ARCADIS Design & Consultancy for natural and built assets

Ron Timm
Toxics Cleanup Program
Washington State Department of Ecology
Northwest Regional Office
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Subject:

Washington State Department of Transportation Stormwater Line Compliance Soil Sampling Work Plan

Environment

Date:
November 29, 2018

Contact:
Samuel Miles

Phone:
206.853.7428

Email:
Samuel.Miles@arcadis.com

Our ref:
B0045362.0012

Dear Mr. Timm:

Arcadis U.S., Inc. (Arcadis), on behalf of Chevron Environmental Management Company (Chevron), is proposing to conduct the Washington State Department of Transportation (WSDOT) stormwater line performance soil sampling at the Lower Yard of the Former Unocal Edmonds Terminal located at 11720 Union Oil Company Road in Edmonds, Washington (Figure 1).

A dual-phase extraction (DPE) system was installed at the Lower Yard near the WSDOT stormwater line as described in the Dual-Phase Extraction System As-Built Report[1] and requested in Washington State Department of Ecology (Ecology) Agreed Order (AO) No. DE 4460. As discussed in the Compliance Monitoring Plan[2] (CMP), the effectiveness of remediation activities will be verified through compliance soil sampling and compliance groundwater analytical sampling to confirm that constituents of concern (COCs) concentrations met the site-specific cleanup levels (CULs) and remediation level (REL). The CMP states that WSDOT stormwater line performance soil sampling will be conducted after the DPE system mass removal rates have reached asymptotic levels or following 12 months of operation, whichever occurs first. The start-up date of the DPE system was December 1st, 2017 and it has been operational for 12 months. Mass removal rates associated with the DPE system have reduced from 40 pounds per day (lbs/day) to 1 lbs/day since December 2017 and have reached asymptotic levels. Mass removal rates are shown on Figure 2. Arcadis proposes to conduct the WSDOT stormwater line compliance soil sampling. It is expected to implement the compliance soil sampling event early December 2018.

[1] Arcadis. 2018. Dual-Phase Extraction System As-Built Report. Former Unocal Edmonds Bulk Fuel Terminal. May 10.
[2] Arcadis. 2017. Compliance Monitoring Plan. Former Unocal Edmonds Bulk Fuel Terminal. July 31.

Compliance soil sampling locations will be along the established Site compliance soil sampling 25-foot grid[3] near the WSDOT stormwater line. The sampling is being completed to assess whether applicable direct contact soil CULs or REL have been met, and to assess the long-term effectiveness of the remediation efforts. The Site compliance soil sampling 25-foot grid was developed using the Model Toxics Control Act (MTCA) compliance assessment, WAC-173-340-740(7) which requires the 95 percent upper confidence limit on the mean (95% UCL) to be less than the CUL, with less than 10 percent of the samples exceeding the CUL and no single sample exceeding twice the CUL. This systematic sampling design is an unbiased approach that results in COC concentrations representative of average exposure conditions across the entire Lower Yard of the Site. If the results of this soil investigation demonstrate that the Site is not in compliance with WAC-173-340-740(7), additional operation of the DPE system may be warranted, and/or additional step-out sampling along the established grid may be completed at the request of Chevron and approval of Ecology. Compliance sample locations are shown on Figure 3. To ensure that conditions in the area have equilibrated, sampling will be conducted with the DPE system turned off at a minimum of 7 days in advance. Groundwater monitoring wells in the area will be gauged and vacuum measurements will be taken from the DPE wells prior to the soil sampling event to confirm that conditions have equilibrated.

Soil borings will be advanced to a minimum depth of 15 feet below ground surface (bgs). The initial 5 feet will be cleared using manual methods to reduce the potential for damage to underground structures. If non-utility obstructions are encountered, mechanical means will be used as necessary. An air knife vacuum truck will not be utilized during this event. Historical soil sample exceedances are listed in Table 1. The borings will then be advanced to total depth using a track mounted full size geoprobe rig. Field screening of soil samples will be performed using a photoionization detector (PID) or a flame ionization detector (FID) to measure volatile organic compounds in soil headspace and visual classification. Both a PID and FID will be onsite with the most appropriate instrument used for site conditions. If field screening indicates petroleum contaminated soil is present at 15 feet bgs, soil borings will be advanced to a maximum depth of 20 feet bgs.

Soil samples will be collected from undisturbed cores. Samples will be collected following the soil Drilling and Sample Collection technical guidance instruction[4] provided as Attachment 1. Up to three samples per boring will be collected for analysis depending on field screening and historical exceedances:

- If field screening indicates COCs are present, then one sample with the highest PID/FID reading will be collected, and at least one additional sample will be collected below the depth of the highest reading.
- If field screening does not indicate the presence of COCs, then one sample will be collected just above the groundwater table and at the depth of the historical maximum exceedance for this location.

Samples will be identified with a unique alpha-numeric code that will identify the type of sample and the location where the sample was collected. Performance soil samples (PSS) will be labeled with the prefix “DPE-“to include the remediation area designation and will include grid cell location, and depth. For

[3] Locations may be adjusted depending on site-specifics constraints.

[4] Other relevant guidances such as Field Equipment Decontamination, Chain-of-Custody, Handling, Packing and Shipping, Photoionization Detector Air Monitoring and Field Screening, Investigation-Derived Waste Handling and Storage and Field Log Book Entries are presented in in the Appendix F - Sampling and Analysis Plan (SAP) of the Final Interim Action Work Plan (Arcadis. 2016. Final Interim Action Work Plan. Former Unocal Edmonds Bulk Fuel Terminal. July 19.)

example, a sample collected from grid cell Y9 at a depth of 7.5 feet bgs would be labeled DPE-PSS-Y9-7.5.

Collected soil samples will be submitted for chemical analysis to an Ecology-approved laboratory for:

- Samples will be analyzed for:
  - Benzene by USEPA Method 8021B
  - GRO (gasoline range organics) by Ecology Method NWTPH-Gx
  - DRO (diesel range organics) and HO (heavy oil range organics) by Ecology Method NWTPH-Dx (after silica gel cleanup)
  - Samples with detectable DRO and/or HO concentrations will also be analyzed for carcinogenic polycyclic aromatic hydrocarbons[5] (cPAHs) by USEPA Method 8270C
- One sample per boring will be analyzed for volatile petroleum hydrocarbon (VPH) and extractable petroleum hydrocarbon (EPH). If field screening indicates COCs are present, then the sample with the highest PID reading will be analyzed for EPH/VPH. If field screening does not indicate the presence of COCs, then one sample will be collected just above the groundwater table. The EPH/VPH data will be used to confirm the site-specific REL for total petroleum hydrocarbons (TPH) in soil, which was calculated from soil samples collected prior to the remedial actions at the Site, is still appropriate. The EPH/VPH data will include aliphatics, aromatics, benzene, toluene, ethylbenzene, xylenes, (BTEX collectively), naphthalene, 1- and 2-methyl naphthalene, n-hexane, and the seven cPAHs. Methyl tert-butyl ether, ethylene dibromide, and ethylene dichloride will not be analyzed since these constituents were not detected in the Lower Yard and were not used in the determination of the TPH REL for the Site as shown in Exhibit B to AO No. DE 4460.

Following the WSDOT stormwater line compliance soil sampling, compliance for soil at the Site will be evaluated using the established 25-foot grid sample locations across the whole Lower Yard by a comparison of the 95% UCL to the applicable CULs or REL. As stated in the CMP, if the compliance soil samples meet the criteria below, the vapor extraction portion of the DPE system will be shut down.

- The 95% UCL for TPH is less than the soil REL.
- The 95% UCLs for total cPAHs toxic equivalency and benzene are less than the soil CULs.
- Less than 10 percent of the samples of the entire Lower Yard contain COC concentrations that exceed the REL or CULs.
- No single sample contains a COC concentration that is equal to or greater than twice the REL or CULs.

As described in the Dual-Phase Extraction System As-Built Report[6] (DPE System As-Built Report), the compliance soil sampling report will be submitted as part of an addendum to this DPE System As-Built Report.

[5] cPAHs: benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene.
[6] Arcadis. 2018. Dual-Phase Extraction System As-Built Report. Former Unocal Edmonds Bulk Fuel Terminal. May 10.

If you have any questions or would like to discuss this matter further, please feel free to contact Samuel Miles of Arcadis at 206.853.7428.

Sincerely,

Arcadis U.S., Inc.

Samuel Miles
AFS Project Manager

Copies:
Kim Jolitz – Chevron EMC
Kevin Bartoy – WSDOT
Scott Zorn – Haley and Aldrich

Enclosures:

Figures

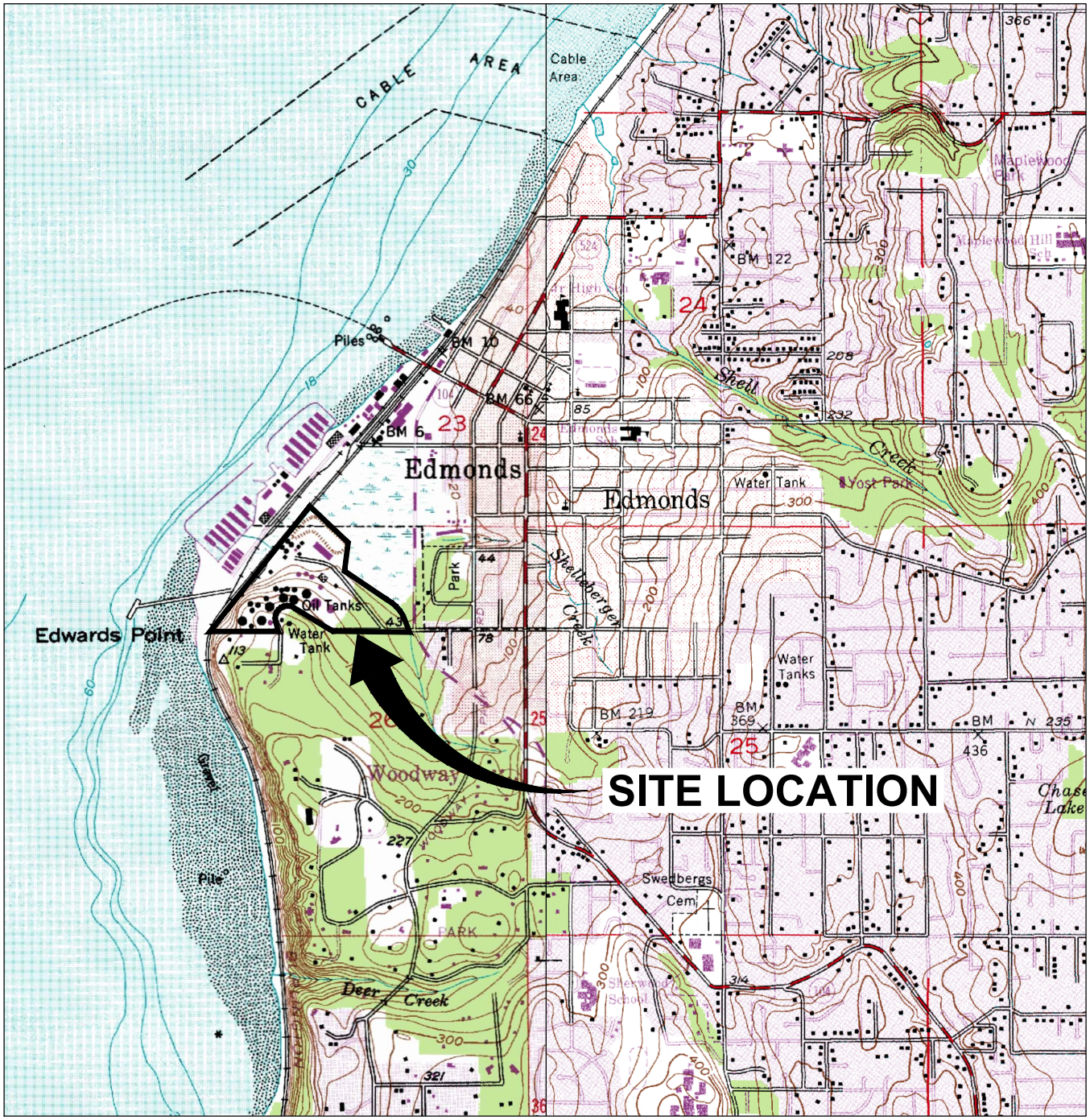
1 Former Unocal Bulk Fuel Terminal Location Ma
2 DPE System Mass Removal Rates
3 Proposed Performance Soil Sampling Locations

Table

1 Historical Soil Concentrations – Washington State Department of Transportation Stormwater Line Area

Attachment

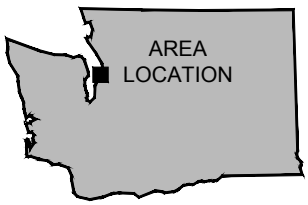
1 Soil Drilling and Sample Collection



REFERENCE: BASE MAP USGS QUADS., 7.5 MIN. SERIES (TOPOGRAPHIC) - EDMONDS EAST, WASH. AND EDMONDS WEST, WASH.

0 2000' 4000'

GRAPHIC SCALE



WASHINGTON

CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
FORMER UNOCAL BULK FUEL TERMINAL
EDMONDS, WASHINGTON

LIMITED SOIL SAMPLING WORK PLAN

FORMER UNOCAL BULK FUEL TERMINAL LOCATION MAP

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FIGURE 1

CITY: MINNEAPOLIS, MN DIV/GROUP: ENV/CAD DB: R. OBERLANDER LD: R. OBERLANDER PIC:(Opt) PM:(Reqd) TM:(Opt) LYR:(Opt)ON=*;OFF=*REF*
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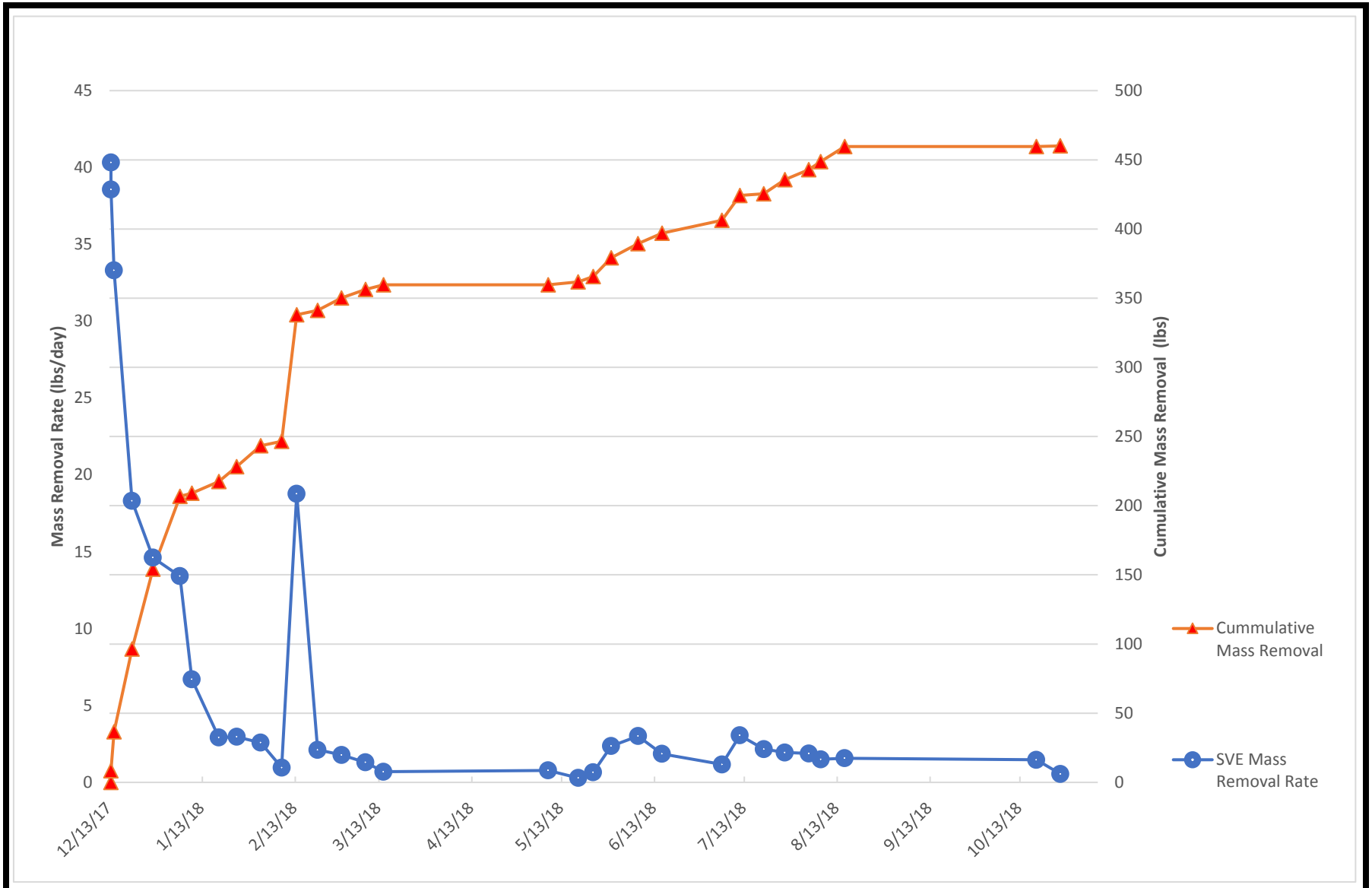
Edmond-W.tif

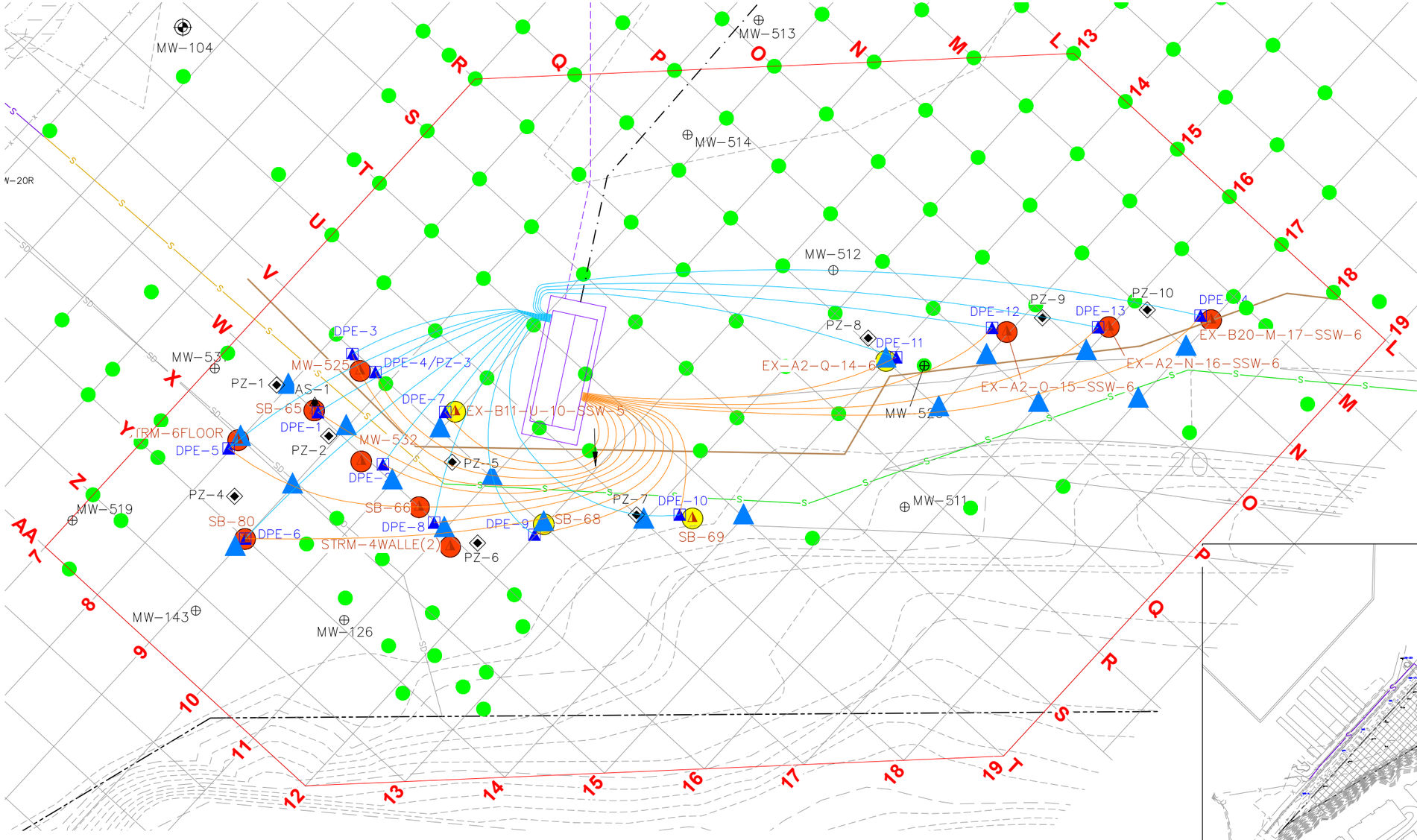


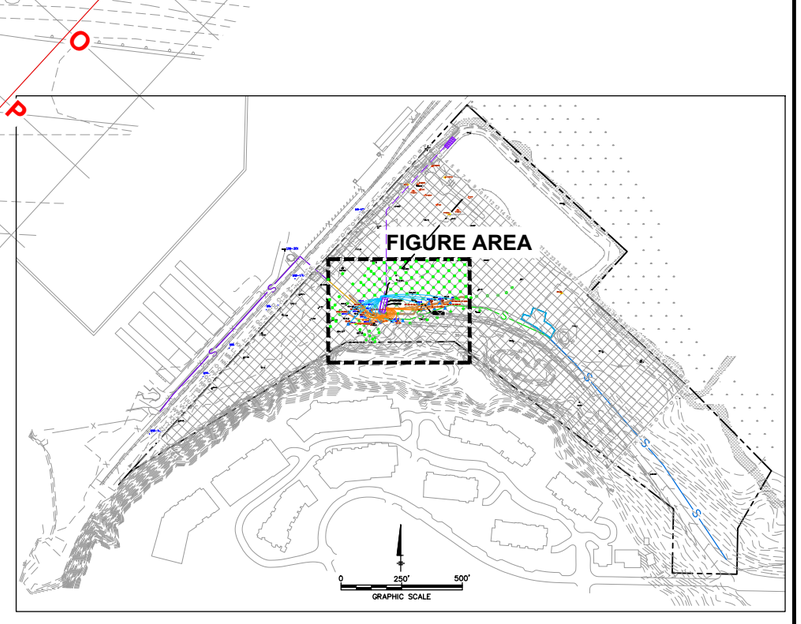
ARCADIS

DPE SYSTEM MASS REMOVAL RATES

FORMER UNOCAL EDMONDS BULK FUEL TERMINAL

FIGURE 2





LEGEND:

- ELECTRICAL CONDUIT TRENCHING (APPROXIMATE LOCATION)
- TREATED GROUNDWATER DISCHARGE LINE (APPROXIMATE LOCATION)
- GROUNDWATER CONVEYING PIPING
- VAPOR CONVEYING PIPING
- PROPERTY BOUNDARY
- S — WASHINGTON STATE DEPARTMENT OF TRANSPORTATION (WSDOT) STORMWATER LINE
- SD — POINT EDWARDS STORM DRAIN LINE
- 20-MIL POLYETHYLENE SHEETING
- DPE-10 — DUAL PHASE EXTRACTION (DPE) WELL LOCATION
- MW-515 — INTERIOR MONITORING WELL LOCATION AND DESIGNATION
- MW-518 — PERIMETER MONITORING WELL LOCATION
- AS-1 — AIR SPARGE WELL LOCATION
- PZ-9 — DPE MONITORING PIEZOMETERS
- SOIL SAMPLE LOCATION WITH ANALYTE CONCENTRATIONS EXCEEDING SITE CULs OR RELs
- SOIL SAMPLE LOCATION WITH ANALYTE CONCENTRATIONS EXCEEDING TWICE THE CUL
- PROPOSED PERFORMANCE SOIL SAMPLE LOCATION
- SOIL SAMPLE LOCATION WITH ANALYTE CONCENTRATIONS LESS THAN SOIL CULs/RELs
- CUL — CLEANUP LEVEL
- REL — REMEDIATION LEVEL

NOTES:

1. HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE (NAD 83/98).
   VERTICAL DATUM: N.A.V.D. 88
   UNITS: U.S. SURVEY FEET
   HORIZONTAL AND VERTICAL CONTROL ESTABLISHED BY GPS VIA VERTICAL REFERENCE STATION NETWORK (VRSN).
2. SOUTHEAST PORTION OF WSDOT STORMWATER LINE HAS NOT BEEN SURVEYED.
3. LOCATION OF EXISTING POWER SUPPLY PANEL HAS NOT BEEN SURVEYED.

CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
FORMER UNOCAL BULK FUEL TERMINAL
EDMONDS, WASHINGTON

DUAL PHASE EXTRACTION SYSTEM - PROPOSED PERFORMANCE SOIL SAMPLE LOCATIONS

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FIGURE 3

CITY: MINNEAPOLIS, MN DIV/GROUP: ENV/CAD DB: R. OBERLANDER
C:\Users\jharris\OneDrive - ARCADIS\BIM 360 Docs\CHEVRON CORPORATION\Edmonds-2018 Project Activities\2018\B00045362.0012\01-DWG\Edmonds - Figure 2 - DPE Proposed Performance Soil Sample Locations.dwg LAYOUT: 2 SAVED: 11/2/2018 11:57 AM ACADVER: 21.0S (LMS TECH) PAGESETUP:
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Table 1
Historical Soil Concentrations - WSDOT Stormwater Line Area
Chevron Environmental Management Company
Limited Soil Sampling Work Plan
Former Unocal Edmonds Bulk Fuel Terminal, Edmonds, Washington

Soil Sample ID		Concentration (mg/kg) Exceeded Site			Proposed Soil Sample Locations	Exceedance Shallowest Depth (feet bgs)
		REL for TPH (2,775 mg/kg)	CUL for cPAHs TEQ (0.14 mg/kg)	CUL for benzene (18 mg/kg)		
STRM-6FLOOR-7		17,439	-	54.9	DPE-PSS-X8	7
STRM-4WALLE(2)-3		15,388	0.56	-	DPE-PSS-W11	3
EX-B11-U-10-SSW-5		-	0.159	-	DPE-PSS-V10	5
EX-A2-Q-14-6		3,060	-	-	DPE-PSS-Q14	6
EX-A2-O-15-SSW-6		7,540	-	-	DPE-PSS-P15	6
EX-A2-N-16-SSW-6		7,550	-	-	DPE-PSS-O16	6
EX-B20-M-17-SSW-6		15,700	0.166	-	DPE-PSS-N17	6
SB-65	SB-65-6.5	16,900	1.01	35.8	DPE-PSS-W8 and DPE-PSS-W9	6.5
	SB-65-8.0	4,390	-	-		
	SB-65-16.0	-	-	-		
	SB-65-20	-	-	-		
	SB-65-23	-	-	-		
SB-66	SB-66-6.0	11,900	0.209	-	DPE-PSS-W10 and DPE-PSS-W11	6
	SB-66-11.5	-	-	-		
	SB-66-15	-	-	-		
SB-68	SB-68-4.0	5,470	0.165	-	DPE-PSS-V12	4
	SB-68-5.5	4,660	-	-		
	SB-68-13.5	-	-	-		
	SB-68-15.0	-	-	-		
SB-69	SB-69-6.0	3,720	0.236	-	DPE-PSS-U13 and DPE-PSS-T14	6
	SB-69-12.0	-	-	-		
	SB-69-15.0	-	-	-		
SB-80	SB-80-7.5	4,660	0.693	-	DPE-PSS-Y9	7.5
	SB-80-11.0	-	-	-		
MW-525	MW-525-4	-	-	-	DPE-PSS-W8 and DPE-PSS-W9	6
	MW-525-6	17,850	0.29	34		
	MW-525-10.5	-	-	-		
MW-532	MW-532-6	-	-	-	DPE-PSS-W9 and DPE-PSS-W10	7
	MW-532-7	10,540	-	-		
	MW-532-10	-	-	-		
	MW-532-13.5	-	-	-		

Notes:

Soil sample ID suffixe is the sample depth in feet below ground surface (bgs).

cPAH = carcinogenic polycyclic aromatic hydrocarbon

CUL = cleanup level

DPE = dual-phase extraction

mg/kg = milligrams per kilogram

Point Edwards = Point Edwards condominium complex

REL = remediation level

TEQ = total cPAHs adjusted for toxicity

TPH = total petroleum hydrocarbons

- = concentration below appropriate CULs/RELs

Shaded cell

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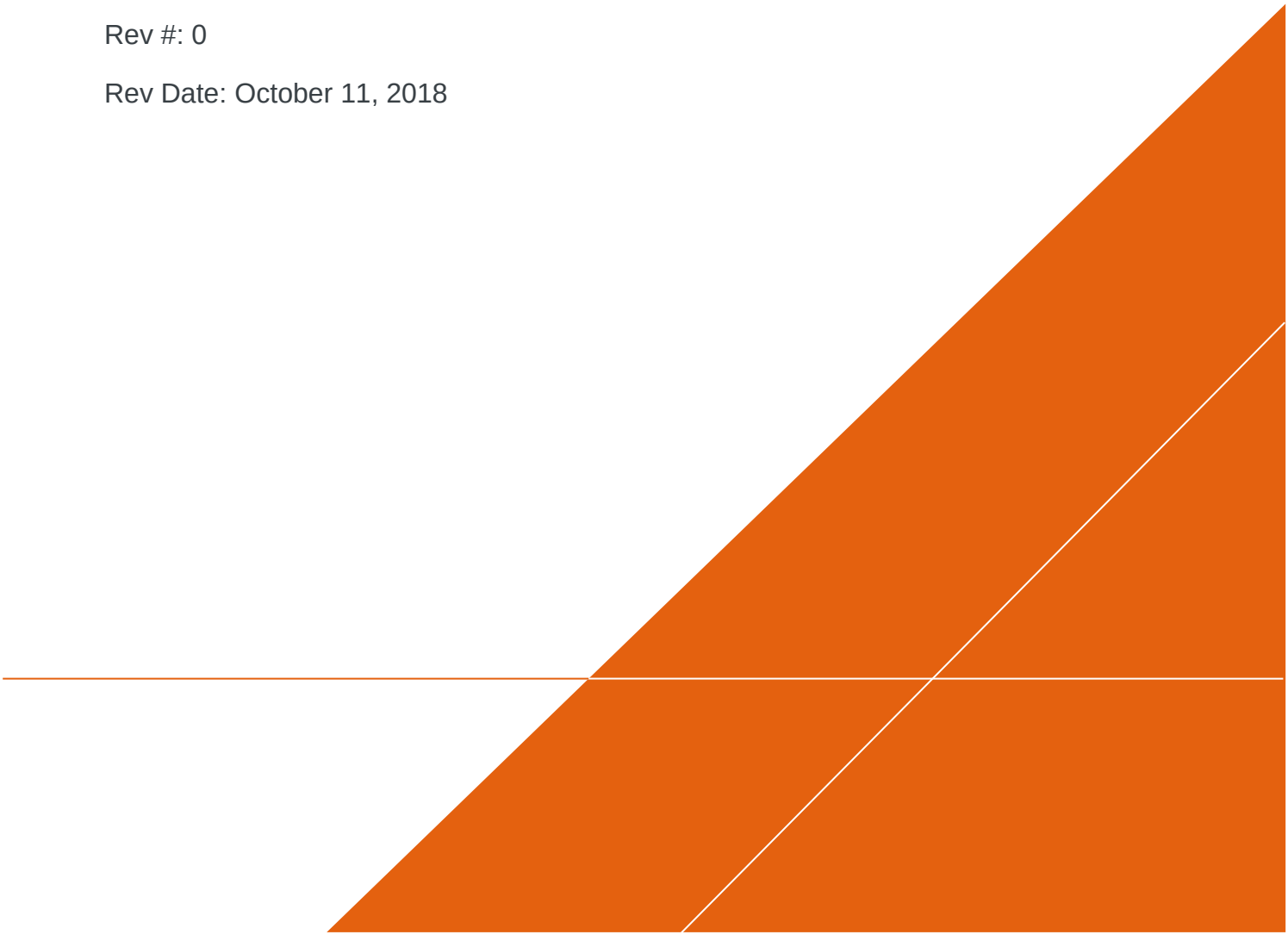
TGI – SOIL DRILLING AND SAMPLE COLLECTION

Rev #: 0

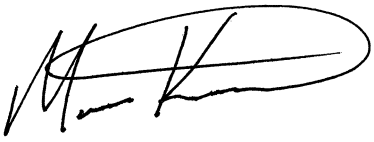
Rev Date: October 11, 2018



VERSION CONTROL

Revision No	Revision Date	Page No(s)	Description	Reviewed by
0	October 11, 2018	All	Updated and re-written as a TGI	Marc Killingstad

APPROVAL SIGNATURES

Prepared by:		10/11/2018
	Christopher Keen	Date:
Technical Expert Reviewed by:		10/11/2018
	Marc Killingstad (Technical Expert)	Date:

1 INTRODUCTION

This document describes general and/or specific procedures, methods, actions, steps, and considerations to be used and observed by Arcadis staff when performing work, tasks, or actions under the scope and relevancy of this document. This document may describe expectations, requirements, guidance, recommendations, and/or instructions pertinent to the service, work task, or activity it covers.

It is the responsibility of the Arcadis Certified Project Manager (CPM) to provide this document to the persons conducting services that fall under the scope and purpose of this procedure, instruction, and/or guidance. The Arcadis CPM will also ensure that the persons conducting the work falling under this document are appropriately trained and familiar with its content. The persons conducting the work under this document are required to meet the minimum competency requirements outlined herein, and inquire to the CPM regarding any questions, misunderstanding, or discrepancy related to the work under this document.

This document is not considered to be all inclusive nor does it apply to any and all projects. It is the CPM's responsibility to determine the proper scope and personnel required for each project. There may be project- and/or client- and/or state-specific requirements that may be more or less stringent than what is described herein. The CPM is responsible for informing Arcadis and/or Subcontractor personnel of omissions and/or deviations from this document that may be required for the project. In turn, project staff are required to inform the CPM if or when there is a deviation or omission from work performed as compared to what is described herein.

In following this document to execute the scope of work for a project, it may be necessary for staff to make professional judgment decisions to meet the project's scope of work based upon site conditions, staffing expertise, state-specific requirements, health and safety concerns, etc. Staff are required to consult with the CPM when or if a deviation or omission from this document is required that has not already been previously approved by the CPM. Upon approval by the CPM, the staff can perform the deviation or omission as confirmed by the CPM.

2 SCOPE AND APPLICATION

This Technical Guidance Instruction (TGI) describes general drilling procedures and the methods to be used to field screen and collect soil samples for laboratory analysis in unconsolidated sediments. For soil description procedures, please refer to the *TGI - Soil Description*. For monitoring well installation in granular aquifers, please refer to the *TGI - Monitoring Well Installation*.

Overburden (unconsolidated sediments) 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 with core barrel or roller bit. Direct-push techniques (e.g., Geoprobe or cone penetrometer) and hand tools may also be used. Drilling within consolidated materials such as fractured bedrock is commonly performed using water-rotary (coring or tri-cone roller bit), air rotary or rotasonic methods. For guidance when drilling in consolidated materials (i.e., bedrock), please refer to the *TGI – Bedrock Core Collection and Description*.

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.

Field screening of soil samples is commonly performed using a photoionization detector (PID) and/or a flame ionization detector (FID). These instruments are used to measure relative concentrations of volatile organic compounds (VOCs) for the selection of samples for further laboratory or field analysis. Field screening for dense non-aqueous phase liquids (DNAPL) may be performed using hydrophobic dye (Oil Red O or Sudan IV), which is pertinent at chlorinated solvent sites.

Collection of soil samples for laboratory analysis may be performed using a variety of techniques including grab samples and composite or homogenized samples. Samples may require homogenization across a given depth interval, or several discrete grabs (usually five) may be combined into a composite sample. Samples for VOC analysis will not be homogenized or composited and are collected as discrete grab samples.

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

3 PERSONNEL QUALIFICATIONS

Arcadis field personnel will have completed or are in the process of completing site-specific training as well as having current health and safety training as required by Arcadis, client, or state/federal regulations, such as 40-hour HAZWOPER training and/or OSHA HAZWOPER site supervisor training. Arcadis personnel will also have current training as identified in the site-specific Health and Safety Plan (HASP) which may include first aid, cardiopulmonary resuscitation (CPR), Blood Borne Pathogens (BBP) as needed. The HASP will also identify any access control requirements.

Prior to mobilizing to the field, Arcadis field personnel will review and be thoroughly familiar with relevant site-specific documents including but not limited to the task-specific work plan or field implementation plan (FIP), Quality Assurance Project Plan (QAPP), HASP, historical information, and other relevant site documents.

Arcadis field personnel will be knowledgeable in the relevant processes, procedures, and TGIs and possess the demonstrated required skills and experience necessary to successfully complete the desired field work. Personnel responsible for overseeing drilling operations will 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.

Arcadis personnel directing, supervising, or leading soil sampling activities will have a minimum of 1 year of previous environmental soil sampling experience. Field employees with less than 6 months of experience will be accompanied by a supervisor (as described above) to ensure that proper sample collection techniques are employed.

Additionally, the Arcadis field team will review and be thoroughly familiar with documentation provided by equipment manufacturers and become familiar with the operation of (i.e., hands-on experience) all equipment that will be used in the field prior to mobilization.

4 EQUIPMENT LIST

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

- Site-specific HASP and health and safety documents identified in the HASP
- Field Implementation Plan (FIP)/work plan that includes site map with proposed boring locations, field sampling plan (with corresponding depths, sample analyses, sample volume required, and sample holding time), and previous boring logs (as available)
- Appropriate personal protective equipment (PPE), as specified in the HASP
- Traffic cones, delineators, and caution tape as appropriate for securing the work area as specified in the Traffic Safety Plan (TSP)
- Photoionization detector (PID), flame ionization detector (FID) or other air monitoring equipment, as needed, in accordance with the HASP
- Drilling equipment required by *ASTM D1586*, when performing split-spoon sampling
- Disposable plastic liners, when drilling with direct-push equipment
- Appropriate soil sampling equipment (e.g., stainless steel spatulas/spoons/bowls, knife)
- Stainless steel hand auger and stainless-steel spade if using manual methods
- Indelible ink pens
- Engineer's ruler or survey rod
- Sealable plastic bags (e.g., Ziploc®)
- Air-tight sample containers and 8-oz. glass Mason jars or driller's jars
- Aluminum foil
- Plastic sheeting (e.g., Weatherall Visqueen)
- Decontamination equipment (buckets, distilled or deionized water, cleansers appropriate for removing expected chemicals of concern, paper towels)
- Appropriate sample blanks (trip blank supplied by the laboratory), as specified in the FSP
- Soil sample containers and labels (supplied by the laboratory) appropriate for the analytical method(s) with preservative, as needed (parameter-specific)
- Appropriate transport containers (coolers) with ice and appropriate labeling, packing, and shipping materials;
- Appropriate soil boring log (**Attachment 1**)
- Chain-of-custody forms
- Field notebook.

- Digital camera (or smart phone with camera)
- Drums or other containers appropriate for soil and decontamination water, as specified by the site investigation-derived waste (IDW) management plan, and appropriate drum labels

5 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 appropriate guidance for proper utility clearance protocol. Work will be performed in accordance with the Arcadis *Utility Location and Clearance Health and Safety Standard* and the *Utilities and Structures Checklist* will be completed before beginning any intrusive work.

Prior to beginning field work, the project technical team will ensure that all field logistics (e.g., access issues, health and safety issues, communication network, schedules, etc.) and task objectives are clearly understood by all team members. An internal call with the project technical team to review the FIP/work plan scope and objectives is strongly recommended prior to mobilization to ensure that the field work will be effectively and efficiently executed.

Some regulatory agencies have specific requirements regarding borehole abandonment and grout mixtures. Determine whether the oversight agency has any such requirements prior to finalizing the drilling plan.

If DNAPL is known or expected to exist at the site, refer to the project specific documents (e.g., DNAPL Contingency Plan) for additional details regarding drilling to reduce the potential for inadvertent DNAPL remobilization.

Similarly, if light non-aqueous phase liquid (LNAPL) is known or expected to be present as “perched” layers above the water table, refer to the DNAPL Contingency Plan. Follow the general provisions and concepts in the DNAPL contingency plan during drilling above the water table at known or expected LNAPL sites.

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

Specifications of materials used for backfilling the borehole will be obtained, reviewed and approved to meet project quality objectives. Bentonite is not recommended where DNAPL is likely to be present or in groundwater with high salinity. In these situations, neat cement grout is preferred.

Store and/or stage empty and full sample containers and coolers out of direct sunlight. Be careful not to over-tighten lids with Teflon® liners or septa. Over-tightening can impair the integrity of the seal and can cause the glass to shatter and create a risk for hand injuries.

NOTE: *Field logs and some forms are considered to be legal documents. All field logs and forms will therefore be filled out in indelible ink. Do not use permanent marker or felt-tipped pens for labels on*

sample container or sample coolers. Permanent markers could introduce volatile constituents into the samples.

NOTE: *An Arcadis employee that is appropriately trained at the correct level of internal hazardous materials/DOT (Department of Transportation) shipping must complete an Arcadis shipping determination to address applicable DOT and IATA (International Air Transport Association) shipping requirements. Review the applicable Arcadis procedures and guidance instructions for sample packaging and labeling. Prior to using air transportation, confirm air shipment is acceptable under DOT and IATA regulations.*

6 HEALTH AND SAFETY CONSIDERATIONS

The HASP will be followed, as appropriate, to ensure the safety of field personnel.

Appropriate personal protective equipment (PPE) will be worn at all times in line with the task and the site-specific HASP.

Review all site-specific and procedural hazards as they are provided in the HASP, and review Job Safety Analysis (JSA) documents in the field each day prior to beginning work.

Working outside at sites with suspected contamination may expose field personnel to hazardous materials such as contaminated groundwater or non-aqueous phase liquid (NAPL) (e.g., oil). Other potential hazards include biological hazards (e.g., stinging insects, ticks in long grass/weeds, etc.), and potentially the use of sharp cutting tools (scissors, knife). Only use non-toxic peppermint oil spray for stinging insect nests. Review client-specific health and safety requirements, which may preclude the use of fixed/folding-blade knives and use appropriate hand protection.

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

7 PROCEDURE

The procedures for drilling and the methods to be used to field screen and collect soil samples for laboratory analysis are presented below:

DRILLING PROCEDURES

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

1. Find/identify boring location, establish work zone, and set up sampling equipment decontamination area.
2. Advance boring to designated depth:
    a. Collect soil samples at appropriate interval as specified in the FIP/work plan (or equivalent)
    b. Collect, document, and store samples for laboratory analysis as specified in the FIP/work plan (or equivalent)

c. Decontaminate equipment between samples in accordance with the FIP/work plan (or equivalent)

d. A common sampling method that produces high-quality soil samples with relatively little soil disturbance is described in *ASTM D1586 – Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils* (ASTM D1586).

   i. Split-spoon samples are obtained during drilling using hollow-stem auger, drive-and-wash, spun casing, and fluid/mud rotary

e. Rotasonic drilling produces soil cores that, for the most part, are relatively undisturbed, but note that when drilling in consolidated or finer-grained sediment the vibratory action during core barrel advancement may create secondary fractures or breaks

f. Dual-rotary removes cuttings by compressed air or water/mud and allow only a general assessment of geology

3. Describe each soil sample as outlined in the appropriate project records (refer to the description procedures outlined in the *TGI - Soil Description*)

   a. Record descriptions on the soil boring log (**Attachment 1**) and/or field notebook.

   b. When possible photo document the samples (e.g., soil cores, split-spoons)

   c. During soil boring advancement, document all drilling events in field notebook, 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) and work stoppages

   d. Blow counts will not be available if rotasonic, dual-rotary, or direct-push methods are used; however, if standard penetration testing is required during rotasonic drilling, an automatic drop hammer may be used in conjunction with the method to switch from core barrel advancement to standard penetration testing

4. The drilling contractor will be responsible for obtaining accurate and representative samples, informing the supervising Arcadis geologist of changes in drilling pressure, and keeping a separate general log of soils encountered, including blow counts

   a. The term “samples” means soil materials from particular depth intervals, whether or not portions of these materials are submitted for laboratory analyses

   b. Records will also be kept of occurrences of premature refusal due to boulders or construction materials that may have been used as fill

   c. 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

   d. Where it is desirable to avoid leaving vertical connections between depth intervals (e.g., if DNAPL or perched LNAPL are known or expected to exist at the site), the borehole will be sealed using cement and/or bentonite (see **Section 5** above)

e. Multiple refusals may lead to a decision by the supervising geologist to abandon that sampling location

Direct-Push Method

The direct-push drilling method may also be used to complete soil borings. Examples of this technique include Geoprobe®, Diedrich Environmental Soil Probe (ESP) System, or AMS PowerProbe. 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 to medium dense soil formations. The hammer simultaneously advances an outer steel casing that contains a dual tube liner for sampling soil (dual tube sampling system).

The outside diameter (OD) of the outer casing ranges from 2.25 to 6 inches and the OD of the inner sampling tube diameter ranges from 1.4 to 4.5 inches. The outer casing isolates overlying soil and permits the unit to continue to probe at depth. The dual tube sampling system provides a borehole that may be tremie-grouted from the bottom up. Alternatively, a single rod system may be used that does not provide a cased boring and which does not allow for tremie-grouting from the bottom up.

The known or expected site conditions (e.g., presence of NAPL) will be evaluated when selecting the type of direct-push sampling system to be employed.

Direct-push drilling can generally achieve target depths 100 feet or less and the achievable depth is based on the site geology.

1. Find/identify boring location, establish work zone, and set up sampling equipment decontamination area
2. Advance soil boring to designated depth.
    a. Collect soil samples at appropriate interval as specified in in the FIP/work plan (or equivalent)
    b. Collect, document, and store samples for laboratory analysis as specified in in the FIP/work plan (or equivalent)
    c. Decontaminate equipment between samples in accordance with in the FIP/work plan (or equivalent)
    d. Samples will be collected using dedicated, disposable, plastic liners
3. Describe samples in accordance with the procedures outlined in **Step 3** under ***Hollow-Stem Auger, Drive-and-Wash, Spun Casing, Fluid/Mud Rotary, Rotasonic, and Dual-Rotary Drilling Methods*** above (refer to the description procedures outlined in the *TGI - Soil Description*)

Manual Methods

Manual methods may also be used to complete shallow soil borings. Examples of this technique include using a spade, spoon, scoop, hand auger, or slide hammer. Manual methods are typically used to collect surface soil samples (0 to 6 inches) or to complete soil borings/collect soil samples from a depth of 5 feet or less.

1. Find/identify boring location, establish work zone, and set up sampling equipment decontamination area
2. Clear the ground surface of brush, root mat, grass, leaves, or other debris
3. Use a spade, spoon, scoop, hand auger, or slide hammer to collect a sample of the required depth interval
4. Use an engineer's ruler or survey rod to verify that the sample is collected to the correct depth and record the top and bottom depths from the ground surface
5. To collect samples below the surface interval, remove the surface interval first; then collect the deeper interval
    a. To prevent the hole from collapsing, it may be necessary to remove a wider section from the surface or use cut polyvinyl chloride (PVC) pipe to maintain the opening
    b. Collect soil samples at appropriate interval as specified in the FIP/work plan (or equivalent)
    c. Collect, document, and store samples for laboratory analysis as specified in the FIP/work plan (or equivalent)
    d. Decontaminate equipment between samples in accordance with the FIP/work plan (or equivalent)
6. Describe samples in accordance with the procedures outlined in **Step 3** under ***Hollow-Stem Auger, Drive-and-Wash, Spun Casing, Fluid/Mud Rotary, Rotasonic, and Dual-Rotary Drilling Methods*** above (refer to the description procedures outlined in the *TGI - Soil Description*)

FIELD SCREENING PROCEDURES

PID and FID Screening

Soils are typically field screened with a PID or FID for a relative measure of the total VOCs at sites where VOCs are known or suspected to exist. The PID employs a UV lamp to measure VOCs and the ionization energy (IE) of the site constituents need to be considered when selecting the type of lamp (e.g., 10.6 eV, 11.7 eV) that will be used. In general, any compound with an IE lower than that of the lamp photons can be measured. The FID has a wide linear range and responds to almost all VOCs. Field screening is performed using one (or both) of the following two methods:

1. 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 will be obtained at several locations along the length of the sample.
2. A portion of the collected soil 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 pierced with the PID or FID probe, and a reading is obtained.

Initial PID readings will be recorded on the soil boring log (**Attachment 1**) and/or in the field notebook. The soil sample will be separated from the slough material (if any) by using disposable gloves and a pre-cleaned stainless-steel spoon.

For the second method, a representative portion of the sample will be placed in a pre-cleaned air-tight 8-ounce container (as quickly as possible to avoid loss of VOCs), filling the container half full to allow for the accumulation of vapors above the soil. An aluminum foil seal will be placed between the glass and metal cap and the cap will be screwed on tightly. Unless the screening will be performed immediately after the sample is placed in the container, the sample containers will be stored in a cooler chilled to approximately 4ºC until screening can be performed.

The headspace of the 8-ounce container will be measured using a PID or FID as follows:

1. Samples will be taken to a warm work space and allowed to equilibrate to room temperature for at least one hour.
2. Prior to measuring the soil vapor headspace concentration, the 8-ounce container will be shaken.
3. The headspace of the sample will then be measured directly from the 8-ounce container by piercing the aluminum foil seal with the probe of the PID or FID and measuring the relative concentration of VOCs in the headspace of the soil sample. The initial (peak) reading must be recorded.

The PID or FID must be calibrated according to the manufacturer's specifications at a minimum frequency of once per day prior to collecting PID or FID readings. The PID will be calibrated to a benzene-related compound (isobutylene) while the FID will be calibrated to methane.

The time, date, and calibration procedure must be clearly documented in the field notebook and/or the calibration log book.

If at any time the PID or FID results appear erratic or inconsistent with field observations, then the instrument will be recalibrated.

If calibration is difficult to achieve, then the PID's lamp will be checked for dirt or moisture and cleaned, or technical assistance will be required. Maintenance and calibration records will be kept as part of the field quality assurance program.

NAPL Screening

To screen for the potential presence of non-aqueous phase liquid (NAPL) in soil, drilling procedures must allow for high-quality porous media samples to be taken. Split-spoon samplers or direct-push samplers will be collected continuously ahead of the auger, drill casing/rods, or probe rods.

Upon opening each split-spoon sampler or direct-push plastic liner sleeve, the soil will immediately be evaluated for the presence of visible NAPL. If NAPL is immediately visible in the sample, its depth will be noted.

Additionally, the soil will be screened for the presence of organic vapors using a PID or 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 (**Method 1** above). Such readings will be obtained along the entire length of the sample. Alternatively, **Method 2** for PID/FID screening (outlined above) may also be performed. 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 NAPL.

The assessment for NAPL will include the following tests/observations:

- Evaluation for Visible NAPL Sheen or Free-Phase NAPL in Soil Sampler
    - 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
    - Particular care will be taken to fully describe any sheens observed, staining, discoloration, droplets (blebs), or NAPL saturation
- Soil-Water Pan Test
    - A portion of the selected soil interval with the highest PID or FID reading above 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
    - 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

NOTE: *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.*

NOTE: *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 hydrophobic dye Safety Data Sheets (SDS) will be incorporated into the HASP and reviewed prior to use and the dyes will be carefully handled and disposed in accordance with regulations*.

SOIL SAMPLE COLLECTION FOR LABORATORY PROCEDURES

If not specifically identified in the FIP, soil samples will be selected for laboratory analysis based on:

1. Their position in relation to identified source areas
2. The visual presence of source residues (e.g., NAPL)
3. The relative levels of total VOCs based on field screening measurements
4. The judgment of the field coordinator

Samples designated for laboratory analysis will be placed in the appropriate containers.

Sample containers for VOC analysis will be filled first immediately following soil core retrieval to reduce loss of VOCs.

If samples will be collected for other analytical parameters, a sufficient amount of the remaining soil will then be homogenized as described below and sample containers will be filled for other parameters.

VOC samples will be collected as discrete samples using a small diameter core sampler (e.g., En Core® Sampler, Terra Core™ Sampler).

The En Core® Sampler is a disposable volumetric sampling device that collects, stores and delivers soil samples without in-field chemical preservation. The En Core® Sampler requires the use of a reusable T-handle.

The Terra Core™ Sampler is a one-time use transfer tool, designed to collect soil samples and transfer them to the appropriate containers for in-field chemical preservation (e.g., methanol).

The small diameter core sampler will be used according to the manufacturer's instructions (e.g., En Novative Technologies). Some regulatory agencies have specific requirements regarding VOC sample collection. Determine whether the oversight agency has specific requirements prior to commencing sampling and collect samples at appropriate interval as specified in the FIP/work plan (or equivalent). Samples may require homogenization across a given depth interval, or several discrete grabs (usually five) may be combined into a composite sample.

NOTE: *Samples for VOC analysis will NOT be homogenized or composited and will be collected as discrete samples as described above*.

The procedure for mixing samples is provided below.

1. Mix the materials in a stainless steel (or appropriate non-reactive material) bowl using a stainless-steel spoon (or disposable equivalents)
    a. When dealing with large sample quantities, use disposable plastic sheeting and a shovel or trowel
    b. NOTE: *When preparing samples for metals analyses, do not use disposable aluminum (or metal tools or trays other than stainless steel), as it may influence the analytical results*
2. Flatten the pile by pressing the top without further mixing
3. Divide the circular pile by into equal quarters by dividing out two diameters at right angles
4. Mix each quarter individually using appropriate non-reactive bowls, spoons and/or sheeting
5. Mix two quarters (as described above) to form halves, then mix the two halves to form a composite or homogenized sample
6. Place composite or homogenized sample into specified containers
7. Remaining material will be disposed of in accordance with project requirements and applicable regulations
8. Sample containers will be labeled with sample identification number, date, and time of collection and placed on ice in a cooler (target 4° Celsius)
9. Samples selected for laboratory analysis will be documented (chain-of-custody forms), handled, packed, and shipped in accordance with the procedures outlined in the FIP/work plan (or equivalent).

8 WASTE MANAGEMENT

Investigative-Derived Waste (IDW) generated during drilling activities, including soil and excess drilling fluids (if used), decontamination liquids, and disposable materials (plastic sheeting, PPE, etc.) will be stored on site in appropriately labeled containers (disposable materials will be contained separately) and disposed of properly. Containers must be labeled at the time of collection and will include date, location(s), site name, city, state, and description of matrix contained (e.g., soil, PPE). Waste will be managed in accordance with the *TGI – Investigation-Derived Waste Handling and Storage,* the procedures identified in the FIP or QAPP as well as state-, federal- or client-specific requirements. Be certain that waste containers are properly labeled and documented in the field log book.

9 DATA RECORDING AND MANAGEMENT

Management of the original documents from the field will be completed in accordance with the site-specific QAPP.

In general, drilling activities will be documented on appropriate field/log forms as well as in a proper field notebook. All field data will be recorded in indelible ink. Field forms, logs/notes (including daily field and calibration logs), digital records, and chain-of-custody records will be maintained by the field team lead.

Initial field logs and chain-of-custody records will be transmitted to the Arcadis Certified Project Manager (CPM) and Technical Lead at the end of each day unless otherwise directed by the CPM. The field team leader retains copies of the field documentation.

Additionally, all documents (and photographs) will be scanned and electronically filed in the appropriate project directory for easy access. Pertinent information will include personnel present on site, times of arrival and departure, significant weather conditions, timing of drilling activities, soil descriptions, soil boring information, and quantities of materials used.

In addition, the locations of soil borings will be documented photographically and in a site sketch. If appropriate, a measuring wheel or engineer's tape will be used to determine approximate distances between important site features.

Records generated as a result of this TGI will be controlled and maintained in the project record files in accordance with project requirements.

10 QUALITY ASSURANCE

Quality assurance procedures shall be conducted in accordance with the Arcadis Quality Management System or the site-specific QAPP.

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 TGI.

Field-derived quality assurance blanks will be collected as specified in the FIP/work plan and/or site-specific QAPP, depending on the project quality objectives. Typically, field rinse blanks (equipment blanks) will be collected when non-dedicated equipment (e.g., split-spoon sampler, stainless steel spoon) is used during soil sampling. Field rinse blanks will be used to confirm that decontamination procedures are sufficient and samples are representative of site conditions. Trip blanks for VOCs, which aid in the detection of contaminants from other media, sources, or the container itself, will be kept with the coolers and the sample containers throughout the sampling activities and during transport to the laboratory.

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.

11 REFERENCES

ASTM D1586 - *Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils*. ASTM International. West Conshohocken, Pennsylvania.

12 ATTACHMENTS

Attachment 1. Soil Boring Log Form

ATTACHMENT 1

Soil Boring Log Form

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SOIL BORING LOG

Boring/Well ____________ Project ______________________________ Page ____ of ____

Site Location ______________________________ Drilling Started ____________

Total Depth Drilled ________ Feet Hole Diameter ________ inches Drilling Completed ____________

Type of Sample or Coring Device ____________ Length and Diameter of Coring Device ____________ Sampling Interval ________ feet

Drilling Method ____________ Drilling Fluid Used ____________

Drilling Contractor ______________________ Driller ____________

Prepared By ______________________ Helper ____________

Core Recovery (feet)	PID Reading (ppm)	Sample Depth (ft bgs)	MUD		SAND					GRAVEL				**Udden-Wentworth Description:** principal components, (angularity, plasticity, dilatency); minor components, (angularity, plasticity, dilatency); sorting, moisture content, consistency/density, color, additional comments
			clay	silt	very fine	fine	medium	coarse	very coarse	granular	pebble	cobble	boulder	

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SOIL BORING LOG (CONT'D)

Boring/Well ____________________ Prepared By ______________________________ Page ____ of ____

Core Recovery (feet)	PID Reading (ppm)	Sample Depth (ft bgs)	MUD		SAND					GRAVEL				Udden-Wentworth Description: principal components, (angularity, plasticity, dilatency); minor components, (angularity, plasticity, dilatency); sorting, moisture content, consistency/density, color, addtl. Comments
			clay	silt	very fine	fine	medium	coarse	very coarse	granular	pebble	cobble	boulder	

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