Worldwide Facilities Group
Environmental Services
Remediation Team

James F. Hartnett
Program Manager

January 18, 2008

Mr. Jaspal S. Walia
New York State Department
Of Environmental Conservation
270 Michigan Avenue
Buffalo, NY 14203

Dear Mr. Walia:

Re: American Axle Plant Site #915196
Buffalo, Erie County, New York

Pursuant to our November 30, 2007 and December 14, 2007 responses to the NYSDEC, General Motors Corporation has prepared the attached work plan to complete supplemental remedial investigation activities at the American Axle Plant Site. A proposed schedule for implementation is presented as part of the work plan. Implementation of field aspects of this work plan will begin upon approval of the NYSDEC, however no earlier than March 1, 2008 to allow time for AAM to complete plant idling activities.

Please contact me if you have any questions regarding this submittal.

Yours truly,

GENERAL MOTORS CORPORATION

Katherine B. Galanti FOR

James F. Hartnett
Remediation Program Manager

JFH//

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December 14, 2007

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M. Desmond – NYSDEC
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M. Williams – AAM
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G. Wygant – AAM
B. Kogut - Bond, Schoeneck & King
T. Graber – Gibson, McAskill & Crosby
G. Litwin – NYSDOH
C. O'Connor – NYSDOH
K. Galanti – CRA
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SUPPLEMENTAL REMEDIAL INVESTIGATION WORK PLAN

AMERICAN AXLE PLANT SITE
NYSDEC SITE NO. 915196

Prepared For:
General Motors Corporation
Worldwide Facilities Group
Environmental Services Group - Remediation

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AMERICAN AXLE PLANT SITE
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JANUARY 2008
REF. NO. 012635-03-201080 (19)

TABLE OF CONTENTS

LIST OF FIGURES
(Following Text)

LIST OF APPENDICES

1.0 INTRODUCTION

This Work Plan has been prepared on behalf of General Motors Corporation (GM) to outline supplemental remedial investigation (RI) activities to further delineate impacts associated with the American Axle Plant Site (the Site). The Site is listed in the Registry of Inactive Hazardous Waste Disposal Sites in New York State as Site Number 915196. The remediation program is being performed in accordance with an Order on Consent (Order) between GM, American Axle & Manufacturing, Inc. (AAM) and the New York State Department of Environmental Conservation (NYSDEC) signed on August 31, 2006. An RI Report summarizing investigation activities was submitted to the NYSDEC in November 2006. This Work Plan is being submitted to address comments received from the NYSDEC in its letter dated February 27, 2007 and subsequently discussed at a meeting between the parties on May 2, 2007, and further clarified in GM's letter to the NYSDEC dated December 14, 2007.

1.1 DEFINITIONS

The following terms are used in the RI/FS and in this IRM WP to describe and define the Site:

i) "Property" refers to the parcels of land formerly owned by GM and now owned by AAM that are located at and in proximity to 1001 East Delavan Avenue in the City of Buffalo, Erie County, New York. The location of the property is shown on Figure 1.1;

ii) "Facility" means the portion of the property bounded by Delavan Avenue on the north, Cornwall Street on the west, Scajaquada Street on the south, and the CSX Corporation railroad right-of-way on the east. The boundary of the Facility is shown on Figure 1.2; and

iii) "Site" means the boundaries of the source areas of PCB-impacted oil beneath the manufacturing floor slab of the Facility that have been identified to date. The boundaries of the Site are shown on Figure 1.3.

1.2 SITE LOCATION

The property is located at 1001 East Delavan Avenue in the City of Buffalo, Erie County, New York. The property is a generally flat parcel of approximately 52 acres on which the main manufacturing buildings (Plant Nos. 81 and 83) and associated facilities are located. The property and facility are currently owned and operated by AAM.

1.3 BACKGROUND

As stated above, the NYSDEC provided comments to the RI Report in its letter dated February 27, 2007. A response to each comment was provided to NYSDEC in a letter from CRA to the agency on April 10, 2007. The parties met on May 2, 2007 to discuss the response to comments and ultimately, four general areas remained unresolved:

i) further investigation of PCB-containing oil impacts identified at select locations;
ii) further delineation of impacts to bedrock;
iii) investigation of potential impacts to the Scajaquada Creek Drain from the Site; and
iv) more extensive sampling for the target compound list (TCL) suite of parameters to confirm the absence of other contaminants of concern.

These four areas are the basis for this work plan.

2.0 SCOPE OF WORK

The following supplemental investigation activities will be conducted to resolve outstanding issues identified by NYSDEC. Field activities will be performed in accordance with GM's standardized Field Method Guidelines (FMGs). The relevant FMGs are provided as Appendix A to this work plan.

2.1 TASK 1 – SOIL BORINGS

The RI and subsequent semiannual sampling rounds have indicated the presence of oil and PCBs north of the Site in the vicinity of well clusters CP-2/2A and MW 402/ MW-403/CP-3B and to the south of the Site in well MW-404. Further investigation will be conducted in these areas to determine the sources and extent of contamination.

Initially, soil borings will be installed as shown on Figure 2.1. Locations were selected based on the historical knowledge, the results of the RI, and subsequent semiannual monitoring data. The locations depicted on Figure 2.1 are approximate and may be adjusted in the field based on underground and/or overhead utilities. If oil is observed in the fill or clay units during installation of a boring, the boring will be grouted and the drill rig relocated to the next point. This method will continue until a "clean" limit is identified at which point a permanent monitoring well will be installed to the base of the clay unit.

Soil borings will be attempted using direct push Geoprobe® technology. Soil samples will be collected using a 2-inch outside diameter by 4-foot long Geoprobe® stainless steel sampler (macro core) lined with a disposable acetate liner. A new liner will be used for each 4-foot interval. All soil borings will be installed to the base of the clay unit unless oil is encountered. The macro core will be decontaminated between each soil boring location using Alconox and water at a contractor-provided decontamination pad. Upon retrieval, samples will be logged noting soil type, moisture, discoloration, and odors; examined for the presence of light non-aqueous phase liquid (LNAPL); and screened for VOCs using a photoionization detector (PID). If Geoprobe® sampling is ineffective due to the presence of sub-slab structures or soil/fill composition, conventional drilling methods using hollow-stem augers will be employed.

All soil borings will be grouted to the surface and soil cuttings will be drummed for waste characterization and disposal.

Upon delineation of the oil impacts at each area, additional clay monitoring wells will be installed. Monitoring wells will be developed no sooner than 48 hours after installation and sampled as part of the May 2008 semiannual groundwater monitoring event. If installation is not complete by that time, the wells will be sampled approximately one month after installation.

2.2 TASK 2 – BEDROCK WELL INSTALLATION

Four bedrock monitoring wells will be installed to monitor groundwater quality to the north, south, east, and west of the Site. The approximate well locations are shown on Figure 2.1. Final drilling locations will be subject to utility clearance by AAM personnel.

Bedrock monitoring wells will be completed as open coreholes. Borings for bedrock wells will be advanced to the top of the bedrock using an auger/rollerbit. After bedrock is encountered, a core barrel will be used to drill approximately 1 to 2 feet into the bedrock, enabling the placement of a 4-inch diameter steel casing to be sealed into the top of the bedrock unit. The installation of the casing will effectively seal off the shallow and deep overburden ensuring no transport between the overburden and bedrock units. These casings will be installed as follows:

i) the casing will be set in place with placement of grout into the annular space between the well pipe and borehole by positive displacement using a tremie tube. The grout shall consist of Portland cement, bentonite, and clean water. 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;

ii) a portion of the grout mixture will be poured into the inside of the casing to create a plug at the base of the casing. The grout will be allowed to set for a minimum 24 hours;

iii) after a minimum 24 hours, a hydrostatic test will be performed on the casing to ensure that the grout has set properly and the shallow overburden is sealed off from the deep overburden. The hydrostatic test will be conducted as follows:

    a) the casing will be filled to the top with clean potable water, and the time noted;

b) at 1-minute intervals for 10 minutes, then 5-minute intervals thereafter, the water level in the casing will be inspected to determine if it is falling;
c) if the water level is falling, the level will be measured and recorded; and
d) after one hour, if the total drop in water level is less than 0.5 feet, the casing can be considered sealed. If the water level drops more that 0.5 feet, the grout in the casing will be reamed out, and new grout will be poured inside. The hydrostatic test will then be repeated after a minimum 24 hours have passed. This process will be repeated as many times as it takes to seal the casing.

After the well casing passes the hydrostatic test, bedrock coring may commence.

The bedrock will be cored in 5-foot runs. Upon completion of each 5 feet of coring, the water producing characteristics of the open interval will be determined by conducting "bail-down" and recovery tests. Coring will be terminated when the first interval producing sufficient water recharge for sampling is encountered.

Bedrock cores will be logged noting the rock description, the core run, depth of the run, percent recovery, and the rock quality designation (RQD). The cores will be retained and stored on site.

Groundwater from the newly installed bedrock wells will be sampled during the May 2008 semiannual groundwater monitoring event. If installation is not complete by that time, the wells will be sampled approximately one month after installation.

2.3 TASK 3 – 5X9 SEWER SAMPLING

The current semi-annual lateral sampling program will be expanded to include sampling of water from the 5x9 Sewer. Grab samples will be collected from two upstream manholes and one downstream manhole, as follows:

i) monitoring station 002 located to the north of the property at Delavan Avenue (upstream location);
ii) monitoring station 003 located to the west of the property near the intersection of Cornwall Avenue and Northland Avenue (upstream location); and
iii) monitoring station 004 located to the south of the property on Colorado Street (downstream location).

The locations of the sampling points are shown on Figure 2.2. Only water samples will be collected as there is minimal sediment accumulation within the combined sanitary/storm sewers due to the volume of flow.

Sampling will commence in March 2008 and will be completed concurrent with the semi-annual lateral sampling. Samples will be submitted to TestAmerica Laboratories of North Canton, Ohio for analysis of total extractable hydrocarbons (USEPA Method 1664A) and total PCBs (USEPA Method 608).

2.4 TASK 4 – SCAJAQUADA CREEK DRAIN SAMPLING

Sampling of the Scajaquada Creek Drain will require sampling personnel to enter the structure for sample collection. Access to the Drain is controlled by the Buffalo Sewer Authority (BSA) and approval must be granted by BSA prior to implementation of any sampling activities. GM and CRA will work with BSA to negotiate access to the Drain.

Once access is granted, actual sampling will be subject to weather conditions as entry can only be completed during dry weather. Entry to the Drain will be scheduled for a date a minimum of three days beyond a forecasted rain event. This will allow sufficient time for elevated water levels due to rainfall to dissipate.

Entry to the Drain will be made via a manhole along Scajaquada Street near the intersection of Colorado Street, south of the Property, and nearest to the location of the 5x9 Sewer combined sewer overflow (CSO). The Drain will be inspected 25 feet upstream and 25 feet downstream of the CSO for the presence of sediment. Samples of water and sediment (if present) will be collected from the Drain at one upstream and one downstream locations. The water and sediment samples will be submitted to TestAmerica Laboratories for PCB analysis by USEPA Method 608 and USEPA Method SW-846 8082, respectively.

2.5 TASK 5 – COLLECTION OF TCL PARAMETERS

Initial investigation activities completed as part of the property sale to AAM established the contaminants of concern for subsequent rounds of investigation. Limited analysis for volatile organic, semivolatile organic, and metals parameters were conducted under these investigations. Redacted versions of the investigation reports were provided to the NYSDEC in the document "Summary of Historical Confidential Documents," dated September 2006. Ultimately, only oil and PCBs were found to be of concern and were the focus of the current investigation. Analysis for Target Compound List (TCL) and Target Analyte List (TAL) parameters will be conducted on groundwater samples from select perimeter wells to establish water quality at the Site/Property perimeter.

Additional groundwater volume will be collected using low-flow sampling techniques during the May 2008 Semiannual Sampling Event from the following monitoring wells/clusters:

- MW-408/MW-409/MW-409B (easternmost fill/clay/bedrock wells)
- MW-4/MW-2A/MW-4B (southernmost fill/clay/bedrock wells)
- MW-204/MW-300A/MW-5B (westernmost fill/clay/bedrock wells)

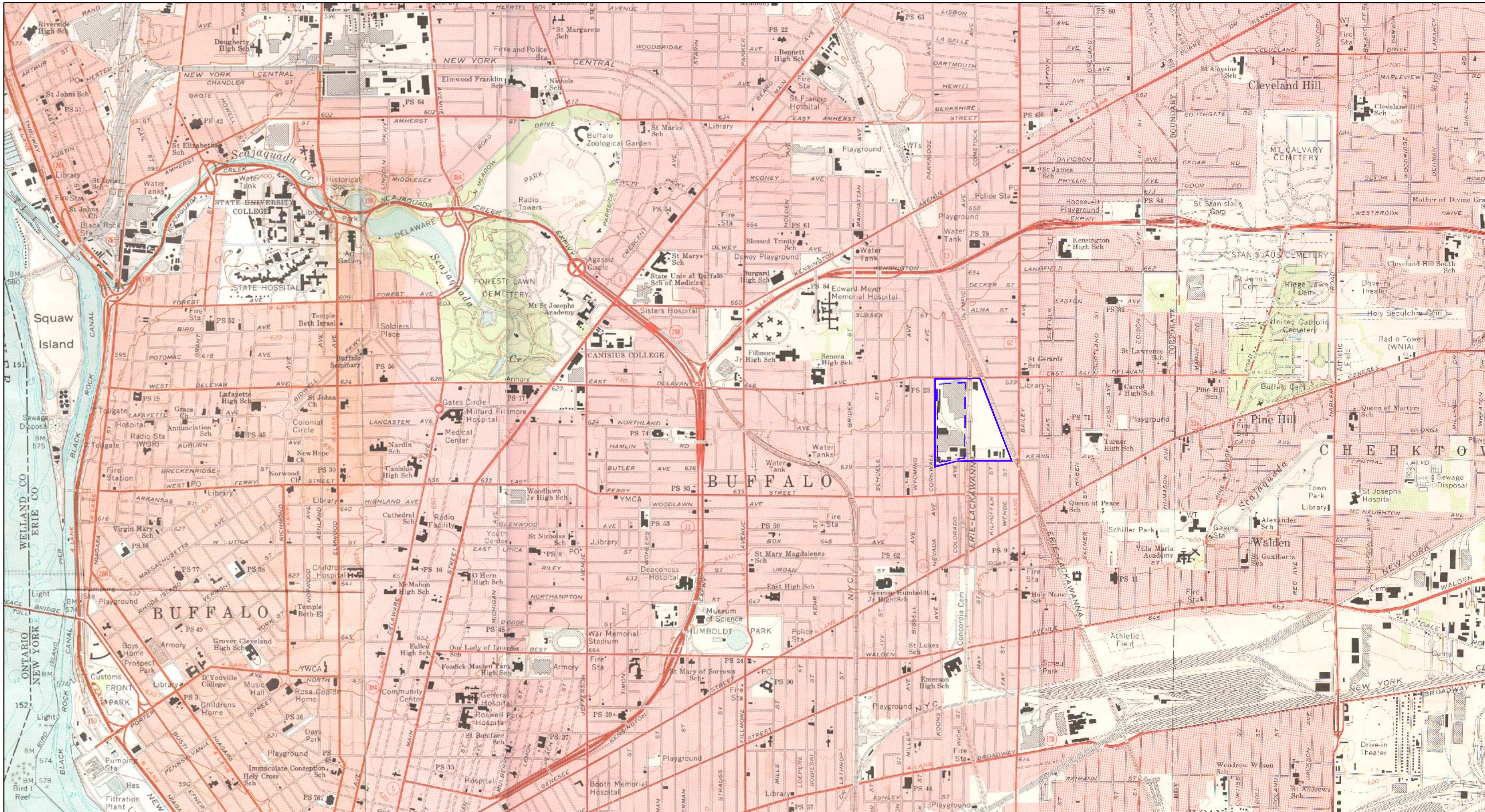
Groundwater samples will be submitted to TestAmerica Laboratories of North Canton, Ohio and analyzed for TCL organics, semivolatile organics, and PCBs, and TAL metals.

2.6 SUPPLEMENTAL RI REPORT

A Supplemental RI Report will be prepared upon completion of the field activities for submission to and review by the NYSDEC.

3.0 SCHEDULE

Implementation of this work plan will begin no earlier than March 1, 2008 to allow time for AAM to complete plant idling activities. A tentative schedule is provided as Figure 3.1, however, actual implementation/completion will be dependent on access to work areas. Any schedule changes will be reported in the monthly progress report.



REFERENCE:

UNITED STATES GEOLOGIC SURVEY
BUFFALO NE QUADRANGLE, NY
TOPOGRAPHIC, 7.5 MINUTES SERIES 1965

N

0 1250 2500ft

LEGEND:

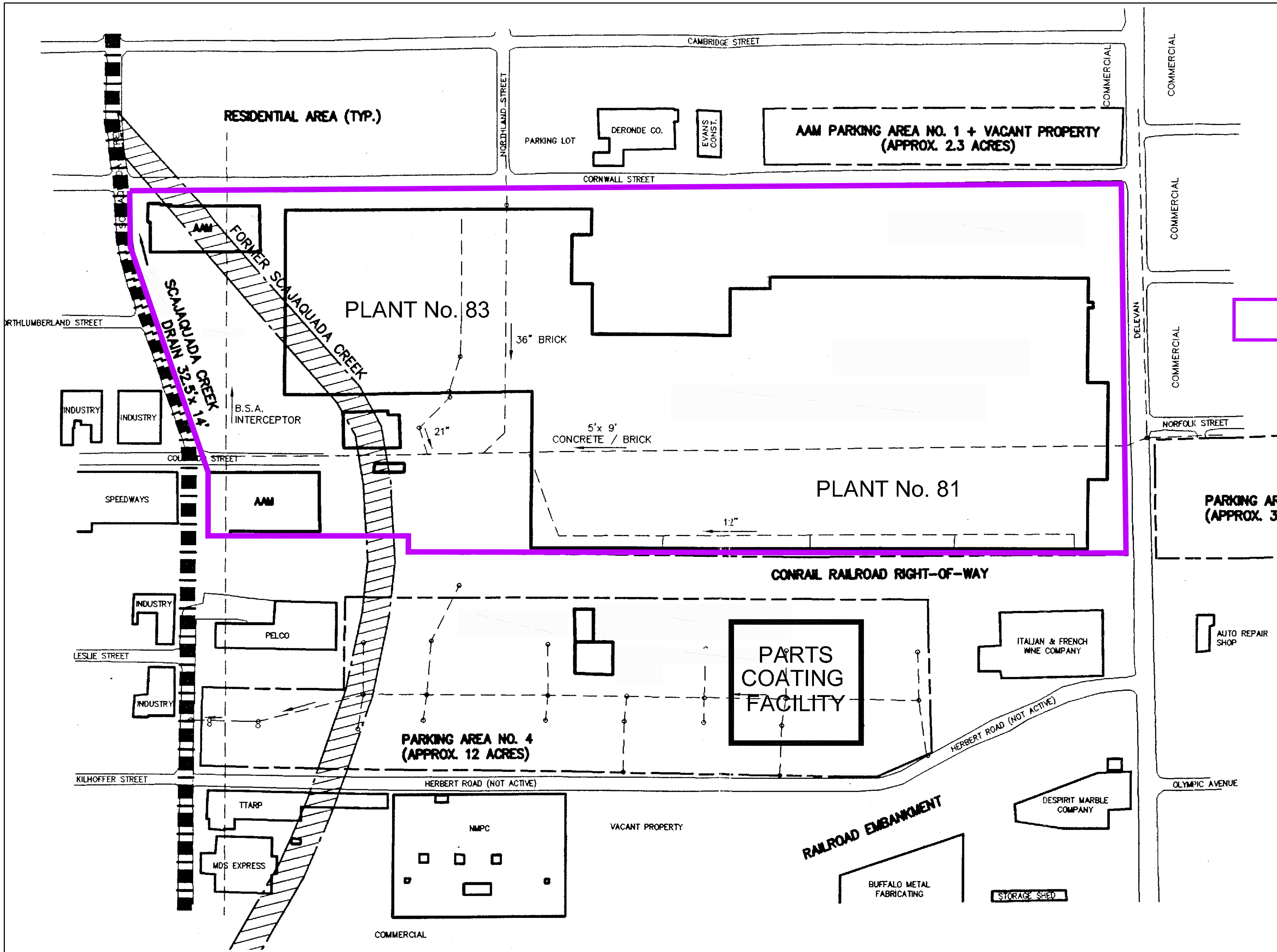
PROPERTY BOUNDARY

FACILITY BOUNDARY

figure 1.1

LOCATION MAP
AMERICAN AXLE PLANT SITE
BUFFALO FACILITY
Buffalo, New York

12635-03(019)GN-BU001 JAN 16/2008



SOURCE: "FACILITY PLAN AND SEWER LOCATION PLAN" PREPARED BY EMCON (PROJECT NO. 84853-0P5) DATED AUGUST 25, 1995.

BOUNDARY OF FACILITY

NOTE:

1. THIS MAP WAS DIGITIZED FROM A BASE MAP PROVIDED BY GENERAL MOTORS CORP., SAGINAW BUFFALO PLANT AND IS APPROXIMATE.
2. UNDERGROUND SEWER INFORMATION TAKEN FROM DRAWING NO. PE-D-10 OF THE SPILL PREVENTION CONTROL & COUNTERMEASURE PLAN, DATED MAY 1994.
3. ONLY THE MAJOR SEWER LINES ARE SHOWN WEST OF THE CONRAIL RAILROAD RIGHT-OF WAY FOR CLARITY.
4. FORMER SCAJAQUADA CREEK LOCATION TAKEN FROM 1917 SANBORN MAP FROM ERIE COUNTY AND BUFFALO HISTORICAL SOCIETY.
5. SCAJAQUADA CREEK STORMDRAIN IS LOCATED USING THE SCAJAQUADA STREET LOCATION AND IS ONLY AS ACCURATE AS THE DIGITIZED MAP.
6. SEWER, WATER, ELECTRICAL AND GAS LINES ARE NOT SHOWN.

figure 1.2

FACILITY PLAN
AMERICAN AXLE PLANT SITE
BUFFALO FACILITY
Buffalo, New York

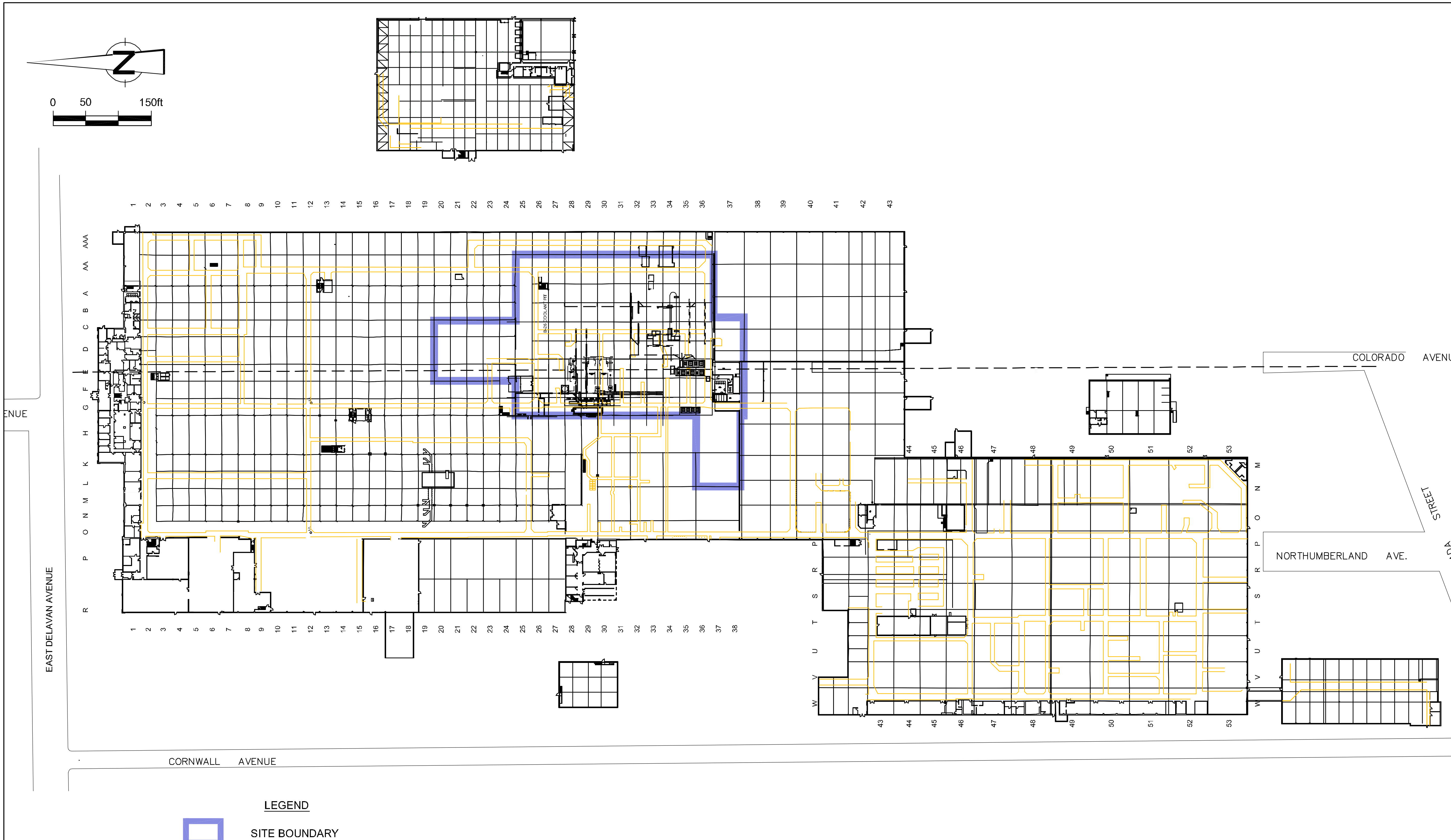
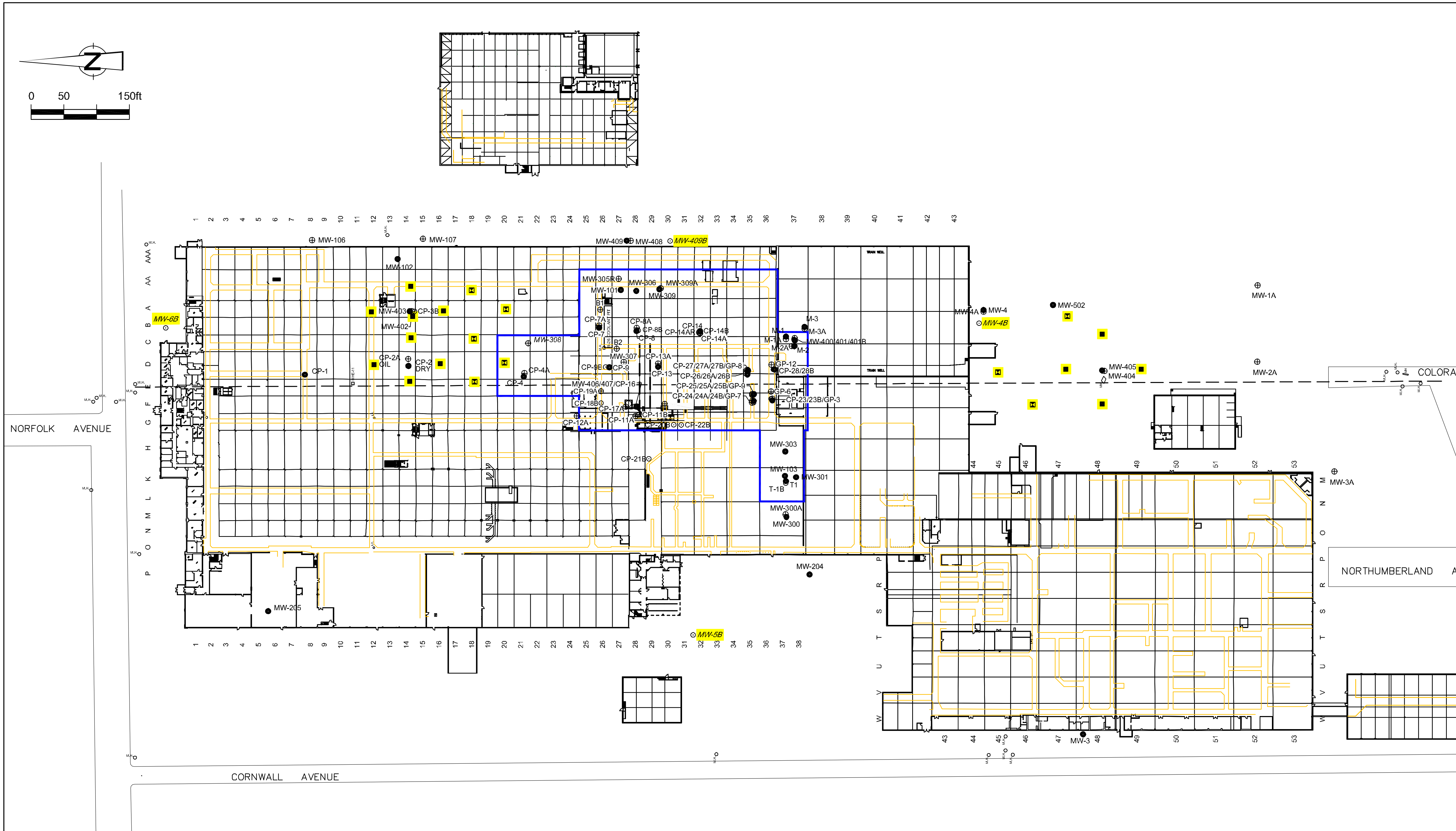


figure 1.3

SITE BOUNDARY
AMERICAN AXLE PLANT SITE
BUFFALO FACILITY
Buffalo, New York

12635-03(019)GN-BU003 JAN 17/2008



LEGEND

MW-403 ● FILL MONITORING WELL

MW-106 ⊕ CLAY MONITORING WELL/PIEZOMETER

CP-9B ⊙ BEDROCK MONITORING WELL

MW-409B ⊙ PROPOSED BEDROCK WELL INSTALLATIONS

■ PROPOSED BORING LOCATIONS

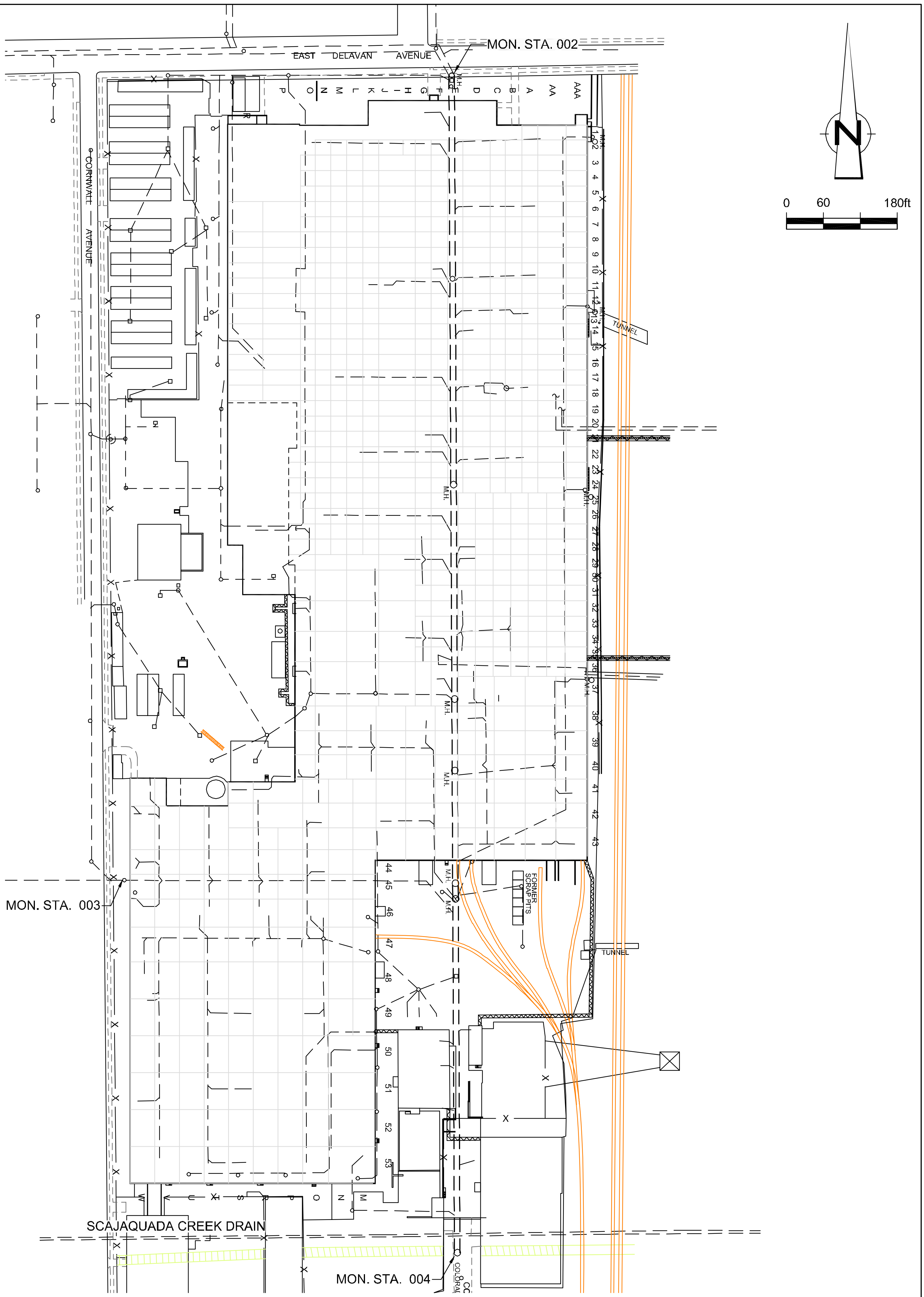
■ PROPOSED BORING LOCATIONS (AS NEEDED)

SITE LIMITS

figure 2.1

PROPOSED DRILLING LOCATIONS
AMERICAN AXLE PLANT SITE
Buffalo, New York

12635-03(019)GN-BU004 JAN 17/2008



LEGEND

M.H. ○ MANHOLE

⚌ 5 x 9 SEWER

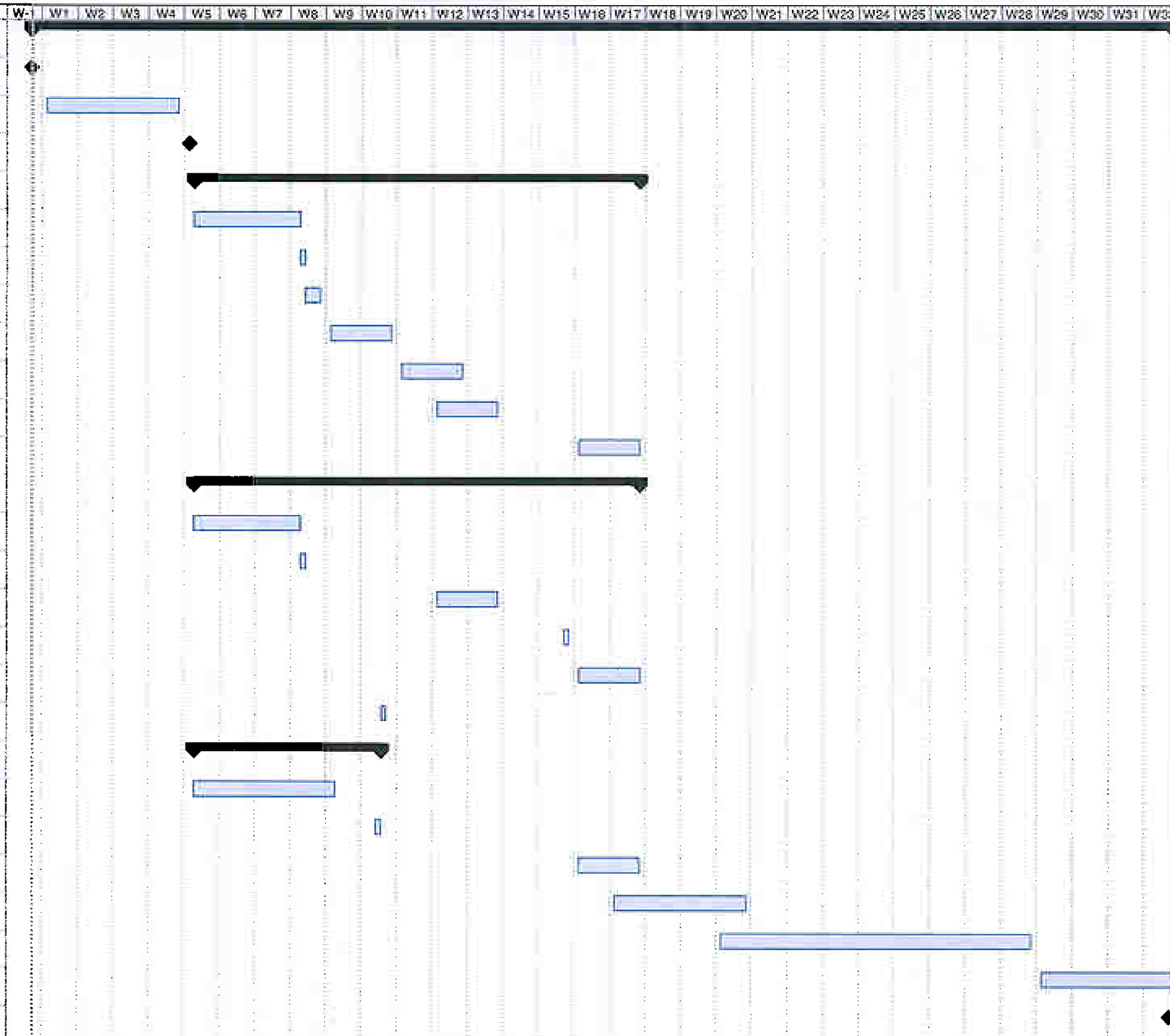
figure 2.2

MANHOLE SAMPLE LOCATIONS
AMERICAN AXLE PLANT SITE
Buffalo, New York

12635-03(019)GN-BU005 JAN 17/2008

FIGURE 3.1
SUPPLEMENTAL REMEDIAL INVESTIGATION WORK PLAN
PROPOSED SCHEDULE
AMERICAN AXLE PLANT SITE, NYSDEC SITE NO. 915196

ID	Task Name
1	**AAM Supplemental Remedial Investigation (RI) Work Plan**
2	**Submission of Supp. RI Work Plan to NYSDEC**
3	**NYSDEC Review**
4	**NYSDEC Work Plan Approval**
5	**Task 1 - Soil Borings**
6	Drilling Contractor Bid/Selection
7	Borehole Site Selection and Utility Clearance
8	Concrete Coring
9	Borehole Installation
10	Monitoring Well Installation
11	Well Development and Hydraulic Monitoring
12	Semi-Annual Groundwater Quality Montioring
13	**Task 2 - Bedrock Well Installation**
14	Drilling Contractor Bid/Selection
15	Borehole Site Selection and Utility Clearance
16	Bedrock Well Installation
17	Hydraulic Monitoring
18	Semi-Annual Groundwater Quality Montioring
19	**Task 3 - 5x9 Sewer Sampling**
20	**Task 4 - Scajaquada Creek Drain Sampling**
21	Coordination with BSA
22	Drain Sampling
23	**Task 5 - Collection of TCL Parameters**
24	**Sample Analysis and Data Validation**
25	**Data Review and Preparation of Draft Supp. RI Report**
26	**Internal Report Review/Final Preparation**
27	**Submission of Supp. RI Report**



Project: 012635-RPT-19-fig3-1
Date: Fri 1/18/08

Task | Split | Progress | Milestone | Summary | Project Summary | External Tasks | External Milestone | Deadline

APPENDIX A

GM FIELD METHOD GUIDELINES

TABLE OF CONTENTS

Page

SOIL BORINGS

REMEDIATION SECTION	FIELD METHOD GUIDELINE NO.: FMG 2.3
WORLDWIDE FACILITIES GROUP	EFFECTIVE DATE: NOVEMBER 20, 2001
GENERAL MOTORS CORPORATION	
REVISION NO.: 0	REVISION DATE:

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) Locating and Marking of Boreholes/Final Visual Check

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.

<u>Thin-Walled Samplers (Shelby Tubes)</u>

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) Borehole Completion

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.

TABLE OF CONTENTS

Page

BEDROCK CORING

REMEDIATION SECTION	FIELD METHOD GUIDELINE NO.: FMG 2.4
WORLDWIDE FACILITIES GROUP	EFFECTIVE DATE: NOVEMBER 20, 2001
GENERAL MOTORS CORPORATION	
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.

TABLE OF CONTENTS

Page

BOREHOLE ABANDONMENT/SEALING

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 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.
- 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.
- 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.
- 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.

TABLE OF CONTENTS

Page

LIST OF FORMS
(Following Text)

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'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.

Criteria for Describing Dilatency

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.

Criteria for Describing Toughness

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.

Criteria for Describing Plasticity

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.

STRATIGRAPHY LOG (OVERBURDEN)

PROJECT NAME ______________________
PROJECT NUMBER ______________________
GM SITE ______________________
LOCATION ______________________

DRILLING CONTRACTOR ______________________
DRILLER ______________________
SURFACE ELEVATION ______________________
WEATHER (A.M.) ______________________
(P.M.) ______________________

HOLE DESIGNATION ______________________
DATE/TIME STARTED ______________________
DATE/TIME COMPLETED ______________________
DRILLING METHOD ______________________
SUPERVISOR ______________________

STRATIGRAPHIC INTERVALS (DEPTHS IN ft/m BGS			SAMPLE DESCRIPTION	SAMPLE DETAILS							PID / FID (ppm)	CHEMICAL ANALYSIS	GRAIN SIZE
FROM	AT	TO	ORDER OF DESCRIPTORS: SOIL TYPE SYMBOL(S) – MAIN COMPONENT(S), (NATURE OF DEPOSIT), SECONDARY COMPONENTS, RELATIVE DENSITY/CONSISTENCY, GRAIN SIZE/PLASTICITY, GRADATION/STRUCTURE (FRACTURE PRESENCE/APPEARANCE),COLOR, MOISTURE CONTENT, SUPPLEMENTARY DESCRIPTORS (FILL OR NATIVE; ROOT PRESENCE/STRUCTURE), NOTE: PLASTICITY DETERMINATION REQUIRES THE ADDITION OF MOISTURE IF THE SAMPLE IS TOO DRY TO ROLL (INDICATE IF MOISTURE WAS ADDED OR NOT).	SAMPLE #	SAMPLING METHOD	PENETRATION RECORD SPLIT SPOON BLOWS (RECORD N–VALUES & RECOVERIES) 6"	6"	6"	6"	SAMPLE INTERVAL			

GENERAL MOTORS CORPORATION
REMEDIATION SECTION

DEPTH OF BOREHOLE CAVING __________ DEPTH OF FIRST GROUNDWATER ENCOUNTER __________ TOPSOIL THICKNESS __________
WATER LEVEL IN OPEN BOREHOLE ON COMPLETION __________, AFTER _____ HOURS _____
COMPLETION DETAILS: ______________________

NOTE: FOR EACH SPLIT–SPOON SAMPLE, RECORD BLOW COUNTS, N–VALUE, SAMPLE RECOVERY LENGTH, AND SAMPLE INTERVAL.

SOIL CLASSIFICATION SYSTEM (MODIFIED U.S.C.S.)

MAJOR DIVISIONS			GROUP SYMBOL	TYPICAL DESCRIPTION
HIGHLY ORGANIC SOILS			PT	PEAT AND OTHER HIGHLY ORGANIC SOILS
COARSE-GRAINED SOILS (MORE THAN HALF BY WEIGHT LARGER THAN NO. 200 SIEVE SIZE)	GRAVELS MORE THAN HALF OF COARSE FRACTION LARGER THAN NO. 4 SIEVE SIZE	CLEAN GRAVELS	GW	WELL GRADED GRAVEL, GRAVEL-SAND MIXTURES, < 5% FINES
			GP	POORLY GRADED GRAVELS AND GRAVEL-SAND MIXTURES, < 5% FINES
		DIRTY GRAVELS	GM	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES, > 12% FINES
			GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES, > 12% FINES
	SANDS MORE THAN HALF OF COARSE FRACTION SMALLER THAN NO. 4 SIEVE SIZE	CLEAN SANDS	SW	WELL GRADED SANDS, GRAVELLY SANDS, < 5% FINES
			SP	POORLY GRADED SANDS, OR GRAVELLY SAND, < 5% FINES
		DIRTY SANDS	SM	SILTY SANDS, SAND-SILT MIXTURES > 12% FINES
			SC	CLAYEY SANDS, SAND-CLAY MIXTURES > 12% FINES
FINE-GRAINED SOILS (MORE THAN HALF BY WEIGHT PASSES NO. 200 SIEVE SIZE)	SILTS BELOW "A" LINE ON PLASTICITY CHART; NEGLIGIBLE ORGANIC CONTENT		ML	INORGANIC SILTS AND VERY FINE SAND, ROCK FLOUR, SILTY SANDS OF SLIGHT PLASTICITY
			MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS, FINE SANDY OR SILTY SOILS
	CLAYS ABOVE "A" LINE ON PLASTICITY CHART; NEGLIGIBLE ORGANIC CONTENT		CL	INORGANIC CLAYS OF LOW PLASTICITY, GRAVELLY, SANDY, OR SILTY CLAYS, LEAN CLAYS
			CI	INORGANIC CLAYS OF MEDIUM PLASTICITY, SILTY CLAYS
			CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
	ORGANIC SILTS & ORGANIC CLAYS BELOW "A" LINE ON PLASTICITY CHART		OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
			OH	ORGANIC CLAYS OF HIGH PLASTICITY

CONVENTIONAL SOIL DESCRIPTIONS

NON-COHESIVE (GRANULAR) SOIL

RELATIVE DENSITY	BLOWS PER FOOT (N-VALUE)
Very loose	less than 5
Loose	5 to 9
Compact	10 to 29
Dense	30 to 50
Very Dense	greater than 50

COHESIVE (CLAYEY) SOIL

CONSISTENCY	BLOWS PER FOOT (N-VALUE)
Very Soft	0 to 2
Soft	3 to 4
Firm	5 to 8
Stiff	9 to 15
Very Stiff	16 to 30
Hard	greater than 30

GRAIN SIZE CLASSIFICATION

COBBLES	Greater than 3 inches (76 mm)
GRAVEL	3 in. to No. 4 (4.76 mm)
Coarse Gravel	3 in. to 3/4 in.
Fine Gravel	3/4 in. to No. 4 (4.76 mm)
SAND	No. 4 (4.76 mm) to No. 200 (0.074 mm)
Coarse Sand	No. 4 (4.76 mm) to No. 10 (2.0 mm)
Medium Sand	No. 10 (2.0 mm) to No. 40 (0.42 mm)
Fine Sand	No. 40 (0.42 mm) to No. 200 (0.074 mm)
SILT	No. 200 (0.074 mm) to 0.002 mm
CLAY	Less than 0.002 mm

NOTE: The "No. __ " refers to the standard sieve sizes.

COMPONENT PERCENTAGE DESCRIPTORS

Noun(s) (e.g. SAND and GRAVEL)	35 to 50%
Adjective (e.g. SANDY)	20 to 35%
With	10 to 20%
Trace	Less than 10%

SOIL STRUCTURE TERMS

Stratified	Blocky
Laminated	Lenses/Seams
Fissured	Homogeneous

NOTE: The presence of soil fractures and their structure / appearance must be described.
(i.e. length, depth, oxidation, weathering)

GENERAL MOTORS CORPORATION - REMEDIATION SECTION

REMEDIATION SECTION	FIELD METHOD GUIDELINE NO.: FMG 2.7
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TABLE OF CONTENTS

LIST OF FORMS
(Following Text)

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.

BEDROCK DRILL AND STRATIGRAPHIC LOG

PROJECT NAME ______________________
PROJECT NUMBER ______________________
GM SITE ______________________
LOCATION ______________________

HOLE DESIGNATION ______________________
DATE COMPLETED ______________________
DRILLING METHOD ______________________
SUPERVISOR ______________________

PAGE ________ OF ________
ELEVATIONS:
TOP OF CASING: ______________
GROUND ______________

SAMPLE DESCRIPTION	STRAT CHANGE DEPTH	RUN NO.	SAMPLE INTERVAL		% RECOV	RQD%	% WATER RETURN	L A B	TEST INTERVAL	
			FROM	TO					FROM	TO

GENERAL MOTORS CORPORATION - REMEDIATION SECTION

TABLE OF CONTENTS

Page

WELL CONSTRUCTION MATERIALS

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

<u>Well Screen</u>

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.

Seals

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.

Campbell, M.D., and Lehr, J.H., Water Well Technology, McGraw Hill, 1973.

Cold Weather Concreting, ACI Committee 306, Materials Journal, Volume 85, Issue 4, July 1, 1988.

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

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

USEPA, 1986, RCRA Groundwater Monitoring Technical Enforcement Guidance Document, Office of Solid Waste and Emergency Response, 1986.

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TABLE OF CONTENTS

PROCEDURES FOR OVERBURDEN MONITORING WELL INSTALLATION

LIST OF FORMS
(Following Text)

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 GM/REALM/ENCORE 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.

Form FMG 3.2 - 01	# OVERBURDEN MONITORING WELL INSTALLATION REPORT	Well No.
		Boring No.

PROJECT ______________________

LOCATION ______________________ **PROJECT MANAGER** ______________

CLIENT ______________________ **FIELD REP.** ______________

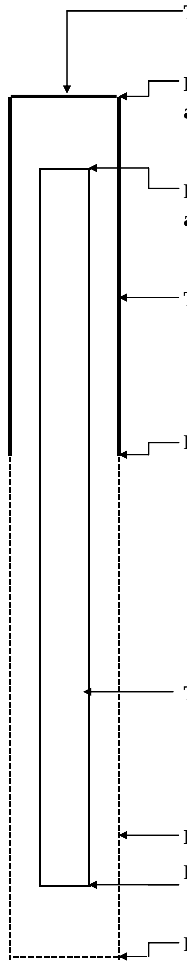
CONTRACTOR ______________________ **DATE INSTALLED** ______________

DRILLER ______________________ **WATER LEVEL** ______________

Ground Elev. ________ ft **Location** ______________________ ☐ **Guard Pipe**

Top of Casing Elev. ________ ☐ **Roadway Box**

SOIL CONDITIONS	BOREHOLE BACKFILL



Type of protective cover/lock ______________

Height/Depth of top of guard pipe/roadway box above/below ground surface ________ ft

Height/Depth of top of riser pipe above/below ground surface ________ ft

Type of protective casing: ______________

Length ________ ft

Inside Diameter ________ in

Depth of bottom of guard pipe/roadway box ________ ft

Type of Backfill	Depth Interval (in ft)

Type of casing pipe: ______________

Inside diameter of casing pipe ________ in

Screen Interval ________ **ft** **Slot size** ______ **Material** ________

Diameter of borehole ________ in

Depth of bottom of well ________ ft

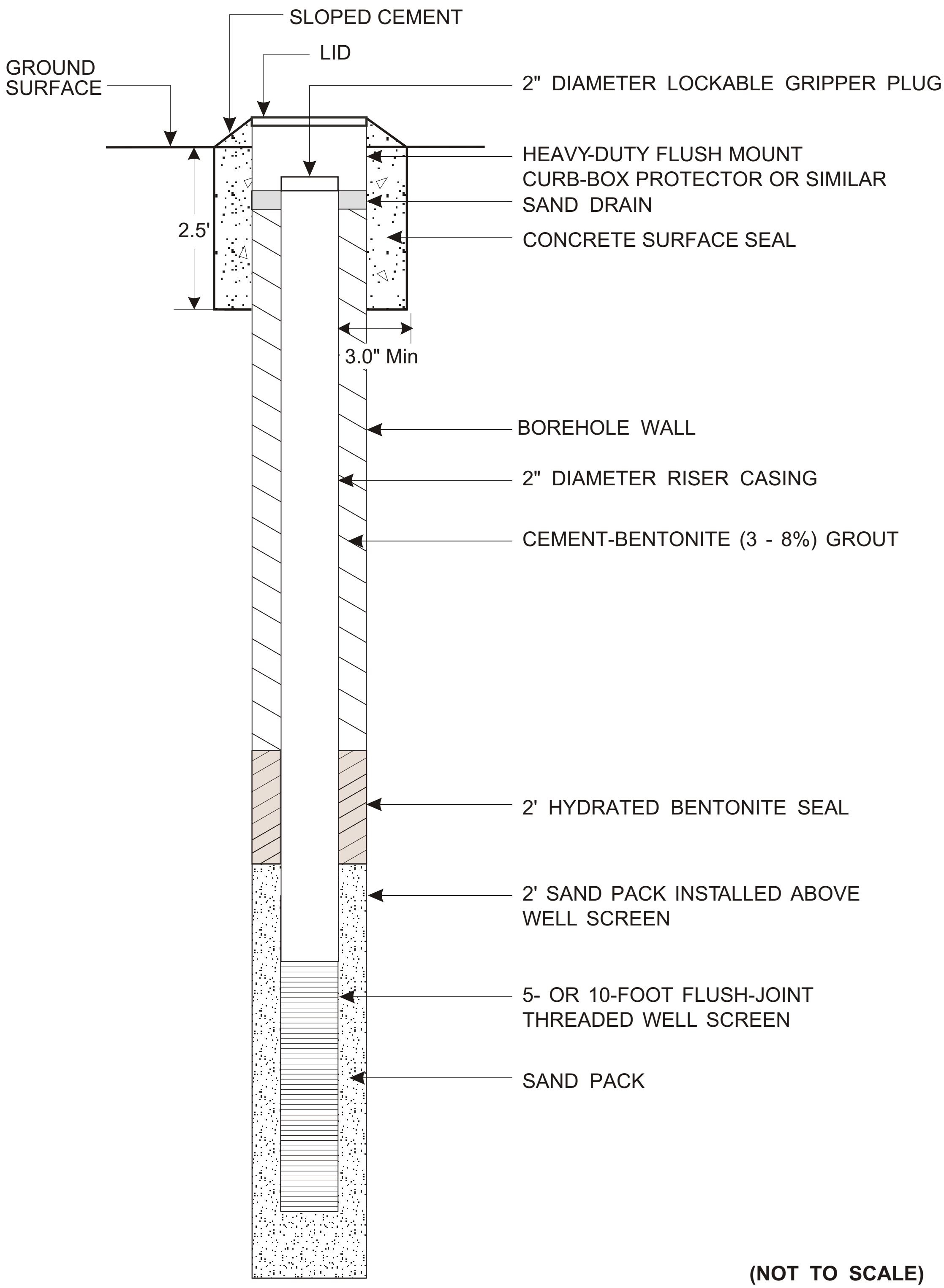
Depth of bottom of test borehole ________ ft

(Bottom of Exploration)
(Numbers refer to depth from ground surface in feet)

(Not to Scale)

* - Elevation Datum = __________________

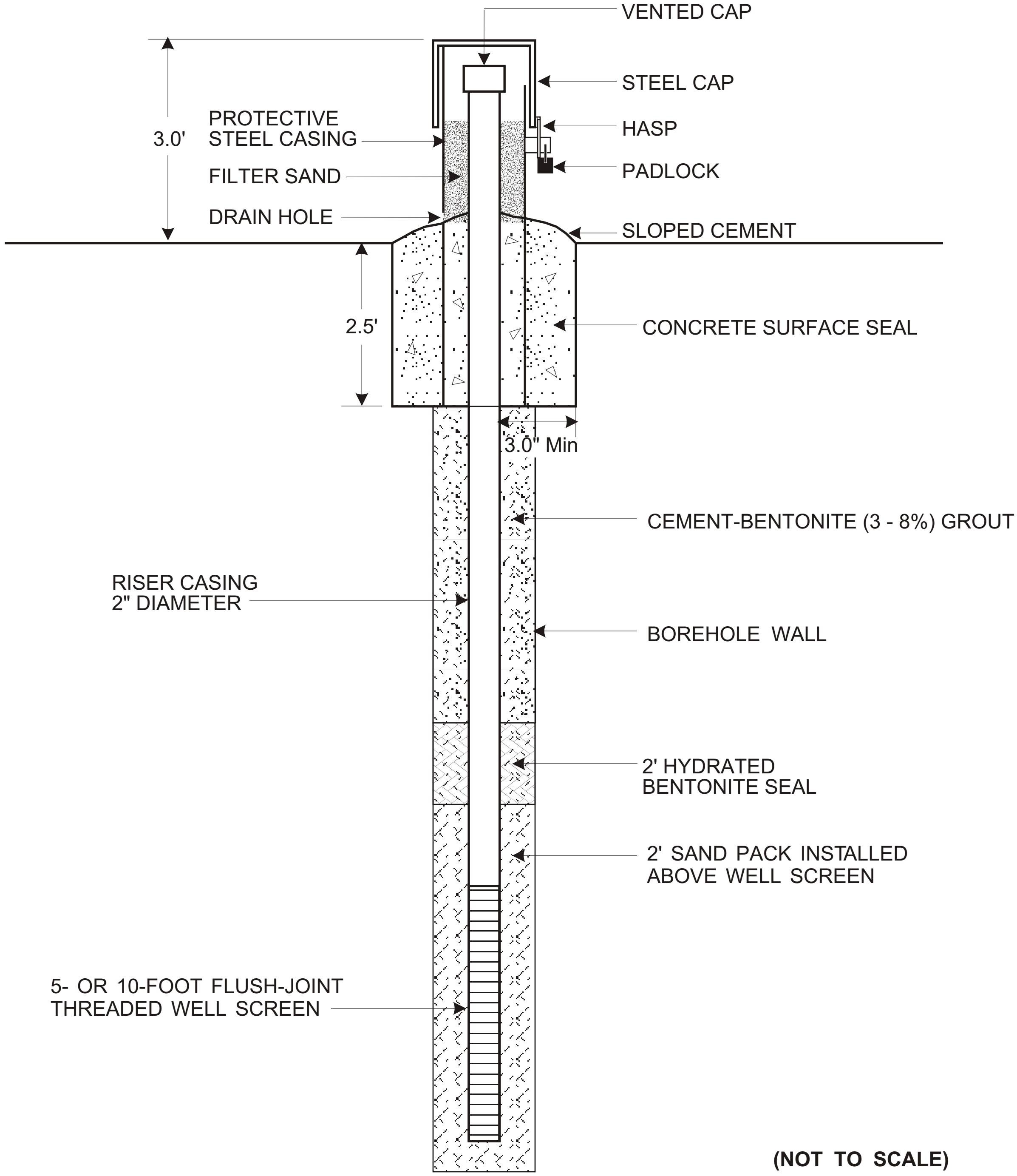
COMMENTS: ____



(NOT TO SCALE)

FMG 3.2-02 TYPICAL FLUSH MOUNT OVERBURDEN MONITORING WELL INSTALLATION

NOTE:
FOR WELLS TO BE SAMPLED FOR TURBIDITY-SENSITIVE PARAMETERS (E.G, PCBs, METALS), A WELL BORE DIAMETER OF GREATER THAN ONE FOOT (1' - 3') IS PREFERRED.



(NOT TO SCALE)

FMG 3.2-03 TYPICAL ABOVE GRADE OVERBURDEN MONITORING WELL INSTALLATION

NOTE:
FOR WELLS TO BE SAMPLED FOR TURBIDITY-SENSITIVE PARAMETERS (E.G, PCBs, METALS), A WELL BORE DIAMETER OF GREATER THAN ONE FOOT (1' - 3') IS PREFERRED.

TABLE OF CONTENTS

Page

DEEP BEDROCK WELLS

LIST OF FORMS
(Following Text)

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.

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.

Campbell, M.D., and Lehr, J.H., Water Well Technology, McGraw Hill, 1973.
Driscoll, Fletcher G., Groundwater and Wells, Johnson Filtration Systems, Inc., 1986.
Freeze, R. Allen, and Cherry, John A., Groundwater, Prentice-Hall, 1979.

Form FMG 3.4 - 01

BEDROCK MONITORING WELL INSTALLATION REPORT

Well No. ____

Boring No. ____

PROJECT ____
LOCATION ____
CLIENT ____
CONTRACTOR ____
DRILLER ____

PROJECT MANAGER ____
FIELD REP. ____
DATE INSTALLED ____
WATER LEVEL ____

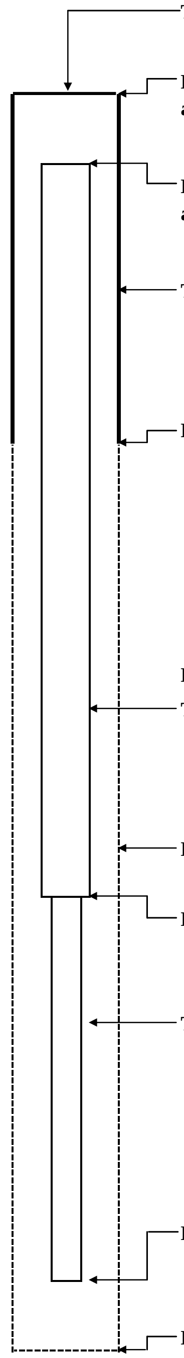
Ground Elev. ____ ft
Top of Casing Elev. ____

Location ____

☐ Guard Pipe
☐ Roadway Box

SOIL/ROCK CONDITIONS	BOREHOLE BACKFILL

(Bottom of Exploration)
(Numbers refer to depth from ground surface in feet)



Type of protective cover/lock ____

Height/Depth of top of guard pipe/roadway box above/below ground surface ____ ft

Height/Depth of top of riser pipe above/below ground surface ____ ft

Type of protective casing: ____
- Length ____ ft
- Inside Diameter ____ in

Depth of bottom of guard pipe/roadway box ____ ft

Type of Seals	Top of Seal (ft)	Thickness (ft)

Depth to the top of bedrock ____ ft

Type of casing pipe: ____
- Inside diameter of casing pipe ____ in
- Type of backfill around riser ____

Diameter of borehole ____ in

Depth to top of open core interval ____ ft

Type of open core interval ____
- Diameter of open core interval ____ in

Depth of bottom of open core interval ____ ft

Depth of bottom of test borehole ____ ft

(Not to Scale)

* - Elevation Datum = ____
COMMENTS: ____

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

REALM/ENCORE

TABLE OF CONTENTS

LIST OF FORMS
(Following Text)

REMEDIATION SECTION	FIELD METHOD GUIDELINE NO.: FMG 5.1
WORLDWIDE FACILITIES GROUP	EFFECTIVE DATE: NOVEMBER 20, 2001
GENERAL MOTORS CORPORATION	
REVISION NO.: 0	REVISION DATE:

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

TABLE OF CONTENTS

Page

SURFACE SEDIMENT

LIST OF FIGURES

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

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 (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.

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 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.

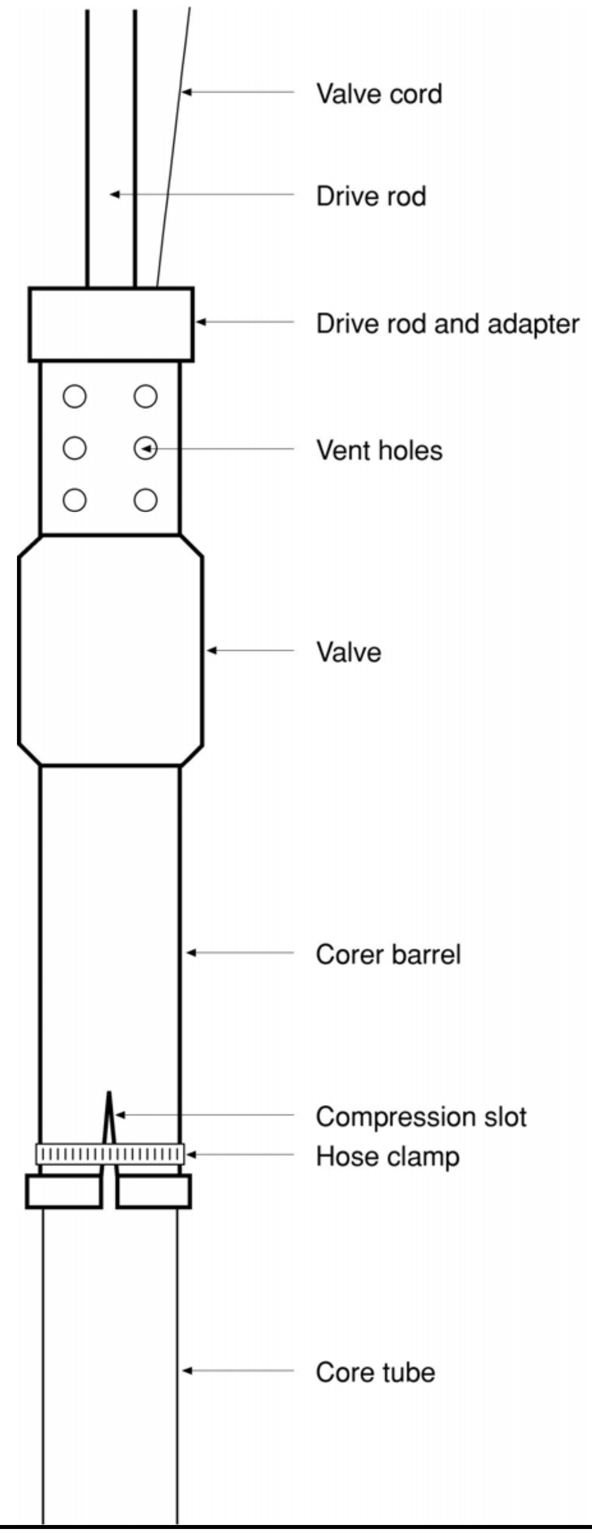


Figure 6.2.C-1 Drive rod check valve corer

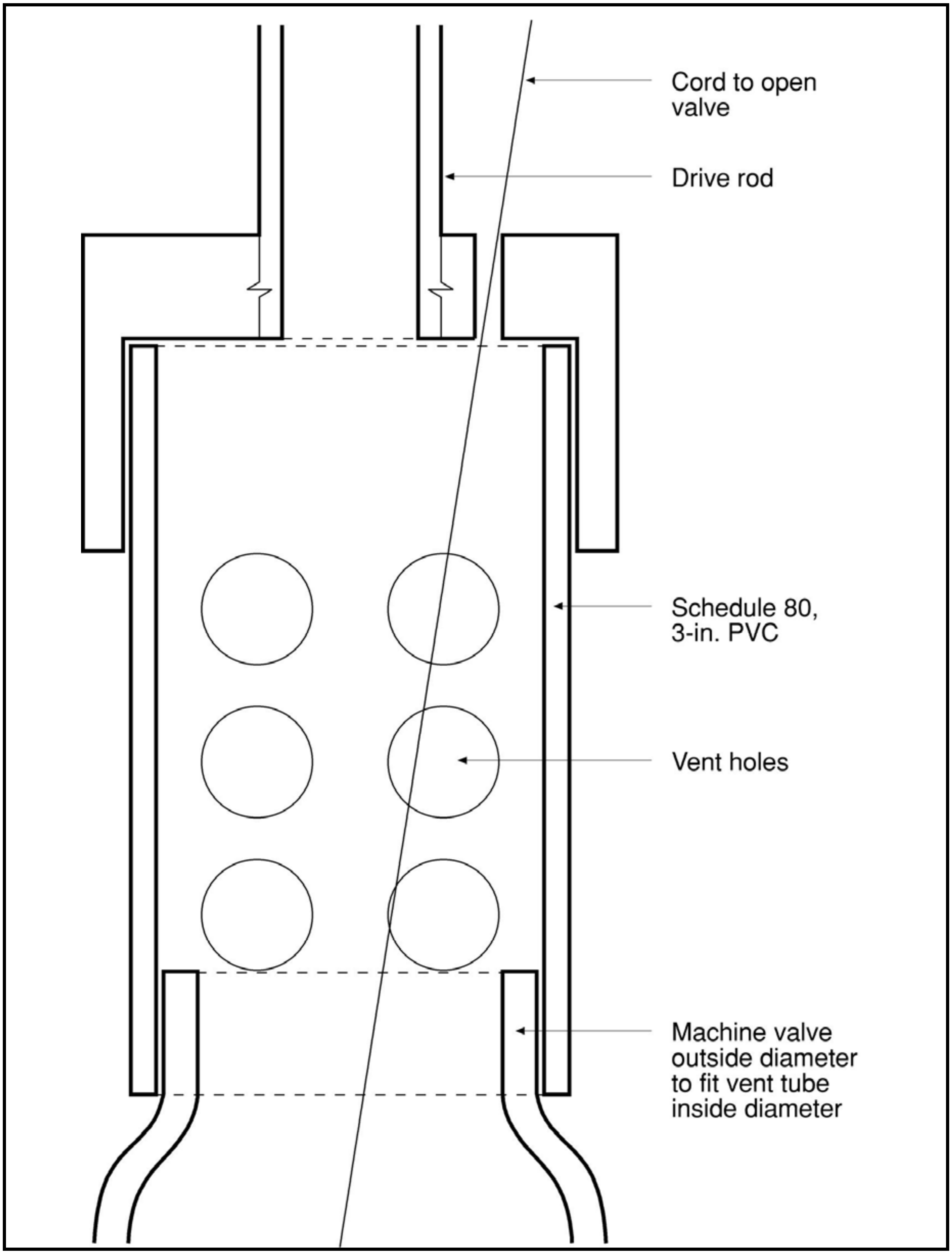


Figure 6.2.C-2 Detail of vent tube

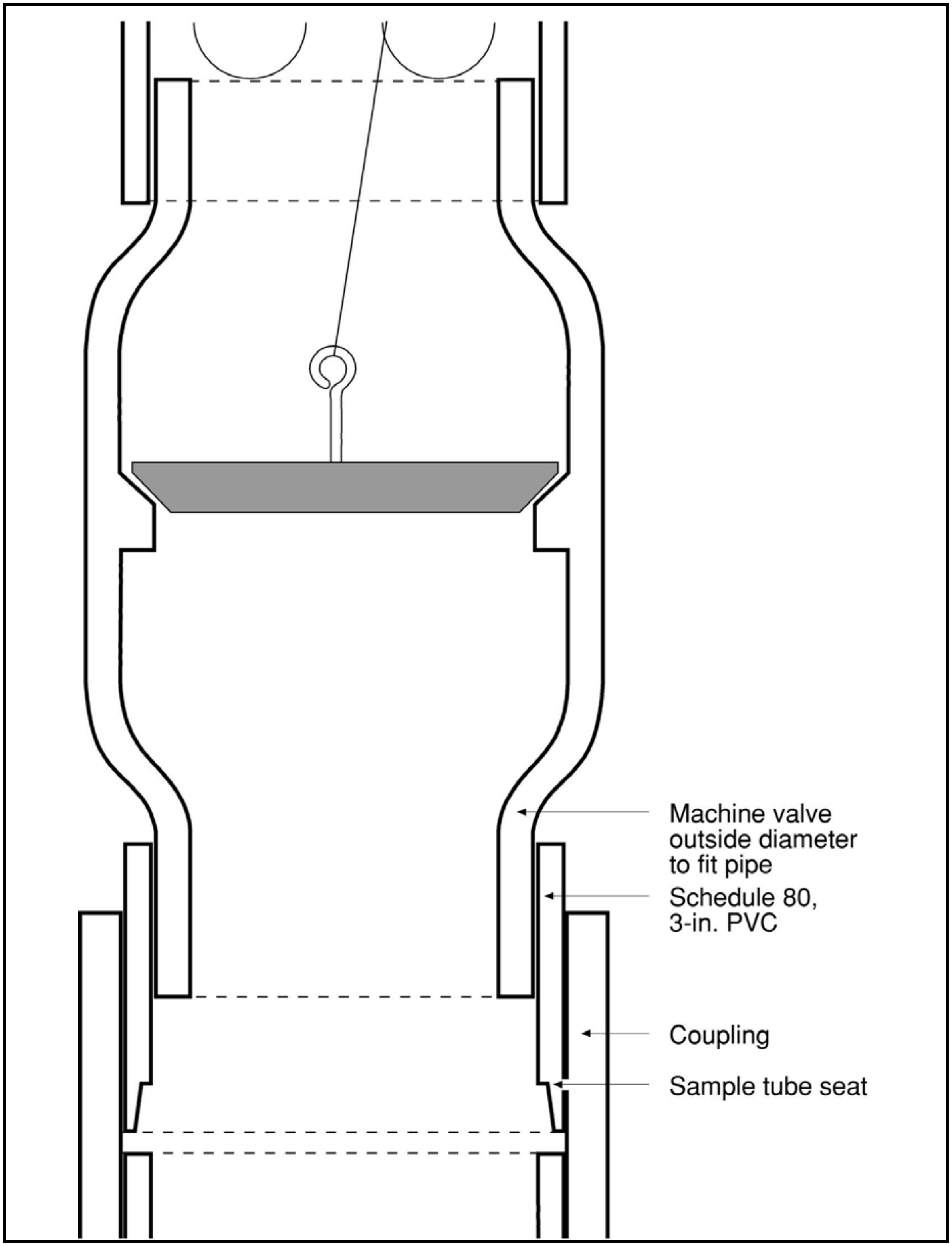


Figure 6.2.C-3 Detail of valve

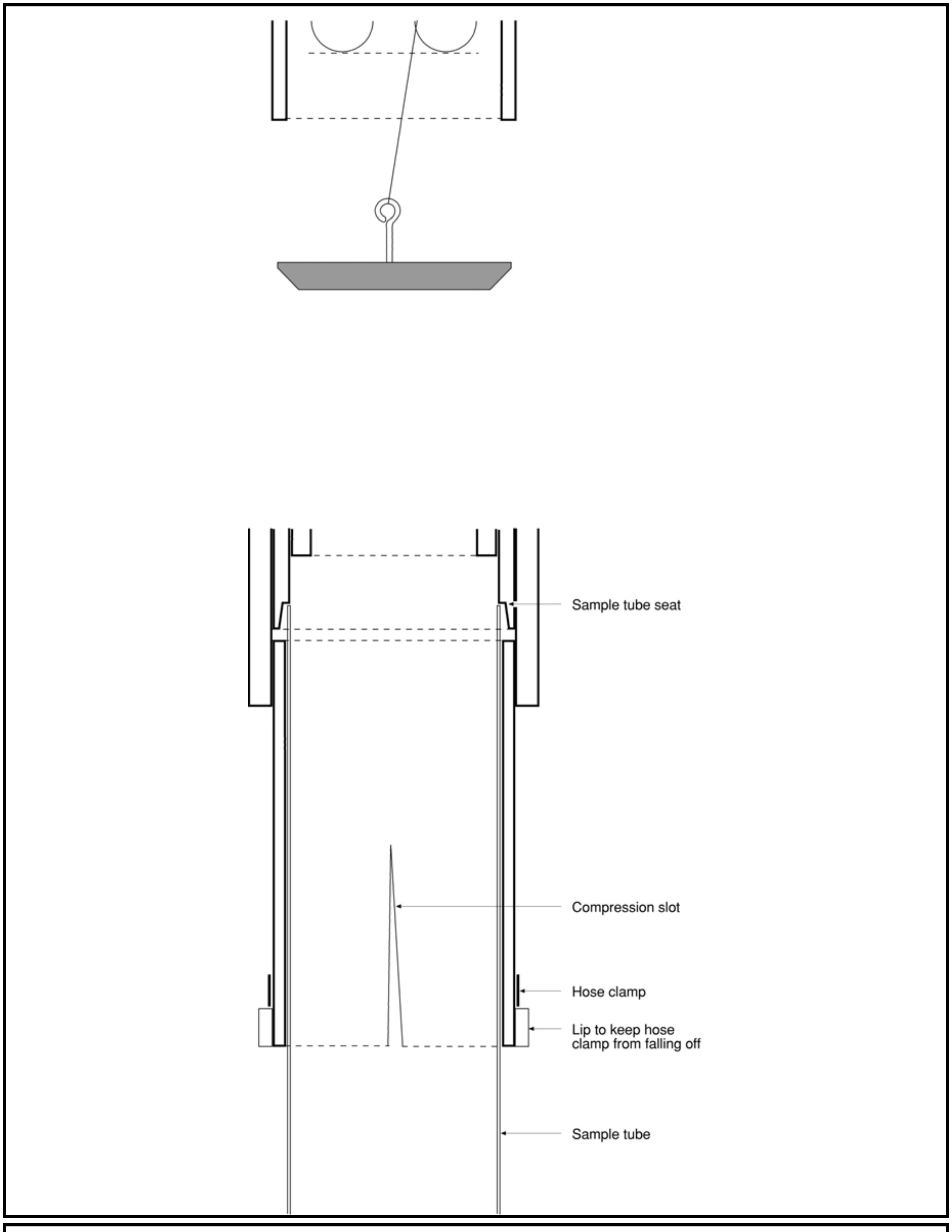


Figure 6.2.C-4 Detail of sample tube holder

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.

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.

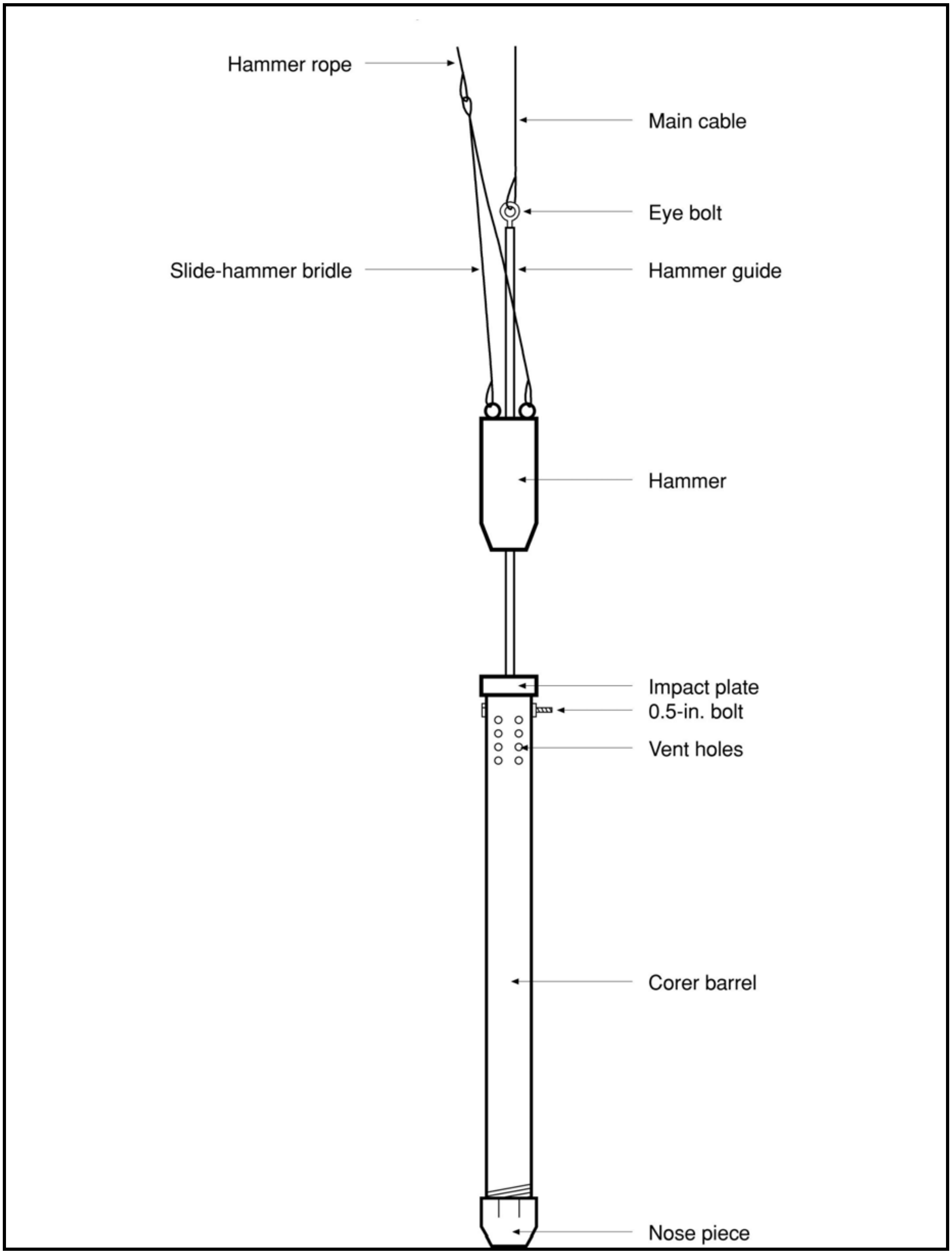


Figure 6.2.D-1 Diagram of slide-hammer corer

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*.

<u>Gravity Coring</u>

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

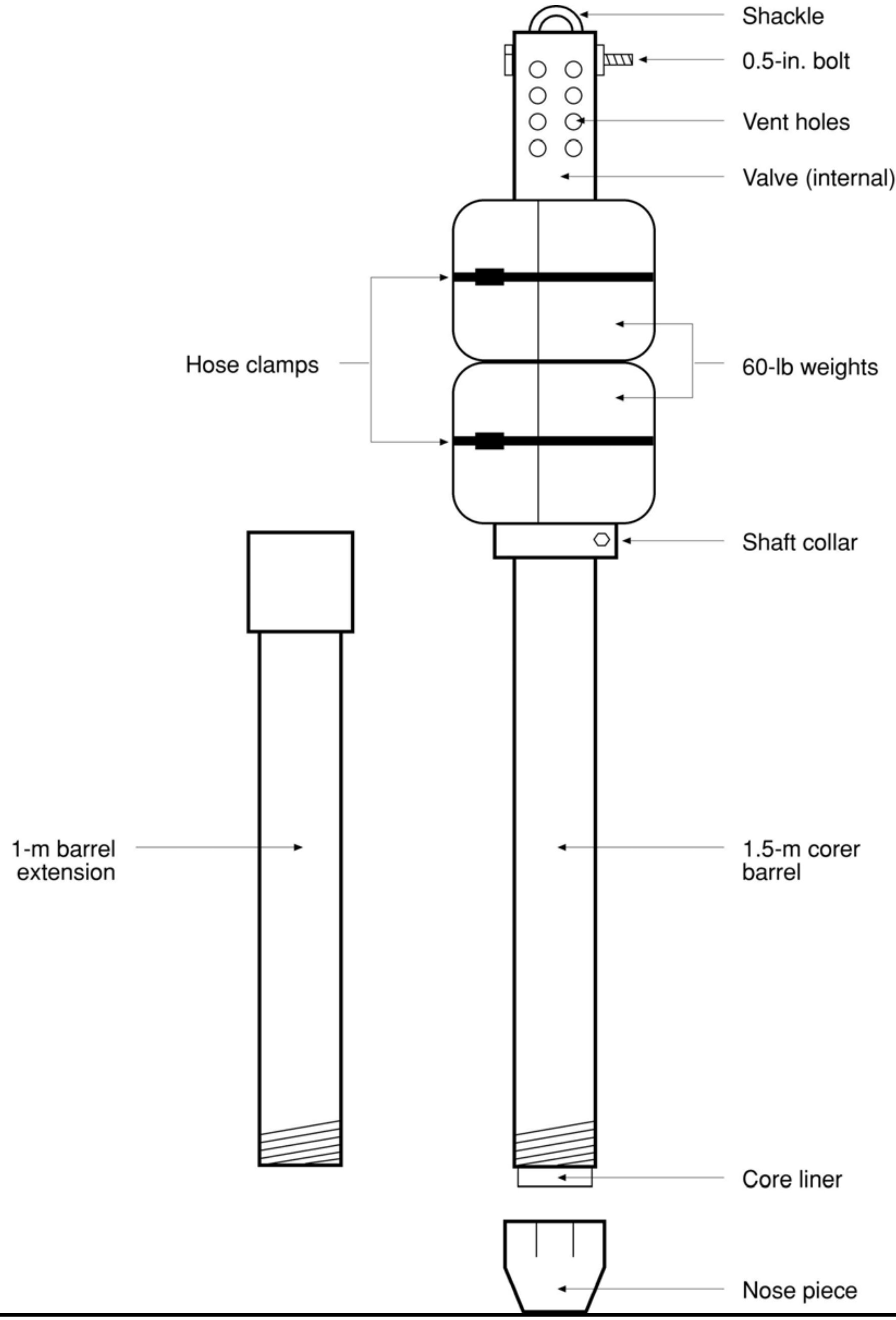


Figure 6.2.D-2 Diagram of 3-inch diameter gravity corer

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:

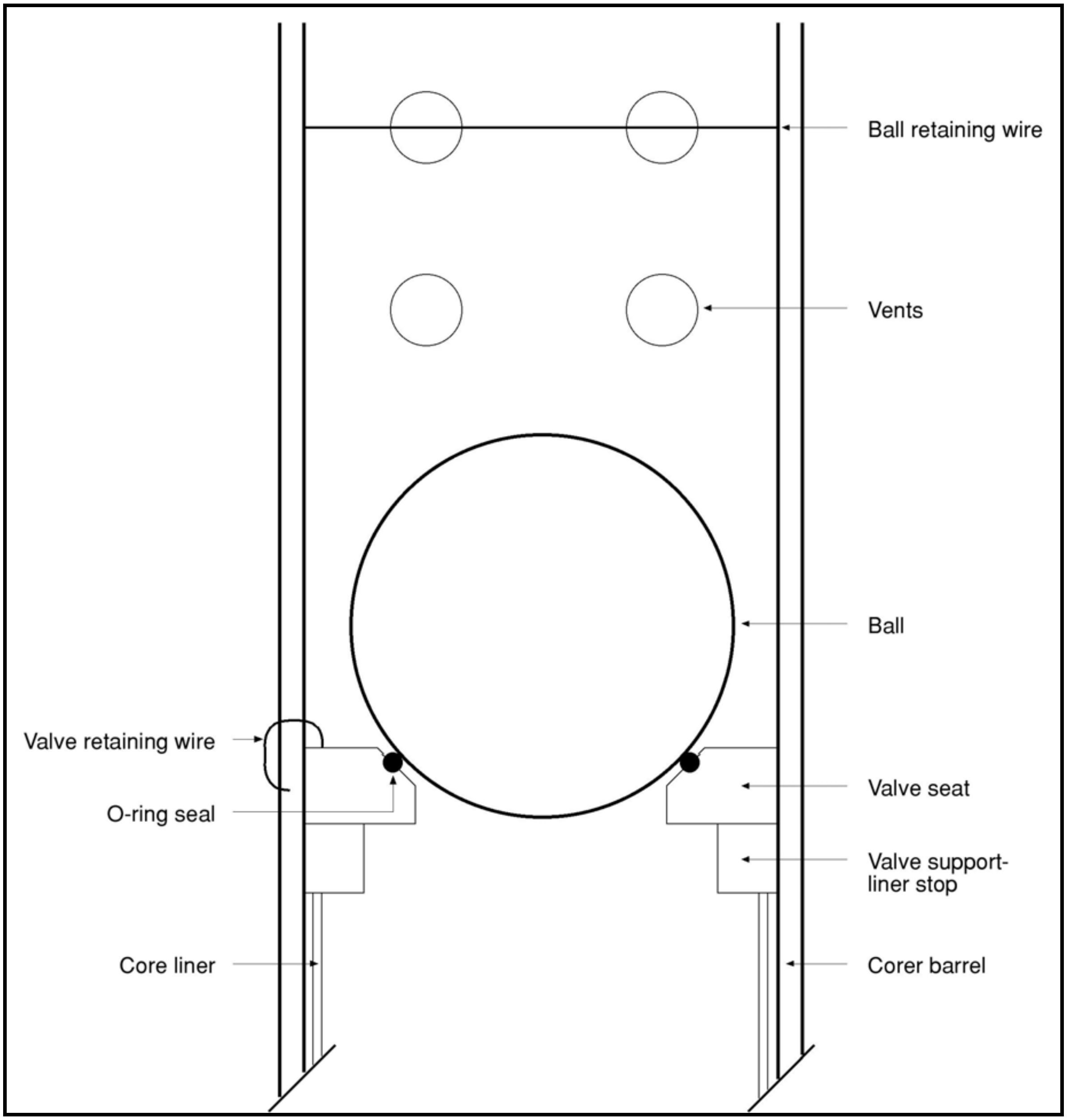


Figure 6.2.D-3 Cross section of ball valve

- **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.

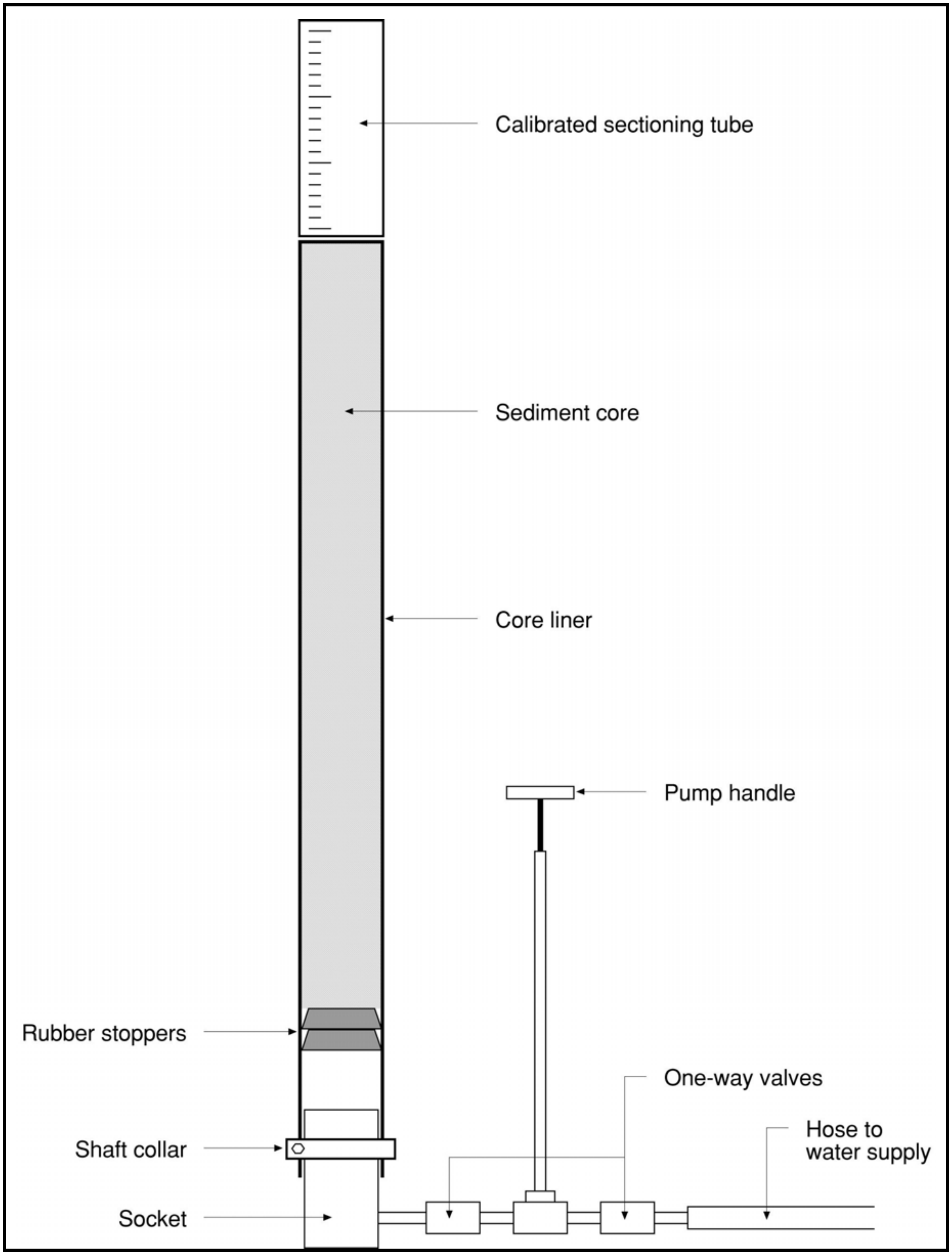


Figure 6.2.D-4 Diagram of core extruder and extrusion tube

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

Field Screening

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

Field Laboratory Method

1. Weigh approximately 100 g of the dried sediment.
2. Sieve the sediment material to <100 μm 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.

TABLE OF CONTENTS

Page

SURFACE WATER

REMEDIATION SECTION	FIELD METHOD GUIDELINE NO.: FMG 6.3
WORLDWIDE FACILITIES GROUP	EFFECTIVE DATE: NOVEMBER 20, 2001
GENERAL MOTORS CORPORATION	
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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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WORLDWIDE FACILITIES GROUP	EFFECTIVE DATE: NOVEMBER 20, 2001
GENERAL MOTORS CORPORATION	
REVISION NO.: 4	REVISION DATE: APRIL 14, 2003

TABLE OF CONTENTS

Page

GROUNDWATER SAMPLING

LIST OF FORMS
(Following Text)

REMEDIATION SECTION	FIELD METHOD GUIDELINE NO.: FMG 6.4
WORLDWIDE FACILITIES GROUP	EFFECTIVE DATE: NOVEMBER 20, 2001
GENERAL MOTORS CORPORATION	
REVISION NO.: 4	REVISION DATE: APRIL 14, 2003

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.

<u>Well Purging and Stabilization Monitoring (Typical Method)</u>

- 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.

Direct-Push Sampling Technique

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.

Sampling Techniques

- 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 ${}^oC$*	*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.

TABLE OF CONTENTS

Page

NON-AQUEOUS PHASE LIQUID (NAPL)

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.