Record this headspace reading on the field form or in the field book.

Note: Perform all headspace readings in an area that is not subject to wind. Also, in the winter, it is necessary to allow the samples to equilibrate in a warm area (e.g., site trailer, van, etc.). This requirement is dictated by the Work Plan.

All head space measurements must be completed under similar conditions to allow comparability of results.

NAPL Detection

During soil examination and logging, the sampler shall carefully check for the presence of light or dense non-aqueous phase liquid (NAPL). NAPL may be present in gross amounts or present in small/minute quantities. The adjectives and corresponding quantities used when describing NAPL within a soil matrix are as follows:

Visual Description	***Fraction of Soil Pore Volume Containing NAPL***
Saturated	>0.5
Some	0.5 to 0.25
Trace	<0.25

A complete description of NAPL, must describe the following:

- Color.
- Quantity.
- Density (compared to water i.e., light/floats or heavy/sinks).
- Odor (if observed).
- Viscosity (i.e., mobile/flowable, non-mobile/highly viscous-tar like).

The presence of an "iridescent sheen" by itself does not constitute "NAPL presence", but may be an indicator that NAPL is close to the area.

NAPL presence within a soil matrix may be confirmed by placing a small soil sample within water, shaking, and observing for NAPL separation (i.e., light or dense), from the soil matrix.

Trace amounts of NAPL are identified/confirmed by a close visual examination of the soil matrix, [i.e., separate soil by hand (wearing disposable gloves)] and perform a careful inspection of the soil separation planes/soil grains for NAPL presence.

Often during the sample examination with a knife, an iridescent sheen will be noted on the soil surface (i.e., clay/silts) if the knife has passed through an area of NAPL.

There are a number of more sophisticated tests available to confirm/identify NAPL presence, these are:

- UV fluorescent analysis.
- Hydrophobic dyes.
- Centrifugation.
- Chemical analysis.

Typically consultants will utilize organic vapor detection results, visual examination, soil/water shake testing, and chemical analysis, to confirm NAPL presence. The more complex techniques described may be incorporated on sites where clear colorless NAPL is present and its field identification is critical to the program.

Note: When describing the presence of vegetative matter in the soil sample, do not use the term "organic" as this often leads to confusion with regards to the presence of organic chemicals (i.e., NAPL).

EQUIPMENT/MATERIALS

- Pocket knife or small spatula.
- Small handheld lense.
- Form FMG 2.6-01 - Stratigraphic Log - Overburden (Page 1/Page 2).
- Tape measure.

REFERENCES

American Society for Testing and Materials (1991), Standard D1452-80, "Practice for Soil Investigation and Sampling by Auger Borings", "Annual Book of ASTM Standard", Section 4, Volume 04.08.

ASTM Standards on Environmental Sampling (1995), Standard D2488-93, "Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)"

ASTM Standards on Environmental Sampling (1995), Standard D4700-91, "Guide for Soil Sampling from the Vadose Zone".

ASTM Standards on Environmental Sampling (1995), Standard D1586-92, "Test Method for Penetration Test and Split-Barrel Sampling of Soils".

ASTM Standard D2487, "Classification of Soils for Engineering Purposes (Unified Soil Classification System)".

Geotechnical Gauge, Manufactured by W.F. McCollough, Beltsville, MD.

Sand Grading Chart, by Geological Specialty Company, Northport, Alabama.

REMEDIATION TEAM	FIELD METHOD GUIDELINE NO.: FMG 2.7
REAL ESTATE & FACILITIES	EFFECTIVE DATE: MARCH 14, 2011
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ROCK CLASSIFICATION

INTRODUCTION

This procedure is for the logging and classification of bedrock cores.

PROCEDURES REFERENCED

- FMG 2.4 - Bedrock Coring.

PROCEDURAL GUIDELINES

- All bedrock logging activities will be conducted according to procedures outlined in ASTM D5434-93.
- All retrieved bedrock core shall be handled in a manner as to cause the least amount of mechanical fractures as possible.
- All retrieved bedrock cores will be placed in an appropriate sized core box with increasing depths aligned left to right.
- All bedrock core runs shall be separated and core depths marked utilizing wooden blocks.
- Upon the completion of each core run, the depth of corehole will be measured to properly document the termination depth of each core run.
- Each stratigraphic bedrock core run will be logged for all structural and lithographic features.
- All natural occurring fractures, structural and lithographic features will be logged for depth and documented on standard Form FMG 2.7-01 - Bedrock Stratigraphic Log.
- Rock Quality Designation (RQD) values and documentation on the bedrock log form will be calculated for each bedrock core run.
- RQD values will be calculated to indicate rock-mass properties according to Deere (1986) by summarizing all the bedrock core portions greater than 4 inches in length and dividing the sum of these pieces by the length of the bedrock core run. RQD is expressed as a percentage.
- The percentage of bedrock core recovery for each core run will be calculated and recorded on Form FMG 2.7-01 - Bedrock Stratigraphic Log.

- If potable water is utilized as a circulating medium, the volume of water lost during each bedrock core run will be recorded on Form FMG 2.7-01 - Bedrock Stratigraphic Log.
- Special attention will be paid to fracture surfaces to indicate if any fracture infilling or groundwater movement is indicated. All fractures will be measured for depth and recorded on Form FMG 2.7-01 - Bedrock Stratigraphic Log.
- A picture of each run of bedrock core will be taken to document each retrieved bedrock core run.
- Each completed core box fill be properly sealed to keep the bedrock core intact.
- Each core box will be labeled on the outside to include site name, job number, boring number, date, bedrock core depth, interval, bedrock core run number, RQD and bedrock core recovery for each core run, fluid loss (if applicable), and bedrock core loggers name.
- Upon completion of bedrock coring activities the corehole should be flushed to remove all residual rock cuttings from the corehole and measured to ensure that the documented termination depth of the corehole is correct.
- Ensure that all bedrock coring equipment is properly decontaminated according to site protocols prior to construction of the next well.

EQUIPMENT/MATERIALS

- Drilling equipment.
- Appropriate coring equipment.
- Form FMG 2.7-01 - Bedrock Stratigraphic Log.
- Tape measure.
- Hand lense.
- Camera.
- Work Plan.
- Health and Safety Plan.

REFERENCES

American Society for Testing and Materials (1991) Standard D2113-8307 "Standard Practice for Diamond Core Drilling for Site Investigations" Annual Book of ASTM Standards, Section 4, Volume 04.08.

American Society for Testing and Material (1991) Standard D5434-93 "Standard Guide for Field Logging of Subsurface Exploration of Soil and Rock" Annual Book of ASTM Standards, Section 4, Volume 04.09.

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WELL CONSTRUCTION MATERIALS

INTRODUCTION

In environmental subsurface investigations, the information used to evaluate subsurface conditions often relies heavily on the installation of quality groundwater monitoring wells. The application and use of the proper well construction materials to the specific well installation is crucial to obtaining representative and reliable groundwater samples.

The two general types of wells are groundwater monitoring wells and pumping (also referred to as recovery, extraction, or withdrawal) wells. The specific use of a groundwater well dictates the types of materials used to construct it.

This FMG outlines the general types and use of well construction materials and considerations involved in selecting appropriate materials for specific well installation applications. Installation of these materials are described in detail in the specific well installation FMGs listed below.

PROCEDURES REFERENCED

- FMG 3.2 - Overburden Wells.
- FMG 3.3 - Top of Bedrock Wells.
- FMG 3.4 - Deep Bedrock Wells.
- FMG 3.5 - Pump Wells.
- FMG 3.6 - Piezometers.

EQUIPMENT DESCRIPTIONS

Well Screen

Well screen is the portion of the well pipe that contains appropriately sized openings and allows groundwater to enter the well. The screen materials used in groundwater monitoring wells are crucial to ensuring the installation of an efficient, productive, and durable groundwater well.

The diameter of the well screen is generally dependent upon the application of the well. For monitoring wells used in groundwater level measurements and groundwater sampling, screen diameter will generally be 2.0-inch inner diameter (ID) flush-threaded screen segments (piezometers are typically 1.0-inch inner diameter but may be 2-inch also). These screen segments are typically available in 10-foot lengths. Four-inch diameter or larger well screens are usually reserved for recovery or production well applications where larger diameters permit greater groundwater withdrawal rates. Larger diameter wells also allow a well to serve additional functions such as housing oil recovery systems.

Screen material will be either thermoplastic Schedule 40 Poly Vinyl Chloride (PVC) (ASTM D1785, ASTM D2665, ASTM F480) or Schedule 5 Type 316 stainless steel, depending primarily on the depth of the well and the groundwater quality (degree and nature of contamination). Shallower depths and generally low levels of contaminants in groundwater allow for PVC applications, whereas greater depths and severely degraded groundwater quality, or the presence of free-phase oils or solvents, may necessitate stainless steel due to its greater strength and resistance to chemical degradation. It should be noted that PVC and stainless steel are appropriate for the vast majority of environmental applications, and are generally accepted by regulatory agencies. Well materials other than PVC or stainless steel should be used only in certain instances, to be determined and approved by the Project Manager on a case-by-case basis.

Certain applications such as investigation of inorganic (metals) concentrations in groundwater, or the presence of low pH (acidic) conditions, may preclude the use of stainless steel wells. Stainless steel, which contains molybdenum in addition to its iron content, may leach out metal compounds which could lead to misleading groundwater analysis results.

PVC may likewise leach out or degrade specific thermoplastic elements of its composition which may compromise the well integrity or groundwater analyses. PVC generally performs well in acidic groundwater conditions; however, it may degrade in the presence of certain organic compounds such as ketones, aldehydes, or chlorinated compounds in high concentrations. Certain additives to the PVC may also affect groundwater quality.

Well screen slot sizes and well screen type will also be consistent for groundwater monitoring wells. Screen slot size is typically 0.010 inches; 0.020-inch slot size may be more appropriate for coarser formation materials or where the well may serve as a recovery well for free-phase oils. For monitoring applications, slot type should be either factory machine-slotted or continuous-wrap slotted. Perforated, bridge-slotted or louver-slotted well screens are generally not acceptable for most environmental applications and should be avoided.

Screen slot sizes may vary from these two sizes when used in production or recovery (pumping) well applications where the need to maximize groundwater withdrawal is essential. In such cases, screen slot sizes can be manufactured to exact specifications for a particular well based on particle size analysis results and formation transmissivity or permeability.

Well Riser Pipes and Casings

Well riser pipe is a solid extension of the well screen that extends from the screen up to the surface. The riser pipe protects the well screen, prevents outside groundwater from entering the well, and allows groundwater pumped from down in the open interval to be routed up through the well to the surface.

Well riser pipe should be of the same material and size as the well screen described above. In instances to be determined and approved by the Project Manager on a case-by-case basis only, differing materials may be approved for use in the same well (e.g., stainless steel well screen connected to PVC riser). Well risers should extend to the surface and should either be cut at grade in flush-mount completions or as an approximately 3-foot stickup to be covered with a steel protective casing.

Well riser pipe sections shall be flush-threaded and fitted with neoprene, rubber, or other appropriately constructed, durable o-rings to properly seal the threaded pipe joints. Glues or cements are not to be used in well construction.

In installations of bedrock monitoring wells, which have an open rock monitoring interval and a permanent well casing that extends from bedrock to the surface, the permanent casing (or casings in telescoping wells) shall be made of carbon steel or low-carbon steel (greater than 0.8 percent carbon and less than 0.8 percent carbon, respectively). The well casing should be a minimum of 4 inches in diameter (at least 4 inches diameter for the innermost casing).

On sites wells where dense, non-aqueous phase liquid (DNAPL) is present or may be a concern, in screened wells it is advisable to install a collection sump on the base of the well below the well screen to collect infiltrated DNAPL for possible measurement and/or sampling. Sumps should be installed as a 1- to 5-foot section of solid riser material with a sealed bottom placed below the well screen.

Sand Packs

The filter pack, or sand pack, installed in a well replaces formation material immediately around a well with a more permeable material (sand). The sand pack separates the well screen from the formation, increases the hydraulic diameter of the well, and prevents fines (silt or clay) from entering or clogging the well screen.

Sand pack of an appropriate size shall be utilized based on the well screen slot size being used. Sand pack size should be chosen so that the majority of the sand (sand pack has inherent variation in its particle grain size distribution) is larger than the screen slot size while sized small enough to prevent deleterious amounts of formation fines from entering the well through the sand pack. Screen slot sizes of 0.010-inch and 0.020-inch typically use a sand pack such as Morie or U.S. Silica No. 1, No. 0, No. 00N, or equivalent.

Sand pack shall be washed silica sand with a silica content of at least 95 percent. Sands should meet one or more of the following requirements: NSF 61, AWWA B-100, ANSI, or equivalent standards for uniformity and chemical inertness. In cases to be determined and approved by the Project Manager on a case-by-case basis only, differing sand pack materials may be approved for use in a well. Sand packs used for production and recovery wells with larger screen slot sizes will use larger particle sized sand packs of the same type and quality. The slot size and sand pack size for recovery wells should be chosen based on results of formation grain size distribution analysis.

<u>Seals</u>

Bentonite and grout seals are installed above the sand pack to isolate the monitoring interval and prevent groundwater from infiltrating into the well screen from other water-bearing zones. Seals also prevent migration of backfill or formation materials downward into the sand pack.

Bentonite is the generic name for a group of a naturally occurring clay minerals (montmorillonites) that come in a variety of forms: pellets, chips, granulated, or powdered. This material is commercially available as "Wyoming Bentonite". When hydrated it swells to many times its original volume and forms an ultra-low permeability clay seal.

Bentonite chips or pellets are generally used to create a seal immediately above the sand pack. The chips/pellets are dropped inside the augers or well casing by hand down through the water column onto the top of the sand pack. Care must be taken to prevent "bridging" of the bentonite particles in the casing above the target zone. Measurements of the depth to the top of the seal must be obtained during installation of the seal to ensure its proper position and thickness. In the absence of significant water in a casing or borehole, potable water must be added to hydrate the bentonite. The bentonite seal will be allowed to set for a minimum of one-half hour, in order to hydrate properly, before additional seals (grout) are applied. Once the bentonite has set for one-half hour the grout seal may be placed, as described below.

In saline groundwater environments, such as where ocean water may infiltrate the monitoring interval, a zeolite-based seal material may be used, as saline conditions may hamper the performance of bentonite pellets.

Portland cement grout (grout) forms a concrete-like seal that can be more manageable than bentonite (e.g., able to be pumped through a water pump). Grout is generally placed on top of the hydrated bentonite seal to form a solid cement seal around the well riser up to the surface. In certain circumstances, only under approval of the GM Project Manager, soil cuttings may be used to backfill the borehole in lieu of grout.

The grout mixture will consist of one 94-pound bag of Portland cement and 3 to 5 pounds of powdered bentonite added per sack of cement. Two pounds of calcium chloride may also be added (under certain conditions, e.g., very cold days) to accelerate the setting time of the grout, as well as to increase the dry strength of the grout. The grout will be thoroughly mixed with 6.5 gallons of potable water per sack of cement. Grout is generally placed using either the tremie or Halliburton grouting methods. These are described in the specific well installation FMGs.

Protective Casings and Surface Seals

Once the well screen, riser, and all seals have been placed to ground surface, the well riser must be protected. This includes protection from vehicles, damage, surface water infiltration, and weather. This is typically accomplished using either a flush-mount roadbox or a stickup casing.

Flush-mount roadboxes are circular steel casing segments with a heavy-duty steel lid with locking bolts. These units are widely available and come in a number of diameters and lengths, depending on the well diameter. A stickup protective casing is generally a length of carbon or stainless steel pipe with a locking top.

For a typical 2-inch monitoring well, the roadbox should be at least 6 inches in diameter; a stickup casing should be at least 4 inches in diameter. A roadbox should be at least 12 inches in length (they are typically 16 to 18 inches long) and is installed flush with the ground surface. A stickup casing should be at least 5 to 6 feet long such that approximately 2.5 to 3 feet is below ground surface and 2.5 to 3 feet is protruding above grade. In wells where a permanent steel casing is installed (serves as the well riser pipe) and brought to the ground surface, it may be used as the protective casing provided it is equipped with a semi-permanent, metal, locking cap or cover that can be affixed to the steel casing.

Flush-mount installations should have at least the last 18 inches of the open borehole filled with coarse sand, placed up to ground surface to allow drainage of surface water infiltration down through and out of the roadbox. This also prevents infiltrating surface water from accumulating up over the top of the well riser and draining down into the well. This sand drain is not necessary in the locking cap stickup casings.

Both roadbox and stickup casings must be secured in the ground with concrete, which also serves as a surface seal.

In areas of high vehicle traffic activity, protective steel bollards should be installed. This is typically a vertically oriented, concrete-filled, steel pipe (minimum 4 inches diameter) cemented at least 3 feet into the ground, acting as a "guard rail" for the well casing and preventing it from being damaged by vehicles. Three bollards should be placed around a well to provide adequate protection.

EQUIPMENT/MATERIALS

- Drilling equipment.
- Well screen and riser materials.
- Sand pack.
- Bentonite pellets/chips.
- Powdered bentonite.
- Portland cement.

REFERENCES

ASTM D1785-99, Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120.

ASTM D2665-00, Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Drain, Waste, and Vent Pipe and Fittings.

ASTM F480-00, Standard Specification for Thermoplastic Well Casing Pipe and Couplings Made in Standard Dimension Ratios (SDR), Schedule 40 and Schedule 80.

ASTM A53/A53M-01, Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless for Ordinary Uses.

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PROCEDURES FOR OVERBURDEN MONITORING WELL INSTALLATION

INTRODUCTION

This procedure describes procedures for the installation of overburden groundwater monitoring wells.

PROCEDURES REFERENCED

- FMG 1.3 – Utility Clearance
- FMG 2.2 – Drilling Techniques
- FMG 3.1 – Well Construction Materials
- FMG 3.7 – Well Development
- FMG 9.0 – Equipment Decontamination
- FMG 10.0 – Waste Characterization

EQUIPMENT/MATERIALS

The following lists the equipment and materials used for the installation of overburden wells.

1. Site Plan, Field Sampling Plan, and/or Work Plan, with proposed soil boring/monitoring well locations.
2. Personal protective equipment (PPE) as required by the site-specific Health and Safety Plan (HASP).
3. Drilling equipment appropriate for the site and investigation objectives.
4. Well construction materials appropriate for the intended use of the groundwater monitoring well. *FMG 3.1 – Well Construction Materials* outlines the general types and use of well construction materials, and considerations involved in selecting materials for specific well applications.
5. Water level meter.

6. Weighted tape measure, graduated in tenths of a foot.
7. Electronic water level probe.
8. Locks and keys for locking the completed groundwater monitoring wells.
9. A heavy-duty folding ruler for measuring soil sample recovery and noting stratigraphic changes.
10. Permanent marker for labeling the well cover or casing.

DRILLING PROCEDURES

FMG 2.2 – Drilling Techniques presents descriptions of various drilling methods that are available, including rotosonic, direct-push, hollow-stem auger, rotary spun casing, and dual-wall reverse circulation air techniques. Regardless of the method chosen, the following procedures will be followed:

- Construct a temporary decontamination pad from plywood sheets, 2 X 6 boards and 6-millimeter (minimum thickness) plastic capable of fitting the drill rig. An alternate containment structure may be used as long as it is suitable to contain the decontamination waste material.

- Drilling and sampling equipment will be decontaminated prior to drilling, between samples that are being collected for laboratory analysis, and prior to leaving the site in accordance with the *FMG 9.0 – Equipment Decontamination*.
- No oils or grease will be used on equipment introduced into the borehole.
- Environmental grade grease may be used to lubricate drill threads.
- Drilling-generated waste materials will be characterized in accordance with *FMG 10.0 - Waste Characterization*.
- The depth to the target interval may be determined from an existing adjacent monitoring well/boring or from information obtained from sampling the borehole. The criteria for determining the target interval to be monitored will be presented in the Project Work Plan. Typically, an 8-inch diameter borehole will be advanced to the target interval, although a larger- or smaller-sized borehole may be necessary based on the objectives of the groundwater monitoring program. For example, a larger diameter sand pack may be desirable to limit the mobilization of particulates from the soil column in response to sampling activities, or a smaller diameter well and sand pack may be practical due to access limitations.
- Unless otherwise approved, a minimum annular space of one inch should be maintained between the well casing and the borehole casing or augers to facilitate proper placement of the sand pack and seal materials and to minimize the chance for “bridging” of the materials.

- In instances where the borehole is advanced deeper than the target interval, a hydrated bentonite pellet seal will be installed to bring the bottom of the boring to within 6 inches of the target interval. Six inches of filter sand will then be placed above the bentonite seal prior to installing the well to prevent the introduction of clay particles into the well.

- In some areas where the water table is known to be at or near the top of bedrock, the base of the overburden well may be installed at the top of bedrock.

WELL INSTALLATION

The well installation procedures presented below are the recommended guidelines. Due to variations in subsurface conditions, changes in these well installation guidelines may be necessary (e.g., to accommodate installation of the protective casing in instances where the water table is very shallow, or to properly monitor a thin water bearing unit). Typical flush-mount and above-grade overburden monitoring well installation details are presented on the attached figures: *FMG 3.2-02 - Typical Flush Mount Overburden Monitoring Well Installation,* and FMG *3.2-03 - Typical Above Grade Overburden Monitoring Well Installation*.

Well construction materials are discussed in *FMG 3.1 – Well Construction Materials*. Well screen lengths of 5 or 10 feet are typically used; however, other screen lengths may be applicable depending on subsurface conditions. Water table monitoring wells will be constructed with the screen straddling the water table, and with approximately 7 feet of a 10-foot well screen or 3-feet of a 5-foot well screen extending below the water table. The screen placement should allow for fluctuation in groundwater levels, and well screen lengths may need to be increased if groundwater is known to fluctuate more than a few feet.

Once the target well depth is reached, a pad of sand is placed below the base of the well screen and the well materials are placed in the borehole. As the augers or drill casing are slowly removed, sand filter pack is placed in the annular space around the well screen and casing from the base of the screen to approximately 2 feet above the screen. A shallow water table may necessitate a shorter sand pack. The filter pack shall consist of clean, uniform, well-rounded silica sand of an appropriate size based on the screen slot size being used and the soil particle size in the screened interval, as specified in the work plan and/or dictated by site conditions. The types of sand used as filter pack are discussed in detail in *FMG 3.1 – Well Construction Materials*.

A hydrated bentonite seal with a minimum thickness of 2 feet is placed above the sand pack. If the water table elevation is at least several feet above the top of the sand pack, a 2-foot thick (minimum) layer of bentonite pellets will be placed above the sand pack using a tremie pipe. No coated bentonite pellets will be used in monitoring well drilling or construction. The seal will be hydrated and allowed to set for approximately 45 minutes. Granular or flaked pH-neutral bentonite will be hydrated and used for seals placed above the water table. The types of sealing and grouting materials are discussed in detail in *FMG 3.1 – Well Construction Materials*.

During the placement of the sand pack and bentonite seal, a weighted tape will be employed to provide constant measurements and help prevent bridging. Above the bentonite seal, Portland cement grout containing three to five percent bentonite will be tremied into place. If the total well depth is 20 feet or less, the bentonite seal may be extended to the base of the surface seal. The augers or drill casing will be gradually pulled during the addition of the filter pack, bentonite seal and cement-bentonite grout seal.

Accurate measurements of the material depths will be made during installation. The volume of materials needed will be calculated and compared to the actual volume used. Materials used and depths of placement will be recorded on *FMG 3.2-01 – Overburden Well Installation Report.*

The well casing will be secured with a vented lockable cap. If the well is located in a high traffic area, the casing will be protected by a flush-mounted roadway box installed with a sand drain and set in a concrete seal. It is recommended that the surface seal extend a minimum of three inches outside the well casing, to allow for a proper seal and to resist damage from frost. A lockable gripper plug will top the inner well casing. Alternatively, in low traffic areas, the well casing may be cut above grade and completed with 4- or 6-inch diameter steel protective, lockable, casing with approximately 3 ft of stick up, set in a concrete surface seal. Details regarding the type of appropriate well covers and concrete surface seals are contained in *FMG 3.1 – Well Construction Materials.*

After installation, the monitoring well will be labeled with the well identification and a reference point for water level and depth measurements will be marked on the inner well casing. The well will also be locked unless deemed unnecessary by the GM Remediation Team Project Manager. Locks placed on site monitoring wells should be keyed alike and made of material that is resistant to corrosion such as heavy-duty aluminum alloy with a chrome-plated hardened steel shackle, brass tumbler, and double steel locking mechanism (e.g., American Lock® brand locks or similar). The well will be allowed to sit for at least 24 hours prior to well development to allow grout to harden, in accordance with *FMG 3.7 – Well Development*. Following installation, tie-in measurements to a minimum of two nearby site features will be made and recorded. Monitoring wells will generally be surveyed following their installation.

DOCUMENTATION OF WELL DESIGN AND CONSTRUCTION

The following information regarding the design and construction of each well will be recorded on the form *FMG 3.2-01 – Overburden Monitoring Well Installation Report*, or equivalent:

- Date/time of installation;
- Drilling method;
- Surveyed well location;
- Borehole diameter and well diameter;
- Well depth;
- Screened Interval;
- Casing materials;
- Screen materials and design;

- Screen slot size/length;
- Filter pack material/grain size;
- Sealant materials (percent bentonite);
- Sealant materials (lbs/gallon of cement);
- Sealant placement method;
- Surface seal design/construction;
- Type of protective well cap; and
- Detailed drawing of well.

EQUIPMENT CLEANING

Drilling equipment and well materials (casing and screen) will be cleaned using high-pressure steam-cleaning equipment and potable water, in accordance with *FMG 9.0 – Equipment Decontamination*. Drilling equipment will be cleaned prior to use on the site, between monitoring well locations, and at the completion of the drilling program, prior to leaving the site.

DISPOSAL METHODS

All Investigation-Derived Waste (IDW), including water generated during decontamination procedures will be handled in accordance with the site waste disposal plan, and *FMG – 10.0 – Waste Characterization*.

REFERENCES

1. American Society for Testing and Materials (ASTM) (1991), Standard D1452-80, "Practice for Soil Investigation and Sampling by Auger Borings", Annual Book of ASTM Standard, Section 4, Volume 04.08.

2. American Society for Testing and Materials (1991), Standard D5092, "Practices for Design and Installation of Ground Water Monitoring Wells in Aquifers", Annual Book of ASTM Standard, Section 4, Volume 04.08.

3. Environmental Protection Agency (1986), RCRA Ground-Water Monitoring Technical Enforcement Guidance Document, OSWER-9950.1.

4. Environmental Protection Agency (1987), A Compendium of Superfund Field Operations Methods, EPA/540/P-87/001.

5. Driscoll, Fletcher G., Groundwater and Wells, Johnson Filtration Systems, Inc., 1986.

6. Environmental Protection Agency (1988), Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final, EPA/540/G-89/004.

7. Freeze, R. Allen, and Cherry, John A., Groundwater, Prentice-Hall, 1979.

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FMG 3.4-01 BEDROCK WELL INSTALLATION

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DEEP BEDROCK WELLS

INTRODUCTION

This procedure is for the installation of deep groundwater monitoring wells in bedrock zones which lie below the top of bedrock groundwater flow zone.

PROCEDURES REFERENCED

- FMG 2.0 - Subsurface Investigations.
- FMG 3.0 - Monitoring Wells, Pump Wells, and Piezometers.
- FMG 5.0 - Aquifer Characterization.
- FMG 9.0 - Equipment Decontamination.
- FMG 10.0 - Waste Characterization.

PROCEDURAL GUIDELINES

- Overburden drilling will be performed down to the top of bedrock surface in accordance with the procedures outlined in FMG 3.3 - Top of Bedrock Wells. Once at the top of bedrock surface, the augers will be advanced a minimum of 1 foot into bedrock, if possible.
- If the augers cannot be advanced the minimum 1 foot into bedrock, the augers will be removed and a temporary 8-inch steel casing will be placed to the bottom of the borehole to seal off the overburden. The seal shall be augmented by either pounding or spinning the casing just into the top of bedrock.
- Once the augers or casing are in place, either bedrock coring or 7 7/8-inch rotary drilling using standard techniques will be performed to advance the corehole to the depth of the top of the desired open monitoring interval. If cored, the core boring will be reamed to a nominal 8-inch diameter with a rotary bit. Bedrock coring will be performed in accordance with procedures outlined in ASTM D2113 and FMG 2.4 - Bedrock Coring.
- Bedrock logging and classification will be performed in accordance with FMG 2.7 - Rock Classification.

- Once at the top of the desired monitoring interval a 4-inch diameter permanent black-iron or steel casing equipped with centralizers will be installed. The casing will be grouted in place to within 6 inches of the base of the borehole using either the Halliburton single-plug grouting method or by tremie grouting, as described below. Grout will be mixed according to the specifications presented in FMG 3.1 - Well Construction Materials.

Halliburton Method

- Approximately 1.5 times the total calculated annular space volume of grout will be mixed. The grout will be placed inside the casing and a drillable plug (made of inert material which shall not result in the introduction of contaminants to the well) will be placed on top of the grout. The plug must fit tight enough to prevent the mixing of the grout with the water above the plug. Potable water will be injected under pressure into the casing, forcing the plug to the bottom of the casing and grout into the annular space. A valve on the freshwater line will be closed to maintain pressure on the plug and the grout will be allowed to set for at least 12 hours. The temporary casing or auger assembly will be gradually withdrawn during the grouting process**.** The Halliburton method may also employ the use of drilling rods, in lieu of pressurized water, to force the plug down through the casing and maintain pressure on the plug.

Tremie Grouting Method

- A temporary tremie pipe will be installed to the depth of the bottom of the 4-inch casing in the annular space between the 4-inch casing and the 8-inch borehole wall. Grout will be pumped through the pipe until undiluted grout return is noted at the ground surface in the annular space between the 4-inch casing and the temporary casing or augers. The temporary casing or auger assembly will then be gradually withdrawn: the tremie pipe will be disconnected from the grout pump without removing it from the bottom of the borehole, temporary casing sections or auger flights will be withdrawn one at a time, the tremie pipe will be reconnected, and additional grout will be pumped until grout return is again observed at the ground surface inside and outside the temporary casing or augers. This procedure will be repeated, thereby maintaining a full head of grout in the casing, until the temporary casing or auger string has been completely withdrawn. Additional grout will then be pumped through the tremie pipe if necessary to achieve and maintain undiluted grout at ground surface outside the 4-inch casing. The tremie pipe will then be withdrawn from the borehole.
- The grout will be allowed to set for a minimum of 12 hours prior to resuming drilling operations.
- Drill excess grout out of the casing first with a tri-cone roller-bit of a diameter just slightly less than the inner diameter of the casing.
- At most locations, after the casing grout has set, an NQ or NX-core boring will be advanced approximately 10 feet (or alternate length to serve as the desired monitoring interval) below

the 4-inch casing seat. The cored interval will serve as the monitoring interval for most locations, or the corehole may be reamed to a nominal 4-inch diameter.

- In some instances, depending on factors such as degree of rock competency (i.e., low-competency rock), groundwater quality, etc., a well screen may be appropriate for the monitoring interval. In such cases, a 2-inch-diameter stainless-steel or PVC well screen, machine-slotted or continuous wrapped, with 0.020-inch slot screen size, and equal in length to the cored interval may be installed within the open bedrock interval. A riser pipe of similar material will be attached to complete the well screen to the surface. In such cases the annular space between the well screen and corehole will be filled with a sandpack of appropriate grain size distribution to match the screen slot size. Seals of bentonite (minimum 2 feet thick) and grout may be installed above the sandpack to fill the annular space between the 2-inch riser and 4-inch casing, although these are not required since the screen is for stability purposes only and the monitoring interval has already been isolated.
- On sites wells where dense, non-aqueous phase liquid (DNAPL) is present or may be a concern, in screened wells it is advisable to install a collection sump on the base of the well below the well screen to collect infiltrated DNAPL for possible measurement and/or sampling. Sumps should be installed as a 1- to 5-foot section of solid riser material with a sealed bottom placed below the well screen.
- Well screen "centralizers" may also be used in deeper wells to ensure that the well screen remains centered in the borehole at depth and facilitating an even distribution of the sand pack around the screen. These are generally a steel bracket or clamping device affixed (prior to installation) at one or more locations along the lower portion of the well screen and riser pipe. Centralizers are recommended but may be omitted if approved by the GM Project Manager. Care must be taken to insure that bridging of sand or bentonite does not occur at the centralizer locations.
- The well casing will be secured with a vented lockable cap. If the well is located in a high traffic area, the casing will be cut below grade and packed in coarse sand for drainage. The casing will be protected by a 9-inch flush-mounted roadway box set in a concrete seal. Alternatively, in low traffic areas, the well casing may be cut above grade and completed with a locking steel protective casing with approximately 3 feet of stickup, set in a concrete surface seal. Protective steel bollards will be installed, where necessary, to protect the well casing. Refer to FMG 3.1 - Well Construction Materials for additional information regarding protective casings.
- For deep bedrock monitoring well installation, where multiple zones of permeable rock may exist, steel casings and rotary drilling bits of larger size than indicated in this FMG may be used to create "telescoping" wells in which the sizes of the casings and boreholes become progressively smaller with increased depth. The deeper the well installation, the larger the diameter required for the near-surface (initial) drilling. Each permanent steel casing shall be grouted in place, using the methods described herein.

- Bedrock coring and deep bedrock well installations may also be performed in conjunction with packer pressure testing (FMG 5.4 - Packer Pressure Testing) in order to define more permeable bedrock zones or to target specific hydrogeologic zones.
- All equipment will be decontaminated in accordance with FMG 9.0 - Equipment Decontamination, and all drilling-related wastes shall be handled and disposed in accordance with FMG 10.0 - Waste Characterization.
- Well installation will be followed by development. The procedure for well development is described in FMG 3.7 - Well Development. Water level monitoring will be performed in accordance with FMG 5.1 - Water Level Measurements.
- If required, in situ hydraulic conductivity testing shall be done in accordance with FMG 5.2 - In Situ Hydraulic Conductivity (Slug Test) Procedure.

EQUIPMENT/MATERIALS

- Well construction materials.
- Water level probe.
- Form FMG 3.4-01 - Bedrock Well Installation.
- Weighted tape measure.

REFERENCES

ASTM D1452-80, "Practice for Soil Investigation and Sampling by Auger Borings", Annual Book of ASTM Standard, Section 4, Volume 04.08.

ASTM D2113-83 (87), "Diamond Core Drilling for Site Investigations", Annual Book of ASTM Standards, Section 4, Volume 04.08.

American Society for Testing and Materials (1991), Standard D5092, "Practices for Design and Installation of Ground Water Monitoring Wells in Aquifers", Annual Book of ASTM Standard, Section 4, Volume 04.08.

New York State Department of Environmental Conservation (1988), Draft Generic Environmental Impact Statement on the Oil, Gas, and Solution Mining Regulatory Program, Division of Mineral Resources.

Environmental Protection Agency (1986), RCRA Ground-Water Monitoring Technical Enforcement Guidance Document, OSWER-9950.1.

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PIEZOMETERS

INTRODUCTION

The term piezometer generally refers to a small-diameter observation well ordinarily installed for the primary purpose of obtaining hydraulic head (i.e., water level measurement) data. The hydraulic information obtained from multiple piezometers allows evaluation of horizontal and vertical components of groundwater flow (flow direction and gradients). Piezometers can be installed as individual, stand-alone wells, arranged in a lateral array to monitor one hydrogeologic unit, zone, or formation. They can also be installed as clusters or nests in one location.

Piezometers are typically installed only in overburden soils due to ease of installation and potential low cost. These installations are not typically used for groundwater sampling applications or other functions, which are usually accomplished with larger-diameter monitoring wells.

PROCEDURES REFERENCED

- FMG 3.1 - Well Construction Materials.
- FMG 3.2 - Overburden Wells.
- FMG 5.1 - Water Level Measurements.

PROCEDURAL GUIDELINES

Application

Piezometers utilize the same general installation protocols as for overburden monitoring wells (see FMG 3.2 - Overburden Wells). In most instances piezometers are installed using direct-push methods (e.g., Geoprobe®), which are rapid and inexpensive subsurface exploration technologies, but piezometers can also be installed with standard drilling rig methods.

In direct-push applications a single piezometer is placed in a single direct-push borehole, typically 2 to 3 inches in diameter.

If information on the vertical component of groundwater flow is required, data from multiple hydrostratigraphic zones must be obtained. This can be accomplished using closely located clusters of piezometers installed at different vertical depths. Care must be taken to install a proper seal above the screened interval to prevent communication with hydrostratigraphic units above the target interval.

Alternatively, a "nest" of piezometers can be co-located in the same borehole. Standard (rotary) drilling rig installations are generally required for such installations, as larger-diameter boreholes are needed to accept multiple casings. The installation process is basically a repetition of overburden well installation procedures on a vertical, "one-atop-the-other" basis, with proper seals in between target intervals.

Materials

Piezometers are usually smaller diameter than monitoring wells, typically 1.0 inch or 1 1/4 inch inside diameter (ID). Well screen and riser should be Schedule 40 PVC. Well screen should be 0.010 inch factory-slotted (piezometers are not typically continuous wrap due to cost limitations) and screen segments should be a maximum 5 feet long. As with overburden wells, the well screen and riser should be O-ring-sealed, flush-threaded, PVC. No glues or solvents should be used to assemble the well casing.

Installation

Piezometer installations, due to their potential low cost, most often accompany direct-push explorations. In small-diameter applications such as direct-push technology, a single piezometer is usually placed within a single direct-push borehole. The piezometer installation is carried out similarly to that for overburden wells (FMG 3.2 - Overburden Wells), upon completion of the borehole to depth:

- Install the direct-push borehole, typically about 2 to 3 inches in diameter.
- Install screen and riser sections as discussed above, to the target depth.
- Place sand pack material of Morie or U.S. Silica No. 1, No. 0, or No. 00N, or equivalent, to 1 to 2 feet above the top of the screen section.
- Place granulated bentonite to form a 1- to 2-foot thick seal above the sand pack (chips or pelletized bentonite can be used but may not fit down the annulus between the piezometer and the borehole). Hydrate the bentonite if sufficient groundwater is not present in the borehole.
- Place clean backfill soil, additional bentonite, or grout if desired, to create final seal around the riser to ground surface. If soil is used to backfill, install a surface seal of bentonite or grout.

Installation of nested piezometers should adhere to the following procedures:

- Completion of 6-inch to 10-inch (4 1/4-inch to 6 1/4-inch ID hollow-stem augers or casing) borehole to depth for two or three piezometers. The actual borehole diameter should be based on the number of piezometers to be installed in the borehole, anticipated soil materials, etc. The inside diameter of the temporary casing or auger must allow sufficient space to install sand pack and seal materials without bridging.
- Use well screens of 5 feet length or less.
- Install the deepest piezometer to the base of the borehole, or to the target depth. (Note: if the bottom depth of the exploration and the bottom depth of the deepest piezometer vary by more than 1 foot this interval will be plugged using either grout or bentonite seal.)
- Place sand pack around the deepest piezometer screen to 1 to 2 feet above the top of the screen.
- Install a minimum 1-foot thick bentonite seal on top of the sand pack (hydrate if necessary based on water level measurements obtained).
- If the next piezometer is to be installed immediately above the first, place 6 inches of sand on top of the bentonite seal before placing the next screen.
- Install the next-deepest piezometer to the desired depth.
- Place similar seals around the second piezometer.
- Continue the above procedures for each multi-level piezometer installed.
- Piezometer installation and seal placement should be performed as the augers or casing is withdrawn from the borehole. Do not install piezometers in an uncased hole, as this presents the possibility of caving and mixture of formation material with sandpack and seal materials, which will compromise the quality of the installation and therefore the data obtained.
- Label each individual piezometer casings appropriately to prevent confusion regarding depth intervals measured.

Concrete surface seals and protective casing installations are also recommended but may be considered optional, depending on factors such as piezometer location, cost considerations, degree of permanence, etc. If installed it is recommended that concrete surface completions be placed to a depth of at least 18 inches below ground surface.

EQUIPMENT/MATERIALS

- Direct-push or standard drilling rig apparatus and equipment.
- Well screen and riser materials.
- Well sand pack and seal materials.
- Surface seal and protective casing materials, if necessary.

REFERENCES

Driscoll, Fletcher G., Groundwater and Wells, Johnson Filtration Systems, Inc., 1986.

Freeze, R. Allen, and Cherry, John A., Groundwater, Prentice-Hall, 1979.

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WELL DEVELOPMENT

INTRODUCTION

This procedure is for the development of groundwater monitoring wells that have been installed in overburden, top of bedrock, or deep bedrock formations. Before a newly constructed well can be used for water quality sampling, measuring water levels, or aquifer testing, it must be developed. Well development refers to the procedure used to clear the well and formation around the screen of fine-grained materials (sands, silts, and clays) produced during drilling or naturally occurring in the formation.

Well development is completed to remove fine grained materials from the well but in such a manner as to not introduce fines from the formation into the sand pack. Well development continues until the well responds to water level changes in the formation (i.e., a good hydraulic connection is established between the well and formation) and the well produces clear, sediment-free water to the extent practical.

PROCEDURES REFERENCED

- FMG 3.2 - Overburden Wells.
- FMG 3.3 - Bedrock Wells.
- FMG 10.0 - Waste Characterization.

PROCEDURAL GUIDELINES

The well development procedures presented below are the recommended standards. However, due to variations in conditions, changes in these standards may be necessary in order to facilitate successful monitoring well development.

Well development can be accomplished by using in-place pumps or by using portable equipment; either peristaltic, bladder, or other appropriate pumps depending on well depth. In the case of developing wells installed utilizing the mud rotary methods (least preferred method) it would be beneficial to surge the well prior to and during development to help break down the filter cake that may have built up on the well screen.

- Don appropriate safety equipment.
- All equipment used for development purposes entering each monitoring well will be cleaned using a soapy wash (laboratory grade), tap water rinse, isopropyl alcohol rinse (or other rinse agent that is appropriate for site-specific conditions), and distilled/deionized water rinse.
- Uncap well and allow water level to stabilize. Attach appropriate pump and lower tubing into well.
- Turn on pump. If well runs dry, shut off pump and allow to recover.
- Collect the groundwater sample in a glass jar to determine relative turbidity, and measure and record the temperature, pH, turbidity, and specific electrical conductance.
- The above steps will be repeated until groundwater is relatively silt-free; no further change is noted; the temperature, pH, turbidity, and specific conductance readings have stabilized to within 10 percent.
- The time period between development and groundwater sampling will be dependent upon the project objectives, and the chemicals of concern (COCs). When sampling for COCs sensitive to turbidity presence (i.e., SVOCs, PCBs, metals), an extended time period between the development activity and the sampling event will be observed. On REALM/ENCORE sites sampling will be conducted in accordance with the following:

Primary COC	***Time Period Between Development and Sampling***
General Chemistry	24 hours
VOCs	24 hours
SVOCs, PCBs, Metals	2 weeks

<u>Waste Disposal</u>

- All waste generated will be disposed in accordance to the methods and procedures contained in FMG 10.0 - Waste Characterization.
- All water generated during cleaning and development procedures will be collected and contained in accordance to the site-specific disposal requirements.
- Personal protective equipment, such as gloves, disposable clothing, and other disposable equipment, resulting from personnel cleaning procedures and from soil sampling and handling activities, will be placed in plastic bags. These bags will be transferred into appropriately labeled 55-gallon drums or a covered roll-off box for appropriate disposal.

EQUIPMENT/MATERIALS

- Appropriate health and safety equipment.
- Knife.
- Power source (e.g., generator, battery).
- Field book.
- Form FMG 3.7-01 - Well Development and Stabilization Form.
- Well keys.
- Graduated pails.
- Pump and tubing.
- Cleaning supplies (including non-phosphate soap, buckets, brushes, laboratory-supplied distilled/deionized water, tap water, isopropyl alcohol or other site-specific rinse agent (e.g., nitric acid solution), aluminum foil, plastic sheeting, etc.).
- Water level meter.
- pH/temperature/conductivity meter.
- Turbidity meter.
- Clear glass jars (e.g., drillers' jars).

REFERENCES

Environmental Protection Agency (1986), RCRA Ground-Water Monitoring Technical Enforcement Guidance Document, OSWER-9950.1.

Environmental Protection Agency (1987), A Compendium of Superfund Field Operations Methods, EPA/540/P-87/001.

Environmental Protection Agency (1988), Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final, EPA/540/G-89/004.

WELL DEVELOPMENT AND STABILIZATION FORM

PROJECT NAME: ______________________ PROJECT NO.: __________

DATE OF WELL DEVELOPMENT: ______________________

DEVELOPMENT CREW MEMBERS: ______________________

PURGING METHOD: ______________________

SAMPLE NO.: ______________________

SAMPLE TIME: ______________________

WELL INFORMATION

WELL NUMBER: ______________________

WELL TYPE (diameter/material) ______________________

MEASURING POINT ELEVATION: ______________________

STATIC WATER DEPTH: ______________________ ELEVATION: __________

BOTTOM DEPTH: ______________________ ELEVATION: __________

WATER COLUMN LENGTH: ______________________

SCREENED INTERVAL: ______________________

WELL VOLUME: ______________________

Note: For 2-inch diameter well: 1 foot = 0.14 gallons (Imp) or 0.16 gallons (US)
1 meter = 2 liters

	UNITS	*1*	*2*	*3*	*4*	*5*	*TOTAL/ AVERAGE*
VOLUME PURGED (volume/total volume):							
FIELD pH:							
FIELD TEMPERATURE:							
FIELD CONDUCTIVITY:							
CLARITY/TURBIDITY VALUES:							
COLOR:							
ODOR:							
COMMENTS:							

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WELL DECOMMISSIONING

INTRODUCTION

This procedure is for the decommissioning/abandonment of groundwater monitoring wells that have been installed in overburden, top of bedrock, or deep bedrock formations. Well decommissioning refers to the procedure used to properly abandon or remove the monitoring well from the formation while taking the proper precautions to help eliminate cross-contamination.

The proper methods for properly abandoning monitoring wells are either by leaving the well materials in place and pressure grouting with a cement/bentonite slurry directly into the well or by over-drilling with augers, removing the well material, and backfilling with a cement-bentonite slurry.

PROCEDURES REFERENCED

- FMG 3.2 - Overburden Wells.
- FMG 3.3 - Bedrock Wells.
- FMG 9.0 - Equipment Decontamination.
- FMG 10.0 - Waste Characterization.

PROCEDURAL GUIDELINES

<u>Pressure Grouting</u>

- The borehole log from the monitoring well needs to be obtained to determine the well construction in order to prepare the proper materials and calculate the quantity of cement/ bentonite slurry that will be required.
- The cement pad and the well protector around the monitoring pad needs to be removed and the immediate area around the monitoring well dug out. The riser pipe is to be cut off approximately 1 to 2 feet below ground surface.

- A tremie pipe will be placed into the well completely to the bottom. A cement/bentonite slurry will then be pressure grouted in to the monitoring well backfilling completely to the surface. The grout will be prepared in the ratio of one bag (94 pounds) of Type I or Type II Portland cement to 3 to 5 pounds of bentonite powder mixed with approximately 7 gallons of potable water. The grout will be allowed to sit for approximately 1 hour to allow any settlement of the cement/bentonite slurry and then augment if needed.

Overdrilling

- Based on the diameter of the monitoring well, this information can be obtained from the well completion diagram, the proper sized augers need to be specified.
- The cement pad and the well protector around the monitoring pad needs to be removed and the immediate area around the monitoring well dug out. The riser pipe is to be cut off approximately 1 to 1 feet below ground surface.
- The augers are then placed over the riser pipe of the monitoring well and then drilling commences. The drilling continues until the final depth to which the monitoring well was installed is reached. The well materials are then removed (pulled) from the augers.
- A cement/bentonite grout will be placed from the bottom of the borehole to the top of the augers. As each flight of augers is removed from the ground, the cement/bentonite grout will continue to be placed in the augers, to the top. This will continue until all the augers have been removed from the borehole. The grout will be prepared in the ratio of one bag (94 pounds) of Type I or Type II Portland cement to 3 to 5 pounds of bentonite powder mixed with approximately 7 gallons of potable water.
- The area final restoration will be completed in accordance with the directions of the GM Facility representative (e.g., asphalt, concrete, vegetation). In active work areas final restoration maybe necessary immediately; or time to allow settlement of the abandoned well area may be permitted prior to final restoration being performed.
- Documentation/Notification requirements include modification of the well log to reflect closure and if necessary notification to the appropriate regulatory agency.

Waste Disposal

- All waste generated will be disposed of in accordance with the methods and procedures contained in FMG 10.0 - Waste Characterization.
- All material generated during well decommissioning procedures will be collected and contained on site in roll-off boxes or 55-gallon drums for future analysis and appropriate disposal.
- Personal protective equipment, such as gloves, disposable clothing, and other disposable equipment, resulting from personnel cleaning procedures and from well closure activities, will be placed in plastic bags. These bags will be handled in accordance with the work plan.

EQUIPMENT/MATERIALS

- Drilling equipment.
- Well supplies.
- Subsurface boring log.
- Tape measure.

REFERENCES

Michigan Department of Public Health, Ground Water Quality Control Section – Division of Water Supply (1988), Michigan Water Well Grouting Manual, MDPH GW-3-302.

ASTM D5229 "Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes and other Devices for Environmental Activities".

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EM SURVEY

INTRODUCTION

This procedure is for the measurement of ground resistivity. Because resistivity of materials varies laterally and with depth, features can be observed. This procedure relates to the operation of the two most common types of EM survey equipment, the EM-31 and EM-34. This procedure can be adopted for use with other EM equipment based on manufactures operating procedures.

The electromagnetometer operates uses a transmitter coil located at one end of the instrument, which induces circular loops of current into the earth. The magnitude of any one of these current loops is directly proportional to the terrain conductivity in the vicinity of that loop. Each one of the current loops generates a magnetic field that is proportional to the value of the current flowing within that loop. A part of the magnetic field from each loop is intercepted by the receiver coil and results in an output voltage that is linearly related to the terrain conductivity.

The electromagnetometer is calibrated to read conductivity when the earth is uniform. If the earth is layered, and each layer has a different conductivity, the instrument will read an intermediate value. The units of conductivity measured by the electromagnetometer will be in millimhos per meter. To obtain resistivity in ohm-meters, the instrument reading is divided into 1,000 (i.e., a reading of 4 millimhos per meter (mmhos/m) divided into 1,000 gives 250 ohm-meters).

Two components of the induced magnetic field will be measured. The first is the quadrature-phase component, which gives the ground conductivity measurement. The second is the in-phase component, used primarily for calibration purposes and when looking for buried metal drums.

PROCEDURAL GUIDELINES

EM31-D

1. Conductivity Measurements

   Electrical conductivity will be measured using the quadrature-phase component, following the procedures listed below.

a. Using the identifying labels on the tubes, select the transmitter coil tube, align it with respect to the main tube, insert it, and fix it with the clamp.

b. Check the battery condition, plus and minus, by setting the Mode switch (MODE SELECTOR SWITCH) to the OPER position and the Range switch to the +B and –B positions, respectively. If the needle registers within the BATT range on the meter, batteries are in good condition. Otherwise, replace the batteries with a fresh set of Size C alkaline batteries.

c. Checking the zero reading will be performed in an area considered representative of background conditions and having minimal interferences. The zero reading is checked by setting the Mode switch to the OPER position and the Range switch to the least sensitive position 1,000 mmhos/m (this minimizes any external noise interference while checking the zero position). If a zero adjustment is required, adjust the DC ZERO CONTROL located under the front panel to obtain a zero reading.

d. Align and connect the receiver coil tube to the main frame tube.

2. <u>Equipment Functional Checks</u>

The Range switch should be set at the 30 mmhos/m position for all of the following tests.

a. Set the MODE switch to the COMP position and adjust the meter reading to zero using the COARSE and FINE COMPENSATION controls.

b. To check the phasing of the instrument, set the Mode switch to the PHASE position. Note the meter reading and rotate the COARSE control one step clockwise. If the meter reading remained the same, the phasing is already correct. Return the COARSE control to its original position (one step counter-clockwise). Nor further adjustment is necessary. If there was a difference in the meter readings taken before and after the COARSE control was rotated one step counter-clockwise, then a phase adjustment is required. With the COARSE control in its original position, adjust the PHASE potentiometer about 1/4-turn clockwise and note the new meter reading. Rotate the COARSE control one step clockwise, take a reading, and return the COARSE control to its original position. Repeat the procedure using a further clockwise adjustment, until rotating the COARSE control one step clockwise produces no change in the meter reading. However, if the difference in meter readings was increased, the PHASE potentiometer should be rotated in a counter-clockwise direction instead.

c. To check the sensitivity of the instrument, set the Mode switch to the COMP position and rotate the COARSE control clockwise one step. The meter should read between 75 percent and 85 percent (22 to 26 mmhos/m) of full-scale deflection (inside black mark). Record the reading. Return the COARSE switch to its original position.

d. The instrument will be worn with the shoulder strap adjusted so that the instrument is at hip height. The Mode switch will be set to the OPER position. Rotate the Range switch so that the meter reads in the upper 2/3 of the scale. The full-scale deflection is now indicated by the Range switch and the instrument will be reading the terrain conductivity directly in mmhos/m.

e. The EM 31 can be operated continuously while moving from one measurement station to the next. However, the instrument has a time constant of about 1 second for which the operator will adjust his walking speed to obtain greatest accuracy. Alternatively, to extend battery life, the instrument will be switched on at each measurement station when not using a recorder. The operator will allow at least 2 seconds warm-up time after turn-on, prior to taking a measurement.

f. The EM 31 has been factory-calibrated. The calibration will be checked at a location in the vicinity of the site where soils are undisturbed and where they are similar to the native soil on site. Calibration will be checked prior to data collection each day and at the end of data collection each day to monitor any drifts in calibration. If the EM 31 shows drifts in calibration, the QF compensation control will be adjusted until the meter reads the background terrain conductivity determined at the start of the survey.

3. <u>Detection of Buried Metal</u>

The in-phase component of the magnetic field is significantly more sensitive to large metallic objects than the quadrature-phase component used for ground conductivity measurements.

a. <u>Operation</u>

1. The in-phase component of the magnetic field is measured with the Geonic EM-31D by taking the reading with the Mode switch in the COMP position. The 30 mmhos/m range will be used because it provides adequate sensitivity; however, more or less sensitive positions of the range switch may also be used.

2. To measure the in-phase component, the Mode switch will be set to the COMP position and adjusted with the COARSE and FINE compensation controls until a meter deflection of about 20 percent of full-scale deflection is obtained. Adjusting to 20 percent of the full-scale deflection, rather than to zero, is a convenience to allow for negative readings on the meter and, under certain conditions, a possible change in the reference level. For example, a sudden jar to the instrument can result in a small positive or negative change in the in-phase reference level.

This lack of a true zero reference should not cause any serious problems since, when using the in-phase component, one is usually only looking for buried metallic objects. These will be easily recognizable by relatively localized meter deflections occurring in response to the number of buried objects, their spacing, and depth of burial.

EM34-3

1. Equipment Setup

   a. At the beginning of the survey, select an area free of "cultural interference" and man-made conductors such as buried pipes, buildings, power lines, and steel reinforced concrete, etc.

   b. Having determined the coil separation to be used for the survey, lay the instrument out on the ground accordingly. Connect one end of the reference cable (10, 20, or 40 meters) to the 8-pin connector on the transmitter (Tx) coil and the other end to the "REFERENCE" connector on the receiver console. See attached sketch for proper use of thimbles and snaps on the cable.

   c. Connect the transmitter console to the transmitter coil using the appropriate short cable.

   d. Put the "LEVEL" switch on the transmitter console to the "NORMAL" position.

   e. Set the receiver and transmitter coils to the selected coil separation with red circles on the coils both facing in the same direction.

   f. Set the "SEPARATION" switch to selected value and turn on transmitter ("POWER/ON" switch to "ON" position).

   g. Check to see that the Battery Monitor Meter indicator is in the black area of the scale. If not, batteries are low or are not making proper contact with the battery clips. During the transmitter battery check, the transmitter coil has to be far from metal objects, including steel reinforced concrete flooring.

   h. Check condition of receiver battery by rotating receiver "SEPARATION" switch to "BATT" position with "POWER/ON" switch in "POWER/OFF" position.

   i. Set receiver "SEPARATION" switch to selected value.

2. Equipment Functional Checks

   a. Electronic nulling will be completed to remove any offsets in the output (DC) circuitry as follows:

      1. Complete equipment setup as described above.

      2. Prior to turning receiver on, insure that meters read zero. If they do not, adjust mechanical meter zero control located on the meters.

3. Turn on receiver ("POWER/ON" switch to "ON" position).

4. With receiver coil disconnected, depress "NULL" push button switch. Both meter needles should go to zero.

5. If either needle is not reading zero, release the lock on the appropriate "NULL" control potentiometer. Keeping the "NULL" switch depressed, adjust the "NULL" control to zero on the meter.

6. Lock the "NULL" control.

7. Connect the receiver coil to the receiver console "COIL" connector via the appropriate short cable.

b. Receiver compensation and gain check will be completed as described below:

1. Maintaining the receiver and transmitter coils in the same plan, adjust the coil separation to obtain a zero reading (center of the green area) on the "SEPARATION" meter (insure that red circles on coils face in the same direction). The coil separation should now measure the selected value and allow from 2 to 4 meters of slack reference cable between the thimbles which attach to the console leather cases.

2. With the "SENSITIVITY RANGE" switch set to the 300 mmhos/m position, move the receiver coil toward the transmitter until the "SEPARATION" meter deflects to the full scale mark.

3. Measure the distance that the receiver coil has moved. This distance should be 10.4 percent of inter-coil spacing.

After the above procedures have been performed, the instrument is ready for data collection. Reading sof apparent terrain conductivity are made directly using either the horizontal or vertical dipole mode, or both. At each measurement station, the position of the transmitter will remain fixed and the position of the receiver coil will be adjusted such that the "SEPARATION" meter is in the green area. The "SENSITIVITY RANGE" switch will be set so that the "CONDUCTIVITY" needle is in the upper 70 percent of the scale. The meter reading will then be recorded in mmhos/m.

During the survey, daily checks of the electronic nulling and receiver and transmitter battery condition will be performed to verify proper data collection.

3. <u>Multiple Coil Separation Surveys</u>

It is possible to use one cable for multiple coil spacing surveys, however, a simple calibration procedure is required. For 10 and 20 meter coil separations, the setup procedure is as follows:

a. Set up the instrument with the 10 meter cable, take and note a reading.

b. Without moving the coils, carefully remove the 10 meter cable and replace it with the 20 meter cable.

c. Take another reading at 10 meter separation with the 20 meter cable and note the reading. It will likely be different from the reading with the 10 meter cable.

d. The difference between the two readings is now your calibration constant to be either added or subtracted from all of you 10 meter readings. 20 meter readings are taken normally.

e. The procedure is the same for 20 and 40 meter separations.

EQUIPMENT

- Geonics Limited EM 31-D and EM 34-3 Terrain Conductivity Meter.
- Eight Size C batteries.
- Field book.
- 100-foot measuring tape.
- Wood stakes.
- Permanent markers.
- Site maps.
- Data logger.
- Laptop computer.
- Floppy diskette.

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FMG 4.2-01 GAMMA RAY LOG

FMG 4.2-02 GAMMA RAY LOGGING RECORD

GAMMA RAY LOGGING

INTRODUCTION

A gamma ray log measures the natural gamma ray radiation which is emitted by the geologic formation at a radius of 6 to 12 inches around the instrument. A downhole gamma ray log can be obtained for each borehole or monitoring well after completion. Differences in geologic composition of soil or rock will produce different gamma ray counts with clays/shales providing a higher natural gamma ray source then sands/sandstone.

To further characterize the hydrostratigraphic units, the deepest well in each cluster will be logged using downhole gamma ray and conductivity techniques. A Gamma Ray Logger and Geonics EM-39 Conductivity Logger, or equivalent, will be used in accordance with the operating instructions. The Gamma Ray Logger instrument has a scintillation detector housed in a brass body approximately 1.35 inches in diameter, which will allow the probe to be used in completed 2-inch diameter monitoring wells. The instrument has a high voltage power supply and pulse amplifier.

Using the inductive electromagnetic technique, the EM-39 provides measurement of the electrical conductivity of the soil and rock surrounding a borehole or monitoring well. The unit employs coaxial coil geometry with an intercoil spacing of 50 centimeters to provide a substantial radius of exploration into a formation while maintaining excellent vertical resolution. The EM-39 probe can be used with many available borehole logging systems or with the dedicated wench or console system. The instrument will be used in accordance with manufacturer's specifications.

PROCEDURES REFERENCED

- FMG 9.0 - Equipment Decontamination.

PROCEDURAL GUIDELINES

- Decontaminate the gamma ray logging probe and cable and the conductivity probe in accordance with FMG 9.0 - Equipment Decontamination.

- Measure the background value of gamma radiation by holding the instrument in the air within the vicinity of the borehole to be tested. The instrument should be equipped with a continuous read strip recorder, however if not then record the value on Form FMG 4.2-01 - Gamma Ray Log and Form FMG 4.2-02 - Gamma Ray Logging Record.
- Locate the measuring reference point on the well casing. If one is not found, initiate a reference point by notching the inner and outer casings with a hacksaw or by using a waterproof marker. If a well has both inner and outer casings, use the top of the inner casing as the reference point. All down-hole measurements will be collected from the reference points. If the logging is to be performed at a boring location, mark to the top of the augers or casing with a waterproof marker and then measure the distance between this temporary reference point to the ground surface so that a permanent reference point can be established.
- Lower the gamma ray logging probe to the bottom of the boring and measure the hole depth and counts per unit time on the gamma ray log sheet.
- Raise the gamma ray logging probe slowly, in increments predetermined by the supervising geologist, recording the depth and the average number of counts per unit time at each increment until the top of the bedrock is reached. (Note: the number of gamma ray counts will fluctuate substantially due to the fact that the tool will be passing by different geologic zones as it moves vertically upward; consequently, an average value will need to be estimated.) Allow the instrument to equilibrate for 1 minute between each increment. Record measurements on log.
- After gamma ray logging is completed, a final background reading will be recorded.
- As the cable and probe come through the top of the borehole, clean it in accordance with FMG 9.0 - Equipment Decontamination.

EQUIPMENT/MATERIALS

- Personal protective and monitoring equipment (as required by the Health and Safety Plan).
- Gamma ray and conductivity logging systems.
- Power source.
- Engineer's scale.
- Log forms.
- Cleaning supplies (including non-phosphate soap, buckets, handiwipes, distilled/deionized water, tap water).

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DOWN HOLE CALIPER LOGGING

INTRODUCTION

The following procedure describes the caliper well logging technique. Caliper logging is a technique used to measure fractures, joints, and caving in bedrock wells, and is not applicable to overburden investigations.

The caliper tool has three or four spring-loaded arms at the base of the cylindrical instrument. The tool is lowered to the bottom of the bedrock well, the springs are released, and the tool is raised up the well. Whenever the arms advance over a fracture or void, they spread out and extend into the feature. These deviations from the well diameter are recorded by the instrument, and recorded on a laptop computer.

PROCEDURES REFERENCED

- FMG 9.0 - Equipment Decontamination.

PROCEDURAL GUIDELINES

- Decontaminate the caliper logging tool and cable in accordance with FMG 9.0 - Equipment Decontamination.
- Setup the tripod and winch and attach the caliper tool. The caliper tool is attached to one end of the signal cable, which is spooled on the winch. The other end of the signal cable is located on the winch, which is connected to a laptop computer or similar onboard hardware, in the case of a multi-tool logging system.
- Locate the measuring reference point on the well casing. If one is not found, initiate a reference point by notching the inner and outer casings with a hacksaw or by using a waterproof marker. If a well has both inner and outer casings, use the top of the inner casing as the reference point. All down-hole measurements will be collected from the reference points.
- Retract the caliper arms, and lower the caliper tool to the bottom of the bedrock well. Release the arms to the extended position, and record data as the caliper tool is retrieved to surface. (Due to the configuration of the caliper arms, this type of logging can only be

completed in an upward direction in the well). The caliper tool will record the trace of each caliper arm individually with depth. Use a sampling interval of 0.02 feet, which may be averaged to 0.1 feet on the caliper log trace.

- As the cable and caliper tool come through the top of the borehole, clean them in accordance with FMG 9.0 - Equipment Decontamination.
- Provide caliper log deliverables including data plots of the caliper logs, and data in ASCII or similar format for possible additional processing. Strip logs may also be provided in the field for preliminary data interpretation, and comparison of caliper response from well to well.

EQUIPMENT/MATERIALS

- Personal protective and monitoring equipment (as required by the Health and Safety Plan).
- Gamma ray and conductivity logging systems.
- Power source.
- Engineer's scale.
- Log forms.
- Cleaning supplies (including non-phosphate soap, buckets, handiwipes, distilled/deionized water, tap water.

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FMG 5.1-01 GROUNDWATER LEVEL MONITORING REPORT

WATER LEVEL MEASUREMENTS

INTRODUCTION

This procedure describes measurement of water levels in groundwater monitoring and extraction wells, piezometers and boreholes. This procedure does not cover automated measurement of water levels with a transducer/datalogger, and does not cover measurement of phase-separated liquids.

Water levels in monitoring wells will be measured prior to each sampling event and at other times as indicated in the project Work Plan. Water levels will be acquired in a manner that provide accurate data that can be used to calculate vertical and horizontal hydraulic gradients and other hydrogeologic parameters. Accuracy in obtaining the measurements is critical to insure the useability of the data.

PROCEDURES REFERENCED

- FMG 6.5 - Non-Aqueous Phase Liquid (NAPL).
- FMG 8.0 - Field Instruments – Use/Calibration.
- FMG 9.0 - Equipment Decontamination.

PROCEDURAL GUIDELINES

In order to provide reliable data, water levels must be collected over as short a period of time as practical. Barometric pressure can affect groundwater levels and, therefore, observation of significant weather changes during the period of water level measurements must be noted. Tidal fluctuations, navigation controls on rivers, rainfall events, and groundwater pumping can also affect groundwater level measurements. Personnel collecting water level data must note if any of these controls are in effect during the groundwater level collection period. Due to possible changes during the groundwater level collection period, it is imperative that the time of data collection at each station be accurately recorded.

In conjunction with groundwater level measurements, surface water (e.g., ponds, lakes, rivers, and lagoons) often are monitored as well. This information is very helpful (and can be critical) in understanding the hydrogeologic setting of the site and most importantly how contaminants may move beneath the site.

The depth to groundwater will be measured with an electronic depth-indicating probe. Prior to obtaining a measurement, a fixed reference point on the well casing shall be established for each well to be measured. Unless otherwise established, the reference point is typically established and marked on the north side of the well casing. Avoid using protective casings or flush-mounted road boxes for reference, due to the greater potential for damage or settlement.

If provided for in the project Work Plan, the elevation of the reference point shall be obtained by accepted surveying methods, to the nearest 0.01 foot.

The water level probe will be lowered into the well until the meter indicates (via indicator light or tone) the water is reached. The probe will be raised above water level and slowly lowered again until water is indicated. The cable will be held against the side of the inner protective casing at the point designated for water level measurements and a depth reading taken. This procedure will be followed three times or until a consistent value is obtained. The value will be recorded to the nearest 0.01 foot on Form FMG 5.1-01 - Groundwater Level Monitoring Report or other designated data recording location if specified in the project Work Plan.

Upon completion, the probe will be raised to the surface and together with the amount of cable that entered the well casing, will be decontaminated in accordance with methods described in FMG 9.0 - Equipment Decontamination.

EQUIPMENT/MATERIALS

- Battery-operated, non-stretch electronic water level probe with permanent markings at 0.01-foot increments (traceable to national measurement standards), such as the Solinst Model 101 or equivalent.
- The calibrated cable on the depth indicator will be checked against a surveyor's steel tape once per quarter year. A new cable will be installed if the cable has changed by more than 0.01 percent (0.01 foot for a 100-foot cable). See also FMG 8.0 - Field Instruments – Use/Calibration.

REFERENCES

ASTM D4750 - Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well).

ASTM D6000 - Guide for Presentation of Water-Level Information from Ground-Water Sites.

Form FMG 5.1-01

GROUNDWATER LEVEL MONITORING REPORT

WELL NUMBER

Page   of

PROJECT ______________________ PROJECT MANAGER ______________

LOCATION ______________________ FIELD REP. ______________

CLIENT ______________________ DATE ______________

ELEVATION REFERENCED TO: ______________________

Date	Time	Elapsed Time (days)	Depth of Water from ( ) in ft	Elevation of Water	Remarks	Read By

FMG MODIFICATIONS MUST BE ACCOMPANIED BY A REVISION REQUEST FORM APPROVED BY THE PROJECT MANAGER

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FMG 5.2-01 SLUG TEST DATA REPORT

REMEDIATION TEAM	FIELD METHOD GUIDELINE NO.: FMG 5.2
REAL ESTATE & FACILITIES	EFFECTIVE DATE: MARCH 14, 2011
GENERAL MOTORS	
REVISION NO.: 0	REVISION DATE:

IN SITU HYDRAULIC CONDUCTIVITY (SLUG TEST) PROCEDURE

INTRODUCTION

This procedure describes the protocol for performing in situ hydraulic conductivity (slug) tests, including preparation, collection of valid field data, and preliminary evaluation of the data.

A slug test is performed to assess the horizontal hydraulic conductivity of a water-bearing zone. Slug tests are accomplished by stressing the screened water-bearing zone through an instantaneous displacement (with a slug) (or removal of water with a bailer) and subsequently measuring and recording the water level response in the well versus time. If the removal of the slug or bailer does not result in the well recovering more than 5 percent of the "90 percent recovery time", then it is considered an "instantaneous" displacement.

Slug testing in select monitoring wells will be performed after the wells have been installed and developed as covered in the Work Plan. Slug testing data will be acquired in a manner that provides valid data that can be used to calculate the horizontal hydraulic conductivity of the formation tested.

There are two types of slug tests: falling-head tests and rising-head tests. It is generally preferable to do a rising-head slug test due to a number of potential problems that can arise with falling-head tests (some of these may lead to inaccurate hydraulic conductivity estimates). It is recommended water level measurements should be collected automatically using a datalogger/ pressure transducer system if at all possible, but they may be collected manually using a battery-operated water level measurement probe if necessary.

PROCEDURES REFERENCED

- FMG 3.0 - Monitoring Wells, Pump Wells, and Piezometers.
- FMG 5.1 - Water Level Measurements.
- FMG 8.0 - Field Instruments – Use/Calibration.
- FMG 9.0 - Equipment Decontamination.
- FMG 10.0 - Waste Characterization.

PROCEDURAL GUIDELINES

A slug test involves rapidly changing the water level in a well and then measuring the water-level response over time. A very quick change in the water level in a well should be effected at the beginning of a slug test using one of several methods:

- Preferably by inserting or withdrawing a solid or sealed object with an appropriate overall density.
- By changing the air pressure in a well (only when a pressure transducer is used).
- Only if absolutely necessary, adding or removing a slug of water (bailer).

The method chosen will depend on project needs, equipment availability, water disposal/ treatment options, pertinent laws and regulations, and operator experience.

The protocols that follow assume that a person effectively can perform one of the above methods for rapidly changing the water level in a well at the start of a slug test, and can then use either a manual or automatic procedure for measuring water level response over time.

<u>Considerations</u>

Certain activities should be avoided in slug testing. In general, a person should **not** conduct any type of slug testing in a well if:

- The well contains a pipe, a tube, or an obstruction in a depth range where the water level would change.
- The casing diameter in a well varies in the depth range where the water level would level change.
- The water level in a well has not yet recovered to nearly static conditions (e.g., 95 percent or more) after a prior disturbance (e.g., drilling, purging, development, previous well testing, etc.).
- Non-aqueous phase liquid (NAPL) is present in a well.

A ***rising-head*** test should generally **not** be conducted:

- By bailing multiple times, rather than creating an instantaneous water level change.
- By pumping to remove water, unless the amount of water to be removed by the pump can be removed nearly instantaneously and any backflush can be eliminated.
- By using bailers. If bailers must be used, avoid:
  - using a bailer that has a leaky check valve, or

- using a bailer with a diameter so close to that of the casing that groundwater is suctioned into the well while the bailer is raised.

- If the slug cannot be removed nearly instantaneously (e.g., if removal takes over 5 percent of the 90 percent recovery time).

Falling-head tests are generally **not** recommended due to inherent problems associated with reproducibility, the introduction of fluids, and general application restrictions. They are recommended in circumstances when no other option is available. Consult with the Project Manager or an experienced hydrogeologist before undertaking a falling-head test program. Note: Under no circumstances should a falling-head test be performed in a well where the static water level is within the screened section of the well.

Field Documentation

The following data should be obtained prior to heading into the field and/or in the field during slug testing and recorded appropriately (e.g., on Form FMG 5.2-01 - Slug Test Data Report), in a field book, and/or onto an electronic form copied to computer disk):

- Client name.
- Site name.
- Testing company.
- Name of tester.
- Date and time of test.
- Well number.
- Well location.
- Well casing, screen and borehole diameters.
- Well open hole section diameter.
- Total depth of well.
- Any unusual well, weather, or hydrologic features or conditions.
- Top-of-riser distance above ground surface.
- Test procedure used (slug, pneumatic, etc.).
- Transport and disposal methods for any water removed.
- Well drilling method (hollow-stem auger, mud rotary, etc.).
- Decontamination procedures.
- Problems and solutions to problems encountered during testing.
- Static water level.

Other information needed for proper slug-test data interpretation includes:

- Depth interval of screen or open section in well.
- Sandpack porosity (if water levels intersect screen).
- Sandpack diameter (if water levels intersect screen).
- Stratigraphic horizon materials and elevations.
- Hydraulic conductivity of bounding low hydraulic conductivity units, if present.
- Ground surface elevation.

Testing

The steps for conducting a slug test are as follows. An attempt to utilize dataloggers to collect water level measurements should be made if at all possible. Manual measurements should only be used if absolutely necessary but can, and should, be used to collect backup data. The steps for conducting a slug test using automatic water level measurements are as follows:

1. Conduct a review of the Work Plan and the Health and Safety Plan with the project field supervisor, and plan, as needed, for notifications to responsible parties and for site access.
2. Gather equipment needed and inspect for operation.
3. Decontaminate all necessary equipment before entering a site and between each well or as required in the Work Plan or in accordance with FMG 9.0 - Equipment Decontamination, if different.
4. Measure and record the static water level (SWL) in the well to be tested, the depth to bottom, and record whether the bottom is a hard or soft (silty) base.
5. Test the pressure transducer and data logger, and obtain well-bottom and SWL pressures, using the following steps:
   - Place the pressure transducer at least several feet below the top of water as well as below the projected depth of the lowest part of the slug to be used.
   - Make pressure readings until three uniform values are read consecutively.
   - Raise the datalogger 1 foot from its original position. View the pressure reading to confirm that the change in position was accurately reported by the transducer. Repeat the procedure, if required, lowering the transducer a greater distance and again confirming the readings.
   - Return the transducer to its original position and secure the suspension cable to the well casing. Again, make pressure readings until three uniform values are read consecutively. Compare with the original readings to make sure no drift occurs.

6. Perform the following pre-test activities if a rising-head test is to be performed:

   - Allow the slug that will be used to move slowly down into the groundwater. If possible, fully immerse the slug. If there is not enough water in the well for the slug to be fully immersed, then let the bottom of the slug gently come to rest on the well bottom if a hard base can be confirmed, or in the case of a soft well base, enough above the well bottom to avoid immersion in silt. For bailers, prevent agitation of sediment on the bottom of the well as sediment in the bailer may keep the check valve from properly sealing. Ensure that the slug will not bind with the transducer cable and cause the transducer to move.
   - Measure falling pressures during recovery using the pressure transducer until the water level in the well re-equilibrates to near-static conditions (95 percent recovery).
   - Set the pressure transducer below the base of the immersed slug.

7. Start the slug test by creating a nearly instantaneous displacement in water level:

   - For a ***rising-head*** test:
     - Pull the slug rapidly upwards, either remove it from the well (preferred), or secure/suspend it within the well several feet above the SWL if conditions prohibit removing it (for example, significant depth to water coincides with taking manual water level measurements). When using a bailer ensure, upon retrieving the bailer to the surface, that it is not leaking and contains the appropriate volume of water (full if entirely immersed, etc.).
     - Simultaneously pull slug and initiate the datalogger, beginning the measuring/ recording of rising water levels in the well at the predetermined time frequencies (a logarithmic time scale is usually employed).
     - If a bailer is used, listen for cascading water while the bailer is being raised or is suspended, a sign of check valve failure; if failure occurs, clean and repair the valve and start over.
     - If a bailer is used, measure the volume of water removed by the bailer after retrieval.
   - For ***falling-head*** tests, if employed, prepare the test in the same manner as for the rising-head test, but instead add a solid slug or a known volume of water as opposed to removing a slug or bailer of water.

8. Continue measuring the water levels as they change over time until the water in the well rises or falls to the limit specified in the Work Plan (if not specified then usually 90 percent recovery or 1 hour, whichever comes first (check with Project Manager to be sure). A preset logarithmic sampling interval, with increasing intervals of time, is ideal, usually predetermined by the datalogger's default setup. Check the datalogger to ensure data were collected.

9. Compare the volume of groundwater recovered in the bailer, if one is used, with the volume of groundwater estimated to have been removed from the well (V) based on the

initial recorded water level displacement (H) and borehole radius (r), e.g., $V=H\pi r^2$. If, for a rising-head test, the static water level lies within the screened section of the well, then the sandpack porosity (n) and radius (R) must accounted for also in the volume calculation, e.g., $V=H\pi r^2 + nH\pi(R-r)^2$. A similar comparison can be performed if a slug is used. If the volume recovered and the calculated volume do not reasonably correlate, based on site-specific conditions, the test should be performed again.

10. Record all general data in a field book and all pertinent testing data on Form FMG 5.2-01 - Slug Test Data Report.
11. Decontaminate all necessary equipment in accordance with the Work Plan or methods described in FMG 9.0 - Equipment Decontamination.
12. Properly containerize and label spent decontamination fluid or groundwater removed from the well in accordance with the Work Plan or methods described in FMG 10.0 - Waste Characterization.
13. Lock all well caps and secure the site as needed.
14. Submit the slug test data to a qualified scientist or engineer assigned by the Project Manager for interpretation. The data should be interpreted by an experienced hydrogeologist. Calculations should be based on an appropriate model for the known hydrogeologic conditions in the field. Evaluation of slug test data should be performed using an acceptable analytical method; GM preference is that slug tests be evaluated using either the Bouwer and Rice (1976) or Hvorslev (1951) method.

Any variations from these procedures should first be approved by the project field supervisor and/or Project Manager.

EQUIPMENT/MATERIALS

- A battery-operated water level measurement probe, marked in 0.01-foot increments.
- Form FMG 5.2-01 - Slug Test Data Report.
- Data logger and laptop computer with fully charged battery (if required).
- A solid or sealed slug (or a clean bailer).
- Clean rope or string for raising and lowering a slug.
- Appropriate container for withdrawn groundwater and/or decontamination fluids.
- If snow or soil removal from over a well might be required, a shovel.
- Site-access and well-cap keys, as needed.
- Site maps (property lines, wells, topography, etc.), as needed.

- If a well to be slug tested is an artesian flowing well, duct tape, couplings, and extra casing of appropriate diameter for increasing casing height so as to enable measurement of a static water level.
- Pressure transducer of appropriate pressure range for the depths of water to be tested, if needed.

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SLUG TEST DATA REPORT

WELL NO.

PROJECT ____________________ **PROJECT MGR.** ____________________

LOCATION ____________________ **FIELD REP.** ____________________

CLIENT ____________________ **TEST DATE** ____________________

Well Type (overburden, bedrock, etc.) ____________________

Installation Date ____________________

Displacement method (slug, bailer, pneumatic) ____________________

Test Section Length, L (ft.) ____________________

Borehole Diameter (in.) ____________________

Casing/Riser Diameter (in.) ____________________

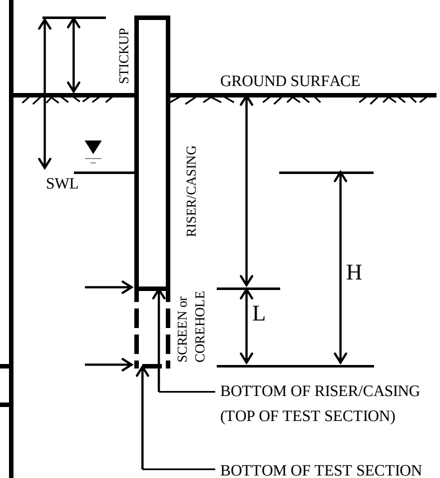
Interval type (screen, open rock, etc.) ____________________

Saturated Thickness, H (ft.) ____________________

Soil Description, depths ____________________

____

SKETCH/REMARKS



ALL DIMENSIONS IN FEET - Not To Scale

DEPTH/HEIGHT/ELEVATION:

Stick-Up/Stick-Down (ft.) __________ Static Water Level (ft.) __________

Top Of Test Interval (ft.) __________ Depth to Bottom (ft.) __________

Bottom Of Test Interval (ft.) __________

WATER LEVEL MEASUREMENT DATA

Clock Time	Time (min:sec)	Elapsed Time (min)	Depth To Water From ________ (ft)	Water Elevation (ft)	Comments

FMG MODIFICATIONS MUST BE ACCOMPANIED BY A REVISION REQUEST FORM APPROVED BY THE PROJECT MANAGER

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(Following Text)

FMG 5.3-01 PUMP TEST DATA FORM

PUMPING TESTS

INTRODUCTION

Pumping tests are performed to evaluate hydraulic properties and response of an aquifer. Accurate measurement of this hydraulic head drop in the pumping well and other observation points provides data which allow estimation of aquifer properties such as hydraulic conductivity, transmissivity, and storativity, radius of influence, boundary conditions (recharge and/or barrier), and pumping well efficiency.

This FMG covers the following procedures:

- Step-drawdown test (often referred to as a step test).
- Constant-rate pumping test (often referred to as an aquifer test or well performance test).
- Recovery test.

These three tests are the most common methods for evaluating aquifer properties. This FMG is meant to provide a reference for performing an aquifer testing program that meets the general data gathering needs and objectives for a pumping test. The protocols presented herein may require modification to meet site- and project-specific needs.

It is essential that an experienced hydrogeologist or groundwater specialist have input on, or at a minimum be allowed to review pumping test work plans prior to testing, especially where installations are required and will be conducted as part of the pumping test program.

PROCEDURES REFERENCED

- FMG 3.0 - Monitoring Wells, Pump Wells, and Piezometers.
- FMG 5.1 - Water Level Measurement Procedures.
- FMG 8.0 - Field Instruments – Use/Calibration.
- FMG 9.0 - Equipment Decontamination.
- FMG 10.0 - Waste Characterization.

PROCEDURAL GUIDELINES

PRE-TEST PREPARATIONS

There are a number of preliminary steps that should be taken prior to conducting any of the following aquifer tests. These include, at a minimum, the following:

- Review requirements of the Work Plan and Health and Safety Plan to assure compliance with any applicable requirements or regulations.
- Clear all necessary access issues (permission, physical access, permits, etc.).
- Gather all necessary equipment, materials, and tools necessary to adequately perform the testing.
- Identify the monitoring wells, piezometers, or other monitoring points to be used in the test.
- Gather all necessary installation information on the well to be pumped and all monitoring locations (total depths, screened intervals, depth of pump intake, etc.).
- Determine the most appropriate method to dispose of or route discharged groundwater. The water pumped during the test must be prevented from returning to the immediate vicinity of the groundwater system being tested for the duration of the test. If the water is not contaminated, it is recommended that the pumped water be discharged into temporary holding vessels, a surface water body that will not impact the groundwater system, or onto the surface a sufficient distance away from the pumping well and away from any monitoring locations. Any necessary approvals or permits required to discharge the water must be obtained prior to initiating the pumping test.

  If potentially contaminated, the water must be containerized for subsequent characterization and proper disposal or treatment in accordance with applicable regulations (FMG 10.0 - Waste Characterization).
- Collect as much pre-test water level measurement data (trend data) as practicable to determine noticeable trends in groundwater levels. Evaluate if the groundwater system is impacted by external and anthropogenic forces (e.g., tides, storm systems, proximal pumping, river recharge, railroads, etc.)
- Synchronize all time devices including watches, computer clocks, datalogger, and transducer clocks, etc.
- For a test well which is known to contain non-aqueous phase liquid (NAPL) or elevated levels of dissolved contaminants above applicable regulatory criteria, an evaluation must be made of whether it is believed the presence of NAPL or contaminants will adversely affect the contaminant plume or the aquifer test, and whether an aquifer test should be performed at all.

TEST PROCEDURES

Pump Discharge Flow Rate

Accurate measurement and maintenance of a constant discharge rate (or pumping rate, or flow rate) of the pumping well are important components of the step test and the pumping test. The measurement and control of the pumping rate are important elements to the collection of pump test data and the subsequent analysis and interpretation of the data.

Pumping discharge rates are most often measured using one of two methods: using an in-line commercial flow meter or using a calibrated container and a timing device. A flow meter is a direct-read device typically placed in line with the discharge tubing or piping. Alternatively, using a calibrated container (e.g., 5-gallon pail or 55-gallon drum) and a timing device (e.g., stopwatch) is an easy and effective method to measure flow.

Other methods also exist and can be employed if needed. Weirs and flumes are also routinely used when the aforementioned methods are not available. Details on the use of these methods can be found in more comprehensive hydrogeology references, which outline the dimensional analyses required based upon the weir shape, water velocity, etc.

Varying the flow rate may be accomplished a number of ways, but it is recommended that a variable, restrictive valve (e.g., ball valve or gate valve) be placed in line (downflow of the flow meter, if used) with the discharge tubing or piping. This allows for small changes to be made in the discharge without varying the power to or speed of the pump, which often cannot be controlled with any precision. If the use of flow control valves is not an option, certain pumps (line-shaft turbine pumps for example) may be employed to control the pumping flow rate using engine speed (rpm).

Discharge rate measurements should be collected frequently until the desired test rate is achieved. Measurements should be subsequently collected at regular intervals throughout the duration of the test, preferably at a 30- to 60-minute frequency.

Water Level Measurements

Water levels taken from the pumping well and adjacent monitoring wells may be gathered either manually using an electronic water level probe or automatically using a datalogger/transducer system. In either case water levels should be recorded as set forth in FMG 5.1 - Water Level Measurements, to the nearest 0.01 foot.

It is recommended that, with the available staffing, the pumping well and as many nearby monitoring locations as possible be manually monitored, even if data are being collected with dataloggers. This ensures that data will be collected in the event of a datalogger failure, and it also provides a quality control check against the datalogger data.

During the step test, pumping test, and recovery test water levels will be measured in the **pumping well** according to the following schedule, at a minimum:

Time Since Pumping Started/Stopped (minutes)	***Time Interval Between Readings (minutes)***
1 to 10	0.25 to 1.0
10 to 15	1
15 to 60	5
60 to 300	30
300 to 1440	60
1440 to End of Test	120 to 240 (2 to 4 hours)

Water levels in adjacent **monitoring wells** should be measured according to the following schedule, although data collection from monitoring wells during the step test is not as critical. NOTE: As a rule of thumb, wells within a distance (from the pumping well) 1.5 times the length of the pumping well screen-length should be monitored at the same schedule as for the pumping well above. Wells at a distance greater than that should be monitored as below:

Time Since Pumping Started/Stopped (minutes)	***Time Interval Between Readings (minutes)***
1 to 60	2
60 to 120	5
120 to 24	10
24 to 360	30
360 to 1440	60
1440 to End of Test	120 to 240 (2 to 4 hours)

These measurement schemes apply primarily to wells which are present within the anticipated zone of influence of the pumping well and to monitoring locations within the same water-bearing zone as the pumping well. Wells or surface water bodies which are expected to be outside the influence of the pumping well may be monitored less frequently in the early stages of monitoring than noted above. After the initial portion of the test they should be monitored as above.

PUMPING TEST PROCEDURES

Step-Drawdown Test

This pre-constant-rate test testing facilitates the evaluation of the flow rate, placement of the pump, and discharge control valve settings for the constant rate test, as well as calculation of a several aquifer/well parameters from a single well. The calculated specific capacities for each discharge pumping rate of the step test can be used to select optimum discharge rates for the constant-rate pump test, as well as other parameters such as head loss, relative proportions of laminar/turbulent flow, well efficiency (when used in conjunction with constant-rate test data), etc.

A step-drawdown test is performed by pumping a well at its lowest constant flow rate (first step) then increasing the flow rate for up to three to five steps through the range of the pumping capacity of the well. Each step should be held from 0.5 to 1 hour in duration, depending on project requirements. Each step should be of similar duration, unless otherwise specified. Each step should be performed at flow rates which range between approximately 50 and 150 percent of the estimated sustainable yield of the pumping well, or other successive rates which will not cause dewatering of the well. Such preliminary information may be obtained during prior well development, sampling, well response tests, or other drilling/ installation procedures. Each successive pumping rate step should be conducted for identical time periods. If time permits, the test well should be allowed to recover to within 90 percent of the SWL before proceeding with the next step.

It should be noted that, in theory, once a pumping well achieves a certain constant drawdown for a given pumping rate this is the actual start of the step test.

The step-drawdown test procedure is as follows:

- Collect a full round of static groundwater levels prior to performing the test.
- Pre-determine the flow rates to be employed during step-testing.
- Start pumping in the pumping well at the lowest rate first.
- Measure and record water levels in the pumping well during each individual step of the step test as set forth in the tables above, or in accordance with project specifications, if different.
- If time permits, allow at least 90 percent recovery between each step. Repeat each step of the step test, increasing the flow rate before the next step.

  The specific capacity value for each discharge rate may be calculated by simply dividing the pumping discharge rate by the final total drawdown value in the pumping well at the end of the test (e.g., 2.0 gpm/4.0 feet = 0.50 specific capacity at the particular time at which the step test ended). Again, it must be noted that the calculated value is essentially a point-in-time value and applies specifically to the end time of each step of the step-drawdown test.

Constant Rate Test

The constant-rate pumping test will be performed at a flow rate based on the results of the step-drawdown test and which will not result in the water level in the test well reaching within 3 to 5 feet of the pump intake or in accordance with the pump manufacturer's recommendations. Recovery to within 90 percent of SWL must be achieved after pumping during the step-test before starting the constant-rate pump test.

A typical duration of a constant-rate pumping test is performed between 48 and 72 hours, or more, as project requirements dictate. The pump-down should be continued long enough to develop drawdown patterns which reveal characteristics of the aquifer. Additional criteria may be utilized to determine the termination time, such as at the discretion of the Project Manager, other project constraints.

Water levels in the pumping well and selected observation wells should be measured as far in advance of, and on as many occasions before pump testing as possible to establish background and trends in the hydrogeologic regime. Observations should also be made in at least one observation well (as available) anticipated to be outside of the area of influence of the pumping well for the purpose of evaluating transient aquifer behavior which is not the result of pumping.

During the constant rate pumping test, the flow rate in the pumping well will be measured and recorded at least once each hour. Once the test has commenced, the designated flow rate of the pump will be maintained as closely as possible for the duration of the test. If equipment fails and cannot be restarted within a reasonable period of time (e.g., water levels in the adjacent observation well have recovered to greater than 50 percent of maximum observed drawdown), the pumping test will have to be repeated once the water levels have recovered to within at least 90 percent of pre-test levels.

The constant-rate test procedure is as follows:

- Collect a full round of static groundwater (and other, e.g., surface water) levels prior to performing the test.
- Install and program all datalogger/transducer systems, as needed, and record all information regarding individual transducer probes and test setups in notebook and/or on forms.
- If not previously done, synchronize all timing devices. Ready all datalogger automated-start times, manual measurements, and the initiation of the pump test.
- Start dataloggers just prior to starting the pump. Start the pump and dataloggers as simultaneously as possible but no more than 1 minute apart (start dataloggers first).
- Simultaneously measure manual water levels in the pumping well and selected monitoring wells according to frequencies set forth in the tables above, or in accordance with project specifications, if different.
- Measure discharge rate on a semi-continuous basis for the first hour or so, and half-hourly to hourly thereafter. Adjust as necessary to maintain the desired rate. Typically a variation of 5 to 10 percent of the desired rate is accepted.
- Measure other less frequently monitored locations as the test progresses, including out-of-range wells, nearby surface water bodies, barometric pressure, precipitation, etc., for the duration of the test.

- Upon terminating the constant-rate pump test but prior to stopping the pump, initiate recovery testing as described below.

<u>Recovery Test</u>

Recovery test data serve to validate the pump test drawdown data and aquifer parameters, as well as to determine if a change in aquifer storage has occurred since or as a result of the constant-rate pumping test.

Once the pumping test has reached the desired duration period, it is necessary to initiate a recovery test to gather water levels in the pumping well and selected monitoring wells once the pump is stopped. The groundwater level recovery within the pumping well and selected observation wells will be monitored at the time intervals indicated above or until at a minimum 90 percent recovery of static level has been achieved. The pump setup should only be removed following collection of the recovery data.

The recovery test procedure is as follows:

- If applicable, terminate datalogger data acquisition in the test well and monitoring wells while maintaining operation of the pump at the desired flow rate. The reason for terminating the datalogger and not allowing it to run is the fact that the datalogger will be collecting data at widely spaced intervals toward the end of the pumping test and the recovery test requires rapid data collection early on.
- If applicable, program parameters for a new datalogger test into the datalogger to monitor the recovery period in the pumping well and selected monitoring wells under a logarithmic schedule. Program the test to start immediately upon stopping the pump.
- End pumping test only after the approved duration.
- Stop the pump.
- Initiate manual or automatic water level measurements upon stopping the pump, according to the same frequency used for the constant-rate test. Again, it is recommended that manual measurements be collected from the pumping well and any nearby monitoring locations as possible to provide additional, backup data collection.
- Stop recovery period data collection upon reaching at least 90 percent recovery to the static water level in the pumping well.

Other individual tasks should be performed prior to, during, or after the constant-rate test as required, such as groundwater discharge sampling, barometer and/or precipitation logging, correspondence with appropriate contacts regarding progress, etc.

If applicable, upon completion of the pumping and recovery tests, all materials entering the well casing that are not disposable will be decontaminated in accordance with methods described in FMG 9.0 - Equipment Decontamination.

DATA EVALUATION

Pumping test data analysis should be performed only by an experienced hydrogeologist or groundwater specialist, and should be done using acceptable analytical methods for the site-specific hydrogeologic conditions encountered.

Typical pumping testing scenarios include steady-state or unsteady-state pumping conditions within either homogeneous unconsolidated materials (soils) or fractured-bedrock systems. Typical geologic conditions may include confined-aquifers (unconsolidated materials), unconfined-aquifers (unconsolidated materials), leaky-confined aquifers (unconsolidated materials), or fractured-bedrock aquifers.

Examples of applicable data analysis methods for homogeneous unconsolidated aquifers include the Thiem equation (for confined aquifers under steady-state flow conditions), Theis or Jacob-Cooper (confined aquifer, unsteady-state flow), Neuman curve-fitting (unconfined, unsteady-state), or Thiem-DuPuit (unconfined, steady-state). Leaky-confined aquifer systems may employ fractured-bedrock systems may require application of methods such as Moench (1984), Bourdet-Gringarten (1980), Kazemi (1969), or Warren-Root (1963).

These example methods are applicable only to very specific pumping test scenarios and require adherence to a number of basic assumptions. If these assumptions cannot be met or if a different hydrogeologic scenario in encountered, there are numerous other analytical tools which exist to evaluate aquifer characteristics.

EQUIPMENT/MATERIALS

- Pumping well "still-tube" (a long, open-bottomed section of small diameter solid pipe or tube (i.e., a piezometer) hung within the well casing that provides an unagitated water level surface for purposes of measuring water levels within the pumping well).
- Appropriately powered pump, wire, cables, and hoisting/securing devices.
- Generator, if needed.
- Flow meter or calibrated container(s) of suitable size.
- Stop watches, watches.
- Water level measurement probe(s).
- Transducer/datalogger setups, as needed.

- Portable laptop computer, as needed.
- Lighting for night operation.
- Auxiliary equipment such as suction hoses, discharge hoses, flow control valves, cables, wiring, tape, clamps, and other miscellaneous tools, materials, and equipment.
- Clipboards and Forms FMG 5.3-01 - Pump Test Data Form.

REFERENCES

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PUMP TEST DATA

WELL NUMBER

Page 1 of

PROJECT
LOCATION
CLIENT
DISTANCE FROM PUMPING WELL:

PROJECT MANAGER
FIELD REP.
DATE
TYPE OF TEST:

TIME DATA
Pump On:
Pump Off:
Duration of Test:

WATER LEVEL DATA
Static Water Level:
Measuring Point:
Elevation of Measuring Point:

DISCHARGE DATA
Measurement Method:
Depth of Pump:
Previous Pumping? (Y/N)
Duration/Period:

Date	Clock Time	Time Since Start *(t)*	Time Since Stop *(t')*	*t/t'*	Water Level Measure-ment	Water Level Change *(s or s ')*	Discharge Measure-ment	Discharge Rate (gpm)	Remarks

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PUMP TEST DATA

WELL NUMBER

Page of

Date	Clock Time	Time Since Start *(t)*	Time Since Stop (*t'*)	*t/t'*	Water Level Measurement	Water Level Change *(s or s')*	Discharge Measurement	Discharge Rate (gpm)	Remarks

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(Following Text)

FMG 5.4-01 WATER PRESSURE TEST LOG SHEETS

PACKER PRESSURE TESTING

INTRODUCTION

This FMG presents guidelines for performing water pressure (packer) testing in bedrock. Water pressure tests are typically performed in the bedrock portion of a borehole to locate and delineate permeable or fractured zones within a rock mass, and to provide quantitative measurements of the capacity of such zones to transmit water. The data collected can be used to calculate coefficient of permeability values for the rock mass within the limits of the test zone.

Assumptions and Limitations

Water pressure testing is a relatively simple way to measure hydraulic conductivity and is less costly than aquifer pumping tests. If performed properly, the test produces results that are sufficiently accurate for most engineering or environmental purposes. The test method analysis in this procedure assumes that water flow in the formation is laminar and that the rock formation is homogeneous. These assumptions, along with the inherent limitations of field measurement, necessitate that care should be used in reporting test results to the appropriate significant figure. (A useful guide for rules of significant figures is provided in Section 4 of American Society for Testing and Materials (ASTM) Standard E380; see References and Attachment A.)

PROCEDURES REFERENCED

- FMG 2.4 - Bedrock Coring.
- FMG 2.7 - Rock Classification.
- FMG 5.1 - Water Level Measurement Procedures.
- FMG 8.0 - Field Instruments – Use/Calibration.
- FMG 9.0 - Equipment Decontamination.
- FMG 10.0 - Waste Characterization.

General Considerations

The field geologist or field engineer in charge of the water pressure test operations is responsible for obtaining all necessary information and ensuring such tests are performed correctly. Any measurements of doubtful accuracy should be noted along with a description of the questionable issues.

Prior to the start of field testing, a determination of which borehole sections will undergo water pressure testing will be established by the project geologist or project engineer. This determination will be based on the following considerations:

- Type of bedrock.
- Quality of bedrock (joints, weathering, etc.).
- Thickness of stratum.
- Desired number of tests.
- Desired interval(s) in which to install well(s).

The field geologist or field engineer should be aware of these considerations and should be familiar with anticipated or known subsurface conditions in the vicinity of the tests. Drilling, logging, and characterization of bedrock is described in FMG 2.4 - Bedrock Coring and FMG 2.7 - Rock Classification, respectively.

PROCEDURAL GUIDELINES

Length, volume, pressure, and time measurements will be made as accurately as the equipment employed will permit. Gauges and meters will be checked for accuracy prior to initiation of field activity and periodically during the course of the work as warranted.

PRE-TEST PROCEDURES

Equipment

- Packer - Pneumatically expandable packer units are preferred to mechanically expandable units because of the superior pressure seal created between the packer and borehole wall in pneumatic units.
- Pump and Surge Tank - A surge tank is required when a centrifugal pump is used. The surge tank insures that a constant non-pulsating flow of water is available for pumping during testing.
- Flow Meter - No single flow meter is sufficiently accurate to be used at all ranges of expected water deliveries (less than 1 gallon per minute (gpm) up to several hundred gpm). Therefore, two meters are recommended:
  - A 1-inch disk-type meter for flow up to 50 gpm, and
  - A 4-inch propeller or impeller type meter that measures flows between 50 and 350 gpm.

- Pressure Gauges.
- Water Level Measurement Probe.
- Stopwatch or Digital Watch.
- Data Sheet (Form FMG 5.4-01 - Water Pressure Test Log Sheets).

The contractor supplying the gauges, meters, and testing equipment will provide manufacturers' specifications and recent (within 1 year) calibration curves by an authorized laboratory for this equipment. In the event that the contractor supplying the gauges, meters, and testing equipment cannot provide recent (within 1 year) calibration charts by an authorized laboratory for the various items, the project geologist or project engineer may require field or laboratory calibration tests on the applicable items (refer to Determination of Friction Losses below).

Setup

The equipment setup is critical for proper water pressure testing. All drill rods and hoses conveying water must be free and clear of any obstruction, debris, dirt, or general contamination prior to testing. In general, the placement order of equipment from the pump to the packer is as follows:

- Pump.
- Bypass/Shutoff Valve(s).
- Flow Meter.
- Pressure Gauge.
- Drill Rods Connecting to the Packer.

It is critical that the pressure gauge be connected as close to the drill string as possible to obtain an accurate measure of the applied pressure.

Determination of Friction Losses

If pressure transducers are placed in the mid-point of the interval to be tested, exact pressure changes due to water injection can be measured and the calibration described below will not be needed.

- Calibration tests are performed to determine internal friction losses of water pressure through the entire assembly. The calibration test is performed with the testing assembly lying the ground in a near-horizontal position and connected with the same equipment arrangement as for an actual test in the hole.
- Suspend the testing assembly slightly above ground level so that the discharge from any of the perforations will not be impeded. In order to establish if the pump can deliver the

specified quantity of water, conduct the calibration test using the same volume of water as that of the actual testing at the hole locations. If the quantity of water pumped falls below that specified, the contractor will be required to furnish a larger pump or hook up several smaller pumps in series or parallel before the calibration is continued.

- Perform the calibration test with three representative assemblies (for example, lengths of 50, 100, and 150 feet) to determine frictional losses in the entire operating range required for a particular installation location.
- Start the calibration test with the shortest-length assembly (50-foot pipe section for the example above; vary as appropriate for the actual test), turn the pump to maximum capacity, and bring the pressure gauge back to the nearest multiple of 5 psi to the maximum pressure by adjusting the valves. Keep the pressure constant while measuring the quantity of water discharged in 5 minutes. Next, lower the pressure to the next required pressure, re-run for the next 5 minutes, and record the discharge volume. Repeat this procedure until the full range of friction losses and related discharges has been determined for the 50-foot testing assembly length. Repeat the complete procedure outlined above with the remaining length test assemblies (100- and 150-foot pipe assemblies for the example above).
- Record calibration test data in applicable sections of Form FMG 5.4-01 - Water Pressure Test Log Sheets. A calibration chart for the field equipment should be prepared from the field data.

Calculation of Maximum Gauge Pressures

- Advance the drill casing or rock core barrel to the desired test interval. Flush the open borehole with clean water until all cuttings are removed.
- Evaluate the type and quality of the rock cored, taking into consideration the presence of any discontinuities which could affect the test procedures or results.
- Determine the static water level (SWL) in the borehole in accordance with FMG 5.1 - Water Level Measurements. Perform testing only once long-term stabilized groundwater levels are observed. If the water level continues to change appreciably or there are unusual hydrogeologic conditions, it may be necessary to determine hydrostatic pressure at individual test sections.
- Determine the allowable Maximum Gauge Pressure (MGP) for each test in order to avoid hydrofracturing or generating dislocations in the rock mass. **Do not** exceed the MGP during testing. However, the MGP may be decreased, depending on the integrity of the rock mass in the test zone and in the packer-seal zone.

  The MGP will vary with each test as it is directly related to the depth below ground surface of the test interval. Hydrologic conditions in the test area also affect the MGP. Under normal conditions the MGP is calculated as follows:

MGP (in psi) = Z * n

where:

Z = depth below ground surface to the bottom of the upper packer (ft.); and

n = a constant varying from 0.5 to 1.0, which a function of rock type and quality, and the vertical stress and static water pressure at the test zone. A value of 0.5 should be used where the rock RQD is less than 50 percent, and 1.0 used where the RQD is greater than 75 percent. Under certain hydrogeologic conditions, "n" may be varied to adjust MGP values as deemed necessary by the project hydrogeologist (high static water levels, artesian conditions, etc.)

In general, an "n" value of 0.75 can be used. The following table of standard MGP values versus depth of test section is calculated by setting n = 0.75 and rounding up to the nearest 5 psi. These standard MGP values will more easily allow for statistical comparison of test results between test sections and/or between boreholes.

Depth to Bottom of Upper Packer (Z) (feet)	***Maximum Gauge Pressure (MGP) (psi) (Z*n, where n = 0.75)***
20 to 40	25
40 to 60	40
60 to 80	55
80 to 100	70
100 to 120	85
120 to 140	100

<u>Single Packer Test Procedures</u>

- Lower the test apparatus to the desired depth for testing, as determined by the project geologist or project engineer. After making all water and pneumatic connections, run pump until water return in the casing is observed to be free of air bubbles. This is done in order to purge the entire system of air. Failure to do so may, under certain conditions, cause the compression of the air left in the system, resulting in water which appears to be flowing into the rock while it is in fact compressing the air.
- Produce a spacing between packers of approximately 5 to 10 feet; this spacing may be adjusted in the field to meet the requirements of the specific test. Accurately measure and record the test section length; do not assume it is precisely 10.0 feet. Note that the inflatable portion of the packer assembly is less than the length of the entire assembly.
- Inflate hard rubber inflatable packers (Lynes type) in the range from 150 to 600 psi. Inflate soft rubber packers (Damco type) in the range from 100 to 300 psi. The applied packer assembly pressure is variable, subject to equipment type, rock quality, and static water pressure. Check with the manufacturer for the maximum allowable pressure then add the water column height (in feet) multiplied by 0.433.

- Pump **clean** water under pressure into the borehole interval. Apply the water pressure in approximately three equal steps (0.4 MGP, 0.7 MGP, and 1.0 MGP), with the highest pressure being the designated MGP for that test section. Record water flow readings every minute for 5 minutes for each of the low and medium pressures. Adjust the water pressure to the MGP peak pressure and again hold for 5 minutes and record flow readings every minute. Repeat the procedure of recording the water flow with elapsed time in descending order for high to low pressure after reaching MGP (this is really only necessary when the formation takes water).
- During any of the test stages outlined above, if the water level in the well casing above the packer assembly is observed to rise or to flow out top of the casing (a water level probe should be used to measure increases in the SWL in the casing), or the entire test apparatus is observed to move up or down within the borehole, it is an indication of leakage of water between the packers and the rock walls of the borehole. In that event, increase pneumatic seal pressure while continuing to pump water until the rise in water level or the flow over the top of the casing is completely stopped. If bubbles are observed, it is an indication of gas leaking from packers, requiring removal of the test assembly from the borehole to correct the problem. Although it is difficult to impossible to determine, occasionally discontinuities in the rock mass, such as open vertical joints, may transmit water into the formation, up and around the packer assembly, and back up into the casing. If such a flow persists following an increase in the pneumatic seal pressure it is considered an intake by the rock mass. However, this should be verified through observation of the rock core by an experienced geologist.
- Record all irregularities which may occur during the test, such as presence of air, fluid leakage, packer movement, pressure fluctuation, etc.
- If leakage of water from the test section into the surrounding rock is so great that the MGP cannot be reached, run the pump at its full capacity with the bypass valve closed. Record the amount of water pumped into the test section, at 1-minute intervals, with associated pressure readings for a minimum of 10 minutes.
- If rock in the test section will not "take" water at MGP, check conditions in vicinity for any indications of unusually high hydrostatic pressure, i.e., artesian condition or nearby high surface water level. However, in most cases the rock mass will not take water because of the general "tightness" of the rock mass.
- Upon completion of the test, deflate the packers while the water pump is running and allow 1 or 2 minutes of water flow. Observe the water meter (gallons) and be sure there is an unrestricted flow through the system. This is especially important during the winter months since water may freeze inside the meter under no-flow conditions.
- If the test does not produce desired pressure and flow information, advise the project geologist who will advise the Project Manager before demobilizing from the site. Testing may need to be repeated.
- Decontaminate all materials/equipment which entered the well in accordance with the procedures in FMG 9.0 - Equipment Decontamination.

- Determine appropriate treatment/disposal of collected decontamination materials in accordance with the procedures in FMG 10.0 - Waste Characterization.

Double Packer Test Procedures

Packer pressure testing with double packer assemblies is similar to single packer testing except that, instead of the base of the corehole serving as the bottom of the test interval, a second packer is used as the base of the test interval. All other procedures are similar as above.

Simplified Test Procedures for Flow-Zone/ Monitoring Zone Profiling Only

An alternative to the full-packer method may be used for flow-zone/monitoring-zone profiling, in which the indication of a zone of adequate groundwater flow is all that is required. This method uses only one pressure (0.5Z, in psi) run for approximately 15 minutes, unless the aquifer takes excessive water (above 300 gallons). Although this method does not provide permeability results that are as accurate as complete testing, it can provide a quick and reasonable estimate for profiling and well installation purposes.

ANALYSIS

The volume of water which enters the bedrock is a function of the hydraulic conductivity. The observed values are related to hydraulic conductivity, K, by the following equation (Earth Manual (1974); see References):

$K = 10{,}809\ (Q/LH) \ln (L/r)$ [Hvorslev, Case 8 (1951)].

where:

K = hydraulic conductivity in cm/sec times 10^{-6}.

Q = rate of water inflow in gpm.

L = test section length in feet.

H = total head which consists of the sum of pressure head (from the gauge, psi*0.433 = feet of water), the depth to groundwater (calculated from vertical gradients determined from nearby monitoring wells) and the height of the pressure gauge above ground surface, all measured in feet.

r = radius of the borehole in feet.

The value 10,809 is a factor that converts gallons to cubic centimeters, feet to centimeters, and minutes to seconds.

Lugeon Method

The Lugeon Method of test result interpretation (Houlsby, 1986; see References) allows determination of the effect of the testing procedure on the hydraulic conductivity values obtained from the test. At least five major conditions may develop during water pressure testing that influence the hydraulic conductivity calculations. These conditions are: laminar flow, turbulent flow, fracture dilation, fracture wash-out, and void filling.

For this method, water pressure tests should be conducted using five pressures in increasing then decreasing pressures with each pressure being conducted in 5-minute increments. The recommended pressures used during each time increment are as follows (following the procedures discussed above):

- The first pressure (P1) is approximately 0.4 times the computed MGP.
- The second pressure (P2) is approximately 0.7 times the MGP.
- The third pressure (P3) is the computed MGP.
- The fourth pressure (P4) is equal to P2.
- The fifth pressure (P5) is equal to P1.

The Lugeon Method provides the following guidelines for selection of the recorded test pressures to be used in calculating hydraulic conductivity (K):

Condition Indicated by Lugeon Evaluation	***Pressure Used for K Calculation***
Laminar Flow	Average of the 5 pressures
Turbulent Flow	Highest test pressure
Dilation	Lowest or medium test pressure
Wash-out	P5
Void Filling	P1

The determination of which condition was predominant, and therefore which single pressure or pressure-suite should be used in calculating K, should be performed in consultation with Houlsby, 1976.

REFERENCES

American Society for Testing and Materials (1991), Standard E380-89a: "Excerpts from Standard Practice for Use of the International System of Units (SI) (the Modernized Metric System)", Annual Book of ASTM Standards, Section 4, Volume 04.08.

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Houlsby, A.C., (1976), "Routine Interpretation of the Lugeon Water-Test, Q. Journal of Engineering Geology, Volume 9, pp. 303-313.

Hvorslev, M.J. 1951. Time Lag and Soil Permeability in Ground-Water Observations. Bull. No. 36, Waterways Exper. Sta., Corps of Engineers., U.S. Army, Vicksburg, Mississippi: 1-50.

ATTACHMENT A

REPORTING CONDITIONS

Measured Flow Rate Q (gpm)	*Depth of Bottom of Upper Packer Z (feet)*	*Maximum Reportable No. of Significant Figures and Order of Magnitude for Values of K*
100	100	1.00×10^{-3}
10		1.0×10^{-4}
1		1×10^{-5}
0.1*		10^{-6}
0.01		not reportable, $<10^{-6}$
100	50	1.00×10^{-3}
10		1.0×10^{-4}
1		1×10^{-5}
0.1*		10^{-6}
0.01		not reportable, $<10^{-6}$
100	10	1.00×10^{-2}
10		1.0×10^{-3}
1		1×10^{-4}
0.1*		10^{-5}
0.01		not reportable, $<10^{-5}$

Note:

* 0.1 gpm is the lower limit of measurement capability for the standard water meter (5/8-inch displacement type) at ~95 percent accuracy.

WATER PRESSURE TEST

BORING No.	TEST No.
Page 1 of	

PROJECT ____________________ **PROJECT MGR.** ____________________
LOCATION ____________________ **FIELD REP.** ____________________
CLIENT ____________________ **DATE** ____________________
CONTRACTOR ____________________ **DRILLER** ____________________

	Packer System	Water Meter	Water Gauge	Surge Chamber
Type				
Mfg.				
Model No.				

MGP = (0.566 to 1.0) x Z: ____________________
Computed Maximum Gauge Pressure (MGP): ____________________
Computed Internal Friction: ____________________

Hole Size (type, diameter): ____________________
Rock Type: ____________________
Recovery (%): __________ RQD (%): __________

DEPTHS: (All distances from ground surface in feet)

To top of bedrock: ____________________
To bottom of boring: ____________________
To water table: ____________________

To top of lower packer: ____________________
To bottom of upper packer: ____________________
Length of test section (L): ____________________
Midpoint of test section (Z): ____________________

HEIGHT of water pressure gauge above ground surface (ft.): __________

Time	Elapsed Time	Packer Pressure (psi)	Gauge Pressure (psi)	Meter Reading (gal)	Flow Rate (gal/min)	Remarks

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WATER PRESSURE TEST

BORING No. | **TEST No.**

Page **of**

PROJECT ______________________________ **DATE** ____________

Time	Elapsed Time	Packer Pressure (psi)	Gauge Pressure (psi)	Meter Reading (gal)	Flow Rate (gal/min)	Remarks

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VERTICAL WATER QUALITY PROFILING

INTRODUCTION

Environmental investigations often involve characterizing the presence of contaminant compounds in groundwater. Such characterization is accomplished a number of ways depending on the site conditions, project objectives and regulatory requirements. Traditionally, site groundwater characterization has involved the installation of monitoring wells for sampling. In recent years, more refined methods of groundwater characterization have been developed. Several studies have shown that vertical mixing of contaminants in groundwater is limited, and that contaminant concentrations can vary by several orders of magnitude within very short vertical distances, even less than 1 foot. As such, installation of conventional monitoring wells, which typically have screen lengths of 5 to 10 feet or more, cannot discern the presence of narrow zones of significant contamination. Moreover, high concentrations of contaminant compounds in a narrow zone can be significantly diluted by cleaner-zone water entering into the well screen from outside the high concentration zone.

As traditional rotary drilling and sampling methods have been supplemented by direct-push methods, equipment has been developed that facilitates sampling groundwater from small, discrete sampling intervals. By obtaining a series of samples in a borehole, a vertical water quality profile can be developed. Such profiling can provide a more detailed understanding of site contaminant distribution and migration than might otherwise have been practical using only standard monitoring well methodology. It can be especially helpful for sites with variable soils that contain seams or zones of greater permeability where contaminants migrate more readily. Depending on regulatory or work plan requirements, the discrete, in situ samples may need to be combined with standard monitoring well samples.

Vertical water quality profiling is most often performed in overburden soils; however, discrete groundwater sampling can also be performed in bedrock, albeit using more time consuming and costly methods.

Although this FMG cannot include a comprehensive discussion of all available methods and equipment, it presents general guidelines for vertical water quality profiling.

PROCEDURES REFERENCED

- FMG 2.2 - Drilling Techniques.
- FMG 2.3 - Soil Borings.
- FMG 2.4 - Bedrock Coring.
- FMG 2.5 - Borehole Abandonment and Sealing.
- FMG 5.4 - Packer Pressure Testing.
- FMG 6.4 - Groundwater.
- FMG 9.0 - Equipment Decontamination.

PROCEDURAL GUIDELINES

In order to obtain a vertical profile of water quality, several discrete samples must be obtained at a subsurface exploration location. A discrete sample contains groundwater from within a short vertical section of the formation being tested, usually less than 1 foot. It must be obtained in a manner that does not allow the sample to be affected by groundwater from above or below the target interval, by drilling or other fluid in the borehole or casing, or by residual fluid in the sampler from previous samples. Thus procedures and sampling equipment designed with these restrictions in mind must be used.

A variation on the method of actually obtaining a sample of groundwater involves advancing through the soil a probe containing a detector designed to continuously measure levels of volatile organic compounds (VOCs). This method was developed by Geoprobe™ and utilizes their Membrane Interface Probe (MIP). This is discussed in further detail below.

<u>Overburden</u>

Several products have been developed to obtain discrete groundwater samples in overburden soils. These include, but are not limited to:

- Hydropunch™, by QED.
- Groundwater Profiler, by Geoprobe™.
- Screenpoint 15, by Geoprobe™.
- Waterloo Profiler, by the University of Waterloo, Ontario.

Each of these tools is generally deployed using direct-push methods, although conventional drop hammer methods can also be used. The tools are advanced by driving them down through saturated overburden soils. Once the desired depth of sampling is reached, a sample of groundwater is obtained from a narrow depth range.

Sample collection is performed differently manner depending on the type of tool used. For the Hydropunch and Screenpoint 15, the outer driving rods are retracted after reaching the desired depth, exposing an inner screened portion of the sampler that allows entry of groundwater into the sample chamber. At that point a sample of the groundwater is withdrawn from the sampling chamber and up through the drill rods using any of the following:

- A foot valve (Waterra or similar product) and tubing.
- A peristaltic pump connected to tubing.
- A small diameter bailer.
- Or other methods.

For the Groundwater Profiler, 6-inch or 12-inch sections of exposed screen are driven to the desired depth. Deionized water can be circulated down the drill rods, through the screen, and into the formation during advancement to prevent screen clogging or entry of unwanted groundwater from non-target zones. A sample is then obtained using one of the sample methods described above.

For the Waterloo Sampler, sample withdrawal tubing is connected to small screened ports in the probe. Deionized water is pumped downward through the tubing and into the formation during probe advancement to minimize clogging of the sampling ports. The tubing passes through the inside of the drive rods to the surface. Once the desired sampling depth is achieved, the tubing is connected to a peristaltic pump at the surface that extracts a groundwater sample.

In the case of the Groundwater Profiler and Waterloo Sampler, the tool is designed to remain in the borehole throughout the profiling effort. In others, the probe and screen may require removal and decontamination after each sample. FMG 9.0 - Equipment Decontamination should be referenced and followed for appropriate decontamination procedures between samples or sample locations, as necessary.

The following is a list of recommendations and/or requirements for effective groundwater profiling that will produce meaningful results:

- It is best if overburden stratigraphic conditions at the site can be evaluated, at least in part, prior to groundwater profiling. This will enable targeting specific zones or strata where soil grain size (and therefore groundwater flow) is most likely to be greatest, thereby increasing the chances of obtaining sufficient sample for analysis.
- The discrete sampling devices discussed herein are designed primarily for obtaining samples from granular soils, and in general, the coarser (grain size) the formation, the more readily it

will yield representative groundwater samples. Fine-grained soils (fine sandy silts, silts and clays) will often clog the intake openings of the samplers, limiting the inward flow of groundwater and necessitating significant and time-consuming efforts to remove and clean the openings. This should be taken into consideration when designing a sampling program.

- It is helpful to know the depth to the water table. Obtaining a sample at that depth will maximize the ability to evaluate the potential presence of light, non-aqueous, phase liquids (LNAPL).
- The length of sample intervals should be kept to a minimum, so that analytical results are representative of a narrow vertical range. If practical sampling intervals should be less than 1 foot.
- Regardless of sampling interval length, it is important to accurately determine the top and bottom limits of the interval. Accurate measurements of the sampling apparatus prior to deployment is essential. In addition, during deployment of the sampling screen, the length of rod retraction must be measured.
- Avoid overlap of sampling intervals, so that analytical results apply only to that interval. Overlap of sampling intervals will cause confusion with regard to the specific location of contaminants.
- When using a sampler that requires removal after each sample, decontamination of the screen and sampling chamber is critical. In addition, the sampler must be designed with measures that prevent infiltration of borehole fluids into the sampling chamber when returning the sampler to the borehole for additional samples. In general, this requires a system of O-rings or other sealing mechanism that keeps water out until the screen is deployed at the desired depth.
- When using the Groundwater Profiler or Waterloo Sampler it is imperative that clean deionized water be circulated down through the probe and into the formation during advancement. The water must be pumped at a rate/pressure that will prevent infiltration of groundwater into the sample screen or ports until the desired depth is reached.

  These units also require sufficient purging of the deionized water prior to obtaining the groundwater sample to insure a representative formation sample is obtained. The length and diameter of the tube must be known to calculate the minimum volume of water to purge. In addition, the water that was pumped into the formation at or near the sampling depth must also be accounted for and purged out if possible.
- If the target analytes are metals, it is recommended that a PVC screen be used in lieu of stainless steel.
- With regard to sampling, be sure that the work plan or regulatory requirements do not prohibit sampling with a tubing/foot valve assembly (e.g., Waterra) due to the potential for cavitation of gases that could affect volatile organics (VOCs) analysis results. It may be necessary to use a small-diameter bailer or other means to retrieve the sample.

- Upon exploration and sampling completion, seal the borehole with grout unless it is to be completed as a permanent well installation. This will minimize or prevent the potential for the borehole to exacerbate the spread of contaminants between zones that are otherwise separated by stratigraphic barriers.

Bedrock

Water quality profiling in bedrock is generally feasible, although obtaining discrete samples in narrow zones within bedrock is generally more time consuming and costly than in overburden. However, obtaining samples in zones as narrow and frequent as in overburden is generally not practical. Bedrock groundwater profiling is generally accomplished using a system of borehole packers (or a single packer) that allows collection of a groundwater sample from an isolated interval, albeit of a generally greater length. The sample collection apparatus may or may not be similar to the overburden equipment.

The following is a partial list of considerations when performing rock corehole water quality profiling:

- The proper description and logging of bedrock core is important in determining potential target sample intervals. The presence of pits, vugs, cavities, and other dissolution features, as well as fractures, bedding planes, and joints should be described and the correct depths of the features assigned. Rock coring should be performed in accordance with FMG 2.4 - Bedrock Coring.
- Packer pressure testing, performed as a precursor to water quality profiling in the corehole, can identify potential yielding transmitting portions of the bedrock that are likely to produce sufficient water quality samples (see FMG 5.4 - Packer Pressure Testing). These tests can also generate relative hydraulic conductivity values for the tested bedrock intervals. As indicated above it is crucial to recover all lost water from the formation prior to collecting representative groundwater samples.
- Development/recovery of all drilling water lost within the target interval is critical to obtaining a representative formation sample that is not diluted or contaminated by drilling water. At least as much water as was initially lost should be recovered during purging. Generally, 1.5 times the volume of drill water lost is an appropriate development quantity to achieve representative formation groundwater.
- It is recommended that maximum 5-foot intervals be sampled so as not to cause overlap of potential zones of interest or to isolate intervals which are too short as to include meaningful bedrock features.
- It is especially important to know the dimensions (i.e., lengths) of the apparatus being used for proper and accurate depth targeting in the bedrock.
- A submersible pump is recommended for collecting representative samples from depth. A submersible pump can operate at a lower flow rate so as to generate minimal turbulence for

VOCs sampling and analysis and can collect samples from deeper intervals. Other sampling apparatus may also be used if required, based on interval depth, etc.

- To prevent cross-contamination, proper decontamination must be performed when using non-dedicated equipment that is to be used at multiple locations or at multiple depths within a single location, including packer assemblies, reusable tubing, pumps, etc.

EQUIPMENT/MATERIALS

- Geoprobe Systems
  601 N. Broadway
  Salina, Kansas 67401
  (800) 436-7762
- QED Environmental Systems, Inc.
  P.O. Box 3726
  Ann Arbor, MI 48106-3726
  (800) 624-2026
- Waterloo Center for
  Groundwater Research
  University of Waterloo
  Waterloo, Ontario, Canada N2L 3G1
- Packer assembly apparatus, if required.
- Sampling pump(s) (Grundfos, peristaltic, bladder, etc.).
- Sampling apparatus (Waterra foot valve, tubing, mini-bailers, etc.).

REFERENCES

Company Literature, Waterloo Center for Groundwater Research, University of Waterloo, Waterloo, Ontario, Canada.

Company Literature, Geoprobe Systems, Salina, Kansas.

Company Literature, QED Environmental Systems, Inc., Ann Arbor, Michigan.

Company Literature, Solinst Canada, Ltd., Georgetown, Ontario, Canada.

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FMG 6.1-01 SOIL SAMPLE SELECTION DETAILS

SOIL

INTRODUCTION

The following procedure describes typical soil sample collection methods for submission of samples to a laboratory for chemical analysis. Three sample situations are presented: soil sampling from surficial soils, soil sampling from subsurface samplers such as a split-spoon sampler or a direct push sampler, and lastly soil sampling from a test pit.

Soil sampling procedures may vary from project to project due to different parameters of concern, different guidance provided by the state/province where the site is located, or the specific objectives for the project. Therefore, it is essential that the sampling team members carefully review the Work Plan requirements and the rationale behind the program. The primary goal of soil sampling is to collect representative samples for examination and chemical analysis (if required).

Grab Versus Composite Samples

A grab sample is collected to identify and quantify compounds at a specific location or interval. The sample shall be comprised of no more than the minimum amount of soil necessary to make up the volume of sample dictated by the required sample analyses. Composite samples are a mixture of a given number of sub-samples and are collected to characterize the average chemical composition in a given surface area or vertical horizon.

PROCEDURES REFERENCED

- FMG 2.1 - Test Pits.
- FMG 2.2 - Drilling Techniques.
- FMG 2.3 - Soil Borings.
- FMG 2.6 - Soil Classification.
- FMG 6.10 - Sample Handling and Shipping.
- FMG 9.0 - Equipment Decontamination.

PROCEDURAL GUIDELINES

1. SURFICIAL SOIL SAMPLE COLLECTION

1.1 Sample Strategy -Random, Biased, and Grid-Based Sampling

Unless there is a strong indication of contaminant presence, such as staining, then soil sample locations may be randomly selected from several areas within the site.

If any areas show evidence of contamination, such as staining or vegetative stress, biased samples shall be collected from each area to characterize the contamination present in each area. Background and control samples are also biased, since they are collected in locations typical of non-site-impacted conditions.

When soil sampling investigations involve large areas, a grid-based soil sampling program is used. There is no single grid size that is appropriate for all sites. Common grid sizes are developed on 50-foot and 100-foot centers. It is acceptable to integrate several different grid sizes in a single investigation.

For surficial soil sampling programs, it is also important to consider the presence of structures and drainage pathways that might affect contaminant migration. It is sometimes desirable to select sampling locations in low lying areas which are capable of retaining some surface water flow since these areas could provide samples which are representative of historic site conditions (worst-case scenario if surface water flow was a concern).

1.2 Sample Interval

Surficial soils are generally considered to be soil between ground surface and 6 to 12 inches below ground surface. However, for risk assessment purposes, regulatory authorities often consider soil from ground surface to 2 feet below ground surface to be surficial soil. The exact interval to be considered as surficial soil is often a matter of discussion with the regulatory authorities that review the Work Plan. The sample interval is important to the manner in which the data are ultimately interpreted. Another important factor is the type of soil. If there are different types of soil present at the site, this may have a bearing on the sample interval. For example, it may be important to separately sample a layer of material with high organic carbon content which overlies a layer of fine grained soil.

1.3 Surface Sampling Procedure

Soil sampling techniques are dependent upon the sample interval of interest, the type of soil material to be sampled, and the requirements for handling the sample after retrieval. The most common method for collection of surficial soil samples involves the use of a stainless steel trowel. Soil samples may also be collected with spoons and push tubes. The sampling equipment is cleaned between sample locations. A typical surficial soil sampling protocol is outlined below:

- Surficial soil samples will be collected using a precleaned stainless steel trowel or other appropriate tool. Each sample will consist of soil from the surface to the depth specified within the Work Plan.
- A new pair of disposable gloves will be used at each sample location.
- Any surficial debris (i.e., grass cover, gravel) should be removed from the area where the sample is to be collected using a separate precleaned device. Gravel presents difficulties for the laboratory in terms of sample preparation and is typically not representative of contaminant concentrations in nearby soil.
- A precleaned sampling tool will be used to remove the sample from the layer of exposed soil.
- When only one sample container is required, the collected soil will be placed directly into the clean, pre-labeled sample jar. When more than one sample container requires filling or samples will be split for duplicate analyses; the soils will first be homogenized in a precleaned stainless steel bowl; and then placed into the respective sample containers. It is important that soil samples be mixed as thoroughly as possible to ensure that the sample is as representative as possible of the sample interval. When round bowls are used for sample mixing, mixing is achieved by stirring the material in a circular motion and occasionally turning the material over. Soil samples collected for volatile organic compounds analyses shall <u>not</u> be mixed.
- Samples will be placed on ice or cooler packs in laboratory supplied shipping coolers after collection.

Exception is noted for the collection of volatile organic compounds (VOCs) which require special sample collection methods. VOCs are collected directly into a sample vial (triplicate volume typically required) without headspace, or collected using an EnCore Sampler™ (triplicate samples collected in accordance with manufacturer's instructions). Samples for VOCs are typically collected first, without homogenization or extra handling to limit the loss of volatile constituents.

The VOC sample collection methodology will be identified in the Work Plan, which will dictate the sample method. The methodology for VOC sampling varies from area to area, so carefull review of this issue in advance of the field efforts is required.

2. SUBSURFACE SAMPLE COLLECTION

Subsurface soil sample collection is typically performed with the help of a drill unit, direct-push probing unit, or hand-driven/held samplers. Typically a boring is advanced incrementally to permit intermittent or continuous sampling to the required depth of chemical sample collection;

or alternatively sampling may be initiated if certain conditions are observed (i.e., chemical presence or volatile presence identified from monitoring). Sample collection criteria and locations, are normally stipulated by the Work Plan.

Any drilling procedure that provides a suitably clean and stable hole before insertion of the sampler and assures that the penetration test or other sampling technique is performed on essentially undisturbed soil is acceptable. The drilling method is to be selected based on the subsurface conditions. Each of the following procedures have proven to be acceptable for specific subsurface conditions:

- Conventional drilling with continuous flight hollow-stem auger (HSA) method (with inside diameter between 2.2 and 6.5 inches) using split-spoon samplers (Standard Penetration Test – STP) or Shelby tube samplers; or
- Direct-push samplers, advanced using a percussion/vibratory hammer (Geoprobe™ or equivalent); or
- Hand–held/driven split-spoon sampling equipment or portable hammer and split-spoon sampling equipment (final depth will be limited).

Several drilling methods are not acceptable. These include: jetting through an open tube sampler and then sampling when the desired depth is reached; use of continuous flight solid auger equipment below the groundwater table in non-cohesive soils; casing driven below the sampling depth prior to sampling; and advancing a borehole with bottom discharge bits.

The following subsections describe the specific methods for completing split-spoon sampling, Shelby tube sampling, and direct-push sampling. Section 2.4 - Soil Core Chemical Sample Collection Procedure describes the soil sampling procedure for chemical analysis, once a soil core is recovered from any of the above sample collection devices.

2.1 Split–Spoon Sampling Method

This method is used to obtain representative samples of subsurface soil materials for sample collection. The test methods described below must be followed to ensure that the soils captured in the split-spoon or Shelby tube are relatively undisturbed/representative of the desired soil interval and obtain accurate SPT values. The SPT values reflect the subsurface soils density and is typically measured when performing geotechnical work or environmental borings. This information although not directly relevant to the collection of chemical samples, is collected because it is beneficail in terms of stratigraphy interpretation and understanding the conditions below grade.

The split barrel sampler, or split spoon, consists of an 18- or 24-inch long, 2-inch outside diameter tube, which comes apart length wise into two halves. Larger spoons are available for use when a larger sample volume is required (4-inch diameter spoons).

Once the borehole (i.e., HSA) is advanced to the target depth and the borehole cleaned of cuttings, representative soil samples are collected in the following manner:

- The split-spoon sampler should be inspected to ensure it is properly cleaned and decontaminated. The driving shoe (tip) should be relatively sharp and free of severe dents and distortions.
- The cleaned split-spoon sampler is attached to the drill rods and lowered into the borehole. Do not allow the sampler to drop onto the soil.
- After the sampler has been lowered to the bottom of the hole, it is given a single blow to seat it and make sure that it is in undisturbed soil. If there still appear to be excessive cuttings in the bottom of the borehole, remove the sampler from the borehole and remove the cuttings.
- Mark the drill rods in three or four successive 6-inch (0.15 m) increments, depending on sampler length, so that the advance of the sampler under the impact of the hammer can be easily observed for each 6-inch (0.15 m) increment.

The sampler is then driven continuously for either 18 or 24 inches (0.45 or 0.60 m) by use of a 140-pound (63.5 kg) hammer. The hammer may be lifted and dropped by either the cathead and rope method, or by using a trip, automatic, or semi-automatic drop system. The hammer should free-fall a distance of 30 inches (±1 inches) (760 mm, ±25 mm) per blow. Measure the drop at least daily to ensure that the drop is correct. To ensure a free-falling hammer, no more than 2 1/4 turns of the rope may be wound around the cathead (see ASTM D1586-84). The number of blows applied in each 6-inch (0.15 m) increment is counted until one of the following occurs:

- A total of 50 blows have been applied during any one of the 6-inch (0.15 m) increments described above;
- A total of 100 blows have been applied;
- There is no advancement of the sampler during the application of ten successive blows of the hammer (i.e., the spoon is "bouncing" on a stone or bedrock); or
- The sampler has advanced the complete 18 or 24 inches (0.45 or 0.60 m) without the limiting blow counts occurring as described above.

In some cases where the limiting number of blow counts has been exceeded, the field supervisor may direct the driller to attempt to drive the sampler more if collection of a greater sample length is essential.

On the field form, record the number of blows required to drive each 6-inch (0.15 m) increment of penetration. The first 6 inches is considered to be a seating drive. The sum of the number of blows required for the second and third 6 inches (0.15 m) of penetration is termed the "standard penetration resistance" or the "N-value".

> *Note: If the borehole has sloughed and there is caved material in the bottom, the split spoon may push through this under its own weight, but now the spoon is partially "pre-filled". When the spoon is driven the 18 or 24 inches representing its supposedly empty length, the spoon fills completely before the end of the drive interval. Two problems arise:*
>
> 1. *the top part of the sample is not representative of the in-place soil at that depth; and*
> 2. *the SPT value will be artificially higher toward the bottom of the drive interval since the spoon was packed full. These conditions should be noted on the field log.*

The sampler is then removed from the borehole and unthreaded from the drill rods. The open shoe (cutting end) and head of the sampler are partially unthreaded by the drill crew and the sampler is transferred to the field supervisors work surface.

The open shoe and head are removed by hand, and the sampler is tapped so that the spoon separates.

Measure and record the length of sample recovered making sure to discount any sloughed material that is present on top of the sample core.

Caution must be used when conducting SPT sampling below the groundwater table, particularly in sand or silt soils. These soils tend to heave or "blow back" up the borehole due to the difference in hydraulic pressures between the inside of the HSA and the undisturbed soil. To equalize the hydraulic pressure, the inside of the HSA must be filled with water. The drilling fluid level within the boring or HSA needs to be maintained at or above the in situ groundwater level at all times during drilling, removal of drill rods, and sampling. Since heave or blow back is not always obvious to the driller, it is essential that the water level in the borehole always be maintained at or above the groundwater level.

Section 2.4 - Soil Core Chemical Sample Collection Procedure describes the soil sampling procedure for chemical analysis, once a soil core is recovered from a split-spoon sampler.

2.2 Thin-Walled (Shelby Tubes) Sample Method

Thin-walled samplers are used to collect relatively undisturbed samples (as compared to split-spoon samples) of soft to stiff clayey soils. Shelby tubes are commonly used. The Shelby tube has an outside diameter of 2 or 3 inches and is 3 feet long. These undisturbed samples are used for certain laboratory tests of structural properties (consolidation, hydraulic conductivity, shear strength) or other tests (such as collection of soils for chemical analysis) that might be influenced by sample disturbance. Procedures for conducting thin-walled tube sampling are provided in ASTM D1587-94, and are briefly described below.

- The soil deposit being sampled must be cohesive in nature, and relatively free of sand, gravel, and cobble materials, as contact with these materials will damage the sampler.

- Clean out the borehole to the sampling elevation using whatever method is preferred that will ensure the material to be sampled is not disturbed. If groundwater is encountered, maintain the liquid level in the borehole at or above groundwater level during the sampling operation.
- Bottom discharge bits are not permitted. Side discharge bits may be used, with caution. Jetting through an open-tube sampler to clean out the borehole to sampling elevation is not permitted. Remove loose material from the center of a casing or HSA as carefully as possible to avoid disturbance of the material to be sampled.
- Place the sample tube so that its bottom rests on the bottom of the hole. Advance the sampler into the formation without rotation by a continuous and relatively rapid motion; usually hydraulic pressure is applied to the top of the drill rods.
- Determine the length of advance by the resistance and condition of the formation, but the length shall never exceed 5 to 10 diameters of the tube in sands and 10 to 15 diameters of the tube in clays.
- In no case should the length of advance be greater than the sample-tube length minus an allowance for the sampler head and a minimum of 3 inches for cuttings.
- The tube may be rotated to shear the bottom of the sample 2 to 3 minutes after pressing in, and prior to retrieval to ensure the sample does not slide out of the tube. Lift the weight of the rods off of the tube prior to rotating.
- Withdraw the sampler from the formation as carefully as possible in order to minimize disturbance of the sample.

On occasion it maybe required that extraction of the sample from the tube be conducted in the field for chemical sample collection. The following procedure should be followed.

- A sample extruder, which consists of a clamp arrangement to hold the tube and a hydraulic ram to push the sample through the tube, is usually mounted on the side of the rig. To prevent cross-contamination, be certain that the extruder is field cleaned between each sample.
- The sample is then extruded into a carrying tray; these are often made from a piece of 4-inch or 6-inch diameter PVC pipe cut lengthwise. Be certain that the carrying tray is field cleaned between each sample. The sample is carried to the work station to describe the sample, trim the potentially cross-contaminated exterior, and select the area for sample collection (see Section 2.4 - Soil Core Chemical Sample Collection Procedure). Form FMG 6.1-01 - Soil Sample Selection Details shows the method for obtaining a soil sample from a Shelby tube soil core.
- The Shelby tube may then be thoroughly field cleaned and decontaminated for reuse. Since they are thin-walled, the tubes are easily damaged, crimped, or otherwise distorted during handling or pushing. The Shelby tube should be inspected before use and any which are significantly damaged should be rejected.

Section 2.4 - Soil Core Chemical Sample Collection Procedure describes the soil sampling procedure for chemical analysis, once a soil core is recovered from a Shelby tube sampler.

2.3 Direct-Push Sample Method

The operation of the direct-push samplers (i.e., Macro-Core™ Soil Sampler or equivalent) consists of "pushing and/or vibrating" the sampler into the subsurface using a direct-push unit (i.e., Geoprobe™ soil probing machine or equivalent). The sampler is typically a hollow tube with a threaded drive head, and threaded cutting shoe; provided with an internal sleeve (i.e., liner) that the soil sample is captured in.

Once driven to the required depth, the sampler body/soil liner and soil core is removed from the borehole for inspection and sample collection. Once above grade the sampler is opened by the probe operator and the liner removed and cut open (opened with a dual blade cutting tool), to expose the soil for inspection and sampling.

The sampler body and ends are decontaminated, and a new liner is inserted and the sampler reassembled for collection of the next interval. The clean sampler is then advanced back down the same hole to collect the next soil sample. The Macro-Core™ sampler can be used in either the open-tube or closed-point sampling mode. The open-tube is most commonly used method, typically employed in stable soil conditions when the borehole does not collapse. The closed-point system seals the cutting shoe opening until the sampler is at the next sample interval, this prevents collapsed soil from entering the sampler as it is advanced back down the hole. Once at the sample depth, the closed-point is unthreaded and released from the cutting shoe area, such that it rides on top of the soil core as it is being driven into the next interval.

Section 2.4 - Soil Core Chemical Sample Collection Procedure describes the soil sampling procedure for chemical analysis, once a soil core is recovered from a direct-push sampler.

2.4 Soil Core Chemical Sample Collection Procedure

The following describes the collection of soil samples for chemical analysis from a split-spoon soil core, Shelby tube soil core, or direct-push sample core. Form FMG 6.1-01 - Soil Sample Selection Details shows the soil sample selection details. Sample preparation and selection is as follows:

- Record soil core recovery and soil stratigraphy data.
- Discard upper and lower ends of sample core (3 inches ±).
- If clayey soils are present use a precleaned stainless steel knife to cut the remaining core longitudinally, alternatively if sandy soils are present, use a clean stainless steel spoon to scrape away the soil surface.
- Screen the exposed soil surface with a PID to monitor for the presence of volatile organics.

- With a sample knife or spoon, remove soil from the center portion of the core and place in the sample jar (when only one aliquot is required), or when more than one aliquot is required place soils in a precleaned stainless steel bowl for homogenization.
- Do not sample large stones and natural vegetative debris.
- Homogenize the soil and place directly into the sample jars.
- Place collected samples on ice or cooler packs in laboratory-supplied shipping coolers.

When only one sample container is required, the collected soil will be placed directly into the clean, pre-labeled sample jar. When more than one sample container requires filling or samples will be split for duplicate analyses; the soils will first be homogenized in a precleaned stainless steel bowl; and then placed into the respective sample containers. It is important that soil samples be mixed as thoroughly as possible to ensure that the sample is as representative as possible of the sample interval. When round bowls are used for sample mixing, mixing is achieved by stirring the material in a circular motion and occasionally turning the material over. Soil samples collected for volatile organic compounds analyses shall <u>not</u> be mixed.

Exception is noted for the collection of VOCs which require special sample collection methods. VOCs are collected directly into a sample vial (triplicate volume typically required) without headspace, or collected in triplicate using an EnCore Sampler™ (triplicate samples collected per manufacturers instructions). Samples for VOCs are typically collected first, without homogenization or extra handling to limit the loss of volatile constituents.

The VOC sample collection methodology will be identified in the Work Plan, which will dictate the sample method. The methodology for VOC sampling varies from area to area, so carefull review of this issue in advance of the field efforts is required.

3. TEST PIT SOIL SAMPLE COLLECTION

Subsurface soil samples from a test pit are usually "grab samples", used to characterize the soil at a specific depth or depth interval (e.g., 2 to 4 feet). On occasion, composite samples are collected from a test pit over a greater depth interval (e.g., 5 to 15 feet) to characterize a soil or fill horizon.

Soil samples can be collected from the soils within the backhoe/excavation bucket or from the test pit excavation face (only after the safety concerns identified below have been addressed). Samples that require a discrete depth interval should be collected from the excavation face. Samples are procured using a cleaned steel trowel, shovel, or stainless steel spoon.

Safety Concerns:

1. *Do not enter the test pit unless Confined Space Entry requirements have been reviewed and applied (if required); and proper shoring of the excavation walls has been performed, (if necessary.)*
2. *Personnel observing or sampling test pit operations must never stand within the "turning radius" or "reach-zone" of the excavation equipment. Operator error, or equipment failure could result in severe injury or death if struck by the backhoe bucket or the backhoe itself.*
3. *Lastly, personnel should be alert to test pit side wall conditions which typically undermine the ground surface and create unstable soils surrounding the test pit area.*

The following describes the collection of grab samples for chemical analysis:

- Record soil stratigraphy and test pit data/observations, select area from which sample is required.
- Direct backhoe operator to scoop up soils from the desired area and place at ground surface.
- If clayey soils are present use a precleaned stainless steel knife to scrape away the surface soils that may have contacted the backhoe bucket; alternatively, if sandy soils are present, use a clean stainless steel spoon to scrape away the soil surface.
- Screen the exposed soil surface with a PID to monitor for the presence of volatile organics.
- With a sample knife or spoon, remove soil from the center portion of the area cleared and place in the sample jar (when only one aliquot is required), or when more than one aliquot is required place soils in a precleaned stainless steel bowl for homogenization.
- Do not sample large stones and natural vegetative debris.
- Homogenize the soil and place directly into the sample jars.
- Place collected samples on ice or cooler packs in laboratory supplied shipping coolers.

When only one sample container is required, the collected soil will be placed directly into the clean, pre-labeled sample jar. When more than one sample container requires filling or samples will be split for duplicate analyses; the soils will first be homogenized in a precleaned stainless steel bowl; and then placed into the respective sample containers. It is important that soil samples be mixed as thoroughly as possible to ensure that the sample is as representative as possible of the sample interval. When round bowls are used for sample mixing, mixing is achieved by stirring the material in a circular motion and occasionally turning the material over. Soil samples collected for VOC analyses shall <u>not</u> be mixed.

Exception is noted for the collection of VOCs which require special sample collection methods. VOCs are collected directly into a sample vial (triplicate volume typically required) without headspace, or collected in triplicate using an EnCore Sampler™ (triplicate samples collected per manufacturers instructions). Samples for VOCs are typically collected first, without homogenization or extra handling to limit the loss of volatile constituents.

The VOC sample collection methodology will be identified in the Work Plan, which will dictate the sample method. The methodology for VOC sampling varies from area to area, so carefull review of this issue in advance of the field efforts is required.

<u>Field Notes</u>

All conditions at the time of sample collection should be properly documented in the field log book. This should include a thorough description of the collection method, sample characteristics, including grain size, color, and general appearance, as well as date/time of sampling and labeling information. The location of the sampling point should be described in a sketch and three measurements (swing ties) should be taken to adjacent permanent structures so that the sample location can be readily identified in the field at a future date if necessary. It is often advisable to have a licensed land surveyor accurately survey the locations.

<u>Decontamination</u>

In all sampling scenarios measures to prevent cross-contamination must be employed. The sampling device selected must be constructed of an inert material with smooth surfaces that can be readily cleaned (see FMG 9.0 - Equipment Decontamination).

Heavy equipment used for test pit operations must also be cleaned between each location when collecting samples for chemical analysis.

EQUIPMENT/MATERIALS

- Drilling equipment and soil sampling tools.
- Decontamination fluids and rinse water.
- Subsurface boring log.
- Tape measure.
- Water level probe.

REFERENCES

ASTM D1452-80 - Practice for Soil Investigation and Sampling by Auger Borings.

ASTM D1586-84 - Test Method for Penetration Test and Split-Barrel Sampling of Soils.

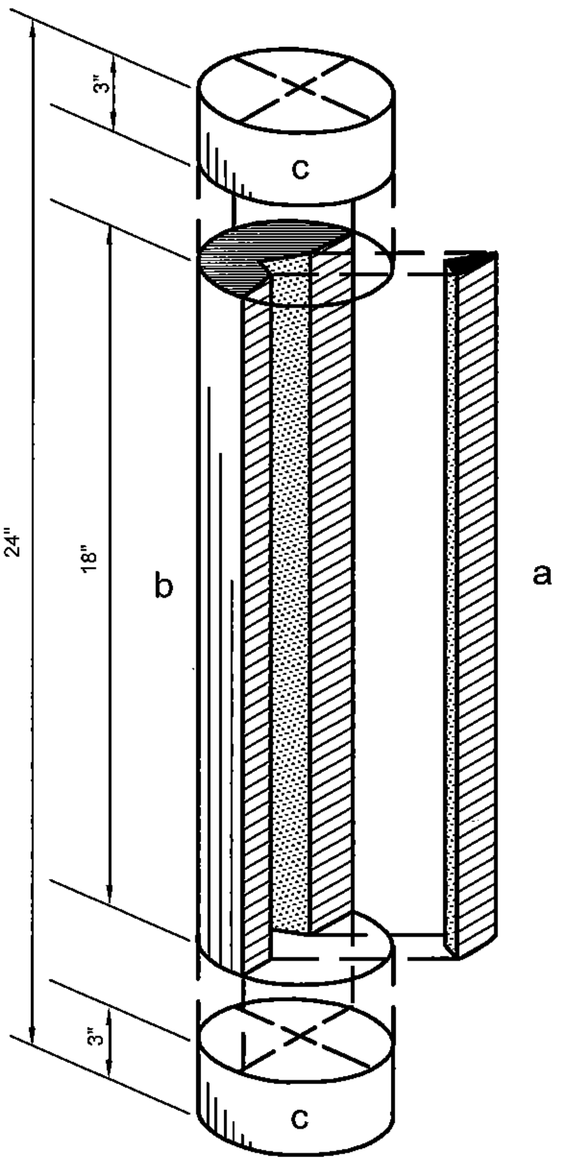
ASTM D1587-94 - Practice for Thin Walled Tube Geotechnical Sampling of Soils.

ASTM D2488-93 - Practice for Description and Identification of Soils (Visual-Manual Procedure).

ASTM D4700-91 - Guide for Soil Sampling from the Vadose Zone.

Environmental Protection Agency (1986), RCRA Ground-Water Monitoring Technical Enforcement Guidance Document, OSWER-9950.1.

Environmental Protection Agency (1987), A Compendium of Superfund Field Operations Methods, EPA/540/P-87/001.



TYPICAL SOIL CORE

a

PORTION OF SAMPLE FOR CHEMICAL ANALYSIS

-CONTACT WITH UNSTERILIZED MATERIALS IS NOT ACCEPTABLE

-STORAGE - REFRIGERATED (4°C)

-SHIPPING - ON ICE BY COURIER TO DESIGNATED LAB

b

PORTION OF SAMPLE TO BE RETAINED FOR GEOLOGIC RECORDS

-CONTACT WITH UNSTERILIZED MATERIALS IS NOT A PROBLEM

-CONTAINER: - CLEAN GLASS JAR
- CLEAR GLASS IS SUITABLE

-STORAGE - IN STANDARD SHIPPING CARTON
- NO REFRIGERATION REQUIRED

c

PORTION OF SAMPLE TO BE DISCARDED

-DISCARDED WITHIN 55 GALLON DRUM MAINTAINED ON-SITE

figure 6.1

SOIL SAMPLE SELECTION DETAILS

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SURFACE SEDIMENT

A. SURFACE SEDIMENT SAMPLING USING AN EKMAN GRAB SAMPLER - INTRODUCTION

This section describes the procedures used to collect surface sediment with an Ekman grab sampler. Surface sediment is typically analyzed for various physical and chemical variables. For the purposes of this section, surface sediment is defined as the upper 10 cm of the sediment column but may vary given the sampling interval specified in the study design.

A stainless steel Ekman grab sampler is capable of collecting acceptable samples from a variety of soft substrates, such as silt, silt mixed with clay, and silt mixed with some sand. The Ekman grab sampler has two doors on top to allow easy access to the sediment for visual characterization and sampling of surface sediments. The procedures for collecting surface sediment samples using the Ekman grab sampler are described below.

PROCEDURAL GUIDELINES

<u>Decontamination</u>

Before each station is sampled, decontaminate the inner surfaces of the grab sampler and all stainless steel sample compositing equipment. Sediment sampling and compositing equipment will be decontaminated using the following general sequence: site water rinse, Alconox scrub and rinse, site water rinse, solvent rinse (if applicable for a specific project) with acetone and hexane (respectively), and a final site water rinse. Equipment used for compositing the sediment samples will follow the same basic decontamination sequence except that the final rinse will be with laboratory-grade distilled/deionized water. If there is a significant lapse of time between decontamination of the sediment sampling and compositing equipment and collection of the sample, then the decontaminated sediment sampling and compositing equipment will be protected from additional contamination by wrapping it in foil (with the dull side of the foil touching the equipment) and placing it in clean bags for transport, if necessary.

All solvent rinsates will be collected into a bucket or tub and allowed to evaporate over the course of the day. Any rinsate that has not evaporated by the end of the sampling event will be containerized and disposed of in accordance with federal regulations.

Grab Sampler Deployment

1. If the water depth is less than 9 feet, attach the grab sampler to the metal handles. If the water depth is greater than 9 feet, use the rope to deploy the grab sampler.
2. Place the grab sampler on a decontaminated surface and open it.
3. Ensure that the two release wires are securely placed around the release pins.
4. Lower the sampler through the water column at a slow and steady speed.
5. Allow the grab sampler to contact the bottom gently, with only its weight being used to force it into the sediments. The sampler should never be allowed to "free fall" to the bottom because this may result in premature triggering, an excessive wake, or improper orientation upon contact with the bottom.
6. Deploy trigger weight (i.e., messenger) to release the doors on the bottom of the grab sampler.

Grab Retrieval

1. After the grab sampler has rested on the bottom for approximately 5 seconds, begin retrieving it at a slow and steady rate.
2. After the grab sampler breaks the water surface, gently lower it into a clean, flat-bottomed container, while maintaining the grab sampler in an upright position.
3. Open the doors on the top of the grab sampler, and inspect the sample for acceptability. The following acceptability criteria should be satisfied:
   - The sampler is not overfilled with sample to the point that the sediment surface presses against the top of the sampler or is extruded through the top of the sampler.
   - Overlying water is present (indicating minimal leakage).
   - The overlying water is not excessively turbid (indicating minimal disturbance or winnowing).
   - The sediment surface is relatively undisturbed.
   - The desired penetration depth is achieved.

If a sample fails to meet the above criteria, it will be rejected and discarded away from the station.

Penetration depth should be determined by placing a decontaminated stainless steel ruler against the center of the inside edge of the opening on the top of one side of the grab sampler and extending it into the grab sampler until it is almost in contact with the top of the sample. The penetration depth is determined by the difference between that measurement and the total depth of the grab sampler.

Sample Removal and Processing

1. For acceptable samples, remove the overlying water by slowly siphoning it off near one or more sides of the grab sampler. Ensure that the siphon does not contact the sediments or that fine grained suspended sediment is not siphoned off. If sediment is suspended in the overlying water, do not proceed with siphoning until the sediment is allowed sufficient time to settle.
2. After the overlying water is removed, characterize the sample as specified in the study design. Characteristics that are often recorded include:
   - Sediment type (e.g., silt, sand).
   - Texture (e.g., fine-grain, coarse, poorly sorted sand).
   - Color.
   - Approximate percentage of moisture.
   - Biological structures (e.g., chironomids, tubes, macrophytes).
   - Approximate percentage of biological structures.
   - Presence of debris (e.g., twigs, leaves).
   - Approximate percentage of organic debris.
   - Presence of shells.
   - Approximate percentage of shells.
   - Stratification, if any.
   - Presence of a sheen.
   - Odor (e.g., hydrogen sulfide, oil, creosote).
3. After the sample is characterized, remove the top 10 cm using a stainless steel spoon (see site-specific study design for project-specific sampling interval). Unrepresentative material (e.g., large shells, stones, leaves, twigs) should be carefully removed without touching the sediment sample under the supervision of the chief scientist and noted on the field logbook.
4. Remove subsamples for analysis of unstable constituents (e.g., volatile organic compounds, acid-volatile sulfides), and place them directly into sample containers without homogenization.
5. Transfer the remaining surface sediment to a stainless steel mixing bowl or pot for homogenization. Additional grab samples may be required to collect the volume of sediment specified in the study design. The mixing bowl should be covered with aluminum foil (dull side down) while additional grab samples are being collected to prevent sample contamination (e.g., from precipitation, splashing water, falling leaves).
6. After a sufficient volume of surface sediment from a grab is collected (i.e., 0 to 10 cm), move away from the station, open the jaws of the grab sampler, and allow the remainder

of the sediment sample to fall out of the grab sampler. Discard this material away from the station, and rinse away any sediment adhering to the inside of the grab sampler. The grab sampler is now ready for additional sampling at the same station or decontamination before sampling at a new station.

7. After a sufficient volume of sediment is transferred to the mixing bowl, homogenize the contents of the bowl using stainless steel spoons until the texture and color of the sediment appears to be uniform.
8. After the sample is homogenized, distribute subsamples to the various containers specified in the study design and preserve the samples as specified in the study design.

EQUIPMENT/MATERIALS

- Stainless steel Ekman grab sampler (typically 0.25 feet^2) with handle and rope.
- Trigger weight (i.e., messenger).
- Teflon® or polyethylene siphon.
- Flat-bottomed container (e.g., dish pan).
- Stainless steel ruler.
- Stainless steel spoons.
- Stainless steel mixing bowl or pot.
- Scrub brush.
- Squirt bottles (for solvents).
- Alconox® (laboratory detergent).
- Acetone and hexane (if applicable for a specific project).

B. SURFACE SEDIMENT SAMPLING USING A MODIFIED VAN VEEN GRAB SAMPLER - INTRODUCTION

This section describes the procedures used to collect surface sediment with a modified van Veen grab sampler. Surface sediment is typically analyzed for various physical and chemical variables. For the purposes of this section, surface sediment is defined as the upper 10 cm of the sediment column.

A modified stainless steel van Veen grab sampler is capable of collecting acceptable samples from a variety of substrates, such as mud, sand, gravel, and pebbles (APHA 1989). The modified van Veen grab sampler incorporates several design improvements over the traditional van Veen grab sampler that improve the quality of the sediment samples. The modified grab sampler has two doors on top to allow easy access to the sediment for visual characterization and subsampling of surface sediments. The interiors of the doors are made of screens to minimize the bow wake and the resulting disturbance of the sediment surface when the grab sampler is lowered to the bottom. Rubber flaps cover each screen as the grab sampler is retrieved to prevent disturbing the sediment sample as it is raised through the water column. The arms of the modified grab sampler are lengthened and arced to provide a stronger seal when the grab sampler is closed, thereby minimizing sample leakage when the grab sample is retrieved. Finally, the modified grab sampler has four detachable, epoxy-coated lead weights that allow the weight and penetration of the grab sampler to be optimized with respect to the kind of sediment being sampled.

PROCEDURAL GUIDELINES

Decontamination

Before each station is sampled, decontaminate the inner surfaces of the grab sampler and all stainless steel sample compositing equipment. Sediment sampling and compositing equipment will be decontaminated using the following general sequence: site water rinse, Alconox scrub and rinse, site water rinse, solvent rinse with acetone and hexane (respectively), and a final site water rinse. Equipment used for compositing the sediment samples will follow the same basic decontamination sequence except that the final rinse will be with laboratory-grade distilled/ deionized water. If there is a significant lapse of time between decontamination of the sample compositing equipment and collection of the sample, then the decontaminated compositing equipment will be protected from additional contamination by wrapping it in foil (with the dull side of the foil touching the equipment) and, if necessary, placing it in clean bags for transport.

All solvent rinsates will be collected into a bucket or tub and allowed to evaporate over the course of the day. Any rinsate that has not evaporated by the end of the sampling event will be containerized and disposed of in accordance with federal regulations.

Grab Sampler Deployment

1. Attach the grab sampler to the hydrowire with a swivel. The swivel minimizes the twisting forces on the sampler during deployment and ensures that proper contact is made with the bottom. For safety, the hydrowire, swivel, and all shackles should have a load capacity at least three times the weight of a full sampler.
2. Place the grab sampler on the sample collection table, and open it.
3. Ensure that the two release chains and the two retrieval chains are hanging free and are not wrapped around the arms of the sampler.
4. Attach the ring of the release chains to the release mechanism, and insert the safety pin to prevent the mechanism from being activated prematurely.

5. Start the winch, raise the release mechanism and the sampler, and swing it outboard.
6. Remove the safety pin from the trigger, and lower the sampler through the water column at a slow and steady speed (e.g., 30 cm/second).
7. Allow the grab sampler to contact the bottom gently, with only its weight being used to force it into the sediments. The sampler should never be allowed to "free fall" to the bottom because this may result in premature triggering, an excessive bow wake, or improper orientation upon contact with the bottom.
8. Allow approximately 60 cm of slack in the hydrowire after contact with the bottom is made to ensure that the release mechanism is activated.

Grab Retrieval

1. After the grab sampler has rested on the bottom for approximately 5 seconds, begin retrieving it at a slow and steady rate (e.g., 30 cm/second).
2. Ensure that the sampling vessel is not headed into any waves before the sampler breaks the water surface to minimize vessel rolling and potential sample disturbance.
3. After the grab sampler breaks the water surface and is raised above the height of the sample collection table, swing the grab sampler inboard, and gently lower it onto the table, maintaining tension on the hydrowire to prevent the grab sampler from rolling when it contacts the table.
4. When the grab sampler contacts the table, insert wedges under both jaws so that the grab sampler will be held in an upright position when tension on the hydrowire is relaxed.
5. Relax the tension on the hydrowire, and remove the release and retrieval chains from the surface of the grab sampler.
6. Open the doors on the top of the grab sampler, and inspect the sample for acceptability. The following acceptability criteria should be satisfied:
   - The sampler is not overfilled with sample to the point that the sediment surface presses against the top of the sampler or is extruded through the top of the sampler.
   - Overlying water is present (indicating minimal leakage).
   - The overlying water is not excessively turbid (indicating minimal disturbance or winnowing).
   - The sediment surface is relatively undisturbed.
   - The desired penetration depth is achieved.

If a sample fails to meet the above criteria, it will be rejected and discarded away from the station.

Penetration depth should be determined by placing a decontaminated stainless steel ruler against the center of the inside edge of the opening on the top of one side of the grab sampler and extending it into the grab sampler until it contacts the top of the sample. The penetration depth is determined by the difference between that measurement and the total depth of the grab sampler.

<u>Sample Removal and Processing</u>

1. For acceptable samples, remove the overlying water by slowly siphoning it off near one or more sides of the grab sampler. Ensure that the siphon does not contact the sediments or that fine grained suspended sediment is not siphoned off. If sediment is suspended in the overlying water, do not proceed with siphoning until the sediment is allowed sufficient time to settle.
2. After the overlying water is removed, characterize the sample as specified in the study design. Characteristics that are often recorded include:
    - Sediment type (e.g., silt, sand).
    - Texture (e.g., fine-grain, coarse, poorly sorted sand).
    - Color.
    - Approximate percentage of moisture.
    - Biological structures (e.g., chironomids, tubes, macrophytes).
    - Approximate percentage of biological structures.
    - Presence of debris (e.g., twigs, leaves).
    - Approximate percentage of organic debris.
    - Presence of shells.
    - Approximate percentage of shells.
    - Stratification, if any.
    - Presence of a sheen.
    - Odor (e.g., hydrogen sulfide, oil, creosote).
3. After the sample is characterized, remove the top 10 cm using a stainless steel spatula or spoon. Unrepresentative material (e.g., large shells, stones) should be carefully removed without touching the sediment sample under the supervision of the chief scientist and noted on the field logbook.
4. Remove subsamples for analysis of unstable constituents (e.g., volatile organic compounds, acid-volatile sulfides), and place them directly into sample containers without homogenization.
5. Transfer the remaining surface sediment to a stainless steel mixing bowl for homogenization. Additional grab samples may be required to collect the volume of sediment specified in the study design. The mixing bowl should be covered with aluminum foil while additional samples are being collected to prevent sample contamination (e.g., from precipitation, splashing water).

6. After the surface sediment for a sample is collected, move the sampling vessel away from the station, open the jaws of the grab sampler, attach the ring of the deployment chains to the release mechanism, insert the safety pin, start the winch, raise the grab sampler, and allow the remainder of the sediment sample to fall onto the sample collection table. Discard this material away from the station, and rinse away any sediment adhering to the inside of the grab sampler. The grab sampler is now ready for additional sampling at the same station or decontamination before sampling at a new station.
7. After a sufficient volume of sediment is transferred to the mixing bowl, homogenize the contents of the bowl using stainless steel spoons until the texture and color of the sediment appears to be uniform.
8. After the sample is homogenized, distribute subsamples to the various containers specified in the study design and preserve the samples as specified in the study design.

EQUIPMENT/MATERIALS

- Stainless steel van Veen grab sampler (typically 0.06 m^2 or 0.1 m^2).
- Winch and hydrowire (with load capacities ≥3 times the weight of a full sampler).
- Sample collection table.
- Teflon® or polyethylene siphon (inner diameter = 1.27 cm, length = 60–90 cm).
- Stainless steel ruler.
- Stainless steel spatulas.
- Stainless steel spoons.
- Stainless steel mixing bowl or pot.
- Scrub brush.
- Squirt bottles (for solvents).
- Alconox® (laboratory detergent).
- Acetone and hexane (if applicable for a specific project).
- Socket and crescent wrenches (for adding or removing the detachable weights of the grab sampler).
- Water pump and hose (for rinsing the grab sampler, sampling utensils, and sample collection table).

C. SEDIMENT CORING USING A DRIVE ROD CHECK VALVE CORER - INTRODUCTION

This section describes the procedure for collecting sediment core samples using a drive rod check valve corer. The drive rod check valve corer is designed for collecting short cores (<60 cm) in water less than about 30 feet deep. The corer is lowered through the water column and then driven into the sediment using drive rods. This corer has the advantage over gravity corers in that the drive rods allow up to 200 pounds of driving force to be used without having to handle or lift a heavy weight.

PROCEDURAL GUIDELINES

The sample is held in the core tube with the suction provided by a check valve at the top of the corer. Unlike free-floating check valves, this valve is actuated from the boat using a cord. As the corer is lowered, the valve is held open so water flows freely through the corer as it approaches the sediment, thus reducing the wake that can disrupt the surficial sediments. Because it is not a piston-type corer, some compaction of the sample will occur depending on the sediment type and core length. The internal cross-sectional area of the 3-inch diameter corer is 39 cm^2, which yields about 2 g of dry solids per centimeter of sample thickness at a porosity of 98 percent and about 15 g of solids per centimeter of thickness at a porosity of 85 percent.

There are five basic steps to collecting sediment with this corer:

1. Prepare the corer.
2. Measure the water depth.
3. Drive the corer.
4. Retrieve the corer.
5. Remove the core.

When reading instructions, refer to Figures 6.2.C-1, 6.2.C-2, 6.2.C-3, and 6.2.C-4.

Preliminary Considerations

It is best to work from a platform that is anchored and will not drift. This setup helps to prevent collecting a poor quality sample and damaging the equipment. A platform with a low free-board, such as a pontoon boat, is best.

Core tubes can vary in length from about 70 to 200 cm. The core tube should be about 50 cm longer than the sample length needed to provide for overlying water and errors in the depth driven. It is desirable to have about 20 to 30 cm of water overlying the sediment in the core tube.

The overlying water provides a buffer that reduces agitation of the surficial sediments when handling the core tube. The corer should be pushed into the sediments deeper than the length of core needed. If the sediments are soft, it is possible to overpenetrate and run the sediment–water interface up into the valve. A long core tube will help prevent such an occurrence. For the tube to retain the sample, the minimum sample length is about three to four times the diameter depending on the sediment type.

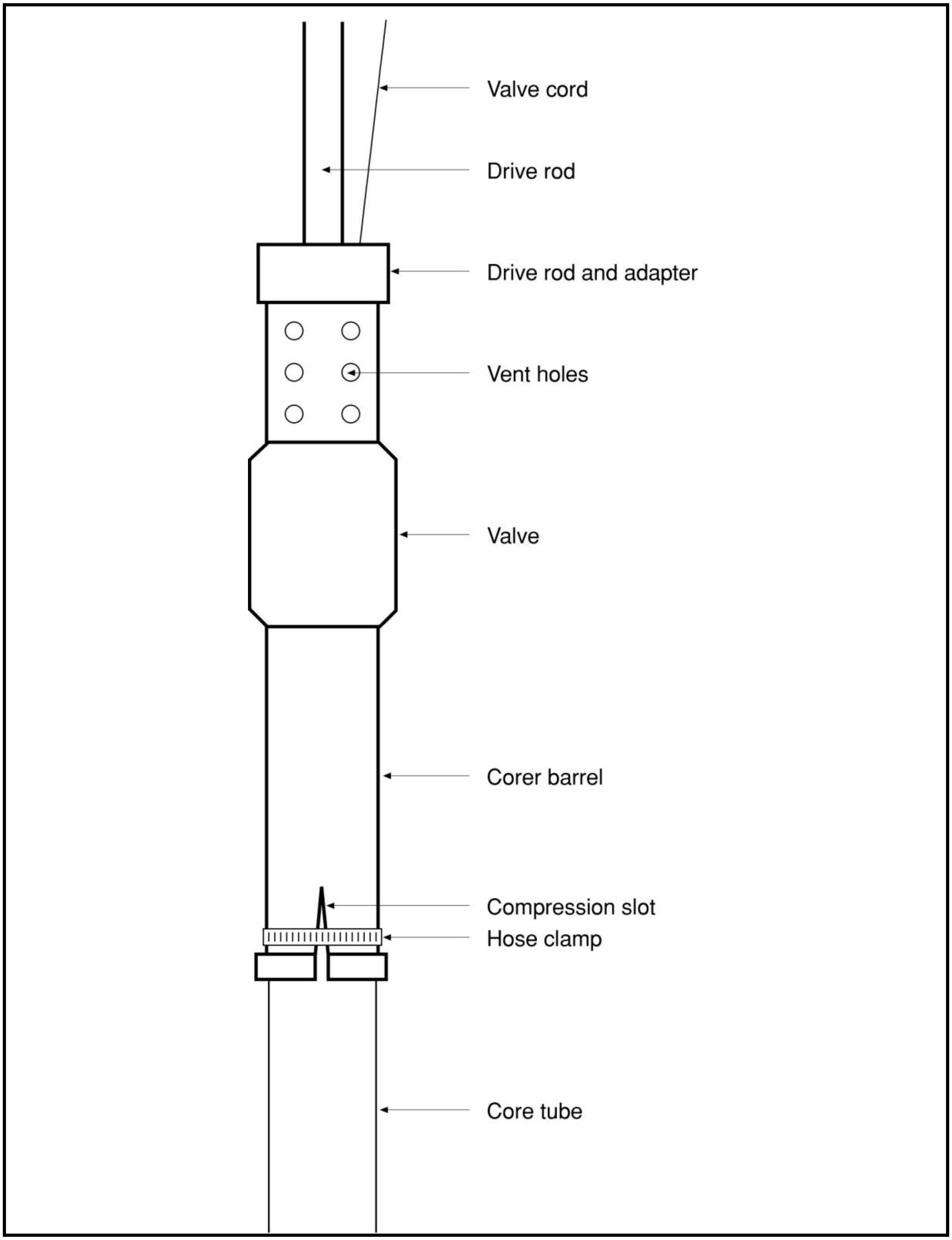

Figure 6.2.C-1 Drive rod check valve corer

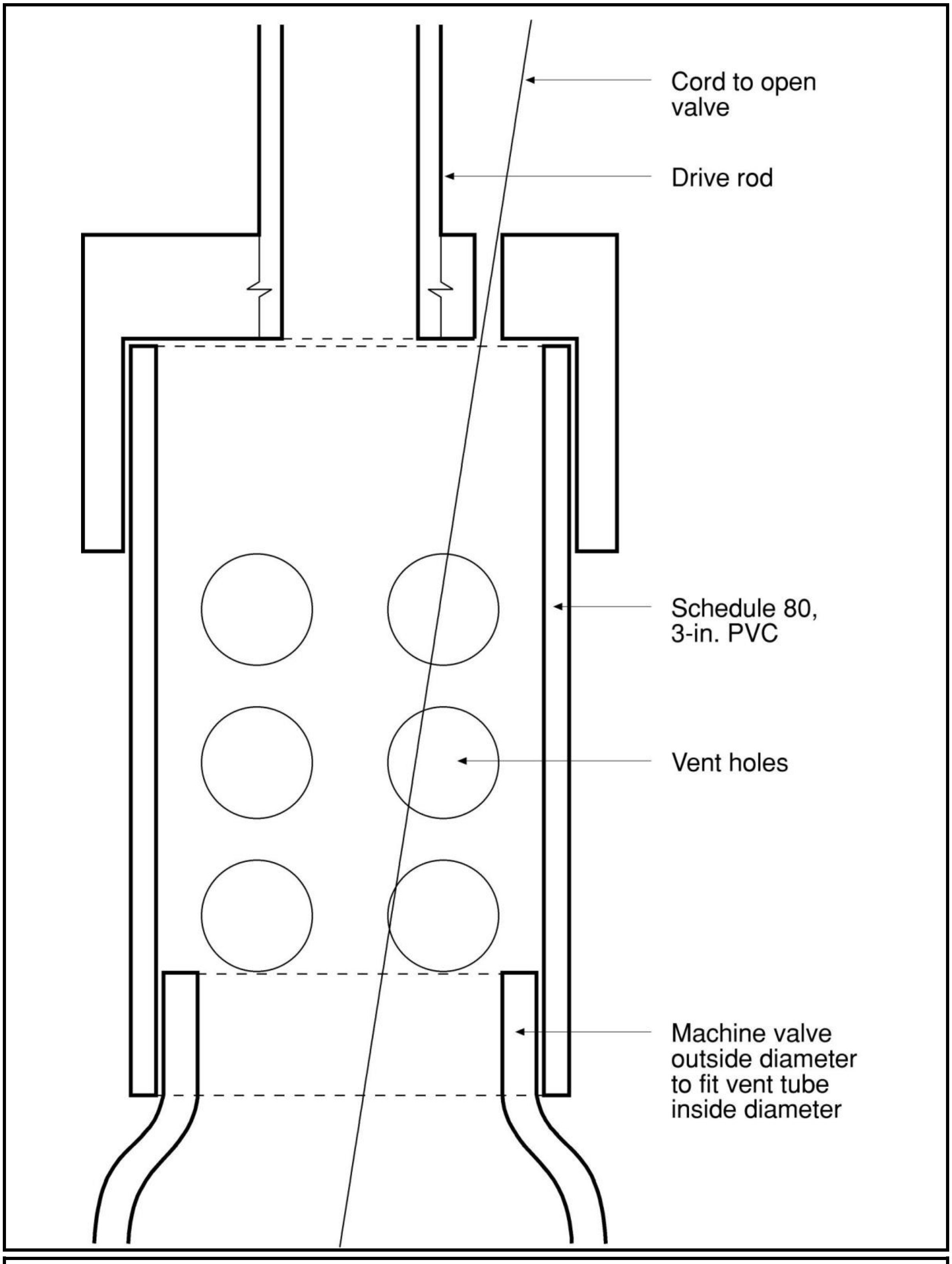

Figure 6.2.C-2 Detail of vent tube

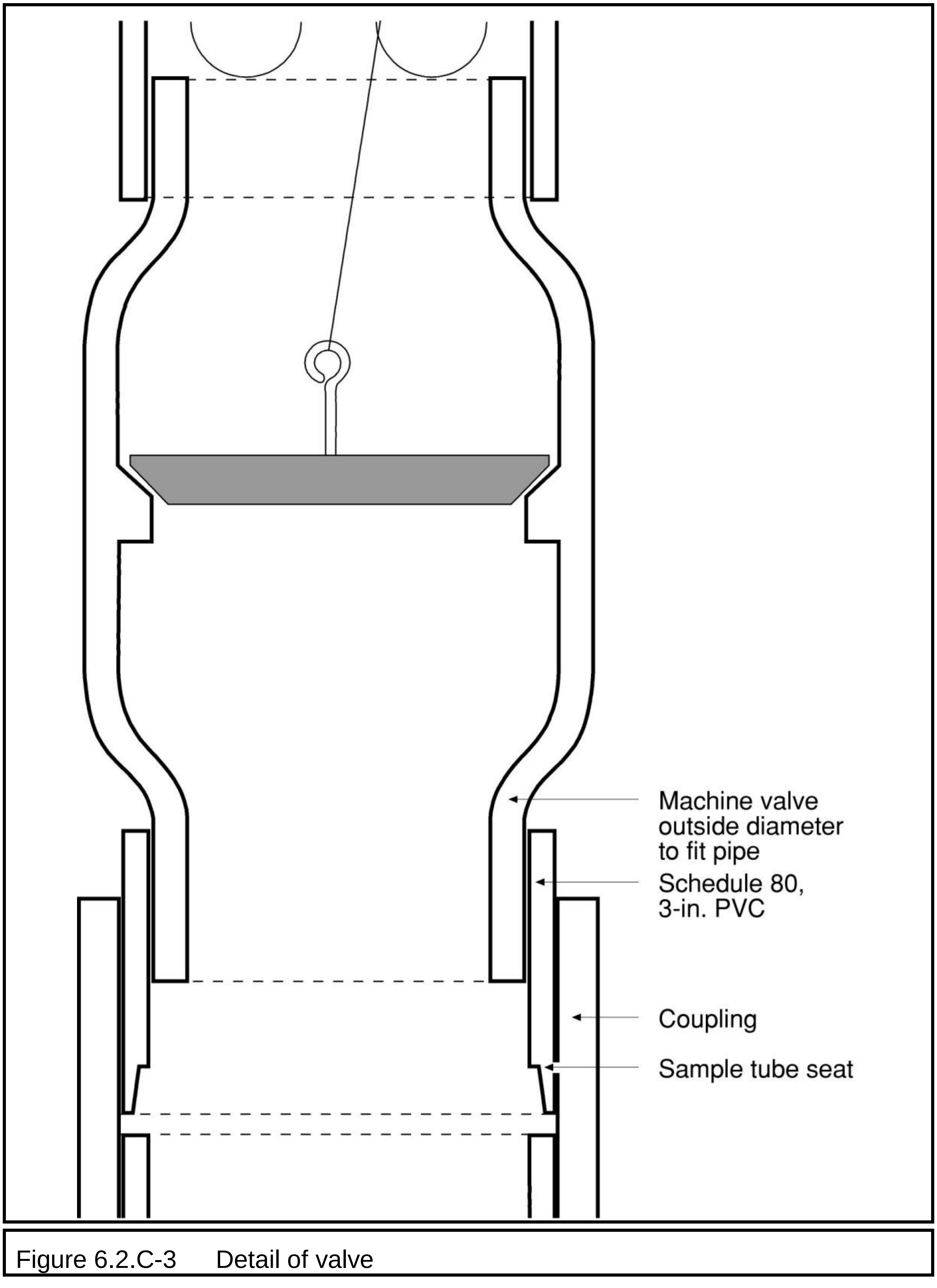

Figure 6.2.C-3 Detail of valve

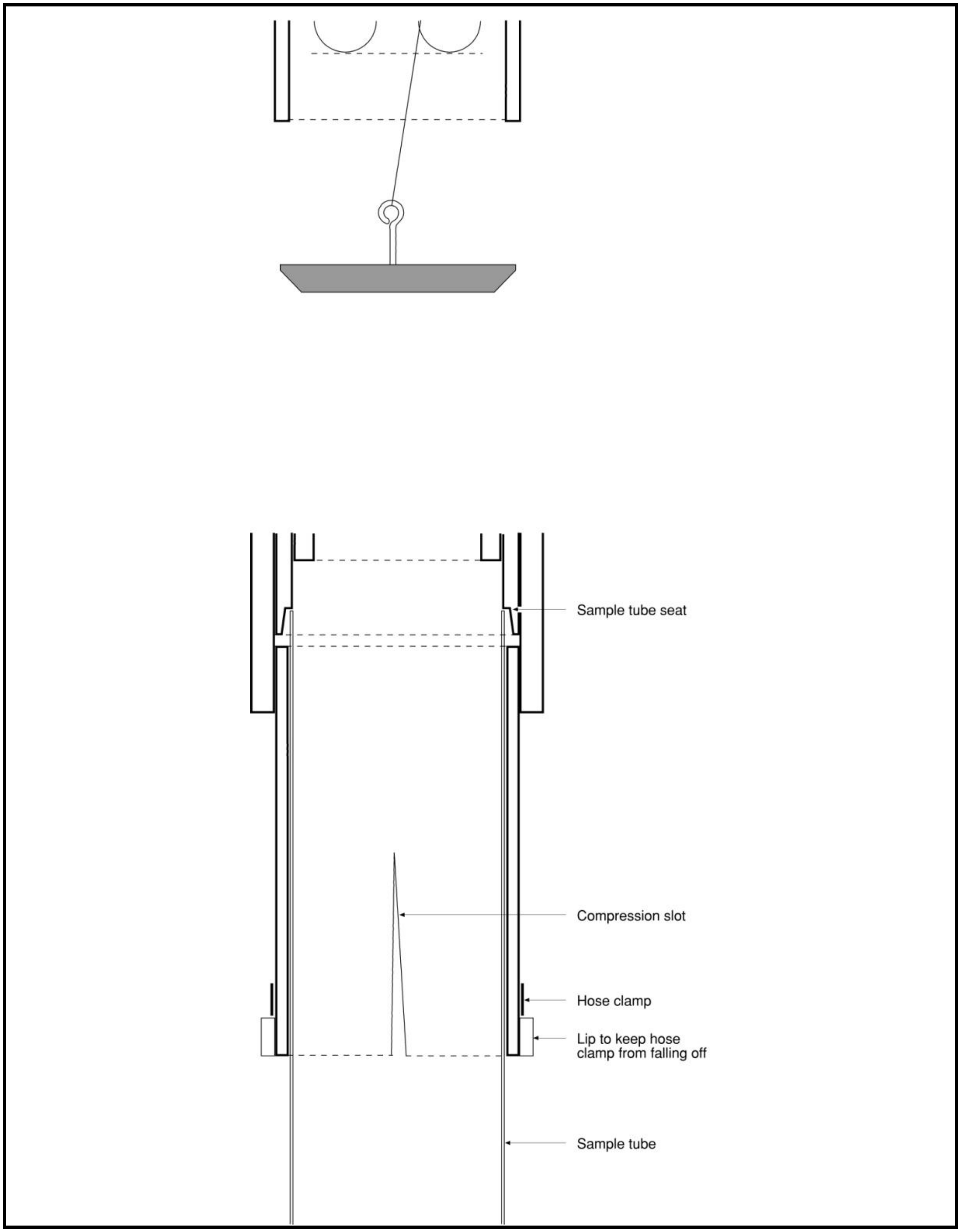

Figure 6.2.C-4 Detail of sample tube holder

Instructions

1. **Prepare the Corer—**Before using the corer, inspect it for worn or broken parts, and repair as necessary.

    1.1 Clean the corer; sandy material in particular can foul the valve and other seals. If the corer has been used in a sandy area, sand caught on the seat might prevent the valve from sealing. To clean the valve, run or spray water through it while repeatedly opening and closing the valve. Test the valve for leaks by releasing the valve cord and pouring water into the top of the corer and watching for leakage. No more than about 1 mL per minute should leak.

    1.2 Insert a core tube into the corer barrel and push it in until you feel the top end of the tube contact the sealing ring at the top of the corer barrel. To seat the tube, push it hard for about a tenth of an inch; you will feel it seat into position. If the bottom edge of the core tube is beveled to improve cutting action, make sure the tube is not upside down. Tighten the hose clamp at the bottom of the barrel so that the core tube cannot be rotated by hand within the corer barrel. Make sure that the drive rod is tightly screwed into the adapter.

2. **Measure the Water Depth —** Measure the water depth to within about a foot of the true depth, using a weighted measuring tape or sonar.

    You will need to know the depth so you can attach the correct length of drive rods and so you can determine how close the corer is to the sediment as it is being lowered.

3. **Drive the Corer**

    3.1 While keeping the valve open with the valve line, lower the corer and keep adding drive rods until the corer is near the sediment. Only a couple pounds of lifting force is required to keep the valve open, so do not lift too hard on the valve line. With the corer and drive rods hanging vertically, lower the corer slowly until you feel it contact the sediment, and then with one smooth motion, push the corer into the sediment. Be careful to push vertically on the corer. If the platform moves laterally and the drive rods are at an angle, attempting to drive the corer may damage it.

    3.2 After the corer is driven to the desired depth, release the valve cord so the valve closes.

4. **Retrieve the Corer—**After the valve is closed, the corer can be retrieved; retrieval is best done with two people.

    4.1 Lift steadily on the drive rods until you feel the corer break loose from the sediments. As the corer approaches the water surface, have a rubber stopper ready to place in the bottom of the core tube. If the sediments are sandy and the samples tend to erode from the bottom of the tube as it is lifted through the water column, it may be necessary to keep the corer submerged just below the surface while another person reaches underwater and places the stopper in the tube. If sampling is performed from a large boat that has a lot of free-board, it may be necessary to have someone near the water level on a skiff to insert the stopper. While the corer is being lifted onboard, support the rubber stopper so it and the sample do not fall out.

4.2 After the corer is onboard, seat the stopper so it is entirely inside the core tube by placing a second stopper on the deck and pushing the corer down on top of it. Keep the corer vertical at all times to prevent the sample from shifting, and avoid rapid movements that can disrupt the interface.

5. **Remove the Core**

5.1 As a second person holds the corer vertical and keeps the valve open, loosen the hose clamp at the bottom of the core barrel and hold the bottom of the core tube firmly against the deck.

5.2 While holding the core tube, have the second person lift the corer off the tube. If the tube is seated very firmly in the barrel from the force of driving the corer, twist the barrel slightly while lifting it off the tube to break it loose. It is best to rotate the barrel, not the core tube, because when it breaks loose, the rapid rotation of the core tube may disrupt the sediment–water interface. As the core barrel is lifted off the tube, the water in the valve assembly will spill. Before moving or lifting the core tube, seal the top of the core tube with a test plug. The core is now ready to be extruded and sectioned.

5.3 If possible, extrude and section the sample immediately in accordance with FMG 6.2.D - Sediment Coring Procedures Using Slide-Hammer and Gravity Corers. Immediate extrusion and sectioning is essential if the sample is to be analyzed for redox-sensitive elements. Oxygen diffuses through the polycarbonate core tube and oxidizes ferrous iron in the pore water. This process is fairly rapid, and an orange iron oxide precipitate will visibly form on the inside walls of the core tube within a day. There is some evidence that this oxidation does not extend more than a couple millimeters into the sample. If the sample cannot be extruded immediately, keep it cool and out of the sun by refrigerating it or wrapping it with aluminum foil.

Troubleshooting

Problem 1: The Corer is Not Retaining the Sample

There are two possible causes to this problem. One is that the sediments are sandy and not cohesive so they do not stick to the core tube walls or themselves. As a result, the core erodes from the bottom as it is lifted through the water. This problem can be solved in several ways.

- Drive the corer deeper into the sediments, where there may be a more cohesive layer. It is not unusual for a fine grained cohesive layer to lie below coarser layers.

- Place a stopper in the bottom of the tube as soon as possible using one of two methods: 1) use a rod that holds the stopper in the correct position, maneuver the rod below the tube, and lift it up to insert the stopper, or 2) have a diver insert the stopper.
- Use a smaller diameter corer so there is relatively more cohesion of the sediment with the walls.

The second possible cause is a leak in the suction of the corer that allows the whole core to start slipping out of the core tube. There are two places where the suction can be lost: the valve, and the seat between the core barrel and the core tube. Inspect and clean both the valve and the seat, and check that the valve is not stuck in the open position.

Problem 2: The Sediment Interface is Not Distinct

There are several possible causes to this problem. One is that the bottom end of the core tube was moving horizontally when it first contacted the sediments. Further evidence of this cause is if the sediment interface is tilted. In this case, make sure the platform is not moving and that the corer and drive rods are allowed to hang vertically just before driving the corer. Another common cause is the formation of gas bubbles in the sediments of productive or eutrophic systems. When a corer is pushed into this type of sediment, bubbles are released that entrain and resuspend sediment. There is no easy solution to this problem other than to let the resuspended sediment settle before processing the sample. Another possible cause is rough handling of the sample.

Problem 3: The Core is Compacted

Little can be done to prevent compaction other than to use a piston corer. However, the amount of compaction can be quantified. One easy method is to apply Velcro® tape to the outside of the corer barrel and determine the depth of penetration by noting where sediment is caught in the Velcro®.

D. SEDIMENT CORING PROCEDURES USING SLIDE-HAMMER AND GRAVITY CORERS - INTRODUCTION

This section describes the procedure for collecting and processing sediment core samples using slide-hammer and gravity corers. These corers can be used for sampling both coarse, consolidated sediment and fine grained, cohesive sediment. The same corer barrel is adapted for use as either a slide-hammer or gravity corer by changing a few parts. In both coring methods, heavy weights are supported overhead by ropes or cables and pulleys. Therefore, hardhats are required in the vicinity of the equipment. Sample processing using a hydraulic extruder is also described.

PROCEDURAL GUIDELINES

Both corers rely on a one-way valve at the top of the corer that allows water to pass through the corer while being lowered and provides suction to prevent the sample from slipping out while being raised. The corers use 3-inch outside diameter tubing with a 1/16-inch wall thickness. The main corer barrel accepts liners that are 150 cm long and can be used for cores of up to about 140 cm long. Cores up to 3 m in length can be collected by adding 1 m and 1.5 m barrel extensions. Before use, the corer should be inspected for worn and damaged parts and should be cleaned.

Slide-Hammer Coring

This coring method uses a slide hammer that pounds the corer into the sediment with repeated impacts. This method is most useful in nearshore zones where the sediment is difficult to penetrate and would require more than 500 pounds of static weight if a gravity corer were used. The slide-hammer corer is illustrated on Figure 6.2.D-1. The slide-hammer corer uses one cable for lowering and retrieving the corer and one rope for actuating the hammer. The slide hammer works best when the hammer is heavier than the rest of the corer so, before use, all of the weights should be removed from the corer. The following procedures are based on using the corer aboard a pontoon boat equipped with a 12-foot tripod, a power winch, and a hole in the floor centered below the tripod. Because the coring is typically done in shallow water, the boat must be anchored with at least three anchors so the boat will not drift.

1. With the corer laying flat on the boat, screw the hammer guide onto the impact plate, slide the hammer onto the hammer guide, and screw the eyebolt onto the top of the hammer guide (see Note 1). Run the main cable and the hammer rope through the appropriate pulleys. Attach the main retrieval line to the eyebolt. Caution: When handling the slide-hammer assembly, be careful to keep hands away from the area where the hammer slides to avoid injury.
2. After the ball and valve are cleaned, align the holes in the top of the corer and impact plate, and attach the impact plate to the top of the corer with the 0.5-inch diameter bolt. Inspect the bolt periodically for wear near the cap and 3.5 inches from the cap.
3. Attach the two thimbles at the ends of the slide-hammer bridle to the two eyebolts at the top of the hammer with small carabiniers, and secure the middle thimble to the hammer rope. The hammer rope should be at least 0.5 inch in diameter so it is easy to hold by hand.
4. Insert the 3-inch outside diameter polycarbonate liner into the corer barrel, making sure that about 0.75 inch protrudes out the end (see Note 2). Wrap the threads on the corer with Teflon® plumber's tape, and screw the nose piece onto the barrel by hand until it is as tight as possible.

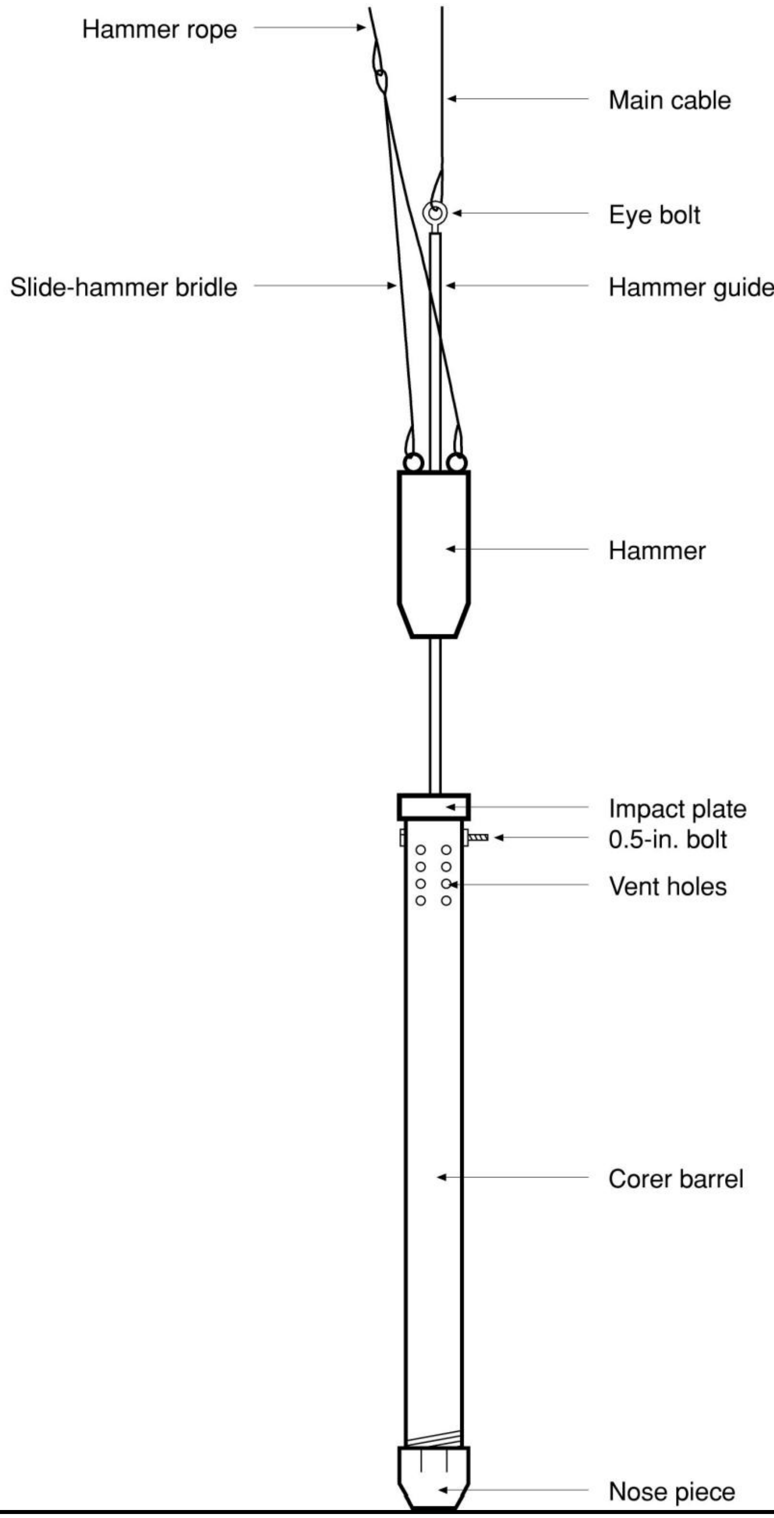

Figure 6.2.D-1 Diagram of slide-hammer corer

5. Slide the hammer down to the impact plate, being careful to keep hands free from the path of the hammer, and raise the corer to the vertical position using the main retrieval cable.

6. Lower the corer and let out the hammer rope at the same rate. As the corer is being lowered, valve popping can be heard as water displaces air inside the corer. Continue lowering the corer slowly until the nose piece contacts the sediment. Keep tension on the main retrieval cable, measure the length of the core needed from the water surface upward, and mark this point on the main cable with a piece of tape.

7. With just enough tension on the main retrieval cable to keep the corer vertical but still allow the cable to be let out at a rate of a few inches per impact, lift the hammer about 4 feet, and release the rope. Caution: Before releasing the hammer rope, be sure that no one is standing on the rope or that the rope is not caught on anything.

8. Repeat Step 7 until the piece of tape is slightly below the water. When lifting the hammer, be careful not to lift so fast and high that it hits the eyebolt at the top of the hammer guide and hammers the corer back out of the sediment. Depending on how much the sediment core is compacted, it may be necessary to pound the corer until the tape is well below the water surface. Penetration should be stopped before the headspace between the sediment-water interface and the valve is less than about 15 to 20 cm.

9. When the corer has been pounded to the necessary depth, start retrieving the corer slowly at first until it is free of the sediment, and then more rapidly until the nose piece is above the water. Slow the rate of retrieval until the nose piece clears the deck, and stop when there is 6 inches of clearance. Have two bolted rubber stoppers on top of one single stopper next to the hole in the deck and lower the corer onto the rubber stoppers until they are completely inside the nose piece. Caution: When guiding the corer onto the stopper, keep hands away from the area between the nose piece and the deck.

10. Cover the hole and tie-off the hammer rope to a cleat. With two people supporting the corer in a vertical position, release some, but not all, tension on the main retrieval cable. Disconnect the impact plate from the corer by removing the 0.5-inch bolt. Increase tension on the main retrieval line until the impact plate is free of the corer. Caution: When the impact plate is free of the corer, it is able to swing so it should be stabilized immediately. This can be a problem when the boat is rocking. While maintaining tension on the main cable, untie the hammer rope, and lower the slide hammer assembly to the deck. Connect the shackle to the top of the corer with the 0.5-inch bolt, and connect the main cable to the shackle.

11. Lift the corer about 1 foot with the main cable. While one person holds the corer barrel so it does not turn, unscrew the nose piece slowly. When it is unscrewed, be prepared to support the weight of the liner and sample by holding the nose piece and the stoppers from the bottom, then lower the nose piece and liner to the deck. While stabilizing the liner and corer, lift the corer until it is free of the liner. Lower the corer onto the deck, and cover the hole. For cores 1.5 m and longer, see Note 3.

12. Remove the nose piece from the liner by pushing down and rocking it slowly from side to side. The single stopper will come off with the nose piece, but the others should remain in place. Watch carefully that the other stoppers do not slip. In moving the liner with the sample, always support the liner from the bottom so the stoppers cannot slip.
13. Process the sample as described in *Sample Extrusion and Sectioning*.

Gravity Coring

This method uses gravity to force the corer into the sediment. It is designed for use in soft sediment that is typically found in more than 20 feet of water. However, it may be used in shallower waters if the sediment is soft. The gravity corer is illustrated on Figure 6.2.D-2. The weight can be adjusted using any combination of six 60-pound weights and one 30-pound weight (in addition to the barrel, which weighs 10 lb/ft) to achieve the necessary penetration. This gravity corer is not designed for free-fall into the sediment. Because gravity coring is much faster than slide-hammer coring and water depths are usually greater, boat drift is not a problem, and anchoring is not necessary.

1. With the corer laying on the deck, insert the liner into the corer barrel until it contacts the bottom of the valve seat; about 0.75 inch of liner should protrude from the corer barrel. Wrap the threads with Teflon® plumber's tape where the nose piece screws in. Screw on the nose piece, making sure the liner seats on the lowest shoulder inside the nose piece (about 1 inch from the bottom edge of the nose piece). Tighten as much as possible by hand.
2. Add the appropriate amount of weight to the corer and secure it with a hose clamp. Slide the weights upward until the top of the top weight is a few inches below the vent holes. Slide the shaft collar upwards until it contacts the bottom of the bottom weight, and tighten it so it will not slip when it supports all the weights. It is a good idea to wrap a few layers of duct tape right below the shaft collar so that if it slips, it will become wedged on the tape.
3. Attach the shackle to the top of the corer with the 0.5-inch bolt, and connect the retrieval cable to the shackle.
4. While supporting the corer so that it does not swing freely, raise it with the winch. Watch the weights to see that they do not slip. Lower the corer at any rate that is practical until the nose is about 10 feet above the sediment, then reduce the rate to about 1 feet/second. This reduces the shock wave preceding the corer and helps retrieve a good interface. Let the line go slack for about 5 seconds (see Note 4).
5. Pull the corer slowly at first to break it loose from the sediment. Raise the corer up through the water column at a rate that is practical until the top of the corer approaches the surface, then slow the retrieval rate to about 1 feet/second. As soon as the nose clears the water surface, stop retrieval, push a double rubber stopper up into the corer, and

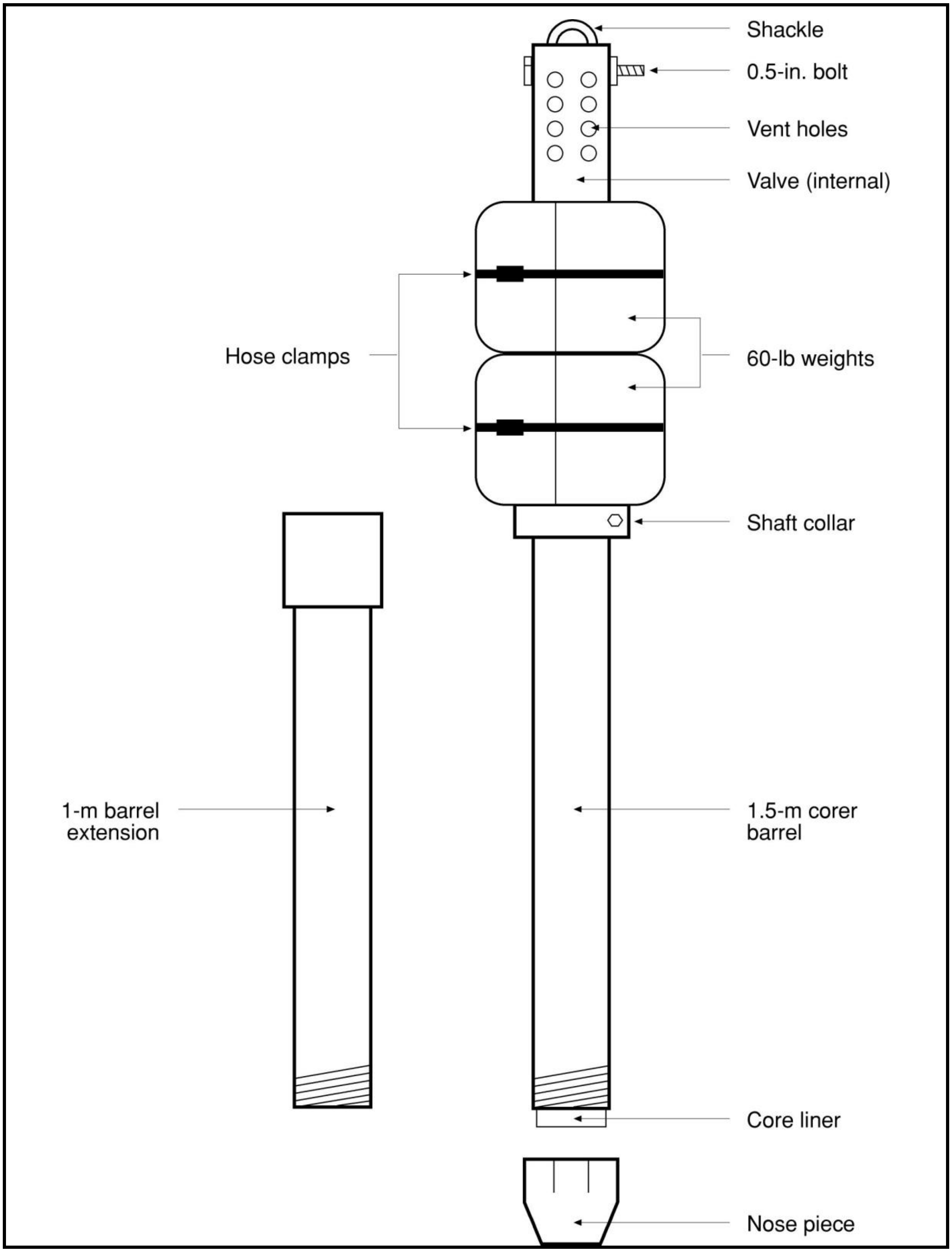

Figure 6.2.D-2 Diagram of 3-inch diameter gravity corer

support the stoppers so they are not pushed out by the sample. Have another stopper ready on the deck. Raise the corer, and lower it onto the other stopper to push the double stopper further into the liner. Caution: When guiding the corer onto the stopper, keep hands away from the area between the nose piece and the deck.

6. Lift the corer about 1 feet with the main cable. With one person holding the corer barrel so that it does not turn, unscrew the nose piece slowly. When it is unscrewed, be prepared to support the weight of the liner and sample by holding the nose piece and the stoppers from the bottom, then lower the nose piece and liner to the deck. While stabilizing the liner and corer, lift the corer until it is free of the liner. Lower the corer onto the deck, and cover the hole. For cores 1.5 m and longer, see Note 3.
7. Remove the nose piece from the liner by pushing down and rocking it slowly from side to side. The single stopper will come off with the nose piece, but the others should remain in place. Watch carefully that the other stoppers do not slip. In moving the liner with the sample, always support the liner from the bottom so the stoppers cannot slip.
8. Process the sample as described in *Sample Extrusion and Sectioning*.

Maintenance and Troubleshooting

Cleaning the Ball Valve

The ball valve should be cleaned 1) at a minimum on each day of sampling, 2) if there is evidence that sediment entered the valve, and 3) whenever coring is conducted in nearshore zones where the sediment is sandy. A diagram of the valve is shown on Figure 6.2.D-3. To clean the valve, remove the 0.5-inch bolt from the top of the corer barrel and disconnect the impact plate or the shackle. Before removing the thin ball retaining wire, make sure the ball cannot roll overboard. Then remove the wire, reach in the corer, and remove the ball. Inspect the ball for materials or scratches that may prevent seating or sealing. Wipe off the ball with a paper towel, and place it in a clean place. Do not drop the ball because this will scratch the surface and prevent the ball from seating properly. Also, be careful not to damage the O-ring seal by placing any tools in the valve assembly. Wash out the valve with a hose to remove most of the dirt. Using a paper towel, reach inside the top of the corer, wipe off the valve seat, and inspect the towel for dirt. Take a small quantity of Vaseline® (about the volume of a typical pencil eraser), and rub it on the ball. If the valve needs to be replaced, remove the two valve retaining wires, and slide the valve out.

Insufficient Sample

The corer may not collect enough sample because of 1) inadequate penetration, 2) good penetration but too much compaction, or 3) adequate penetration but loss of sample during retrieval. Solutions to these problems are as follows:

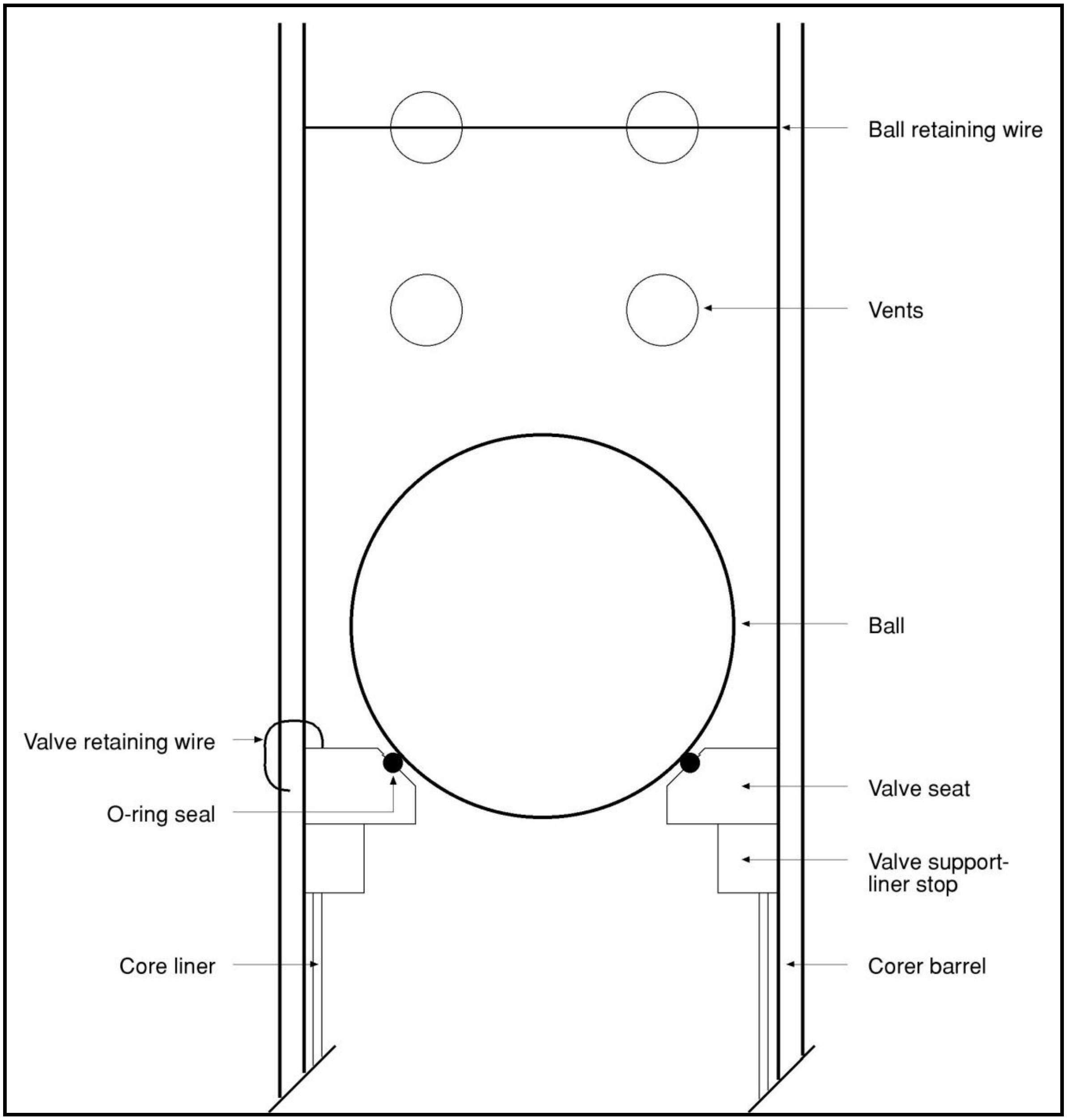

Figure 6.2.D-3 Cross section of ball valve

- **Inadequate Penetration—**Add more weight to the corer, or pound it in farther.
- **Too Much Compaction—**Add an extension and more weight to get more penetration.
- **Loss of Sample During Retrieval—**Sample slipping out the bottom of the corer is caused by a loss of suction. There are several places at which suction can be lost: the valve seat, the valve assembly, the nose piece, and couplings between the barrel and extensions. To reduce sample loss, clean the valve seat/O-ring, and grease the ball as described above. Make sure

the valve assembly is sealed. Use Teflon® plumber's tape on the threads and duct tape on the outside of the couplings and nose piece.

Penetration of the corer can be measured by putting white Velcro® tape on the outside of the corer. Velcro® tape can also be used on the inside of the liner during testing to see how far up inside the liner the interface moves, how much sample slips out the bottom, and how much compaction occurs.

Sample Extrusion and Sectioning

Sediment samples are extruded from the core liner using a hydraulic or mechanical extruder and are cut into desired section thicknesses using a calibrated sectioning tube. A diagram of the hydraulic extruder and sectioning apparatus is shown on Figure 6.2.D-4. The extruder can be used for 2- to 3-inch diameter cores and can be used vertically or horizontally.

1. With no core liner attached to the extruder, submerge the inlet hose of the extruder in a bucket of water or overboard into the lake. Pump water through the system rapidly to clear all air out of the hose, valves, pump, and socket. Observe the water coming out of the socket and pump until no air bubbles come out.
2. Rinse grit from the bottom of the core liner so that the liner will slip smoothly onto the socket. With the shaft collar loosened and already around the socket, lift the core liner onto the socket, and push it down onto the socket with a twisting motion. While holding the liner down, pump water through the socket slowly to remove air bubbles at the base of the rubber stoppers. While still holding the liner down, slip the shaft collar up and around the liner, and tighten it very tightly with the hexagonal wrench. Push gently on the pump to check for leaks. Pump until the sediment-water interface is level with the top of the core liner.
3. Place the calibrated sectioning tube on the top of the liner. Hold it down so it seats firmly on the liner, and pump until the desired sample thickness is extruded into the tube. The extruder will extrude about 1 inch of sample per pump. While one person holds the liner steady, another person holds the sectioning tube and cuts the extruded sample by inserting the semicircular cutter between the liner and the tube. Cut the core and slide (do not lift) the cutter and the tube horizontally off the top of the liner. Hold the cutter and tube firmly together. Invert the tube, and slide the cutter out to discharge the sample into the mixing bowl.
4. Repeat Step 3 until the lowest desired depth of sample is collected. Pump the rest of the sample out of the liner with the rubber stoppers.

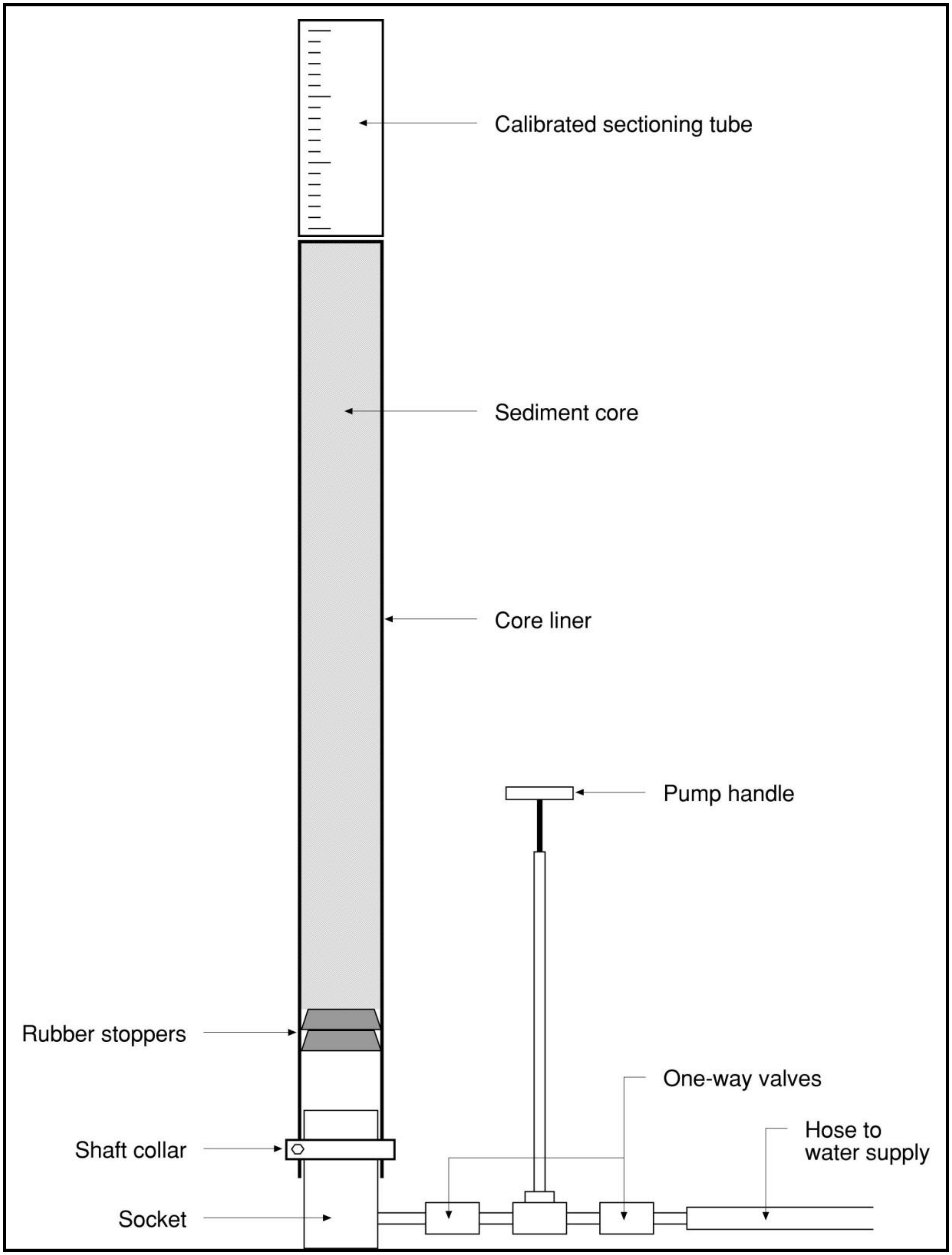

Figure 6.2.D-4 Diagram of core extruder and extrusion tube

Note:

1. *The eyebolt at the top of the hammer guide may become unscrewed because of the pounding vibrations and should be checked at each station before coring.*
2. *For long cores that require more than one piece of liner, butt the ends of the two pieces of liner squarely together and tape them securely so no leaks occur. Do not use too many layers of tape or the liner will not fit into the barrel.*
3. *For cores 1.5 m and longer, the tripod is not tall enough to lift the corer so that the barrel will clear the top edge of the liner when removing the liner. To remove the liner in this case, upon unscrewing the nose piece, lower the nose piece and liner into a pail that has a rope securely tied to the handle. While the corer is raised by the winch, lower the pail through the hole in the deck and into the water (if necessary) until the top edge of the liner clears the bottom edge of the barrel. Then lift it back onto the deck.*
4. *If the sediment is too hard for the amount of weight on the corer, and the corer does not penetrate significantly, the corer will contact the bottom, tip over, and fall sideways. When this happens, the line will initially go slack, then quickly snap to the side as the tension increases. In this case, try doubling the weight; if this does not work, try using the slide hammer.*
5. *Periodically check the water level in the bucket. If air gets into the system, pumping becomes less efficient. At the end of each day, unscrew the cap at the top of the pump, lift the pump handle to remove it, wipe the O-rings with a paper towel, and grease the O-rings with Vaseline®. Avoid using water with coarse particles because they may interfere with proper valve function.*

E. DETERMINATION OF GRAIN SIZE DISTRIBUTION IN SEDIMENT - INTRODUCTION

PROCEDURAL GUIDELINES

<u>Field Screening</u>

Grain-size distribution in sediment is measured in the field because the information is needed to direct further sampling. This procedure provides a gross field measurement of percent fines in a sediment sample. This field measurement is not intended to take the place of grain size distribution analysis in the laboratory, but to aid in directing collection of toxicity test samples and reference samples, which can be dependent upon percent fines. Equipment required to perform this field measurement includes:

After collecting a sediment sample, perform the following procedures:

1. Thoroughly rinse the sieve and all other equipment and visually inspect to ensure that no sediment or other detritus is present.
2. Collect a sediment aliquot from the grab sampler in the 50 mL cup, ensuring that exactly 50 mL is collected by "shaving" excess sediment from the top of the cup and rinsing any sediment off the sides of the cup.
3. Transfer the sediment aliquot from the 50 mL cup to the sieve using the spoon. Thoroughly rinse the cup and the spoon into the sieve with water to ensure that the entire aliquot has been transferred.
4. Gently rinse the sieve with running water and observe the stream of water coming from the bottom of the sieve. During this step, the fines are being rinsed away. Rinse until the stream of water appears clear, indicating that all fines have passed through the sieve. Gently rinse the remaining sediment to one side of the sieve.
5. Place the plastic funnel into the 100 mL graduated cylinder and position the lip of the sieve over the funnel. Using the squirt bottle, rinse the sediment into the graduated cylinder, directing the stream of water through the back of the sieve. Continue rinsing until all sediment has been transferred to the graduated cylinder. If needed, rinse any sediment that may have adhered to the funnel. The rinse water should not overflow the graduated cylinder. If it appears that the graduated cylinder will overflow before all sediment has been transferred, discard the sample and repeat the entire procedure.
6. Allow the sediment to settle completely in the graduated cylinder and record the amount of sediment present. This measurement represents the volume retained. Also record any turbidity observed in the overlying water.

The volume retained (in mL), subtracted from the original 50 mL aliquot, provides the volume that passed through the sieve, or volume of fines in 50 mL of sample. Multiplying this difference by 2 gives the volume of fines in 100 mL, or percent fines. The formula can be stated as:

Percent fines = (50 mL – Volume Retained in mL) $\times$ 2

<u>Field Laboratory Method</u>

1. Weigh approximately 100 g of the dried sediment.
2. Sieve the sediment material to $<100\ \mu$m using a stainless steel sieve.
3. Determine the weights of the >100- and 100 μm size fractions.
4. Determine the sand/silt/clay fractions by the pipette method (Day 1965).

Contract Laboratory Method

Analysis for grain size distribution will be completed using the wet sieve and hydrometer technique described in ASTM Method D422 (ASTM 1998).

Quality Assurance and Quality Control

Quality assurance and quality control samples will consist of duplicates (1 in 20).

EQUIPMENT/MATERIALS

- USA Standard Testing Sieve #230 (63 μm opening).
- 50 mL measuring cup.
- 100 mL graduated cylinder.
- Small plastic funnel.
- Teaspoon.
- Squirt bottle filled with water.

REFERENCES

APHA. 1989. Standard methods for the examination of water and waste water. Seventeenth Edition. Prepared and published by American Public Health Association, the American Water Works Association, and the Water Pollutant Control Federation.

Day, P.R. 1965. Particle fractionation and particle-size analysis. pp. 545–566. In: Methods of Soil Analysis. C.A. Black (ed). American Society of Agronomy, Incook of ASTM Standards. American Society for Testing and Materials, West Conshohocken, PA.

REMEDIATION TEAM	FIELD METHOD GUIDELINE NO.: FMG 6.3
REAL ESTATE & FACILITIES	EFFECTIVE DATE: MARCH 14, 2011
GENERAL MOTORS	
REVISION NO.: 0	REVISION DATE:

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SURFACE WATER

INTRODUCTION

Surface water sampling locations for water quality studies may be selected based on many factors, including: study objectives; the location of point source discharges, non-point source discharges and tributaries; the presence of structures (bridges, dams, etc.), and accessibility.

PROCEDURES REFERENCED

- FMG 9.0 - Equipment Decontamination.

PROCEDURAL GUIDELINES

Before any sampling is conducted, the first requirement is to consider suitable sampling locations. Bridges and piers are normally good choices for surface water sampling since they provide access and permit water sampling at any point across the width of the water body. Sampling locations should be selected in accordance with the Work Plan and discussed with the Project Manager.

Wading for water samples in lakes, ponds, and slow-moving rivers and streams must be done with caution since bottom deposits are easily disturbed. Samples must be collected without entrained suspended sediments. All surface water samples are to be collected commencing with the most downstream sample to avoid sediment interference with other samples. A life vest and safety line will be worn in all cases where footing is unstable or where water is fast moving or over 3 feet (0.85 m) in depth. A second person may also be required for most of the sampling scenarios.

Prior to entering select areas it may be necessary to acquire property access permission from the land owner. Access permission must be acquired in advance of the sampling program and may require a written agreement.

Rivers, Streams, and Creeks

Surface water samples should usually be collected in areas of the surface water body that are representative of the surface water body conditions. Representative samples can usually be collected in portions of the surface water body that have a uniform cross section and flow rate. Since mixing is influenced by turbulence and water velocity, the selection of a site immediately downstream of a riffle area (e.g., fast flow zone) will ensure good vertical mixing. These locations are also likely areas for deposition of sediment since the greatest deposition occurs where stream velocity slows.

A site that is clear of immediate point sources (e.g., tributaries and industrial and municipal effluents) is preferred for the collection of surface water samples unless the sampling is being performed to assess these sources.

Tributaries should be sampled as near the mouth as is feasible. However, it is important to select the sample location taking into consideration the impact that the downstream receiving water body has on the tributary flow and sediments. The downstream water body may change the water quality (salinity), temperature, or turbidity in the tributary near its mouth.

Sediment samples shall be collected along a cross-section of a river or stream in order to adequately characterize the bed material or as described in the Work Plan. A common procedure is to sample at quarter points along the cross-section of the sampling site selected. Samples may be composited as described in the Work Plan. Samples of dissimilar composition should not be combined.

In some instances sediment sampling may be performed along the shore only; depending upon the study needs.

Lakes, Ponds, and Impoundments

The water in lakes, ponds, and impoundments has a much greater tendency to stratify than water in rivers and streams. The lack of mixing may require that more samples be obtained. An extreme turbidity difference may occur where a highly turbid river enters a lake. Therefore, each layer of the stratified water column may need to be considered separately. Stratification is caused by water temperature differences; the cooler, heavier water is beneath the warmer water.

Sample selection also should adequately represent the conditions of the lagoon or settling pond. Attention must be given to identify intakes and outflows within the lagoon or settling pond which may provide biased sample representation. Sample locations with adjacent structures (i.e., banks, piers, etc.) may also provide biased samples within active lagoons or settling ponds, as the potential for boundary flow and eddies exist.

The number of water sampling sites on a lake, pond, or impoundment will vary with the purpose of the investigation, as well as the size and shape of the basin. In ponds and small impoundments, a single sample should be collected at the deepest point. In naturally formed ponds, the deepest point is usually near the center. In impoundments the deepest point is usually near the dam.

In lakes and larger impoundments, several subsamples may be composited to form a single sample. These vertical sampling locations are often taken along a grid.

In lakes with irregular shape, with several bays and coves that are protected from the wind, additional samples may be needed to represent water quality at various points in the lake. Additional samples may be taken where discharges, tributaries, and other such factors are suspected of influencing water quality.

When collecting sediment samples in lakes, ponds, and reservoirs, samples should be collected at approximately the center of the water body or as directed by the Work Plan. This is also the case for reservoirs that are formed by the impoundment of rivers or streams. The coarse grained sediments are deposited near the headwaters of the reservoir, and the fine grained sediments near the center. The shape, inflow pattern, and circulation must be considered when selecting sediment sampling sites in lakes and reservoirs.

In all instances, the sampling locations should be properly documented with field notes and photographs, as appropriate.

Sampling Techniques

Any equipment or sampling technique(s) used to collect a sample is acceptable as long as it provides a sample which is representative of the stream being sampled and is consistent with the Work Plan. Typically sample aliquots are collected from the area of concern directly, or a compositing approach is considered using a plastic bucket to collect a representative sample, then individual aliquots are collected from the sample bucket.

When collecting surface water samples, direct dipping of the sample container into the stream is acceptable unless the sample bottles contain preservatives. If the bottles are preserved, then precleaned unpreserved bottles should be used to collect the sample. The water sample should then be transferred to the appropriate preserved bottles. When collecting samples, submerse the inverted bottle to the desired sample depth and then tilt the opening of the bottle upstream to fill. When composting across a stream and/or water channel is typically performed using a pre-rinsed 1 to 2 L plastic bottle collecting sub-samples for final mixing sample aliquot collection. Volatile organic compounds (VOCs) must not be collected from the compositing bucket and are sampled directly from the stream cross section.

Wading may cause bottom sediment deposits to be re-suspended and therefore could result in a biased sample. Wading is acceptable if the stream has a noticeable current and the samples are collected directly into the bottle while pointed upstream. If the stream is too deep to wade or if the sample must be collected from more than one water depth, additional sampling equipment will be required. Samples should be collected approximately 6 inches (15 cm) below the surface with the sample bottles completely submerged. This will keep floating debris from entering the sample bottles. Floating debris could result in unrepresentative analytical data.

Sample collection when the flow depth is minimal (i.e., <1 inch (<2.5 cm)) will require special consideration to prevent sediment disturbance. Sampling might be conducted with a container then transferred to the appropriate glassware, or collection may be permissible with a peristaltic pump using a 'fixed' suction line, secured to prevent sediment collection. A small excavation in the stream bed to create a 'sump' for sample collection may be permissible but should be prepared well in advance of the sample collection event to allow sediment settlement.

Teflon bailers may be used for surface water sampling if it is not necessary to collect a sample at a specified interval. A top-loading bailer with a bottom check-valve is sufficient for many studies. As the bailer is lowered through the water, water is continually displaced through the bailer until a desired depth is reached, at which point the bailer is removed. This technique is not suitable where strong currents are encountered (because the ball may not seat effectively), or where a discrete sample at a specific depth is required.

If discrete samples are required from a specific depth, and the parameters to be measured do not require a Teflon-coated sampler, a standard Kemmerer, or Van Dorn sampler may be used. The Kemmerer sampler is a brass cylinder with rubber stoppers that leave the ends of the sampler open while being lowered in a vertical position to allow for passage of water through the cylinder. The Van Dorn sampler is plastic and is lowered in a horizontal position. In each case, a messenger is sent down a rope when the sampler is at the required depth to cause the stoppers to close the cylinder. The sampler is then raised to the surface. Water is removed through a valve to fill respective sample bottles. Dissolved oxygen (DO) sample bottles can be properly filled by allowing overflow using a rubber tube attached to the valve. When performing multiple depth sampling, care should be taken not to stir up the bottom sediment.

A glass beaker or stainless steel scoop may be used to collect samples if the parameters to be analyzed are not interfered with. The beaker or scoop should be rinsed three times with the sample water prior to collection of the sample. All field equipment should follow standard cleaning procedures.

EQUIPMENT/MATERIALS

- Sampling device [plastic bucket, pump, depth integrated sampler (D15)].
- Flow measurement device (velocity meter, survey equipment, measuring tape).
- Sampling materials (sample containers, log book, cooler, chain-of-custody).
- Camera.
- Work Plan.
- Health and Safety Plan.

REFERENCES

ASTM D4841 - Practice for Estimation of Holding Time for Water Samples Containing Organic and Inorganic Constituents

ASTM D4581 - Guide for Measurement of Morphologic Characteristics of Surface Water Bodies

ASTM D5906 - Guide for Measuring Horizontal Positioning During Measurements of Surface Water Depths

ASTM D5073 - Practice for Depth Measurement of Surface Water

ASTM D5413 - Test Methods for Measurement of Water Levels in Open-Water Bodies

Greenberg, A.E., R.R. Trussell, and C.S. Clesceri (eds). 1985. Standard methods for the examination of water and wastewater. 16th Edition. American Public Health Association, Washington, DC. p. 37.

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FMG 6.4-02 SAMPLE COLLECTION DATA SHEET

FMG 6.4-03 MONITORING WELL RECORD FOR LOW-FLOW PURGING

GROUNDWATER SAMPLING

INTRODUCTION

This procedure is for the collection of groundwater samples for laboratory analysis.

The objective of most groundwater quality monitoring programs is to obtain samples that are representative of existing groundwater conditions, or samples that retain the physical and chemical properties of the groundwater within an aquifer.

One of the most important aspects of groundwater sampling is acquiring samples that are free of suspended silt, sediment, or other fine grained particulates. Fine grain materials may often have a variety of chemical components sorbed to the particle or have the ability to sorb chemicals from the aqueous phase to the particle which will bias the subsequent analytical results.

Constituents known to have an affinity for fine grained particulates are: polychlorinated biphenyls (PCBs), semivolatile organic compounds (SVOCs), and inorganics. Monitoring programs where these constituents are suspected or known to be prevalent must employ sampling methods that minimize particulate presence.

The sampling method of "preference" for GM sites where particulate sorption is an issue is the "low stress/low flow" technique described within this FMG. Experience has shown that the "low stress/low flow" technique typically achieves representative groundwater samples with minimal particulate interference. In addition to the "low stress/low flow" technique, a "typical sample method" has been presented for the collection of constituents less sensitive to particulates presence (i.e., VOCs), or "direct-push sample methods" generally employed as a "pre-screening tool" to evaluate VOC presence. Direct-push sample procedures will result in groundwater samples with particulates present.

Lastly, in "extreme" cases "ultra-low flow" techniques have been employed at select sites where "low stress/low flow" methods were used, yet particulate-sensitive constituents continue to bias the analytical results. Ultra-low flow techniques are conducted at purging rates below 100 mL per minute, and should only be utilized after careful review and a procedural variance has been approved.

PROCEDURES REFERENCED

- FMG 1.4 - Data Recording - Field Books/Digital Recording.
- FMG 5.1 - Water Level Measurements.
- FMG 8.0 - Field Instruments - Use/Calibration
- FMG 9.0 - Equipment Decontamination.

PROCEDURAL GUIDELINES

The following describes three techniques for groundwater sampling: "Low Stress/Low Flow Methods", "Typical Sample Methods", and "Direct-Push Methods".

"Low Stress/Low Flow Methods" will be employed when it is critical to collect groundwater samples truly representative of the groundwater present, and to minimize the impact of sediment/ colloid presence. Analysis typically sensitive to turbidity/sediment issues are PCBs, SVOCs, and inorganic constituents.

The "Typical Sample Methods" will be employed where the collection of parameters less sensitive to turbidity/sediment issues are being collected (VOCs and general chemistry).

The "Direct-Push Methods" are typically employed for pre-screening areas for chemical presence to aid in determining well placement, or the need for further study.

Note: If non-aqueous phase liquids (NAPL) (light or dense) are detected in a monitoring well, groundwater sample collection will not be conducted and the Project Manager must be contacted to determine a course of action.
If deemed necessary to sample groundwater from below a LNAPL layer, a suggested sampling procedure has been presented at the end of this Procedural Guidelines section.

Preparatory Requirements

- Verify well identification and location using borehole log details and location layout figures. Note the condition of the well and inform the Project Manager of any required repair work.
- Prior to opening the well cap, measure the breathing space above the well casing with a PID to establish baseline levels. Repeat this measurement once the well cap is opened. If either of these measurements exceeds the air quality criteria in the Health and Safety Plan, field personnel should adjust their PPE accordingly.
- Prior to commencing the groundwater purging/sampling tasks, water level and total well depth measurements must be obtained to determine the volume of water in the well. Refer to

FMG 5.1 - Water Level Measurements for details. In some settings it maybe necessary to allow time for the water level to equilibrate. This condition exists if a water tight seal exists at the well cap and the water level has fluctuated above the top of screen; creating a vacuum or pressurized area within the well casing. Three water level checks will verify static water level conditions or changing conditions.

- Calculate the water volume in the well. Typically overburden well volumes consider only the quantity of water standing in the well screen and riser; bedrock well volumes are calculated on the quantity of water within the open corehole and within the overburden casing.
- Estimate the natural groundwater flow rate into well to determine the approximate pumping rate for purging/sampling activities.

Well Purging and Stabilization Monitoring (Low Stress/Low Flow Method)

- The GM method of preference for groundwater sampling will be the low stress/low flow method described below.
- Bladder pumps/submersible variable rate pumps (i.e., Grundfos™ Rediflo or equivalent) or peristaltic pumps are typically employed.
- Slowly lower the pump, safety cable, tubing and electrical lines into the well to the depth specified by the project requirements. The pump or tubing should be placed in the well as early as possible before sampling is initiated (this is to minimize well disturbance). In some programs it may be necessary to install the pumping equipment/tubing approximately 24 hours prior to purging. Peristaltic tubing placement should include a tubing "clamp" at the well head, to minimize vibration transfer into the water column. The pump or tubing intake must be at the mid-point of the well screen to prevent disturbance and resuspension of any sediment in the screen base. Bedrock well sampling may require pump/tubing placement in specific fracture zone areas or other areas which will be identified within the project Work Plan.
- Before starting the pump, measure the water level again with the pump in the well leaving the water level measuring device in the well when completed.
- Purge the well at 100 to a maximum of 500 milliliters per minute (mL/min). During purging, the water level should be monitored approximately every 5 minutes, or as appropriate. A steady flow rate should be maintained that results in drawdown of 0.3 feet or less. The rate of pumping should not exceed the natural flow rate conditions of the well being sampled. Care should be taken to maintain pump suction and to avoid entrainment of air in the tubing. Record adjustments made to the pumping rates and water levels immediately after each adjustment.
- Calibrate field instrument and document calibration activity. Calibration shall be performed in accordance with manufacturer's recommendations and FMG 8.0 - Field Instruments - Use/Calibration.

- During the purging of the well, monitor and record the field indicator parameters (pH, temperature, conductivity, oxidation-reduction (redox) reaction potential (ORP), dissolved oxygen (DO), and turbidity) approximately every 5 minutes. Stabilization is considered to be achieved when the final groundwater flow rate is achieved, and three consecutive readings for each parameters are within the following limits:
  - pH ±0.1 pH units of the average value of the three readings;
  - temperature ±3 percent of the average value of the three readings;
  - conductivity ±0.005 milliSiemen per centimeter (mS/cm) of the average value of the three readings for conductivity <1 mS/cm and ±0.01 mS/cm of the average value of the three readings for conductivity >1 mS/cm;
  - ORP ±10 millivolts (mV) of the average value of the three readings;
  - DO ±10 percent of the average value of the three readings; and
  - turbidity ±10 percent of the average value of the three readings, or a final value of less than 5 nephelometric turbidity units (NTU).
- Should stabilization not be achieved for all field parameters, purging is continued until a maximum of 20 well screen volumes have been purged from the well. Since low-flow purging (LFP) likely will not draw groundwater from a significant distance above or below the pump intake, the screen volume is based upon a 5-foot (1.4 m) screen length. After purging 20 well screen volumes, purging is continued if the purge water remains visually turbid and appears to be clearing, or if stabilization parameters are varying slightly outside of the stabilization criteria listed above and appear to be approaching stabilization.
- If low-turbidity samples are critical to the project goals, purging will be extended until turbidity has been reduced to 5 NTU or less.
- The pump must not be removed from the well between purging and sampling.

Well Purging and Stabilization Monitoring (Typical Method)

- Typically peristaltic pumps or bladder pumps or submersible pumps are preferred. In most cases bailer use is not desirable due to the "surging" action of bailer entry and removal. Exception is noted for VOC sampling where bailers are often used.
- The pump intake/tubing is typically placed at the mid-point of the screen within overburden wells. Bedrock well sampling may require pump/tubing placement in specific fracture zone areas or other areas which will be identified within the project Work Plan.
- Purge the well until three consecutive well volume measurements of temperature and specific conductivity are approximately plus or minus 10 percent and if the pH values are within 1 pH unit of the last three value averages, and the groundwater turbidity values are less than the project Work Plan requirements. If stabilization has not occurred within the first five well volumes removed, continue purging and monitoring until eight well volumes have been pumped. Purging rates should not exceed the natural flow rate of groundwater into the well.

Elevated purging rates may result in excessive drawdown of the water column, introducing sediment/particulate presence.

- Groundwater turbidity may be evaluated by a visual examination for sediment/silt presence or use of a nephlometer. Work Plan-specific goals may exist for turbidity values which may require extending the purging, or require an alternate pumping system.
- Purging and stabilization activities using a bailer are generally performed at the top of the water column, within the riser piping/above the well screen. This will minimize sediment disturbance/suspension in the screen area, and move water from the formation into the well screen/riser area in an effort to remove stagnant groundwater within the well. Bottom-loading bailers are generally employed. The lowering and removal actions are performed slowly to minimize well disturbance. Once stabilization has been attained, the sample aliquots are collected directly from the bailer.
- In the event the well goes dry (poor yielding formations), the purging activities will be performed on 3 consecutive days, noting the field stabilization parameters on each day. After the third day of purging is complete, the sample collection will be performed once sufficient groundwater recharge has occurred.

<u>Direct-Push Sampling Technique</u>

Generally, the direct-push sampling methods are employed for "pre-screening" groundwater quality (typically VOCs) in selected areas. This method is generally used to evaluate the need for permanent monitoring wells, or determine the need for further study. The sampling technique is a direct-push protected-screen sampling technique as described in ASTM D6001 (Standard Guide for Direct Push Water Sampling for Geoenvironmental Investigations). The direct-push sampling technique is summarized as follows:

- Advance borehole to the target depth below the groundwater table.
- Remove the drill rod, assemble the direct–push sample tool and attach it to the drill rod.
- Lower the sample device to the bottom of the borehole using the drill rod.
- Advance the sample device approximately 3 feet into the bottom of the borehole by hydraulically pushing the drill rod.
- Withdraw the drill rods approximately 1 to 2 feet to retract the screen sleeve and to expose the sampler screen to the formation.
- Alternatively a number of direct-push tools exist that do not require an advance borehole, and can be driven directly to the target depth and retracted for sample collection.
- Allow at least 15 minutes from exposing the sampler screen to sample collection to allow silt in the sampler to settle. In tight formations, a longer wait time may be required to allow sufficient groundwater to enter the screen. In some clays the sample device may not collect sufficient water volume to obtain a sample.

- Lower a small bailer into the sampler, discard initial bail (to acclimate bailer), and collect a water sample. A few bailer volumes may be required to obtain a sufficient volume of water sample. Alternatively, a "Waterra" check ball affixed to tubing maybe employed to collect a groundwater sample, or a peristaltic pump.
- Remove and clean the sampler device after completion of sample collection. Decontaminate sampler for next sample event.

This sampling technique is prone to sediment presence due to the lack of a screen sandpack and the limited purging performed before sample collection. A project variance will be required if non-VOC constituents are being considered for analysis.

<u>Sampling Techniques</u>

- If an alternate pump is utilized (i.e., typical method), the first pump discharge volumes (or bailer volumes) should be discarded to allow the equipment a period of acclimation to the groundwater.
- Samples are typically collected directly from the pump with the groundwater being discharged directly into the appropriate sample container. Avoid handling the interior of the bottle or bottle cap and don new gloves for each well sampled to avoid contamination of the sample.
- Order of sample collection:
  - VOCs;
  - SVOCs and PCBs;
  - Total organic carbon (TOC);
  - Total organic halogens (TOX);
  - Extractable organics;
  - Total metals;
  - Dissolved metals;
  - Phenols;
  - Cyanide;
  - Sulfate and chloride;
  - Nitrate and ammonia; and
  - Radionuclides.
- For low stress/low flow sampling, samples should be collected at a flow rate between 100 and 250 mL/min and such that drawdown of the water level within the well does not exceed the maximum allowable drawdown of 0.3 feet.
- The pumping rate used to collect a sample for VOCs should not exceed 100 mL/min. Samples should be transferred directly to the final container 40 mL glass vials completely full

and topped with a teflon cap. Once capped the vial must be inverted and tapped to check for headspace/air presence (bubbles). If air is present the sample vial will be discarded, and re-collected until free of air.

- Field filtration will be performed if dictated by the project Work Plan. Sediment presence can interfere or bias sample results; false positive findings have been observed when turbid samples for hexavalent chromium (and other analytes) are analyzed. Field filtration can eliminate this concern; generally applicable to only inorganic/PCB analysis. In-line disposable filter cartridges are generally the easiest and quickest method for field filtration.
- Sample labels/sample identification. All samples must be labeled with:
  - A unique sample number;
  - Date and time;
  - Parameters to be analyzed;
  - Project Reference ID; and
  - Sampler's initials.
- Labels should be secured to the bottle(s) and should be written in indelible inks.

<u>Groundwater Sampling Techniques Below LNAPL Layers</u>

Sampling and analysis of groundwater below a LNAPL layer is typically discouraged, and not performed at REALM/ENCORE sites. The rationale for avoiding groundwater analysis below a LNAPL layer is as follows:

- The potential for sample "contamination" with a trace amount of NAPL is very possible; analytical data will be biased "high" based upon this concern.
- Analytical data generated from this scenario does not represent "dissolved" constituent presence in groundwater. Dissolved constituents are "best" determined in downgradient locations.

In some instances it may be required to perform groundwater sampling and analysis below a LNAPL layer, possibly at the request of a regulatory group. If absolutely necessary, this type of sampling may be accomplished in accordance with the following:

- Determine the LNAPL depth and thickness using an interface probe or clear bottom loading bailer.
- Determine the sampling depth, selecting a sample point as far away as possible from the LNAPL interface.
- Using a "capped" outer tube or piping (i.e., 1-inch diameter polyethylene), insert the outer tube to the selected sample interval. The cap should be a slip-on cap affixed to the outer tube using a short "leash" (i.e., stainless steel wire or equivalent). This allows cap recovery once the sampling is complete.

- Insert the sample line (3/8-inch diameter tubing) into the outer tube and "push out" the end cap for sample line entry into the sampling interval.
- Perform purging and sampling using a peristaltic pump.
- Monitor the groundwater level and/or the NAPL level to ensure the LNAPL layer is not drawn to sampling depth. If LNAPL drawdown occurs evaluate the need to proceed further, and consider terminating sampling activity.
- This sample should not be referred to on any analysis as a groundwater sample. It should always be referred to as a groundwater/NAPL mixture (GW/NAPL designation).

EQUIPMENT/MATERIALS

- pH meter, conductivity meter, nephlometer, ORP meter, DO meter, temperature gauge.
- Field filtration units (if required).
- Purging/sampling equipment:
  - Peristaltic pump (not suitable for VOCs[1]/SVOCs, or drawing water from depths greater than 25 feet[2]);
  - Suction pumps (not suitable for LFP, VOCs/SVOCs, or depths greater than 25 feet);
  - Submersible pumps (suitable for VOCs/SVOCs only at low flow rates);
  - Air lift pumps (not suitable for VOCs/SVOCs);
  - Bladder pumps (suitable for LFR and VOCs/SVOCs);
  - Inertia pumps (gaining acceptability for VOCs/SVOCs, generally not suited for GM programs); and
  - Bailers.
- Water level probe.
- Sampling materials (containers, log book/forms, coolers, chain-of-custody).
- Project Work Plan.
- Health and Safety Plan.

Note[1]: Peristaltic pump use for VOC collection is acceptable on select EPA/RCRA sites; this technique has gained acceptance in select areas. Where it is permissible to collect VOCs using a peristaltic pump, collection must be performed at a low flow rate (Michigan allows VOC sampling with the peristaltic pump).
Acceptability of the collection of VOCs using the peristaltic pump should be evaluated before the sampling program commences, commonly performed during the project Work Plan development and approval process.

Note[2]: Exception is noted in locations that the suction line can be placed at the desired sample depth (i.e., 100 feet), and the natural recharge maintains a water level within 25 feet of the ground surface.

Field Notes

Field notes must document field activities and measurements collected during the sampling activities. FMG 1.4 - Data Recording - Field Books/Digital Recording describes the data/recording procedure for field activities. The log book/field file should document the following for each well sampled:

- Identification of well.
- PID readings before and after well opening (if required).
- Well depth.
- Static water level depth and measurement technique.
- Sounded well depth.
- Presence of immiscible layers and detection/collection method.
- Well yield – high or low.
- Purge volume, pumping rate, and final disposition.
- Time well purged.
- Measured field parameters and meter calibration records.
- Purge/sampling device used.
- Well sampling sequence.
- Sample appearance.
- Sample odors.
- Sample volume.
- Types of sample containers and sample identification.
- Preservative(s) used.
- Parameters requested for analysis.
- Field analysis data and method(s).
- Sample distribution and transporter.
- Analytical laboratory.
- Chain-of-custody number for shipment to laboratory.
- Field observations on sampling event.
- Name(s) of sampling personnel.

- Climatic conditions including air temperature.
- Problems encountered and any deviations made from the established sampling protocol.

A standard log form for documentation and reporting groundwater purging and sampling events are presented on Form FMG 6.4-01 - Well Purging Field Information, Form FMG 6.4-02 - Sample Collection Data Sheet, and Form FMG 6.4-03 - Monitoring Well Record for Low-Flow Purging.

Groundwater/Decontamination Fluid Disposal

The project Work Plan will identify the required disposal procedures for groundwater and decontamination fluids. Groundwater disposal methods will vary on a case-by-case basis but may range from:

- Off-site treatment at private treatment/disposal facilities or public owned treatment facilities.
- On-site treatment at Facility-operated facilities.
- Direct discharge to the surrounding ground surface, allowing groundwater infiltration to the underlying subsurface regime.
- Direct discharge to impervious pavement surfaces, allowing evaporation to occur.

Decontamination fluids should be segregated and collected separately from wash waters/groundwater containers. Often small volumes of solvents used during the day can be allowed to evaporate if left in an open pail. In the event evaporation is not possible or practical, off-site disposal arrangements must be made.

REFERENCES

ASTM D5474 - Guide for Selection of Data Elements for Groundwater Investigations.

ASTM D4696 - Guide for Pore-Liquid Sampling from the Vadose Zone.

ASTM D5979 - Guide for Conceptualization and Characterization of Groundwater Systems.

ASTM D5903 - Guide for Planning and Preparing for a Groundwater Sampling Event.

ASTM D4448 - Standard Guide for Sampling Groundwater Wells.

ASTM D6001 - Standard Guide for Direct Push Water Sampling for Geo-Environmental Investigations.

USEPA Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures (EPA/540/S-95/504).

USEPA RCRA Groundwater Monitoring: Draft Technical Guidance (EPA/530-R-93-001).

WELL PURGING FIELD INFORMATION FORM

JOB# ________ - ____

SITE/PROJECT NAME: ______________________ WELL# ________

WELL PURGING INFORMATION

PURGE DATE (MM DD YY)	SAMPLE DATE (MM DD YY)	WATER VOL. IN CASING (LITRES/GALLONS)	ACTUAL VOLUME PURGED (LITRES/GALLONS)

PURGING AND SAMPLING EQUIPMENT

PURGING EQUIPMENT.........DEDICATED Y N (CIRCLE ONE)

SAMPLING EQIPMENT.........DEDICATED Y N (CIRCLE ONE)

PURGING DEVICE ____ A - SUBMERSIBLE PUMP D - GAS LIFT PUMP G - BAILER X- ________ PURGING OTHER (SPECIFY)

B - PERISTALTIC PUMP E - PURGE PUMP H - WATERRA®

SAMPLING DEVICE ____ C - BLADDER PUMP F - DIPPER BOTTLE X- ________ SAMPLING OTHER (SPECIFY)

PURGING DEVICE ____ A - TEFLON D - PVC X- ________ PURGING OTHER (SPECIFY)

B - STAINLESS STEEL E - POLYETHYLENE

SAMPLING DEVICE ____ C - POLYPROPYLENE X- ________ SAMPLING OTHER (SPECIFY)

PURGING DEVICE ____ A - TEFLON D - POLYPROPYLENE F - SILICONE X- ________ PURGING OTHER (SPECIFY)

B - TYGON E - POLYETHYLENE G - COMBINATION TEFLON/POLYPROPYLENE

SAMPLING DEVICE ____ C - ROPE X- ________ (SPECIFY) X- ________ SAMPLING OTHER (SPECIFY)

FILTERING DEVICES 0.45 ____ A - IN-LINE DISPOSABLE B - PRESSURE C - VACUUM

FIELD MEASUREMENTS

WELL ELEVATION ________ (m/ft) GROUNDWATER ELEVATION ________ (m/ft)

DEPTH TO WATER ________ (m/ft) WELL DEPTH ________ (m/ft)

pH	TURBIDITY	CONDUCTIVITY	ORP	DO	SAMPLE TEMPERATURE
(std)	(ntu)	(µm/cm) AT 25°C	(mV)	(mg/L)	(°C)
(std)	(ntu)	(µm/cm) AT 25°C	(mV)	(mg/L)	(°C)
(std)	(ntu)	(µm/cm) AT 25°C	(mV)	(mg/L)	(°C)
(std)	(ntu)	(µm/cm) AT 25°C	(mV)	(mg/L)	(°C)
(std)	(ntu)	(µm/cm) AT 25°C	(mV)	(mg/L)	(°C)

FIELD COMMENTS

SAMPLE APPEARANCE: ________ ODOR: ________ COLOR: ________ TURBIDITY: ________

WEATHER CONDITIONS: WIND SPEED ________ DIRECTION ________ PRECIPITATION Y/N OUTLOOK ________

SPECIFIC COMMENTS ________

I CERTIFY THAT SAMPLING PROCEDURES WERE IN ACCORDANCE WITH APPLICABLE GM PROTOCOLS

DATE PRINT SIGNATURE

FMG MODIFICATIONS MUST BE ACCOMPANIED BY A REVISION REQUEST FORM APPROVED BY THE PROJECT MANAGER

SAMPLE COLLECTION DATA SHEET - GROUNDWATER SAMPLING PROGRAM

PROJECT NAME ______________________________ PROJECT NO. ____________

SAMPLING CREW MEMBERS ______________________________ SUPERVISOR ____________

DATE OF SAMPLE COLLECTION ______________________________

[Note: For 2" dia. well, 1 ft. = 0.14 gal (imp) or 0.16 gal (us)]

Sample I.D. Number	Well No.	Measuring Point Elev. (ft. AMSL)	Bottom Depth (ft. btoc)	Water Depth (ft. btoc)	Water Elevation (ft. AMSL)	Well Volume (gallons)	Bailer Volume No. Bails	Volume Purged (gallons)	Field pH	Field Temp.	Field Cond.	Time	Sample Description & Analysis

Additional Comments: ______________________________

Copies to: ______________________________

FMG MODIFICATIONS MUST BE ACCOMPANIED BY A REVISION REQUEST FORM APPROVED BY THE PROJECT MANAGER

MONITORING WELL RECORD FOR LOW-FLOW PURGING

Project Data:

Project Name: ____________________ Date: ____________________

Ref. No.: ____________________ Personnel: ____________________

____

Monitoring Well Data:

Well No.: ____________________ Screen Length (ft): ____________________

Measurement Point: ____________________ Depth to Pump Intake (ft)[(1)]: ____________________

Constructed Well Depth (ft): ____________________ Well Diameter, D (in): ____________________

Measured Well Depth (ft): ____________________ Well Screen Volume, V_s (mL)[(2)]: ____________________

Depth of Sediment (ft): ____________________ Initial Depth to Water (ft): ____________________

Time	*Pumping Rate (mL/min)*	*Depth to Water (ft)*	*Drawdown from Initial Water Level [(3)] (ft)*	*pH*	*Temperature ^{o}C*	*Conductivity (mS/cm)*	*ORP (mV)*	*DO (mg/L)*	*Turbidity (NTU)*	*Volume Purged, V_p (mL)*	*No. of Well Screen Volumes Purged [(4)]*

Notes:

(1) The pump intake will be placed at the well screen mid-point or at a minimum of 2 ft above any sediment accumulated at the well bottom.

(2) The well screen volume will be based on a 5-foot screen length, $V_s = p*(D/2)^2*(5*12)*(2.54)^3$

(3) The drawdown from the initial water level should not exceed 0.3 ft.

(4) Purging will continue until stabilization is achieved or until 20 well screen volumes have been purged (unless purge water remains visually turbid and appears to be clearing, or unless stabilization parameters are varying slightly outside of the stablization criteria and appear to be stablizing), No. of Well Screen Volumes Purged= Vp/Vs.

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NON-AQUEOUS PHASE LIQUID (NAPL)

INTRODUCTION

This procedure is for monitoring the presence of dense and light non-aqueous phase liquids (DNAPL and LNAPL), and collection of NAPL samples for laboratory analysis in monitoring, observation, and extraction wells.

It should be noted that groundwater sampling and analysis should not be performed in locations where NAPL has been identified.

PROCEDURES REFERENCED

- FMG 5.1 - Water Level Measurements.
- FMG 9.0 - Equipment Decontamination.

PROCEDURAL GUIDELINES

- Conduct well identification, inspection, and opening in accordance with FMG 5.1 - Water Level Measurements.
- NAPL level measurements are best conducted using a dual phase interface probe. The interface probe uses an optical liquid sensor, in conjunction with an electric circuit to detect the top of a phase-separated liquid and the interface between the phase layer and water (water level). The procedure for use of this probe is:
- For LNAPL:
  - Lower the probe tip into the center of the well until discontinuous beeping is heard (this indicates the top of the LNAPL has been detected). Grasp the calibrated tape at the reference point and note reading. Confirm the reading by slowly raising and lowering the probe to the level of the phase layer.
  - Once the top of the phase layer is confirmed, slowly lower the probe until a continuous sound is heard. This indicates that the water level has been encountered. Grasp the tape at the reference point and note the reading. Confirm this water level measurement.

- Decontaminate the submerged end of the tape and probe prior to the next use in accordance with the Work Plan requirements.

- For DNAPL:
  - Lower the probe tip in the center of the well to the bottom of the well, a discontinuous beeping will be heard if DNAPL is present. Grasp the calibrated tape at the reference point and note reading.
  - Once the bottom of the well is confirmed, slowly raise the probe until a continuous sound is heard. This indicates that the water level has been encountered and represents the top of the DNAPL layer. Grasp the tape at the reference point and note the reading. Confirm this water level measurement.
  - Decontaminate the submerged end of the tape and probe prior to the next use.

- Alternative NAPL measurement methods exist in the event an interface probe is unavailable or not functioning properly. These methods tend to be less accurate than the interface probe but may be used to establish an estimated NAPL measurement.
  - **Clear Bailer** – A clear bottom-loading bailer may be used to estimate NAPL thickness if floating or denser than water. If NAPL presence is suspected, the bailer is carefully lowered to the location of suspected NAPL presence (top of water column/base of water column), and slowly removed and examined for NAPL. If present, the column of NAPL within the clear bailer can be measured to estimate the NAPL thickness within the groundwater column.
  - **Weighted Cord** – Primarily used for DNAPL measurements, a weighted "cotton" string or cord may be lowered to the base of the well and inspected upon retrieval. Typically, the lower DNAPL layer will "coat" the string indicating the approximate thickness of this layer.

<u>Well NAPL Sampling</u>

- Prior to sampling, the level of NAPL in the well should be measured as identified above.
- Various sampling devices can be employed to acquire fluid samples from the top and bottom of the well, including the following:
  - Bottom-loading bailer;
  - Double check value bailer (produces most reliable results);
  - Peristaltic pump for shallow wells (<25 feet in depth); or
  - Inertia pump for deeper wells (up to 300 feet in depth).
- Transfer NAPL to sample containers for shipment to laboratory. NAPL can be sampled to evaluate the physical properties of the fluid or to evaluate chemical composition.
- Decontaminate equipment prior to next use.

Note: Groundwater sampling shall not be performed in locations where NAPL is present.

EQUIPMENT/MATERIAL

- Interface probe.
- Bottom-loading bailer.
- Double check valve bailer.
- Peristaltic pump.
- Inertia pump.
- Work Plan.
- Health and Safety Plan.

REFERENCES

Cohen, Robert M., Mercer, James W. (GeoTrans, Inc.), Robert S. Kerr Environmental Research Laboratory "DNAPL Site Evaluation" Office Research and Development. U.S. Environmental Protection Agency

Cohen, R.M., Brayda, A.P., Shaw, S.T., and Spaulding, C.P.; Fall 1992 "Evaluation of Visual Methods to Detect NAPL in Soil and Water", Groundwater Monitoring Review, Volume 12 No. 4, pp. 132-141.

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FMG 6.6-01 RESIDENTIAL/DOMESTIC WELL SAMPLING

RESIDENTIAL/DOMESTIC WELLS

INTRODUCTION

Sampling of residential/domestic wells can be performed using either the existing pumping system or Consultant-provided pumping equipment. Use of the existing pumping system is preferred as this is more representative of the water quality being provided to the residence/service area and there is less chance of damage to the well and existing pumping system. Sample collection should always be performed in advance of any treatment or storage devices. It should be noted, however, that the actual groundwater quality could be affected by dissolution of well casing and submersible pump components (e.g., lead and zinc from a galvanized casing or lead from brass fittings). In some cases it will be preferable, or necessary, to sample directly from the well after sufficient purging using Consultant-supplied equipment.

When water samples are collected from wells, either by mechanical or hand pumping, the wells must be purged before the sample is collected. Purging ensures that water representative of the formation is collected, not the standing water in the well casing, pipes, or holding tanks. At least one volume of water in the well casing and storage tank shall be evacuated (a 15-minute period is usually sufficient for residential wells).

PROCEDURES REFERENCED

- FMG 6.4 - Groundwater.
- FMG 6.10 - Sample Handling and Shipping.

PROCEDURAL GUIDELINES

- The domestic well inventory in the area of intent must be developed using a high standard of practice, including:
  - Review of local, state, and federal data bases;
  - Contact with local, state, and federal agencies;
  - Reconnaissance of area;
  - Review of municipal water supply records and billings; and

- Door-to-door survey.

- Prior planning and preparation tasks in advance of residential/domestic well sampling may include:
  - Owner/municipality contact to arrange access;
  - Analytical arrangements (laboratory, glassware, shipping); and
  - Equipment preparation/calibration.

Note: Analysis must be performed by a laboratory certified to perform drinking water analysis using applicable drinking water methods in the state of concern.

- Fully document the well configuration (i.e., depth, casings, construction date), pumping system (pump type, pump capacity, storage tank capacity), piping system (i.e., pipe type - copper, lead-joint construction), and presence of treatment devices (softeners, filters, UV treatment, carbon treatment). Document well proximity to site buildings/septic system using a field sketch within sampling notes. If available also document depth to water level within well.

  Name(s) shall always be obtained of the water supply owner(s), as well as the water supply owner's exact mailing address and home and work telephone numbers. This information is required in order to inform the water supply owner(s) of the results of the sampling program.

  If well information is not available from resident/owner, drilling logs maybe available from the driller, County Health Department, State Health Department, USGS, etc.

  Form FMG 6.6-01 - Residential/Domestic Well Sampling has been prepared for documentation of these sample events.

- Taps selected for sample collection should be located <u>as close to the well as possible</u> and upstream of any treatment system or storage/pressure tank, often outdoor taps are not connected to the treatment or storage components. This should be verified with owner before sample collection. Leaking taps that allow water to flow out from around the stem of the valve handle and down the outside of the lip are to be avoided as sampling locations. Aerator, strainer, and hose attachments on the tap must be removed before sampling. Whenever a steady flow of water cannot be obtained, sample collection shall be avoided because the temporary fluctuation in line pressure may cause sheets of microbial growth that are lodged in some pipe sections or faucet connections to break loose.
- The cold water tap shall be opened for 10 to 15 minutes to permit cleaning/purging of the service line. A smooth-flaring water stream at moderate pressure without splashing shall be obtained. Then, without changing the water flow which could dislodge some particles in the faucet, the samples may be collected.

- After purging for about 15 minutes, the pH, conductivity, turbidity, dissolved oxygen, and temperature shall be measured prior to sample collection and recorded on field log.

- Regardless of the type of sample bottle being used, the bottle cap shall never be placed on the ground or in a pocket. Instead, hold the bottle in one hand and the cap in the other, exercising care not to touch the inside of the cap. Disposable gloves shall be worn and changed between sample locations. Avoid contaminating the sample bottle with fingers or permitting the faucet to touch the inside of the bottle. When sampling for bacteria, the bottle shall not be rinsed before use. Flame sterilization of the tap outlet maybe a requirement of some Work Plans.

- The following shall be performed once the sample activities are complete:
  - i) Check that aerator/faucet screen has been replaced, and work area is clean.
  - ii) Double check Work Plan to ensure all samples and correct parameters have been collected.
  - iii) Decontaminate water monitoring probes/sample equipment (if used) prior to next sample event. Decontamination sequence will be in accordance with Work Plan.
  - iv) Notify the contract laboratory as to when to expect the samples. The Chain-of-Custody and covering letter, indicating the parameters and number of samples, shall be enclosed in the sample cooler.
  - v) Complete Form FMG 6.6-01 - Residential/Domestic Well Sampling for each residential/domestic well sampled.

<u>Community Relations</u>

- Ensure all activities are conducted in accordance with an appropriate Community Relations Plan.

EQUIPMENT/MATERIALS

- pH meter, conductivity meter, nephlometer, temperature gauge, dissolved oxygen meter.
- Pumping equipment (if required).
- Sample equipment/materials (containers, log book, coolers, chain-of-custody).
- Disposable gloves (non-powdered nitrile or latex).
- Work Plan.
- Health and Safety Plan.

RESIDENTIAL/DOMESTIC WELL SAMPLING FORM

PROJECT NAME:	PROJECT NO.:
OWNER/RESIDENT(S):	DATE:
ADDRESS:	TIME:
PHONE (H): PHONE (W):	SAMPLE PERSONNEL:

INTERVIEW

WATER SOURCE	☐ CITY ☐ WELL ☐ OTHER:	DATE OF WELL INSTALLATION:	☐UNKNOWN
WELL DEPTH (FEET BGS):	☐UNKNOWN		
WELL LOCATION:	☐UNKNOWN	TREATMENT ON PROPERTY	☐ FILTRATION: ☐ SOFTENER: ☐ OTHER:
STATIC WATER DEPTH:	☐UNKNOWN	AESTHETIC QUALITIES	TASTE:
BOTTOM DEPTH:	☐UNKNOWN		ODOR:
			OTHER:
PLUMBING MATERIAL:	SPICKET:	HOLDING TANK:	☐ YES ☐ NO LOCATION:
	PIPES:		
SCREENED INTERVAL:	☐UNKNOWN	CAPACITY:	☐UNKNOWN

SAMPLE PROPERTIES

SAMPLE LOCATION:	SAMPLE ID:
	DUPLICATE(S):
TIME PURGED:	
FLOW RATE:	SAMPLE DATE:
SAMPLE TEMPERATURE (° CELSIUS):	SAMPLE TIME:
FIELD PH:	FIELD CONDUCTIVITY (MS/CM):
CLARITY/TURBIDITY:	D.O. (MG/L):
COLOR:	OBSERVATIONS/COMMENTS:
ODOR:	

**DRAW MAP OF WELL AND SAMPLE LOCATIONS ON THE BACK OF THIS FORM

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FISH/CRAYFISH COLLECTION

A. FISH COLLECTION PROCEDURES USING A SEINE NET - INTRODUCTION

This section discusses the sampling of fishes by use of a seine net.

PROCEDURAL GUIDELINES

A seine net is used as an active sampling device to capture fish along a segment of shallow shoreline by encircling them. Each encircling effort or sweep of shoreline with the net is referred to as a "haul". The number of hauls and number of fish collected in each haul can be documented to yield quantitative (i.e., catch-per-unit-effort) information as a standard method of reporting fisheries seine data. Sampling by seine net is generally most effective in areas with smooth substrate and few underwater obstructions. A seine net consists of a length of mesh fabric, usually made of nylon or polyester, vertically suspended between a float line on top and a weighted lead line at the bottom. Seine nets can be obtained from commercial net vendors in a variety of dimensions and mesh sizes. Seine nets commonly used for fisheries work have mesh sizes that range from 1/16 inch to 4 inch Specific seine dimensions are selectively used by stream investigators depending on the needs of the fish survey, fish sizes, or life stages of the fish sought.

Each end of the net is fastened to a metal or wooden pole referred to as a braille. Seine nets can be constructed with an extended bag at the center that aids in the entrapment of fish during the seine haul.

Sampling Procedures

1. Mark off the segment of shoreline to be sampled.
2. Hold the inner end of the seine at the beginning of the shoreline sampling segment.
3. Carry the other end of the seine into the water perpendicular to the shore (a second person is needed to complete this task). When sampling areas are difficult or dangerous to wade in, or when a very long seine (e.g., for seining an ocean beach) is deployed, a boat can be used to manipulate the outer end of the seine. When using a boat, one person should hold the seine pole while a second person rows the boat. Alternatively, the shoreward end of

the seine can be tethered to a fixed object on the shore while the boat maneuvers the outer end of the seine.

4. Extend the seine away from shore until it is fully extended or until the water becomes too deep to maneuver the outer end of the net. Ideally, the water depth to be sampled is no deeper than the mesh wall on the seine net. If an extra bag is sewn into the seine net, make sure the bag is extended out behind the seine.
5. With the first person pulling the inner seine pole from shore and the second person pulling the outer pole in the water, drag the seine parallel to the shoreline for the length of the sampling segment. Make sure the lead line drags along the substrate so that fish cannot escape under the net.
6. If necessary, a third person can follow behind the seine as it is being pulled to free the net from any snags that are encountered.
7. When the end of the sampling segment is reached, swing the outer end of the seine shoreward and continue moving (sweeping) the seine toward shore until both ends meet at the shoreline.
8. Pull the remainder of the seine toward shore, making sure that the lead line drags along the substrate.
9. Check the net for fish after the entire seine is brought onto the shore.
10. Transfer the captured individuals to collection buckets.
11. Process the fish in accordance with study design specifications and FMG 6.7.E - Fish Processing Procedures.
12. If replicate shoreline segments are to be sampled, repeat Steps 1 to 10 for each replicate segment.
13. If a quantitative analysis of the fish community is being conducted (i.e., catch-per-unit-effort, total enumeration, or mark-recapture), it is recommended that the upper and lower boundaries of the stream segment be blocked by nets of the same mesh as the seine net. These nets should be strung across the channel, ensuring that the bottom of the net contacts the sediments so fish cannot move out of the stream segment being sampled.

EQUIPMENT/MATERIALS

- Seine net.
- Brailles.
- Hip boots or chest waders.
- Life jackets.
- Collection buckets or sample containers.
- Boat (for difficult access).

- Tape measure or hip chain.

B. FISH COLLECTION PROCEDURES USING AN ELECTROSHOCKER - INTRODUCTION

This section discusses the sampling of fishes by use of an electrofishing device referred to as an "electroshocker".

PROCEDURAL GUIDELINES

An electroshocker is an active fish collection device that sends an electric current through the water, temporarily stunning or directing the movements of fish. Stunned fish are collected by using a dip net. Because an electric current is generated during sampling, several precautions must be taken when using an electroshocker to avoid being electrocuted. Electroshocking should not be conducted without knowledge of the safety procedures described below. All equipment should be maintained and operated according to the manufacturer's instructions.

Basic procedures for using electroshockers are described below. One of four general electroshocker configurations can be used for fish collections. A backpack-mounted electroshocker is used in shallow streams where wading is safe. A pram shocker is used when wading in small and medium sized shallow streams. The pram is a small barge-mounted electrofishing unit that allows one or more fish collectors to work simultaneously without the encumbrance of backpack-mounted units. A bankside shocker offers alternative sampling flexibility in that it can be stationed along an embankment and deployed throughout small or medium-size streams by the use of handheld electrodes with extended conductor cables. Pram and bankside shockers offer more power output than backpack shockers and, as such, potentially pose higher risks. A boat electroshocker is used along shorelines of deeper or open waters where wading is not possible or safe.

<u>Safety Precautions</u>

Electrofishing is hazardous work. The following safety precautions must be taken when using an electroshocker:

1. Never electrofish alone. The buddy system must always be enforced.
2. Ensure that all persons in the sampling crew wear proper sampling attire.
3. Ensure that all members of an electrofishing crew understand the system they are using and the risks involved. Before a field operation begins, new crew members should

receive orientation on equipment and procedures. At least one member of the electrofishing crew must have CPR and first aid training.

4. Ensure that people, livestock, or pets are not in the water either upstream or downstream from the sampling site.
5. Do not use the electroshocker during an electrical storm or periods of heavy rainfall.
6. Limit the number of sampling crew to maximize safety through increased freedom of movement on deck or in the stream and to reduce confusion.
7. Make sure that the person-in-charge has ultimate control of the power source.
8. Never reach into the water with hands or feet for any reason while the electrosystem is operating..
9. Turn off the electroshocker immediately if a person falls into the water. All sampling crew must know how to turn off the electroshocker.
10. When electroshocking in streams, proceed upstream at a slow pace. Do not chase the fish.
11. With the exception of standard shoreline fish community surveys, do not shock constantly; it is preferable to shock for a few seconds, stop shocking while continuing to move, and then begin shocking again.

Operating the Electroshocker

1. Mark off the stream segment to be sampled, if applicable to the needs of the study.
2. Set up the electroshocking equipment according to the manufacturer's instructions. Each electroshocker configuration has unique setup procedures.
3. Have all members of the sampling crew put on appropriate attire (e.g., gloves, chest waders, etc.).
4. Designate one person as the operator of the electroshocker (i.e., the "shocker").
5. Adjust the voltage and ampere settings to the appropriate levels for the conductivity and velocity of the water that will be sampled and the size range of the target fish. This decision is deferred to the experienced operator.
6. If so equipped, adjust the setting for the electroshocker timer to zero before each electroshocking effort to document "on-time" electrofishing effort.
7. Have the crew members that will collect the shocked fish (i.e., the "dip-netters") stand by with dip nets.
8. If sampling a small stream, have all sampling crew members enter the water at the downstream end of the survey stream segment.
9. In small streams, have the crew face upstream while the "shocker" begins moving the anode through the water by extending it in an upstream direction and then pulling it away from fish cover or back in a downstream direction. At the same time, have the

"dip-netters" position themselves slightly downstream on either side of the "shocker" to capture the shocked fish and transfer them to collection buckets.

10. Have the sampling crew proceed in an upstream direction while electrofishing available fish micro-habitats until the end of the sampling segment is reached or until a pre-determined sampling time is expended. If electroshocking from a boat, the dip netters will position themselves at the handrail on the bow, from which point they can safely net the stunned fish.
11. Where quantitative fish data is not required, sample distances and times may be limited only by the needs of the survey.
12. When the end of the sampling segment is reached, record the number of electroshocker seconds elapsed during sampling plus the number of fish collected during that period.
13. Process the fish according to study design specifications and the procedures described in FMG 6.7.E - Fish Processing Procedures.
14. If replicate stream segments will be sampled, repeat Steps 1 to 13 for each replicate.

EQUIPMENT/MATERIALS

- Electroshocker unit (backpack, pram, bankside, boat).
- Hip boots or chest waders (if wading).
- Rubber gloves.
- Personal floatation device.
- Dip nets.
- Buckets.

C. FISH COLLECTION PROCEDURES USING GILL NETS AND TRAMMEL NETS - INTRODUCTION

This section discusses the sampling of fishes by use of gill nets and trammel nets.

PROCEDURAL GUIDELINES

Gill nets and trammel nets are typically used as passive sampling devices to capture fish as they swim through the water column, generally in shallow water. A gill net consists of a single wall of multi- or mono-filament nylon mesh netting vertically suspended between a float line on top and a weighted lead line at the bottom. Fish are captured in a gill net when they swim into the mesh and their bodies and gill coverings become entangled. A trammel net consists of an inner wall of a smaller fixed-size mesh with an outer wall on either side made of larger fixed-size mesh. A trammel net entraps fish, especially larger bodied fish, by catching them inside a pocket of small-mesh net which is pushed through an opening of the larger outer mesh by the fishes own movement.

To keep nets in a vertical orientation, especially in areas where strong water currents are present, anchors are attached to the ends of the lead line, and the ends of the float line are tied to small buoys. The lengths of the anchor and buoy lines can be adjusted so that the net is suspended at a target water depth. Gill nets and trammel nets are frequently used to fish in relatively shallow water with the lead line lying on the substrates. A gill net typically has a uniform mesh size and it is fish-size selective. However, the gill net can be composed of multiple panels with each panel a different mesh size, in which case it is referred to as an "experimental mesh" gill net. These types of nets are effective at sampling a broader range of fish body sizes than a traditional gill net.

Setting the Gill Net

1. Attach anchors to both ends of the lead line, and attach buoys to both ends of the float line with extension lines, if needed.
2. Stack the gill net in a large container by placing the end with the larger mesh size in the tub first (if the net has variable mesh sizes) and coiling the rest of the net into the tub. This step facilitates setting the net. Alternatively, the net can be "flaked-out" onto an open bow for easy deployment.
3. Beginning close to or on the shore, remove the outer end of the net from the storage bucket, and drop the anchor (attached to the lead line) and buoy (attached to the float line) over the bow of the boat. Adjust the buoy line so that the buoy is floating and the line is relatively taut. Allow plenty of extra line where tidal amplitudes fluctuate several feet.
4. Begin to set the net by slowly backing the boat away from shore.
5. Carefully let out (pay-out) the remainder of the net as the boat is moving backwards, shaking out any tangles.
6. Once the inner end of the net is reached, stop the boat, and pull on the net until it is taut.
7. Drop the anchor (attached to the lead line) overboard.
8. If setting a suspended gill net, pull on the float line to make sure the net is taut. Drop the buoy that is attached to the float line into the water. Adjust the buoy line so that the buoy is floating and the line is relatively taut.
9. Allow the gill net to fish for the prescribed sampling period (e.g., 1 to 24 hours).

Retrieving the Net

1. Start at the deeper end of the net, and retrieve the buoy and anchor.

2. Begin pulling the net on board the boat and stacking it in coils in the storage bucket as the boat moves toward the shoreward end of the net.

3. As fish are encountered in the net, remove them by lifting the mesh over their opercula (gill coverings) and sliding it off their bodies. The mesh is frequently extremely tight around the fish's body and may require the use of a net pick, toe-nail clippers, or knife to free the fish.

4. Transfer the captured fish to collection buckets.

5. Process the fish in accordance with study design specifications and FMG 6.7.E - Fish Processing Procedures.

6. If sampling will continue at the collection site, the net can be reset in the original manner.

7. If the objective is to capture live fish, gill nets must be checked about every 4 hours or sooner depending on conditions and the presence of fish-eating predators. If gill nets are left in place overnight, many fish will be dead, and depending on the type of aquatic habitat being sampled, many may be partially eaten by turtles or crabs.

8. In many aquatic habitats, turtles or other animals including water fowl, small diving mammals, and various invertebrates may become entangled in the gill net. Most species can be removed with a low likelihood of harm to the researcher. However, snapping turtles should be approached with extreme caution; it may be advisable to cut the mesh around the turtle to free it from the net.

Gill nets can also be used as an active collection device, by using the net as a large seine. When used as a large seine, one end of the net is held or fastened to a structure on the shoreline at the start point. The other end is taken downstream until the net is nearly extended, then across the channel and up the far bank to above the start point. The end of the net is then brought back to the first bank and returned to the start point. At this time, both persons slowly pull in the gill net, now functioning as a large seine. If the net becomes snagged, it will be necessary for one person to follow back in the boat along the net to free the net. This method is successful in obtaining a large number of fish from many taxa at one time.

EQUIPMENT/MATERIALS

- Gill or trammel net.
- Net containers (large plastic tubs or trash cans).
- Buoys, floats, or jugs.
- Anchors (traditional, bricks, concrete blocks, etc.).
- Small diameter line.
- Collection buckets.
- Boat.

- Gill net pick or pocket knife, scissors, or large toe-nail clippers (for cutting mesh) if needed.

D. FISH COLLECTION PROCEDURES USING FISH TRAPS - INTRODUCTION

This section discusses the sampling of fishes by use of traps including trap nets, hoop nets, and minnow traps.

PROCEDURAL GUIDELINES

SAMPLE COLLECTION USING A TRAP NET OR HOOP NET

Trap nets and hoop nets are used as passive sampling devices to capture fish as they swim along the shoreline. Although the nets can be set in different configurations to sample deeper open waters as well. Trap nets are particularly effective in capturing several migratory species. A trap net consists of a leader (wall of mesh fabric) and a series of hoops or compartments that entrap fish after they pass through a series of funnels or openings. Panels of mesh referred to as "wings" can be added to either side of the openings on these traps and serve to guide otherwise passing fishes into the net funnels. The net is commonly set perpendicular to the shore with its mouth facing the shoreline. When fish encounter the leader or wings, they are directed into the mouth of the net. As fish move through the series of hoops or compartments, escape becomes increasingly difficult. Fish may be attracted to the net by other fish that are already captured in it. Bait may be added to trap nets and hoop nets to attract species such as catfish.

Setting the Net

1. Bait the inside of the last compartment of the net if catfish or other bottom feeders are desired.
2. Anchor the shoreward end of the leader near the shoreline, or attach it to the shoreline by tying it to a fixed object onshore (e.g., a tree, a root, etc.).
3. Extend the leader line out into the water and perpendicular to shore until it is taut.
4. Extend each wing at a 45 to 90° angle to the leader line. This step can be done either by boat or by wading, depending on water depth and substrate characteristics.
5. Anchor the lower ends of both wings with anchors, and attach buoys to the upper ends of the wings. Adjust the buoy lines so that the buoys are floating and the lines are relatively taut.
6. Extend the hoops of the trap away from shore in line with the leader line, and pull on the end of the net until all of the hoops are upright.

7. Close the back end (cod end) of the net with a piece of line.
8. Attach an anchor to the end of the net to keep it submerged, and attach a buoy to the anchor to mark the location of the end of the net.
9. Allow the net to soak for the prescribed sampling period (e.g., 24 to 48 hours).

Retrieving the Net

1. Arrive at the buoy at the end of the net, snag the buoy line with a boat hook, and pull the buoy and its anchor into the boat.
2. Retrieve the hoops in sequence while moving toward shore.
3. Starting at the mouth of the net, shake the captured fish into the closed end of the net.
4. Once all captured fish are in the back end of the net, empty them into the collection buckets.
5. Process the fish according to study design specifications and FMG 6.7.E - Fish Processing Procedures.
6. If sampling will continue at the collection site, reset the net according to Steps 5 to 8 of the above procedures for setting a net.

SAMPLE COLLECTION BY USING A MINNOW TRAP

A minnow trap is used as a passive sampling device to capture juvenile fish as well as the adult individuals of small fish species. Minnow traps can also be effective in capturing crayfish and tadpoles. Fish are captured when they swim into the trap through a funnel-shaped opening that makes escape difficult. The trap is generally set in shallow nearshore areas and should have a buoy attached to facilitate retrieval. Multiple traps can also be strung together with line to facilitate retrieval. The trap can be deployed with bait inside to attract fish or without bait. Fish may be attracted to the trap by other fish that are already captured in it.

Setting the Minnow Trap

1. Attach a buoy to the trap with enough line to ensure that the line will remain slack at the highest water level expected for the period of deployment. If sufficient line is not used, the buoy can reduce the negative buoyancy of the trap, allowing the trap to be moved by waves or currents. The use of an excessive length of line should also be avoided because it will increase the probability of the line becoming snagged as it is moved around by waves or currents.
2. Assemble the trap. If bait will be used, the trap can be baited at this time.
3. Deploy the trap at the sampling station by lowering it over the side of the boat, making sure that it does not get tangled in the buoy line. If a string of traps will be deployed,

attach the trap to the next one in the sequence before deploying it. Buoys do not need to be attached to any of the additional traps.

4. After the trap is placed on the bottom, adjust the length of the buoy line on the basis of the considerations discussed in Step 1. If a string of traps is used, move the boat to the prescribed location of each additional trap in sequence, and deploy each of those traps.
5. Allow the trap to soak for the prescribed sampling period (e.g., 24 to 48 hours).
6. If the minnow traps are being set from the shoreline, tie a long piece of rope onto the trap, and lower the minnow trap out into the stream channel, or place it at the edge of habitat along the shoreline or adjacent to habitat structure (e.g., a downed tree limb).
7. Secure the end of the line to a structure on the shoreline, and use surveyor flagging to mark where the line is tied.
8. If motorized boats are expected to traverse the channel, fasten a buoy to the trap with a length of line sufficient to allow the buoy to float above the trap. Ensure a sufficient amount of line is attached to keep the buoy afloat during high water conditions.

Retrieving the Minnow Trap

1. Arrive at the buoy attached to the trap, and snag the buoy line by using a boat hook or similar device.
2. Pull the trap to the water surface by using the buoy line, and bring the trap onboard the boat.
3. Open the trap, and transfer the captured fish to the collection buckets. If a string of traps is used, proceed to the next trap in sequence, and follow Steps 2 and 3.
4. Process the fish according to study design specifications and FMG 6.7.E - Fish Processing Procedures.
5. If sampling will continue at the collection site, reset the trap according to Steps 3 to 5 of the above procedures for setting a minnow trap.
6. In habitats influenced by tidal flux, check minnow traps before low tide is reached because the trap may become exposed during low tides, leading to mortality of the organisms in the trap or serving as an attractant to other wildlife.

EQUIPMENT/MATERIALS

Sample Collection Using a Trap Net or Hoop Net

- Trap net or hoop net.
- Buoys.
- Anchors (traditional, bricks, or concrete blocks, etc.).

- Line.
- Boat hook.
- Collection buckets.
- Boat.

Sample Collection Using a Minnow Trap

- Minnow trap(s).
- Buoy(s) or surveyor flagging.
- Line.
- Boat hook.
- Boat.

E. FISH PROCESSING PROCEDURES - INTRODUCTION

This section discusses the procedures for making biological measurements of individual fish and for resecting fillets from individual fish for analysis of chemical concentrations in edible muscle tissue.

PROCEDURAL GUIDELINES

Biological Measurements/Observations

The biological measurements and observations commonly made of individual fish include length, weight, gender, reproductive condition, presence or absence of physical anomalies, parasites, or disease, and age using scales or hard body parts.

Length and Weight Measurements and Other Observations

Length and weight measurements should be made on unpreserved fish as soon as possible after collection. Preservation techniques such as freezing and fixation with formalin and ethanol can alter length and weight measurements relative to the values that would be found for unpreserved individuals immediately after capture. The procedure described below for measuring length addresses total length (i.e., the distance from the most anterior part of the fish to the tip of the longest caudal fin ray):

1. Examine each fish for signs of physical anomalies, disease, or external parasites. Examples of physical anomalies include eroded fins, missing eyes, scoliosis or other body

or mouth deformities, and skin lesions. Examples of disease symptoms include hemorrhagic sores, skin fungi, or grossly undernourished body condition. Examples of external parasites include attached leeches or worms, or cysts embedded in the skin or fin membranes. Detailed observations should be noted on appropriate data sheets for each fish examined. Note the location of the anomalies (i.e., caudal fin, left mandible).

2. Place each fish on the measuring board, with its head touching the wall of the board and its side resting along the ruler of the board. Do not squeeze the head of the fish against the wall of the board.
3. Push the caudal fin together, and record the measurement for the longest part of the fin to the specified accuracy (e.g., the nearest 1.0 mm).
4. Place the balance tray on the analytical balance, and press TARE. Wait for a reading of 0.0 g.
5. Place the fish in the balance tray.
6. Allow the weight reading to stabilize, and record the weight to the specified accuracy (e.g., 1.0 g).

Fish Filleting Procedures

Fish are commonly filleted to resect edible muscle tissue for analysis of chemical concentrations. The filleting process is the same one used by fishermen to remove edible muscle tissue from fish. The results of the chemical analyses are therefore directly related to the tissue that is frequently consumed by humans. Filleting should occur after length and weight measurements and other observations have been recorded for each fish, as follows:

1. Decontaminate all filleting equipment (filleting knife, scaler, fillet board) with Alconox®, methanol, and hexane, in sequence. After the hexane rinse, allow the equipment to air dry.
2. Cover the cutting board with a piece of aluminum foil, dull side facing up.
3. Place each fish on its side on the fillet board.
4. Remove all scales from the caudal fin to the head. Do not remove the skin from fish that are commonly eaten with the skin attached to the fillet. For species that are commonly skinned before eating (e.g., catfish), remove the skin from the entire fish by cutting the skin around the head and peeling it off with pliers.
5. Make a cut along the ventral midline of the fish from the vent to the base of the jaw.
6. Make a diagonal cut from the base of the cranium, following just behind the gill to the ventral side just behind the pectoral fin.
7. Remove the flesh and rib cage from each side of the fish by cutting from the cranium along the spine and dorsal fin to the caudal fin. Leave the ribs attached to the main fillet. When removing the fillet, it is common to leave the fatty "belly" meat on the fish carcass.

Consult specific project study plans regarding inclusion of belly meat or rib bones with the fillet portions because this procedural requirement may vary among agencies.

8. Wrap the fillets in aluminum foil with the dull side facing the tissue.
9. Label the wrapped sample according to job-specific study plan instructions.
10. Place the labeled, wrapped sample in a labeled Ziploc® bag, and preserve as indicated in the project-specific study plan.

Determination of Gender and Reproductive State

1. After filleting each fish, examine the gonads, and determine whether they are ovaries or testes. Record the gender of the fish.
2. Identify the reproductive state of the gonads according to the following scale:
   - **Stage I -** Ovaries are wine-colored and shaped like torpedoes, and no eggs are visible; testes are small, flat, whitish in color, and cling closely to the spine.
   - **Stage II -** Ovaries resemble those in Stage I, except that small black (but color may vary) eggs are visible to the naked eye; testes are swollen and milky in appearance.
   - **Stage III -** Ovaries are somewhat swollen and yellowish in color; testes are large, lobed, and freely emit a milky liquid.
   - **Stage IV -** Ovaries are greatly swollen, their texture resembles tapioca, and the largest eggs are transparent and more than 1 mm in diameter; testes are slack and contain an abundance of connective tissue.
   - **Stage V -** Ovaries are slack and contain only a matrix and a few residual eggs.

Age Determination

The age of fish is commonly determined by counting the number of annual check marks (i.e., annuli) on hard structures such as scales, spines, otoliths, vertebrae, and opercular bones. The procedures described below are based on the use of scales for age determination. If otoliths, opercular bones, or vertebrae are required for age analysis, follow procedures specified in Nielsen et al. (1983) or as otherwise indicated in the project-specific work plan.

1. Only personnel experienced in the process of fish-scale age determinations should be assigned to this task. At least one experienced peer should validate age determinations.
2. Before collecting scales for age determinations, remove mucous, dirt, and epidermis from the area by gently wiping the side of the fish in the direction of the tail with a blunt-edged knife.
3. Remove about 20 scales from the left side of each fish from areas suitable for the particular species being aged. Consult standardized methods manuals or experienced fisheries workers to obtain this information. Removal must be done carefully. Blunt

forceps or a knife tip may be very useful for this task. Be careful not to break the margins of the scales or scratch the surfaces. Scales that are broken or irregularly shaped should be discarded.

4. Transfer fish scales to a labeled coin envelope for later age determination. For bullheads and catfishes, remove the dorsal spine for age determination instead of the scales. If otoliths, opercular bones, or vertebrae are required for age analysis, follow procedures specified in Nielson et al. (1983) or as otherwise indicated in the project-specific work plan.

5. A scale sample number should be included on the coin envelope for each fish sampled. The sample number should cross reference vital data for each fish including information such as species, length, weight, sex, date, location, and project number.

6. Scales should be inspected and cleaned before mounting them for microscopic viewing. If mucus, skin pigments, or dirt is present on the scale, soak them in water for about two hours, and scrub off any remaining deposits with a small brush or piece of cloth after the soaking period. Retain the best 5 to 10 scales for mounting and viewing.

7. Mount the viewing scales between two microscope slides, making sure that the scales do not overlap.

8. Project the mounted scales with a microprojector (microfiche reader) and identify the scale(s) that have a complete set of rings emanating outward from their center. The microprojector should provide an enlarged image to about 50 times the natural size of the scale.

9. The number of annual rings (annuli) on each scale are counted. Each "true" annulus represents one year of growth. Care must be taken not to misinterpret "false" annuli, "split" annuli, checks, crowded annuli, or accessory rings. An important consideration for aging fish via scale marks is to understand the time of annulus formation which can vary with latitude, spawning, migration, and feeding habits of the sampled fish population as well as with environmental data and water temperature range.

10. Scale and age data are recorded on Figure 6.7.E-1 - Scale Analysis Summary Sheet. The scale analyst must sign and date the sample control sheet.

Exponent

Scale Analysis Summary Sheet

Project Name:________________________

Project Number:____________________

Water Body:________________________

Sample No.	Date Collected	Location	Species	Length (mm)	Weight (g)	Sex	Age	Remark

Analyst:________________________ Date:________

Witness:________________________ Date:________

Figure 6.7.E-1 Scale analysis summary sheet

EQUIPMENT/MATERIALS

- Measuring board.
- Analytical balance.
- Stainless-steel filleting knife.
- Skinning pliers (if needed for removing catfish skins).
- Blunt-point forceps.
- Fish scale-remover ("scaler").
- Fillet board.
- Microprojector.
- Coin envelopes.
- Aluminum foil.
- Ziploc® bags.
- Disposable nitrile gloves.
- Alconox®.
- Hexane.
- Methanol.
- Collection buckets.

F. CRAYFISH COLLECTION PROCEDURES - INTRODUCTION

This section discusses collection of crayfish by use of kick-nets and crayfish traps and the procedures for processing captured crayfish.

PROCEDURAL GUIDELINES

Sampling can be conducted at day or night. Crayfish can be caught by passive or active means. A passive technique entails the baiting of crayfish traps which are placed in the water during the day and left to fish overnight. If more intensive (active) methods are required, kick-nets can be deployed in shallow streams to seek out crayfish. When working in small streams, if electrofishing gear is available, crayfish may be incidentally collected along with fish. Night sampling in shallow water is often the most productive approach because a number of species venture out of their burrows or out from other cover at night. Captured crayfish should be handled with care because of their pinchers.

Collection With Kick-Net

Kick-net sampling is an active method of sampling benthic organisms by vigorously kicking and disturbing bottom sediments and catching the dislodged organisms with an aquatic net. Kick-net sampling is most effective in shallow streams (<1 m deep) with substrates of rock, rubble, or gravel in the riffle/run areas with light to moderate currents.

1. The kick-net is positioned in the stream about 0.5 m downstream.
2. The stream bottom including stones and debris is vigorously disturbed by foot so that the dislodged organisms are carried by the current into the net.
3. Sampling can be continued for a specified time and for a specified distance in the stream if standard effort is required.
4. The preferred line of sampling is a diagonal transect of the stream.
5. The net contents are emptied into a pan of stream water.
6. Crayfish are removed from the net and washed with water from the stream being sampled then placed in collection bucket. Other benthic macroinvertebrates are removed from the net and discarded into the stream.
7. The net is vigorously rinsed in the stream between sample efforts.

Collection With Crayfish Trap

Crayfish traps provide a passive means of collecting crayfish. The use of bait (usually some type of meat) attracts scavenging crayfish into the traps. Traps can be deployed in shallow or deep water. An experienced biologist should determine how to most efficiently bait and deploy the traps for the habitats being investigated. Crayfish traps are commonly identical to minnow traps used to catch small fish. The funnel shaped entrance of a minnow trap should be widened beyond the factory dimension to accommodate the capture of larger crayfish. Traps can be set individually with a line and a float or in a series with several traps attached to a single line and float.

Deployment of Crayfish Traps

1. Determine the number of sample locations to be sampled.
2. Bait and assemble each two-piece trap by using the hinges provided around the rim of each trap.
3. Attach a buoy (small visible float) to the trap to aid in retrieval of the trap at a later time.
4. Deploy the trap at the sampling station by lowering it into the water (or over the side of the boat), making sure that it does not get tangled in the buoy line. If a series of traps will be deployed, attach the trap to the next one in the sequence before deploying it. Floats do not need to be attached to any of the additional traps.

5. Allow the trap to soak for the prescribed sampling period (e.g., 24 hours).
6. If the traps are being set from the shoreline, tie a long piece of rope onto the trap and lower the trap at the edge of the habitat along the shoreline.
7. Secure the end of the line to a structure on the shoreline, and use surveyor flagging to mark where the line is tied.

Retrieving the Crayfish Trap

The trap will be retrieved and the crayfish collected as follows:

1. Arrive at the buoy attached to the trap, and snag the buoy line with a boat hook if using a boat to retrieve the traps.
2. Pull the trap to the water surface by using the buoy line, and bring the trap onboard the boat or onto shore if wading.
3. Open the trap and transfer the captured crayfish into the collection buckets. If a string of traps is used, proceed to the next trap in sequence, and follow Steps 2 and 3.
4. Process the crayfish for length, weight, and enumeration according to study design specifications.
5. If sampling will continue at the collection site, reset the trap according to Steps 3 to 5 of the above procedures for setting a crayfish trap.

Crayfish Length and Weight Measurements

The following measurements and preparations for shipping shall be made:

1. Place each crayfish on a measuring board, and record its total length to the nearest millimeter from the tip of its rostrum to the end of the telsun (central tail section or uropod).
2. Place a balance tray on an analytical scale, and press TARE. Wait for a reading of 0.0 g.
3. Place the crayfish in the balance tray.
4. Allow the weight reading to stabilize, and record the weight to the specified accuracy (e.g., 1.0 g).
5. Record measurements on a field collection log.
6. Place crayfish in decontaminated 8-ounce glass jars or into aluminum foil with the dull side facing the sample.
7. Label jars or foil packets with an adhesive label.
8. Labeled sample containers should be placed in a clean plastic outer bag and stored on dry ice or wet ice pending shipment to the laboratory for tissue analysis. Frozen crayfish in

glass jars may be transferred to double polyethylene bags to avoid breakage during shipment and storage.

9. If required sample sizes are greater than the mass of individual organisms, the composition of any composite samples should be noted in the field notebook (number of organisms, species, if possible).
10. Sample preparation and analysis, problems encountered, and corrective action taken during sample collection, preparation, and delivery shall be recorded in the field notebook.

Quality Control

At no time should organisms that are found dead in traps or that are known to have been caught more than 24 hours before collection be retained for analysis. Checking traps on a daily basis is required.

EQUIPMENT/MATERIALS

Collection With Kick-Net

- Hip boots or chest waders.
- Kick-net with a mesh opening size less than 2 mm^2.
- Sample collection pan or bucket.
- Measuring board.
- 8-ounce glass jars or aluminum foil.
- Cooler with ice.
- Adhesive labels.
- Space pen and field collection logs.

Collection With Crayfish Trap

- Minnow/crayfish traps.
- Bait (cheese whey, beef or pork, chicken parts, fish, peanut butter, or other suitable baits).
- Chest waders or rubber boots (if deployed in wading conditions).
- Sample collection pan or bucket.
- Measuring board.
- Small floats or surveyor flagging.
- Boat hook.

- Twine.
- 8-ounce glass jars or aluminum foil.
- Cooler with ice.
- Adhesive labels.
- Space pen and field collection logs.

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REMEDIATION TEAM	FIELD METHOD GUIDELINE NO.: FMG 6.8
REAL ESTATE & FACILITIES	EFFECTIVE DATE: MARCH 14, 2011
GENERAL MOTORS	
REVISION NO.: 0	REVISION DATE:

TERRESTRIAL INVERTEBRATES COLLECTION

INTRODUCTION

This procedure is applicable for the capture of aboveground terrestrial arthropods.

PROCEDURES REFERENCED

- FMG 1.4 - Data Recording - Field Books/Digital Recording.

PROCEDURAL GUIDELINES

Pitfall Traps

Pitfall traps are used for sampling active arthropods that tend to be strictly ground-dwellers, including many beetles and spiders. Pitfall traps are containers sunk into the ground so the open end of the container is flush with the ground surface. The size of the containers varies with the size of the organism targeted for capture. Pitfall traps for invertebrates are typically the size of waxed Dixie® cups. These cups, glass jars, or other suitable containers can be used as pitfall traps. If containers are reused, they should be thoroughly decontaminated between sampling events.

Depending on the goal of the study, pitfall traps can be arrayed in a grid, along a linear trap line, or adjacent to particular locations (e.g., soil sampling stations). The array of pitfall traps must be clearly identified in the project sampling and analysis plan (SAP). "Wings" made from lumber or garden edging can also be used to guide ground-dwelling insects to the pitfall traps.

Traps should be emptied at regular intervals. The length of the interval may vary depending on the weather and the sampling goals. Sampling for volatile contaminants in hot weather may require checking on a daily basis. Sampling for metals in cool weather may only require checking pitfall traps at 2 or 3-day intervals. If containers much larger than a quart jar are used, pitfall traps should be checked daily because small mammals and other nontarget animals may be captured.

After emptying pitfall traps, invertebrates should be sorted in the field into the lowest desired taxonomic level that is practical. Sorted samples should be placed in plastic bags with labels with assigned sample numbers that clearly identify the station (trap) location, date, and other pertinent information. Samples that are being retained for chemical analyses should be placed on ice in ice chests until returned to the field laboratory, at which point the sample bags should be placed in a freezer. Invertebrates destined for chemical analyses should not be killed by using chemicals. Many commonly used chemicals may cause regurgitation and/ or defecation, which may result in the loss of an analyte and therefore lead to underestimation of contamination. Freezing is therefore recommended for killing invertebrates.

Cover Boards

Cover boards are used for capturing what have been called "cryptozoa." These are invertebrates that seek a microclimate refuge from otherwise harsh conditions. Typical types of organisms found under cover boards may include crickets, slugs, wood lice, certain beetles, and spiders. The surface of the flipped cover board should also be checked for organisms clinging to its surface. The sampler should be prepared to capture swiftly moving organisms in bottles or other containers. Note: Cover boards are also refuges for creatures such as venomous reptiles, scorpions, centipedes, or spiders. Personnel should never lift a cover board with unprotected fingers. If poisonous snakes are a potential problem, a cover board should always be lifted with a long-handled instrument. If a problem snake or other unwanted organism is encountered, the sampler should not try to remove it. If possible, the cover board should be removed, and personnel should leave the immediate area. The disappearance of the microclimate should lead to the disappearance of the snake. The site health and safety plan should be followed at all times.

Cover boards are conveniently and inexpensively made from 2 feet by 2 feet squares of untreated 0.75-inch plywood. Cover boards can be arrayed in grids, trap lines, opportunistically, or at particular locations (e.g., soil sampling stations) as desired. The SAP should specify the trapping design. Cover boards can also be used with pitfall traps to gain additional taxa, especially when pitfall traps cannot be checked regularly. Use boards that are wider than the pitfall trap, and suspend the board above the top of the trap with four small (0.5 to 1 inch thick) blocks of wood.

Time between sample collections is not critical for cover boards because the invertebrates are free to move about between intervals. Thus, this parameter is a matter of convenience and logistics. Invertebrates should be collected and processed in the same manner as described under *Pitfall Traps*.

Invertebrates should be sorted in the field into the lowest desired taxonomic level that is practical. Sorted samples should be placed in plastic bags with labels with assigned sample numbers that clearly identify the station (trap) location, date, and other pertinent information. Samples that are being retained for chemical analyses should be placed on ice in ice chests until returned to the field laboratory, at which point the sample bags should be placed in a freezer. Invertebrates destined for chemical analyses should not be killed by using chemicals. Many commonly used materials may cause regurgitation and/or defecation, which may result in the loss of an analyte. For invertebrate samples destined for use in ecological risk assessments, this may result in an underestimate of contamination.

Malaise Trap

Malaise traps are used to collect flying or emerging arthropods, such as wasps, flies, and moths. These traps are designed to intercept arthropods flying in any direction. They are tent-like structures made of netting, which funnel flying insects into a collection jar located at the top of the tent. For best results, the trap should be placed where wind currents are common or where natural travel corridors exist. Examples of such areas include along a ridge top or along a stream stretch. These traps can be used to inventory rare or elusive insects and are not typically used in tissue collection studies.

Sweep Netting

Sweep netting is used to capture flying insects or insects that live on bushes, high grasses, or low trees. Insect groups readily captured by sweep netting include many grasshoppers, butterflies, flies, bees, and wasps.

Sweep nets come in two basic designs. Lighter butterfly nets are designed to be easily moved about in pursuit of an active single prey that is capable of effective evasive action. Heavier nets are used to sweep through vegetation, capturing all insects that are present. Both methods are effective, and the choice of nets depends on the targeted group of arthropods.

The net is swept quickly in an arc through the vegetation or to capture a targeted insect (e.g., a butterfly), and the netting is then flipped quickly over the mouth of the net so the insects can not escape. The net is then maneuvered to place the insect in a jar or plastic bag (special care is taken with bees and wasps).

Samples can be taken along transects and the results reported in captures per unit of time. Because this method of reporting is highly variable among individuals, sampling should be done by the same individuals at all stations. Alternatively, formulas can be used to estimate the volume of a sweep net, and results can be reported in those terms. The area should be sampled for 30 minutes unless there is an abundance of invertebrates, in which case 15 minutes should be sufficient. The amount of time spent sweep netting is noted on the data sheet and in the field log book.

Beating Trays

Areas too lush for sweep netting, such as woody plant communities, can be sampled by using beating trays. This method takes advantage of the response of some insects dropping from vegetation when disturbed. The beating tray or sheet is held under the vegetation while the vegetation is beaten or shaken. A number of trays can be used together to sample a larger area. Typically, a time interval is used to standardize sampling. In this manner, captures can be reported per unit of time.

Sorting

Invertebrates should be sorted in the field into the lowest desired taxonomic level that is practical. Sorted samples should be placed in plastic bags with labels with assigned sample numbers that clearly identify the station (trap) location, date, and other pertinent information. Samples that are being retained for chemical analyses should be placed on ice in ice chests until returned to the field laboratory, at which point the sample bags should be placed in a freezer. Invertebrates destined for chemical analyses should not be killed by using chemicals. Many commonly used materials may cause regurgitation and/or defecation, which may result in the loss of an analyte. For invertebrate samples destined for use in ecological risk assessments, this may result in an underestimate of contamination.

SMALL MAMMAL TRAPPING

This section describes procedures for collecting small mammals for population analysis or tissue collection. These techniques are generally useful for the collection of mammals ranging in body size from a shrew to an adult raccoon. The methods described in this section include both live-collection and kill-collection techniques. The section discusses the use of live traps, snap traps, and pitfall traps.

Personnel

Only personnel trained to use small mammal traps, and whose names are listed on the appropriate permits are authorized to capture and handle small mammals. All required research protocols, federal regulations, and other applicable regulatory guidelines should be studied before initiating trapping operations. Personnel without previous experience should be under the guidance and direct supervision of an experienced trapper.

Collection Methods and Trap Types

The choice of collection method will be specific to the size of the animals being sought and the objectives of the sampling and analysis plan (SAP). If animals are to be captured, marked, and released, Sherman live traps or their equivalent (i.e., Longworth traps, Havahart traps) should be used. The 3 x 3.5 x 9-inch traps will capture most small mammal species, including most species of shrews and most species of microtine, cricetid, and heteromyid rodents. The traps are also capable of capturing young rabbits, young opossums, young raccoons, and adult squirrels.

If it is necessary to collect animals for analyses, Museum Special snap traps or their equivalent (i.e., Victor traps) may be used for rodents up to small ground squirrel size. For kill-trapping of large squirrels, rats, and mammals up to the size of small rabbits, Victor Rat traps or their equivalent should be used. For larger animals, a .22-caliber rifle or shotgun is necessary. However, live traps can be used when a specific species or sex of animals is needed for analysis. Once the desired animals are captured, animals can be dispatched by cervical dislocation or by placing them in a cloth bag in a cooler of dry ice. Specific collection methods should be detailed in the SAP.

Grids vs. Trap Lines

The trapping method used (grids, trap lines, or randomly placed traps) is determined from the SAP. Whenever possible, traps should be set in a single habitat type, not overlapping habitat types. If density information is sought, grids should be used whenever possible. The approach recommended by White et al. (1982) requires a sufficient grid size to contain at least three, preferably four, nested subgrids for use in density estimation models, with the subgrids preferably separated by two rings of traps. Density estimation lines may also be used with trapping grids. Analysis with density estimation lines is more complex and should only be performed after consultation with a statistician to ensure an adequate study trapping design. It is also necessary for density estimation to uniquely mark individuals so that capture histories and capture probabilities of individuals can be calculated. Finally, the grid method has a high trapping success. Grids may be square or rectangular, with one, two, or three traps set at each grid intersection. Thus, a 10 x 10 m grid would contain 100 grid intersections. One trap per grid intersection requires placement of 100 traps. If all traps were left open for one 24-hour day, the total trapping effort would be 100 trapnights, less any correction for sprung traps. More traps per station are required in habitats with greater densities of small mammals, where competition for the traps (as shelter) or the food resources within (bait) is likely to occur.

If the habitats to be sampled are too small to permit use of grids, randomly placed trap lines or individual traps may be used. If the study objectives require only a general description or assessment of the small mammal fauna (indices of relative frequency or relative abundance), randomly placed trap lines or individual traps may be preferable. The number of trap lines per habitat type, length of trap lines, and number of traps per station will be specified in the SAP and be dependent on the extent of area to be sampled and features of the habitat.

The distance between adjacent trap stations, adjacent trap lines, or grid lines will also be stated in the SAP. If the study objectives require an assessment of a single species, trap spacing and traps per station should be based on the home range size of the species being studied, with a minimum of three trap stations within each animal's home range (White et al. 1982). If a multispecies habitat assessment is required, traps are generally set at a spacing of 5.0 m, 7.5 m, 10.0 m, 15.0 m, or 22.5 m. If multiple traps are placed per station, they should be approximately equidistant and within 1.0 to 1.5 m of the station center.

Grid/Trap Line Marking

Individual traps at a station should be placed in locations that sample various microhabitat features because microhabitat differences have been shown to influence small mammal occurrence. For example, traps should be set at the bases of trees and shrubs, at the edge of the shrub canopy, in the open, in microtine runways, alongside fallen trees, in short and tall grass, and in disturbed areas of forbs and shrubs.

The beginning and end of trap lines, the corners of grids, and individual stations should be marked whenever possible. Generally, the fewer markers the better to avoid attracting predators (ground and aerial) that may cue on the markers, which would thereby increase mortality in the trapping area and influence the density/abundance/occurrence estimations. If wire flags are used, the flag should be trimmed to a 1-inch width to reduce flapping. A color visible to humans but not readily visible (and therefore an attractant) to wildlife should also be used. An alternative to the use of wire flags is to use painted wooden stakes, willow stems, or rebar driven into the ground to mark the station center, with only the top few inches painted. In wooded habitats, surveyor flagging may be tied to the vegetation to mark the station center. All grid and trap line locations should be marked on field site maps to aid relocation and provide a permanent record of where trapping occurred and what trapping method was used. If a global positioning system unit is available, readings of the beginning and end markers of a trapline or the corners of the grid should be logged.

Trap Functioning

Each trap should be cleaned and checked for proper functioning before placing it in the field. In when trapping is being conducted to address small mammal tissue contamination or bioaccumulation, or where the hantavirus is of concern, all traps should be cleaned and disinfected before placement at a station or before moving to a different station. Disinfection of traps is discussed in the health and safety plan. All urine and fecal materials should be washed off. Traps may be disassembled for cleaning beneath the treadle mechanism by removing the wires from selected trap sides, permitting easy access to the trap interior.

Treadles on live traps should release doors with only very light fingertip pressure on the treadle or a light tap on the top of the trap. Sensitivity of the mammal trap is varied by pulling forward or pushing back the treadle lock mechanism.

Snap traps should be checked to ensure that all parts are securely fastened so that when the trap is sprung, the trap does not disassemble. Trap sensitivity is adjustable on all snap traps. To adjust the sensitivity of Museum Special snap traps, bow (i.e., bend) or straighten the holding bar that passes across the snap bar and inserts into the bait treadle (bowing the holding bar increases sensitivity, straightening the holding bar decreases sensitivity). On Victor snap traps (mouse or rat size), push the metal bait treadle holder to the sides of the trap to increase or decrease sensitivity.

Pitfall traps cannot be adjusted and can fill with water, either from groundwater seepage, percolation from the surrounding soil, or rainfall entering the trap. Animals will drown in water-filled pitfalls if a dry refuge is not provided. Holes can be punched in pitfalls to allow water to drain out, although in some habitats and soil types, this step may cause the pitfall to fill with water more quickly. In conical pitfalls, synthetic batting (i.e., Dacron) or rocks can be placed in the bottom to keep the animals out of the water. In flat-bottomed pitfalls (e.g., buckets or cans), a rock or brick can be placed in the bottom to provide a dry resting area for captured animals.

Bait

Dry baits are readily available and easy to use. Rolled oats or horse feeds, such as Purina Omelene, make good dry baits. Dry baits may not be as effective as moist baits, but this may be advantageous depending on study objectives. Care should be taken, when using live traps, to ensure dry bait does not prevent the treadle from working properly.

Bait balls are very attractive to a wide variety of small mammals ranging from shrews to raccoons. Bait balls are made by mixing peanut butter, rolled oats, and sunflower seeds and/or cornmeal. Peanut butter should first be warmed until easily stirred, then the remaining ingredients should be added. This mixture is then allowed to cool. A small amount of the peanut butter mixture (approximately the size of an M&M® peanut candy) is spooned into the middle of a 4 x 4-inch, waxed paper square. The waxed paper is folded around the bait ball and the ends are twisted (so that the bait ball looks like a Hershey's® kiss).

Snap traps can be baited with the mixture above or with pure peanut butter. In some instances (e.g., tundra areas in Alaska), it may not be necessary to apply any bait because many of the species are herbivores and thus unlikely to be attracted to bait. These species will be caught as they encounter traps through their daily movements (i.e., if the trap is in the runway or an area the animal is foraging in). Pitfalls are not typically baited, although a bait such as sardines that provide an attractant for some species (i.e., shrews) may be considered.

Trap Placement

The following procedures should be used to place traps:

1. Clear the immediate area where each trap will be placed of grass and other ground clutter so that each trap sets firmly on the ground. Personnel may level the ground, but do not disturb an area much larger than the size of the trap.
2. Check to be sure that when the door of a live trap is set open, there is no wobble as the animals step into the entrance of the trap. For snap traps, ensure that the entire platform

sits firmly on the ground. If the trap moves when a small mammal begins to enter, it may retreat and thereafter avoid the trap.

3. If wind or a steep slope cause trap instability, anchor each trap with a U-shaped piece of No. 12 wire, open end down, that straddles the center of each trap. Force the wire ends into the ground to prevent each trap from being moved. For large snap traps (i.e., rat traps), attach a small screw eye to the back edge of the trap, attach a length of wire or rope (i.e., 12 to 18 inch), and attach the second end to a large nail or spike. The nail or spike is driven into the ground to secure the trap in the event the animal is caught but not immediately killed and attempts to escape.
4. If using dry bait, place a handful of bait inside the trap, turn the trap upside down, and shake it so that the bait is on the opposite side of the treadle, then quickly turn the trap right side up. The dry bait should now be on the treadle. Be sure the bait is on the treadle and not under it. Too much bait under the treadle will hamper operation of the trap. If using bait balls to bait traps, determine which is the front end of the trap by pressing open each door in turn and looking inside. The front of the trap is the end that has the metal door catch on the floor of the trap. Then hold the twisted ends of a bait ball, and push the ball through the top of the back door. Once it is inside the trap, pull the ball back toward you. The bait ball will catch the inside the trap door and pull it shut.
5. If temperatures below 5°C are expected or extended periods of rain are anticipated, place a wad of bedding material (polyester fiberfill or similar nonabsorbent material) in each trap to serve as nesting material. This step will help insulate animals from potentially fatal cold weather.
6. For pitfalls, use a shovel, post-hole digger, or sharp metal rod to create a hole in the soil of sufficient depth to hold the pitfall. The pitfall is placed correctly if the lip of the pitfall is slightly below the level of the surrounding soil or duff.

<u>Trap Checking</u>

If traps are left open all day, they should be checked at least twice daily. Heavy rain, cold, or extreme heat can kill trapped animals; trap checks should be performed as expeditiously as possible. Pitfalls may need to be checked more frequently. Pitfalls are the most successful method for capturing shrews, and shrews will tend to eat any other animals in the trap, including other shrews. Extra bait should be carried during trap checks. Soiled bedding material should be replaced as needed.

The suspension of trapping due to inclement weather will be at the discretion of designated field personnel. Any time trapping efforts are suspended, entrance doors on live traps should be shut and snap traps deactivated. All traps should be closed or deactivated before any scheduled days off. Pitfalls should be covered, either with a board, a lid, or some type of plug placed into the container when not in use.

Field personnel must immediately capture and relocate predators that begin preying on trapped animals and killing captured small mammals. Mammalian predators can be caught in larger live traps and released several miles from the research sites. Predators may be destroyed only if the proper permits have been obtained. Additionally, some states have regulations regarding the relocation of predators. Be sure to learn about these regulations before relocating animals.

COLLECTION BY FIREARMS

Larger-bodied animals that are unable to be caught in live traps must be collected by using a firearm. Preferred types are a .177-caliber pellet gun for smaller animals, .22-caliber rifle for animals the size of ground squirrels and rabbits, and a shotgun for animals the size of a raccoon. Extreme care must be exercised at all times in transporting and handling a firearm. Only people experienced with firearm use and authorized by the health and safety officer should use this type of equipment. Anyone collecting samples by using this method should have completed a firearm safety course.

ANIMAL HANDLING

Review the health and safety plan for specific protective requirements before handling animals.

The Pesola scale should be tared to the weight of the capture bag, or the bag should be weighed before being used to weigh any small mammals captured in the field.

The following procedures are used to remove and weigh captured animals:

1. A shut door may indicate a capture. To check, hold the trap with the baited end of the trap facing the ground. Gently press the front door open only as far as necessary to determine if an animal is inside.
2. If you have captured an animal, press the front door open further, adjusting the trigger mechanism slightly with a finger of the hand that is holding the trap so that the door remains open. Shield the opening of the trap with the other hand to prevent escape by the animal.
3. Once the door is secure, place the capture bag over the mouth of the trap, gathering any loose edges.
4. Turn the trap upside down. If the animal does not readily fall out, gently shake the trap.
5. Once the animal is in the bag, make sure it is not near the open end, quickly close the bag, and set the trap down.
6. Remove any foreign objects that have fallen into the trap with the animal (e.g., bait, bedding, sticks).
7. Weigh the bag. If the scale is not pre-tared, subtract the weight of the bag from the weight of the bag and the animal.

8. Record the weight.

9. Live animals in pitfalls should be removed by personnel wearing heavy leather gloves to avoid being bitten.

10. Removing larger animals in Tomahawk and Havahart traps requires particular caution. Tip the trap up on its end, and carefully reach in a gloved hand to grasp the animal. An alternative is to lock the door open and shake the animal out of the trap into a cloth holding bag (e.g., a pillow-case type of bag).

<u>Other Measurements</u>

Additional measurements beyond weight can be helpful if the identification of the animal is in question. Measurements that are often used for identification are the total length (including the tail), tail length, hind foot length, and ear length. These measurements require use of a specific method to ensure proper identification. Refer to the field sampling plan, field guides, or mammalogy laboratory books for the proper method.

<u>Sexing Animals</u>

Experience is necessary for sexing small mammals. Males and females may be differentiated by using the following guidelines:

- Males - Check for the presence of testes (only visible during periods of reproductive activity). The penis is directed anteriorly and may be covered with a sheath. The distance between the papillae and the anus is greater in males than in females.
- Females - Check for the presence of mammae, a vaginal opening, and a clitoral sheath. The distance between the papillae and the anus is shorter than in males.

Record sex information.

<u>Aging Animals</u>

The most accurate and cost-efficient method of aging small mammals currently in practice is the use of eye-lens weights, as described in Rowley et al. (1983) and Thomas and Bellis (1980). An approximation of age can be made in the field by using details of pelage coloration, body weight, and meristic measurements (i.e., length of hind foot or tail length). Local keys or field guides are moderately useful in aging animals. A good source for age characteristics, if available, is a small mammal collection maintained at a college, university, or natural history museum.

<u>Trap Cleanup</u>

Due to the risk of hantavirus in small mammal populations across the country, any traps that have been used should be treated as if they contain hantavirus. Risk of hantavirus is greatest in closed air environments. Therefore, traps should be transported in an open-air vehicle such as the back of a pickup truck or a trailer. If this is not possible, the traps should be bagged in large plastic bags, and care should be taken not to tear the bags while placing the traps in the vehicle. Alternatively, traps can be washed in the field provided a means of transporting wastewater is available.

Once traps are transported to an area for washing, all traps should be washed with soap and water, decontaminated with bleach, and rinsed thoroughly whether traps were used in a treated (e.g., contaminated) or an untreated area. Traps should then be allowed to air dry and be packed away. Refer to the health and safety plan for further precautions regarding hantavirus and small mammal handling. Traps from treated sites should be washed with soap and water, decontaminated with bleach, air dried, and packed as described in the health and safety plan.

<u>Safety Precautions</u>

1. All work, including the transfer of samples from bags into the blender and from the blender into sample bottles, will be performed inside a biological safety cabinet (BSC). The blender and utensils must be thoroughly disinfected before removal from the BSC.
2. Laboratory personnel performing the work will be trained in BSC use and made aware of biosafety hazards.
3. Disposable latex or nitrile gloves must be worn at all times when handling small mammals and/or samples.
4. Gloves must be disinfected before removal.
5. Hands must be washed after removing gloves.
6. Disinfect all surfaces coming in contact with samples after they are used. Suitable disinfectants include a bleach/water solution, alcohol, or commercial products such as Lysol®.
7. Spray or soak all trash, including plastic bags and gloves, with disinfectant, then double bag trash for disposal as solid waste.
8. Workers who become ill or who develop a febrile or respiratory illness within 45 days of the last potential exposure should immediately seek medical attention and inform the attending physician of the potential occupational risk of hantavirus infection. The physician should contact local health authorities promptly if hantavirus-associated illness is suspected. A blood sample should be obtained and forwarded through the state health department to the Centers for Disease Control for hantavirus antibody testing.

SMALL MAMMAL NECROPSY

This section outlines procedures for gross (nonhistological) examination of small mammals after their death.

Health and Safety Considerations

Many of the infectious diseases of wildlife are transmissible to humans, and no necropsy should be done without adequate protection. Protection consists of wearing protective outer clothing, such as overalls or laboratory coat[1], impermeable gloves, and the appropriate respiratory protection as outlined in the project health and safety plan.

Safety Precautions

- All work, including the transfer of samples from bags into the blender and from the blender into sample bottles, will be performed inside a biological safety cabinet (BSC). The blender and utensils must be thoroughly disinfected before removal from the BSC.
- Laboratory personnel performing the work will be trained in BSC use and made aware of biosafety hazards.
- Disposable latex or nitrile gloves must be worn at all times when handling samples.
- Gloves must be disinfected before removal.
- Hands must be washed after removing gloves.
- Disinfect all surfaces coming in contact with samples after they are used. Suitable disinfectants include a bleach/water solution, alcohol, or commercial products such as Lysol®.
- Spray or soak all trash, including plastic bags and gloves, with disinfectant, then double bag for disposal as solid waste.
- Workers who become ill or who develop a febrile or respiratory illness within 45 days of the last potential exposure should immediately seek medical attention and inform the attending physician of the potential occupational risk of hantavirus infection. The physician should contact local health authorities promptly if hantavirus-associated illness is suspected. A blood sample should be obtained and forwarded through the state health department to the Centers for Disease Control for hantavirus antibody testing.
- See http://www.cdc.gov/ncidod/diseases/hanta/hantvrus.htm to learn more about hantavirus.

Field measurements include age class, reproductive status (open or closed vagina, testes ascended or descended, lactating or not), and general comments regarding any obvious abnormalities or behavioral disturbances observed before death. The pertinent field notes should be copied from the field data sheets and attached as part of the permanent record of the necropsy proceedings.

[1] During the initial hantavirus outbreak, the Centers for Disease Control recommended wearing Tyvek coveralls when working with animals suspected to be infected with hantavirus. This measure might be a good precaution in that situation to prevent contamination of street clothes, which could happen with a laboratory coat.

Necropsies can be performed without significant deterioration up to several hours after collection if the specimen is refrigerated. Samples to be necropsied should not be frozen, if possible, because freezing may make interpretation of effects more difficult. Each animal should be examined in the same way so inconsistencies are not introduced. An external examination should be performed before invasive necropsy procedures. External examination should include a general survey of the external morphology. Particular attention should be paid to any abnormalities including, but not limited to, cleft palate, cleft lip, microphthalmia, polydactyly, and aberrations of fur. A qualitative estimate of parasites (external and internal) should be recorded, including the number, types (e.g., tapeworm, roundworm, tick), and locations of the parasites. All observations should be noted on the necropsy report.

DISSECTION AND EXAMINATION PROCEDURES

The following procedures should be followed for dissection and examination of small mammals.

Opening and Removal of Viscera

Small mammals are necropsied more easily if some method of immobilization is used. A soft board or sheet of cardboard and four stout pins can be used (Figure 6.8-1). Biologists performing this procedure should review their project field sampling plan for specific necropsy endpoints and any project-specific details of this procedure.

The animal is placed in the right lateral recumbent position, with the legs facing the dissector and the head to the dissector's left. The initial skin incision passes from the lips along the ventral midline to the perineum.

The incision should pass to the left of the mammary glands in the female. The skin is reflected, the left foreleg is raised, and the axillary muscles are cut so that the leg may be reflected dorsally. The hind leg is raised, the muscles are cut along the pelvis, and the hip joint is severed.

The abdomen is opened by cutting the body wall along the ventral midline from the pelvis to the sternum, and then by a second cut following the last rib on both sides. The sternum and ribs are removed as a unit, exposing the abdominal viscera. The thoracic viscera are examined, and the condition of the pleural membranes is noted on the necropsy report.

The tongue, larynx, thyroids, parathyroids, trachea, esophagus, lungs, heart, and thymus are removed from the body by cutting between the lateral margins of the tongue and the mandible, freeing the tongue, and then by using a process of traction and cutting, freeing the larynx and other structures. The aorta, posterior vena cava, and esophagus are transected at the diaphragm. (If the stomach is full, the esophagus should be tied before cutting.)

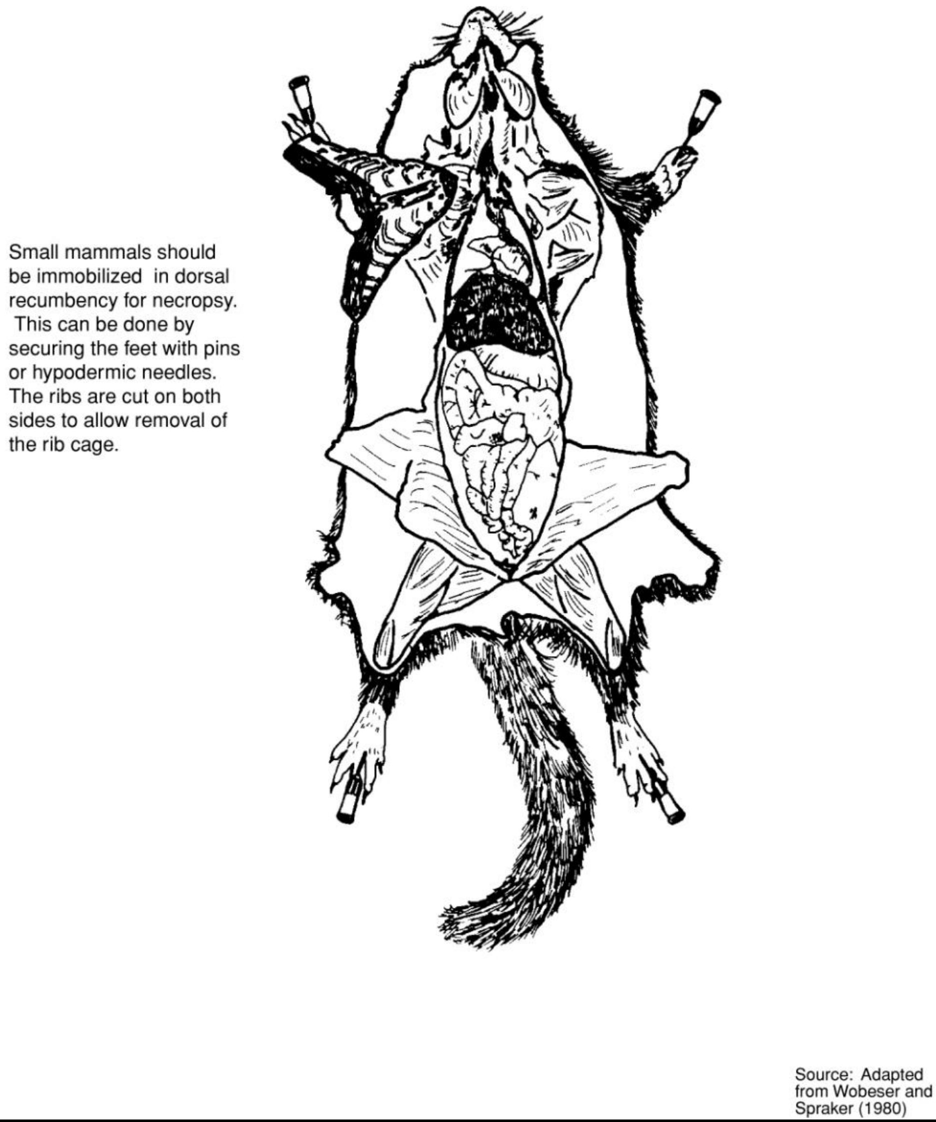

Figure 6.8-1 Small mammal necropsy example

The liver, spleen, and digestive system are removed as a block by severing the esophagus caudal to the diaphragm, freeing the liver from the kidneys by blunt dissection, and severing the mesentery. The colon is transected at the pelvic brim (if the feces are fluid the colon is tied). The adrenal glands are identified at the anterior pole of the kidneys and removed. The urogenital system is removed from the body as a unit by splitting the pelvis at the symphysis pubis in young animals or by removing the ventral portion of the pelvis in adults.

Examination of the Thoracic Viscera

The external surfaces of the lungs are thoroughly inspected, and any lobular differences in color, inflation, and firmness are noted on the necropsy report. The larynx and trachea are opened by a dorsal longitudinal incision with scissors. The nature and consistency of any exudate in the airways are noted. The pericardial sac is opened, and the fluid therein noted. The heart and great vessels are examined while attached to the lungs (which permits easy reorientation if some anomalous condition of the vessels exists.) The epicardial surface of the heart is inspected, and the size and contour of the heart is noted. The heart is usually opened by following the normal path of blood flow beginning in the right atrium.

Examination of the Abdominal Viscera

The spleen is dissected free from the omentum and sectioned longitudinally. The initial examination of the liver is conducted while it is attached to the duodenum by the bile duct. The shape, size, and color of the liver are noted, and incisions are made to inspect the parenchyma.

The intestines are dissected free from the mesentery and straightened. The stomach is opened by an incision from the cardia along the greater curvature of the pylorus. This incision can then be extended the length of the intestine. The contents are examined for parasites, and the mucosa is inspected.

The kidneys are opened by a longitudinal incision, and the capsule is stripped with forceps to expose the cortex. The ureters, bladder, and urethra are opened with scissors. The uterus in the female is opened and inspected. The gonads are identified and incised. The amount of perirenal and omental fat should be noted.

Specific reproductive endpoints to note at the time of necropsy include dark bands on uteri, implantation sites, number of embryos, and bleeding at the urogenital region.

Carcass Disposal

Carcasses may generally be disposed of as ordinary waste as long as they are not thought to contain pathogens. If there is a possibility that they do contain pathogens (e.g., hantavirus), they should be disposed of as biological waste. Consult the project-specific health and safety plan for more information on pathogens, and a local veterinary clinic for disposal options, if necessary.

SMALL MAMMAL TISSUE HOMOGENIZATION

Each animal will be individually bagged. Each sample will consist of several animals that will be composited (blended together). The individually bagged animals comprising each sample will be placed in one large bag.

1. Inside a biological safety cabinet (BSC), open the outer bag containing individually packaged animals, then open the individually packaged animals and combine all animals for the sample in an industrial blender.
2. Homogenize the sample and record the length of time required for complete homogenization. All samples must be homogenized for the same length of time.
3. Pour or scrape the homogenized sample into one or more trace-metal clean, Teflon® bottle(s). These bottles will be provided by the analytical laboratory.
4. Transfer all information printed on the original sample container onto the Teflon® bottle(s).
5. The blender must be decontaminated before each sample is homogenized and must be disinfected after each sample.
6. A record must be maintained that includes the date and time at which all samples and blanks were prepared, the length of time each sample was blended, and any notes regarding deviations from protocol. This record will be forwarded to the project quality assurance and quality control coordinator.

Blender Decontamination and Disinfection

The blender must be decontaminated before use and between all samples and must be disinfected after use.

Disinfection

Disinfect the blender before removal from the BSC by soaking or spraying with a bleach solution, alcohol, or household disinfectant such as Lysol®.

Decontamination

1. Rinse the blender with HOT soapy water (tap water and Alconox®), and scrub with a clean bottle brush or other utensil to loosen residual tissue.
2. Rinse the blender with HOT tap water three times.
3. Rinse the blender with deionized water three times.
4. Any instrument used in sample homogenization (e.g., scraper or utensils) must also be decontaminated before each sample (including the cross-contamination blanks) is not homogenized by using the same method described for the blender decontamination. The instrument must also be disinfected after use.

Cross-Contamination Blanks

Cross-contamination blanks must be prepared at a frequency of 1 blank per 20 samples or 1 blank per batch of samples, whichever is more frequent.

1. Fill the blender to the same level as the samples with deionized water, and record the volume of water used.
2. Blend the deionized water for the same length of time as the samples were homogenized.
3. Pour the cross-contamination blank into a clean Teflon® bottle, and label the bottle as a cross-contamination blank.

Safety Precautions

1. All work, including the transfer of samples from bags into the blender and from the blender into sample bottles, will be performed inside a BSC. The blender and utensils must be thoroughly disinfected before removal from the BSC.
2. Laboratory personnel performing the work will be trained in BSC use and made aware of biosafety hazards.
3. Disposable latex or nitrile gloves must be worn at all times when handling samples.
4. Gloves must be disinfected before removal.
5. Hands must be washed after removing gloves.
6. Disinfect all surfaces coming in contact with samples after they are used. Suitable disinfectants include a bleach/water solution, alcohol, or commercial products such as Lysol®.
7. Spray or soak all trash, including plastic bags and gloves, with disinfectant, then double bag trash for disposal as solid waste.
8. Workers who become ill or who develop a febrile or respiratory illness within 45 days of the last potential exposure should immediately seek medical attention and inform the attending physician of the potential occupational risk of hantavirus infection. The physician should contact local health authorities promptly if hantavirus-associated illness is suspected. A blood sample should be obtained and forwarded through the state health department to the Centers for Disease Control for hantavirus antibody testing.

EQUIPMENT/MATERIALS

For Small Mammal Trapping

- Sherman live traps (or equivalent).
- Museum special snap traps (or equivalent).

- Tomahawk live traps (or equivalent).
- Drift fences (e.g., metal or plastic sheeting).
- Pitfall traps (e.g., metal cones, metal or plastic buckets).
- Rifle or pistol (e.g., 177-caliber pellet gun or .22-caliber rifle).
- Shotgun (e.g., 12-gauge shotgun).
- Bait balls (peanut butter, rolled oats, and sunflower seeds and/or corn meal).
- Brightly colored wire flags or wooden stakes (1 x 2 x 24 inches or 1 x 2 x 36 inches).
- Clipboard and data sheets.
- Small mammal identification book.
- Keys to identification, sex, and age.
- Copy of applicable trapping and salvage permits and scientific collection permits.
- Research site map with grid overlay.
- Pesola scales:
  - 0 to 10 g for shrews.
  - 100 g for most rodents.
  - 300 g for Sigmodon, large Microtus, rats (i.e., Neotoma, Rattus).
  - 1.5 to 2.5 kg for ground squirrels, tree squirrels, and rabbits.
- Weighing bag or Ziploc® bags.
- Extra 4 x 4-inch waxed paper squares.
- Markers (i.e., dissecting scissors for pelage clipping, paint, fingernail polish) or PIT tags.
- Appropriate safety equipment (Tyvek® suits and respirators) as required by the health and safety plan.

The following equipment is optional:

- Polyester fiberfill (or similar nonabsorbent material) - during cold or inclement weather.
- Flashlights/headlamps.

<u>For Small Mammal Necropsy</u>

- Protective clothing (i.e., laboratory coat, impermeable gloves, and appropriate respiratory protection).
- Tape measure or caliper and accurate scale (e.g., Pesola scale).
- Camera with flash attachment (if indoors) and film.
- Containers for specimens.

- Decontamination supplies.
- Paper towels.
- Scalpel with replacement blades.
- Straight blade scissors.
- Straight pins.
- Insulated cooler containing ice for preservation of specimens.
- Field notebook.

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FIELD QUALITY CONTROL SAMPLES

INTRODUCTION

This section describes the preparation and frequency of analysis of field quality control blanks, replicates, and interlaboratory splits for water and solids sampling.

PROCEDURES REFERENCED

- FMG 6.4 - Groundwater.
- FMG 6.10 - Sample Handling and Shipping.

PROCEDURAL GUIDELINES

Not all of the field quality control samples may be required for a given project. The specific field quality control samples will be specified in the project work plan, field sampling plan (FSP), or quality assurance project plan (QAPP).

As part of the QA/QC program, all field quality control samples will be sent blind to the laboratories. To accomplish this, the samples will be sent in the same form as regular samples, including all containers, sample numbers, and analytes. The sample ID for field quality control samples should allow data management and data validation staff to identify them as such. Under no circumstances should the laboratory be allowed to use reference materials, rinsate blanks, or trip blanks for matrix spike and matrix spike duplicate analysis. The laboratory should be instructed to contact the project QA/QC coordinator when a laboratory quality control sample is not specified on the sample analysis request form for a sample digestion group so that one can be assigned.

All field quality control samples will be packaged and shipped with other samples in accordance with procedures outlined in FMG 6.10 - Sample Handling and Shipping. Sample custody will be maintained in accordance with procedures outlined in FMG 6.10 - Sample Handling and Shipping.

Field quality control samples will be prepared at least once per sampling event, and certain types will be prepared more often at predetermined frequencies. If the number of samples taken does not equal an integer multiple of the intervals specified in the project work plan, field sampling plan (FSP), or quality assurance project plan (QAPP), the number of field quality control samples is specified by the next higher multiple. For example, if a frequency of 1 quality control sample per 20 is indicated and 28 samples are collected, 2 quality control samples will be prepared.

WATER SAMPLING

Table 6.9-1 lists the quality control sample types and suggested frequencies for surface water and groundwater sampling programs. Because groundwater quality control sampling may require assessment of drill rig cross-contamination, additional blanks of the solids sampling type may be required. A detailed explanation of each quality control sample type with the required preparation follows.

TABLE 6.9-1

FIELD QUALITY CONTROL SAMPLE REQUIREMENTS FOR WATER SAMPLING

Quality Control Sample Name	*Abbreviation*	*Preparation*		*Frequency*[a]
		Location	*Method*	
Bottle blank	BB	Field	Unopened bottle	1 per sample episode, 1 per bottle lot, 1 per bottle type
Travel blank	TTB	Laboratory	Deionized water and preserved, if necessary	1 per sample episode, 1 per preservative
Trip blank	TB	Laboratory	Deionized water and preserved	1 pair per cooler or VOA samples
Equipment rinsate (unfiltered)	ER-U	Sampling site	Deionized water collected after pouring through and over decontaminated equipment	1 per 20 samples, 1 per preservative
Equipment rinsate (filtered)	ER-F	Sampling site	Deionized water from collection container, filtered and preserved	1 per 20 samples, 1 per preservative
Replicate	DUP or TRIP	Sampling site	Natural sample	1 replicate per 20 samples
Laboratory split	LS	Sampling site	Natural sample	1 per 20 samples
Reference material	RM	Field laboratory (in large container), sample bottle filled at site	RM ampules for each analyte group	1 set per 50 samples, 1 per episode to alternate laboratory

[a] Frequencies provided here are general recommendations; specific frequencies should be provided in the project work plan, field sampling plan, or quality assurance project plan.

Bottle Blank

The bottle blank is an unopened sample bottle. One bottle blank per bottle lot is included in the sample chain for each sampling episode. If more than one type of bottle will be used in the sampling (e.g., poly or glass), then a bottle blank should be submitted for each type of bottle.

To prepare a bottle blank in the field, set aside one unopened sample bottle from each bottle lot sent from the analytical laboratory. If bottles are purchased directly from a supply house, all bottles should first be cleaned in accordance with FMG 6.10 - Sample Handling and Shipping. Label the bottle as "Bottle Blank" on the sample label, and send the bottle to the laboratory with the field samples in accordance with FMG 6.10 - Sample Handling and Shipping.

Travel Blank

The travel blank is a sample bottle prepared in the laboratory containing deionized water and preservative. This blank is carried to each sample site with the other filled sample bottles. One travel blank is sent to the laboratory. The travel blank is prepared at the laboratory by filling a sample bottle with deionized water and adding appropriate preservative (i.e., for metals samples use a 10 percent nitric acid solution to bring sample pH to 2 or less). In the field, label the bottle as "Travel Blank" on the sample label, place the travel blank sample in a cooler or other sample-receiving container for transport to each sample site during a sampling episode, and send the travel blank to the laboratory in accordance with FMG 6.10 - Sample Handling and Shipping.

Trip Blank

Trip blanks will be used to help identify cross-contamination in the shipment of water samples for analyzing volatile organic compounds (VOCs) only. Trip blanks will be prepared in the laboratory by pouring deionized water into two 40 mL VOC vials and tightly closing the lids. Each vial will be inverted and tapped lightly to ensure no air bubbles exist.

The blanks will be transported unopened to and from the field in the cooler with the VOC samples. One trip blank pair will be sent with each cooler of samples for analyzing VOCs. The exception is high-flow tributary sampling, which requires that the trip blank be prepared after the samples have been brought in from the field.

Equipment Rinsate Blank

Equipment rinsate blanks will be used to help identify possible contamination from the sampling environment or from improperly decontaminated sampling equipment. Equipment rinsate blanks will be prepared by processing a representative amount of laboratory deionized water through the decontaminated sample collection equipment, then transferring the water to the appropriate sample containers and adding any necessary preservatives. Equipment rinsate blanks will be prepared for all inorganic, organic, and conventional analytes at least once per sampling event.

The actual number of equipment rinsate blanks prepared during an event will be determined on a case-by-case basis by the project QA/QC coordinator.

Low-Flow Tributary Sampling

Because the sampling container for low-flow sampling is a laboratory-cleaned, amber glass jug, the only piece of equipment that is likely to contribute to contamination is the Teflon®/ polyethylene sample intake. The intake will be thoroughly decontaminated using industrial detergent, methanol, and hexane. After the intake is air-dried, it will be screwed into a newly opened 2.5 L jug of deionized water (the deionized water containers supplied by the laboratory are identical to those used for sampling). The deionized water will be poured through the intake into the appropriate sample containers, which will be preserved as needed. Because the intake tube extends to the back of the jug, not all of the deionized water in the jug can be transferred to the sample containers. When water can no longer pour through the intake, the jug will be replaced with a full one; any remaining water in the old jug will be discarded. When preparation of the rinsate blank is completed, the intake will be removed from the jug and placed in a sealable bag or screwed onto a sampling jug and covered with a plastic bag.

High-Flow Tributary Sampling

Before high-flow tributary sampling begins, a test run on one of the ISCO automatic samplers that will double as an equipment rinsate blank will be performed. Preparation of the blank will consist of running deionized water through the ISCO sampler and into a set of sampling containers at predetermined intervals.

Groundwater Sampling

GM Remediation Team-preferred protocols for groundwater sampling are presented in FMG 6.4 - Groundwater.

Field Replicates

Field replicate (duplicate or triplicate) samples are co-located samples collected in an identical manner over a minimum period of time to provide a measure of the analytical (field and laboratory) variance, including variance resulting from sample heterogeneity. Field replicates will consist of two or three samples collected consecutively at the same location and placed in different bottles for separate analysis. The exception to this is high-flow tributary sampling, which requires the procedure given below. Each replicate will have a unique sample number to distinguish it from the others. The replicate samples will be sent to the laboratory and analyzed for identical chemical parameters but will not be distinguishable by the laboratory as being replicates. Field replicates will be collected at a minimum frequency of 1 per 20 samples or once per sampling event, whichever is more frequent.

High-Flow Tributary Sampling

Collection of field replicate samples for high-flow events will differ from the other elements because of the nature of the sample preparation, which requires the samples to be homogenized before replication. Replicates will always be made from the composited portion of the sample because the grab sample does not provide enough sample volume for all the parameters. For each analyte group, a composite sample will be prepared using the six flow-weighted aliquots in the same manner that a regular sample is prepared. To prepare the replicates, the container with the composited sample will be inverted three times for proper mixing (very lightly for organic compounds) and split evenly into two to three identical containers. This process will be repeated until sufficient volume is obtained.

1. At the appropriate frequency during sample collection, collect an adequate volume of sample at the sample site to accommodate duplicate samples. For example, if 40 mL water samples are taken and two sample bottles are required for analysis of all parameters, collect a total of at least six additional water samples (i.e., two 40 mL samples for each of the triplicate samples).
2. Label one bottle as a normal field sample and label the other bottles according to the numbering sequence described in the sample identification system in the SAP.
3. Send the bottles to the primary CLP laboratory with the field samples in accordance with FMG 6.10 - Sample Handling and Shipping.

Reference Material

Reference materials are materials of known composition that have been prepared by and obtained from EPA-approved sources and that have undergone multilaboratory analyses using a standard method. Reference material samples provide a measure of analytical performance and/or analytical method bias of the laboratory. Several reference materials may be required to cover all analytical parameters.

SOLIDS SAMPLING

Table 6.9-2 lists the quality control sample types and frequencies to be incorporated into a solids sampling program. A detailed explanation of each quality control sample type with the required preparation follows.

TABLE 6.9-2

FIELD QUALITY CONTROL SAMPLE REQUIREMENTS FOR SOLIDS SAMPLING

Quality Control Sample Name	*Abbreviation*	*Preparation*		*Frequency*
		Location	*Method*	
Bottle blank	BB	Field	Unopened bottle	1 per sample episode, 1 per bottle lot
Travel blank	TTB	Laboratory	Opened at sample site and closed	1 per sample episode
Trip blank	TB	Laboratory	Deionized water and preserved, if necessary	1 pair per cooler or VOA samples
Equipment rinsate blank	ER-5	Sample site	Deionized water collected after pouring through/over decontaminated equipment	1 per 20 samples
Field cross-contamination blank	CCB	Sample site	Filter wipe with decontaminated collection equipment	1 per 20 samples
Field external contamination blank	ECB	Sample site	Unused material used for CCB	1 per 20 samples
Replicate	DUP or TRIP	Sample site	Natural sample	1 replicate per 20 samples
Laboratory split	LS	Sample site	Natural sample	1 per 20 samples
Reference material	RM	Sample site	RM	1 set per 40 samples, 1 per episode to alternate laboratory

[a] Frequencies provided here are general recommendations; specific frequencies should be provided in the project work plan, field sampling plan, or quality assurance project plan.

Bottle Blanks

The bottle blank is an unopened sample bottle. One bottle blank per bottle lot is included in the sample chain for each sampling episode. Bottle blanks are prepared in the field by setting aside one unopened sample bottle from each bottle lot sent from the analytical laboratory. If bottles are purchased directly from a supply house, all bottles should first be cleaned in accordance with FMG 6.10 - Sample Handling and Shipping. Label the bottle "Bottle Blank" on the sample label, and send the bottle to the laboratory with field samples in accordance with FMG 6.10 - Sample Handling and Shipping.

Travel Blank

The travel blank is an unopened sample bottle carried to each sample site with the other filled sample bottles. The bottle is then opened at a single site for a short period to reflect the sampling time. The purpose of this blank is to evaluate possible contamination from sample bottle handling and transport and from airborne materials. The travel blank is prepared by labeling one bottle as "Travel Blank" on the sample label and placing the travel blank bottle in the sample receiving container for transport to each sample site during each sampling episode. At a single sample site, preferably the one with the highest potential for airborne contamination, open the bottle for a time equal to that required to fill a sample bottle with solids. Cap the bottle and place it in the sample-receiving container. Send the bottle to the laboratory with the field samples in accordance with FMG 6.10 - Sample Handling and Shipping.

Trip Blank

Trip blanks will be used to help identify cross-contamination in the shipment of water samples for analyzing volatile organic compounds (VOCs) only. Trip blanks will be prepared in the laboratory by pouring deionized water into two 40 mL VOC vials and tightly closing the lids. Each vial will be inverted and tapped lightly to ensure no air bubbles exist.

The blanks will be transported unopened to and from the field in the cooler with the VOC samples. One trip blank pair will be sent with each cooler of samples for analyzing VOCs. The exception is high-flow tributary sampling, which requires that the trip blank be prepared after the samples have been brought in from the field.

Equipment Rinsate Blank

Equipment rinsate blanks will be used to help identify possible contamination from the sampling environment or from improperly decontaminated sampling equipment. Equipment rinsate blanks will be prepared by processing a representative amount of laboratory deionized water through the decontaminated sample collection equipment, then transferring the water to the appropriate sample containers and adding any necessary preservatives. Equipment rinsate blanks will be prepared for all inorganic, organic, and conventional analytes at least once per sampling event. The actual number of equipment rinsate blanks prepared during an event will be determined on a case-by-case basis by the project QA/QC coordinator.

Field Cross-Contamination Blank

The field cross-contamination blank is a sample bottle prepared at the sample site that contains filter wipes of decontaminated field collection equipment. This blank will check the effectiveness of the decontamination procedures. At the appropriate frequency during sample collection, prepare a field cross-contamination blank at the sample site by vigorously rubbing the sample collection equipment with two clean filter blanks. Do not use Kimwipes® because they contain significant impurities. Place the filters in the sample bottle and label it as the "Cross-Contamination Blank" on the sample label. Send the bottle to the laboratory with the field samples in accordance with FMG 6.10 - Sample Handling and Shipping.

Field External Contamination Blank

The field external contamination blank is a sample bottle prepared at the sample site containing a single unused filter wipe used for the field cross-contamination blank. At the appropriate frequency during sample collection, prepare a field external contamination blank at the sample site by placing a clean, unused filter blank from the same lot used for the cross-contamination in a sample bottle. Label the bottle "External contamination Blank" on the sample label, note filter name and lot number in the field logbook, and send the bottle to the laboratory with the field samples in accordance with FMG 6.10 - Sample Handling and Shipping.

Replicates

A replicate (duplicate or triplicate) sample consists of two or three samples taken from the same location and time and placed in different sample bottles for separate analysis. Each replicate will be analyzed for all chemical parameters. The laboratory split sample bottles are also filled at this time (see below). At the appropriate frequency during sample collection, collect an adequate volume of sample at the sample site to accommodate the replicate and laboratory split samples per the appropriate SAP; process the samples per the SAP for each replicate; and send the bottles to the laboratory with the field samples in accordance with FMG 6.10 - Sample Handling and Shipping.

Laboratory Split

The laboratory split sample is sent to the referee laboratory. The sample is taken with the replicate sample. As with the replicates, the laboratory split will be analyzed for all chemical parameters. To prepare the laboratory split, follow sample bottle filling and processing instructions for replicates above, label the bottle "Laboratory Split" on the sample label, and send the bottle to the referee CLP laboratory in accordance with FMG 6.10 - Sample Handling and Shipping.

Reference Material

Reference materials are materials of known composition that have been prepared by and obtained from EPA-approved sources and that have undergone multilaboratory analyses using a standard method. Reference material samples provide a measure of analytical performance and/or analytical method bias of the laboratory. Several reference materials may be required to cover all analytical parameters.

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SAMPLE HANDLING AND SHIPPING

INTRODUCTION

Sample management is the continuous care given to each sample from the point of collection to receipt at the analytical laboratory. Good sample management ensures that samples are properly recorded, properly labeled, not lost, broken, or exposed to conditions which may affect the sample's integrity.

All sample submissions must be accompanied with a chain-of-custody (COC) document to record sample collection and submission.

The following sections provide the minimum standards for sample management.

PROCEDURAL GUIDELINES

<u>Field Handling</u>

Prior to entering the field area where sampling is to be conducted, especially at sites with defined exclusion zones, the sampler should ensure that all materials necessary to complete the sampling are on hand.

If samples must be maintained at a specified temperature after collection, proper coolers and ice/cool-packs must be brought out to the field. Consideration should be given to keeping reserve cooling media on hand if sampling events will be of long duration. Conversely, when sampling in extremely cold weather, proper protection of water samples, trip blanks, and field blanks must be considered.

Personnel performing groundwater sampling tasks must check the sample preparation and preservation requirements to ensure compliance with the Work Plan QAPP. Typical sample preparation may involve pH adjustment (i.e., preservation), sample filtration and preservation, or simply cooling to 4°C. Sample preparation requirements vary from site to site and vary depending upon the analytical method for which the samples will be analyzed.

The sampling personnel must also confirm before the sample event, the amount of bottle filling required for the respective sample containers. VOC samples must not have any headspace within the sample collection vial; whereas when collecting select analytes (i.e., metals) a headspace must be provided to allow addition of the required preservative.

Sample Labeling

Samples must be properly labeled as soon as practical after collection.

Note that the data shown on the sample label is the minimum data required. The sample label data requirements are listed below for clarity.

i) Project name.
ii) Sample number.
iii) Sampler's initials.
iv) Date of sample collection.
v) Time of sample collection.
vi) Analysis required.
vii) Preservatives.

The Work Plan Quality Assurance/Quality Control (QA/QC) specification should be reviewed to determine any additional requirements.

Quite often the analytical laboratory supplying the containers will provide blank sample labels. If these are adequate and convenient they can be used.

Under certain field conditions it is impractical to complete and attach sample labels to the container at the point of sample collection. However, to ensure that samples are not confused, a clear notation should be made on the container with a permanent marker indicating the last three digits of the sample number. If the containers are too soiled or small for marking, the container can be put into a zip-lock bag which can then be labeled.

No one sample number format is adequate for every type of sampling activity. Prior to the start of every project or sub-sampling event within the project, Project Managers and field personnel should devise a sample number format. Sample number formats should be as simple and short as possible. Simple number formats will reduce transcription errors by both Consultants and lab personnel. The sample number format should be comprehensive enough to allow for easy location of detailed sample data within the Site log books. Sample format must also be consistent with any future data management activities.

Unless otherwise instructed, labels should not contain specific names of the sample source (i.e., "Well No. 16"). Provision of such specific data on the label can produce biased lab results.

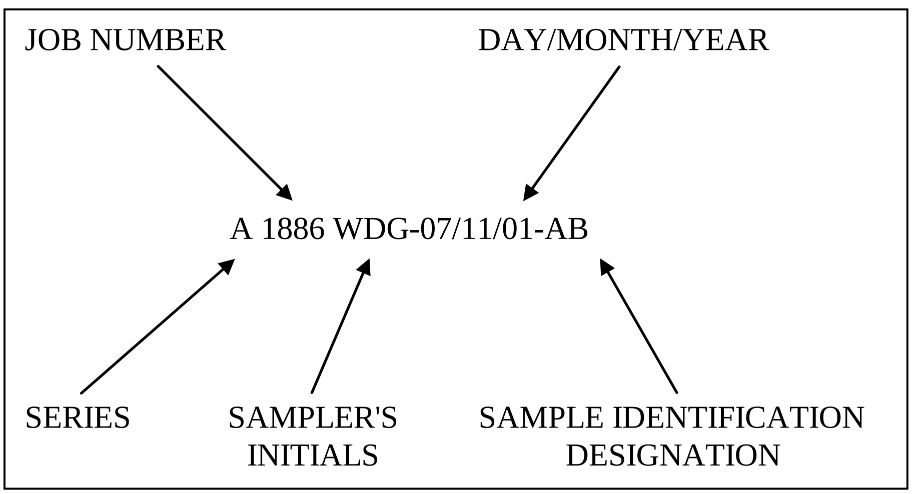
Sample Labels/Sample Identification

All samples must be labeled with:

- A unique sample number (never to be re-used, nor likely to be).
- Date and time.
- Parameters to be analyzed.
- Job number.
- Sampler's initials.

Labels should be secured to the bottle and should be written in indelible inks. It is also desirable to place wide clear tape over the label before packing in a cooler for label protection during transportation.

The unique sample identification number may follow the format recommended below, or a specific sample protocol for labeling may be specified in the project Work Plan.



This format has been selected to maximize the information content of the sample number. Minor modifications are certainly reasonable.

i) Series is a letter which designates a group of samples. This might include sample round, or might designate sample type (e.g., sediment, soil, volatile analysis, Round 2 Lower Aquifer wells), or sample source. For example, "A" might mean samples of influent to some treatment system, "B" might mean samples of effluent. Letters should be used, not numbers. Series is optional.

ii) Job number together with the series number, will allow easier tracking of samples.

iii) Sampler's initials will allow identification of the sampler, and so allow all project personnel to contact the correct person for information regarding that sample and its collection. The use of three initials is requested. Special arrangements will need to be made if two individuals have the same initials.

iv) Sample date will allow monitoring of actual holding time of samples and should ensure that all sample numbers are unique, even if sample location designation is used in a system, as opposed to assigned at random.

v) Sample identification designation will identify the sample, and can be any numerical or letter designation.

The decision of how to assign sample numbers should be made at the beginning of a job or phase, and should be consistent throughout the job.

Packaging

When possible, sample container preparation and packing for shipment should be completed in a well organized and clean area, free of any potential cross-contaminants.

Sample containers should be prepared for shipment as follows:

i) Containers should be wiped clean of all debris/water using paper towels (paper towels must be disposed of with other contaminated materials).

ii) Clear, wide packing tape should be placed over the sample label for protection.

While there is no one "best" way to pack samples for shipment, the following packing guidelines should be followed.

i) Plan time to pack your samples (and make delivery to shipper if applicable). Proper packing and manifesting takes time. A day's worth of sampling can be easily wasted due to a few minutes of neglect when packing the samples.

ii) Always opt for more coolers and more padding rather than crowd samples. The cost associated with the packing and shipment of additional coolers is usually always small in comparison with the cost of having to re-sample due to breakage during shipment.

iii) Do not bulk pack. Each sample must be individually padded.

iv) Large glass containers (1 L and up) require much more space between containers.

v) Ice is not a packing material due to the reduction in volume when it melts.

The following is a list of standard guidelines which must be followed when packing samples for shipment.

i) When using ice for a cooling media, always double bag the ice in zip-lock bags.

ii) Double-check to ensure trip and temperature blanks have been included for all shipments containing VOCs, or where otherwise specified in the QA/QC plan.

iii) Enclose the COC form in a zip-lock bag.

iv) Ensure custody seals (two, minimum) are placed on each cooler. Coolers with hinged lids should have both seals placed on the opening edge of the lid. Coolers with "free" lids should have seals placed on opposite diagonal corners of the lid. Place clear tape over custody seals.

v) Ensure that all "Hazardous Material" stickers/markings have been removed from coolers being used which previously contained such materials.

Note: Never store sterile sample containers in enclosures containing equipment which use any form of fuel or volatile petroleum based product. An alternate means of secure storage must be planned for.

When conducting sampling in freezing conditions at sites without a heated storage area (free of potential cross contaminants), trip blanks and temperature blanks not being used in a QA/QC role should be isolated from coolers immediately after receipt. Trip and temperature blanks should be double-bagged and kept from freezing.

<u>Chain-of-Custody</u>

COC forms will be completed for all samples collected. The form documents the transfer of sample containers.

The COC record, completed at the time of sampling, will contain, but not be limited to, the sample number, date and time of sampling, and the name of the sampler. The COC document will be signed and dated by the sampler when transferring the samples.

Each sample cooler being shipped to the laboratory will contain a COC form. The COC form will consist of four copies which will be distributed as follows: The shipper will maintain a copy while the other three copies will be enclosed in a waterproof envelop within the cooler with the samples. The cooler will then be sealed properly for shipment. The laboratory, upon receiving the samples, will complete the three remaining copies. The laboratory will maintain one copy for their records. One copy will be returned to the Field QA/QC Officer upon receipt of the samples by the laboratory. One copy will be returned with the data deliverables package.

COC records are legal documents. They must be completed and handled accordingly.

The following list provides guidance for the completion and handling of all COCs.

i) COCs used should be Consultant standard forms or those supplied by the analytical laboratory. Do not use any COC forms from other labs, even if the heading is blocked out.

ii) COCs must be completed in black ball-point ink only.

iii) COCs must be completed neatly using printed text.

iv) If a simple mistake is made, line out the error with a single line and initial and date next to it.

v) Each separate sample entry must be sequentially numbered.

vi) The use of "Ditto" or quotation marks to indicate repetitive information in columnar entries should be avoided. If numerous repetitive entries must be made in the same column, place a continuous vertical arrow between the first entry and the next different entry.

vii) When more than one COC form is used for a single shipment, each form must be consecutively numbered using the "Page ___ of ___" format.

viii) If necessary, place additional instructions directly onto the COC. Do not enclose separate loose instructions.

ix) Include a contact name and phone number on the COC in case there is a problem with the shipment.

x) Do not indicate the source of the sample as this may produce a biased lab result.

xi) Before using an acronym on a COC, define clearly the full interpretation of your designation [i.e., Polychlorinated Biphenyls - (PCBs)].

<u>Shipment</u>

In all but a few cases the QA/QC plan for the field work will require shipment of samples by overnight carrier. A great many problems can be avoided by proper advance planning.

Prior to the start of the field sampling, the carrier should be contacted to determine if pickup can be made at the field site location. If pickup at the field site can be made, the "no-later-than" time for having the shipment ready must be determined.

If no pickup is available at the site, the nearest pickup or drop-off location should be determined. Again, the "no-later-than" time for each location should be determined.

Sufficient time must be allowed not only for packaging but also for delivery of samples if this becomes necessary. Driving at high rates of speed in order to make the drop time is unacceptable.

Sample shipments must not be left at unsecured or questionable drop locations (i.e., if the cooler will not fit in a remote drop box do not leave the cooler unattended next to the drop box).

Some overnight carriers do not in fact provide "overnight" shipment to/from some locations. Do not assume; call the carrier in advance before the start of the field work.

Copies of all shipment manifests must be maintained in the field file.

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INCREMENTAL SOIL SAMPLING

INTRODUCTION

The following procedure describes typical soil sample collection methods for submission of samples to a laboratory for chemical analysis via Incremental Sampling Methodology (ISM). Four sample situations are presented: soil sampling from surficial soil, soil sampling from subsurface samplers such as a split-spoon sampler or a direct push sampler, soil sampling from a stockpile, and confirmation sampling.

Soil sampling procedures may vary from project to project due to different parameters of concern, different guidance provided by the state/province where the site is located, or the specific objectives for the project. Therefore, it is essential that the sampling team members carefully review the Work Plan requirements and the rationale behind the program. The primary goal of Incremental Soil Sampling is to collect representative samples for examination and chemical analysis (if required) within previously established Decision Units (DU). The size and locations of DUs, as well as the number and method of determining locations of individual increments will be pre-described in the site-specific Work Plan.

It is also essential to have all project stakeholders (e.g., client, regulatory agencies, outside parties, etc.) in agreement with the project scope of work, establishment of DUs, statistical analyses, and project goals prior to field implementation.

Grab Versus Composite Versus Incremental Samples

A grab sample is collected to identify and quantify compounds at a specific location or interval. The sample shall be comprised of no more than the minimum amount of soil necessary to make up the volume of sample dictated by the required sample analyses. Composite samples are a mixture of a given number of subsamples and are collected to characterize the average chemical composition in a given surface area or vertical horizon. ISM is a specialized type of composite sampling with specific structure and requirements that stand apart from common compositing practices. ISM is designed to provide more precise and less biased estimates of the mean concentration in soil by addressing specific sampling errors. Consequently, ISM can result in better performance in terms of decision error reduction than other sampling methodologies.

PROCEDURES REFERENCED

- FMG 2.2 - Drilling Techniques
- FMG 2.3 - Soil Borings
- FMG 2.6 - Soil Classification
- FMG 6.1 – Soil Sampling
- FMG 6.10 - Sample Handling and Shipping
- FMG 9.0 - Equipment Decontamination

PROCEDURAL GUIDELINES

1. SURFICIAL ISM SAMPLE COLLECTION

1.1 Surficial ISM Sample Strategy

A defined DU is first subdivided or gridded-off into uniform cells or subareas based on the desired number of increments to be obtained. That is, the number of cells is equivalent to the number of increments (usually 30-50). Note that regulatory agencies may sometimes request up to 100 increments. The actual number of increments should be developed based on expected variability of the chemical of concern and media.

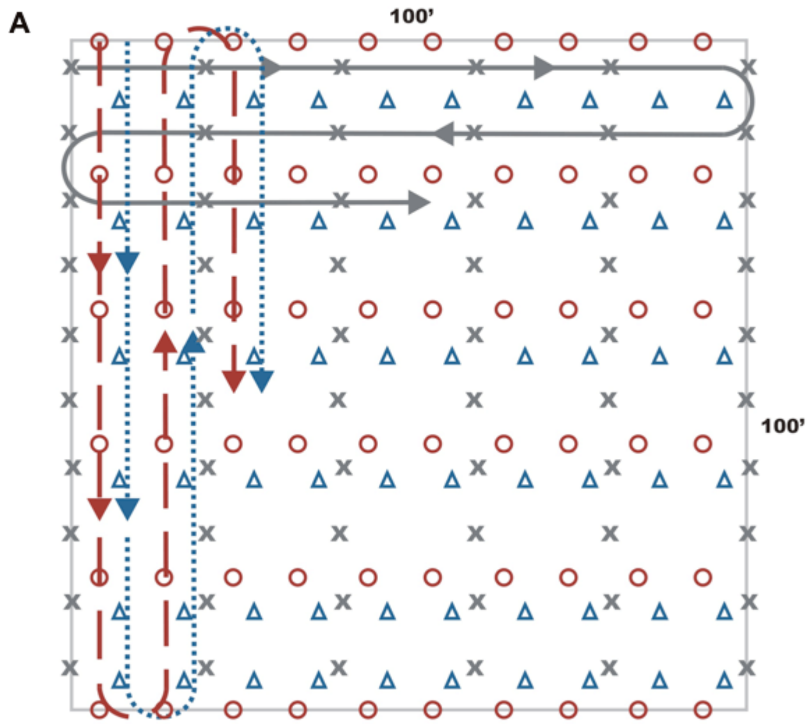
- Using the systematic random design, a random position is established for a given cell, and then the same position is repeated in all of the remaining cells in the DU.
- For the random sampling within grids design, a random position is designated and sampled in each cell. A random starting point or random position for each cell can be obtained with dice or a random number generator. The process is repeated for replicate samples: i.e., a new random position is established for the single collection point to be repeated in all of the cells, or for each cell, depending on the sampling design.

A DU may be pre-surveyed, or a Global Positioning System (GPS) device should be used to delineate the DU. It may or may not be necessary to determine the exact location of each increment depending upon the Work Plan requirements.

Depending on the size of the DU and terrain features, placement of markers (e.g., pin flags and posts) at the corners and or edges can assist with a visual delineation of the cells or subareas where increments are to be collected. That is, the markers can define lanes, grids, or collection points. When DUs are square or rectangular, the conversions for the spacing (steps) between increment collection points (cells) are fairly straightforward to calculate. For example, a square-shaped DU could be divided into five rows, with six increments collected from each row in a systematic random fashion, with an initial random starting point. For more rectangular-shaped DUs, fewer rows might be used with more increments per row collected. Row lengths and increments per row may be modified as needed for odd-shaped DUs. However, with other shapes, it is recommended that the perimeter be marked and flags be prepositioned across the DU in one or more perpendicular lines. Then a trial run with no sample collection is performed to quickly establish the distance between increment collection points to achieve the desired number of increments, while using the flags as guides that were positioned within or around the DU. This will be described in the project-specific Work Plan, however, field modifications may be required depending upon a number of factors (e.g., safety, heterogeneity, etc.).

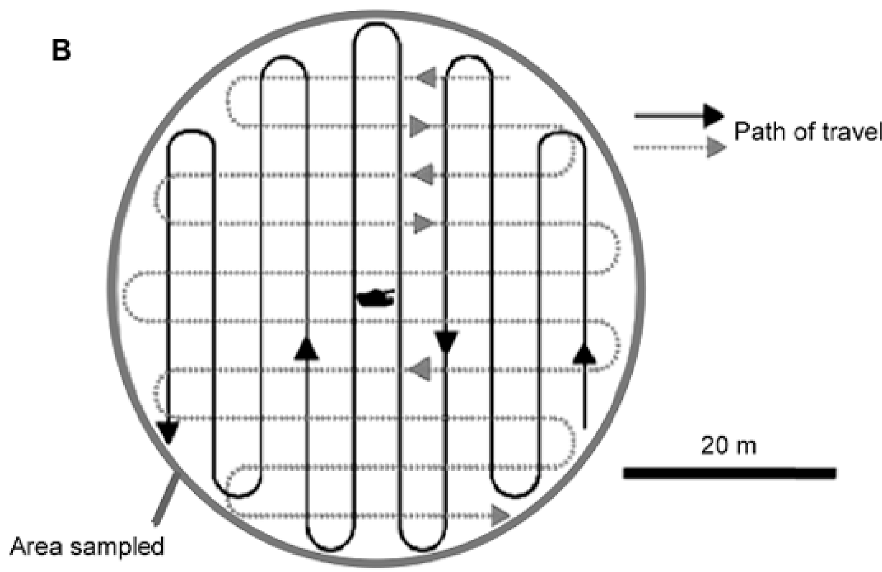
1.2 Surface ISM Sampling Procedure

Although ISM sample collection may be performed by a single individual, a two-person team is often the most efficient method: ideally one person collects the increments and the other holds the sample container (e.g., clean polyethylene bag) and keeps track of the number of increments. Flags may be used to mark DU boundaries and to aid in visualizing the travel paths and/or to mark the actual increment locations. The ISM sampler starts in one corner or end of the DU and collects an increment at the predetermined positions. For the systematic random sampling design, the location of the first increment is determined randomly, and subsequent increments are collected in the same relative location within each grid, resulting in a serpentine collection pattern ending at the opposite corner or end of the DU from where sampling was started (see examples below). Refer to FMG 6.1: SOIL.



Systematic-random incremental methodology sampling (ISM) pattern used for collecting ISM samples

1st path of travel (Original)
2nd path of travel (Duplicate)
3rd path of travel (Triplicate)
Sample collection points (60 per path of travel)



2. SUBSURFACE ISM SAMPLE COLLECTION

2.1 Subsurface ISM Sample Strategy

Decision Units are three-dimensional and are intended to focus the investigation on a specified volume or mass of soil. Obtaining good spatial coverage and data quality for subsurface soil is more challenging but is still necessary. The objectives for surface vs. subsurface ISM investigations may be similar in nature, for example, to estimate the representative concentration of targeted contaminants for targeted depth intervals (e.g., within the defined vertical limits) or to determine or confirm the lateral boundaries of the source area. For remedial purposes, the estimation of contaminant mass within the DU is also sometimes critical. The practical application of subsurface ISM sampling must be considered during project planning, especially when considering implementing it for nature and extent investigations of subsurface contamination. Often, alternative sampling techniques (e.g., discrete sampling, field screening, or field analytical methods) may be more applicable and/or cost-efficient.

Soil samples collected as part of a subsurface investigation are intended to be representative of a specific depth interval. Discrete soil samples from borings or excavations have traditionally been used to characterize subsurface soil. In most cases, however, discrete samples may provide less spatial coverage of the targeted depth intervals and also increase laboratory analytical costs. As discussed below, alternative sample collection approaches to improve sample data quality and reduce laboratory costs include options for ISM core sampling across targeted depth intervals.

As with surface ISM samples, it is recommended that a minimum of 30 increments be collected for each DU. In some cases, collecting the recommended minimum of 30 soil increments per subsurface DU may not be feasible or practical. Reducing the number of increments collected per sample may be the only viable option. In this situation, it is important to recognize that collection of a reduced number of sample increments generally increases the gross sampling error and results in a less precise and more biased estimate of the mean contaminant concentration. Depending on the degree of data variability that can be tolerated within the project-specific data quality objectives (DQOs), a significant reduction in the number of increments may result in a decision error. A sample containing fewer increments than required to estimate the DU mean concentration within the project-specific uncertainty level may not be considered a defensible ISM sample. Consequently, in these circumstances careful review of DQOs as well as any other sampling options that may be available is warranted.

2.2 Subsurface ISM Sampling Procedure

Ideally, to be representative, the entire core depth interval should be considered as an increment, collected, combined with additional increments for an ISM sample and submitted to the laboratory. Collection of the complete core interval as an increment is the recommended subsurface ISM procedure. This method can result in large ISM samples, making logistics, such as field storage and shipping, problematic. Additionally, the selected laboratory must have facilities available to store, dry (if required), and process these large amounts of soil mass. Consequently, depending on the core diameter and interval depth, inclusion of the entire core increment across a targeted depth interval in an ISM sample may be impractical. In such cases, individual cores may be subsampled to reduce the final mass of the ISM sample. Two options are described below.

The preferred option for collecting a representative subsample from a subsurface core increment for nonvolatile contaminants is to collect a "core wedge" sample. The simplest approach is to split the core in half vertically along the axis, reducing the increment mass by half. Alternatively, a single wedge of soil is taken from the entire length of the targeted depth interval. Removing a wedge of soil across the length of a larger core to encompass the entire depth interval rather than collecting the entire core depth interval as a whole, constitutes the mass of an individual increment of an ISM sample. Individual wedges from 30 or more separate increment cores are then combined to form the complete subsurface ISM sample. This option results in a more biased and less precise estimate of the DU mean as compared with collecting the entire core. However, since the mass of each increment (and thus the ISM sample mass) is reduced, some of the practical constraints associated with handling full core increments are addressed.

Replicate samples can be collected from the same core, combined with other wedge increments, and submitted as separate ISM sample(s) to assess the precision of this subsampling strategy. However, core wedge replicates are not the same as ISM field replicates because ISM field replicates require completely separate incremental locations. Thus, core wedges should not be used as a measure of DU or overall sampling and analysis variability. Core wedge replicates evaluate only the variability in the subsampling process as opposed to collecting the entire core interval as the increment. The variability of wedge subsamples from alternative areas of the core is evaluated, e.g., replicate wedge collected 180° opposite the initial wedge subsample. ISM field replicates provide information on spatial variability and the variance in the estimate of the mean without specifically separating out the contribution of field and/or laboratory sample processing/subsampling from other sources of variance. ISM field replicates are discussed in Section 5.3.5. Core wedge replicates may also be collected when COPCs require separate laboratory processing procedures.

This approach is not appropriate when VOCs are of concern since they can be quickly lost from an exposed surface. For VOCs, multiple “plugs” representative of the desired core depth are collected and immediately preserved in methanol, or alternatively, individual increments could be collected in separate sampling devices that have vapor-tight seals and are designed for zero headspace (e.g., Core N’ One™, EnCore, or equivalent type sampler), and submitted to the laboratory at the appropriate temperature and within appropriate time frames (see Section 6.2).

The least preferred option for subsampling individual subsurface cores for nonvolatile contaminants is to collect a "core slice" from the targeted DU layer. In this approach, a randomly selected perpendicular "slice" from within the larger targeted depth interval is collected as the ISM increment. For example, if the targeted depth interval was 2 feet in length (e.g., 8–10 feet bgs), a 4-inch perpendicular slice is randomly selected from within the targeted depth interval of each individual core and collected as the ISM increment. Individual, randomly selected core slices from 30 or more separate DU cores are then combined to form the complete subsurface ISM sample. This option introduces more bias than whole-core increment or core-wedge approaches. However, by reducing the increment mass, some of the logistical issues associated with handling the full core or the wedge increments are addressed. This is the least recommended approach for subsurface ISM core sampling since it is least likely to accurately represent the complete vertical length of the targeted DU layer.

3. STOCKPILE ISM SAMPLING

Special considerations for selecting DUs during the systematic planning process for sampling soil stockpiles include the following:

- The source of the soil in the stockpile
- How the stockpile was created (over time, if applicable)
- How best to access the pile for sampling, (e.g., large or unstable)
- Contaminants targeted for lab analyses

One of the best options is to coordinate sampling with the formation of any stockpiles on the site. When the stockpile is being formed, there is generally good access to sampling each portion of the pile over time, and ensuring access to the entire stockpile DU is provided for good sample representativeness. If an existing stockpile is relatively small, good options may include moving the pile and collecting the increments while it is being moved (e.g., from the front-end loader buckets, at appropriate intervals), or flattening or spreading out the stockpile sufficiently so that it is safely accessible to sample with a hand coring or other device, as discussed above. If the stockpile is very large or unstable, all available sampling tools or methods that safely provide access should be considered, with the goal of coming as close as possible to collecting a minimum of 30 systematic random or random within grids increments throughout the stockpile (both vertical and horizontal locations). Replicates are important to evaluate the precision of stockpile sampling and should be collected similarly to the original sample except in separate random locations. Large stockpiles could be divided or segregated into separate DUs, especially a specific portion or volume of the stockpile will be used in a manner that will become the primary exposure unit of concern in the future (e.g., certain portions or volumes of the stockpile will be hauled to residential lots as surface fill for backyards).

4. ISM CONFIRMATION SAMPLING

Confirmation sampling may be performed during post-removal activities to verify that residual concentrations of target analytes are below the predetermined cleanup goals for the site. Confirmation sampling is often a requirement to achieve final clean closure certification. Confirmation samples are typically collected from the side walls and floors of an excavation to confirm that concentrations remaining after excavation are below specified concentration limits. Results from individual grab samples, an average or a 95% UCL from discrete samples, are often compared with the cleanup criteria for the site for this purpose.

An incremental sample result is specifically designed to estimate the mean concentration in a volume of soil designated as a DU. If excavation is performed for a site based on results from ISM sampling, it is usually because one or more DUs "failed" (i.e., had concentrations above the specified cleanup goals). Once the soil in a failed DU has been removed, the motivation for sampling the sidewalls and floor of the excavated DU is presumably to determine whether surrounding potential DUs also require remediation. If adjacent areas have already been designated as DUs, evaluated, and found to have soil concentrations within acceptable limits, confirmatory sampling in the conventional sense may not be necessary. If adjacent areas have not been adequately characterized, collecting ISM samples around the excavation can inform the need for or against further removal. In this situation, the expanded investigation requires new planning, including the designation of additional DUs and the determination of appropriate cleanup goals. One approach is to designate a volume of soil surrounding the excavated area as a new DU and sample from the walls and floor accordingly. This process is somewhat analogous to conventional confirmatory sampling. However, it is important to consider how the areas of the walls and floor relate to the volume of soil in the new DU and take increments in a manner that ensures a sample is representative of the DU. It is also important to recognize that the cleanup goal for a DU consisting of soil immediately surrounding an excavated area might be different from the original cleanup goals used for site evaluation because the objectives (e.g., addressing concern for potential for direct contact, leaching to groundwater, etc.) may be different, given the size and location of the new DU. As always, clear articulation of objectives and proper planning are essential.

In summary, the use of ISM samples to confirm excavation of a source area DU can be highly advantageous over a traditional, small number of discrete samples. The excavation floor and sidewalls should be treated as individual DUs, with the investigation objective of determining whether the estimated mean concentration of COPCs for these areas exceeds targeted screening levels. Again, these issues should be evaluated and determined as part of the planning and DQO process. Collecting ISM samples within these areas rather than single discrete samples ensures good DU spatial coverage and a more representative estimate of mean analyte concentrations. There may be regulatory limitations to this approach, however. For example, if regulations require cleanup of releases to a not-to-exceed regulatory level (e.g., the maximum concentration determined by discrete samples), then an ISM mean concentration may not be applicable and/or accepted by the regulating authority.

5. FIELD REPLICATE ISM SAMPLING

In the field, replicate incremental samples should be taken to ensure reliable estimates of the mean concentration within the DU. The number of replicates and frequency of taking replicate incremental samples should be specified in the site-specific Work Plan and comply with project DQOs.

To statistically evaluate sampling precision for each DU, additional completely separate replicate ISM samples are collected. The increments are collected in simple random, systematic random, or random within grid locations within the DU that are different from those used for the initial ISM sample. ISM field replicates are made of the same number of increments collected in the initial ISM sample and collected using the same sampling pattern from within the same DU. The replicate samples are prepared and analyzed in the same manner as the initial sample. Three replicate samples (i.e., the initial ISM sample plus two additional samples) should be considered the minimum. In some cases, more replicates may be necessary to reduce data variability and/or to calculate a 95% UCL of the mean that is closer to the actual mean of the DU. When sampling in a systematic random sampling pattern, the increments for an ISM replicate sample are generally collected along the same approximate directional lines established through the DU for the initial ISM sample. Increment locations for ISM replicate samples differ from each other by the selection of different random starting locations on the first line/row of the DU and continuing to sample at this different random interval throughout the DU for each replicate (refer to Section 1.2). Thus, the increments for ISM replicates should not be collected from the same locations or collocated with those used for the initial ISM sample. When using the random sampling within grid pattern, replicates are constructed from increments taken from different, randomly selected locations within each gridded area. With simple random sampling, three sets of random locations across the DU are selected and increments collected for each set are used to create the replicates. Replicate ISM samples should be submitted to the laboratory as "blind" samples, meaning the laboratory does not know they are replicate samples of the initial ISM samples.

If only one DU is being investigated, a minimum of three replicate samples should be collected to provide a measure of variability. For sites with multiple similar DUs, "batch" type replicates may be a consideration; for example, three replicates in one DU could be used to provide an estimate of variability that is extrapolated to a number of similar DUs (similar to how labs use batch replicates for determining lab analysis precision). Each site and/or project is unique in terms of numbers of DUs and how similar these DUs are, so decisions on numbers of replicates are unique to each site and should be addressed clearly in the site-specific Work Plan.

6. ISM SAMPLING HANDLING

6.1 Non-VOC ISM Samples

ISM sample processing techniques, such as milling and representative subsampling, are designed to ensure that the (typically small) mass of sample analyzed by the laboratory is representative of the DU from which it was collected. These techniques reduce data variability as compared with conventional sample handling and processing approaches. However, these techniques introduce some amount of sampling error. It is recommended that all ISM sample processing be performed in a controlled laboratory setting to minimize these sampling errors.

6.2 VOC ISM Samples

For exposed soil, such as surface soil or exposed excavation sidewalls/bottom soil, the entire mass of soil collected at a single point represents an increment. These increments are collected using VOC sampling devices that have vapor-tight seals and are designed for zero headspace (e.g., Core N' One™, EnCore, or equivalent type sampler), and submitted to the laboratory at the appropriate temperature and within appropriate time frames.) Thus, VOC ISM samples of exposed soil are collected and combined in similar fashion as non-VOC ISM samples with the exception that they are collected directly into the sampling devices.

ISM sampling may also be used for VOCs in the subsurface. The collected core may be subsampled by collecting numerous, small (e.g., 5 g) "plugs" at regularly spaced intervals along the targeted DU depth interval of the subsurface core. As with ISM VOC sampling of exposed soil, the plugs are collected in the zero headspace sampling devices. The spacing interval of the VOC plugs along the core interval should be determined during the systematic planning process. It is possible to determine the optimal spacing on a site-specific basis, through the collection and analysis of differently spaced plugs along the core interval. However, plugs should be located no more than two inches apart as a starting point. It may be necessary to decrease the spacing depending on the site-specific distribution of contaminant concentrations and DQOs. The coring device used to collect the increments should be filled completely so that each increment has the same volume of soil.

Individual increments that are collected in the zero headspace samplers would be submitted to the laboratory at the appropriate temperature and within appropriate time frames (typically 24–48 hours) for combined placement in methanol before analysis of a single ISM VOC sample. Careful consideration should be given to the handling and shipping of increments so that it is clear at the laboratory as to which increments should be combined to comprise the single ISM sample.

Decontamination

Sampling devices can be used within a DU without decontamination but should be decontaminated or disposed of between DUs. If sampling tools will be used for two or more DUs, they should be cleaned of soil particles, decontaminated with the appropriate solutions or solvents, and dried between DUs. Typically, rinse (decontamination) blanks can be used to evaluate the potential effects of cross contamination, if needed.

In all sampling scenarios measures to prevent cross-contamination must be employed. The sampling device selected must be constructed of an inert material with smooth surfaces that can be readily cleaned (see FMG 9.0 - Equipment Decontamination).

EQUIPMENT/MATERIALS

The sampling tools required to collect core-shaped soil increments of required length in the field are necessarily site specific. Alternate sampling tools that meet the basic ISM principles and project-specific objectives may be available currently or in the future. A variety of tools to address different soil types or site conditions should be taken into the field for any given project. Cylindrical increments of a controlled depth can be obtained from cohesive soil with a variety of commercially available manually- and machine-operated coring tools. For depths of 10 cm (3.9 inches) or less, individual increments often can be rapidly collected and dispensed into a sample container using hand-operated tools. For noncohesive soil and sediment, short- and long-nose scoops (trowels) can be used; however, care should be taken to obtain a "core-shaped" increment over the entire depth of interest. For depths greater than 10 cm, or for hardened and unconsolidated rocky geological materials, coring devices can be advanced with a hammer, slide bar, or some other means of mechanical assistance. Depending on site familiarity, one or several sampling tools should be readily accessible during all sampling activities.

- Drilling equipment and soil sampling tools.
- Decontamination fluids and rinse water.
- Subsurface boring log.
- Tape measure.
- Water level probe.

REFERENCES

ITRC (Interstate Technology & Regulatory Council). 2012. Incremental Sampling Methodology. ISM-1. Washington, D.C.: Interstate Technology & Regulatory Council, Incremental Sampling Methodology Team. www.itrcweb.org.

MULTI INCREMENT® sampling methology, EnviroStat, Inc., www.envirostat.org [i]

[i] *MULTI INCREMENT*® is a registered trademark of EnviroStat, Inc.

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LIST OF FORMS
(Following Text)

FMG 8.0-01 INSTRUMENT CALIBRATION RECORD

FIELD INSTRUMENTS – USE/CALIBRATION

INTRODUCTION

A significant number of field activities involve usage of electronic instruments to monitor for environmental screening and heath and safety purposes. It is imperative the instruments are used and maintained properly to optimize their performance and minimize the potential for inaccuracies in the data obtained, and to insure worker's health and safety is not compromised.

This FMG provides guidance on the usage, maintenance and calibration of electronic field equipment, whether for equipment owned by the Consultant or Contractor, or equipment obtained from a rental agency.

PROCEDURES REFERENCED

- FMG 1.4 - Data Recording – Field Books/Digital Recording.

PROCEDURAL GUIDELINES

- All monitoring equipment will be in proper working order, and operated for the purpose for which it was intended, in accordance manufacturer's recommendations.
- Field personnel will be responsible for insuring the equipment is maintained and calibrated in the field to extent practical, or returned for office or manufacturer maintenance or calibration if warranted. Calibration is discussed in greater detail below.
- A copy of the Operating Instructions, Maintenance and Service Manual for each instrument used on a project will be kept on site at all times.
- Instruments will be operated only by personnel trained in the proper usage and calibration. In the event certification of training is required, personnel will have documentation of such certification with them on site at all times.
- Personnel must be aware that certain instruments are rated for operation within a limited range of conditions such as temperature and humidity. Usage of such instruments in conditions outside these ranges will only proceed with proper approval by a project manager and/or health and safety supervisor as appropriate.

- Instruments that contain radioactive source material, such as x-ray fluorescence analyzers or moisture-density gauges require specific transportation, handling, and usage procedures that are generally associated with a license from the Nuclear Regulatory Commission (NRC) or an NRC-Agreement State. Under no circumstance will operation of such instruments be allowed on site unless by properly authorized and trained personnel, using the proper personal dosimetry badges or monitoring instruments.

Calibration

Calibration of an electronic instrument is critical to insure it is operating properly for its intended use. Such instruments are often sensitive to changes in temperature or humidity, or chemical vapors in the working atmosphere, and as a result their response and ability to monitor conditions and provide data can change significantly.

Calibration of instruments shall be performed in accordance with the manufacturer's recommendations. This includes the following parameters:

- Frequency.
- Use of proper calibration gases or chemical standards.
- Requirements for factory calibration.

Instrument calibration shall be performed in accordance with the following manufacturer recommendations or the suggested "minimum" calibration frequency:

Instrumentation Classification/Group		***Instrumentation***	***Representative Manufacturer Recommended Calibration Frequency***	***Minimum Recommended Calibration Frequency***
Health and Safety	Air Monitoring (Real-Time):	PID, FID, compound-specific or multi-gas meter (typ.), etc.	No Recommendation, Daily or As Needed	Daily
	Air Sampling (non-Real-Time):	Flow meter, personal air sampling device, etc.	Per Manufacturer's Recommendations	Per Manufacturer's Recommendations
Other Monitoring	Water Sampling:	pH, Cond., Temp., ORP, DO, etc.	Per Manufacturer's Recommendations	Daily, or As Needed
	Physical Parameters:	Velocity/flow meter, pressure transducer, water level meter, oil-water interface probe, etc.	Per Manufacturer's Recommendations	Per Manufacturer's Recommendations
	Other:	Miscellaneous (Troxler nuclear density, etc.)	Per Manufacturer's Recommendations	Per Manufacturer's Recommendations

Notes:

1. Some instrumentation requires factory calibration only.

2. If a significant change in conditions occurs, or in dangerous atmosphere conditions, more frequent calibration should be performed.

Calibration Gas Safety

Several instruments such as photoionization detectors (PIDs), flame ionization detectors (FIDs), oxygen meters, explosimeters, combustible gas indicators, and many others require use of calibration gasses contained in compressed gas cylinders. Many of these gases are combustible or explosive. Care shall be taken to minimize the potential for injury from the use of such compressed gases. Transport, handling, and storage of cylinders, where necessary, shall be performed in accordance with applicable DOT regulations and site requirements.

Calibration will only be performed in areas free of sources of spark, flame, or excessive heat. Smoking will not be allowed in the vicinity of calibration gas usage areas.

Documentation of Calibration

Instrument calibration activities will be documented. Form FMG 8.0-01 - Instrument Calibration Record shall be used to record applicable calibration and maintenance activities. In addition, protocol for documentation outlined in FMG 1.4 - Data Recording - Field Books/Digital Recording shall be followed.

Intrinsically Safe Requirements

Certain work locations may be such that dangerous, ignitable, or explosive conditions exist. In such cases, it may be necessary to utilize only equipment that is rated as "Intrinsically Safe". Intrinsically safe instrumentation is designed with limited electrical and thermal energy levels to eliminate the potential for ignition of hazardous mixtures.

For site work requiring operation of monitoring instruments in Class I, Division I locations [as defined by the National Fire Protection Agency (NFPA)] only instrumentation rated as Intrinsically Safe will be used. Such equipment (including all accessories and ancillary equipment) must be rated to conform to Underwriters Laboratories (UL) Standard 913, for use in a Class I, Division 1, Groups A, B, C, and D locations. It is also recommended the equipment conform with CSA Standard 22.2, No. 157-92.

Upon completion of the field activities, equipment shall be returned to the possession of the Consultant, Contractor, or Rental Agency accompanied by a written summary of any problems encountered with its use or calibration.

Equipment shall be properly prepared for shipping, including insuring that residual gases (if applicable) are removed from the instrument, and accompanying containers of compressed gases or fluids are properly labeled and sealed.

Equipment Decontamination

Equipment that comes in contact with Site media (water level meters, water quality meters) must be cleaned **before** removal from the site to ensure that chemicals are not transferred to other sites. It is the responsibility of the person who requisitioned the equipment to ensure appropriate cleaning before returning the equipment. Equipment decontamination procedures are typically site specific for unique site compounds.

EQUIPMENT/MATERIALS

- Monitoring equipment specific to work plan tasks.
- Manufacturer's instructions, operation and maintenance information.
- Associated calibration gases, aqueous standards, etc.
- Appropriate shipping containers to facilitate transport without damage to equipment.

REFERENCES

Underwriters Laboratories, Inc. (http://www.ul.com/hazloc/define.htm) Standard UL 913.

National Fire Protection Agency (http://www.nfpa.org/).

Canadian Standards Association (CSA) (http://www.csa.ca) Standard 22.2 No. 157.

Form FMG 8.0-01

INSTRUMENT CALIBRATION RECORD

PROJECT ______________________ PROJECT MANAGER ______________

LOCATION ______________________ FIELD REP. ______________

CLIENT ______________________ DATE ______________

Instrument	Date Calibrated	By	Standard Used	Decontamination, Maintenance, or Repair Performed	Remarks

Other Remarks: ____

FMG MODIFICATIONS MUST BE ACCOMPANIED BY A REVISION REQUEST FORM APPROVED BY THE PROJECT MANAGER

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EQUIPMENT DECONTAMINATION

INTRODUCTION

This procedure describes decontamination of field equipment potentially exposed to contaminants. Proper decontamination is required to reduce the risk of transfer of contaminants from areas of contamination to other areas and to minimize the potential for cross-contamination that would compromise sample quality. The degree of decontamination required will be dependent on the nature of the activity, equipment used, and on the amount of exposure to contaminants.

PROCEDURES REFERENCED

- FMG 2.0 - Subsurface Investigations.
- FMG 5.0 - Aquifer Characterization.
- FMG 6.0 - Sample Collection for Laboratory Analysis.
- FMG 8.0 - Field Instruments – Use/Calibration.
- FMG 10.0 - Waste Characterization.

PROCEDURAL GUIDELINES

Decontamination activities must be performed in a controlled area outside any exclusion zones established on the site. Care must be taken to minimize the potential for transfer of contaminated materials to the ground or onto other materials. Regardless of the size or nature of the equipment being decontaminated, the process will utilize a series of steps that involve removal of gross material (dirt, grease, oil, etc.), washing with a detergent, and multiple rinsing steps. In lieu of a series of washes and rinse steps, steam cleaning with low-volume, high-pressure equipment (i.e., steam cleaner) is acceptable.

Drill rigs, backhoes, and other exploration equipment must be decontaminated prior to initiating site activities, in between exploration locations to minimize cross-contamination potential, and prior to mobilizing off site after completion of site work. Heavy equipment is generally best deconned with a combination of steam-cleaning equipment and detergent scrubbing. Particular attention should be paid to parts in direct contact with contaminants, e.g., shovels, tires, augers, drilling decks, etc.

Control and containerization of all decontamination fluids is critical. A decontamination pad must be constructed that is appropriate for the size and type of equipment being decontaminated. At a minimum, the decontamination pad will have the following elements:

- An impermeable barrier capable of containing decontamination fluids.
- A low point where fluids will collect and can be pumped into appropriate containers.
- Durability to withstand equipment such as vehicle and foot traffic.
- Appropriate ancillary equipment such as racks to place decontaminated equipment to drain without further exposure to contaminated fluids.
- Labels to alert personnel as to the potential presence of contaminated materials.

Decontamination of Specific Sampling Equipment

The following specific decontamination procedure is recommended:

- Brush loose soil off of equipment.
- Wash equipment with laboratory grade detergent (i.e., Alconox or equivalent).
- Rinse with tap water (three rinses minimum).
- Rinse equipment with reagent grade methanol for VOC samples (this requirement may not be appropriate for sites where methanol is a contaminant of concern).
- Rinse equipment with nitric acid for metal samples (especially important for sites with potentially high metals concentrations.
- Rinse equipment with distilled water.
- Allow water to evaporate before reusing equipment

Decontamination of Monitoring Equipment

Because monitoring equipment is difficult to decontaminate, care should be exercised to *prevent* contamination. Sensitive monitoring instruments should be protected when they are at risk of exposure to contaminants. This may include enclosing them in plastic bags allowing an opening for the sample intake. Ventilation ports should not be covered.

If contamination does occur, decontamination of the equipment will be required; however, immersion in decontamination fluids is not possible. As such, care much be taken to wipe the instruments down with detergent-wetted wipes or sponges, and then with deionized water-wetted wipes or sponges.

Disposal of Wash Solutions and Contaminated Equipment

All contaminated wash water, rinsates, solids and materials used in the decontamination process that cannot be effectively decontaminated (such as polyethylene sheeting) will be containerized and disposed of in accordance with applicable regulations and GM requirements. All containers will be labeled with an indelible marker as to contents and date of placement in the container, and any appropriate stickers required (such as PCBs).

Sampling of containerized wastes will be performed immediately upon completion of the investigations to minimize storage time on site. Storage of decontamination wastes on site will not exceed 90 days under any circumstances.

EQUIPMENT/MATERIALS

Decontamination equipment and solutions are generally selected based on ease of decontamination and disposability.

- Polyethylene sheeting.
- Metal racks to hold decontaminated equipment.
- Soft-bristle scrub brushes or long-handle brushes for removing gross contamination and scrubbing with wash solutions.
- Large galvanized wash tubs, stock tanks, or wading pools for wash and rinse solutions.
- Plastic buckets or garden sprayers for rinse solutions.
- Large plastic garbage cans or other similar containers lined with plastic bags can be used to store contaminated clothing.
- Contaminated liquids and solids should be segregated and containerized in DOT-approved plastic or metal drums, appropriate for off-site shipping/disposal if necessary.

REFERENCES

ASTM D5088 - Practice for Decontamination of Field Equipment Used at Non-Radioactive Waste Sites.

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WASTE CHARACTERIZATION

INTRODUCTION

The following procedure describes the techniques for characterization of investigation derived waste (IDW) for disposal purposes.

PROCEDURAL GUIDELINES

IDW may consist of soil cuttings (augering, boring, well installation soils, test pit soils), rock core or rock flour (from coring, reaming operations), groundwater (from well development, purging, and sampling activities), decontamination fluids, personal protective equipment (spent gloves, tyveks), (PPE), and disposal equipment (DE).

This procedure applies when disposition of investigation soils and/or groundwater is required in accordance with the project Work Plan. Generally, this procedure is applicable to Facilities where the Project Manager has assessed the areas of investigation and has developed a waste handling plan. In some areas and/or sections within a Facility it is permitted to return soil cuttings/test pit soils and groundwater to the source area (RCRA guidance allows waste management techniques within an area of concern without 'triggering' new points of waste generation). In other areas it may not be practical to return cutting/soils to their origin, and are better handled by this characterization/disposal procedure. This practice is consistent with USEPA procedure for IDW at RCRA facilities and CERCLA sites (Reference 1, 2).

Typically investigative derived wastes are dealt with following "Best Management Practices"; and are not handled under RCRA regulations until proven to be listed and/or identified characteristically hazardous waste. Investigative soils and groundwater cannot be considered a listed waste (in most circumstances) due to the lack of generator knowledge concerning chemical source, chemical origin and timing of chemical introduction to the subsurface. Consequently, waste sampling and characterization is performed to determine if the wastes exhibit a characterization of hazardous waste. Once the waste characterization is complete RCRA regulations apply if determined hazardous, if determined to be non-hazardous solid wastes, best management practices apply.

The disposal of soil cuttings and/or purged groundwater must be reviewed on a case by case basis prior to initiation of field activities. Two scenarios typically exist:

i) Sufficient Facility and/or site information exists that allows investigative cutting and/or purged groundwater to be placed back into the borehole or spread on the ground surface; or discharged or in the case of purged water directly onto the ground surface - No disposal required.

ii) Site conditions warrant that all materials handled will be contained and disposed of.

DISPOSAL PROCEDURES

The following outlines the waste characterization procedures to be employed when IDW disposal is required.

Soil/Rock Cuttings

Soils removed from boring activities and well construction tasks (including, rock flour from bedrock coring) will be contained within an approved container, suitable for transportation and disposal.

- Once placed into the approved container, any free liquids (i.e., groundwater) will be poured off for disposal as waste fluids, or solidified within the approved container using a solidification agent such as speedy-dri (or equivalent). No free liquid as determined by the "paint filter test" shall be present.
- Contained soils will be screened for the presence of Volatile Organic Compounds (VOCs), using a photoionization detector (PID); this data will be logged for future reference.
- Once screened, full and closed the container will be labeled in accordance with the Facility labeling requirements and placed into the Facility container storage area. At a minimum the following information will be shown a each container label: date of filling/generation, Facility name, source of soils (i.e., borehole or well), and Facility contact. If necessary, the exterior of the container will be cleaned to remove any lose dirt/cuttings.
- Prior to container closure, representative samples from a percentage of the containers will be collected for waste characterization purposes and submitted to the project laboratory. The waste characterization sampling scheme will be dictated by the Work Plan and establish the volume of soils required for analysis (depending on parameters required), the number of containers considered representative, the homogenization procedure, volatile analysis collection procedure (if required) and preparation handling requirements. Typically at a location where an undetermined site-specific parameter group exists, sampling and analysis may consist of the full RCRA Waste Characterization (ignitability, corrosivity, reactivity, toxicity), or a subset of the above based upon data collected, historical information and generator knowledge.

Groundwater

Well construction development, purging and sampling groundwater which requires disposal will be contained. Containment may be performed in 55-gallon drums, tanks suitable for temporary storage (i.e., Nalgene or Facility provided tanks 500 to 1,000 gallons) or if large volumes of groundwater are anticipated, drilling "frac" tanks may be utilized (20,000 gallons ±), or tanker trailer (5,000 to 10.000 gallons ±). In all cases the container/tank used for groundwater storage must be clean before use such that cross-contamination does not occur.

Decontamination Waters/Decontamination Fluids

- Decontamination waters and/or fluids will be segregated, contained, and disposed of accordingly.
- Decontamination waters may be disposed of with the contained groundwater once analytical results have been acquired. Depending on the extent of chemistry present it may be appropriate to discharge the decontamination waters to the Publicly Owned Treatment Works (POTW); or discharge to an on-site treatment system; or send off site for treatment. (Proper permitting may be required.)
- Spent Solvent/Acid Rinses - Solvents and acids used during decontamination activities must be segregated and disposed separately from the groundwater/decontamination water. Often if only small amounts of solvents are involved these can be left to evaporate. If large volumes are involved then containerization, labeling, and storage is required.

PPE/DE

- A number of disposal options exists for spent PPE/DE generated from investigation tasks. The options typically employed are:
  - i) Immediately disposed of within on-site dumpster/municipal trash; or
  - ii) If known to be contaminated with RCRA hazardous waste, disposed of off site at a RCRA Subtitle C facility; or alternatively PPE/DE decontaminated and disposed of on site within dumpster/municipal trash; or
  - iii) Contained and stored until the final remedy is implemented.

WASTE CHARACTERIZATION PROCEDURES

The Work Plan will identify the appropriate sampling strategy and analytes required to determine the IDW characteristics and disposal requirements. USEPA SW-846 (Reference 5, Chapters 9 and 10) describes the rationale for sampling plan development and sampling procedures. Generally random sampling and preparation of a composite sample of the media is employed for most investigative programs. The "GM Statistical Guidance – 2nd Edition" (Reference 4, Section 2.5) outlines the statistical rationale and approaches applicable to one-time waste streams. Often a minimum of four representative samples are required to gain valid waste characteristic data to determine the disposal option applicable (if statistics are employed).

Sampling procedures for IDW are:

- Solid Wastes - Grab sampling using precleaned sample spoons from bulk piles, lugger boxes, or as drums are being filled is commonly employed. In some instances sufficient media mixing may be evident to permit drum sampling from a random number of drums by accessing only the top solids. In other instances where stratification is evident, a sample trier/hand auger or device to collect from the entire vertical profile is required. Typically, a composite sample(s) from representative areas of the container(s) is homogenized and submitted for analysis. If VOCs are being evaluated, compositing and homogenization is not permitted. Individual grab samples are typically required for VOCs.
- Waste Waters - Grab sampling techniques using precleaned bailers or sampling pumps are typically employed. Waters in bulk are typically sampled once using a bailer or pump. The Work Plan will outline the appropriate sample frequency and analytes necessary to adequately characterize the contained waters. Facility sewer discharge permit parameters will be evaluated when disposal to the POTW is being considered.

  Note: If NAPL is present special sampling and handling requirements will apply. Precautions to separate the NAPL from the wastewater will commonly be employed, due to the special material handling and waste disposal requirements when dealing with phase materials.
- Spent Solvent/Acid Rinses - The need for sampling must be determined in consultation with the waste management organization handling the materials. If known that only the solvent and/or acids are present, then direct disposal/treatment using media specific options maybe possible without sampling (i.e., incineration).
- PPE/DE - Typically not sampled and included with the disposal of the solid wastes.

EQUIPMENT/MATERIALS

- Sample spoons, trier, auger.
- Sample mixing bowl.
- Sampling bailer, or pump.
- Sample glassware.

REFERENCES

USEPA RCRA - Guidance and Policies: Management of Remediation Waste Under RCRA (October 1998).

USEPA RCRA - Management of Contaminated Media (October 1998).

USEPA CERCLA Guidance (Options Relevant to RCRA Facilities): Guide to Management of Investigation-Derived Wastes (January 1992).

2nd Edition - GM Statistical Guidance Section 2.5.1. Solid Waste Characterization Subsection 2.5.1.1. One-Time Waste Stream Characterization (July, 2000).

USEPA Office of Solid Waste - SW-846 Chapter 9 Sampling Plan, Chapter 10 Sampling Methods (September 1986).