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Revitalizing Auto Communities Environmental Response (RACER) Trust

Field Sampling Plan

Lansing Plants 2, 3 and 6 Industrial Land

Lansing, Michigan

August 26, 2011

ARCADIS

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Field Sampling Plan

Lansing Plants 2, 3 and 6
Industrial Land
Lansing, Michigan

Prepared for:
Revitalizing Auto Communities
Environmental Response (RACER) Trust

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Date:
August 26, 2011

Figures

Appendices

Acronyms and Abbreviations

COC	Chain of Custody
DNAPL	Dense Non-Aqueous Phase Liquids
DO	Dissolved Oxygen
EM	Electromagnetic
FSP	Field Sampling Plan
Ft	Feet
GPR	Ground Penetrating Radar
HSA	Hollow Stem Auger
IDW	Investigation-Derived Wastes
LIF	Laser Induced Fluorescents
LNAPL	Light Non-Aqueous Phase Liquids
LCA	Lansing Car Assembly
MDEQ	Michigan Department of Environmental Quality
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ORP	Oxidation Reduction Potential
PCB	Poly-Chlorinated Biphenyl
PPE	Personal Protective Equipment
QAC	QA Coordinator

QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
RACER	Revitalizing Auto Communities Environmental Response
RCRA	Resource, Conservation, and Recovery Act
RFI	RCRA Facility Investigation
RRD	Remediation and Redevelopment Division
SOP	Standard Operating Procedure
SOW	Scope of Work
SVOC	Semi-Volatile Organic Compound
TAL	Target Analyte List
TCL	Target Compound List
USEPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound
WWTP	Waste Water Treatment Plant

1. Introduction

This *Field Sampling Plan* (FSP) has been prepared by ARCADIS-US (ARCADIS), to support the *RCRA Facility Investigation Work Plan* (Work Plan) for data collection activities associated with Revitalizing Auto Communities Environmental Response (RACER) Trust Plants 2, 3 and 6 Industrial Land in Lansing, Michigan (the Site). A *Quality Assurance Project Plan* (QAPP) has been prepared in conjunction with this FSP, in support of the Work Plan, to provide quality assurance/quality control (QA/QC) procedures and protocols for planned field activities, as described in applicable scopes of work (SOWs) to be performed at the Site.

1.1 Site Description

Plants 2, 3 and 6 are located at 2801 West Saginaw Street, 2800 West Saginaw Street and 401 North Verlinden Street, respectively, in Lansing, Michigan. Plant 2 encompasses approximately 63 acres of land, Plant 3 encompasses approximately 104 acres of land and Plant 6 encompasses approximately 72 acres of land. The location of the Site is shown on Figure 1. A Site overview of each plant is shown on Figures 2, 3 and 4.

The buildings comprising Plant 2 were constructed between 1900 and 1910. Past Site operations have included automobile parts manufacturing, foundry operations and welding operations. Most recently, Plant 2 assembled the Chevrolet SSR. With the exception of the wastewater treatment plant (WWTP), Plant 2 ceased operations on March 17, 2006 and decommissioning activities began July 2007.

The buildings comprising Plant 3 were constructed in the 1930s. Past Site operations at Plant 3 have included stamping and electroplating bumpers, general machining of crankshafts and connecting rods, and machining, welding, and stamping of automobile parts. In May 1987, electroplating operations at Plant 3 ceased, and decommissioning activities began July 2007.

Plant 6 has been used to manufacture automobiles and automobile parts since 1921. The plant previously manufactured the bodies for the Pontiac Grand Am and Chevrolet Classic, and is currently considered part of Lansing Car Assembly (LCA). Plant 6 decommissioning began in February 2006.

1.2 Project Objectives

The primary objectives of the data collection activities are:

- Define the nature and extent of releases of hazardous wastes, hazardous substances and/or hazardous constituents in environmental media (soil, sediment, groundwater, and/or surface water) at the Site.
- Collect data and information to aid in evaluation of the risk to human health and the environment, if any, associated with releases of hazardous waste, hazardous substances and/or hazardous constituents.

1.3 Overview of Field Activities

The anticipated field activities include:

- complete soil borings using direct-push or Rotosonic drilling methods;
- complete soil borings using hollow-stem auger or Rotosonic drilling methods, for the purpose of installation of permanent groundwater monitoring wells;
- collect unsaturated soil samples, including Quality Assurance/Quality Control (QA/QC) samples, for analytical testing for Target Compound List (TCL) and select Target Analyte List (TAL) analytes;
- develop permanent and temporary monitoring wells.
- collect groundwater samples, including QA/QC samples, for analytical testing for TCL and select TAL analytes.
- provide survey control for all soil borings and monitoring wells.

ARCADIS has developed uniform standard operating procedures (SOPs) to be used by the field teams. These procedures are referenced in this FSP and included in Appendix A.

As existing ARCADIS SOPs are modified or new SOPs are developed, the updated SOPs will be used for activities covered by this FSP as appropriate.

2. Field Procedures and Activities

This section provides an overview of the field procedures to be implemented during the investigation activities at Plants 2, 3 and 6.

2.1 Sample Designation System

Each soil sample will be assigned an identifying name (sample designation). The prefix for each sample will begin with the associated plant number, P2 for Plant 2, P3 for Plant 3 or P6 for Plant 6. The root sample designation will consist of the location, followed by a suffix that provides information regarding the sampled interval and the date the sample was collected. For example, P2-SB-1(8-10)060811 would identify a sample from Plant 2 in the 8- to 10-foot depth interval, the location of soil boring SB-1 on June 8, 2011.

Each groundwater sample will be assigned an identifying name (sample designation) according to the following system. The root sample designation will consist of the name of the monitoring well by monitoring well location. This designation will be followed by a suffix that provides information regarding the sample collection date. The date will be provided in parentheses after the designation. For example, MW-1 (061011) would identify a groundwater sample collected on June 10, 2011, from monitoring well MW-1.

Duplicate field samples for both soil and groundwater samples for QA/QC purposes will be indicated by the prefix “DUP,” followed by the number of the duplicate in sequence, and then the date sampled in parentheses. For example, the tenth duplicate collected at the Site on July 1, 2011 would be labeled DUP-10(070111).

Additional sample volumes collected for matrix spike (MS) and matrix spike duplicate (MSD) analyses will be noted on the chain of custody (COC) forms, and the associated additional sample containers will be labeled with the appropriate suffix (MS or MSD) followed by the sample collection date.

Equipment rinsate blank samples will be collected when non-dedicated or non-disposable sampling equipment is used to collect samples. Equipment rinse blanks consist of laboratory-provided water that has been routed through decontaminated sampling equipment and collected into the appropriate containers. The containers will be filled in order of decreasing volatility (i.e., volatile organic compounds [VOCs] first, semivolatile organic compounds [SVOCs] second, followed by containers for the remaining analyses). Equipment rinsate blank samples will be assigned as follows: the prefix “EB” followed by a dash and a numerical designation beginning with 01, which will be assigned sequentially in the field, and then the date sampled in parentheses. For example, EB-10 (070811) would identify the tenth equipment blank sampled on July 8, 2011.

Similarly, trip blank samples will be sent for analysis at the laboratory. One trip blank per cooler will be sent to the laboratory for analysis of TCL VOCs. Trip blanks will be noted on the COC forms, and the associated additional sample containers will be labeled with the appropriate prefix “TB” followed by a dash and a numerical designation beginning with 01, which will be assigned sequentially in the field, and then the date sampled in parentheses. For example TB-01 (083011) would identify the first trip blank collected on August 30, 2011.

2.2 Field Documentation

Field personnel will provide comprehensive documentation covering all aspects of field sampling, field analysis and sample COC. This documentation will constitute a record that will allow reconstruction of field events to aid in the data review and interpretation process. All documents, records and information relating to the performance of the fieldwork will be retained in the project file.

The various forms of documentation to be maintained during field procedures include:

- *Daily Documentation* – A field logbook will be kept, consisting of a waterproof, bound notebook that will record all Site activities. All logbook entries will be made with permanent ink. Any additions or corrections to the field logbook information will be single-lined out, dated, and initialed. Field logbooks will be filled out in accordance with the Field Logbook SOP found in Appendix A.

- *Sampling Information* – Detailed notes will be made as to the exact Site of sampling, physical observations, personnel present and weather conditions (as appropriate).

- *Sample Chain of Custody* – COC forms will be handled in accordance with the COC Sampling, Handling and Shipping SOP.

- *Field Equipment, Calibration, and Maintenance Logs* – To document the calibration and maintenance of field instruments, calibration and maintenance logs will be maintained for each piece of field equipment that is not factory-calibrated. Field instrument calibration will be documented in accordance with the calibration manuals included with the sampling equipment.

Information collected in the field through visual observation, manual measurement, or field instrumentation will be recorded in field notebooks or data sheets, or on prepared forms. Such data will be reviewed by the appropriate task manager for adherence to the specific requirements associated with the investigation requirements and for consistency. Concerns identified as a result of this review will be discussed with field personnel, corrected if possible and, as necessary, incorporated into the data evaluation process.

Where appropriate, field data forms and calculations will be processed and included in appendices to investigation reports. The original field logs, documents and data reductions will be maintained with the project file at the ARCADIS office in Brighton, Michigan.

2.3 Soil Boring Installation and Sampling Procedures

Soil borings will be completed using hollow-stemmed auger (HSA) with split-spoon samplers, Rotosonic drilling methods, or to the extent feasible, direct push (Geoprobe) technology. The borings will be abandoned after sampling according to the ARCADIS SOP for Soil Drilling and Sample Collection in Appendix A. Soil samples for stratigraphic definition will be collected continuously as described in the above referenced SOP.

If boring refusal is encountered, a new boring will be initiated and the previous boring abandoned. Any indication of petroleum observed during the drilling and monitoring well installation will be noted on the boring logs and an Oil-n-Soil™ Shake test will be completed to evaluate the presence of Non-Aqueous Phase Liquids (NAPL). If during the investigation there are indications of Dense NAPL (DNAPL), the DNAPL Contingency Plan SOP (Appendix A) will be followed.

A PID will be used to obtain headspace readings of each sample interval, as well as to provide health and safety monitoring for field personnel during the drilling program, in accordance with the SOP for PID Air Monitoring and Field Screening included in Appendix A.

2.4 Lithologic Characterization

To provide a vertical profile of the subsurface conditions, soil samples will be collected continuously for visual classification using split-spoon, Rotosonic, or direct push sampling methods from the ground surface to the bottom of each boring. Lithologic characterization of soils will be performed in accordance with the ARCADIS SOP for Soil Description located in Appendix A.

Visual descriptions of the subsurface lithology will be evaluated to assess the extent to which the geologic unit may influence migration of NAPL and dissolved-phase constituents at the Site. The visual descriptions will also provide a vertical profile of the subsurface. This information will be used to prepare detailed boring/well logs and geologic cross sections of the subsurface area. Specific details in the lithologic descriptions normally include the following:

2.5 Monitoring Well Installation Procedures

Monitoring wells (permanent and temporary) will be installed and developed in accordance with the ARCADIS SOP for Monitoring Well Installation located in Appendix A. However, the temporary wells will not be completed with a surface cover and will consist of PVC well materials. Once sampled, temporary well will be abandoned (Appendix A). Monitoring wells will generally be screened to straddle the encountered water table. However, if permeable soil layers are present below the water table, it may be appropriate to screen the monitoring well across these layers. In addition, although deeper wells are not anticipated to be installed during the initial drilling mobilization, it is likely that for future mobilizations, deeper wells (paired with shallow wells) will be installed.

In some cases it may be necessary to add drilling fluid to borings in which wells will be installed. If the occurs, a visible tracer will be added to the drilling fluid to better track when the fluid is removed prior to well sampling. The use of the visible tracer will follow the methods presented in Appendix A.

2.6 Geophysical Survey Procedures

Geophysical survey methods, such as ground penetrating radar (GPR) may be used to verify documented or suspected locations of contaminant sources in accordance with ARCADIS SOP. In addition, a geophysical survey may also be conducted to locate buried utilities that may be serving as conduits for the movement of LNAPL and dissolved constituents in the groundwater across the Site. A geophysical survey may also serve as a guide to assist ARCADIS in determining the best locations for temporary monitoring wells and permanent monitoring wells designed to monitor the direction(s) of groundwater flow at the Site. If the geophysical survey results in the field appear to be consistently inconclusive, the survey would be terminated.

GPR measures ground resistivity. Subsurface features can be observed because the resistivity of materials varies laterally and with depth. GPR systems consist of a transceiver (the antenna), cables, and electronics package, including a printer, and a power source. As the transceiver is pulled across the ground, a series of high frequency radio wave pulses are radiated downward into the subsurface. Some of the wave pulses are reflected back to the surface when they encounter a material having different electrical properties than the propagating media (like soil). An example of such a reflector would be a steel pipe buried in a sandy soil. This procedure relates to the operation of the two most common types of electromagnetic (EM) survey equipment, the EM31 and EM34. The EM31 can read to a depth of approximately 16 ft, whereas the EM34 can read to a depth of approximately 60 ft. Over this depth the instrument averages the resistivity readings. This procedure can be adopted for use with other EM equipment based on manufactures operating procedures.

2.7 Medium-Specific Procedures and Sampling Methods

Procedures for the various data collection tasks are summarized in the following subsections. Detailed field procedures are included in Appendix A. Appendix A also contains other investigation-related procedures, such as cleaning equipment; packing, handling and shipping samples; executing and monitoring sample COC; and obtaining field measurements.

2.7.1 Soil Sampling Methods

Procedures for collecting soil samples for chemical analysis are included in the ARCADIS SOP for Soil Drilling and Sampling (Appendix A) as well as the Michigan Department of Environmental Quality (MDEQ) Remediation and Redevelopment Division (RRD) Memorandum 2, Sampling and Analysis (Op Memo 2) (MDEQ, 2004).

Soil samples will be selected for analytical characterization from samples collected during installation of the soil boreholes as stated in the applicable SOP. The soil samples will be analyzed TCL VOCs, TCL SVOCs, PCBs, and select TAL metals. See Table 1 of the RFI Work Plan for more information on sample analysis. Field QC and MS/MSD samples will be collected and analyzed in accordance with the QAPP.

PID readings will be recorded throughout the length of the soil boring at 2 foot intervals.

2.7.2 Monitoring Well Development

Each monitoring well installed, permanent or temporary, will be allowed to sit for at least 24 hours after installation. Well development will be completed according to the methods described in Appendix A.

2.7.3 Groundwater Elevation and Non-Aqueous Phase Liquids (NAPL) Measurements

Water-level measurements will be collected from each monitoring well in accordance with procedures set forth in the ARCADIS SOP for Water-Level and NAPL Thickness Measurement Procedures and the interface-probe will be taken to the bottom of the well to investigate for potential presence of DNAPL. Measurements will be collected with a water-level probe or an oil/water interface probe, as appropriate, and measured to the nearest 0.01 foot (ft). Water levels will be converted to elevations using the surveyed measurement point (i.e., top of casing) elevations.

The water-level measurements will be used to calculate groundwater elevations and to estimate groundwater flow direction.

2.7.4 NAPL Sampling Methods

Based on the operations at the Site and the wastes managed, sampling of NAPL (LNAPL and DNAPL) may be warranted. If LNAPL sampling is performed, the ARCADIS SOP for LNAPL Fluid Sample Collection will be followed (Appendix A).

If DNAPL is suspected to be present or is encountered the ARCADIS SOP DNAPL Contingency Plan will be followed (Appendix A). The DNAPL Contingency Plan will also be followed during future site investigations that involve the installation of deep bedrock groundwater monitoring wells.

2.7.5 Groundwater Sampling and Analysis

PID readings of the well headspace of each monitoring well will be recorded in the field log book or monitoring well log.

Groundwater samples will be collected from existing and newly installed monitoring wells and from temporary monitoring wells. When collecting samples from existing and newly installed monitoring wells low-flow sampling techniques will be used. This includes using a peristaltic pump, using the sampling procedures described in the SOP for Low-Flow Groundwater Purging and Sampling.

Groundwater will be purged and groundwater parameter readings will be recorded every 5 minutes to verify stabilization. The parameters should be stabilized for at least 3 consecutive readings before a sample is collected. One representative groundwater sample from each monitoring well will be collected in the field and measured for dissolved oxygen (DO), temperature, specific electrical conductance, turbidity, pH, and oxidation-reduction potential (ORP).

When collecting groundwater samples from temporary monitoring wells the temporary well will be developed according to the ARCADIS SOP Monitoring Well Development, located in Appendix A. After completion of the well development a grab water sample will be collected using a peristaltic Pump with disposable tubing.

Groundwater samples will be analyzed following the MDEQ's Op. Memo 2 – Attachment 5 guidelines as established in the Work Plan. Field QC samples will be collected and analyzed in accordance with the QAPP (ARCADIS, August 2011).

2.7.6 Free Product Sampling and Analysis

Investigating for Free Product involves techniques that are similar to standard subsurface investigations or sediment investigations. However, since one of the primary objectives of Free Product investigations is to delineate the free product, it is necessary to use tools that are specifically designed to detect Free Product. Some Free Product NAPLs, such as coal tar and creosote, are readily visible in soil or sediment samples, or fluid samples obtained from wells. These types of Free Products have an obvious black appearance and pungent odor. Other types of Free Products, however, are colorless. Many pure chlorinated solvents fit this description. To assist in identifying the presence of relatively light-colored or clear NAPLs, hydrophobic dyes are used.

The presence of Free Product will be documented through the use of Oil-In-Soil ™ Test Kits. This method follows the MDEQ Effective Solubility Workgroup recommended alternative field methods. The shake testing is conducted on select soil samples based on field observations including visual, olfactory, and PID readings and previous soil analytical results. The shake tests consist of placing the soil sample in a container that contains a hydrophobic dye (Red Azo Dye) that is soluble in most petroleum compounds. The dye stains petroleum products red if Free Product is present in the soil.

Oil-In-Soil ™ Test Kits described above will document the presence of free product. To help delineate the extents of Free Product Laser-Induced Fluorescence (LIF) investigations may be completed. LIFs allow rapid and highly adaptable assessment of Free Product impacts. LIF technology is based on fluorescent properties of polyaromatic hydrocarbon (PAH) compounds, which are found in the complex hydrocarbon mixtures that make up petroleum products. When PAHs are excited by the focused energy of a pulsed laser, they release photons that can be observed using a fluorometer. The magnitude (strength) of the fluorescence is related to the Free Product saturation within the aquifer matrix.

Petroleum constituents present in groundwater in dissolved-phase are not sensed by LIF. This specificity is an advantage that allows for very accurate vertical and horizontal characterization of gross contamination in source areas.

2.8 Monitoring Well Abandonment

Select monitoring wells installed during previous investigations may be abandoned as part of phase II, or later, activities. Monitoring well abandonments will be completed in accordance with MDEQ requirements and performed as described in ARCADIS SOPs located in Appendix A.

2.9 Equipment Cleaning

Prior to collecting any samples for laboratory analyses, all reusable sampling equipment and tools or dedicated equipment will be thoroughly cleaned before and after use in accordance with the ARCADIS SOP for Field equipment Decontamination.

Per the MDEQ request, effective August 18, 2011 field equipment blanks will be collected at least once per week from the drill rig cores after decontamination and analyzed for TCL VOCs, TCL SVOCs, TAL Metals and PCBs.

2.10 Waste Handling

Water associated with sample collection and handling, as well as excess waters from well development and sample equipment cleaning, will be placed in drums or other appropriate containers, stored on-Site, and labeled appropriately. The material contained within the drums will be analyzed for waste characterization parameters by the analytical laboratory prior to disposal. Other waste materials developed as a result of sampling activities, such as personal protective equipment (PPE), will be placed in drums and stored on-Site. An inventory of drums containing waste materials will be kept by the supervising geologist.

Investigation-derived waste (IDW), including soil cuttings generated as a result of drilling and sampling, will be placed in drums or other appropriate containers (e.g., roll-off boxes), stored on-Site, and labeled by the supervising geologist. An inventory of all IDW generated during the investigation will be kept by the field QA officer.

Disposal of IDW will be facilitated through third-party carriers and disposal facilities.

3. Field Instruments

All field screening equipment will be calibrated immediately prior to each day's use and more frequently if required. Information regarding calibration and use of various field instruments will be provided with each piece of equipment. The calibration procedures will conform to the manufacturer's standard instructions. Records of all instrument calibration will be maintained by field personnel, and copies of the instrument manuals will be maintained on-Site with each corresponding piece of equipment.

3.1 Portable Photoionization Analyzer

The photoionization analyzer will be a Photovac MicroTip (or equivalent) (Photovac), equipped with a 10.6 eV lamp. The Photovac is capable of ionizing and detecting compounds with an ionization potential of less than 10.6 eV. Calibration will be performed according to the procedures outlined in user's manual.

3.2 Oil Interface Probe

The thickness of NAPL, if present in monitoring wells, will be measured using an oil interface probe. The interface probe will be checked once to a standard to assess if the meter has been correctly calibrated by the manufacturer or vendor. If the markers are incorrect, the probe will be sent back to the manufacturer or vendor.

3.3 Groundwater Field Parameter Measurements

All groundwater samples will be analyzed for field parameters. The groundwater will be collected using a flow through cell, equipped with meters to continuously read pH, specific conductivity, dissolved oxygen (DO), oxidation reduction potential (ORP), and temperature. Each meter will have separate calibration solution provided with the equipment and will be calibrated according to manufacturer's instructions.

3.3.1 pH Meter

The pH of the groundwater will be measured with a pH meter. The meter will be calibrated at the start of each day of use, and after very high or low readings as required by this plan. National Institute of Standards and Technology traceable standard buffer solutions that bracket the expected pH range will be used. The standards will most likely be a pH of 4.0, 7.0, and 10.0 standard units. The pH calibration and slope knobs will be used to set the meter to display the value of the standard being checked. The calibration data will be recorded on the calibration log or in the field logbook.

3.3.2 Specific Conductivity Meter

Specific conductivity will be measured with a specific-conductivity meter. Calibration checks using the appropriate conductivity standard for the meter will be performed at the start of each day of use, and after very high or low readings, as required by this plan. Successive readings must be within five percent to be acceptable. The calibration data will be recorded on the calibration log or in the field logbook.

3.3.3 Dissolved Oxygen (DO) Meter

DO will be measured through a DO meter, which will be calibrated, and the condition of the DO sensor will be checked at the start of each day of use. Calibration and maintenance of the DO meter will be conducted in accordance with the manufacturer's specifications. The calibration data will be recorded in the calibration log or the field logbook.

3.3.4 Oxidation-Reduction Potential (ORP) Meter

The ORP meter will be calibrated at the start of each day of use. Calibration and maintenance of the ORP meter will be conducted in accordance with the manufacturer's specifications. The calibration data will be recorded in the calibration log field logbook.

3.3.5 Groundwater Level Meter

Groundwater elevation will be measured with a water-level meter. The water-level cable will be checked once to a standard to assess if the meter has been correctly calibrated by the manufacturer or vendor. If the markers are incorrect, the probe will be sent back to the manufacturer or vendor.

3.3.6 Turbidity Meter

Groundwater turbidity will be measured using a turbidity meter. The turbidity meter will be calibrated daily prior to use. Calibration and maintenance will be conducted in accordance with the manufacturer's specifications. Calibration and maintenance information will be recorded in the calibration log or field logbook.

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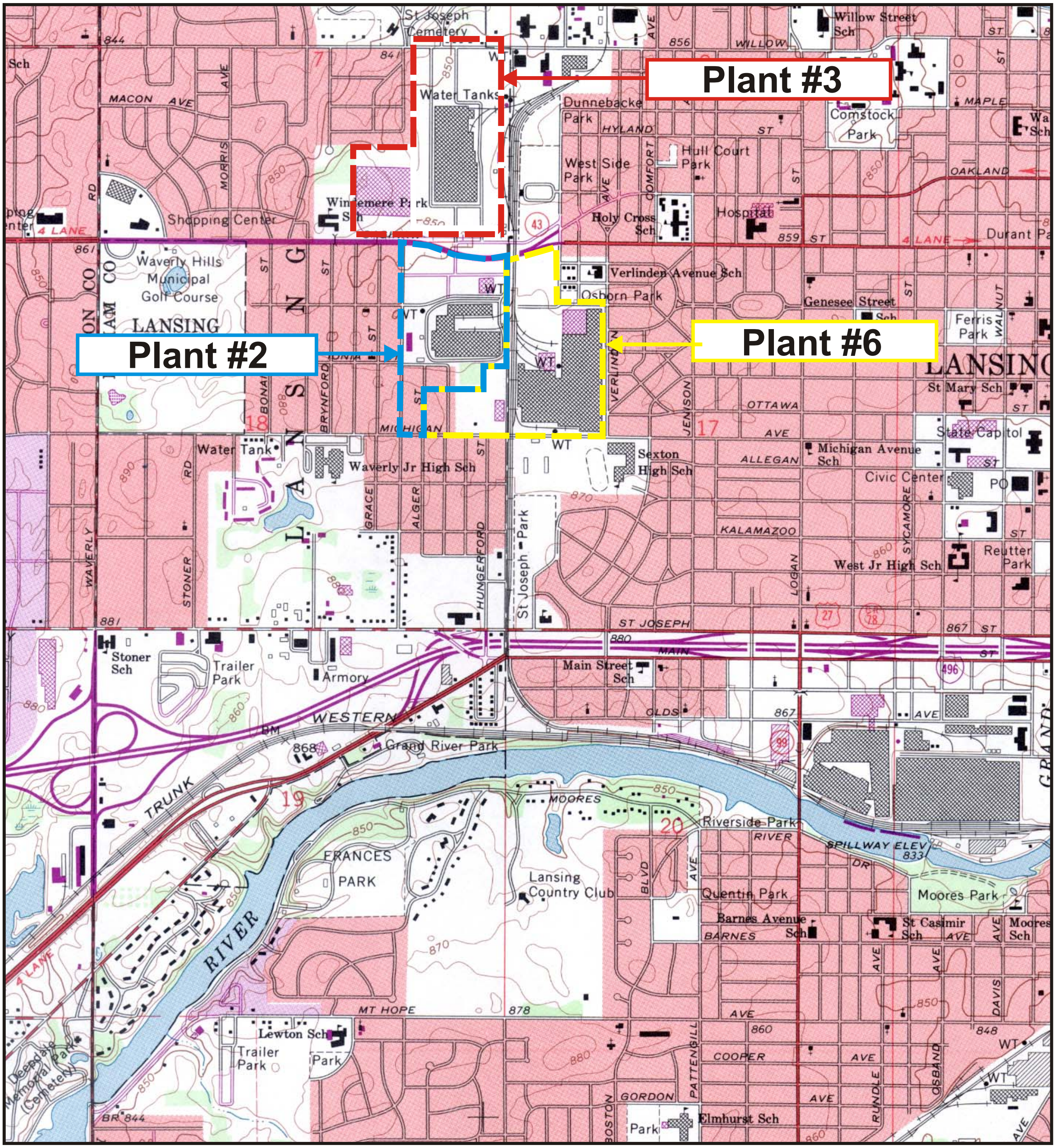
Figures



REFERENCE: BASE MAP SOURCE: USGS 7.5 MIN. QUAD., LANSING SOUTH, MICHIGAN, 1965.

2000' 0 2000'

Approximate Scale: 1" = 2000'

Area Enlargement

RACER TRUST
LANSING, MICHIGAN
RFI WORK PLAN - PLANTS 2, 3, & 6

SITE LOCATION MAP

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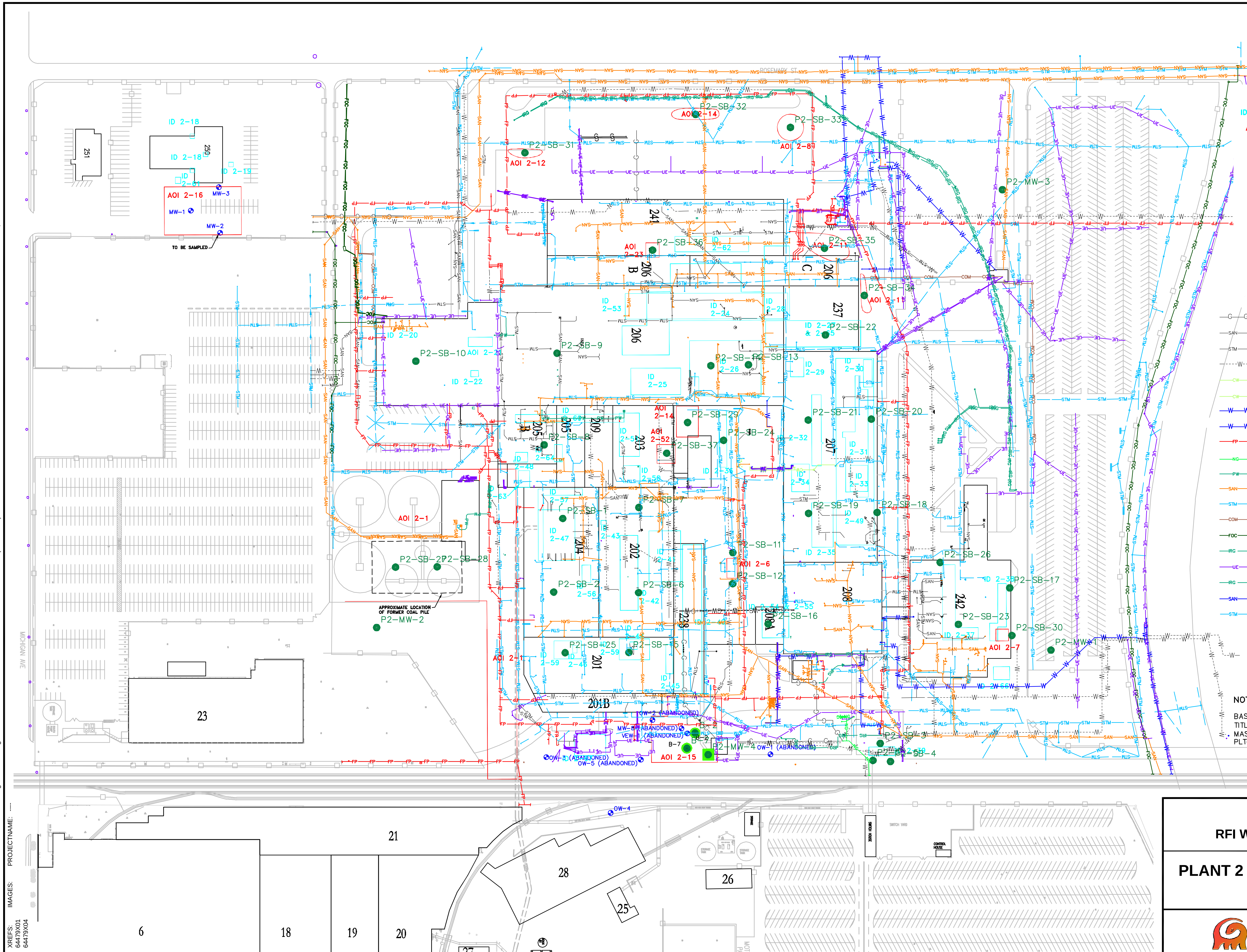
FIGURE
1

08/26/2010 SYR-141ENV-DJHOWES
B0064479/2010/00001/CDR/64479N02.CDR



LEGEND:

ID 2-18	MISCELLANEOUS ITEMS
AOI 2-7	AREA OF INTEREST (AOI)
229	BUILDING NUMBER
	APPROXIMATE PROPERTY BOUNDARY
	BUILDING LINE
	COLUMN LINE
	RAILROAD
	PROPOSED SOIL BORING
	PROPOSED WELL CLUSTER LOCATION OF OVERBURDEN MONITORING WELLS
	MONITORING WELL
	PROPOSED LOCATION FOR RE-OCCUPATION
	PROPOSED SOIL BORING LOCATION TO BE CONVERTED INTO A MONITORING WELL
G	ABNGAS
SAN	ABNSAN
STM	ABNSTM
W	ABNWATER
CW	C-CTWR
CW	C-CTWS
W	C-DOMW-SERVICE
W	C-DOMW-UNDR
FP	C-FIRE-UNDR
NG	C-NGAS-UNDR
PW	C-PWSR-UNDR
SAN	C-SANR-UNDR
STM	C-STRM-UNDR
COM	E-SITE-COMM-UNDR
FOC	E-SITE-FIBR-UNDR
IRG	E-SITE-POWR-IRRG
UE	E-SITE-POWR-UNDR
IRG	L-IRRG-PIPE
SAN	M-SANR-PIPE
STM	M-STRM-PIPE

NOTE:

BASE MAP SUPPLIED BY GM, FROM A FIGURE TITLED "LANSING CAR ASSEMBLY BODY PLANT MASTER UNDERGROUND UTILITY DRAWING", FILE NO. PLT6MASTER-UNDERGROUND-UTILITIES.DWG.

0 200'
GRAPHIC SCALE

RACER TRUST
LANSING, MICHIGAN
RFI WORK PLAN - PLANTS 2, 3, & 6

PLANT 2 MISCELLANEOUS ITEMS AND AOI'S

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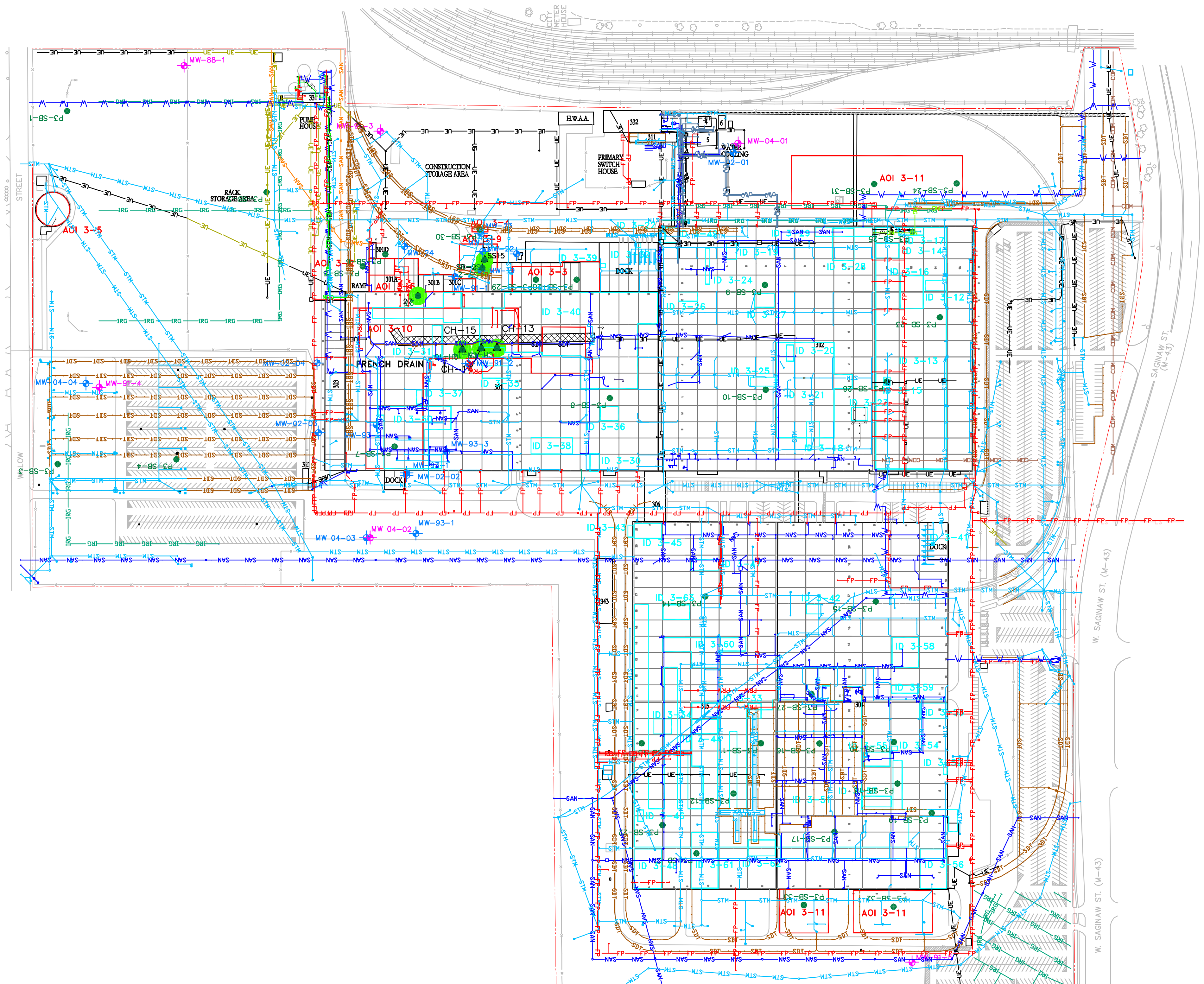
FIGURE
2



LEGEND:

- AOI 3-4 — AREA OF INTEREST (AOI)
- ID 3-1 — MISCELLANEOUS ITEMS
- 301 — BUILDING NUMBER
- APPROXIMATE PROPERTY BOUNDARY
- BUILDING LINE
- COLUMN LINE
- RAILROAD
- PROPOSED SOIL BORING
- OVERBURDEN MONITORING WELL
- BEDROCK MONITORING WELL
- PROPOSED LOCATION FOR RE-OCCUPATION
- —W—W—W— ABNWATER
- —UE—UE—UE— CECUN
- —W—W—W— CITY_WATER
- —COM—COM—COM— COMMUNICATION
- —CON—CON—CON— CONDENSATE
- —CW—CW—CW— COOLING_WATER
- —SAN—SAN—SAN— CSSUN
- —SDT—SDT—SDT— DRAIN_TILE
- —IRG—IRG—IRG— E-SITE-POWR-IRRG
- —UE—UE—UE— ELECT_PLANT
- —FP—FP—FP— FIRE_SPRINK
- —IRG—IRG—IRG— LAWN_SPRINK
- LIGHT
- —LS—LS—LS— LIR
- —SAN—SAN—SAN— M-SANR-PIPE
- —STM—STM—STM— M-STRM-PIPE
- —NG—NG—NG— NATURAL_GAS
- —SDT—SDT—SDT— PERF_DRAIN_TILE
- —PRW—PRW—PRW— PROCESS
- —SAN—SAN—SAN— SAN-ABAND
- —SEM—SEM—SEM— STEAM
- —W—W—W— TWP_WATER
- UNKNOWN
- —WSO—WSO—WSO— WASTE_OIL

NOTES:

1. BASE MAP INFORMATION BASED ON INFORMATION PROVIDED BY URS CONSULTANTS, INC. FROM MAPS ENTITLED "ANALYTES DETECTED IN GROUNDWATER – 4/94 (ug/L)", DATED APRIL, 1994, AND "SOIL BORING LOCATIONS, GM LAD PLANT NO. 3, BLDG. NO. 301C" (UNDATED); BY EDI ENGINEERING & SCIENCE FROM MAPS ENTITLED "TOTAL CHROMIUM CONCENTRATION HORIZ. EXTENT OF CHROMIUM IMPACT" DATED APRIL, 1990, "BORING AND CROSS-SECTION LOCATION MAP", DATED JUNE, 1989, "SOIL BORING LOCATIONS INSIDE OF THE PLANT", DATED JUNE, 1989, "LOCATION OF FRENCH DRAIN", DATED JUNE, 1989, AND "SOIL SAMPLING LOCATIONS", DATED JUNE, 1989, AND BY ENVIRONMENTAL SERVICES DIVISION FROM FIGURE ENTITLED "STORAGE TANK #12" DATED JUNE, 1990.
2. ALL LOCATIONS ARE APPROXIMATE

0 150' 300'
GRAPHIC SCALE

RACER TRUST
LANSING, MICHIGAN
RFI WORK PLAN - PLANTS 2, 3, & 6

PLANT 3 MISCELLANEOUS ITEMS AND AOIs

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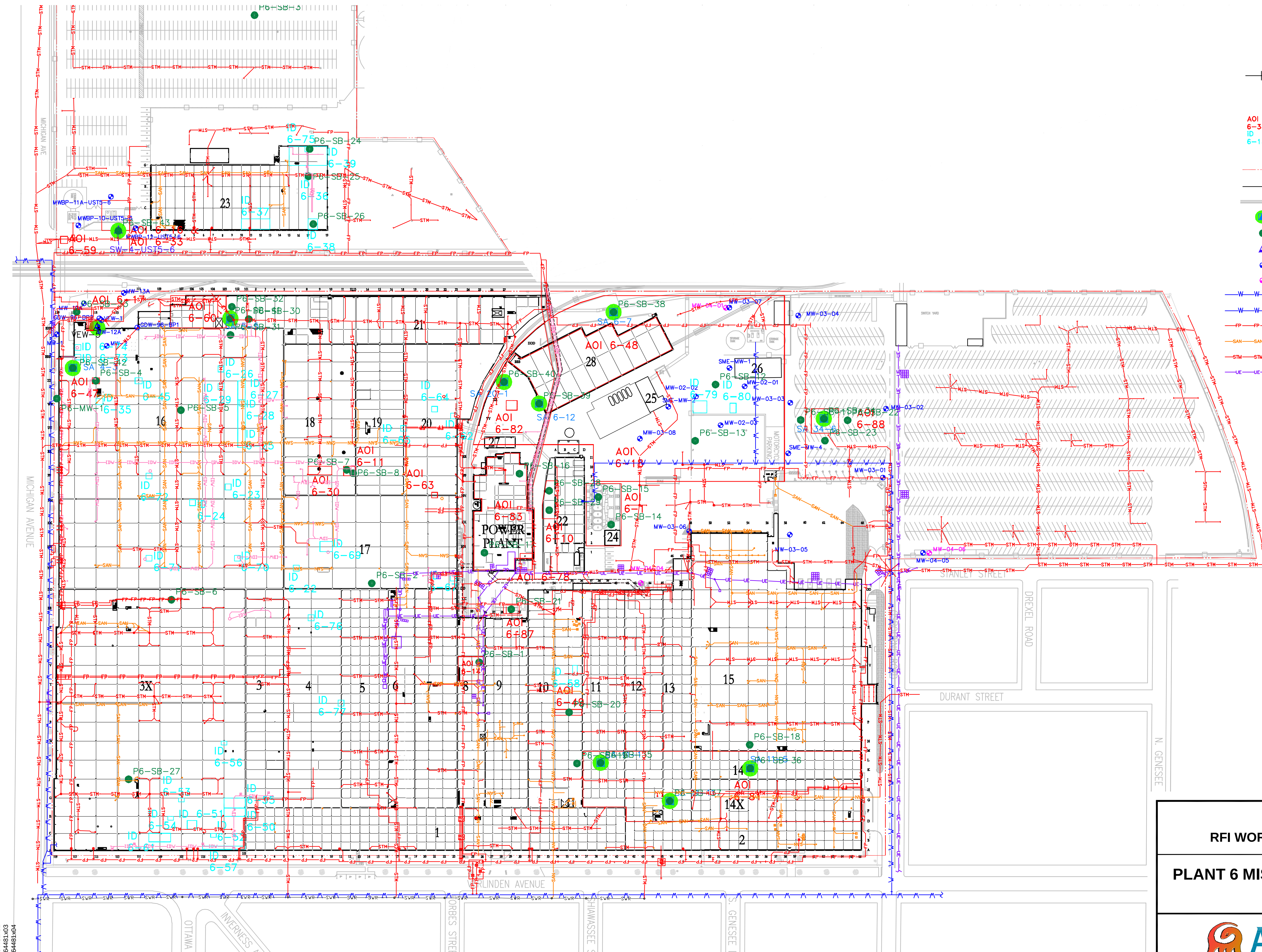
FIGURE
3



LEGEND:

AOI 6-34	AREA OF INTEREST (AOI)
ID 6-14	MISCELLANEOUS ITEMS
15	BUILDING NUMBER
	APPROXIMATE PROPERTY BOUNDARY
	BUILDING LINE
	RAILROAD
	PROPOSED LOCATION FOR RE-OCCUPATION
	PROPOSED SOIL BORING LOCATION
	PROPOSED OVERBURDEN MONITORING WELL CLUSTER
	OVERBURDEN MONITORING WELL LOCATION
	BEDROCK MONITORING WELL LOCATION
W	C-DOMW-SERVICE
W	C-DOMW-UNDR
FP	C-FIRE-UNDR
SAN	C-SANR-UNDR
STM	C-STRM-UNDR
UE	E-SITE-POWR-UNDR

NOTE:

BASE MAP SUPPLIED BY GM, FROM A FIGURE TITLED "LANSING CAR ASSEMBLY BODY PLANT MASTER UNDERGROUND UTILITY DRAWING", FILE NO. PLT6MASTER-UNDERGROUND-UTILITIES.DWG.

0 200'
GRAPHIC SCALE

RACER TRUST
LANSING, MICHIGAN
RFI WORK PLAN - PLANTS 2, 3, & 6

PLANT 6 MISCELLANEOUS ITEMS AND AOIs

ARCADIS

FIGURE
4

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Appendix A

ARCADIS Standard Operating Procedures (SOPs)

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Infrastructure, environment, buildings

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Chain-of-Custody, Handling, Packing and Shipping

Rev. #: 2

Rev Date: March 6, 2009

Approval Signatures

Prepared by: ____________________ Date: 3/6/09
Caron Koll

Reviewed by: ____________________ Date: 3/6/09
Jane Kennedy(Technical Expert)

I. Scope and Application

This Standard Operating Procedure (SOP) describes the chain-of-custody, handling, packing, and shipping procedures for the management of samples to decrease the potential for cross-contamination, tampering, mis-identification, and breakage, and to insure that samples are maintained in a controlled environment from the time of collection until receipt by the analytical laboratory.

II. Personnel Qualifications

ARCADIS field sampling personnel will have current health and safety training, including 40-hour HAZWOPER training, Department of Transportation (DOT) training, site supervisor training, and site-specific training, as needed. In addition, ARCADIS field sampling personnel will be versed in the relevant SOPs and possess the skills and experience necessary to successfully complete the desired field work.

III. Equipment List

The following list provides materials that may be required for each project. Project documents and sample collection requirements should be reviewed prior to initiating field operations:

- indelible ink pens (black or blue);
- polyethylene bags (resealable-type);
- clear packing tape, strapping tape, duct tape;
- chain of custody
- DOT shipping forms, as applicable
- custody seals or tape;
- appropriate sample containers and labels,;
- insulated coolers of adequate size for samples and sufficient ice to maintain 4°C during collection and transfer of samples;
- wet ice;
- cushioning and absorbent material (i.e., bubble wrap or bags);

- temperature blank
- sample return shipping papers and addresses; and
- field notebook.

IV. Cautions

Review project requirements and select appropriate supplies prior to field mobilization.

Insure that appropriate sample containers with applicable preservatives, coolers, and packing material have been supplied by the laboratory.

Understand the offsite transfer requirements for the facility at which samples are collected.

If overnight courier service is required schedule pick-up or know where the drop-off service center is located and the hours of operation. Prior to using air transportation, confirm air shipment is acceptable under DOT and International Air Transport Association (IATA) regulation

Schedule pick-up time for laboratory courier or know location of laboratory/service center and hours of operation.

Understand DOT and IATA shipping requirements and evaluate dangerous goods shipping regulations relative to the samples being collected (i.e. complete an ARCADIS shipping determination). Review the ARCADIS SOPs for shipping, packaging and labeling of dangerous goods. Potential samples requiring compliance with this DOT regulation include:

- Methanol preservation for Volatile Organic Compounds in soil samples
- Non-aqueous phase liquids (NAPL)

V. Health and Safety Considerations

Follow health and safety procedures outlined in the project/site Health and Safety Plan (HASP).

Use caution and appropriate cut resistant gloves when tightening lids to 40 mL vials. These vials can break while tightening and can lacerate hand. Amber vials (thinner glass) are more prone to breakage.

Some sample containers contain preservatives.

- The preservatives must be retained in the sample container and should in no instance be rinsed out.

- Preservatives may be corrosive and standard care should be exercised to reduce potential contact to personnel skin or clothing. Follow project safety procedures if spillage is observed.

- If sample container caps are broken discard the bottle. Do not use for sample collection.

VI. Procedure

Chain-of-Custody Procedures

1. Prior to collecting samples, complete the chain-of-custody record header information by filling in the project number, project name, and the name(s) of the sampling technician(s) and other relevant project information. Attachment 1 provides an example chain-o- custody record

2. Chain-of-custody information MUST be printed legibly using indelible ink (black or blue).

3. After sample collection, enter the individual sample information on the chain-of-custody:

   a. Sample Identification indicates the well number or soil location that the sample was collected from. Appropriate values for this field include well locations, grid points, or soil boring identification numbers (e.g., MW-3, X-20, SB-30). When the depth interval is included, the complete sample ID would be “SB-30 (0.5-1.0) where the depth interval is in feet. Please note it is very important that the use of hyphens in sample names and depth units (i.e., feet or inches) remain consistent for all samples entered on the chain-of-custody form. DO NOT use the apostrophe or quotes in the sample ID. Sample names may also use the abbreviations “FB,” “TB,” and “DUP” as prefixes or suffixes to indicate that the sample is a field blank, trip blank, or field duplicate, respectively. NOTE: The sample nomenclature may be dictated by the project database and require unique identification for each sample collected for the project. Consult the project data management plan for additional information regarding sample identification.

b. List the date o sample collection. The date format to be followed should be mm/dd/yy (e.g., 03/07/09) or mm/dd/yyyy (e.g. 03/07/2009).

c. List the time that the sample was collected. The time value should be presented using military format. For example, 3:15 P.M. should be entered as 15:15.

d. The composite field should be checked if the sample is a composite over a period of time or from several different locations and mixed prior to placing in sample containers.

e. The “Grab”. field should be marked with an “X” if the sample was collected as an individual grab sample. (e.g. monitoring well sample or soil interval).

f. Any sample preservation should be noted.

g. The analytical parameters that the samples are being analyzed for should be written legibly on the diagonal lines. As much detail as possible should be presented to allow the analytical laboratory to properly analyze the samples. For example, polychlorinated biphenyl (PCB) analyses may be represented by entering “PCBs” or “Method 8082.” Multiple methods and/or analytical parameters may be combined for each column (e.g., PCBs/VOCs/SVOCs or 8082/8260/8270). These columns should also be used to present project-specific parameter lists (e.g., Appendix IX+3 target analyte list. Each sample that requires a particular parameter analysis will be identified by placing the number of containers in the appropriate analytical parameter column. For metals in particular, indicate which metals are required.

h. Number of containers for each method requested. This information may be included under the parameter or as a total for the sample based on the chain of custody form used.

i. Note which samples should be used for site specific matrix spikes.

j. Indicate any special project requirements.

k. Indicate turnaround time required.

l. Provide contact name and phone number in the event that problems are encountered when samples are received at the laboratory.

m. If available attach the Laboratory Task Order or Work Authorization forms

n. The remarks field should be used to communicate special analytical requirements to the laboratory. These requirements may be on a per sample basis such as “extract and hold sample until notified,” or may be used to inform the laboratory of special reporting requirements for the entire sample delivery group (SDG). Reporting requirements that should be specified in the remarks column include: 1) turnaround time; 2) contact and address where data reports should be sent; 3) name of laboratory project manager; and 4) type of sample preservation used.

o. The “Relinquished By” field should contain the signature of the sampling technician who relinquished custody of the samples to the shipping courier or the analytical laboratory.

p. The “Date” field following the signature block indicates the date the samples were relinquished. The date format should be mm/dd/yyyy (e.g., 03/07/2005).

q. The “Time” field following the signature block indicates the time that the samples were relinquished. The time value should be presented using military format. For example, 3:15 P.M. should be entered as 15:15.

r. The “Received By” section is signed by sample courier or laboratory representative who received the samples from the sampling technician or it is signed upon laboratory receipt from the overnight courier service.

3. Complete as many chain-of-custody forms as necessary to properly document the collection and transfer of the samples to the analytical laboratory.

4. Upon completing the chain-of-custody forms, forward two copies to the analytical laboratory and retain one copy for the field records.

5. If electronic chain-of-custody forms are utilized, sign the form and make 1 copy for ARCADIS internal records and forward the original with the samples to the laboratory.

Handling Procedures

1. After completing the sample collection procedures, record the following information in the field notebook with indelible ink:

    - project number and site name;
    - sample identification code and other sample identification information, if appropriate;
    - sampling method;
    - date;
    - name of sampler(s);
    - time;
    - location (project reference);
    - location of field duplicates and both sample identifications;
    - locations that field QC samples were collected including equipment blanks, field blanks and additional sample volume for matrix spikes; and
    - any comments.

2. Complete the sample label with the following information in indelible ink:

    - sample type (e.g., surface water);
    - sample identification code and other sample identification information, if applicable;
    - analysis required;
    - date;
    - time sampled; and
    - initials of sampling personnel;

- sample matrix; and
- preservative added, if applicable.

3. Cover the label with clear packing tape to secure the label onto the container and to protect the label from liquid.

4. Confirm that all caps on the sample containers are secure and tightly closed.

5. In some instances it may be necessary to wrap the sample container cap with clear packing tape to prevent it from becoming loose.

6. For some projects individual custody seals may be required. Custody seal evidence tape may be placed on the shipping container or they may be placed on each sample container such that the cooler or cap cannot be opened without breaking the custody seal. The custody seal should be initialed and dated prior to relinquishing the samples.

Packing Procedures

Following collection, samples must be placed on wet ice to initiate cooling to 4°C immediately. Retain samples on ice until ready to pack for shipment to the laboratory.

1. Secure the outside and inside of the drain plug at the bottom of the cooler being used for sample transport with "Duct" tape.

2. Place a new large heavy duty plastic garbage bag inside each cooler

3. Place each sample bottle wrapped in bubble wrap inside the garbage bag. VOC vials may be grouped by sample in individual resealable plastic bags). If a cooler temperature blank is supplied by the laboratory, it should be packaged following the same procedures as the samples. If the laboratory did not include a temperature blank, do not add one. Place 1 to 2 inches of cushioning material (i.e., vermiculite) at the bottom of the cooler.

4. Place the sealed sample containers upright in the cooler.

5. Package ice in large resealable plastic bags and place inside the large garbage bag in the cooler. Samples placed on ice will be cooled to and maintained at a temperature of approximately 4°C.

6. Fill the remaining space in the cooler with cushioning material such as bubble wrap. The cooler must be securely packed and cushioned in an upright position and be surrounded (Note: to comply with 49 CFR 173.4, filled cooler must not exceed 64 pounds).

7. Place the completed chain-of-custody record(s) in a large resealable bag and tape the bag to the inside of the cooler lid.

8. Close the lid of the cooler and fasten with packing tape.

9. Wrap strapping tape around both ends of the cooler.

10. Mark the cooler on the outside with the following information: shipping address, return address, "Fragile, Handle with Care" labels on the top and on one side, and arrows indicating "This Side Up" on two adjacent sides.

11. Place custody seal evidence tape over front right and back left of the cooler lid, initial and date, then cover with clear plastic tape.

Note: Procedure numbers 2, 3, 5, and 6 may be modified in cases where laboratories provide customized shipping coolers. These cooler types are designed so the sample bottles and ice packs fit snugly within preformed styrofoam cushioning and insulating packing material.

Shipping Procedures

1. All samples will be delivered by an express carrier within 48 hours of sample collection. Alternatively, samples may be delivered directly to the laboratory or laboratory service center or a laboratory courier may be used for sample pickup.

2. If parameters with short holding times are required (e.g., VOCs [EnCore™ Sampler], nitrate, nitrite, ortho-phosphate and BOD), sampling personnel will take precautions to ship or deliver samples to the laboratory so that the holding times will not be exceeded.

3. Samples must be maintained at 4°C+2°C until shipment and through receipt at the laboratory

4. All shipments must be in accordance with DOT regulations and ARCADIS dangerous goods shipping SOPs.

5. When the samples are received by the laboratory, laboratory personnel will complete the chain-of-custody by recording the date and time of receipt of samples, measuring and recording the internal temperature of the shipping container, and checking the sample identification numbers on the containers to ensure they correspond with the chain-of-custody forms.

Any deviations between the chain-of-custody and the sample containers, broken containers, or temperature excursions will be communicated to ARCADIS immediately by the laboratory.

VII. Waste Management

Not applicable

VIII. Data Recording and Management

Chain-of-custody records will be transmitted to the ARCADIS PM or designee at the end of each day unless otherwise directed by the ARCADIS PM. The sampling team leader retains copies of the chain-of-custody forms for filing in . the project file. Record retention shall be in accordance with project requirements.

IX. Quality Assurance

Chain-of-custody forms will be legibly completed in accordance with the applicable project documents such as Sampling and Analysis Plan (SAP), Quality Assurance Project Plan (QAPP), Work Plan, or other project guidance documents. A copy of the completed chain-of-custody form will be sent to the ARCADIS Project Manager or designee for review.

X. References

Not Applicable

Attachment 1

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ID#:

CHAIN OF CUSTODY & LABORATORY ANALYSIS REQUEST FORM

Page ___ of ___

Lab Work Order #

Send Results to:

Contact & Company Name:	Telephone:
Address:	Fax:
City State Zip	E-mail Address:
Project Name/Location (City, State):	Project #:
Sampler's Printed Name:	Sampler's Signature:

Preservative								
Filtered (✓)								
# of Containers								
Container Information								

PARAMETER ANALYSIS & METHOD

Keys

Preservation Key:
A. H_2SO_4
B. HCL
C. HNO_3
D. NaOH
E. None
F. Other: ________
G. Other: ________
H. Other: ________

Container Information Key:
1. 40 ml Vial
2. 1 L Amber
3. 250 ml Plastic
4. 500 ml Plastic
5. Encore
6. 2 oz. Glass
7. 4 oz. Glass
8. 8 oz. Glass
9. Other: ________
10. Other: ________

Matrix Key:
SO - Soil SE - Sediment NL - NAPL/Oil
W - Water SL - Sludge SW - Sample Wipe
T - Tissue A - Air Other: ________

Sample ID	Collection Date	Collection Time	Type (✓) Comp	Type (✓) Grab	Matrix								REMARKS

Special Instructions/Comments:

☐ **Special QA/QC Instructions(✓):**

Laboratory Information and Receipt		Relinquished By	Received By	Relinquished By	Laboratory Received By
Lab Name:	Cooler Custody Seal (✓)	Printed Name:	Printed Name:	Printed Name:	Printed Name:
☐ Cooler packed with ice (✓)	☐ Intact ☐ Not Intact	Signature:	Signature:	Signature:	Signature:
Specify Turnaround Requirements:	Sample Receipt:	Firm:	Firm/Courier:	Firm/Courier:	Firm:
Shipping Tracking #:	Condition/Cooler Temp: ________	Date/Time:	Date/Time:	Date/Time:	Date/Time:

20730826 CofC AR Form 01.12.2007 **Distribution:** **WHITE – Laboratory returns with results** **YELLOW – Lab copy** **PINK – Retained by BBL**

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DNAPL Contingency Plan

Rev. #: 3

Rev Date: May 1, 2010

Approval Signatures

Prepared by: ____________________ Date: 5/1/10
David Lipson

Reviewed by: ____________________ Date: 5/1/10
Michael Gefell (Technical Expert)

I. Scope and Application

This document has been prepared to guide drilling activities at sites where there is a reasonable expectation that dense, non-aqueous phase liquid (DNAPL) may be present, and provide procedures to be implemented in the event that DNAPL is encountered during subsurface investigations. These procedures are proposed to limit the potential of remobilizing DNAPL, if any, in response to drilling and sampling activities. In addition, the procedures are designed to optimize the recovery of encountered DNAPL (if any) in a safe and efficient manner. This DNAPL Contingency Plan was developed based on a similar document prepared by DNAPL expert Bernard H. Kueper, Ph.D., P.Eng., of Queens University, for an EPA Region 1 Superfund Site (Kueper, May 1995).

Downward DNAPL mobilization may occur in response to drilling activities (short-circuiting along drill stem and/or completed well screen) and groundwater extraction (creation of downward hydraulic gradient in excess of previously measured downward gradients). This DNAPL Contingency Plan addresses drilling-related issues.

II. Personnel Qualifications

DNAPL contingency field activities will be performed by persons who have been trained in proper drilling and well installation procedures under the guidance of an experienced field geologist, engineer, or technician.

III. Equipment List

The following materials will be available during soil boring and monitoring well installation activities, as required:

- Work Plan, Field Sampling Plan (FSP), and site Health and Safety Plan (HASP);
- personal protective equipment (PPE), as required by the HASP;
- equipment specified under drilling and well installation SOPs;
- photo-ionization detector (PID) or flame ionization detector (FID)
- hydrophobic dye (Oil Red O or Sudan IV), pertinent at chlorinated solvent sites;
- disposable pans for performing soil-water pan tests; and
- clean, empty jars for performing soil-water shake tests.

- field notebooks and/or personal digital assistant (PDA)

IV. Cautions

Downward Mobilization

DNAPL can migrate downward during drilling and well installation processes, or via the sand pack or screen of a monitoring well. This caution is applicable to all DNAPL sites, but may be especially important at solvent sites, where DNAPL is likely to have relatively high density and low viscosity; also, pure solvents may be clear and colorless, and therefore difficult to detect visually. Other DNAPLs such as coal tar and creosote, or waste solvents that have been used in degreasing operations, commonly have a dark color and are readily visible in soil or water samples. The principles in this SOP may also apply to light NAPL (LNAPL) at sites with strong downward hydraulic gradients or LNAPL layers perched in the vadose zone.

Direct-Push Drilling

DNAPL can be indirectly detected in the soil using direct-push instruments such as TarGost (which detects coal tar or creosote DNAPL due to fluorescence) or membrane interface probe (also known as MIP, which detects volatile organic compounds). These types of devices can also be used with a cone-penetration tool (CPT) to rapidly characterize stratigraphy in addition to potential DNAPL presence. However, currently-available direct push tools do not allow the borehole to be grouted as the direct-push tool is extracted from the subsurface. Therefore, use of direct-push tools within zones that are known or likely to contain DNAPL should be limited to one or more the following situations: 1) each direct-push boring is terminated at the first indication of potential DNAPL; 2) direct-push is used for lateral DNAPL delineation above a widespread, thick capillary barrier that has been previously characterized using standard soil borings; 3) a direct-push tool is advanced inside of an outer casing, such that the boring can be tremie-grouted from the bottom upward during removal of the outer casing. Wherever possible, direct-push detectors (e.g., MIP or TarGOST) should be "calibrated" in terms of their response using a series of standards prepared using site soil and DNAPL – this process can significantly improve the reliability of interpretations regarding DNAPL presence.

Other Considerations

The presence or absence of DNAPL at a site can have significant implications in terms of site management, health and safety, and the feasibility of potential remedial alternatives. Therefore, field personnel must be attentive to the potential for DNAPL, recognize when DNAPL is encountered during drilling, and accurately document field observations indicating the presence of DNAPL and interpreted DNAPL depth. In addition, opportunities to characterize DNAPL, when present, may be rare. When practicable, DNAPL samples should be collected and analyzed for physical and chemical characteristics.

Shipping

A Shipping Determination must be performed, by DOT-trained personnel, for all environmental and geotechnical samples that are to be shipped, as well as some types of environmental equipment/supplies that are to be shipped.

V. Health and Safety Considerations

Field activities associated with this DNAPL Contingency Plan will be performed in accordance with the site HASP, a copy of which will be present on site during such activities.

VI. Procedure

DNAPL Screening During Overburden Drilling

To screen for the potential presence of DNAPL in soil, drilling procedures must allow for high-quality porous media samples to be taken. Split-spoon samples or direct-push samplers should be taken continuously in 2-foot intervals ahead of the auger or drill casing. Upon opening each split-spoon sampler or direct-push plastic liner sleeve, the soil will immediately be evaluated for the presence of visible non-aqueous phase liquid (NAPL), screened for the presence of organic vapors using a portable photo-ionization detector (PID) or flame ionization detector (FID). During screening, the soil will be split open using a clean spatula or knife and the PID or FID probe will be placed in the opening and covered with a gloved hand. Such readings will be obtained along the entire length of the sample. If NAPL is immediately visible in the sample, its depth should be noted and the sampling team should skip to the fourth bullet below.

If the PID or FID examination reveals the presence of organic vapors above 100 parts per million (ppm), the sample will undergo further detailed evaluation for visible non-aqueous phase liquid (NAPL). The assessment for NAPL will include a combination of the following tests/observations:

- Evaluation for Visible NAPL Sheen or Free-Phase NAPL in Soil Sampler – The NAPL sheen will be a colorful iridescent appearance on the soil sample. NAPL may also appear as droplets or continuous accumulations of liquid with a color typically ranging from yellow to brown to black, depending on the type of NAPL.

Creosote DNAPL (associated with wood-treating sites) and coal-tar DNAPL (associated with manufactured gas plant [MGP] sites) are typically black and have a characteristic, pungent odor. Pure chlorinated solvents may be colorless in the absence of hydrophobic dye. Solvents mixed with oils may appear brown.

- Soil-Water Pan Test – A portion of the selected soil interval with the highest PID or FID reading > 100 ppm will be placed in a disposable polyethylene dish along with a small volume of potable or distilled water. The dish will be gently tilted back and forth to mix the soil and water, and the surface of the water will be viewed in natural light to observe the development of a sheen, if any. A small quantity of Oil Red O or Sudan IV hydrophobic dye powder will be added and the soil and dye will be manually mixed for approximately 30 to 60 seconds and smeared in the dish to create a paste-like consistency using a new nitrile glove-covered hand. A positive test result will be indicated by a sheen on the surface of the water and/or a bright red color imparted to the soil following mixing with dye.

- Soil-Water Shake Test – A small quantity of soil (up to 15 cc) will be placed in a clear, colorless, jar containing an equal volume of potable or distilled water (40-mL vials are well suited to this purpose, but not required). After the soil settles into the water, the surface of the water will be evaluated for a visible sheen under natural light. The jar will be closed and gently shaken for approximately 10 to 20 seconds. Again, the surface of the water will be evaluated for a visible sheen or a temporary layer of foam. A small quantity (approximately 0.5 to 1 cc) of Oil Red O or Sudan IV powder will be placed in the jar. The sheen layer, if present, will be evaluated for a reaction to the dye (change to bright red color). The jar will be closed and gently shaken for approximately 10 to 20 seconds. The contents in the closed jar will be examined under natural light for visible bright red dyed liquid inside the jar. A positive test result will be indicated by the presence of a visible sheen or foam on the surface of water, a reaction between the dye and the sheen layer upon first addition of the dye powder, a bright red coating on the inside of the vial (particularly above the water line), or red-dyed droplets within the soil.

- Estimation of Relative Degree of NAPL Saturation – When NAPL is interpreted as present in a particular portion of soil, the field geologist should attempt to estimate the relative degree of NAPL saturation in the soil. Specifically, based on the apparent, visible continuity of NAPL within the soil, an interpretation should be made as to whether the observed NAPL is: apparently pooled (continuous interval of soil across entire diameter of soil sample in which the pore spaces are filled with a mixture of NAPL and water); apparently residual (isolated droplets or blebs of NAPL, surrounded by pore spaces containing only water); or inconclusive (unclear whether pooled or residual). If NAPL freely drains out of a soil sample, that indicates that the NAPL is in the form of a pool – however, pooled NAPL may not always freely drain out of soil samples.

As mentioned previously, if NAPL is obviously present upon opening the soil sampler or evaluating the soil sample within the split-spoon sampler or direct-push liner sleeve, it is not necessary to perform a soil-water pan test or soil-water shake test. In addition, it is not necessary to perform both a soil-water pan test and a soil-water shake test; either test method is acceptable. The pan test may be preferred in some circumstances because the presence of a sheen may be easier to see on a wider surface.

When using hydrophobic dye in the tests above, color will be assessed outdoors under natural light during the period between sunrise and sunset, regardless of the degree of cloud cover.

The results of each test or observation will be recorded in the field notebook and/or PDA.

DNAPL Screening During Bedrock Drilling

To screen for the potential presence of DNAPL in bedrock, drilling fluids, rock cuttings, and/or core samples are monitored for the presence of sheens. During drilling using rotary methods (coring or roller bit drilling with water or drilling mud), the return fluid will be screened with a PID or FID and evaluated continuously for the presence of a sheen in the recirculation tub. Where core samples are obtained, they will be carefully evaluated for the presence of a sheen on fracture surfaces. During drilling using air-rotary methods, rock cuttings will be continuously screened using a PID or FID and evaluated for the presence of a sheen. During drilling with rotary methods, the positive head level at the borehole will reduce the potential for DNAPL short-circuiting via the borehole.

If a sheen is observed with any of these methods, drilling will be temporarily discontinued and an evaluation will be undertaken to determine whether pooled DNAPL is present. The drill stem will be retracted to a few feet above the apparent depth where the sheen was first encountered. Groundwater will be extracted from the borehole to produce a drawdown of approximately 5 feet below the approximate static, non-pumping water level for a period of 20 minutes to test for the presence of pooled, mobilizable DNAPL in the fractures surrounding the open borehole. The bottom of the borehole will then be evaluated for the presence of DNAPL using an interface probe or bottom-loading bailer. If no DNAPL is observed, the interpretation will be made that the sheen was not produced by pooled DNAPL. In this case, if drilling by the rotary method, the recirculation water will be replaced by clean water and drilling will continue. Replacing the recirculation water reduces the potential for cross-contamination and facilitates observation of a newly created sheen, if any, at a deeper interval. Accumulation of DNAPL in the bottom of the borehole, however, indicates that the boring has encountered pooled DNAPL. If DNAPL has accumulated, it will be removed using a bottom-loading bailer or pump.

Data Collection Below Zone Containing Pooled DNAPL

If pooled DNAPL is encountered in a borehole and deeper drilling is required to collect data below the zone containing pooled DNAPL, one of the following actions will be taken.

1. Adjustment of Drilling Location - The boring where pooled DNAPL was encountered will be abandoned by tremie grouting using neat cement grout and a replacement boring will be re-attempted at a nearby location.

2. DNAPL Sump Installation - A DNAPL collection well will be installed with a blank sump properly grouted in place below the screen and the boring will be re-attempted at a nearby location. In this case, after removing the DNAPL in the borehole, the boring may be advanced an additional 1 to 2 feet to accommodate a blank sump below the interval with apparent pooled DNAPL.

3. Casing Off DNAPL Layers - If pooled DNAPL is found to be present throughout an area where deeper drilling is essential, a permanent, grouted casing should be installed. The bottom of the pooled DNAPL likely coincides with the top of a relatively fine-grained, low permeability, stratum (capillary barrier). Permanent casing will be installed to the bottom of the borehole and grouted in place using the displacement method prior to advancing the borehole any further. Via the displacement method (also known as the Halliburton Method or the packer-injection method), grout is displaced out the bottom of the casing and fills the annulus outside the casing from the bottom upward. In this case, after removing any DNAPL that may have accumulated in the borehole, the boring may be advanced a few feet into the top of the underlying confining layer or up to 5 feet in bedrock prior to grouting the casing to assist in isolating the zone containing apparently pooled DNAPL. The bottom of the borehole should be checked for the DNAPL accumulation prior to installing and grouting the casing in the drilled “socket”. When the casing is grouted in place and the grout has set, the drilling recirculation water will be replaced with clean water to prevent cross-contamination and facilitate observation of a newly created sheen (if any) at a deeper interval, and drilling will continue.

DNAPL Monitoring

New wells installed in borings where DNAPL was encountered during drilling will be monitored for DNAPL accumulation in the DNAPL sump using an oil-water interface probe or bottom-loading bailer within approximately one day following initial installation. If DNAPL is encountered, a bottom-loading bailer or pump will be used to remove the DNAPL, the final DNAPL thickness will be recorded, and the DNAPL thickness will be reassessed after another day of accumulation (if any). This process will be repeated until DNAPL no longer accumulates overnight, at which point the accumulation monitoring and removal period will extend to one-week intervals. If no DNAPL accumulation is observed over a period of one week, further DNAPL monitoring may be continued with a longer period between monitoring events.

Any DNAPL recovered during drilling and monitoring activities should be analyzed for chemical composition, DNAPL-water interfacial tension, density, and viscosity. The physical tests should be performed at the approximate groundwater temperature at the site where the DNAPL sample was obtained, typically between 10ºC and 20ºC. These parameters will allow for correlation of groundwater chemistry with suspected DNAPL locations and will allow an estimate to be made of the volume and potential mobility of DNAPL, if any, in the formation.

VII. Waste Management

DNAPL removed from wells will be temporarily stored on-site in metal drums for subsequent appropriate off-site disposal. The locations and volumes of recovered DNAPL will be noted.

VIII. Data Recording and Management

Any occurrence of DNAPL encountered during subsurface investigations will be documented in an appropriate field notebook in terms of the drilling location (boring or well identification), depth below surface, type of geologic material in which DNAPL was observed, field screening and testing results, and apparent degree of DNAPL saturation (pooled or residual), and visual characteristics of DNAPL (e.g., color or qualitative viscosity). DNAPL locations and depths will be recorded in a field book and/or on subsurface log forms, as appropriate.

IX. Quality Assurance

DNAPL can be mobilized downward as a result of drilling operations. It is very difficult to drill through DNAPL without bringing about vertical DNAPL mobilization. This opinion is stated by USEPA (1992): “In DNAPL zones, drilling should generally be minimized and should be suspended when a potential trapping layer is first encountered. Drilling through DNAPL zones into deeper stratigraphic units should be avoided." The DNAPL screening procedure outlined in this plan should, therefore, be implemented while drilling at all locations and depths within overburden or bedrock where potential DNAPL presence is suspected. If data collection is required below a zone containing DNAPL, the interval containing DNAPL will be cased off prior to drilling deeper.

X. References

Kueper, B.H., May 11, 1995. DNAPL Contingency Plan. [Prepared at the request of *de maximis, inc*.].

United States Environmental Protection Agency (USEPA), 1992. Memorandum from D. Clay: Considerations in Ground-Water Remediation at Superfund Sites and RCRA Facilities – Update. OSWER Directive No. 9283.1-06.

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Field Equipment Decontamination

Rev. #: 3

Rev Date: April 26, 2010

Approval Signatures

Prepared by: ______________________ Date: 4/26/2010

Keith Shepherd

Reviewed by: ______________________ Date: 4/26/2010

Richard Murphy (Technical Expert)

I. Scope and Application

Equipment decontamination is performed to ensure that sampling equipment that contacts a sample, or monitoring equipment that is brought into contact with environmental media to be sampled, is free from analytes of interest and/or constituents that would interfere with laboratory analysis for analytes of interest. Equipment must be cleaned prior to use for sampling or contact with environmental media to be sampled, and prior to shipment or storage. The effectiveness of the decontamination procedure should be verified by collecting and analyzing equipment blank samples.

The equipment cleaning procedures described herein includes pre-field, in the field, and post-field cleaning of sampling tools which will be conducted at an established equipment decontamination area (EDA) on site (as appropriate). Equipment that may require decontamination at a given site includes: soil sampling tools; groundwater, sediment, and surface-water sampling devices; water testing instruments; down-hole instruments; and other activity-specific sampling equipment. Non-disposable equipment will be cleaned before collecting each sample, between sampling events, and prior to leaving the site. Cleaning procedures for sampling equipment will be monitored by collecting equipment blank samples as specified in the applicable work plan or field sampling plan. Dedicated and/or disposable (not to be re-used) sampling equipment will not require decontamination.

II. Personnel Qualifications

ARCADIS field sampling personnel will have current health and safety training, including 40-hour HAZWOPER training, site supervisor training, and site-specific training, as needed. In addition, ARCADIS field sampling personnel will be versed in the relevant SOPs and possess the skills and experience necessary to successfully complete the desired fieldwork. The project HASP and other documents will identify any other training requirements such as site specific safety training or access control requirements.

III. Equipment List

- health and safety equipment, as required in the site Health and Safety Plan (HASP)
- distilled water

- Non-phosphate detergent such as Alconox or, if sampling for phosphorus phosphorus-containing compounds, Luminox (or equivalent).
- tap water
- rinsate collection plastic containers
- DOT-approved waste shipping container(s), as specified in the work plan or field sampling plan (if decontamination waste is to be shipped for disposal)
- brushes
- large heavy-duty garbage bags
- spray bottles
- (Optional) – Isoprophyl alcohol (free of ketones) or methanol
- Ziploc-type bags
- plastic sheeting

IV. Cautions

Rinse equipment thoroughly and allow the equipment to dry before re-use or storage to prevent introducing solvent into sample medium. If manual drying of equipment is required, use clean lint-free material to wipe the equipment dry.

Store decontaminated equipment in a clean, dry environment. Do not store near combustion engine exhausts.

If equipment is damaged to the extent that decontamination is uncertain due to cracks or dents, the equipment should not be used and should be discarded or submitted for repair prior to use for sample collection.

A proper shipping determination will be performed by a DOT-trained individual for cleaning materials shipped by ARCADIS.

V. Health and Safety Considerations

Review the material safety data sheets (MSDS) for the cleaning materials used in decontamination. If solvent is used during decontamination, work in a well-ventilated area and stand upwind while applying solvent to equipment. Apply solvent in a manner that minimizes potential for exposure to workers. Follow health and safety procedures outlined in the HASP.

VI. Procedure

A designated area will be established to clean sampling equipment in the field prior to sample collection. Equipment cleaning areas will be set up within or adjacent to the specific work area, but not at a location exposed to combustion engine exhaust. Detergent solutions will be prepared in clean containers for use in equipment decontamination.

Cleaning Sampling Equipment

1. Wash the equipment/pump with potable water.

2. Wash with detergent solution (Alconox, Liquinox or equivalent) to remove all visible particulate matter and any residual oils or grease.

3. If equipment is very dirty, precleaning with a brush and tap water may be necessary.

4. (Optional) – Flush with isopropyl alcohol (free of ketones) or with methanol. This step is optional but should be considered when sampling in highly impacted media such as non-aqueous phase liquids or if equipment blanks from previous sampling events showed the potential for cross contamination of organics.

5. Rinse with distilled/deionized water.

Decontaminating Submersible Pumps

Submersible pumps may be used during well development, groundwater sampling, or other investigative activities. The pumps will be cleaned and flushed before and between uses. This cleaning process will consist of an external detergent solution wash and tap water rinse, a flush of detergent solution through the pump, followed by a flush of potable water through the pump. Flushing will be accomplished by using an appropriate container filled with detergent solution and another contained filled with potable water. The pump will run long enough to effectively flush the pump housing and hose (unless new, disposable hose is used). Caution should be exercised to avoid contact with the pump casing and water in the container while the pump is running (do not use metal drums or garbage cans) to avoid electric shock. Disconnect the pump from the power source before handling. The pump and hose should be placed on or in clean polyethylene sheeting to avoid contact with the ground surface.

VII. Waste Management

Equipment decontamination rinsate will be managed in conjunction with all other waste produced during the field sampling effort. Waste management procedures are outlined in the work plan or Waste Management Plan (WMP).

VIII. Data Recording and Management

Equipment cleaning and decontamination will be noted in the field notebook. Information will include the type of equipment cleaned, the decontamination location and any deviations from this SOP. Specific factors that should be noted include solvent used (if any), and source of water.

Any unusual field conditions should be noted if there is potential to impact the efficiency of the decontamination or subsequent sample collection.

An inventory of the solvents brought on site and used and removed from the site will be maintained in the files. Records will be maintained for any solvents used in decontamination, including lot number and expiration date.

Containers with decontamination fluids will be labeled.

IX. Quality Assurance

Equipment blanks should be collected to verify that the decontamination procedures are effective in minimizing potential for cross contamination. The equipment blank is prepared by pouring deionized water over the clean and dry tools and collecting the deionized water into appropriate sample containers. Equipment blanks should be analyzed for the same set of parameters that are performed on the field samples collected with the equipment that was cleaned. Equipment blanks are collected per equipment set, which represents all of the tools needed to collect a specific sample.

X. References

USEPA Region 9, Field Sampling Guidance #1230, Sampling Equipment Decontamination.

USEPA Region 1, Low Stress (low flow) Purging and Sampling Procedure for the Collection of Groundwater Samples from Monitoring Wells.

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Field Log Book Entries

Rev. #: 0

Rev Date: 11 August 2009

Approval Signatures

Prepared by: Andrew Kanik Date: 8/11/09

Reviewed by: Michael J Gefell Date: 8/11/09
(Technical Expert)

I. Scope and Application

This ARCADIS Standard Operating Procedure covers the entries needed in a field log book for environmental investigations.

This SOP does not address all of the entries that may be needed for a specific project, and does not address health and safety, equipment decontamination, field parameter measurements, sample preservation, chain-of-custody, or laboratory analysis. For direction on requirements in these areas, refer to other ARCADIS SOPs, the project work plans including the quality assurance project plan, sampling plan, and health and safety plan, as appropriate.

II. Personnel Qualifications

ARCADIS personnel participating in fieldwork and making entries into the field log book should have a minimum of one (1) year of field experience (or be under the supervision and accompanied in the field by someone who does) and current health and safety training including 40-hour HAZWOPER training, site supervisor training, site-specific training, first aid, and CPR, as needed. Field personnel will also be compliant with client-specific training requirements. In addition, ARCADIS field sampling personnel will be versed in the relevant SOPs and posses the required skills and experience necessary to successfully complete the desired field work.

III. Equipment List

- Field Log Book

- Ball point (medium point) pen with blue or black ink (black preferred). A fine point Sharpie pen may be used if the ink does not bleed through the page and become visible on back side of the page. If weather conditions prevent the use of a pen, indicate so in the log and use an alternate writing instrument .

- Zip-lock baggie or other weather-proof container to protect the field log book from the elements.

IV. Cautions

All entries in the field log must be legible and archivable. Do not leave the field log book exposed to the elements or other conditions that might moisten the pages and smear/dissolve the entries. When not in the field, the log book should be stored in a location that is easily accessible to field crews.

V. Health and Safety Considerations

ARCADIS field personnel will be familiar and compliant with Client-specific health and safety requirements.

VI. Procedure

- Print legibly. Do not use cursive writing.
- The name of the project, project number and project location should be written in indelible ink on the outside of the field log book.
- On the inside of the front cover, write "If Found, Please Return to ARCADIS" and include the appropriate address and phone number, the name of the person to which the book is assigned, and the name of the project manager.
- Reserve the first page of the book for a Table of Contents.
- Reserve the last five (5) pages of the book for important contacts, notes, reminders, etc.
- Each day of field work, the following should be recorded in the field log book as applicable:

  a) Project Name

  b) Date and time arrived

  c) Work Site Location

  d) Names of people on-site related to the project including ARCADIS employees, visitors, subcontractor employees, agency personnel, client representative, etc.

  e) Describe the work to be performed briefly, and list the equipment on-site

  f) Indicate the health and safety (H&S) level to be used

  g) Record instrument calibrations and checks

  h) Record time and general content of H&S briefing

  i) Describe the weather conditions, including temperature, precipitation, and wind speed and direction

  j) List periodic time entries in the far left hand column of each page

  k) Minimize unused space on each page

- The tailgate meeting must be recorded in the log book and the tailgate form completed. If H&S monitoring is performed, record the time and results of initial and followup monitoring.

- Note factual observations including collection of QA/QC samples, delays, well damage, accidents, work plan deviations, instrument problems, and problem resolutions.

- Describe work performed and how documented such as photographs, sample core logs, water sampling logs, etc.

- Describe bases for field decisions including pertinent conversations with visitors, regulators, or project personnel.

- Note final instrument calibrations and checks.

- Sign the log book at the end of each day at a minimum. Draw a line to the end of the page to indicate no further entries on that page. Sign the bottom of each page if possible.

- If an entry to the log book is changed, strike out the deleted text or item with a single line such that the entry remains legible, and initial and date the change. Such changes should only be made by the same person that made the initial entry.

- Field log book entries must be made in the field at the site, not at a later time at a different location. Supplemental entries to the log book may be made at a later date. The supplemental entry must be clearly identified as such and the entry must be signed and dated as described in this SOP.

- Problems noted in the field log book must be brought to the attention of the project manager and task manager in a timely fashion. Problems may be reported in person, on the telephone, or in a written daily log form. If daily logs are prepared and you will not be able to personally give the daily log to the project manager, send the daily log via FAX or overnight courier to the project manager and task manager.

VII. Waste Management

Investigation-derived waste will be managed as described in the Investigation-Derived Waste Handling and Storage SOP. A drum/waste inventory should be maintained on a pre-designated page in the field log book.

VIII. Data Recording and Management

Each page of the field log book should be scanned for electronic/digital archiving at periodic intervals. This will ensure that copies of the field notes are available in the event the field book is lost or damaged, and that field data can be easily disseminated to others without the risk of physically sending the field log book. Field log books that are full should be archived with the project files, and readily retrievable.

IX. Quality Assurance

Be mindful that the field log book may be produced in court. All entries should be legible (as discussed above). Entries should also be in English, unless working in a country where English is not the predominant language or you are directed otherwise by the project manager.

X. References

Not Applicable

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Standard Operating Procedure for LNAPL Sample Collection and Shipping

Rev. #: 1.0

Rev Date: March 26, 2009

Approval Signatures

Prepared by: ______________________ Date: 3/26/09
(Trika Nelson-Kalmes)

Reviewed by: ______________________ Date: 3/26/09
(Brad Koons)

I. Scope and Application

Subsurface fluid sample collection is often required to characterize Light Nonaqueous Phase Liquid (LNAPL) properties at petroleum-impacted sites. The subsurface fluids (groundwater and separate-phase petroleum product) are submitted to an analytical laboratory(s) for specialized physical testing (e.g., density, viscosity, interfacial tension) and/or chemical speciation testing. It is important to note that the physical parameters are temperature sensitive. Therefore, the laboratory should be directed to analyze the samples at representative subsurface fluid temperatures. The fluid data are used to support site-specific LNAPL mobility calculations and development of the LNAPL site conceptual model.

This SOP does not address details of drilling method selection; soil description; or laboratory analysis. Refer to other ARCADIS SOPs and the project work plan, as appropriate.

II. Personnel Qualifications

ARCADIS personnel overseeing, directing, or supervising LNAPL fluid collection shall have previous related experience (minimum of 2 years) collecting fluid samples from wells and shall be trained in shipping of hazardous materials.

III. Equipment List

- personal protective equipment (PPE), items specified by the site Health and Safety Plan (HASP), and first aid kit;
- measuring tape;
- scissors;
- indelible ink pens;
- site map;
- contact names and numbers;
- well lock keys;
- logbook;
- interface probe;
- cleaning equipment/supplies, including deionized (DI) water and LiquiNox or equivalent;
- plastic sheeting;
- sampling containers;
- bailers, rope, and bailer retrieval device;
- buckets;
- bubble wrap and Styrofoam peanuts;
- duct tape and clear packaging tape;
- shippable cooler or sturdy box;
- shipping labels;
- chain of custody forms;
- garbage bags; and
- drum bung wrench.

IV. Cautions

Please refer to the Site specific HASP and JSAs for the Site.

V. Health and Safety Considerations

Field activities associated with collection of nonaqueous phase liquids and water will be performed in accordance with a site specific HASP, a copy of which will be present on site during such activities. The field staff must be made aware of hazardous substances that may be present in the groundwater and nonaqueous phase liquids and understand the associated health hazards.

VI. Fluid Sample Collection Procedure

1. Measuring the static water level: Proper PPE must be worn (i.e. gloves, safety glasses, steel-toed boots, etc.). Remove cap from well and deploy the oil/LNAPL and water interface probe into the well. Measure the static LNAPL and water levels in each well before sampling. Decontaminate the interface probe using LiquiNox (or equivalent) and DI water between well measurements. Read fluid level measurements to the nearest 0.01 foot on the north side, top of casing. Use the same electronic oil and water interface probe for all wells. Make sure to record all depths to product (DTP) and depths to water (DTW) in the field book. Depending on the probe, it will make different sounds for water and oil/LNAPL.

2. Collecting LNAPL and groundwater samples: Dedicated bailer and rope must be used for each well. Make sure to sample in the same order that water and LNAPL levels were collected to avoid any cross contamination. Collect the LNAPL sample by slowly lowering the bailer into the LNAPL, but not into the water. Pull the bailer out of the well. If both water and LNAPL are present, allow the liquids to separate. Collect the groundwater sample by lowering the bailer below the groundwater/LNAPL interface and slowly removing the bailer. Use a bottom emptying device to decant (drain) the appropriate amount of LNAPL or water into the appropriate container(s), as described below. Drain off remaining, unneeded liquids into a 5 gallon “waste” bucket. Record the amount of LNAPL bailed from each well in the logbook. The required sample volumes and containers, indicated below, are dependent upon the laboratory analyses to be performed.

    a. Fluid Properties Analysis: Requires 250 mL (minimum) of site groundwater and 250 mL (minimum) of LNAPL. The groundwater and LNAPL must be separated and placed into separate 1-liter glass containers.

b. Water/LNAPL Relative Permeability: Requires 1 to 2 liters (minimum) of field water and 1 liter (minimum) of LNAPL, placed in up to three 1-liter glass containers. It is preferable that LNAPL and field water are separated into separate sample containers.

3. Use waterproof labels for the containers and permanent waterproof marking devices for labeling. Labels are to include unique sample IDs, collection date and time, sampler initials, and lab analyses to be performed. These samples **DO NOT** need to be chemically preserved or shipped on ice.

4. Once sampling is complete, put the cap back on the well, close, and secure it as necessary. Personal protective equipment (such as gloves and disposable clothing) and other disposable equipment resulting from cleaning procedures and LNAPL and water sampling/handling activities (such as paper towels, rope, and bailers) will be placed in plastic garbage bags. Disposable PPE and equipment should not be re-used. Dispose of any excess water/LNAPL from the well into a 55-gallon drum or on site poly tank for proper disposal at a later date. Follow the procedures outlined in the Waste Management section below for further waste handling.

VII. Sample Shipping Procedure

The United States Department of Transportation (DOT) hazardous shipping guidelines must be followed when shipping LNAPL. Hazardous samples being shipped by ARCADIS staff must have completed current training through ARCADIS for DOT training for hazardous material shipping. A shipping determination form must be completed for all samples being shipped along with following all ARCADIS and DOT shipping guidelines. All forms and guidelines can be found online at http://team/sites/hazmat/default.aspx. If there are additional questions contact Sam Moyers (ARCADIS H&S).

VIII. Waste Management

The plastic garbage bags containing disposable PPE and equipment will be transferred into appropriately labeled 55-gallon drums or disposed of in a designated debris box for disposal. All decontamination and well water will be placed in separate sealed 55-gallon steel drums and stored in a secured area. Once full, the material will be analyzed to determine the appropriate disposal method.

IX. Data Recording and Management

The supervising geologist/engineer will be responsible for documenting sampling events using a logbook to record all relevant information in a clear and concise format. The sampling event record shall include:

- name and location of project;
- project number, client, and site location;
- names of Contractor, Contractor personnel, inspectors, and other people onsite;
- weather conditions;
- depth to groundwater and depth to LNAPL;
- type of sampling method;
- start and finish dates and times of sampling;
- volume of groundwater bailed and sampled;
- LNAPL as measured in a graduated cylinder and sampled; and
- photo document the LNAPL and cooler packaging.

X. Quality Assurance

Equipment will be cleaned prior to use onsite, between each sampling location, and prior to leaving the site.

Review bottle labels and the COC prior to shipping to ensure everything is labeled and documented correctly.

XI. References

PTS Laboratories, 2009. www.ptslabs.com

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Low-Flow Groundwater Purging and Sampling Procedures for Monitoring Wells

Rev. #: 3

Rev Date: March 9, 2009

Approval Signatures

Prepared by: ______________________ Date: 3/9/2009

Reviewed by: ______________________ Date: 3/9/2009
(Technical Expert)

I. Scope and Application

Groundwater samples will be collected from monitoring wells to evaluate groundwater quality. The protocol presented in this standard operating procedure (SOP) describes the procedures to be used to purge monitoring wells and collect groundwater samples. This protocol has been developed in accordance with the United States Environmental Protection Agency (USEPA) Region I Low Stress (Low Flow) Purging and Sampling Procedures for the Collection of Groundwater Samples from Monitoring Wells (USEPA SOP No. GW0001; July 30, 1996). Both filtered and unfiltered groundwater samples may be collected using this low-flow sampling method. Filtered samples will be obtained using a 0.45-micron disposable filter. No wells will be sampled until well development has been performed in accordance with the procedures presented in the SOP titled Monitoring Well Development, unless that well has been sampled or developed within the prior 1-year time period. Groundwater samples will not be collected within 1 week following well development.

II. Personnel Qualifications

ARCADIS personnel directing, supervising, or leading groundwater sample collection activities should have a minimum of 2 years of previous groundwater sampling experience. ARCADIS personnel providing assistance to groundwater sample collection and associated activities should have a minimum of 6 months of related experience or an advanced degree in environmental sciences, engineering, hydrogeology, or geology.

The supervisor of the groundwater sampling team will have at least 1 year of previous supervised groundwater sampling experience.

Prior to mobilizing to the field, the groundwater sampling team should review and be thoroughly familiar with relevant site-specific documents including but not limited to the site work plan, field sampling plan, QAPP, HASP, and historical information. Additionally, the groundwater sampling team should review and be thoroughly familiar with documentation provided by equipment manufacturers for all equipment that will be used in the field prior to mobilization.

III. Equipment List

Specific to this activity, the following materials (or equivalent) will be available:

- Health and safety equipment (as required in the site Health and Safety Plan [HASP]).

- Site Plan, well construction records, prior groundwater sampling records (if available).
- Sampling pump, which may consist of one or more of the following:
  - submersible pump (e.g., Grundfos Redi-Flo 2);
  - peristaltic pump (e.g., ISCO Model 150); and/or
  - bladder pump (e.g., Marschalk System 1, QED Well Wizard, etc.).
- Appropriate controller and power source for pump:
  - Submersible and peristaltic pumps require electric power from either a generator or a deep cell battery.
  - Submersible pumps such as Grundfos require a pump controller to run the pump
  - Bladder pumps require a pump controller and a gas source (e.g., air compressor or compressed N_2 or CO_2 gas cylinders).
- Teflon® tubing or Teflon®-lined polyethylene tubing of an appropriate size for the pump being used. For peristaltic pumps, dedicated Tygon® tubing (or other type as specified by the manufacturer) will also be used through the pump apparatus.
- Water-level probe (e.g., Solinist Model 101).
- Water-quality (temperature/pH/specific conductivity/ORP/turbidity/dissolved oxygen) meter and flow-through measurement cell. Several brands may be used, including:
  - YSI 6-Series Multi-Parameter Instrument;
  - Hydrolab Series 3 or Series 4a Multiprobe and Display; and/or
  - Horiba U-10 or U-22 Water Quality Monitoring System.
- Supplemental turbidity meter (e.g., Horiba U-10, Hach 2100P, LaMotte 2020). Turbidity measurements collected with multi-parameter meters have been shown to sometimes be unreliable due to fouling of the optic lens of the

turbidity meter within the flow-through cell. A supplemental turbidity meter will be used to verify turbidity data during purging if such fouling is suspected. Note that industry improvements may eliminate the need for these supplemental measurements in the future.

- Appropriate water sample containers (supplied by the laboratory).
- Appropriate blanks (trip blank supplied by the laboratory).
- 0.45-micron disposable filters (if field filtering is required).
- Large glass mixing container (if sampling with a bailer).
- Teflon® stirring rod (if sampling with a bailer).
- Cleaning equipment.
- Groundwater sampling log (attached) or bound field logbook.

Note that in the future, the client may acquire different makes/models of some of this equipment if the listed makes/models are no longer available, or as a result of general upgrades or additional equipment acquisitions. In the event that the client uses a different make/model of the equipment listed, the client will use an equivalent type of equipment (e.g., pumps, flow-through analytical cells) and note the specific make/model of the equipment used during a sampling event on the groundwater sampling log. In addition, should the client desire to change to a markedly different sampling methodology (e.g., discrete interval samplers, passive diffusion bags, or a yet to be developed technique), the client will submit a proposed SOP for the new methodology for USEPA approval prior to implementing such a change.

The maintenance requirements for the above equipment generally involve decontamination or periodic cleaning, battery charging, and proper storage, as specified by the manufacturer. For operational difficulties, the equipment will be serviced by a qualified technician.

IV. Cautions

If heavy precipitation occurs and no cover over the sampling area and monitoring well can be erected, sampling must be discontinued until adequate cover is provided. Rain water could contaminate groundwater samples.

Do not use permanent marker or felt-tip pens for labels on sample container or sample coolers – use indelible ink. The permanent markers could introduce volatile constituents into the samples.

It may be necessary to field filter some parameters (e.g., metals) prior to collection, depending on preservation, analytical method, and project quality objectives.

Store and/or stage empty and full sample containers and coolers out of direct sunlight.

To mitigate potential cross-contamination, groundwater samples are to be collected in a pre-determined order from least impacted to impacted based on previous analytical data. If no analytical data are available, samples are collected in order of upgradient, then furthest downgradient to source area locations.

Be careful not to over-tighten lids with Teflon liners or septa (e.g., 40 mL vials). Over-tightening can cause the glass to shatter or impair the integrity of the Teflon seal.

V. Health and Safety Considerations

Use caution and appropriate cut resistant gloves when tightening lids to 40 mL vials. These vials can break while tightening and can lacerate hand. Amber vials (thinner glass) are more prone to breakage.

If thunder or lighting is present, discontinue sampling and take cover until 30 minutes have passed after the last occurrence of thunder or lighting.

Use caution when removing well caps as well may be under pressure, cap can dislodge forcefully and cause injury.

Use caution when opening protective casing on stickup wells as wasps frequently nest inside the tops of the covers. Also watch for fire ant mounds near well pads when sampling in the south or western U.S.

VI. Procedure

Groundwater will be purged from the wells using an appropriate pump. Peristaltic pumps will initially be used to purge and sample all wells when applicable. If the depth to water is below the sampling range of a peristaltic pump (approximately 25 feet), submersible pumps or bladder pumps will be used provided the well is constructed with a casing diameter greater than or equal to 2 inches (the minimum well diameter capable of accommodating such pumps). Bladder pumps are preferred over peristaltic and submersible pumps if sampling of VOCs is required to prevent volatilization. For smaller diameter wells where the depth to water is below the sampling range of a peristaltic pump, alternative sampling methods (i.e., bailing or small diameter bladder pumps) will be used to purge and sample the groundwater. Purge water will be collected and containerized.

1. Calibrate field instruments according to manufacturer procedures for calibration.

2. Measure initial depth to groundwater prior to placement of pumps.

3. Prepare and install pump in well: For submersible and non-dedicated bladder pumps, decontaminate pump according to site decontamination procedures. Non-dedicated bladder pumps will require a new Teflon® bladder and attachment of an air line, sample discharge line, and safety cable prior to placement in the well. Attach the air line tubing to the air port on the top of the bladder pump. Attach the sample discharge tubing to the water port on the top of the bladder pump. Care should be taken not to reverse the air and discharge tubing lines during bladder pump set-up as this could result in bladder failure or rupture. Attach and secure a safety cable to the eyebolt on the top of bladder pump (if present, depending on pump model used). Slowly lower pump, safety cable, tubing, and electrical lines into the well to a depth corresponding to the approximate center of the saturated screen section of the well. Take care to avoid twisting and tangling of safety cable, tubing, and electrical lines while lowering pump into well; twisted and tangled lines could result in the pump becoming stuck in the well casing. Also, make sure to keep tubing and lines from touching the ground or other surfaces while introducing them into the well as this could lead to well contamination. If a peristaltic pump is being used, slowly lower the sampling tubing into the well to a depth corresponding to the approximate center of the saturated screen section of the well. The pump intake or sampling tube must be kept at least 2 feet above the bottom of the well to prevent mobilization of any sediment present in the bottom of the well.

4. Connect the pump to other equipment. If using a bladder pump, the discharge water line should be connected to the bottom inlet port on the flow-through cell connected to the water quality meter. Connect the air line to the pump controller output port. The pump controller should then be connected to a supply line from an air compressor or compressed gas cylinder using an appropriate regulator and air hose. Take care to tighten the regulator connector onto the gas cylinder (if used) to prevent leaks. Teflon tape may be used on the threads of the cylinder to provide a tighter seal. Once the air compressor or gas cylinder is connected to the pump controller, turn on the compressor or open the valve on the cylinder to begin the gas flow. Turn on the pump controller if an on/off switch

is present and verify that all batteries are charged and fully operating before beginning to pump.

5. Measure the water level again with the pump in the well before starting the pump. Start pumping the well at 200 to 500 milliliters (mL) per minute (or at lower site-specific rate if specified). The pump rate should be adjusted to cause little or no water level drawdown in the well (less than 0.3 feet below the initial static depth to water measurement) and the water level should stabilize. The water level should be monitored every 3 to 5 minutes (or as appropriate, lower flow rates may require longer time between readings) during pumping if the well diameter is of sufficient size to allow such monitoring. Care should be taken not to break pump suction or cause entrainment of air in the sample. Record pumping rate adjustments and depths to water. If necessary, pumping rates should be reduced to the minimum capabilities of the pump to avoid pumping the well dry and/or to stabilize indicator parameters. A steady flow rate should be maintained to the extent practicable. Groundwater sampling records from previous sampling events (if available) should be reviewed prior to mobilization to estimate the optimum pumping rate and anticipated drawdown for the well in order to more efficiently reach a stabilized pumping condition.

   If the recharge rate of the well is very low, alternative purging techniques should be used, which will vary based on the well construction and screen position. For wells screened across the water table, the well should be pumped dry and sampling should commence as soon as the volume in the well has recovered sufficiently to permit collection of samples. For wells screened entirely below the water table, the well should be pumped until a stabilized level (which may be below the maximum displacement goal of 0.3 feet) can be maintained and monitoring for stabilization of field indicator parameters can commence. If a lower stabilization level cannot be maintained, the well should be pumped until the drawdown is at a level slightly higher than the bentonite seal above the well screen. Sampling should commence after one well volume has been removed and the well has recovered sufficiently to permit collection of samples.

   During purging, monitor the field indicator parameters (e.g., turbidity, temperature, specific conductance, pH, etc.) every 3 to 5 minutes (or as appropriate). Field indicator parameters will be measured using a flow-through analytical cell or a clean container such as a glass beaker. Record field indicator parameters on the groundwater sampling log. The well is considered stabilized and ready for sample collection when turbidity values remain within 10% (or within 1 NTU if the turbidity reading is less than 10 NTU), the specific conductance and temperature values remain within 3%, and pH remains within 0.1 units for three consecutive readings collected at 3- to 5-minute intervals (or other appropriate interval, alternate stabilization goals may exist in different geographic regions, consult the site-specific Work Plan for stabilization criteria). If the field indicator parameters do not stabilize within 1 hour of the start of purging, but the groundwater turbidity is below the goal of 50 NTU and the values for all other parameters are within 10%, the well can be sampled. If the parameters have stabilized but the turbidity is not in the range of the 50 NTU goal, the pump flow rate should be decreased to a minimum rate of 100 mL/min to reduce turbidity levels as low as possible. If dissolved oxygen values are not within acceptable range for the temperature of groundwater (Attachment 1), then check for and remove air bubbles on probe or in tubing. If the dissolved oxygen value is 0.00 or less, then the meter should be serviced and re-calibrated.

During extreme weather conditions, stabilization of field indicator parameters may be difficult to obtain. Modifications to the sampling procedures to alleviate these conditions (e.g., measuring the water temperature in the well adjacent to the pump intake) will be documented in the field notes. If other field conditions exist that preclude stabilization of certain parameters, an explanation of why the parameters did not stabilize will also be documented in the field logbook.

6. Complete the sample label and cover the label with clear packing tape to secure the label onto the container.

7. After the indicator parameters have stabilized, collect groundwater samples by diverting flow out of the unfiltered discharge tubing into the appropriate labeled sample container. If a flow-through analytical cell is being used to measure field parameters, the flow-through cell should be disconnected after stabilization of the field indicator parameters and prior to groundwater sample collection. Under no circumstances should analytical samples be collected from the discharge of the flow-through cell. When the container is full, tightly screw on the cap. Samples should be collected in the following order: VOCs, TOC, SVOCs, metals and cyanide, and others (or other order as defined in the site-specific Work Plan).

8. If sampling for total and filtered metals and/or PCBs, a filtered and unfiltered sample will be collected. Install an in-line, disposable 0.45-micron particle filter on the discharge tubing after the appropriate unfiltered groundwater sample has been collected. Continue to run the pump until an initial volume of “flush” water has been run through the filter in accordance with the manufacturer’s directions (generally 100 to 300 mL). Collect filtered groundwater sample by diverting flow out of the filter into the appropriately labeled sample container. When the container is full, tightly screw on the cap.

9. Secure with packing material and store at 4°C in an insulated transport container provided by the laboratory.

10. Record on the groundwater sampling log or bound field logbook the time sampling procedures were completed, any pertinent observations of the sample (e.g., physical appearance, and the presence or lack of odors or sheens), and the values of the stabilized field indicator parameters as measured during the final reading during purging (Attachment 2 – Example Sampling Log).

11. Turn off the pump and air compressor or close the gas cylinder valve if using a bladder pump set-up. Slowly remove the pump, tubing, lines, and safety cable from the well. Do not allow the tubing or lines to touch the ground or any other surfaces which could contaminate them. .

12. If tubing is to be dedicated to a well, it should be folded to a length that will allow the well to be capped and also facilitate retrieval of the tubing during later sampling events. A length of rope or string should be used to tie the tubing to the well cap. Alternatively, if tubing and safety line are to be saved and reused for sampling the well at a later date they may be coiled neatly and placed in a clean plastic bag that is clearly labeled with the well ID. Make sure the bag is tightly sealed before placing it in storage.

13. Secure the well and properly dispose of personal protective equipment (PPE) and disposable equipment.

14. Complete the procedures for packaging, shipping, and handling with associated chain-of-custody.

15. Complete decontamination procedures for flow-through analytical cell and submersible or bladder pump, as appropriate.

16. At the end of the day, perform calibration check of field instruments.

If it is not technically feasible to use the low-flow sampling method, purging and sampling of monitoring wells may be conducted using the bailer method as outlined below:

1. Don appropriate PPE (as required by the HASP).

2. Place plastic sheeting around the well.

3. Clean sampling equipment.

4. Open the well cover while standing upwind of the well. Remove well cap and place on the plastic sheeting. Insert PID probe approximately 4 to 6 inches into the casing or the well headspace and cover with gloved hand. Record the PID reading in the field log. If the well headspace reading is less than 5 PID units, proceed; if the headspace reading is greater than 5 PID units, screen the air within the breathing zone. If the breathing zone reading is less than 5 PID units, proceed. If the PID reading in the breathing zone is above 5 PID units, move upwind from well for 5 minutes to allow the volatiles to dissipate. Repeat the breathing zone test. If the reading is still above 5 PID units, don appropriate respiratory protection in accordance with the requirements of the HASP. Record all PID readings. For wells that are part of the regular weekly monitoring program and prior PID measurements have not resulted in a breathing zone reading above 5 PID units, PID measurements will be taken monthly.

5. Measure the depth to water and determine depth of well by examining drilling log data or by direct measurement. Calculate the volume of water in the well (in gallons) by using the length of the water column (in feet), multiplying by 0.163 for a 2-inch well or by 0.653 for a 4-inch well. For other well diameters, use the formula:

   Volume (in gallons) = • TIMES well radius (in feet) squared TIMES length of water column (in feet) TIMES 7.481 (gallons per cubic foot)

6. Measure a length of rope or twine at least 10 feet greater than the total depth of the well. Secure one end of the rope to the well casing and secure the other end to the bailer. Test the knots and make sure the rope will not loosen. Check bailers so that all parts are intact and will not be lost in the well.

7. Lower bailer into well and remove one well volume of water. Contain all water in appropriate containers.

8. Monitor the field indicator parameters (e.g., turbidity, temperature, specific conductance, and pH). Measure field indicator parameters using a clean container such as a glass beaker or sampling cups provided with the instrument. Record field indicator parameters on the groundwater sampling log.

9. Repeat Steps 7 and 8 until three or four well volumes have been removed. Examine the field indicator parameter data to determine if the parameters have stabilized. The well is considered stabilized and ready for sample collection when turbidity values remain within 10% (or within 1 NTU if the turbidity reading is less than 10 NTU), the specific conductance and temperature values remain

within 3%, and pH remains within ±0.1 units for three consecutive readings collected once per well volume removed.

10. If the field indicator parameters have not stabilized, remove a maximum of five well volumes prior to sample collection. Alternatively, five well volumes may be removed without measuring the field indicator parameters.

11. If the recharge rate of the well is very low, wells screened across the water table may be bailed dry and sampling should commence as soon as the volume in the well has recovered sufficiently to permit collection of samples. For wells screened entirely below the water table, the well should only be bailed down to a level slightly higher than the bentonite seal above the well screen. The well should not be bailed completely dry, to maintain the integrity of the seal. Sampling should commence as soon as the well volume has recovered sufficiently to permit sample collection.

12. Following purging, allow water level in well to recharge to a sufficient level to permit sample collection.

13. Complete the sample label and cover the label with clear packing tape to secure the label onto the container.

14. Slowly lower the bailer into the screened portion of the well and carefully retrieve a filled bailer from the well causing minimal disturbance to the water and any sediment in the well.

15. The sample collection order (as appropriate) will be as follows:

    a. VOCs;

    b TOC;

    c. SVOCs;

    d. metals and cyanide; and

    e. others.

16. When sampling for volatiles, collect water samples directly from the bailer into 40-mL vials with Teflon®-lined septa.

17. For other analytical samples, remove the cap from the large glass mixing container and slowly empty the bailer into the large glass mixing container. The sample for dissolved metals and/or filtered PCBs should either be placed directly from the bailer into a pressure filter apparatus or pumped directly from the bailer with a peristaltic pump, through an in-line filter, into the pre-preserved sample bottle.

18. Continue collecting samples until the mixing container contains a sufficient volume for all laboratory samples.

19. Mix the entire sample volume with the Teflon® stirring rod and transfer the appropriate volume into the laboratory jar(s). Secure the sample jar cap(s) tightly.

20. If sampling for total and filtered metals and/or PCBs, a filtered and unfiltered sample will be collected. Sample filtration for the filtered sample will be performed in the field using a peristaltic pump prior to preservation. Install new medical-grade silicone tubing in the pump head. Place new Teflon® tubing into the sample mixing container and attach to the intake side of pump tubing. Attach (clamp) a new 0.45-micron filter (note the filter flow direction). Turn the pump on and dispense the filtered liquid directly into the laboratory sample bottles.

21. Secure with packing material and store at 4°C in an insulated transport container provided by the laboratory.

22. After sample containers have been filled, remove one additional volume of groundwater. Measure the pH, temperature, turbidity, and conductivity. Record on the groundwater sampling log or bound field logbook the time sampling procedures were completed, any pertinent observations of the sample (e.g., physical appearance, and the presence or lack of odors or sheens), and the values of the field indicator parameters.

23. Remove bailer from well, secure well, and properly dispose of PPE and disposable equipment.

24. If a bailer is to be dedicated to a well, it should be secured inside the well above the water table, if possible. Dedicated bailers should be tied to the well cap so that inadvertent loss of the bailer will not occur when the well is opened.

25. Complete the procedures for packaging, shipping, and handling with associated chain-of-custody.

VII. Waste Management

Materials generated during groundwater sampling activities, including disposable equipment, will be placed in appropriate containers. Containerized waste will be disposed of by the client consistent with the procedures identified in the HASP.

VIII. Data Recording and Management

Initial field logs and chain-of-custody records will be transmitted to the ARCADIS PM at the end of each day unless otherwise directed by the PM. The groundwater team leader retains copies of the groundwater sampling logs.

IX. Quality Assurance

In addition to the quality control samples to be collected in accordance with this SOP, the following quality control procedures should be observed in the field:

- Collect samples from monitoring wells in order of increasing concentration, to the extent known based on review of historical site information if available.
- Equipment blanks should include the pump and tubing (if using disposable tubing) or the pump only (if using tubing dedicated to each well).
- Collect equipment blanks after wells with higher concentrations (if known) have been sampled.
- Operate all monitoring instrumentation in accordance with manufacturer's instructions and calibration procedures. Calibrate instruments at the beginning of each day and verify the calibration at the end of each day. Record all calibration activities in the field notebook.
- Clean all groundwater sampling equipment prior to use in the first well and after each subsequent well using procedures for equipment decontamination.

X. References

United States Environmental Protection Agency (USEPA). 1986. RCRA Groundwater Monitoring Technical Enforcement Guidance Document (September 1986).

USEPA Region II. 1998. *Ground Water Sampling Procedure Low Stress (Low Flow) Purging and Sampling*.

USEPA. 1991. Handbook Groundwater, Volume II Methodology, Office of Research and Development, Washington, DC. USEPN62S, /6-90/016b (July, 1991).

U.S. Geological Survey (USGS). 1977. National Handbook of Recommended Methods for Water-Data Acquisition: USGS Office of Water Data Coordination. Reston, Virginia.

Attachment 1

Groundwater Sampling Log

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Low-Flow Groundwater Sampling Log

Project ______________________________

Project Number ____________ **Site Location** ____________ **Well ID** ____________

Date ____________ **Sampled By** ____________

Sampling Time ____________ **Recorded By** ____________

Weather ____________ **Coded Replicate No.** ____________

Instrument Identification

Water Quality Meter(s) ____________ **Serial #** ____________

Casing Material ____________ **Purge Method** ____________

Casing Diameter ____________ **Screen Interval (ft bmp)** **Top** ____________ **Bottom** ____________

Sounded Depth (ft bmp) ____________ **Pump Intake Depth (ft bmp)** ____________ ____________

Depth to Water (ft bmp) ____________ **Purge Time** **Start** ____________ **Finish** ____________

Field Parameter Measurements During Purging

Time	Minutes Elasped	Flow Rate (mL/min)	Volume Purged	Temp (°C)	pH (s.u.)	Conductivity (umhos or mS/cm) [1]	ORP (mV)	DO (mg/L)	Turbidity (NTU)	Depth to Water (ft bmp)

Collected Sample Condition **Color**__________ **Odor**__________ **Appearance**__________

Parameter	Container	No.	Preservative

PID Reading ____________

Comments ______________________________

1) Circle one unit type

Attachment 2

Oxygen Solubility in Fresh Water

Temperature (degrees C)	**Dissolved Oxygen** (mg/L)
0	14.6
1	14.19
2	13.81
3	13.44
4	13.09
5	12.75
6	12.43
7	12.12
8	11.83
9	11.55
10	11.27
11	11.01
12	10.76
13	10.52
14	10.29
15	10.07
16	9.85
17	9.65
18	9.45
19	9.26
20	9.07
21	8.9
22	8.72
23	8.56
24	8.4
25	8.24
26	8.09
27	7.95
28	7.81
29	7.67
30	7.54
31	7.41
32	7.28
33	7.16
34	7.05
35	6.93

Reference: Vesilind, P.A., *Introduction to Environmental Engineering*, PWS Publishing Company, Boston, 468 pages (1996).

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Monitoring Well Decommissioning

Rev. #: 0

Rev Date: July 25, 2010

Approval Signatures

Prepared by: ______________________ Date: 07/25/2010

Reviewed by: ______________________ Date: 07/26/2010
(Technical Expert)

I. Scope and Application

This standard operating procedure (SOP) describes the procedures for decommissioning groundwater monitoring wells. Monitoring wells may be decommissioned when it is found they are no longer suitable for collection of groundwater data (i.e., groundwater quality or groundwater elevation) due to damaged and/or questionable construction, when they must be removed to avoid interference to/from other construction activities in the area, or when groundwater monitoring is no longer required at the location. The purpose for decommissioning monitoring wells no longer in use is to:

- Eliminate physical hazards associated with an out-of-use monitoring well;
- Conserve the yield and hydrostatic head of confining aquifers;
- Prevent the intermingling of separate aquifers; and
- Remove a potential conduit for the vertical migration of constituents in groundwater along the well casing.

This SOP covers the decommissioning of single-cased overburden monitoring wells when a replacement well will not be installed within the same borehole. Three potential decommissioning methods (i.e., plugging-in-place, casing removal, and overdrilling) are described below.

Although these procedures are generally applicable for the decommissioning of double-cased monitoring wells or wells installed within bedrock, in most cases a decommissioning strategy should be developed on a well-by well basis. Additional information regarding potential methods to decommission these types of wells may be found in ASTM D5299-99 - Standard Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities.

II. Personnel Qualifications

The well decommissioning procedures described below will be carefully adhered to and conducted under the supervision of an experienced geologist, engineer, or other qualified individual. If the overdrilling decommissioning method is utilized, drilling activities will be conducted by a registered well driller.

III. Equipment List

The following materials, as required, shall be available during pre-decommissioning and decommissioning activities:

- Site Health and Safety Plan (HASP);
- Health and safety equipment, as required in the HASP (e.g., air monitoring equipment, personal protective equipment);
- Information concerning the construction of the well to be decommissioned;
- Appropriate field forms or field notebook;
- Well keys;
- Water level probe;
- Cleaning materials;
- Drill rig with registered well driller and experienced personnel if the overdrilling method is utilized;
- Tremie pipe;
- Type I Portland cement;
- Uncoated bentonite pellets;
- Potable water;
- Containers for collecting spoils; and
- Any necessary specialized well drilling/decommissioning equipment.

IV. Cautions

Avoid using drilling fluids or materials that could impact groundwater or soil quality, or could be incompatible with the subsurface conditions.

Water used for over drilling or grouting boreholes upon completion will be of a quality acceptable for project objectives. If the water quality is unknown, testing of water supply should be considered.

Specifications of materials used for backfilling the bore hole will be obtained, reviewed and approved to meet project quality objectives.

No coated bentonite pellets will be used in monitoring well decommissioning, as the coating could be a source of contamination.

V. Health and Safety Considerations

Health and safety protocols should be described in the site-specific health and safety plan.

VI. Procedures

Plug-In Place Method

The plug-in-place method is applicable at locations where available information indicates that the annular space contains an adequate seal and vertical migration of constituents across a confining layer is not a concern in the well casing and screen interval, or if other considerations (e.g., double-cased well construction) preclude removal of the well casing. The well screen is left in place and may be additionally perforated, along with the base of the well, to allow the grout seal to penetrate the surrounding filter pack. The decommissioning process will consist of the following steps:

1. Perform a search of available records concerning the well to be decommissioned. The following activities should be performed to identify the location, construction, and condition of the well, and to determine the appropriate equipment to be utilized based on the depth, diameter, and access to the monitoring well:

    - Review the existing monitoring well log to identify construction characteristics (e.g., total depth, casing diameter, initial borehole diameter, type of casing, type of material(s) used);

    - Locate the monitoring well in the field;

    - Identify if the decommissioning equipment can access the monitoring well and/or if special considerations (e.g., construction of an access road) are necessary to gain access;

    - Conduct total depth measurements and water level measurements;

- Calculate the volume of the well that will need to be filled utilizing field measurements and formulas provided above; and

- Record all observations and measurements.

2. Remove the protective casing and well casing to a depth of approximately 3 to 4 feet below ground surface (bgs), if possible.

3. Perforate the base of the well screen utilizing a length of drilling rod or other equipment.

4. Prepare a neat cement grout. (Note: A neat cement grout is preferred for application through an in-place well; whereas, a bentonite grout or hydrated bentonite pellets may also be considered at locations where the well casing is removed or the well is overdrilled).

5. Place the neat cement grout in the perforated well casing via the tremie method (i.e., the grout will be pumped from the bottom of the well upward). The grout will be added until the well is filled to above the top of the well casing remaining in place (i.e., typically approximately 3 to 4 feet bgs). Verify that the amount of grout added equals or exceeds the calculated volume of the void to be filled.

6. The grout will be allowed to set for a minimum of 24 hours and the remainder of the borehole will be filled with concrete and/or other surface finish materials (see Step 7 below).

7. Where appropriate, a concrete surface finish will be installed by constructing an above-grade concrete slab a minimum of 6 inches thick, with a diameter at least 2 feet greater than the diameter of the borehole. If such a concrete surface finish is not compatible with the existing land use (e.g., roadway, parking lot, residential), the borehole shall be terminated with a minimum 1-foot-thick concrete plug above the grout and the remaining portion of the borehole shall be filled flush with grade with material(s) compatible with the surrounding land surface (e.g., asphalt, gravel, topsoil).

8. A Well Abandonment Log will be completed. A state specific Well Abandonment Log should be used and submitted to the appropriate state agency if required. .

Casing Removal Method

The casing removal method is applicable at shallow locations where vertical migration of constituents across a confining layer is not a concern and where the integrity of the borehole is reasonably expected to be maintained following removal of the well materials. The decommissioning process will consist of the following steps:

1. Perform a search of available records concerning the well to be decommissioned. The following activities should be performed to identify the location, construction, and condition of the well, and determine the appropriate equipment to be utilized based on the depth, diameter, and access to the monitoring well:

   - Review the existing monitoring well log to identify construction characteristics (e.g., total depth, casing diameter, initial borehole diameter, type of casing, type of material(s) used);

   - Locate the monitoring well in the field;

   - Identify if the decommissioning equipment can access the monitoring well and/or if special considerations (e.g., construction of an access road) are necessary to gain access;

   - Conduct total depth measurements and water level measurements;

   - Calculate volume of well that will need to be filled utilizing field measurements and formulas provided above; and

   - Record all observations and measurements.

2. Remove the protective casing, if possible.

3. Remove the well materials (riser and screen).

4. Examine removed well materials to ensure that the entire section has been removed. Also ensure that the borehole has not collapsed and that the tremie pipe will be able to be inserted to the base of well depth. Well decommissioning should be completed by using the overdrilling method if the well casing is broken below grade and cannot be retrieved, or if the tremie pipe will not reach the base of the well.

5. Prepare a neat cement grout or a bentonite grout that is compatible with the soil and groundwater conditions present at the monitoring well. (Note: A neat cement grout or a bentonite grout is preferred for this application. Hydrated bentonite pellets may also be considered if the entire well boring is overdrilled, using procedures similar to those for abandoning boreholes).

6. Place the cement grout in the borehole via tremie method (i.e., the grout will be pumped from the bottom of the borehole upward). The grout will be added until the borehole is filled to approximately 3 to 4 feet bgs. Verify that amount of grout added equals or exceeds the calculated volume of the void to be filled.

7. The grout will be allowed to set for a minimum of 24 hours and the remainder of the borehole will be filled with concrete and/or other surface finish materials (see Step 8 below).

8. Where appropriate, a concrete surface finish will be installed by constructing an above-grade concrete slab a minimum of 6 inches thick, with a diameter at least 2 feet greater than the diameter of the borehole. If such a concrete surface finish is not compatible with the existing land use (e.g., roadway, parking lot, residential), the borehole shall be terminated with a minimum 1-foot-thick concrete plug above the grout and the remaining portion of the borehole shall be filled flush with grade with material(s) compatible with the surrounding land surface (e.g., asphalt, gravel, topsoil).

A Well Abandonment Log will be completed. A state specific Well Abandonment Log should be used and submitted to the appropriate state agency if required.

Overdrilling Method

The overdrilling method is the most conservative decommissioning procedure and should be utilized at locations where a well has penetrated a confining layer and there is no evidence that the annular space around the well casing was adequately sealed, or if attempts to remove the well casing are unsuccessful. The decommissioning process will consist of the following steps:

1. Perform a search of available records concerning the well to be decommissioned. The following activities should be performed to identify the location, construction, and condition of the well, and determine the appropriate equipment to be utilized based on the depth, diameter, and access to the monitoring well:

    - Review the existing monitoring well log to identify construction characteristics (e.g., total depth, casing diameter, initial borehole diameter, type of casing, type of material(s) used);

    - Locate the monitoring well in the field;

- Identify if a drill rig can access the monitoring well and/or if special considerations (e.g., construction of an access road) are necessary to gain access;

- Conduct total depth measurements and water level measurements;

- Calculate the volume of the well/borehole that will need to be filled utilizing field measurements and formulas provided above; and

- Record all observations and measurements.

2. Remove the protective casing, if possible.

3. If the protective casing has been removed, advance a hollow-stem auger or other drill casing (with an outside diameter larger than the well diameter) over the well casing to the bottom of the original borehole.

4. Prepare a neat cement grout or a bentonite grout that is compatible with the soil and groundwater conditions present at the monitoring well. Alternatively, hydrated bentonite pellets may be used to plug the borehole, using procedures similar to those for abandoning boreholes.

5. Place the cement grout in the borehole via tremie method (i.e., the grout will be pumped from the bottom of the borehole upward) at the same time the hollow-stem augers or drill casing are removed from the borehole. Grout will be added until the borehole is filled to approximately 3 to 4 feet bgs. Verify that the amount of grout added equals or exceeds the calculated volume of the void to be filled. If hydrated bentonite pellets are utilized, measure deposition depth with a weighted tape as the hollow-stem augers or drill casing are removed from the borehole to ensure that bridging does not occur. At certain shallow well locations installed in competent formations, it may be possible to remove the hollow-stem augers or drill casing prior to installing the sealant. If this is attempted, confirmatory measurements must be taken to verify that borehole integrity was maintained prior to plugging the hole.

6. The grout will be allowed to set for a minimum of 24 hours and the remainder of the borehole will be filled with concrete and/or other surface finish materials (see Step 7 below).

7. Where appropriate, a concrete surface seal will be installed by constructing an above-grade concrete slab a minimum of 6 inches thick, with a diameter at least 2 feet greater than the diameter of the borehole. If such a concrete surface seal is not compatible with the existing land use (e.g., roadway, parking lot,

residential), the borehole shall be terminated with a minimum 1-foot-thick concrete plug above the grout and the remaining portion of the borehole shall be filled flush with grade with material(s) compatible with the surrounding land surface (e.g., asphalt, gravel, topsoil).

8. A Well Abandonment Log will be completed. A state specific Well Abandonment Log should be used and submitted to the appropriate state agency if required.

Abandoning a Soil Boring

The following steps for abandoning a soil boring are summarized from ASTM D 5299-99:

1. Prepare a neat cement grout using Type I Portland cement and potable water mixed according to the following ratios:

   One (1) 94-pound bag of Type I Portland cement; and 5.5 gallons potable water.

2. As soon as the borehole is completed, place a grout pipe (tremie pipe) to the bottom of the boring and pump sealing grout slowly through the pipe to displace material in the borehole. Inject grout starting from the bottom of the hole. Grout slowly to prevent channeling of the grout. As the grouting progresses, slowly raise the pipe. Complete the grouting in one continuous operation, continuing to pump grout until overflowing grout is seen at the surface. The overflowing grout should be similar in appearance and characteristics to the grout being pumped down the hole.

3. Grout may settle over a 24-hour period. After 24 hours, check the grout in the borehole for settlement. If settling has occurred, place additional grout to the surface. When grouting is complete, finish the surface in a manner appropriate for final use (e.g., concrete).

VII. Waste Management

Waste management protocols should be described in the site-specific work plan.

VIII. Data Recording and Management

To assure that a well is properly plugged and there has been no bridging of the plugging materials, verification calculations and measurements are required to determine whether the volume of material placed in the well/borehole equals or exceeds the volume of the void being filled. Some useful formulas for calculating well and material volumes are provided below.

- 7.481 gallons = 1 cubic foot
- 202.0 gallons = 1 cubic yard
- Volume of well/borehole (in gallons) = π TIMES well/borehole radius (in feet) squared TIMES length of well/borehole (in feet) TIMES 7.481 (gallons per cubic foot)

IX. Quality Assurance

Quality assurance protocols should be described in the site-specific work plan.

X. References

ASTM. D5299-99. Standard Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities.

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Monitoring Well Installation

Rev. #: 2

Rev Date: August 22, 2008

Approval Signatures

Prepared by: ______________________ Date: 07/22/2010

Reviewed by: ______________________ Date: 8/25/08
(Technical Expert)

I. Scope and Application

The procedures set out herein are designed to produce standard groundwater monitoring wells suitable for: (1) groundwater sampling, (2) water level measurement, (3) bulk hydraulic conductivity testing of formations adjacent to the open interval of the well.

Monitoring well boreholes in unconsolidated (overburden) materials are typically drilled using the hollow-stem auger drilling method. Other drilling methods that are also suitable for installing overburden monitoring wells, and are sometimes necessary due to site-specific geologic conditions, include: drive-and-wash, spun casing, Rotasonic, dual-rotary (Barber Rig), and fluid/mud rotary with core barrel or roller bit. Direct-push techniques (e.g., Geoprobe or cone penetrometer) and driven well points may also be used in some cases within the overburden. Monitoring wells within consolidated materials such as bedrock are commonly drilled using water-rotary (coring or tri-cone roller bit), air rotary or Rotasonic methods. The drilling method to be used at a given site will be selected based on site-specific consideration of anticipated drilling/well depths, site or regional geologic knowledge, type of monitoring to be conducted using the installed well, and cost.

No oils or grease will be used on equipment introduced into the boring (e.g., drill rod, casing, or sampling tools). No polyvinyl chloride (PVC) glue/cement will be used in constructing or retrofitting monitoring wells that will be used for water-quality monitoring. No coated bentonite pellets will be used in the well drilling or construction process. Specifications of materials to be installed in the well will be obtained prior to mobilizing onsite, including:

- well casing;
- bentonite;
- sand; and
- grout.

Well materials will be inspected and, if needed, cleaned prior to installation.

II. Personnel Qualifications

Monitoring well installation activities will be performed by persons who have been trained in proper well installation procedures under the guidance of an experienced field geologist, engineer, or technician. Where field sampling is performed for soil or bedrock characterization, field personnel will have undergone in-field training in soil or bedrock description methods, as described in the appropriate SOP(s) for those activities.

III. Equipment List

The following materials will be available during soil boring and monitoring well installation activities, as required:

- Site Plan with proposed soil boring/well locations;
- Work Plan or Field Sampling Plan (FSP), and site Health and Safety Plan (HASP);
- personal protective equipment (PPE), as required by the HASP;
- traffic cones, delineators, caution tape, and/or fencing as appropriate for securing the work area, if such are not provided by drillers;
- appropriate soil sampling equipment (e.g., stainless steel spatulas, knife);
- soil and/or bedrock logging equipment as specified in the appropriate SOPs;
- appropriate sample containers and labels;
- drum labels as required for investigation derived waste handling;
- chain-of-custody forms;
- insulated coolers with ice, when collecting samples requiring preservation by chilling;
- photoionization detector (PID) or flame ionization detector (FID);
- ziplock style bags;
- water level or oil/water interface meter;
- locks and keys for securing the well after installation;
- decontamination equipment (bucket, distilled or deionized water, cleansers appropriate for removing expected chemicals of concern, paper towels);

- field notebook.

Prior to mobilizing to the site, ARCADIS personnel will contact the drilling subcontractor or in-house driller (as appropriate) to confirm that appropriate sampling and well installation equipment will be provided. Specifications of the sampling and well installation equipment are expected to vary by project, and so communication with the driller will be necessary to ensure that the materials provided will meet the project objectives. Equipment typically provided by the driller could include:

- drilling equipment required by the American Society of Testing and Materials (ASTM) D 1586, when performing split-spoon sampling;
- disposable plastic liners, when drilling with direct-push equipment;
- drums for investigation derived waste;
- drilling and sampling equipment decontamination materials;
- decontamination pad materials, if required; and
- well construction materials.

IV. Cautions

Prior to beginning field work, underground utilities in the vicinity of the drilling areas will be delineated by the drilling contractor or an independent underground utility locator service. See separate SOP for utility clearance.

Some regulatory agencies require a minimum annular space between the well or permanent casing and the borehole wall. When specified, the minimum clearance is typically 2 inches on all sides (e.g., a 2-inch diameter well requires a 6-inch diameter borehole). In addition, some regulatory agencies have specific requirements regarding grout mixtures. Determine whether the oversight agency has any such requirements prior to finalizing the drilling and well installation plan.

If dense non-aqueous phase liquids (DNAPL) are known or expected to exist at the site, refer to the DNAPL Contingency Plan SOP for additional details regarding drilling and well installation to reduce the potential for inadvertent DNAPL remobilization.

Avoid using drilling fluids or materials that could impact groundwater or soil quality, or could be incompatible with the subsurface conditions.

Similarly, consider the material compatibility between the well materials and the surrounding environment. For example, PVC well materials are not preferred when DNAPL is present. In addition, some groundwater conditions leach metals from stainless steel.

Water used for drilling and sampling of soil or bedrock, decontamination of drilling/sampling equipment, or grouting boreholes upon completion will be of a quality acceptable for project objectives. Testing of water supply should be considered.

Specifications of materials used for backfilling bore hole will be obtained, reviewed and approved to meet project quality objectives. Bentonite is not recommended where DNAPLs are likely to be present. In these situations, neat cement grout is preferred.

No coated bentonite pellets will be used in monitoring well construction, as the coating could impact the water quality in the completed well.

Monitoring wells may be installed with Schedule 40 polyvinyl chloride (PVC) to a maximum depth of 200 feet below ground surface (bgs). PVC monitoring wells between 200 and 400 feet total depth will be constructed using Schedule 80 PVC. Monitoring wells deeper than 400 feet will be constructed using steel.

V. Health and Safety Considerations

Field activities associated with monitoring well installation will be performed in accordance with a site-specific HASP, a copy of which will be present on site during such activities.

VI. Procedures

The procedures for installing groundwater monitoring wells are presented below:

Hollow-Stem Auger, Drive-and-Wash, Spun Casing, Fluid/Mud Rotary, Rotasonic, and Dual-Rotary Drilling Methods

1. Locate boring/well location, establish work zone, and set up sampling equipment decontamination area.

2. Advance boring to desired depth. Collect soil and/or bedrock samples at appropriate interval as specified in the Work Plan and/or FSP. Collect, document, and store samples for laboratory analysis as specified in the Work Plan and/or FSP. Decontaminate equipment between samples in accordance with the Work Plan and/or FSP. A common sampling method that produces

high-quality soil samples with relatively little soil disturbance is the ASTM D 1586 - Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils. Split-spoon samples are obtained during drilling using hollow-stem auger, drive-and-wash, spun casing, and fluid/mud rotary. Rotasonic drilling produces large-diameter soil cores that tend to be more disturbed than split-spoon samples due to the vibratory action of the drill casing. Dual-rotary removes cuttings by compressed air and allows only a general assessment of geology. High-quality bedrock samples can be obtained by coring.

3. Describe each soil or bedrock sample as outlined in the appropriate SOP. Record descriptions in the field notebook and/or personal digital assistant (PDA). It should be noted that PDA logs must be electronically backed up and transferred to a location accessible to other project team members as soon as feasible to retain and protect the field data. During soil boring advancement, document all drilling events in field notebook, including blow counts (number of blows required to advance split-spoon sampler in 6-inch increments) and work stoppages. Blow counts will not be available if Rotasonic, dual-rotary, or direct-push methods are used. When drilling in bedrock, the rate of penetration (minutes per foot) is recorded.

4. If it is necessary to install a monitor well into a permeable zone below a confining layer, particularly if the deeper zone is believed to have water quality that differs significantly from the zone above the confining layer, then a telescopic well construction should be considered. In this case, the borehole is advanced approximately 3 to 5 feet into the top of the confining layer, and a permanent casing (typically PVC, black steel or stainless steel) is installed into the socket drilled into the top of the confining layer. The casing is then grouted in place. The preferred methods of grouting telescoping casings include: pressure-injection grouting using an inflatable packer installed temporarily into the base of the casing, such that grout is injected out the bottom of the casing until it is observed at ground surface outside the casing; displacement-method grouting (also known as the Halliburton method), which entails filling the casing with grout and displacing the grout out the bottom of the casing by pushing a drillable plug, typically made of wood to the bottom of the casing, following by tremie grouting the remainder of the annulus outside the casing; or tremie grouting the annulus surrounding the casing using a tremie pipe installed to the base of the borehole. In all three cases, the casing is grouted to the ground surface, and the grout is allowed to set prior to drilling deeper through the casing. Site-specific criteria and work plans should be created for the completion of non-standard monitoring wells, including telescopic wells.

5. In consolidated formations such as competent bedrock, a monitoring well may be completed with an open borehole interval without a screen and sandpack. In these cases, the borehole is advanced to the targeted depth of the top of the open interval. A permanent casing is then grouted in place following the procedures described in Step 4 above. After the grout sets, the borehole is advanced by drilling through the permanent casing to the targeted bottom depth of the open interval, which then serves as the monitoring interval for the well. If open-borehole interval stability is found to be questionable or if a specific depth interval is later selected for monitoring, a screened monitoring well may later be installed within the open-borehole interval, depending on the annular space and well diameter requirements.

6. Prior to screened well installation or after the completion of an open-bedrock well, the water level or oil/water interface probe should be used to determine the static water level in the borehole in relation to the proposed well screen or open-interval location. If necessary, an open-bedrock well may be drilled deeper to intersect the water table or a permeable water-bearing zone.

7. Upon completing the borehole to the desired depth, if a screened well construction is desired, install the monitoring well by lowering the screen and casing assembly with sump through the augers or casing. Monitoring wells typically will be constructed of 2-inch-diameter, flush-threaded PVC or stainless steel slotted well screen and blank riser casing. Smaller diameters may be used if wells are installed using direct-push methodology or if multiple wells are to be installed in a single borehole. The screen length will be specified in the Work Plan or FSP based on regulatory requirements and specific monitoring objectives. Monitoring well screens are usually 5 to 10 feet long, but may be up to 25 feet long in very low permeability, thick geologic formations. The screen length will depend on the purpose for the well and the objectives of the groundwater investigation. Typically, the slot size will be 0.010 inch and the sand pack will be 20-40, Morie No. 0, or equivalent. In very fine-grained formations where sample turbidity needs to be minimized, it may be preferred to use a 0.006-inch slot size and 30-65, Morie No. 00, or equivalent sand pack. Alternatively, where monitoring wells are installed in coarse-grained deposits and higher well yield is required, a 0.020-inch slot size and 10-20, Morie No. 1, or equivalent sand pack may be preferred. To the extent practicable, the slot size and sand pack gradation may be predetermined in the Work Plan or FSP based on site-specific grain-size analysis or other geologic considerations or monitoring objectives. A blank sump may be attached below the well screen if the well is being installed for DNAPL recovery/monitoring purposes. If so, the annular space around the sump will be backfilled with neat cement grout to the bottom of the well screen prior to placing the sand pack around the screen. A

blank riser will extend from the top of the screen to approximately 2.5 feet above grade or, if necessary, just below grade where conditions warrant a flush-mounted monitoring well. For wells greater than 50 feet deep, centralizers may be desired to assist in centralizing the monitoring well in the borehole during construction.

8. When the monitoring well assembly has been set in place and the grout has been placed around the sump (if any), place a washed silica sand pack in the annular space from the bottom of the boring to a height of 1 to 2 feet above the top of the well screen. The sand pack is placed and drilling equipment extracted in increments until the top of the sand pack is at the appropriate depth. The sand pack will be consistent with the screen slot size and the soil particle size in the screened interval, as specified in the Work Plan or FSP. A hydrated bentonite seal (a minimum of 2 feet thick) will then be placed in the annular space above the sand pack. If non-hydrated bentonite is used, the bentonite should be permitted to hydrate in place for a minimum of 30 minutes before proceeding. No coated bentonite pellets will be used in monitoring well drilling or construction. Potable water may be added to hydrate the bentonite if the seal is above the water table. Monitor the placement of the sand pack and bentonite with a weighted tape measure. During the extraction of the augers or casing, a cement/bentonite or neat cement grout will be placed in the annular space from the bentonite seal to a depth approximately 2 feet bgs.

9. Place a locking, steel protective casing (extended at least 1.5 feet below grade and 2 feet above grade) over the riser casing and secure with a neat cement seal. Alternatively, for flush-mount completions, place a steel curb box with a bolt-down lid over the riser casing and secure with a neat cement seal. In either case, the cement seal will extend approximately 1.5 to 2.0 feet below grade and laterally at least 1 foot in all directions from the protective casing, and should slope gently away to promote drainage away from the well. Monitoring wells will be labeled with the appropriate designation on both the inner and outer well casings or inside of the curb box lid.

   When an above-grade completion is used, the PVC riser will be sealed using an expandable locking plug and the top of the well will be vented by drilling a small-diameter (1/8 inch) hole near the top of the well casing or through the locking plug, or by cutting a vertical slot in the top of the well casing. When a flush-mount installation is used, the PVC riser will be sealed using an unvented, expandable locking plug.

10. During well installation, record construction details and actual measurements relayed by the drilling contractor and tabulate materials used (e.g., screen and riser footages; bags of bentonite, cement, and sand) in the field notebook.

11. After completing the well installation, lock the well, clean the area, and dispose of materials in accordance with the procedures outlined in Section VII below.

Direct-Push Method

The direct-push drilling method may also be used to complete soil borings and install monitoring wells. Examples of this technique include the Diedrich ESP vibratory probe system, GeoProbe®, or AMS Power Probe® dual-tube system. Environmental probe systems typically use a hydraulically operated percussion hammer. Depending on the equipment used, the hammer delivers 140- to 350-foot pounds of energy with each blow. The hammer provides the force needed to penetrate very stiff/medium dense soil formations. The hammer simultaneously advances an outer steel casing that contains a dual-tube liner for sampling soil. The outside diameter (OD) of the outer casing ranges from 1.75 to 2.4 inches and the OD of the inner sampling tube ranges from 1.1 to 1.8 inches. The outer casing isolates shallow layers and permits the unit to continue to probe at depth. The double-rod system provides a borehole that may be tremie-grouted from the bottom up. Alternatively, the inside diameter (ID) of the steel casing provides clearance for the installation of small-diameter (e.g., 0.75- to 1-inch ID) micro-wells. The procedures for installing monitoring wells in soil using the direct-push method are described below.

1. Locate boring/well location, establish work zone, and set up sample equipment decontamination area.

2. Advance soil boring to designated depth, collecting samples at intervals specified in the Work Plan. Samples will be collected using dedicated, disposable, plastic liners. Describe samples in accordance with the procedures outlined in Step 3 above. Collect samples for laboratory analysis as specified in the Work Plan and/or FSP.

3. Upon advancing the borehole to the desired depth, install the micro-well through the inner drill casing. The micro-well will consist of approximately 1-inch ID PVC or stainless steel slotted screen and blank riser. The sand pack, bentonite seal, and cement/bentonite grout will be installed as described, where applicable, in Step 7 and 8 above.

4. Install protective steel casing or flush-mount, as appropriate, as described in Step 9 above. During well installation, record construction details and tabulate materials used.

5. After completing the well installation, lock the well, clean the area, and dispose of materials in accordance with the procedures outlined in Section VII below.

Driven Well Point Installation

Well points will be installed by pushing or driving using a drilling rig or direct-push rig, or hand-driven where possible. The well point construction materials will consist of a 1- to 2-inch-diameter threaded steel casing with either 0.010- or 0.020-inch slotted stainless steel screen. The screen length will vary depending on the hydrogeologic conditions of the site. The casings will be joined together with threaded couplings and the terminal end will consist of a steel well point. Because they are driven or pushed to the desired depth, well points do not have annular backfill materials such as sand pack or grout.

VII. Waste Management

Investigation-derived wastes (IDW), including soil cuttings and excess drilling fluids (if used), decontamination liquids, and disposable materials (well material packages, PPE, etc.), will be placed in clearly labeled, appropriate containers, or managed as otherwise specified in the Work Plan, FSP, and/or IDW management SOP.

VIII. Data Recording and Management

Drilling activities will be documented in a field notebook. Pertinent information will include personnel present on site, times of arrival and departure, significant weather conditions, timing of well installation activities, soil descriptions, well construction specifications (screen and riser material and diameter, sump length, screen length and slot size, riser length, sand pack type), and quantities of materials used. In addition, the locations of newly-installed wells will be documented photographically or in a site sketch. If appropriate, a measuring wheel or engineer's tape will be used to determine approximate distances between important site features.

The well or piezometer location, ground surface elevation, and inner and outer casing elevations will be surveyed using the method specified in the site Work Plan. Generally, a local baseline control will be set up. This local baseline control can then be tied into the appropriate vertical and horizontal datum, such as the National Geodetic Vertical Datum of 1929 or 1988 and the State Plane Coordinate System. At a minimum, the elevation of the top of the inner casing used for water-level measurements should be measured to the nearest 0.01 foot. Elevations will be established in relation to the National Geodetic Vertical Datum of 1929. A permanent mark will be placed on top of the inner casing to mark the point for water-level measurements.

IX. Quality Assurance

All drilling equipment and associated tools (including augers, drill rods, sampling equipment, wrenches, and any other equipment or tools) that may have come in contact with soil will be cleaned in accordance with the procedures outlined in the appropriate SOP. Well materials will also be cleaned prior to well installation.

X. References

American Society of Testing and Materials (ASTM) D 1586 - *Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils*.

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Monitoring Well Development

Rev. #: 2.2

Rev. Date: March 22, 2010

Approval Signatures

Prepared by: ______________________ Date: 03/22/2010

Reviewed by: ______________________ Date: 03/22/2010
(Technical Expert)

I. Scope and Application

Monitoring wells (or piezometers, well points, or micro-wells) will be developed to clear them of fine-grained sediment to enhance the hydraulic connection between the well and the surrounding geologic formation. Development will be accomplished by evacuating well water by either pumping or bailing. Prior to pumping or bailing, the screened interval will be gently surged using a surge block, bailer, or inertia pump with optional surgeblock fitting as appropriate. Accumulated sediment in the bottom of the well (if present) will be removed by bailing with a bottom-loading bailer or via pumping using a submersible or inertia pump with optional surge-block fitting. Wells will also be gently brushed with a weighted brush to assist in removing loose debris, silt or flock attached to the inside of the well riser and/or screen prior to development. Pumping methods will be selected based on site-specific geologic conditions, anticipated well yield, water table depth, and groundwater monitoring objectives, and may include one or more of the following:

- submersible pump
- inertial pump (Waterra™ pump or equivalent)
- bladder pump
- peristaltic pump
- centrifugal pump

When developing a well using the pumping method, the pump (or, with inertial pumps, the tubing) is lowered to the screened portion of the well. During purging, the pump or tubing is moved up and down the screened interval until the well yields relatively clear water.

Submersible pumps have a motor-driven impeller that pushes the groundwater through discharge tubing to the ground surface. Inertial pumps have a check valve at the bottom of stiff tubing which, when operated up and down, lifts water to the ground surface. Bladder pumps have a bottom check valve and a flexible internal bladder that fills from below and is then compressed using pressurized air to force water out the top of the bladder through the discharge tubing to the ground surface. These three types of pumps have a wide range of applicability in terms of well depth and water depth.

Centrifugal and peristaltic pumps use atmospheric pressure to lift water from the well, and therefore can only be practically used where the depth to water is less than 25 feet.

II. Personnel Qualifications

Monitoring well development activities will be performed by persons who have been trained in proper well development procedures under the guidance of an experienced field geologist, engineer, or technician.

III. Equipment List

Materials for monitoring well development using a pump include the following:

- health and safety equipment, as required by the site Health and Safety Plan (HASP):
- cleaning equipment
- photoionization detector (PID) to measure headspace vapors
- pump
- polyethylene pump discharge tubing
- plastic sheeting
- power source (generator or battery)
- field notebook and/or personal digital assistant (PDA)
- graduated pails
- appropriate containers

- monitoring well keys
- water level indicator

Materials for monitoring well development using a bailer include the following:

- personal protective equipment (PPE) as required by the HASP
- cleaning equipment
- PID to measure headspace vapors
- bottom-loading bailer, sand bailer
- polypropylene or nylon rope
- plastic sheeting
- graduated pails
- appropriate containers
- keys to wells
- field notebook and/or PDA
- water level indicator
- weighted brush for well brushing

IV. Cautions

Where surging is performed to assist in removing fine-grained material from the sand pack, surging must be performed in a gentle manner. Excessive suction could promote fine-grained sediment entry into the outside of the sand pack from the formation.

Avoid using development fluids or materials that could impact groundwater or soil quality, or could be incompatible with the subsurface conditions.

In some cases it may be necessary to add potable water to a well to allow surging and development, especially for new monitoring wells installed in low permeability formations. Before adding potable water to a well, the Project Manager (PM) must be notified and the PM shall make the decision regarding the appropriateness and applicability of adding potable water to a well during well development procedures. If potable water is to be added to a well as part of development, the potable water source should be sampled and analyzed for constituents of concern, and the results evaluated by the PM prior to adding the potable water to the well. If potable water is added to a well for development purposes, at the end of development the well will be purged dry to remove the potable water, or if the well no longer goes dry then the well will be purged to remove at least three times the volume of potable water that was added.

V. Health and Safety Considerations

Field activities associated with monitoring well development will be performed in accordance with a site-specific HASP, a copy of which will be present on site during such activities.

VI. Procedure

The procedures for monitoring well development are described below. (Note: Steps 7, 8, and 10 can be performed at the same time using an inertial pump with a surge-block fitting.)

1. Don appropriate PPE (as required by the HASP).

2. Place plastic sheeting around the well.

3. Clean all equipment entering each monitoring well, except for new, disposable materials that have not been previously used.

4. Open the well cover while standing upwind of the well, remove well cap. Insert PID probe approximately 4 to 6 inches into the casing or the well headspace and cover with gloved hand. Record the PID reading in the field notebook. If the well headspace reading is less than 5 PID units, proceed; if the headspace reading is greater than 5 PID units, screen the air within the breathing zone. If the PID reading in the breathing zone is below 5 PID units, proceed. If the PID reading is above 5 PID units, move upwind from well for 5 minutes to allow the volatiles to dissipate. Repeat the breathing zone test. If the reading is still above 5 PID units, don the appropriate respiratory protection in accordance with the requirements of the HASP. Record all PID readings.

5. Obtain an initial measurement of the depth to water and the total well depth from the reference point at the top of the well casing. Record these measurements in the field log book.

6. Prior to redeveloping older wells that may contain solid particulate debris along the inside of the well casing and screen, gently lower and raise a weighted brush along the entire length of the well screen and riser to free and assist in removing loose debris, silt or flock. Perform a minimum of 4 “passes” along the screened and cased intervals of the well below the static water level in the well. Allow the resulting suspended material to settle for a minimum of one day prior to continuing with redevelopment activities.

7. Lower a surge block or bailer into the screened portion of the well. Gently raise and lower the surge block or bailer within the screened interval of the well to force water in and out of the screen slots and sand pack. Continue surging for 15 to 30 minutes.

8. Lower a bottom-loading bailer, submersible pump, or inertia pump tubing with check valve to the bottom of the well and gently bounce the bailer, pump, pump tubing on the bottom of the well to collect/remove accumulated sediment, if any. Remove and empty the bailer, if used. Repeat until the bailed/pumped water is free of excessive sediment and the bottom of the well feels solid. Alternatively, measurement of the well depth with a water level indicator can be used to verify that sediment and/or silt has been removed to the extent practicable, based on a comparison with the well installation log or previous measurement of total well depth.

9. After surging the well and removing excess accumulated sediment from the bottom of the well, re-measure the depth-to-water and the total well depth from the reference point at the top of the well casing. Record these measurements in the field log book.

10. Remove formation water by pumping or bailing. Where pumping is used, measure and record the pre-pumping water level. Operate the pump at a relatively constant rate. Measure the pumping rate using a calibrated container and stop watch, and record the pumping rate in the field log book. Measure and record the water level in the well at least

once every 5 minutes during pumping. Note any relevant observations in terms of water color, visual level of turbidity, sheen, odors, etc. Pump or bail until termination criteria specified in the Field Sampling Plan (FSP) are reached. Record the total volume of water purged from the well.

11. If the well goes dry, stop pumping or bailing. Note the time that the well went dry. After allowing the well to recover, note the time and depth to water. Resume pumping or bailing when sufficient water has recharged the well.

12. Contain all water in appropriate containers.

13. When complete, secure the lid back on the well.

14. Place disposable materials in plastic bags for appropriate disposal and decontaminate reusable, downhole pump components and/or bailer.

VII. Waste Management

Materials generated during monitoring well installation and development will be placed in appropriate labeled containers and disposed of as described in the Work Plan or Field Sampling Plan.

VIII. Data Recording and Management

Well development activities will be documented in a proper field notebook and/or PDA. Pertinent information will include personnel present on site; times of arrival and departure; significant weather conditions; timing of well development activities; development method(s); observations of purge water color, turbidity, odor, sheen, etc.; purge rate; and water levels before and during pumping.

IX. Quality Assurance

All reused, non-disposable, downhole well development equipment will be cleaned in accordance with the procedures outlined in the Field Equipment Cleaning-Decontamination SOP.

X. References

Not applicable.

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Photoionization Detector Air Monitoring and Field Screening

Rev. #: 1

Rev Date: November 8, 2009

Approval Signatures

Prepared by: (the late) Maureen Geisser Date: July 28, 2003

Reviewed/revised by: Christopher C. Lutes Date: November 8, 2009
(Technical Expert)

I. Scope and Application

Field screening with a photoionization detector (PID), such as an HNu™, Photovac™, MicroTIP™, or MiniRAE™, is a procedure to measure relative concentrations of volatile organic compounds (VOCs) and other compounds. Characteristics of the PID are presented in Attachment 1 and the compounds a PID can detect are presented in Attachment 2. Field screening will frequently be conducted on the following:

- Work area air to assess exposure to on-site workers of air contaminants via the air pathway;
- Well headspaces as a precautionary measure each time the well cover is opened; and
- Headspace of soil samples to assess the relative concentration of volatile organics in the sample or to select particular intervals for off-site analysis for VOCs.

II. Personnel Qualifications

Personnel performing this method should be familiar with the basic principles of quantiative analytical chemistry (such as calibration) and familiar with the particular operation of the instrument to be used.

III. Equipment List

The following materials, as required, shall be available while performing PID field screening:

- personal protective equipment (PPE), as required by the site Health and Safety Plan (HASP);
- PID and operating manual;
- PID extra battery pack and battery charger;
- calibration canisters for the PID;
- sample jars;
- Q-tips;

- aluminum foil;
- field calibration log (attached); and
- field notebook.

IV. Cautions

PIDs are sensitive to moisture and may not function under high humidity. PIDs cannot be used to indicate oxygen deficiency or combustible gases.

V. Health and Safety Considerations

Since the PIDs cannot detect all of the chemicals that may be present at a sample location, a zero reading on either instrument does not necessarily signify the absence of air contaminants. PIDs cannot be used as an indicator for oxygen deficiency.

VI. Procedure (*Note these procedures were written particular to one specific instrument model, therefore please also refer to your owners manual.Hhowever the general principles – such as always measuring both a zero and span gas after an instrument adjustment/at the beginning of the analytical day, after four hours of testing and again at the end of an analytical day can be applied to all instruments.)*

PID Calibration

PID field instruments will be calibrated and operated to yield "total organic vapor" in parts per million (ppm) (v/v) relative to benzene or isobutylene (or equivalent). Operation, maintenance, and calibration shall be performed in accordance with the manufacturer's instructions and entered on the PID calibration and maintenance log (Attachment 3).

1. Don PPE, as required by the HASP.

2. Perform a BATTERY CHECK. Turn the FUNCTION switch to the BATTERY CHECK position. Check that the indicator is within or beyond the green battery arc. If battery is low, the battery must be charged before calibration.

3. Allow the instrument to warm up, then calibrate the PID. If equipped, turn the FUNCTION switch to the STANDBY position and rotate the ZERO

POTENTIOMETER until the meter reads zero with the instrument sampling clean air. Wait 15 to 20 seconds to confirm the adjustment. If unstable, readjust. If equipped, check to see that the SPAN POTENTIOMETER is adjusted for the probe being used (e.g., 9.8 for 10.2 electron volts [eV]). Set the FUNCTION switch to the desired ppm range (0-20, 0-200, or 0-2,000). A violet glow from the ultraviolet (UV) source should be visible at the sample inlet of the probe/sensor unit.

4. Listen for the fan operation to verify fan function.

5. Connect one end of the sampling hose to the calibration canister regulator outlet and the other end to the sampling probe of the PID. Crack the regulator valve and take a reading after 5 to 10 seconds. Adjust the span potentiometer to produce the concentration listed on the span gas cylinder. Record appropriate information on a PID Calibration and Maintenance Log (Attachment 3, or equivalent).

6. If so equipped, set the alarm at desired level.

7. Recheck the zero with fresh/clean air

8. Always recheck both zero and span after making any instrment adjustment, after four hours of screenign work and again after sample analysis.

Work Area Air Monitoring

1. Measure and record the background PID reading.

2. Measure and record the breathing space reading.

Well Headspace Screening

1. Measure and record the background PID reading.

2. Unlock and open the well cover while standing upwind of the well.

3. Remove the well cap.

4. Place the PID probe approximately 6 inches above the top of the casing.

5. Record all PID readings and proceed in accordance with the HASP.

Field Screening Procedures

Soil samples will be field screened upon collection with the PID for a relative measure of the total volatile organic concentration. The following steps define the PID field screening procedures.

1. Half-fill two clean glass jars with the sample (if sufficient quantities of soil are available) to be analyzed. Quickly cover each open top with one or two sheets of clean aluminum foil and subsequently apply screw caps to tightly seal the jars. Sixteen-ounce (approximately 500 mL) soil or "mason" type jars are preferred; jars less than 8 ounces (approximately 250 mL) total capacity may not be used.

2. Allow headspace development for at least 10 minutes. Vigorously shake jars for 15 seconds at both the beginning and end of the headspace development period. Where ambient temperatures are below 32°F (0°C), headspace development should be within a heated building.

3. Subsequent to headspace development, remove screw lid to expose the foil seal. Quickly puncture foil seal with instrument sampling probe, to a point about one-half of the headspace depth. Exercise care to avoid contact with water droplets or soil particulates.

4. Following probe insertion through foil seal, record the highest meter response for each sample as the jar headspace concentration. Using the foil seal/probe insertion method, maximum response should occur between 2 and 5 seconds. Erratic meter response may occur at high organic vapor concentrations or conditions of elevated headspace moisture, in which case headspace data should be recorded and erratic meter response noted.

5. The headspace screening data from both jar samples should be recorded and compared; generally, replicate values should be consistent to plus or minus 20%. It should be noted that in some cases (e.g., 6-inch increment soil borings), sufficient sample quantities may not be available to perform duplicate screenings. One screening will be considered sufficient for this case.

6. PID field instruments will be operated and calibrated to yield "total organic vapors" in ppm (v/v) as benzene. PID instruments must be operated with at least a 10.0 eV (+) lamp source. Operation, maintenance, and calibration will be performed in accordance with the manufacturer's specifications presented in Attachment 12-1. For jar headspace analysis, instrument calibration will be checked/adjusted at least twice per day, at the beginning and end of each day

of use. Calibration will exceed twice per day if conditions and/or manufacturer's specifications dictate.

7. Instrumentation with digital (LED/LCD) displays may not be able to discern maximum headspace response unless equipped with a "maximum hold" feature or strip-chart recorder.

VII. Waste Management

Do not dispose canisters of compressed gas, if there is still compressed gas in the canister. Return the canister to the manufactuer for proper disposal.

VIII. Data Recording and Management

Measurements will be record in the field notebook or boring logs at the time of measurement with notation of date, time, location, depth (if applicable), and item monitored. If a data memory is available, readings will be downloaded from the unit upon access to a computer with software to retrieve the data.

IX. Quality Assurance

After each use, the readout unit should be wiped down with a clean cloth or paper towel.

For a HNu, the UV light source window and ionization chamber should be cleaned once a month in the following manner:

1. With the PID off, disconnect the sensor/probe from the unit.

2. Remove the exhaust screw, grasp the end cap in one hand and the probe shell in the other, and pull apart.

3. Loosen the screws on top of the end cap and separate the end cap and ion chamber from the lamp and lamp housing.

4. Tilt the lamp housing with one hand over the opening so that the lamp slides out into your hand.

5. Clean the lamp with lens paper and HNu cleaning compound (except 11.7 eV). For the 11.7 eV lamp, use a chlorinated organic solvent.

6. Clean the ion chamber using methanol on a Q-tip and then dry gently at 50ºC to 60ºC for 30 minutes.

7. Following cleaning, reassemble by first sliding the lamp back into the lamp housing. Place ion chamber on top of the housing, making sure the contacts are properly aligned.

8. Place the end cap on top of the ion chamber and replace the two screws (tighten the screws only enough to seal the o-ring).

9. Line up the pins on the base of the lamp housing with pins inside the probe shell and slide the housing assembly into the shell.

X. References

Denahan, S.A. et. all *“*Relationships Between Chemical Screening Methodologies for Petroleum Contaminated Soils: Theory and Pracice” *Chapter 5 In Principles and Practices for Petroleum Contaminated Soils,* E.J. Calabrese and P.T. Kostecki Eds., Lewis Publishers 1993.

Fitzgerald, J. “Onsite Analytical Screening of Gasoline Contaminated Media Using a Jar Headspace Procedure” Chapter 4 *in Principles and Practices for Petroleum Contaminated Soils,* E.J. Calabrese and P.T. Kostecki Eds., Lewis Publishers 1993.

ATTACHMENT 1

Characteristics of the Photoionization Detector (PID)

I. Introduction

PIDs are used in the field to detect a variety of compounds in air. PIDs can be used to detect leaks of volatile substances in drums and tanks, to determine the presence of volatile compounds in soil and water, and to make ambient air surveys. If personnel are thoroughly trained to operate the instrument and interpret the data, these PID instruments can be a valuable tool. Its use can help in deciding the level of protection to be worn, assist in determining the implementation of other safety procedures, and in determining subsequent monitoring or sampling locations.

Portable PIDs detect the concentration of organic gases, as well as a few inorganic gases. The basis for detection is the ionization of gaseous species. The incoming gas molecules are subjected to UV radiation, which ionizes molecules that have an ionization potential (IP) less than or equal to that rated for the UV source. Every molecule has a characteristic IP, which is the energy required to remove an electron from the molecule, thus yielding a positively charged ion and the free electron. These ions are attracted to an oppositely charged electrode, causing a current and an electric signal to the LED display. Compounds are measured on a ppm volume basis.

II. HNu PI-101 / MiniRAE or Equivalent PID

The PIDs detect the concentration of organic gases, as well as a few inorganic gases. The basis for detection is the ionization of gaseous species. The incoming gas molecules are subjected to UV radiation, which is energetic enough to ionize many gaseous compounds. Each molecule is transformed into charged ion pairs, creating a current between two electrodes. Every molecule has a characteristic IP, which is the energy required to remove an electron from the molecule, yielding a positively charged ion and the free electron.

Three probes, each containing a different UV light source, are available for use with the PID. Probe energies are typically 9.5, 10.2, and 11.7 eV, respectively. All three probes detect many aromatic and large-molecule hydrocarbons. In addition, the 10.2 eV and 11.7 eV probes detect some smaller organic molecules and some halogenated hydrocarbons. The 10.2 eV probe is the most useful for environmental response work, as it is more durable than the 11.7 eV probe and detects more compounds than the 9.5 eV probe. A listing of molecules and compounds that the HNu can detect is presented in Attachment 2.

The primary PID calibration gas is either benzene or isobutylene. The span potentiometer knob is turned to 9.8 for benzene calibration. A knob setting of zero increases the sensitivity to benzene approximately 10-fold. Its lower detection limit is in the low ppm range. Additionally, response time is rapid; the dot matrix liquid crystal displays 90% of the indicated concentration within 3 seconds.

III. Limitations

The PID instrument can monitor several vapors and gases in air. Many non-volatile liquids, toxic solids, particulates, and other toxic gases and vapors, however, cannot be detected with PIDs (such as methane). Since the PIDs cannot detect all of the chemicals that may be present at a sample location, a zero reading on either instrument does not necessarily signify the absence of air contaminants.

The PID instrument is generally not specific and their response to different compounds is relative to the calibration gases. Instrument readings may be higher or lower than the true concentration. This effect can be observed when monitoring total contaminant concentrations if several different compounds are being detected at once. In addition, the response of these instruments is not linear over the entire detection range. Therefore, care must be taken when interpreting the data. Concentrations should be reported in terms of the calibration gas and probe type.

PIDs are small, portable instruments and may not yield results as accurate as laboratory instruments. PIDs were originally designed for specific industrial applications. They are relatively easy to use and interpret when detecting total concentrations of known contaminants in air, but interpretation becomes more difficult when trying to identify the individual components of a mixture. PIDs cannot be used as an indicator for combustible gases or oxygen deficiency.

ATTACHMENT 2

Molecules and Compounds Detected by a PID

Some Atoms and Simple Molecules

	IP(eV)		IP(eV)
H	13.595	I_2	9.28
C	11.264	HF	15.77
N	14.54	HCl	12.74
O	13.614	HBr	11.62
Si	8.149	HI	10.38
S	10.357	SO_2	12.34
F	17.42	CO_2	13.79
Cl	13.01	COS	11.18
Br	11.84	CS_2	10.08
I	10.48	N_2O	12.90
H_2	15.426	NO_2	9.78
N_2	15.580	O_3	12.80
O_2	12.075	H_2O	12.59
CO	14.01	H_2S	10.46
CN	15.13	H_2Se	9.88
NO	9.25	H_2Te	9.14
CH	11.1	HCN	3.91
OH	13.18	C_2N_2	13.8
F_2	15.7	NH_3	10.15
Cl_2	11.48	CH_3	9.840
Br_2	10.55	CH_4	12.98

Paraffins and Cycloparaffins

Molecule	IP(eV)
methane	12.98
ethane	11.65
propane	11.07
n-butane	10.63
i-butane	10.57
n-pentane	10.35
i-pentane	10.32
2,2-dimethylpropane	10.35
n-hexane	10.18
2-methlypentane	10.12
3-methlypentane	10.08
2,2-dimethlybutane	10.06
2,3-dimethlybutane	10.02
n-heptane	10.08
2,2,4-trimethlypentane	9.86
cyclopropane	10.06
cyclopentane	10.53
cyclohexane	9.88
methlycyclohexane	9.8

Alkyl Halides

IP(eV)	IP(eV)
HCl	12.74
Cl_2	11.48
CH_4	12.98
methyl chloride	11.28
dichloroemethane	11.35
trichloromethane	11.42
tetrachloromethane	11.47
ethyl chloride	10.98
1,2-dichloroethane	11.12
1-chloropropane	10.82
2-chloropropane	10.78
1,2-dichloropropane	10.87
1,3-dichloropropane	10.85
1-chlorobutane	10.67
2-chlorobutane	10.65
1-chloro-2-methylpropane	10.66
2-chloro-2-methylpropane	10.61
HBr	11.62
Br_2	10.55
methyl bromide	10.53
dibromomethane	10.49
tribromomethane	10.51
CH_2BrCl	10.77
$CHBr_2Cl$	10.59
ethyl bromide	10.29
1,1-dibromoethane	10.19
1-bromo-2-chloroethane	10.63
1-bromopropane	10.18
2-bromopropane	10.075
1,3-dibromopropane	10.07
1-bromobutane	10.13
2-bromobutane	9.98
1-bromo-2-methylpropane	10.09
2-bromo-2-methylpropane	9.89
1-bromopentane	10.10
HI	10.38
I_2	9.28

Alkyl Halides

Molecule	IP(eV)
methyl iodide	9.54
diiodomethane	9.34
ethyl iodide	9.33
1-iodopropane	9.26
2-iodopropane	9.17
1-iodobutane	9.21
2-iodobutane	9.09
1-iodo-2-methylpropane	9.18
2-iodo-2-methylpropane	9.02
1-iodopentane	9.19
F_2	15.7
HF	15.77
$CFCl_3$ (Freon 11)	11.77
CF_2Cl_2 (Freon 12)	12.31
CF_3Cl (Freon 13)	12.91
$CHClF_2$ (Freon 22)	12.45
$CFBR_3$	10.67
CF_2Br_2	11.07
CH_3CF_2Cl (Genetron 101)	11.98
$CFCl_2CF_2Cl$	11.99
CF_3CCl_3 (Freon 113)	11.78
$CFHBrCH_2Cr$	10.75
CF_2BrCH_2Br	10.83
CF_3CH_2I	10.00
n-C_3F_7I	10.36
n-$C_3F_7CH_2Cl$	11.84
n-$C_3F_7CH_2I$	9.96

Aliphatic Alcohol, Ether, Thiol, and Sulfides

Molecule	IP(eV)
H_2O	12.59
methyl alcohol	10.85
ethyl alcohol	10.48
n-propyl alcohol	10.20
i-propyl alcohol	10.16
n-butyl alcohol	10.04
dimethyl ether	10.00
diethyl ether	9.53
n-propyl ether	9.27
i-propyl ether	9.20
H_2S	10.46
methanethiol	9.440
ethanethiol	9.285
1-propanethiol	9.195
1-butanethiol	9.14
dimethyl sulfide	8.685
ethyl methyl sulfide	8.55
diethyl sulfide	8.430
di-n-propyl sulfide	8.30

Aliphatic Aldehydes and Ketones

Molecule	IP(eV)
CO_2	13.79
formaldehyde	10.87
acetaldehyde	10.21
propionaldehyde	9.98
n-butyraldehyde	9.86
isobutyraldehyde	9.74
n-valeraldehyde	9.82
isovaleraldehyde	9.71
acrolein	10.10
crotonaldehyde	9.73
benzaldehyde	9.53
acetone	9.69
methyl ethyl ketone	9.53
methyl n-propyl ketone	9.39
methyl i-propyl ketone	9.32
diethyl ketone	9.32
methyl n-butyl ketone	9.34
methyl i-butyl ketone	9.30
3,3-dimethyl butanone	9.17
2-heptanone	9.33
cyclopentanone	9.26
cyclohexanone	9.14
2,3-butanedione	9.23
2,4-pentanedione	8.87

Aliphatic Acids and Esters

Molecule	IP(eV)
CO_2	13.79
formic acid	11.05
acetic acid	10.37
propionic acid	10.24
n-butyric acid	10.16
isobutyric acid	10.02
n-valeric acid	10.12
methyl formate	10.815
ethyl formate	10.61
n-propyl formate	10.54
n-butyl formate	10.50
isobutyl formate	10.46
methyl acetate	10.27
ethyl acetate	10.11
n-propyl acetate	10.04
isopropyl acetate	9.99
n-butyl acetate	10.01
isobutyl acetate	9.97
sec-butyl acetate	9.91
methyl propionate	10.15
ethyl propionate	10.00
methyl n-butyrate	10.07
methyl isobutyrate	9.98

Aliphatic Amines and Amides

Molecule	IP(eV)
NH_3	10.15
methyl amine	8.97
ethyl amine	8.86
n-propyl amine	8.78
i-propyl amine	8.72
n-butyl amine	8.71
i-butyl amine	8.70
s-butyl amine	8.70
t-butyl amine	8.64
dimethyl amine	8.24
diethyl amine	8.01
di-n-propyl amine	7.84
di-i-propyl amine	7.73
di-n-butyl amine	7.69
trimethyl amine	7.82
triethyl amine	7.50
tri-n-propyl amine	7.23
formamide	10.25
acetamide	9.77
N-methyl acetamide	8.90
N,N-dimethyl formamide	9.12
N,N-dimethyl acetamide	8.81
N,N-diethyl formamide	8.89
N,N-diethyl acetamide	8.60

Other Aliphatic Molecules with N Atom

Molecule	IP(eV)
nitromethane	11.08
nitroethane	10.88
1-nitropropane	10.81
2-nitropropane	10.71
HCN	13.91
acetonitrile	12.22
propionitrile	11.84
n-butyronitrile	11.67
acrylonitrile	10.91
3-butene-nitrile	10.39
ethyl nitrate	11.22
n-propyl nitrate	
methyl thiocyanate	10.065
ethyl thiocyanate	9.89
methyl isothiocyanate	9.25
ethyl isothiocyanate	9.14

Olefins, Cyclo-ofefins, Acetylenes

Molecule	IP(eV)
ethylene	10.515
propylene	9.73
1-butene	9.58
2-methylpropene	9.23
trans-2-butene	9.13
cis-2-butene	9.13
1-pentene	9.50
2-methyl-1-butene	9.12
3-methyl-1-butene	9.51
3-methyl-2-butene	8.67
1-hexene	9.46
1,3-butadiene	9.07
isoprene	8.845
cyclopentene	9.01
cyclohexene	8.945
4-methylcyclohexene	8.91
4-cinylcylohexene	8.93
cyclo-octatetraene	7.99
acetylene	11.41
propyne	10.36
1-butyne	10.18

Some Derivatives of Olefins

Molecule	IP(eV)
vinyl chloride	9.995
cis-dichloroethylene	9.65
trans-dichloroethylene	9.66
trichloroethylene	9.45
tetrachloroethylene	9.32
vinyl bromide	9.80
1,2-dibromoethylene	9.45
tribromoethylene	9.27
3-chloropropene	10.04
2,3-dichloropropene	9.82
1-bromopropene	9.30
3-bromopropene	9.7
$CF_3CCl=CClCF_3$	10.36
n-$C_5F_{11}CF=CF_2$	10.48
acrolein	10.10
crotonaldehyde	9.73
mesityl oxide	9.08
vinyl methyl ether	8.93
allyl alcohol	9.67
vinyl acetate	9.19

Aromatic Compounds

Molecule	IP(eV)
benzene	9.245
toluene	8.82
ethyl benzene	8.76
n-propyl benzene	8.72
i-propyl benzene	8.69
n-butyl benzene	8.69
s-butyl benzene	8.68
t-butyl benzene	8.68
o-xylene	8.56
m-xylene	8.56
p-xylene	8.445
mesitylene	8.40
durene	8.025
styrene	8.47
alpha-methyl styrene	8.35
ethynylbenzene	8.815
naphthalene	8.12
1-methylnapthalene	7.69
2-methylnapthalene	7.955
biphenyl	8.27
phenol	8.50
anisole	8.22
phenetole	8.13
benzaldehyde	9.53
acetophenone	9.27
benzenethiol	8.33
phenyl isocyanate	8.77

Aromatic Compounds

Molecule	IP(eV)
phenyl isothiocyanate	8.520
benzonitrile	9.705
nitrobenzene	9.92
aniline	7.70
fluoro-benzene	9.195
chloro-benzene	9.07
bromo-benzene	8.98
iodo-benzene	8.73
o-dichlorobenzene	9.07
m-dichlorobenzene	9.12
p-dichlorobenzene	8.94
1-chloro-2-fluorobenzene	9.155
1-chloro-3-fluorobenzene	9.21
1-chloro-4-fluorobenzene	8.99
o-fluorotoluene	8.915
m-fluorotoluene	8.915
p-fluorotoluene	8.785
o-chlorotoluene	8.83
m-chlorotoluene	8.83
p-chlorotoluene	8.70
o-bromotoluene	8.79
m-bromotoluene	8.81
p-bromotoluene	8.67
o-iodotoluene	8.62
m-iodotoluene	8.61
p-iodotoluene	8.50
benzotrifluoride	9.68
o-fluorophenol	8.66

Heterocyclic Molecules

Molecule	IP(eV)
furan	8.89
2-methyl furan	8.39
2-furaldehyde	9.21
tetrahydrofuran	9.54
dihydropyran	8.34
tetrahydropyran	9.26
thiophene	8.860
2-chlorothiophene	8.68
2-bromothiophene	8.63
pyrrole	8.20
pyridine	9.32
2-picoline	9.02
3-picoline	9.04
4-picoline	9.04
2,3-lutidine	8.85
2,4-lutidine	8.85
2,6-lutidine	8.85

Miscellaneous Molecules

Molecule	IP(eV)
ethylene oxide	10.565
propylene oxide	10.22
p-dioxane	9.13
dimethoxymethane	10.00
diethoxymethane	9.70
1,1-dimethoxyethane	9.65
propiolactone	9.70
methyl disulfide	8.46
ethyl disulfide	8.27
diethyl sulfite	9.68
thiolacetic acid	10.00
acetyl chloride	11.02
acetyl bromide	10.55
cyclo-$C_6H_{11}CF_3$	10.46
$(n\text{-}C_3F_7)(CH_3)C{=}O$	10.58
trichlorovinylsilane	10.79
$(C_2F_5)_3N$	11.7
isoprene	9.08
phosgene	11.77

Notes:

Reference: HNu Systems, Inc., 1985
IP = Ionization Potential

ATTACHMENT 3

PID CALIBRATION AND MAINTENANCE LOG

Instrument Model Number

Instrument Serial Number

Calibration Gas **ppm**

Date/Time	Initials	Battery Check	Calibration			
			Background Value	True Gas Value	Measured Gas Value	Adjust

COMMENTS:

Infrastructure, environment, facilities

Imagine the result

Soil Drilling and Sample Collection

Rev. #: 1

Rev Date: March 3, 2009

Approval Signatures

Prepared by: ______________________ Date: 3/3/09

Reviewed by: ______________________ Date: 3/3/09
(Technical Expert)

I. Scope and Application

Overburden drilling is commonly performed using the hollow-stem auger drilling method. Other drilling methods suitable for overburden drilling, which are sometimes necessary due to site-specific geologic conditions, include: drive-and-wash, spun casing, Rotasonic, dual-rotary (Barber Rig), and fluid/mud rotary. Direct-push techniques (e.g., Geoprobe or cone penetrometer) may also be used. The drilling method to be used at a given site will be selected based on site-specific consideration of anticipated drilling depths, site or regional geologic knowledge, types of sampling to be conducted, required sample quality and volume, and cost.

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

II. Personnel Qualifications

The Project Manager (a qualified geologist, environmental scientist, or engineer) will identify the appropriate soil boring locations, depth and soil sample intervals in a written plan.

Personnel responsible for overseeing drilling operations must have at least 16 hours of prior training overseeing drilling activities with an experienced geologist, environmental scientist, or engineer with at least 2 years of prior experience.

III. Equipment List

The following materials will be available during soil boring and sampling activities, as required:

- Site Plan with proposed soil boring/well locations;
- Work Plan or Field Sampling Plan (FSP), and site Health and Safety Plan (HASP);
- personal protective equipment (PPE), as required by the HASP;
- drilling equipment required by the American Society for Testing and Materials (ASTM) D 1586, when performing split-spoon sampling;
- disposable plastic liners, when drilling with direct-push equipment;
- appropriate soil sampling equipment (e.g., stainless steel spatulas, knife);

- equipment cleaning materials;
- appropriate sample containers and labels;
- chain-of-custody forms;
- insulated coolers with ice, when collecting samples requiring preservation by chilling;
- photoionization detector (PID) or flame ionization detector (FID); and
- field notebook and/or personal digital assistant (PDA).

IV. Cautions

Prior to beginning field work, underground utilities in the vicinity of the drilling areas will be identified by one of the following three actions (lines of evidence):

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

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

- Private utility locating service
- Research of state, county or municipal utility records and maps including computer drawn maps or geographical information systems (GIS)
- Contact with the utility provider to obtain their utility location records
- Hand augering or digging
- Hydro-knife
- Air-knife

- Radio Frequency Detector (RFD)
- Ground Penetrating Radar (GPR)
- Any other method that may give ample evidence of the presence or location of subgrade utilities.

Overhead power lines also present risks and the following safe clearance must be maintained from them.

Power Line Voltage Phase to Phase (kV)	Minimum Safe Clearance (feet)
50 or below	10
Above 50 to 200	15
Above 200 to 350	20
Above 350 to 500	25
Above 500 to 750	35
Above 750 to 1,000	35

ANSI Standard B30.5-1994, 5-3.4.5

Avoid using drilling fluids or materials that could impact groundwater or soil quality, or could be incompatible with the subsurface conditions.

Water used for drilling and sampling of soil or bedrock, decontamination of drilling/sampling equipment, or grouting boreholes upon completion will be of a quality acceptable for project objectives. Testing of water supply should be considered.

Specifications of materials used for backfilling borehole will be obtained, reviewed and approved to meet project quality objectives.

V. Health and Safety Considerations

Field activities associated with overburden drilling and soil sampling will be performed in accordance with a site-specific HASP, a copy of which will be present on site during such activities.

VI. Procedure

Drilling Procedures

The drilling contractor will be responsible for obtaining accurate and representative samples; informing the supervising geologist of changes in drilling pressure; and keeping a separate general log of soils encountered, including blow counts (i.e., the number of blows from a soil sampling drive weight [140 pounds] required to drive the split-barrel sampler in 6-inch increments). Records will also be kept of occurrences of premature refusal due to boulders or construction materials that may have been used as fill. Where a boring cannot be advanced to the desired depth, the boring will be abandoned and an additional boring will be advanced at an adjacent location to obtain the required sample. Where it is desirable to avoid leaving vertical connections between depth intervals, the borehole will be sealed using cement and/or bentonite. Multiple refusals may lead to a decision by the supervising geologist to abandon that sampling location.

Soil Sampling Procedures

Samples of subsurface materials encountered while drilling soil borings will be collected using one of the following methods:

- 2-inch split-barrel (split-spoon) sampler, if using the ASTM D 1586 - Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils

- Plastic internal soil sample sleeves if using direct-push drilling.

Soil samples are typically field screened with an FID or PID at sites where volatile organic compounds are present in the subsurface. Field screening is performed using one of the following methods:

- Upon opening the sampler, the soil is split open and the PID or FID probe is placed in the opening and covered with a gloved hand. Such readings should be obtained at several locations along the length of the sample

- A portion of the collected sample is placed in a jar, which is covered with aluminum foil, sealed, and allowed to warm to room temperature. After warming, the cover is removed, the foil is pieced with the FID or PID probe, and a reading is obtained.

Samples selected for laboratory analysis will be handled, packed, and shipped in accordance with the procedures outlined in the Work Plan, FSP, or Chain-of-Custody, Handling, Packing, and Shipping SOP.

A geologist will be onsite during drilling and sampling operations to describe each soil sample on the soil boring log, including:

- percent recovery;
- structure and degree of sample disturbance;
- soil type;
- color;
- moisture condition;
- density;
- grain-size;
- consistency; and
- other observations, particularly relating to the presence of waste materials

Further details regarding geologic description of soil samples are presented in the Soil Description SOP.

Particular care will be taken to fully describe any sheens observed, oil saturation, staining, discoloration, evidence of chemical impacts, or unnatural materials.

VII. Waste Management

Water generated during cleaning procedures will be collected and contained onsite in appropriate containers for future analysis and appropriate disposal.

PPE (such as gloves, disposable clothing, and other disposable equipment) resulting from personnel cleaning procedures and soil sampling/handling activities will be placed in plastic bags. These bags will be transferred into appropriately labeled 55-gallon drums or a covered roll-off box for appropriate disposal.

Soil materials will be placed in sealed 55-gallon steel drums or covered roll-off boxes and stored in a secured area. Once full, the material will be analyzed to determine the appropriate disposal method.

VIII. Data Recording and Management

The supervising geologist or scientist will be responsible for documenting drilling events using a bound field notebook and/or PDA to record all relevant information in a clear and concise format. The record of drilling events will include:

- start and finish dates of drilling;
- name and location of project;
- project number, client, and site location;
- sample number and depths;
- blow counts and recovery;
- depth to water;
- type of drilling method;
- drilling equipment specifications, including the diameter of drilling tools;
- documentation of any elevated organic vapor readings;
- names of drillers, inspectors, or other people onsite; and
- weather conditions.

IX. Quality Assurance

Equipment will be cleaned prior to use onsite, between each drilling location, and prior to leaving the site. Drilling equipment and associated tools, including augers, drill rods, sampling equipment, wrenches, and other equipment or tools that may have come in contact with soils and/or waste materials will be cleaned with high-pressure steam-cleaning equipment using a potable water source. The drilling equipment will be cleaned in an area designated by the supervising engineer or geologist that is located outside of the work zone. More elaborate cleaning procedures may be required for reusable soil samplers (split-spoons) when soil samples are obtained for laboratory analysis of chemical constituents.

X. References

American Society of Testing and Materials (ASTM) D 1586 - *Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils*.

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Soil Description

Rev. #: 0

Rev Date: May 20, 2008

Approval Signatures

Prepared by: ______________________ Date: 5/22/08

Reviewed by: ______________________ Date: 5/22/08
(Technical Expert)

Reviewed by ______________________ Date: 5/22/08
(Technical Expert)

I. Scope and Application

This ARCADIS standard operating procedure (SOP) describes proper soil description procedures. This SOP should be followed for all unconsolidated material unless there is an established client-required specific SOP or regulatory-required specific SOP. In cases where there is a required specific SOP, it should be followed and should be referenced and/or provided as an appendix to reports that include soil classifications and/or boring logs. When following a required non-ARCADIS SOP, additional information required by this SOP should be included in field notes with client approval.

This SOP has been developed to emphasize field observation and documentation of details required to:

- make hydrostratigraphic interpretations guided by depositional environment/geologic settings;

- provide information needed to understand the distribution of constituents of concern; properly design wells, piezometers, and/or additional field investigations; and develop appropriate remedial strategies.

This SOP incorporates elements from various standard systems such as ASTM D2488-06, Unified Soil Classification System, Burmister and Wentworth. However, none of these standard systems focus specifically on contaminant hydrogeology and remedial design. Therefore, although each of these systems contain valuable guidance and information related to correct descriptions, strict application of these systems can omit information critical to our clients and the projects that we perform.

This SOP does not address details of health and safety; drilling method selection; boring log preparation; sample collection; or laboratory analysis. Refer to other ARCADIS SOPS, the project work plans including the quality assurance project plan, sampling plan, and health and safety plan (HASP), as appropriate.

II. Personnel Qualifications

Soil descriptions will be completed only by persons who have been trained in ARCADIS soil description procedures. Field personnel will complete training on the ARCADIS soil description SOP in the office and/or in the field under the guidance of an experienced field geologist. For sites where soil descriptions have not previously been well documented, soil descriptions should be performed only by trained persons with a degree in geology or a geology-related discipline.

III. Equipment List

The following equipment should be taken to the field to facilitate soil descriptions:

- field book, field forms or PDA to record soil descriptions;
- field book for supplemental notes;
- this SOP for Soil Descriptions and any project-specific SOP (if required);
- field card showing Wentworth scale;
- Munsell® soil color chart;
- tape measure divided into tenths of a foot;
- stainless steel knife or spatula;
- hand lens;
- water squirt bottle;
- jar with lid;
- personal protective equipment (PPE), as required by the HASP; and
- digital camera.

IV. Cautions

Drilling and drilling-related hazards including subsurface utilities are discussed in other SOPs and site-specific HASPs and are not discussed herein.

Soil samples may contain hazardous substances that can result in exposure to persons describing soils. Routes for exposure may include dermal contact, inhalation and ingestion. Refer to the project specific HASP for guidance in these situations.

V. Health and Safety Considerations

Field activities associated with soil sampling and description will be performed in accordance with a site-specific HASP, a copy of which will be present on site during such activities. Know what hazardous substances may be present in the soil and understand their hazards. Always avoid the temptation to touch soils with bare hands, detect odors by placing soils close to your nose, or tasting soils.

VI. Procedure

1. Select the appropriate sampling method to obtain representative samples in accordance with the selected sub-surface exploration method, e.g. split-spoon or Shelby sample for hollow-stem drilling, Lexan or acetate sleeves for dual-tube direct push, etc.

2. Proceed with field activities in required sequence. Although completion of soil descriptions is often not the first activity after opening sampler, identification of stratigraphic changes is often necessary to select appropriate intervals for field screening and/or selection of laboratory samples.

3. Examine all of each individual soil sample (this is different than examining each sample selected for laboratory analysis), and record the following for each stratum:

- depth interval;
- principal component with descriptors, as appropriate;
- amount and identification of minor component(s) with descriptors as appropriate;
- moisture;
- consistency/density;
- color; and
- additional description or comments (recorded as notes).

The above is described more fully below.

DEPTH

To measure and record the depth below ground level (bgl) of top and bottom of each stratum, the following information should be recorded.

1. Measured depth to the top and bottom of sampled interval. Use starting depth of sample based upon measured tool length information and the length of sample interval.

2. Length of sample recovered, not including slough (material that has fallen into hole from previous interval), expressed as fraction with length of recovered sample as numerator over length of sampled interval as denominator (e.g. 14/24 for 14 inches recovered from 24-inch sampling interval that had 2 inches of slough discarded).

3. Thickness of each stratum measured sequentially from the top of recovery to the bottom of recovery.

4. Any observations of sample condition or drilling activity that would help identify whether there was loss from the top of the sampling interval, loss from the bottom of the sampling interval, or compression of the sampling interval. Examples: 14/24, gravel in nose of spoon; or 10/18 bottom 6 inches of spoon empty.

DETERMINATION OF COMPONENTS

Obtain a representative sample of soil from a single stratum. If multiple strata are present in a single sample interval, each stratum should be described separately. More specifically, if the sample is from a 2-foot long split-spoon where strata of coarse sand, fine sand and clay are present, then the resultant description should be of the three individual strata unless a combined description can clearly describe the interbedded nature of the three strata. Example: Fine Sand with interbedded lenses of Silt and Clay, ranging between 1 and 3 inches thick.

Identify principal component and express volume estimates for minor components on logs using the following standard modifiers.

Modifier	Percent of Total Sample (by volume)
and	36 - 50
some	21 - 35
little	10 - 20
trace	<10

Determination of components is based on using the Udden-Wentworth particle size classification (see below) and measurement of the average grain size diameter. Each size grade or class differs from the next larger grade or class by a constant ratio of ½. Due to visual limitations, the finer classifications of Wentworth's scale cannot be distinguished in the field and the subgroups are not included. Visual determinations in the field should be made carefully by comparing the sample to the field gauge card that shows Udden-Wentworth scale or by measuring with a ruler. Use of field sieves s recommended to assist in estimating percentage of coarse grain sizes. Settling test or wash method (Appendix X4 of ASTM D2488) is recommended for determining presence and estimating percentage of clay and silt.

Udden-Wenworth Scale Modified ARCADIS, 2008			
Size Class	Millimeters	Inches	Standard Sieve #
Boulder	256 – 4096	10.08+	
Large cobble	128 - 256	5.04 -10.08	
Small cobble	64 - 128	2.52 – 5.04	
Very large pebble	32 – 64	0.16 - 2.52	
Large pebble	16 – 32	0.63 – 1.26	
Medium pebble	8 – 16	0.31 – 0.63	
Small pebble	4 – 8	0.16 – 0.31	No. 5 +
Granule	2 – 4	0.08 – 0.16	No.5 – No.10
Very coarse sand	1 -2	0.04 – 0.08	No.10 – No.18
Coarse sand	½ - 1	0.02 – 0.04	No.18 - No.35
Medium sand	¼ - ½	0.01 – 0.02	No.35 - No.60
Fine sand	1/8 -¼	0.005 – 0.1	No.60 - No.120
Very fine sand	1/16 – 1/8	0.002 – 0.005	No. 120 – No. 230
Silt (subgroups not included)	1/256 – 1/16	0.0002 – 0.002	Not applicable (analyze by pipette or hydrometer)
Clay (subgroups not included	1/2048 – 1/256	.00002 – 0.0002	

Identify components as follows. Remove particles greater than very large pebbles (64-mm diameter) from the soil sample. Record the volume estimate of the greater than very large pebbles. Examine the sample fraction of very large pebbles and smaller particles and estimate the volume percentage of the pebbles, granules, sand, silt and clay. Use the jar method, visual method, and/or wash method (Appendix X4 of ASTM D2488) to estimate the volume percentages of each category.

Determination of actual dry weight of each Udden-Wentworth fraction requires laboratory grain-size analysis using sieve sizes corresponding to Udden-Wentworth fractions and is highly recommended to determine grain-size distributions for each hydrostratigraphic unit.

Lab or field sieve analysis is advisable to characterize the variability and facies trends within each hydrostratigraphic unit. Field sieve-analysis can be performed on selected samples to estimate dry weight fraction of each category using ASTM D2488 Standard Practice for Classification of Soils for Engineering Purposes as guidance, but replace required sieve sizes with the following Udden-Wentworth set: U.S. Standard sieve mesh sizes 6; 12; 20; 40; 70; 140; and 270 to retain pebbles; granules; very coarse sand; coarse sand; medium sand; fine sand; and very fine sand, respectively.

PRINCIPAL COMPONENT

The principal component is the size fraction or range of size fractions containing the majority of the volume. Examples: the principal component in a sample that contained 55% pebbles would be “Pebbles”; or the principal component in a sample that was 20% fine sand, 30% medium sand and 25% coarse sand would be “Fine to coarse Sand” or for a sample that was 40% silt and 45% clay the principal component would be “Clay and Silt”.

Include appropriate descriptors with the principal component. These descriptors vary for different particle sizes as follows.

Angularity – Describe the angularity for very coarse sand and larger particles in accordance with the table below (ASTM D-2488-06). Figures showing examples of angularity are available in ASTM D-2488-06 and the ARCADIS Soil Description Field Guide.

Description	Criteria
Angular	Particles have sharp edges and relatively plane sides with unpolished surfaces.
Subangular	Particles are similar to angular description but have rounded edges.
Subrounded	Particles have nearly plane sides but have well-rounded corners and edges.
Rounded	Particles have smoothly curved sides and no edges.

Plasticity – Describe the plasticity for silt and clay based on observations made during the following test method (ASTM D-2488-06).

- As in the dilatancy test below, select enough material to mold into a ball about ½ inch (12 mm) in diameter. Mold the material, adding water if necessary, until it has a soft, but not sticky, consistency.
- Shape the test specimen into an elongated pat and roll by hand on a smooth surface or between the palms into a thread about 1/8 inch (3 mm) in diameter. (If the sample is too wet to roll easily, it should be spread into a thin layer and allowed to lose some water by evaporation.) Fold the sample threads and reroll repeatedly until the thread crumbles at a diameter of about 1/8 inch. The thread will crumble when the soil is near the plastic limit.

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 rerolled 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 rolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit

Dilatancy – Describe the dilatancy for silt and silt-sand mixtures using the following field test method (ASTM D-2488-06).

- From the specimen select enough material to mold into a ball about ½ inch (12 mm) in diameter. Mold the material adding water if necessary, until it has a soft, but not sticky, consistency.

- Smooth the ball in the palm of one hand with a small spatula.

- Shake horizontally, striking the side of the hand vigorously with the other hand several times.

- Note the reaction of water appearing on the surface of the soil.

- Squeeze the sample by closing the hand or pinching the soil between the fingers, and not the reaction as none, slow, or rapid in accordance with the table below. The reaction is the speed with which water appears while shaking and disappears while squeezing.

Description	Criteria
None	No visible change in the specimen.
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.

MINOR COMPONENT(S)

The minor component(s) are the size fraction(s) containing less than 50% volume. Example: the identified components are estimated to be 60% medium sand to granules, 25 % silt and clay; 15 % pebbles – there are two identified minor components: silt and clay; and pebbles.

Include a standard modifier to indicate percentage of minor components (see Table on Page 5) and the same descriptors that would be used for a principal component. Plasticity should be provided as a descriptor for the silt and clay. Dilatancy should be provided for silt and silt-sand mixtures. Angularity should be provided as a descriptor for pebbles and coarse sand. For the example above, the minor constituents with modifiers could be: some silt and clay, low plasticity; little medium to large pebbles, sub-round.

SORTING

Sorting is the opposite of grading, which is a commonly used term in the USCS or ASTM methods to describe the uniformity of the particle size distribution in a sample. Well-sorted samples are poorly graded and poorly sorted samples are well graded. ARCADIS prefers the use of sorting for particle size distributions and grading to describe particle size distribution trends in the vertical profile of a sample or hydrostratigraphic unit because of the relationship between sorting and the energy of the depositional process. For soils with sand-sized or larger particles, sorting should be determined as follows:

- Well sorted – the range of particle sizes is limited (e.g. the sample is comprised of predominantly one or two grain sizes)
- Poorly sorted – a wide range of particle sizes are present

You can also use sieve analysis to estimate sorting from a sedimentological perspective; sorting is the statistical equivalent of standard deviation. Smaller standard deviations correspond to higher degree of sorting (see Remediation Hydraulics, 2008).

MOISTURE

Moisture content should be described for every sample since increases or decreases in water content is critical information. Moisture should be described in accordance with the table below (percentages should not be used unless determined in the laboratory).

Description	Criteria
Dry	Absence of moisture, dry to touch, dusty.
Moist	Damp but no visible water.
Wet (Saturated)	Visible free water, soil is usually below the water table.

CONSISTENCY or DENSITY

This can be determined by standard penetration test (SPT) blow counts (ASTM D-1586) or field tests in accordance with the tables below. For SPT blow counts the N-value is used. The N-value is the blows per foot for the 6" to 18" interval. Example: for 24-inch spoon, recorded blows per 6-inch interval are: 4/6/9/22. Since the second interval is 6" to12", the third interval is 12" to 18", the N value is 6+9, or 15. Fifty blow counts for less than 6 inches is considered refusal.

Fine-grained soil – Consistency

Description	Criteria
Very soft	N-value < 2 or easily penetrated several inches by thumb.
Soft	N-value 2-4 or easily penetrated one inch by thumb.
Medium stiff	N-value 9-15 or indented about ¼ inch by thumb with great effort.
Very stiff	N-value 16-30 or readily indented by thumb nail.
Hard	N-value > than 30 or indented by thumbnail with difficulty

Coarse-grained soil – Density

Description	Criteria
Very loose	N-value 1- 4
Loose	N-value 5-10
Medium dense	N-value 11-30
Dense	N-value 31- 50
Very dense	N-value >50

COLOR

Color should be described using simple basic terminology and modifiers based on the Munsell system. Munsell alpha-numeric codes are required for all samples. If the sample contains layers or patches of varying colors this should be noted and all representative colors should be described. The colors should be described for moist samples. If the sample is dry it should be wetted prior to comparing the sample to the Munsell chart.

ADDITIONAL COMMENTS (NOTES)

Additional comments should be made where observed and should be presented as notes with reference to a specific depth interval(s) to which they apply. Some of the significant information that may be observed includes the following.

- **Odor -** You should not make an effort to smell samples by placing near your nose since this can result in unnecessary exposure to hazardous materials. However, odors should be noted if they are detected during the normal sampling procedures. Odors should be based upon descriptors such as those used in NIOSH "Pocket Guide to Chemical Hazards", e.g. "pungent" or "sweet" and should not indicate specific chemicals such as "phenol-like" odor or "BTEX" odor.
- Structure
- Bedding planes (laminated, banded, geologic contacts)
- Presence of roots, root holes, organic material, man-made materials, minerals, etc.
- Mineralogy
- Cementation
- NAPL presence/characteristics, including sheen (based on client-specific guidance)
- Reaction with HCl (typically used only for special soil conditions)
- Origin, if known (capital letters: LACUSTRINE; FILL; etc.)

EXAMPLE DESCRIPTIONS

51.4 to 54.0' Clay, some silt, medium to high plasticity; trace small to large pebbles, subround to subangular up to 2" diameter; moist; stiff; dark grayish brown (10YR 4/2) NOTE: Lacustrine; laminated 0.01 to 0.02 feet thick, laminations brownish yellow (10 YR 4/3).

32.5 to 38.0' Sand, medium to Pebbles, coarse; sub-round to sub-angular; trace silt; poorly sorted; wet; grayish brown (10YR5/2). NOTE: sedimentary, igneous and metamorphic particles.

Unlike the first example where a density of cohesive soils could be estimated, this rotosonic sand and pebble sample was disturbed during drilling (due to vibrations in a loose Sand and Pebble matrix) so no density description could be provided. Neither sample had noticeable odor so odor comments were not included.

The standard generic description order is presented below.

- Depth

- Principal Components
    - Angularity for very coarse sand and larger particles
    - Plasticity for silt and clay
    - Dilatancy for silt and silt-sand mixtures
- Minor Components
- Sorting
- Moisture
- Consistency or Density
- Color
- Additional Comments

VII. Waste Management

Project-specific requirements should be identified and followed. The following procedures, or similar waste management procedures are generally required.

Water generated during cleaning procedures will be collected and contained onsite in appropriate containers for future analysis and appropriate disposal. PPE (such as gloves, disposable clothing, and other disposable equipment) resulting from personnel cleaning procedures and soil sampling/handling activities will be placed in plastic bags. These bags will be transferred into appropriately labeled 55-gallon drums or a covered roll-off box for appropriate disposal.

Soil materials will be placed in sealed 55-gallon steel drums or covered roll-off boxes and stored in a secured area. Once full, the material will be analyzed to determine the appropriate disposal method.

VIII. Data Recording and Management

Upon collection of soil samples, the soil sample should be logged on a standard boring log and/or in the field log book depending on Data Quality Objectives (DQOs) for the task/project. Two examples of standard boring logs are presented below.

The general scheme for soil logging entries is presented above; however, depending on task/project DQOs, specific logging entries that are not applicable to task/project goals may be omitted at the project manager's discretion. In any case, use of a consistent logging procedure is required.

Completed logs and/or logbook will be maintained in the task/project field records file. Digital photographs of typical soil types observed at the site and any unusual features should be obtained whenever possible. All photographs should include a ruler or common object for scale. Photo location, depth and orientation must be recorded in the daily log or log book and a label showing this information in the photo is useful.

ARCADIS Page _____ of _____

Sample Log

Well/Boring ________________ Project Name and No. ________________

Site Location ________________ Drilling Started ________________ Drilling Completed ________________

Total Depth Drilled ________ feet Hole Diameter ________ inches Sampling Interval ________________ feet

Length and Diameter of Sampling Device ________________ Type of Sampling Device ________________

Drilling Method ________________ Drilling Fluid Used ________________

Drilling Contractor ________________ Driller ________________ Helper ________________

Prepared By ________________ Hammer Weight ________________ Hammer Drop ________ inches

Sample Depth (feet below land surface) From	To	Sample Recovery (feet)	Time/Hydraulic Pressure or Blows per 6 inches	Sample Description	PID (ppm)

http://team/Sites/Offices/North/Northeast Area/Northeast Area Geoscience Forms/Sample Core Log.XLS - Sheet1

IX. Quality Assurance

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

X. References

ARCADIS Soil Description Field Guide, 2008 (in progress)

Munsell® Color Chart – available from Forestry Suppliers, Inc.- Item 77341 "Munsell® Color Soil Color Charts

Field Gauge Card that Shows Udden-Wentworth scale – available from Forestry Suppliers, Inc. – Item 77332 "Sand Grain Sizing Folder"

ASTM D-1586, Test Method for Penetration Test and Split-Barrel Sampling of Soils

ASTM D-2488-00, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)

United States Bureau of Reclamation. Engineering Geology Field Manual. United States Department of Interior, Bureau of Reclamation. http://www.usbr.gov/pmts/geology/fieldmap.htm

Petrology of Sedimentary Rocks, Robert L. Folk, 1980, p. 1-48

NIOSH Pocket Guide to Chemical Hazards

Remediation Hydraulics, Fred C. Payne, Joseph A. Quinnan, and Scott T. Potter, 2008, p 59-63

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Use of Visible Tracer in Drilling Fluid to Obtain Representative Groundwater Samples During Drilling

September 2010

Approval Signatures

Prepared by: ______________________ Date: September 27, 2010
Trika Nelson-Kalmes

Reviewed by: ______________________ Date: September 27, 2010
Craig Divine
(Technical Expert)

I. Scope and Application

This SOP describes field procedures for using nontoxic fluorescent tracer (e.g., fluorescein dye) in drilling fluid during drilling to assist in determining when sufficient purging has been performed prior to collecting screening-level groundwater samples during the drilling process. Screening level groundwater samples may be obtained by evacuating water from the drill casing or from intervals of geologic formations isolated by inflatable packers. This procedure improves the quality of screening-level groundwater samples by providing a technical basis to determine when purging has sufficiently removed drill water prior to collecting screening-level groundwater samples.

II. Personnel Qualifications

ARCADIS personnel overseeing, directing, or supervising tracer drilling shall have previous related experience (minimum of 2 years) drilling and groundwater sampling.

III. Equipment List

- Sodium fluorescein (also known as fluorescein or uranine dye) tracer (to be added to drilling water to produce a vibrant yellow-green color); 38 grams of dye will be added to each 500 gallons of drilling water (potable water) to achieve target applied tracer concentration of 20 milligrams per liter (mg/L)
- Bottles for retaining dyed drilling water samples and preparing visual dye standards (clear, colorless, 40 mL unpreserved VOA bottles or equivalent)
- Graduated cylinders (50 mL and 1 L)
- Scale for measuring mass of dye to the nearest 1 gram
- Bottles for groundwater samples to be analyzed for tracer dye (if necessary) and chemicals of concern (COCs)
- Digital camera
- Poly storage tank (typically 550 to 1,000 gallon capacity)
- Potable water source
- Generator
- Utility pump for mixing dye

- Pump for groundwater purging and sampling
- Chain of custody forms
- Field forms
- Flashlight or other portable lighting device
- Blue ice (for tracer dye samples)

IV. Cautions

Please refer to the Site specific HASP.

V. Health and Safety Considerations

Drilling and groundwater sampling field activities will be performed in accordance with a site specific HASP, a copy of which will be present on site during such activities. Field staff (including subcontractors) will be aware of tracer hazards and understand the associated health hazards. Please be sure to read the Material Safety Data Sheet (MSDS; included as Attachment 1) for fluorescein dye. Note that some individuals can experience a mild allergic reaction to skin contact with fluorescein. Protective gloves should be worn during dye handling and mixing activities. Rinse bottles should be readily available for washing affected areas in case of accidental contact.

VI. Procedure

Potable water is commonly used as a drilling fluid during drilling to remove cuttings of geologic materials from the borehole (e.g., coring or roller-bit rotary drilling), cool the drill bit (e.g, sonic drilling) and/or maintain sufficient hydraulic pressure within the drilling tools to prevent heaving of aquifer solids into the drilling casings. If groundwater sampling is performed during drilling, purging is commonly performed until at least as much is removed as was lost during drilling. However, accurately determining the volume of water lost to the formation, or to specific intervals of the borehole, is not always feasible.

To ensure that groundwater samples accurately represent groundwater quality and are not significantly influenced by unrecovered drilling fluid, fluorescein can be added to the drilling water. The target concentration of dye is approximately 20 mg/L, which is greater than two orders of magnitude above its visual threshold (approximately 0.1 mg/L) and over five orders of magnitude above its typical laboratory detection limit (less than 0.001 mg/L). Once the drilling tool has been advanced to a particular depth for groundwater sampling, water will be pumped from the borehole until the discharge water is relatively clear of fluorescein. The goal of purging is to reach the clarity of a prepared visual standard, indicating that the discharge water is comprised of at least 95 percent formation water and less than 5 percent drilling water. Groundwater samples will then be collected for COC analysis. If the visual standard is still not reached after a reasonable period and volume of purging, then COC sampling can still be performed, provided that samples of the dyed drilling water and groundwater are also be sent for fluorescein analysis. The fluorescein data can then be used to calculate a quantitative correction factor to be applied to COC analytical results.

Set-Up Procedures

a. Dye Batch Preparation

- Prior to initiating drilling activities, measure the proper mass of powdered dye for mixing with drilling water - 38 grams of fluorescein (provided by Ozark Underground Laboratory) will be added to every 500 gallons of water to yield an average tracer concentration of approximately 20 mg/L.

- If the drilling water “batch” is larger or smaller than 500 gallons, the same ratio of dye to drilling water will be used.

- Measure the mass of dye using a scale with an accuracy of +/- 1 gram.

- Add the dye to the drilling water batch tank while also adding the potable water to provide agitation to assist in mixing the dye.

- A utility pump should also be used to mix the tracer with the drilling water by recirculating water in the tank for at least 15 minutes.

- Place 40 mL of the dyed drilling water into the 50 mL graduated cylinder for use in preparing the visual standard discussed below.

- Collect 4 additional 40 ml unpreserved VOA vials of drilling water from each batch of drilling water – label all four of these vials “DW1” for the first batch of drilling water, “DW2” for the second batch, etc. These samples will be archived for potential use in preparing other standards with other dilutions (optional) or for submittal for laboratory analysis, if necessary.

b. Preparation of Visual Standard: A visual standard will be prepared for each batch of dyed drilling water, as follows.

- Pour the 40 mL volume of dyed drilling water from the 50 mL graduated cylinder into the 1 L graduated cylinder.
- Add 760 mL of un-dyed potable water (from the same potable water source used to prepare the dyed drilling water) to the 1 L graduated cylinder to produce 800 mL of "visual standard".
- Fill one 40-mL unpreserved VOA vial with visual standard solution and label this "VS1" for the visual standard from the first batch of drilling water, "VS2" for the visual standard from the second batch of drilling water, etc.
- These visual standards represent a 95% dilution of the drill water, and will provide a visual standard to verify that sufficient purging has been performed to remove at least 95% of the drilling water from a given interval, indicating that the purge water consists of at least 95% formation water.
- Discard the remaining fluid within the graduated cylinder using an appropriate container.
- Photograph the "DW" samples and the "VS" sample from each batch of drilling water with adequate, consistent light, against a white background.
- Keep all of the dyed drilling water ("DW") samples and visual standard ("VS") samples in a cooler to keep them dark, as the dye will degrade with exposure to light.

Drilling Procedures

- Fresh drilling water from the dyed drilling water batch tank will be used during drilling operations. In general, a positive head should be maintained during drilling, which should prevent dilution of the drilling water by formation water. However, any water upwelling from the casing during drilling will be contained in a tub positioned over the borehole. As needed, recovered water in the tub will be pumped to a frac tank.

- The drilling water source should be sampled for chlorine and pH at the start of the project. Chlorine will consume fluorescein; if present in detectable quantities, there should be a “wait” period of at least four hours between dye addition and sampling (and use) of the drilling fluid. Below pH values of about 5 fluorescein results in reduced fluorescence. Depending on the source of the drilling fluid and project objectives, the source water may also be sampled for COCs and fluorescein.

- In open sunlight, fluorescein photodegrades rapidly. If the tracer batch tank is translucent, black, 1 millimeter plastic will be used to cover the tank during the day to minimize photodegradation of the tracer batch water.

- After tracer addition, each batch of drilling fluid should be sampled at least once for fluorescein.

- At the end of the day, any excess tracer batch water can be stored for use the following day, or it may be disposed of as investigation derived waste. Alternatively, fluorescein concentrations can be reduced to below visible concentrations with granular activated carbon, UV-oxidation, chemical oxidants, or direct exposure to sunlight for several days.

- The field geologist will record the amount of drilling water lost to the formation during drilling of each sampling depth interval.

- At the end of the project, any excess tracer batch water can be disposed of as investigation derived waste. Alternatively, fluorescein concentrations can be reduced to below visible concentrations with granular activated carbon, UV-oxidation, chemical oxidants, or direct exposure to sunlight for several days. Depending on project and regulatory requirements, excess batch water with fluorescein concentrations below the visible limit could be discharged to a sanitary sewer or other discharge location.

Purging and Sampling Procedures

- After a given groundwater sampling interval is reached, purging and screening-level groundwater sampling will be performed.

- The targeted sample interval will be purged using a pump. During purging, purge water will be periodically collected in a 40-mL unpreserved VOA vial and compared to the visual standard ("VS" sample) prepared from the drilling water used to drill that depth interval.

- If the purge water contains significant suspended particulates/turbidity, it may be necessary to allow particulates to settle before comparing the purge water sample to the visual standard.

- Purging will continue until one of these two conditions is met:

  1) the purge water clarity in terms of remaining dye content matches or exceeds the clarity of the visual standard, indicating that the purge water consists of at least 95% formation water.

    - In this case, the purge water sample and the associated visual standard will be photographed against a white background to document that the purging goal has been reached

  2) a different practical purging limit has been reached, based on purge volume or time

    - In this case, the purge water sample and the associated visual standard will be photographed against a white background to document the degree of purge water visual clarity that was attained

    - Also, a sample of the purge water will be obtained in a 40mL unpreserved VOA vial; this sample, and one of the vials of dyed drilling water, will be submitted to Ozark Underground Laboratories for quantitative analysis of fluorescein. These samples will be shipped in a cooler with reusable "Blue Ice" rather than wet ice. The analytical results for fluorescein will be used to calculate a COC correction factor, as discussed below.

- After purging has been completed, screening level groundwater samples will be collected from the discharge end of the pump tubing for COC analysis in accordance with the approved work plan.

Calculation of Correction Factor

In the event that the purge water does not reach the clarity goal indicated by the visual standard ("VS" sample), a sample of the drilling water and a sample of the purge water (obtained immediately prior to sampling for COC analysis) will be sent for laboratory analysis of fluorescein.

Representative COC concentrations in groundwater (C_{gw}) can then be calculated as:

$$C_{gw} = C_m [F_d / (F_d - F_s)]$$

where: C_m = measured COC concentration, as reported by the lab

F_d = fluorescein concentration in drilling water

F_s = fluorescein concentration in groundwater sample

The term $[F_d / (F_d - F_s)]$ is the COC correction factor.

VII. Waste Management

Equipment decontamination materials will be managed in conjunction with all other waste produced during the field sampling effort. Excess drilling water and purge water shall be managed as outlined in the Field Sampling Plan (FSP).

VIII. Data Recording and Management

The supervising geologist/engineer will be responsible for documenting sampling events using a logbook to record relevant information in a clear and concise format. The sampling and drilling event record shall include:

- name and location of project;

- project number, client, and site location;
- names of Contractor, Contractor personnel, inspectors, and other people onsite;
- weather conditions;
- mass of dye and volume of drilling water used in dyed drilling water batches;
- volume of drilling water lost to the formation in each sampled depth interval;
- depth to groundwater;
- type of sampling method;
- start and finish dates and times of sampling;
- volume of groundwater purged and sampled; and
- photo documentation of all retained drill water ("DW") samples, visual standard ("VS") samples, and groundwater samples, against a white background in adequate and consistent light, with groundwater samples placed next to appropriate visual standards.

IX. Quality Assurance

Equipment will be cleaned prior to use onsite, between each drilling and sampling location, and prior to leaving the site. Review bottle labels and the COC prior to shipping to ensure everything is labeled and documented correctly.

X. References

No references are cited in this SOP.

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Water Level Measurement

Rev. #: 1

Rev Date: March 17, 2004

Approval Signatures

Prepared by: ______________________________ Date: ________________________

Reviewed by: ______________________________ Date: ________________________
(Technical Expert)

Reviewed by: ______________________________ Date: ________________________
(Project Manager)

I. Scope and Application

The objective of this Standard Operating Procedure (SOP) is to describe the procedure to measure and record groundwater and surface-water elevations. Water levels may be measured using an electronic oil-water level indicator or a pressure transducer from established reference points (e.g. top of casing). Reference points will be surveyed to evaluate their elevations relative to mean sea level (msl). This SOP describes the equipment, field procedures, materials, and documentation procedures necessary to measure and record groundwater and surface-water elevations using the aforementioned equipment.

This is a standard (i.e., typically applicable) operating procedure which may be varied or changed as required, dependent upon site conditions, equipment limitations, or limitations imposed by the procedure. The ultimate procedure employed will be documented in the project work plans or reports. . If changes to the sampling procedures are required due to unanticipated field conditions, the changes will be discussed with DTSC as soon as practicable and documented in the report.

II. Personnel Qualifications

ARCADIS field sampling personnel will have current health and safety training including 40-hour HAZWOPER training, site supervisor training, site-specific training, first aid, and CPR, as needed. In addition, ARCADIS field sampling personnel will be versed in the relevant SOPs and posses the required skills and experience necessary to successfully complete the desired field work.

III. Equipment List

The following materials, as required, shall be available during water level measurements:

- Appropriate personal protective equipment as specified in the Site Health and Safety Plan
- Equipment decontamination supplies (See *Field Sampling Equipment Decontamination Procedures SOP* No. 1213199)
- Electronic oil-water level indicator
- Mini-Troll® pressure transducer

- In-Situ™ data logger
- Laptop computer with the Win-Situ software package installed
- Photoionization detector (PID) and/or organic vapor analyzer
- Non-phosphate laboratory soap (Alconox or equivalent)
- Deionized/distilled water
- 150-foot measuring tape
- Solvent (methanol/acetone) rinse
- Portable containers
- Hacksaw or
- Pliers
- Plastic sheeting
- Field logbook
- Indelible ink pen.

IV. Cautions

Water level measurements will be recorded within 24-hours of monitoring well development as recommended by CalEPA (CalEPA, 1995). However, water level measurements will be recorded within 12-hours when the aquifer is influenced by tides, river stages, bank storage, impoundments, and/or unlined ditches. Finally, aquifers stressed by intermittent pumping and aquifers recharged from confined or semi-confined aquifers may demonstrate significant water level fluctuations.

V. Health and Safety Considerations

Volatile organics present in the monitoring well head space should be measured with a photoionization detector (PID) to evaluate potential hazards and recorded in the field logbook.

Well covers and casing should be removed carefully to avoid potential contact with insects or animal nesting in the well casings.

VI. Procedure

Oil-Water Indicators

Calibration procedures and groundwater level measurement procedures for oil-water indicators are described in the sections below.

Calibration Procedures

The oil-water indicator will be tested to verify that the meter has been correctly calibrated by the manufacturer. The following steps will be used to verify the accuracy of the oil-water indicator:

1. Measure the lengths between each increment marker on the oil-water indicator with a 150-foot tape measuring tape. The first 150 feet of the oil-water indicator measuring tape will be checked for accuracy.

2. If the oil-water indicator measuring tape is inaccurate, the probe will be sent back to the manufacturer.

3. Equipment calibration will be recorded in the field logbook.

Groundwater Level Measurement Procedures

A detailed procedure for obtaining water elevations using an electronic oil-water level indicator will be as follows:

1. Identify site and monitoring well number in field notebook along with date, time, personnel and weather conditions using indelible ink.

2. Use safety equipment as specified in the Health and Safety Plan.

3. Decontaminate the oil-water level indicator with an Alconox and water scrub, a distilled water rinse, a solvent rinse, and another distilled water rinse between each well in accordance with the *Field Sampling Equipment Decontamination Procedures* SOP (No. 1213199).

4. Place clean plastic sheeting on the ground next to the well.

5. Unlock and open the monitoring well cover while standing upwind from the well.

6. Measure the volatile organics present in the monitoring well head space with a PID and record the PID reading in the field logbook.

7. Allow the water level in the well to equilibrate with atmospheric pressure for a few minutes. Locate a measuring reference point on the monitoring well casing. If one is not found, create a reference point by notching the inner casing (or outer if an inner casing is not present) with a hacksaw. All downhole measurements will be taken from the reference point. Document the creation of any new reference point or alteration of the existing reference point.

8. Measure to the nearest 0.01 foot and record the height of the inner and outer casing from reference point to ground level.

9. Slowly lower the oil-water level indicator probe until it touches the bottom of the well. Record the depth of the well. Make water level, oil-water interface, and oil level measurements as the probe is drawn back up through the water column. Double check all measurements and record depths to the nearest 0.01 foot.

10. Decontaminate the instrument with an Alconox and water scrub, a distilled water rinse, a solvent rinse, and another distilled water rinse between each well in accordance with the *Field Sampling Equipment Decontamination Procedures* SOP (No. 1213199).

11. Lock the well when all activities are completed.

Pressure Transducers

The detailed procedure for obtaining water elevations using a Mini-Troll® pressure transducer with an In-Situ™ data logger and the Win-Situ software package will be as follows:

Setup Procedures

1. Connect the Mini-Troll® to a laptop computer serial port.

2. Open the Win-Situ software package on the laptop computer.

3. Verify that the Win-Situ software recognizes the Mini-Troll®.

4. Synchronize the clock on the laptop computer with that of the Mini-Troll®.

5. Add a test to the Mini-Troll® and input the specifications of the test (e.g., frequency of data collection, start data collection).

6. Disconnect the Mini-Troll® from the laptop computer, and prepare the Mini-Troll® for field deployment.

Field Procedures

1. Decontaminate all equipment entering the monitoring well with an Alconox and water scrub, a distilled water rinse, a solvent rinse, and another distilled water rinse between each well in accordance with the *Field Sampling Equipment Decontamination Procedures* SOP (No. 1213199).

2. Connect Mini-Troll® to laptop computer, and start the Win-Situ program.

3. Lower the Mini-Troll® gently below the water table.

4. Take a water level reading from the Mini-Troll® using the Win-Situ software package.

5. Lift the Mini-Troll® approximately 1-foot, and verify the Mini-Troll® response on the Win-Situ program (i.e. depth to water should be 1-foot lower).

6. Upon verification, set the Mini-Troll® to the desired depth. Position the instrument below the lowest anticipated water level, but not so low that its range will be exceeded at the highest anticipated water level.

7. Secure the cable to prevent drift and movement.

8. Set reference point (e.g. depth to water, groundwater elevation) and input it into the Win-Situ software package.

9. Periodically download data and collect manual depth to water measurements using the same oil-water indicator probe used during the equipment setup to verify the accuracy of the Mini-Troll®.

VII. Waste Management

Decontamination water should be containerized and characterized in accordance with California Environmental Protection Agency's procedures for *Representative Sampling of Groundwater for Hazardous Substances* (CalEPA, 1995). Rinse water, personal protective equipment, and other residuals generated during equipment decontamination will be placed in appropriate containers and labeled. Containerized waste will be disposed of consistent with appropriate procedures as outlined in the *Handling and Storage of Investigation-Derived Waste SOP* (No. 152319).

VIII. Data Recording and Management

Groundwater level measurements should be documented in the field logbook. The following information will be documented in the field logbook:

- Sample identification
- Measurement time
- Total well depth
- Depth to water
- Depth to product, if encountered
- Product thickness, if encountered.

Groundwater elevations recorded using a Mini-Troll® pressure transducer with an In-Situ™ data logger and the Win-Situ software package will be downloaded and stored in the central project file.

IX. Quality Assurance

The oil-water indicator tape may need to be weighted for deeper monitoring wells. The amount of weight added should be sufficient enough to keep the oil-water indicator tape straight. Standing water level measurement devices are not appropriate for recording the depth of monitoring wells (CalEPA, 1995).

X. References

California Environmental Protection Agency (CalEPA). 1995. *Representative Sampling of Groundwater for Hazardous Substances. Guidance Manual for Ground Water Investigations*. July 1995.

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Water-Level and NAPL Thickness Measurement Procedures

Rev. #: 0

Rev Date: February 27, 2009

Approval Signatures

Prepared by: ______________________ Date: 2/27/09
Andrew Korik

Reviewed by: ______________________ Date: 2/27/09
Michael Gefell (Technical Expert)

I. Scope and Application

Monitoring well water levels and thickness of non-aqueous phase liquids (NAPLs) will be determined, as appropriate, to develop groundwater elevation contour maps and to assess the presence or absence of NAPL in wells. This SOP applies to light and/or dense NAPLs (LNAPLs and DNAPLs, respectively). In addition, because this SOP describes water-level measurement from surveyed measurement points, this SOP can be followed, to obtain surface water level measurements from surveyed measurement points.

Fluid levels will be measured using an electric water-level probe and/or NAPL-water interface probe from established reference points. Reference points are surveyed, and are established at the highest point at the top of well riser, and will be based on mean sea level, or local/onsite datum. The Operating and Maintenance (O&M) Instruction Manual for the electric water level probe and/or and interface probe should be reviewed prior to commencing work for safe and accurate operation.

II. Personnel Qualifications

Individuals conducting fluid level measurements will have been trained in the proper use of the instruments, including their use for measuring fluid levels and the bottom depth of wells. In addition, ARCADIS field sampling personnel will have current health and safety training including 40-hour HAZWOPER training, site supervisor training, site-specific training, first aid, and CPR, as needed. In addition, ARCADIS field sampling personnel will be versed in the relevant SOPs and posses the required skills and experience necessary to successfully complete the desired field work. ARCADIS field personnel will also be compliant with client-specific training requirements, such as (but not limited to) LPS or other behavior-based training, and short-service employee restrictions.

III. Equipment List

The following materials, as required, shall be available during fluid level measurements.

- photoionization detector (PID)
- appropriate health and safety equipment, as specified in the site Health and Safety Plan (HASP)

- laboratory-type soap (Alconox or equivalent), methanol/hexane rinse, potable water, distilled water, and/or other equipment that may be needed for decontamination purposes
- electronic NAPL-water interface probe
- electronic water-level meter
- 6-foot engineer's rule
- portable containers
- plastic sheeting
- field logbook and/or personal digital assistant (PDA)
- indelible ink pen
- digital camera (optional, if allowed by site policy)

IV. Cautions

Electronic water-level probes and NAPL-water interface probes can sometimes produce false-positive readings. For example, if the inside surface of the well has condensation above the water level, then an electronic water-level probe may produce a signal by contacting the side of the well rather than the true water level in the well. In addition, NAPL-water interface probes can sometimes indicate false positive signals when contacting a sediment layer on the bottom of a well. In contrast, a NAPL-water interface probe may produce a false-negative (no signal) if a floating layer of non-aqueous phase liquid (NAPL) is too thin, such as a film or sheen. To produce reliable data, the electronic water level probe and/or interface probe should be raised and lowered several times at the approximate depth where the instrument produces a tone indicating a fluid interface to verify consistent, repeatable results. In addition, a bottom-loading bailer should periodically be used to check for the presence of NAPLs rather than relying solely on the NAPL-water interface probe.

The graduated tape or cable with depth markings is designed to indicate the depth of the electronic sensor that detects the fluid interface, but not the depth of the bottom of the instrument. When using these devices to measure the total well depth, the additional length of the instrument below the electronic sensor must be added to the apparent well depth reading, as observed on the tape or cable of the instrument, to obtain the true total depth of the well. If the depth markings on the tape or cable are worn or otherwise difficult to read, extra care must be taken in obtaining the depth readings.

V. Health and Safety Considerations

The HASP will be followed, as appropriate, to ensure the safety of field personnel. Access to wells may expose field personnel to hazardous materials such as contaminated groundwater or NAPL. Other potential hazards include stinging insects that may inhabit well heads, other biologic hazards, and potentially the use of sharp cutting tools (scissors, knife). Appropriate personal protective equipment (PPE) will be worn during these activities. Field personnel will thoroughly review client-specific health and safety requirements, which may preclude the use of fixed/folding-blade knives.

VI. Procedure

Calibration Procedures

If there is any uncertainty regarding the accuracy of the tape or cable associated with the electronic water-level probe or NAPL-water interface probe, it should be checked versus a standard length prior to use to assess if the tape or cable above the meter has been correctly calibrated by the manufacturer, and to identify evidence of tape or cable stretching, etc.

1. Measure the lengths between markers on the cable with a 6-foot engineer’s rule or a fiberglass engineer’s tape. The tape or cable associated with the electronic water-level probe or NAPL-water interface probe should be checked for the length corresponding to the deepest total well depth to be monitored during the data collection event.

2. If the length designations on the tape or cable associated with the electronic water-level probe or NAPL-water interface probe are found to be incorrect, the probe will not be used until it is repaired by the manufacturer.

3. Record verification of this calibration process in field logbook or PDA.

Measurement Procedures

The detailed procedure for obtaining fluid level depth measurements is as follows. Field notes on logs will be treated as secured documentation and indelible ink will be used. As a general rule, the order of measuring should proceed from the least to most contaminated monitoring wells, based on available data.

1. Identify site and well number in field logbook using indelible ink, along with date, time, personnel, and weather conditions.

2. Field personnel will avoid activities that may introduce contamination into monitoring wells. Activities such as dispensing gasoline into vehicles or generators should be accomplished well in advance of obtaining field measurements.

3. Don PPE as required by the HASP..

4. Clean the NAPL/water interface probe and cable in accordance with the appropriate cleaning procedures. Down-hole instrumentation should be cleaned prior to obtaining readings at the first monitoring well and upon completion of readings at each well.

5. Clean the NAPL/water level interface probe and cable with a soapy (Alconox) water rinse followed by a solvent rinse (if appropriate based on site-specific constituents of concern) an analyte-free water rinse Contain rinse water in a portable container that will be transferred to an on-site container.

6. Put clean plastic sheeting on the ground next to the well.

7. Unlock and open the well cover while standing upwind from the well. Place the well cap on the plastic sheeting.

8. Locate a measuring reference point on the well casing. If one is not found, initiate a reference point at the highest discernable point on the inner casing (or outer if an inner casing is not present) by notching with a hacksaw, or using an indelible marker. All down-hole measurements will be taken from the reference point established at each well on the inner casing (on the outer only if an inner casing is not present).

9. Measure to the nearest hundredth of a foot and record the height of the inner and outer casings (from reference point, as appropriate) to ground level.

10. Record the inside diameter of the well casing in the field log.

11. If an electronic water level probe is used to measure the water level, lower the probe until it emits a signal (tone and or light) indicating the top of the water surface. Gently raise and lower the instrument through this interface to confirm its depth. Measure and record the depth of the water surface, and the total well depth, to the nearest hundredth of a foot from the reference point at the top of

the well. Lower the probe to the bottom of the well to obtain a total depth measurement.

12. If a NAPL/water interface probe is being used to measure the depth and thickness of NAPL, lower the instrument until it emits a signal (tone and or light) indicating whether LNAPL is present. Continue to lower the NAPL/water level interface probe until it indicates the top of water. Lower the probe to the bottom of the well to obtain a total depth measurement. Note also of the depth indicating the bottom of water and top of DNAPL layer, if any, based on the signal emitted by the interface probe. At each fluid interface, gently raise and lower the instrument through each the interface to confirm its depth. Measure to the nearest hundredth of a foot and record the depth of each fluid interface, and the total well depth, from the reference point.

13. Clean the NAPL/water interface probe and cable in accordance with the appropriate cleaning procedures.

14. If using a bailer to confirm the presence/absence of NAPL, the bailer should either have been previously dedicated to the well, or be a new previously unused bailer.

15. Compare the depth of the well to previous records, and note any discrepancy.

16. Lock the well when all activities are completed.

VII. Waste Management

Decontamination fluids, PPE, and other disposable equipment will be properly stored on site in labeled containers and disposed of properly. Be certain that waste containers are properly labeled and documented in the field log book. Review appropriate waste management SOPs, which may be state- or client-specific.

VIII. Data Recording and Management

Fluid level measurement data will be recorded legibly on “write-in-the-rain” field notebook in indelible pen and/or a PDA. Field situations such as apparent well damage or suspected tampering, or other observations of conditions that may result in compromised data collection will be photographically documented where practicable.

IX. Quality Assurance

As described in the detailed procedure, the electronic water-level meter and/or NAPL-water interface probe will be calibrated prior to use versus an engineer's rule to ensure accurate length demarcations on the tape or cable. Fluid interface measurements will be verified by gently raising and lowering the instrument through each interface to confirm repeatable results.

X. References

No literature references are required for this SOP.