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FINAL

United States Army Corps of Engineers
New England District

Post-Record of Decision Supplemental Remedial Investigation Work Plan

Area of Contamination 69W

Former Fort Devens Army Installation

Devens, Massachusetts

Contract No. W912WJ-19-D-0014

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June 2023

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Devens, Massachusetts

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CERTIFICATION

I hereby certify that the enclosed Report, shown and marked in this submittal, is that proposed to be incorporated with Contract Number W912WJ-19-D-0014. This document was prepared in accordance with the U.S. Army Corps of Engineers (USACE) Scope of Work and is hereby submitted for Government approval.

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NOTICE

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Contents

Exhibits

Tables

Figures

Appendices

Acronyms and Abbreviations

%	percent
µg/L	microgram per liter
ABB	ABB Environmental Services, Inc.
AOC	Area of Contamination
Army	U.S. Army
bgs	below ground surface
BRAC	Base Realignment and Closure
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
Charter School	Francis W. Parker Charter Essential School
CMR	Code of Massachusetts Regulations
COC	contaminant of concern
CSM	conceptual site model
cy	cubic yards
Devens	Former Fort Devens Army Installation
DO	dissolved oxygen
DQO	data quality objectives
EPH	extractable petroleum hydrocarbons
ESMA	Excavated Soils Management Area
FFA	Federal Facility Agreement
FFS	focused feasibility study
ft/day	feet per day
FYR	Five Year Review
gpm	gallons per minute
GPR	ground-penetrating radar
GW-1	MCP groundwater standards for potable water
HAZWOPER	Hazardous Waste Operations and Emergency Response
HHRA	human health risk assessment
HLA	Harding Lawson Associates
IC	institutional control
ID	Identification
IDW	investigation-derived waste
JV	joint venture
K	potassium
KGS	KOMAN Government Solutions, LLC
LLC	Limited Liability Company
LOD	limit of detection
LOQ	limit of quantitation
LTM	long-term monitoring
LTMMP	long-term monitoring & maintenance plan
LUC	land use control
LUCIP	land use control implementation plan

MassDEP	Massachusetts Department of Environmental Protection
MassDevelopment	Massachusetts Development and Finance Agency
MCL	Maximum Contaminant Level
MCP	Massachusetts Contingency Plan
MEC	munitions and explosives of concern
MNA	monitored natural attenuation
NA	not applicable/not available
NAPL	non-aqueous phase liquid
NAVD	North American Vertical Datum
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPL	National Priorities List
ng/L	nanograms per liter
ORP	oxidation-reduction potential
OU	operable unit
PID	photoionization detector
PVC	polyvinyl chloride
QA	quality assurance
QAPP	quality assurance project plan
QC	quality control
RAO	remedial action objective
RI	remedial investigation
RfD	reference dose
ROD	record of decision
S-1	MCP Method 1 S-1 Soil Category
SARA	Superfund Amendments and Reauthorization Act
SHL	Shepley’s Hill Landfill
SOP	standard operating procedure
SPLP	Synthetic Precipitation Leaching Procedure
SRI	supplemental remedial investigation
TGI	technical guidance instruction
TOC	total organic carbon
UFP-QAPP	Uniform Federal Policy for Quality Assurance Project Plans
U.S.	United States
USACE	United States Army Corps of Engineers
USC	United States Code
USEPA	United States Environmental Protection Agency
UST	underground storage tank
UU/UE	unlimited use and unrestricted exposure
VAP	vertical aquifer profile
VPH	volatile petroleum hydrocarbon
Weston	Roy F. Weston, Inc.
WP	work plan

1. Introduction

The SERES-Arcadis Joint Venture (JV), Limited Liability Company (LLC)[1] (hereafter referred to as the S-A JV) has prepared this work plan (WP) on behalf of the United States (U.S.) Army Corps of Engineers (USACE) to conduct a Comprehensive Environmental Response, Compensation, and Liability Act- (CERCLA) compliant supplemental remedial investigation (SRI) at the former Fort Devens Army Installation (Devens) located in Devens, Massachusetts.

1.1. Purpose

This Post – Record of Decision (ROD) SRI WP has been prepared to confirm groundwater conditions at the Former Elementary School Spill Site (Operable Unit [OU]7 / Area of Contamination [AOC] 69W) located at the former Fort Devens Army Installation (Devens) in Devens, Massachusetts related to the contaminants arsenic and volatile petroleum hydrocarbons (VPH) / extractable petroleum hydrocarbons (EPH), identified in the OU7/AOC 69W ROD (Harding Lawson Associates [HLA] 1999) for monitoring, and additional contaminants identified in the 1998 RI (ABB Environmental Services, Inc. [ABB]) as contributing to unacceptable risk.

Historical impacts at AOC 69W are attributed to two separate releases of No. 2 heating oil in 1972 and 1978. Remedial actions, including installation of an oil recovery system, were performed to recover released fuel and oily water from each release (HLA 1999). A subsequent removal action was performed in 1998 for impacted soils and to remove the oil recovery system. The extent of the soil removal action was limited by the presence of the building.

The ROD issued for AOC 69W in June 1999 selected Limited Action as the remedy to address soil and groundwater contamination attributed to historical fuel oil releases at the former Fort Devens Elementary School. The Limited Action consisted of long-term monitoring (LTM) of groundwater to verify that elevated arsenic concentrations continue to decrease over time and not migrate downgradient, land use controls (LUCs) to restrict or prevent potential human exposure to site soil and groundwater contaminants left in place, and five-year reviews to review the data collected and assess the effectiveness of the remedy.

The 1999 ROD specifically called for arsenic and VPH/EPH to be monitored. A United States Environmental Protection Agency (USEPA)-approved LTM plan was implemented in 2000 to monitor for potential off-site migration of all contaminants of concern (COCs) identified as contributing to unacceptable risk (arsenic, iron, manganese, bis[2-ethylhexyl]phthalate], and VPH C9-C10 aromatics) and to verify that elevated concentrations of site COCs decreased over time (HLA 2000a). Action Levels were established as USEPA Maximum Contaminant Levels (MCLs) for arsenic and bis(2-ethylhexyl)phthalate, Devens background levels for iron, a risk-based concentration for a child receptor for manganese, and the Massachusetts Contingency Plan (MCP) GW-1 groundwater standards (i.e., groundwater that may potentially be used for potable water use) for VPH/EPH carbon fractions.

In the 23 years since implementation of the LTM program at AOC 69W, COCs have been dropped from the program for varying reasons (discussed further in **Section 1.4.2**). The current LTM program includes monitoring for arsenic, iron, manganese, and EPH. The LTM dataset from 2000 through 2022 indicates that while concentrations are above cleanup goals, arsenic concentrations have remained stable since 2009. EPH concentrations exhibit a statistically significant decreasing trend at the two wells where exceedances have occurred since fall 2002 (ZWM-99-22X and 69W-94-13), and EPH has not been detected above cleanup goals at either location since fall 2019.

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[1] The SERES-Arcadis JV is composed of protégé firm SERES Engineering & Services, LLC (SERES) and its mentor, Arcadis U.S., Inc. (Arcadis).

This SRI WP has been prepared to confirm the current and future protectiveness of the remedy at AOC 69W. The available data and current data collection methods were reviewed to determine what additional types of samples should be collected as part of the SRI to confirm groundwater conditions and our understanding of the conceptual site model (CSM).

In September 2020, during discussions between the Army and the USEPA concerning the 2020 Final Five-Year Review (FYR) Report for the Former Fort Devens (KOMAN Government Solutions, LLC [KGS] 2020), the Army and the USEPA came to the conclusion that the two agencies would not be able to timely resolve outstanding comments to issue joint protectiveness statements by the statutory deadline of September 28, 2020. Consequently, the Army and the USEPA agreed that the two agencies would issue their own protectiveness statements to meet the statutory deadline. Thus, the USEPA's protectiveness statements included in their September 25, 2020 letter (received September 28, 2020) were different from the Army's protectiveness statements released on September 28, 2020 in the Final FYR Report.

The Army and the USEPA also agreed that, after the statutory deadline, the two agencies would work together to reconcile their differences. In the USEPA's letters to Army on September 25 and September 29, 2020, USEPA issued their independent findings of protectiveness with issues and recommendations that included 19-pages of "Additional Work." USEPA's additional work requirements were provided as an attachment to USEPA's letter to the Army dated September 29, 2020.

On December 11, 2020, the Army submitted a letter to USEPA which included a statement of work for the additional work determined by USEPA to be necessary to assess the short- and long-term protectiveness of the ongoing remedial actions at the Operable Units evaluated in the 2020 Final FYR Report (KGS 2020).

As it pertains to this SRI WP and the additional work determined by the USEPA to be necessary to assess protectiveness, the USEPA concluded that the remedy at AOC 69W was not protective in the long-term. The USEPA stated, "… *for the remedy to be protective in the long-term, the following actions need to be taken to ensure protectiveness:*

- *Submit documentation to verify that soil excavation activities performed within a restricted area of the site were compliant with ROD-required restrictions;*
- *Amend/revise the existing [land use control implementation plan] LUCIP to ensure accurate identification, thorough awareness of /familiarity with and effective communication of ROD-specified LUCs/ICs [institutional controls];*
- *Provide details associated with the suspected LUC/IC breach and describe how the issue will be resolved to ensure short- and long- term protectiveness of the selected remedy;*
- *Revise/amend the current [long-term monitoring and maintenance plan] LTMMP to ensure collection of site-specific data necessary to confirm/deny and resolve long-standing disputes/disagreement with Army continued reliance on predictions/generalizations in annual LTM reports; and,*
- *Expand the scope of the existing LTMMP to provide sufficient and accurate collection of site-specific data needed to accurately define/confirm the lateral and vertical extent of contamination, effectively evaluate/identify current and potential human health risks, monitor attainment of ROD-specified RAOs and cleanup goals; and ensure short- and long-term protectiveness of the selected remedy."*

The Army disagrees with the USEPA's assessment but has agreed to perform additional work determined by the USEPA to be necessary to document the protectiveness of the current remedy. The following items listed by the USEPA in the bullets above are not addressed in this SRI for the following reasons:

- *Submit documentation to verify that soil excavation activities performed within a restricted area of the site were compliant with ROD-required restrictions;*

  - Proposed soil excavation work at the former Devens Elementary School was cancelled and not completed, therefore, no documentation submitted or needed.

- *Amend/revise the existing LUCIP to ensure accurate identification, thorough awareness of /familiarity with and effective communication of ROD-specified LUCs/ICs;*
  - The Army is preparing under separate cover a stand-alone LUCIP specific for AOC 69W, which describes the LUCs that have been implemented at this site as part of the remedy. LUCs for AOC 69W are described and implemented under the 2015 Long-Term Monitoring and Maintenance Plan for Former Fort Devens Army Installation and Sudbury Annex (Main Post LTMMP; Sovereign/HGL), but to ensure future protectiveness the LUCs for AOC 69W will be highlighted in a separate stand-alone document.
- *Provide details associated with the suspected LUC/IC breach and describe how the issue will be resolved to ensure short- and long- term protectiveness of the selected remedy;*
  - Proposed soil excavation work at the former Devens Elementary School was cancelled and not completed, therefore, there was no LUC/IC breach.
- *Revise/amend the current LTMMP to ensure collection of site-specific data necessary to confirm/deny and resolve long-standing disputes/disagreement with Army continued reliance on predictions/generalizations in annual LTM reports;*
  - The results of the SRI will be used to determine how, or if, the existing LTM Program at AOC 69W needs to be revised.

This SRI WP details the proposed supplemental investigation of AOC 69W to confirm the Army Protectiveness Statement in the 2020 Five-Year Review Report (KGS 2020). To address the USEPA's requirement for a revised LTMMP, the Army offered to prepare this SRI WP and an SRI report. Based on the results of the SRI, historical site data, and an updated conceptual site model (CSM), the Army will prepare a focused feasibility study (FFS) to evaluate changes to the remedy, including updates to the LTMMP, if necessary, and prepare any applicable ROD amendments.

- The SRI WP will focus on collection of data needed to evaluate remedial alternatives and to estimate remedy timeframes in an FFS, with particular focus on site-specific data needed to accurately define/confirm the lateral and vertical extent of contamination.
- Using data collected during the SRI, Army will prepare an SRI report which will:
  - Evaluate/identify current and potential human health risks
  - Monitor attainment of ROD-specified RAOs and cleanup goals
  - Assess short- and long-term protectiveness of the selected remedy
  - Update the CSM, as necessary
- After approval of the SRI report, Army will prepare an FFS using the results of the SRI, historical site data, and the updated CSM. The FFS will develop and assess a range of remedial alternatives to address any contamination remaining at the site. The FFS will include an evaluation of alternatives for any continuing sources that are contributing to groundwater contamination.
- After approval of the FFS, Army will make appropriate changes to the remedy, including updates to the LTMMP, if necessary, and prepare any applicable ROD amendments.

In addition, the SRI will use historical and new data to evaluate the ROD-stipulated remedy for possible modification.

1.2. Regulatory Requirements

Activities completed under this AOC 69W SRI WP are subject to and consistent with CERCLA as amended (42 United States Code [USC] § 9601 et seq.), and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), with regulatory coordination from the Massachusetts Department of Environmental Protection (MassDEP) and the USEPA.

As discussed in more detail in **Section 2.1**, the USEPA interprets CERCLA section 101(14), which defines the term “hazardous substances”, to exclude petroleum, including crude oil and fractions of crude oil. As such, petroleum spills are normally regulated under state requirements, not CERCLA, unless the petroleum contains hazardous contaminants. However, the 1991 Devens Federal Facility Agreement (FFA) that requires that the Army perform CERCLA investigations to characterize the nature and extent of threats to human health and the environment caused by the release or threatened release of hazardous substances, pollutants, or contaminants, also includes the requirement that oil (petroleum) contamination be addressed through the CERCLA process. Therefore, petroleum contamination at AOC 69W is addressed under CERCLA.

1.3. Site Background

1.3.1. Fort Devens

1.3.1.1. Fort Devens Site Background

Former Fort Devens is located in the Towns of Ayer and Shirley in Middlesex County, and the Towns of Harvard and Lancaster in Worcester County, Massachusetts, approximately 35 miles northwest of Boston, Massachusetts (**Figure 1-1**). The former installation occupied approximately 9,260 acres. Fort Devens was divided into the North Post, Main Post, and South Post, with state highway Route 2 dividing the South Post from the Main Post. The Nashua River runs through the North, Main, and South Posts. The area surrounding the installation is primarily composed of rural residential properties. Portions of Devens have been redeveloped for commercial/industrial use. Several of the surrounding areas and portions of Devens are undeveloped, and consist of hardwood vegetated uplands, riparian corridors, old fields, wet meadows, emergent and forested wetlands, and open waters.

Camp Devens was established in 1917 as a temporary training area for soldiers during World War I. In 1932, the site was renamed Fort Devens and made a permanent installation with the primary mission of commanding, training, and providing logistical support for non-divisional troop units. Fort Devens was used for a variety of training missions between 1917 and 1990.

Fort Devens was identified for cessation of operations and closure under Public Law 101-510, the Defense Base Realignment and Closure (BRAC) Act of 1990, and officially closed in March 1996.

1.3.1.2. Fort Devens Regulatory Background

The former Fort Devens was placed on the National Priorities List (NPL) update of November 21, 1989 (54 Fed. Reg. 48187) due to environmental contamination at several sites and became subject to the special provisions for federal facility NPL sites in CERCLA (§ 120, 42 USC § 9620) and the Superfund Amendments and Reauthorization Act (SARA; § 211, 10 USC. § 2701, Defense Environmental Restoration Program et seq.). In 1991, the Army and the USEPA signed an FFA that established the procedural framework and timetables for identifying, investigating, and remediating human health and environmental impacts associated with the past and present activities at Devens.

Since 1991, OUs (USEPA CERCLIS identifier) and AOCs (Army Administrative Record identifier) within Devens have been evaluated under the CERCLA process to identify and address risk to human health or the environment.

Five Year Reviews for OUs/AOCs are required at a minimum every 5 years when, upon completion of a remedial action, hazardous substances, pollutants, or contaminants will remain on site above levels that allow for unlimited use and unrestricted exposure (UU/UE).

During the FYR process, an assessment of each OU/AOC at a Site that has an active ROD and has not met UU/UE must be conducted to determine whether the ROD-specified remedy remains protective of human health and the environment and whether alternative remedial actions are needed to ensure adequate protection. The first statutory FYR for Devens was completed in 2000. Subsequent FYRs were submitted in 2005, 2010, 2015, and 2020.

1.3.2. AOC 69W (Former Elementary School Spill Site)

1.3.2.1. AOC 69W Site Background

AOC 69W is located at the site of the former Fort Devens Elementary School (Building 215), the associated parking lot, and adjacent lawn extending approximately 300 feet northwest to Willow Brook (**Figure 1-2**). A summary of the site background is provided below:

- In 1951, the Fort Devens Elementary School was built at the northeast corner of the intersection of Jackson Road and Antietam Street on the northern portion of the former Main Post. The school was operated and maintained by the Ayer School Department. The building was heated by an oil-fired boiler, and the heating oil was stored in a 10,000-gallon underground storage tank (UST) located in what is currently the school courtyard.
- In 1972, an addition to the school was built, forming the current school structure. The original building forms the east/southeast half of the present school. Although a new boiler room was constructed, the old boiler room remained operational. During construction of the addition, the original 10,000-gallon UST was removed, and a new 10,000-gallon UST was installed north of the school in the middle of the current parking lot. During the UST installation, the underground fuel line leading to the new boiler room was accidentally crimped, causing the pipe to leak approximately 7,000 to 8,000 gallons of No. 2 fuel oil to the ground. As a result of the fuel release, an oil recovery system was installed in the vicinity of the 10,000-gallon UST. The system consisted of underground piping connected to a buried 250-gallon concrete vault that acted as an oil/water separator.
- In 1978, underground fuel piping near the original boiler room failed at a pipe joint. Approximately 7,000 to 8,000 additional gallons of oil were released into the soil during the incident. Soil was excavated to locate the source of the release and approximately 2,600 gallons of residual oil was pumped from the oil recovery system.

- In 1993, the Ayer School Department closed the Fort Devens Elementary School because the facility was no longer needed (Roy F. Weston, Inc. [Weston] 1998). A historical site plan showing the Former Devens Elementary School and associated site features (boiler room, soil removal excavation area, former underground fuel line, former underground concrete vault) is provided in **Appendix B.** The Excavated Soils Management Area (ESMA) boundary is also shown on **Figure 1-2.**In September 2000, the former Fort Devens Elementary School was reopened as the Francis W. Parker Charter Essential School (Charter School), and currently occupies the site.
- In November 2006, the U.S. Army (Army) finalized the Findings of Suitable Transfer for AOC 69W and the property was formally transferred from Army ownership to the Massachusetts Development and Finance Agency (MassDevelopment) in August 2007.

1.3.2.2. AOC 69W Regulatory Background

As part of the BRAC closure process, the Army performed a base wide evaluation of past spill sites and concluded that residual fuel contamination might have been present in the soil and groundwater at the site. Subsequently the spill site was designated OU7/AOC 69W.

Under the CERCLA process, an RI (ABB 1998) and subsequent removal action were conducted at AOC 69W between 1994 and 1998. As part of the RI, the Army excavated approximately 3,500 cubic yards (cy) of petroleum-contaminated soil associated with the 1972 fuel oil leak. The 10,000-gallon fuel oil UST, oil recovery system’s 250-gallon vault, and associated piping were also removed. Although confirmatory soil sampling in excavated areas after the removal action indicated that EPH and VPH concentrations immediately adjacent to the school still exceeded MCP S-1/GW-1 soil standards (i.e., residential soil exposure in an area where groundwater may potentially be used for potable water use), the RI risk assessment concluded that under current conditions and uses, (including re-use as a school), AOC 69W did not present unacceptable risks to human health or the environment from soils, sediment, groundwater discharge, or indoor air. While estimated cancer and non-cancer risks associated with hypothetical exposures to AOC 69W groundwater used as a residential drinking water source exceeded levels generally considered acceptable to the USEPA, these risks were primarily due to the presence of arsenic in the groundwater (specifically monitoring wells 69W-94-10 and 69W-94-13. Monitoring well 69W-94-10 was subsequently removed during excavation of contaminated soils in 1997/1998. Current well ZWM-99-22X was installed as a replacement well, adjacent to former well 69W-94-10 (**Figure 1-2**).

1.4. AOC 69W CERCLA Remedial Actions

Based on the results of the RI, a Limited Action ROD was signed in 1999 to restrict or prevent potential human exposure to site soil and groundwater contaminants left in place.

To address potential risk to human health at AOC 69W, the 1999 ROD stipulated the following remedial action objectives (RAOs) for AOC 69W:

- Restore the aquifer to drinking water standards within a reasonable period.
- Monitor potential future migration of groundwater contamination.
- Eliminate risk from potential consumption of groundwater.
- Reduce or eliminate the direct contact threat of contaminated soils.

The Limited Action alternative for AOC 69W stated that the remedy “will consist of will consist of long-term groundwater monitoring to verify that elevated arsenic concentration will continue to decrease over time and not migrate downgradient Institutional controls will also be implemented at AOC 69W to limit the potential exposure to the contaminated soil and groundwater under both existing and future site conditions These institutional controls will ensure that exposure to remaining contaminated soils beneath and adjacent to the building are controlled and the extraction of groundwater from the site for industrial and/or potable uses would not be permitted These institutional controls will be incorporated either in full or by reference into all deeds, easements, mortgages, leases or any other instruments of transfer prior to the transfer of the property to MassDevelopment Overall protectiveness will be assessed during five-year site reviews Alternatively, if the Army can demonstrate based on currently available or newly acquired data, that site access restriction can be relaxed or removed while protection of human health is maintained, the Army may petition USEPA for such a relaxation or removal of restrictions." (HLA 1999).

No time frame for LTM or completion of the remedy was noted in the ROD. The current Main Post LTMMP (Sovereign/HGL 2015) calls for the analysis of the analytes noted in the ROD for monitoring (EPH and arsenic) as well as dissolved iron and manganese, which are noted for monitoring in the ROD. The evolution of AOC 69W LTM analytes is discussed below in **Section 1.4.2.**

1.4.1. Institutional Controls

LUCs put in place for AOC 69W were enforced in the transfer of the property from the Army to MassDevelopment in 2007. Specifically, LUCs restricting educational, institutional, and open space use, groundwater use, soil excavation, modification, or release of environmental protection provisions, and requiring project notifications if any of the above restrictions are modified were included in the August 2007 Quitclaim Deed to MassDevelopment. The ESMA boundary for soil restrictions and the site boundary for groundwater restrictions are shown on **Figure 1-2**.

The specific soil LUC language includes a requirement for: "*...implementation of soil management and health and safety plans prepared by a Licensed Site Professional and Certified Industrial Hygienist, or other qualified professionals, prior to initiating excavations. The Grantee, its successors and assigns, shall not excavate soil from areas of the Property identified as the Soil Management Area for any purpose without the prior written approval of the Grantor, the EPA, and the DEP*."

The specific groundwater LUC language includes: "*The Grantee, its successors and assigns, shall not access or use ground water underlying the Property for any purpose without the prior written approval of the Grantor, the EPA, and the DEP*."

The LUC Implementation Plan for AOC 69W is included in Section 4.0 of the 2015 Main Post LTMMP (Sovereign/HGL). The ESMA is monitored during sampling events for broken ground or excavations. The Charter School is abiding by the LUCs imposed on the property, and annual groundwater sampling continues as recommended in the Main Post LTMMP.

1.4.2. Long Term Monitoring

The USEPA-approved 2000 AOC 69W LTM Plan (HLA 2000a) called for the sampling of groundwater monitoring wells in the former petroleum release area and in downgradient locations to monitor for off-site migration. The wells were to be initially monitored on a semiannual basis for contaminants of potential concern (COPCs; referred to as CPCs in the ROD) that contributed greater than or equal to a hazard quotient (HQ) of 1.0 in the child resident (and adult resident RME scenario and were, therefore, considered COCs. The COCs included arsenic (HQ=40), iron (HQ=5.5), manganese (HQ=7.2), bis(2-ethylhexyl)phthalate (HQ=1.6), and VPH C9-C10 aromatics (HQ=1.3). Arsenic was the only COC that also contributed a carcinogenic risk greater than 1 x 10^{-4}.

In accordance with the ROD requirement to restore the AOC 69W aquifer to drinking water standards, arsenic concentrations are compared to the federal MCL. Dissolved iron and manganese are compared to background levels established in the 1998 AOC 69W RI (ABB 1998). Because the monitoring wells for AOC 69W fall within groundwater protection Zone II for the MacPherson supply well, VPH/EPH concentrations in samples collected from the AOC 69W wells are compared to GW-1 screening criteria (310 Code of Massachusetts Regulations

[CMR] 40 Subpart P). There are no enforceable risk-based cleanup standards established by the USEPA for VPH and EPH. The first round of groundwater sampling was conducted in the spring of 2000, in accordance with the LTM Plan (HLA 2000a), with semiannual sampling continuing through 2005.

The 2000 LTMP noted that, although bis(2-ethylhexyl)phthalate was carried through as a COC for the risk assessment, it was also detected within laboratory method blanks and was suspected of being a laboratory artifact. In 2002, based on evaluation of the LTM data, bis(2-ethylhexyl)phthalate was dropped from the LTM program(KGS 2005).

The 2000 FYR (HLA 2000b) recommended that iron be dropped from the LTM program because USEPA Region 1 no longer endorsed use of the iron reference dose (RfD) used for the RI HHRA (ABB 1998); however, iron was retained in the monitoring program as an indicator of remedial progress (KGS 2005).

The groundwater sampling frequency was reduced from semiannual to annual in 2006. A site-specific annual LUC checklist, including a physical onsite inspection and interview components, was developed in 2007 for use during LUC verification activities. Sampling for VPH was discontinued in 2014, as concentrations were observed to be below criteria from 2009 through 2013. Downgradient well 69WP-13-01 was installed in 2013 to monitor for potential migration of manganese based on concentrations detected in well 69WP-08-01 in 2008.

In 2015, the *Long-Term Monitoring and Maintenance Plan for Former Fort Devens Army Installation and Sudbury Annex* (Main Post LTMMP; Sovereign/HGL) was prepared, replacing the AOC 69W LTM Plan. The 2015 Main Post LTMMP was finalized in accordance with provisions of the 1991 Devens FFA Section 7.8 and released without USEPA concurrence.

The current LTM program for AOC 69W as presented in the 2015 Main Post LTMMP (Sovereign/HGL 2015) identifies the groundwater analytes to be monitored as EPH carbon fractions, arsenic, iron, and manganese.

Exhibit 1-1 summarizes the COCs and additional analytes historically and currently included in the AOC 69W LTM program.

Exhibit 1-1: AOC 69W Screening Limits

Analyte	Original Screening Standard (µg/L) [a]	Current Action Levels (µg/L) [b]	Selection Basis
VPH			
C5-C8 Aliphatics	300	NA	MCP [b]
C9-C12 Aliphatics	700	NA	MCP [b]
C9-C10 Aromatics	200	NA	MCP [b]
EPH			
C9-C18 Aliphatics	1,000	700	MCP [b]
C19-C36 Aliphatics	5,000	14,000	MCP [b]
C11-C22 Aromatics	200	200	MCP [b]
Semivolatile Compounds			
Bis(2-eylhexyl)phthalate	6	NA	MCL (2000 LTMP)
Metals (dissolved)			
Arsenic	10.5 [c]	10	MCL (ROD)
Iron	9,100 [c]	9,100 [c]	Background [c] (2000 LTMP)
Manganese	291 [c]	375 [d]	MCL (2008 LTMP)

Notes:
MCL =Maximum Contaminant Level (USEPA)
µg/L = micrograms per liter
a. Screening levels as noted in 2000 LTMP (HLA).

b. MCP 2021 https://www.mass.gov/regulations/310-CMR-4000-massachusetts-contingency-plan. There are no enforceable risk-based cleanup standards established by the USEPA for VPH and EPH.
c. Background concentrations determined from 10 wells at select locations on base (HLA 1998).
d. The 2008 LTM Plan (HGL) updated the cleanup goal for manganese to the approved MCL for a child.

1.4.3. Five-Year Reviews

Because contaminants would remain on-site above concentrations that allow for UU/UE, statutory reviews must be performed. Five-year reviews must be performed as long as hazardous substances, pollutants, or contaminants remain on-site above concentrations that allow for UU/UE.

FYRs were completed for AOC 69W beginning in 2000 to confirm the Limited Action alternative for AOC 69W selected in the ROD continued to be protective of human health and the environment. The 2015 FYR (KGS 2015) noted and the 2020 FYR (KGS 2020) confirmed that the petroleum hydrocarbons identified in the AOC 69W ROD for monitoring have attenuated and are only slightly above comparison criteria at one monitoring well location (ZWM-99-22X) installed adjacent to the former source petroleum release area. Arsenic in groundwater at AOC 69W remains above the ROD cleanup levels at some locations.

The 2015 FYR Protectiveness Statement declared *"The remedy at AOC 69W is protective of human health and the environment and exposure pathways that could result in unacceptable risk are being controlled. All soil and groundwater contamination remains within the confines of this AOC and ICs are in place that limits exposure to the soil and groundwater at the site."*

The 2020 FYR confirmed that the remedy remained protective and concluded:

> "*The remedy at AOC 69W is protective of human health and the environment. The pre-ROD removal actions have eliminated underground storage tanks and the majority of contaminated soils that would otherwise be a continuing source of downgradient groundwater contamination. Exposure pathways that could result in unacceptable risks are being controlled. The RAOs are achieved through LUCs and groundwater monitoring. The LUCs prevent potential human exposure to site soil and ground water contaminants left in place. The LUCs are enforced and no exposures are currently occurring or imminent. Groundwater monitoring confirms that off-site migration of contaminated groundwater above cleanup levels is not occurring. The FYR site inspection and interviews, and annual LUC inspections and interviews, confirmed that site use remains consistent with the risk scenarios identified in the ROD (i.e., maintenance worker and elementary school children.)"*

The USEPA disagreed with the Army's protectiveness statement and issued a separate independent Protectiveness Statement (USEPA 2020):

> *"The remedy for OU07* [AOC 69W] *currently protects human health and the environment because LUCs are implemented, monitored and enforced and no unpermitted activities (i.e. exposures) are currently occurring or imminent. However, for the remedy to be protective in the long-term, the following actions need to be taken to ensure protectiveness:*
>
> - *Submit documentation to verify that soil excavation activities performed within a restricted area of the site were compliant with ROD-required restrictions;*
> - *Amend/revise the existing LUCIP to ensure accurate identification, thorough awareness of /familiarity with and effective communication of ROD-specified LUCs/ICs;*
> - *Provide details associated with the suspected LUC/IC breach and describe how the issue will be resolved to ensure short- and long- term protectiveness of the selected remedy;*

- *Revise/amend the current LTMMP to ensure collection of site-specific data necessary to confirm/deny and resolve long-standing disputes/disagreement with Army continued reliance on predictions/generalizations in annual LTM reports; and,*
- *Expand the scope of the existing LTMMP to provide sufficient and accurate collection of site-specific data needed to accurately define/confirm the lateral and vertical extent of contamination, effectively evaluate/identify current and potential human health risks, monitor attainment of ROD-specified RAOs and cleanup goals; and ensure short- and long-term protectiveness of the selected remedy."*

1.5. Work Plan Organization

This SRI WP includes:

- Project objectives.
- A CSM.
- Sampling design and rationale.
- A discussion of deliverables; and
- Project schedule.

This SRI WP was prepared consistent with USEPA Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA (USEPA 1988). All work will be conducted in accordance with procedures developed in the *Uniform Federal Policy for Quality Assurance Project Plan (UFP-QAPP) for Annual Long-Term Monitoring and Maintenance Program, Former Fort Devens Army Installation* (LTMMP QAPP; SERES-Arcadis JV 2020) and the LTMMP QAPP Addendum for Post-Record of Decision Supplemental Remedial Investigation at AOC 69W (AOC 69W QAPP Addendum; **Appendix A**). The AOC 69W QAPP Addendum describes sampling and analysis procedures for implementation of the SRI along with quality assurance (QA)/ quality control (QC) criteria. The QAPP Addendum will facilitate the generation of data with acceptable precision, accuracy, representativeness, comparability, and completeness.

This AOC 69W SRI WP is organized as follows:

- **Section 1** – Introduction: Presents the purpose of the SRI, the regulatory background guiding the SRI, the project background, provides the site history, and summarizes the previous CERCLA investigations/actions.
- **Section 2** – Project Approach and Objectives: Presents the regulatory approach and overall objectives of the SRI.
- **Section 3** – CSM: Summarizes the physical characteristics of Devens and AOC 69W; describes and presents the nature and extent of COCs in AOC 69W, describes any changes to current and future land use, and confirms receptors and exposure pathways used to evaluate potential risk.
- **Section 4** – SRI Implementation: Summarizes the planned SRI activities, including field methodologies.
- **Section 5** – Deliverables: Identifies the deliverables that will be generated for the project.
- **Section 6** – Project Schedule: Presents the AOC 69W SRI WP schedule.
- **Section 7** – References: Provides a list of references used in preparing the AOC 69W SRI WP.

In addition, the following appendices are provided to supplement the SRI WP:

- **Appendix A**: AOC 69W QAPP Addendum - Describes the site-specific chemical data quality objectives, field data-gathering methods and analytical methods and measurements not included in the LTMMP QAPP.
- **Appendix B**: Historical Site Plan.
- **Appendix C -** Response to Comments

2. Project Approach and Objectives

This section discusses the work plan approach and the data quality objectives (DQOs) for the project.

2.1. Evaluation of Petroleum Sites

As noted in **Section 1.2**, since 1991, AOCs within Devens have been evaluated under the CERCLA process to identify and address risk to human health or the environment from hazardous substances. Investigation, cleanup, and identification of a remedy for petroleum spills at AOC 69W was completed under the CERCLA process. However, the USEPA interprets CERCLA section 101(14) to exclude petroleum, including crude oil and fractions of crude oil, as hazardous substances. As such, petroleum spills are normally regulated under state requirements, unless the petroleum contains hazardous contaminants. However, under the 1991 Devens FFA, impacts from oil are investigated under CERCLA.

Typically, when there is an active release of petroleum, such as from a tank or piping system containing petroleum; an initial or emergency response action is conducted to stop the ongoing release and mitigate long term impacts by containing and cleaning up accessible petroleum before it seeps into the ground or impacts groundwater. Once the ongoing release source and obviously impacted soil are removed, a site investigation may be conducted to define the nature and extent of remaining contamination in soil and groundwater and determine what, if any, long term remedial actions are needed to address risk to human health or the environment.

Generally, if residual petroleum remains in groundwater after removal of petroleum-impacted soil, the long-term remedial actions chosen for the site are 1) monitored natural attenuation (MNA) to confirm that concentrations of contaminants in groundwater are reducing over time and 2) LUCs to restrict exposure to soil and/or groundwater. Under CERCLA, site closure occurs when all regulated soil and groundwater contaminants have been eliminated or reduced to levels where they no longer represent a significant risk to human health or the environment.

The term “natural attenuation” refers to a variety of physical, chemical, and biological processes that under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of hazardous substances in the environment. Although some degree of natural attenuation typically occurs at most contaminated sites, the effectiveness of these processes varies depending on the types and concentrations of contaminants present at the site and the physical, chemical, and biological characteristics of the site.

In 1993, the National Research Council proposed lines of evidence to assess natural attenuation processes.

- Decreasing trends in groundwater quality data for the contaminants of concern, using historical data (primary line of evidence).
- Geochemical data indicative of biodegradative processes in the groundwater (secondary line of evidence). Geochemical parameters for petroleum contaminants typically include dissolved oxygen (DO), nitrate, dissolved manganese, dissolved ferrous iron, sulfate, methane, alkalinity, oxidation-reduction potential (ORP), pH, temperature, and conductivity. If, in addition to observed reductions in petroleum contamination, geochemical indicators clearly exhibit the expected trends (either decreases in reactants or increases in electron acceptors or metabolic by-products) compared to their background, then it can be concluded that substantial biodegradation is occurring at the site (American Society for Testing and Materials [ASTM] 1998).

At AOC 69W, emergency response actions were conducted for petroleum spills in 1972 and 1978, with additional excavation of impacted soil completed between 1997 and 1998. Ongoing LTM of groundwater has been conducted since 2000. No specific timeframe for LTM was identified in the ROD. Based on LTM site data collected between 2000 and 2020, the following observations can be made:

- Historical groundwater quality data for petroleum-related COCs indicate decreasing trends:
    - VPH is no longer monitored. Sampling for VPH was discontinued in 2014, as concentrations were observed to be below criteria from 2009 through 2013.
    - EPH concentrations exhibit a statistically significant decreasing trend at the two wells where exceedances have occurred since fall 2002 (69W-94-13 and ZWM-99-22X). All EPH results were below monitoring criteria in 2020.
- Historical geochemical data indicate active biodegradative processes:
    - Dissolved arsenic concentrations have been detected above cleanup goals, primarily at petroleum release area monitoring well ZWM-99-22X and downgradient monitoring wells closest to the petroleum release area (69W-94-13 and ZWM-99-23X). Reducing conditions (low dissolved oxygen [DO] and oxidation reduction potential [ORP]) have been observed historically at these monitoring well locations and dissolved arsenic concentrations have remained stable since 2009.
    - Dissolved iron and manganese concentrations have been detected above background levels, primarily at petroleum release area monitoring well ZWM-99-22X and downgradient monitoring wells closest to the petroleum release area (69W-94-13 and ZWM-99-23X). Manganese has also been detected above background levels in monitoring wells located further downgradient (ZWM-01-25X, ZWM-95-15X), where oxidizing conditions have been observed historically. Dissolved iron and manganese concentrations have remained stable historically.

This SRI WP incorporates elements of the following guidance documents to assess the AOC 69W LTM data for the ROD-listed COC arsenic contributing to unacceptable risk in groundwater to confirm the protectiveness of the remedy at AOC 69W:

- American Petroleum Institute. *Methods for Measuring Indicators of Intrinsic Bioremediation: Guidance Manual*. Publ. No. 4658, November 1997.
- American Petroleum Institute. *Groundwater Arsenic Manual, Attenuation of Naturally-Occurring Arsenic at Petroleum Impacted Sites*. 2011.
- American Society for Testing and Materials. *Standard guide for remediation of ground water by natural attenuation at petroleum release sites*, ASTM E 1943-98. Conshohocken, Pennsylvania. 1998.
- USEPA. *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites*, OSWER Directive 9200.4-17, November 1997.

2.2. Data Quality Objectives

The objectives of the AOC 69W SRI are to confirm the Army Protectiveness Statement in the 2020 Five-Year Review Report (KGS 2020) and address items specified in the USEPA Additional Work Requirements Table. As discussed in **Section 1.1,** to address the USEPA's requirement for a revised LTMMP, the Army offered to prepare this SRI WP and an SRI report. Based on the results of the SRI, historical site data, and an updated CSM, the Army would prepare an FFS to evaluate changes to the remedy, including updates to the LTMMP, if necessary, and prepare any applicable ROD amendments. Therefore, the first step is to prepare an SRI WP. Specifically, the goals of the SRI are to:

- Collect sufficient and accurate site-specific data needed to accurately define/confirm the lateral and vertical extent of contamination
- Evaluate/identify current and potential human health risks
- Monitor attainment of ROD-specified RAOs and cleanup goals
- Assess short- and long-term protectiveness of the selected remedy.

Results of the SRI will be used to evaluate if changes to the AOC 69W ROD or AOC 69W LTM program are necessary. The evaluation will also include a comparison of current site conditions to remedial endpoints for similar sites in the state of Massachusetts.

DQOs are qualitative and quantitative statements that clarify study objectives, define the appropriate type of data, and specify the tolerable levels of potential decision errors that are used as the basis for establishing the quality and quantity of data needed to support decisions. These project-specific statements describe the intended data use; the data need requirements; and the means to achieve acceptable data quality for the intended use. Guidelines followed in the preparation of DQOs for remedial investigations are set out as steps in the *Data Quality Objectives Process for Hazardous Waste Site Investigations, EPA QA/G-4 HW* (USEPA 2000a) and *Guidance for the Data Quality Objectives Process, USEPA QA/G-4, EPA/600/R-96/055* (USEPA 2000b). These seven steps are listed below and were used to develop the DQOs for this SRI WP:

Step 1. State the Problem: Summarize the problem that will require environmental data, the resources required, and the preliminary site conceptual model.

Step 2. Identify the Decision (Project Goals): Identify the decisions needed to solve the problem.

Step 3. Identify Information Inputs: Identify the information and measurements needed to make the decisions.

Step 4. Define the Boundaries of the Study: Identify the conditions such as spatial and temporal boundaries.

Step 5. Develop a Decision Rule: Define the conditions under which the data will be utilized.

Step 6. Specify Limits on Decision Errors: Identify the limits on decision errors to establish performance goals.

Step 7. Develop/Optimize the Plan for Obtaining Data: Design an effective data collection strategy based on the previous steps.

2.2.1. Problem Statement / Study Questions

To address potential risk to human health at AOC 69W, the 1999 ROD stipulated the following RAOs for AOC 69W:

- Restore the aquifer to drinking water standards within a reasonable period.
- Monitor potential future migration of groundwater contamination.
- Eliminate risk from potential consumption of groundwater.
- Reduce or eliminate the direct contact threat of contaminated soils.

As presented in the 2015 (KGS 2015) and 2020 FYRs (KGS 2020) and described below in **Section 3**, significant progress has been completed towards achieving the RAOs for the analytes in groundwater identified in the RI

(ABB 1998) as contributing to unacceptable risk that still remain in the LTM program: arsenic, EPH, and manganese:

- EPH concentrations in groundwater have attenuated and are only slightly above comparison criteria at one monitoring well location (ZWM-99-22X) installed adjacent to the former petroleum release area.
- Consistent with the CSM which indicates that concentrations of naturally occurring metals in groundwater will remain elevated due to residual petroleum hydrocarbons degradation, concentrations of dissolved arsenic in groundwater remain above the ROD cleanup levels primarily at petroleum release area monitoring well ZWM-99-22X and downgradient monitoring wells 69W-94-13 and ZWM-99-23X (JV 2021). The elevated dissolved arsenic (as well as iron and manganese) concentrations generally correlate with areas adjacent to the former petroleum release area, where reducing conditions (low DO and ORP) are observed.
- As discussed in **Section 3.2.5**, localized reducing or near-reducing conditions may also exist adjacent to Willow Brook due to the observed native geology (historical peat layers). In some areas where dissolved manganese, iron, and arsenic are present but other redox indicators (e.g., DO and ORP) do not indicate a strongly reducing condition, it is possible that the reducing condition has partially attenuated and adsorption of metals to site soils is still ongoing. Dissolved manganese is slower to oxidize than dissolved iron in the presence of oxygen, but it is anticipated that continued manganese oxidation and arsenic attenuation will occur.
- Annual groundwater monitoring confirms that arsenic and EPH in groundwater are not migrating offsite at concentrations above monitoring criteria (KGS 2020). As discussed in **Section 3.2.5**, dissolved arsenic (as well as EPH) has not been historically detected above the ROD cleanup levels in monitoring wells, with the exception of petroleum release area monitoring well ZWM-99-22X and downgradient monitoring wells 69W-94-13 and ZWM-99-23X. Dissolved iron and manganese have been detected above background levels in these same wells, in addition to two wells further downgradient (ZWM-01-25X and ZWM-95-15X).The RAOs to eliminate risk from potential consumption of groundwater and to reduce or eliminate the direct contact threat of contaminated soils are achieved via LUCs that were incorporated into the deed between Army and MassDevelopment. The LUCs for AOC 69W are discussed in **Section 1.4.1.**

The Army is conducting this SRI to confirm that the selected remedy for AOC 69W remains protective and that site conditions indicate natural attenuation of petroleum in groundwater is occurring. Historical and new data collected will also be used to evaluate the ROD-stipulated remedy for possible modification or site close-out. To meet the SRI objectives, the study questions for this SRI are:

- What is the current lateral and vertical extent of the petroleum-related COC, EPH, in groundwater?
- What is the current lateral and vertical extent of the geochemical-related COCs, arsenic, iron, and manganese in groundwater?
- Are EPH, arsenic, iron, and manganese currently present in groundwater at concentrations above action levels and /or that present a current or potential human health risk?
- Is there a stable or decreasing trend of EPH, arsenic, iron, and manganese in groundwater?
- Are current reducing aquifer conditions associated with a petroleum release or are they naturally occurring?

2.2.2. Project Goals

To support the SRI objectives and answer the study questions, the goals of the AOC 69W SRI field activities are to:

- Confirm the current lateral and vertical extent of EPH, arsenic, iron, and manganese to assess contaminant distribution and possible off-site migration and assess concentration trends over time.
- Confirm the CSM, including the residual petroleum remaining in groundwater and aquifer conditions (including reducing conditions and associated impacts on naturally occurring arsenic concentrations).

2.2.3. Information Inputs / Data Needs

The information inputs required to accomplish the project goals are:

- Historical information reviewed/gathered to-date, including the results of previous investigations and remedial actions, and 20 years of LTM groundwater data to evaluate historical trends EPH, arsenic, iron, and manganese.
- Current groundwater analytical data for EPH, arsenic, iron, and manganese from existing and proposed monitoring wells, as well as a proposed vertical aquifer profile (VAP) location in the former petroleum release area, to determine vertical and lateral extent of EPH, arsenic, iron, and manganese.
- Current soil analytical data from the proposed monitoring well installation locations and the proposed VAP location.
  - Soil samples will be collected from the proposed VAP boring and analyzed for EPH to assess the degree of residual petroleum remaining in soil.
  - Soil samples will be collected from the saturated/proposed screen interval at the proposed VAP location and each of the proposed monitoring wells; samples will be collected for Synthetic Precipitation Leaching Procedure (SPLP) and acid digestion testing, with arsenic, aluminum, iron, manganese, and pH analyzed on the leachate. The SPLP-leachable arsenic will be compared with the groundwater arsenic in the same location, providing qualitative evidence for arsenic sorption potential.
- Historical geologic, hydrogeologic/hydraulic, and chemical data required to evaluate fate and transport.
- Current geologic, hydrogeologic/hydraulic, and chemical data required to evaluate fate and transport.
  - Geologic information from the proposed VAP location to evaluate potential natural sources of reducing conditions
  - Water levels for hydrogeologic/hydraulic evaluation
  - Field parameters for evaluating temporal trends in general water quality conditions that affect stability and solubility of arsenic: DO, ORP, specific conductance, temperature, turbidity, and pH
  - Groundwater laboratory analyses for geochemical evaluation in addition to EPH and total/dissolved arsenic, iron, and manganese:
    - Aluminum (total and dissolved) –Used as a non-redox-active proxy for evaluating potential for fine suspended particulates to influence other dissolved metals analyses (including iron and arsenic).

- Total organic carbon (TOC) – Used to evaluate residual reducing potential in the aquifer (specifically, potential for ongoing dissolved oxygen consumption, limiting the rate of arsenic natural attenuation).
- Sulfate – Used as secondary line of evidence for aquifer reducing potential resulting from potential historical sulfate reduction in petroleum hydrocarbon biodegradation zones.
- Nitrate/nitrite – Used to assess redox status and residual reducing potential for metals dissolution.

Site conditions at AOC 69W are well documented from 20 years of historical LTM data. However, during the 20 years of LTM, the number of monitoring wells sampled was reduced due to optimization. Therefore, to evaluate the ROD-stipulated remedy for possible modification or site close-out, the Army will collect supplemental data at AOC 69W from all existing monitoring wells and piezometers.

In addition, as presented herein, the Army will install and sample one new monitoring well to the west of the former petroleum release area, and two new monitoring wells to the west of Willow Brook to address data gaps and further confirm the lateral extent of contamination. The Army will also install two staff gauges in Willow Brook to further evaluate groundwater-surface water interaction in the study area.

2.2.4. Boundaries of Study

The general areal boundaries for the SRI are the former petroleum release area, associated downgradient extents of EPH, arsenic, iron, and manganese, and the area of Willow Brook (**Figure 1-2**).

The release of No. 2 fuel oil occurred over 49 years ago. In 1972, piping leading from a heating oil UST located north of the school in the middle of the current parking lot to a boiler room in an addition to the school was accidentally crimped, causing the pipe to leak approximately 7,000 to 8,000 gallons of No. 2 fuel oil to the ground. In 1978, underground fuel piping near the boiler room in the original school building failed at a pipe joint. Approximately 7,000 to 8,000 additional gallons of oil were released into the soil during the incident. An emergency action at the time of the 1978 release removed fuel oil and impacted soil. In 1997 and 1998 an additional excavation removed impacted soil from the location of the 1972 release.

2.2.5. Decision Rules

To meet the goals of the SRI, groundwater samples will be collected from new and existing monitoring wells and the new VAP location to accurately define/confirm the lateral and vertical extent of contamination, effectively evaluate/identify current and potential human health risks, monitor attainment of ROD-specified RAOs and cleanup goals; and confirm the protectiveness of the remedy. All groundwater samples will be collected and analyzed in accordance with the technical guidance instruction (TGI) and Standard Operating Procedure (SOP) documents included in the LTMMP QAPP to ensure that subsequent decisions are made based on valid data. Presence/absence of EPH, arsenic, iron, and manganese will be based on the laboratory limits of detection (LODs) presented in the LTMMP QAPP.

Based on data collected during the SRI and historical data, the following questions will be asked. If answered yes, then the Army will propose to USEPA and MassDEP that additional sampling is not required and LTM remedy is protective and may be suitable for reduced monitoring. If answered no, the Army will propose additional activities and/or evaluations to USEPA and MassDEP to ensure the remedy is protective.

- Is there sufficient data to confirm the current lateral and vertical extent of the ROD-specified COCs in groundwater (i.e., are locations with samples exceeding screening criteria bounded by samples from locations not exceeding screening criteria)?

  - If yes, the Army will propose to USEPA and MassDEP that no additional sampling is required during the SRI to confirm the current lateral and vertical extent of EPH.
  - If no, the Army will propose activities to USEPA and Mass DEP to collect additional data as needed.
- Is there sufficient data to confirm the current lateral and vertical extent of the ROD-specified COCs in groundwater (i.e., are locations with samples exceeding screening criteria bounded by samples from locations not exceeding screening criteria)?
  - If yes, the Army will propose to USEPA and MassDEP that no additional sampling is required during the SRI to confirm the current lateral and vertical extent of arsenic, iron, and manganese.
  - If no, the Army will propose to USEPA and Mass DEP to collect additional data as needed.
- Is there sufficient data to evaluate/identify current and potential human health risks? Are samples collected from locations representative of exposure scenarios evaluated?
  - If yes, the Army will propose to USEPA and MassDEP that no additional sampling is required during the SRI.
  - If no, the Army will propose to USEPA and Mass DEP to collect additional data as needed.
- Does data indicate a stable or decreasing trend of EPH, arsenic, iron, or manganese in groundwater?
  - If yes for a decreasing trend, the Army will propose to USEPA and MassDEP that no additional sampling is required, LTM remedy is protective, and the analyte may be recommended for reduced monitoring.
  - If yes for a stable trend below screening criteria, the Army will propose to USEPA and MassDEP that no additional sampling is required, LTM remedy is protective, and the analyte may be suitable for reduced monitoring or removal from LTM program.
  - If yes for a stable trend above screening criteria, additional sampling may be required, but the analyte may be suitable for reduced monitoring.
  - If no, the Army will propose additional activities to USEPA and Mass DEP as needed based on the data.
- Is there sufficient data to determine if reducing aquifer conditions associated with a petroleum release are occurring?
  - If yes, the Army will propose to USEPA and MassDEP that no additional sampling is required during the SRI.
  - If no, the Army will propose to USEPA and Mass DEP to collect additional data as needed.

3. Conceptual Site Model

This section presents a discussion of the CSM for Devens and, specifically, for AOC 69W.

3.1. Regional

3.1.1. Physical Characteristics

The regional topography of Devens is characterized as an undulating glacial terrain derived from glacial erosion and deposition on crystalline bedrock. Landforms at Devens include areas of extensive flat uplands interspersed with kame and kettle topography that range from areas of comparatively low topographic relief to elongated hills (i.e., drumlins) (HLA 2000a). Terrain generally falls into three types encountered at Devens:

- **Bedrock Terrain** – Least common; generally consisting of crystalline bedrock topographical highs that are resistant to both glacial and fluvial erosion. Where bedrock is not directly exposed, a thin veneer of glacial sediments may be present.
- **Glacial Till** – More common; primarily consisting of highly variable sediments deposited by glaciers and conforming to the underlying bedrock surface.
- **Glacial-Meltwater Streams and Lake Deposits** – Most common; predominantly consisting of sediments deposited by glacial-meltwater outwash and ancient proglacial lake accumulations.

The major glacial sediment units consist of glacial till, deltaic deposits from former glacial Lake Nashua, and deposits from glacial meltwater streams. The thickness of glacial till at Devens varies between 10 and 60 feet, consists of unstratified gravel to silt, and typically contains boulders. The glacial lake deposits consist chiefly of sand and gravelly sand. Lake bottom deposits consist of sand, silt, and clay. Post-glacial deposits consist of river terrace sands and gravels, fine alluvial sands, and silts, as well as peat, silt, and sands in swampy areas. Overburden deposits are up to 300 feet thick (areas along Cold Spring Brook), whereas lowland Nashua River floodplain deposits, consisting of sand, fine gravel, and silt, are up to 25 feet thick.

The crystalline bedrock at Devens consists of slightly weathered, sparsely fractured, low-grade gneiss and granite (HLA 2000a). Bedrock strike and dip are variable across Devens due to the folded nature of the formations and the presence of numerous faults that align with major unit contacts.

3.1.2. Hydrogeology

Regionally, groundwater and surface water bodies across Devens ultimately discharge into the Nashua River, whose tributaries include Nonacoicus Brook and Walker Brook on the former North Post. Willow Brook, a tributary to Nonacoicus Brook, flows through the former Main Post and adjacent to AOC 69W. Willow Brook originates from Robbins Pond to the south and is fed by Robbins Pond, surface water runoff, stormwater discharge, and groundwater.

Overburden (glacial meltwater deposits) constitutes the primary groundwater aquifer at Devens. Zones of highest transmissivity within the overburden are generally found in areas of thick glacial meltwater deposits, including the former Main Post area where AOC 69W is located. Several public water supply wells, including the Shabokin, Patton, MacPherson, and Grove Pond wells, are all installed within these meltwater deposits and can reportedly yield several hundred gallons per minute (gpm). Hydraulic conductivity values have been reported to vary between 30 to 300 feet per day (ft/day) in meltwater deposits, while lake bottom sediments are significantly less permeable with reported hydraulic conductivities ranging from 0.002 to 0.3 ft/day (HLA 2000a). The zones of lowest groundwater transmissivity at Devens are typically associated with exposed till and fractured bedrock. The depth to groundwater across the former Main Post OUs/AOCs (including AOC 69W) ranges from less than 1-foot bgs to more than 40 feet bgs and averages approximately 15 feet bgs. Overburden groundwater is recharged in upland areas, and flow generally follows topography—from topographic highs to topographic lows, where it discharges to wetlands, ponds, streams, and directly into the Nashua River.

3.2. AOC 69W

The physical characteristics and hydrogeology for AOC 69W are summarized in the following sections.

3.2.1. Physical Characteristics

The predominant soil type at AOC 69W consists of dark yellowish-brown fine to coarse sands, gravely sands, and silty sands. Explorations in the vicinity of Willow Brook and its associated wetlands revealed a 4- to 5-foot layer of dark grayish-brown, sandy silt overlying the sands. Organic material, believed to be from undisturbed native peat deposits, has been observed in the area north of the Charter School at a maximum depth of 4 feet bgs. Shallow subsurface soils beneath the Charter School and parking lot area consist of reworked native soils. During the remedial investigation in 1998, bedrock was not encountered in any of the soil borings or monitoring well installed at the site, which reached depths of up to 25 feet (ABB 1998).

3.2.2. Hydrogeology

The depth to groundwater at AOC 69W ranges from approximately 1-foot bgs (adjacent to Willow Brook) to approximately 13 feet bgs (south/upgradient of the Charter School) (**Table 3-2**). The groundwater flow direction is predominately to the north-northwest, and the most recent groundwater elevation map prepared for AOC 69W in November 2022 is included as **Figure 3-1**. Vertical gradients have not been calculated historically, as there are no deep overburden wells at the site. Calculated groundwater flow velocities are consistent with the observed sandy soils with a maximum calculated flow velocity of 2 feet/day and a mean flow velocity of 0.7 feet/day (ABB 1998). AOC 69W is located within the delineated Zone II for the MacPherson production well located approximately 3,000 feet to the north, and downgradient of AOC 69W (KGS 2020).

3.2.3. Contaminant Source

The 1995 and 1996 RIs (ABB 1998) indicated that there were two areas of fuel-related soil contamination at AOC 69W (**Figure 1-2**). The larger area extended from the new boiler room to the 250-gallon concrete vault that acted as an oil water separator (located in the wooded area approximately 300 feet northwest of the school). The contamination was attributed to the 1972 release of fuel oil from piping between the 10,000-gallon UST and the new boiler room. Detected contaminants were primarily petroleum-related analytes at approximately 6 feet to 10 feet bgs adjacent to the school and 0 to 4 feet bgs downgradient in the grassy area and in the vicinity of the 250-gallon underground concrete vault. Subsurface contaminants were located primarily at or near the water table. Surficial contamination downgradient of the school (near Willow Brook) was attributed to sorption during times of high groundwater levels (ABB 1998).

Based on the nature and distribution of contaminants, a Removal Action (Weston 1998) was undertaken in the winter of 1997 and 1998 to remove contaminated soil associated with the 1972 release. Soil was excavated to a maximum depth of 13 feet bgs near the school, and 8 feet bgs near the 250-gallon underground concrete vault. Confirmatory subsurface soil sample results from the removal action showed that concentrations of fuel-related contaminants still exceeded MCP S-1/G-1 standards for EPH in subsurface soils immediately adjacent to the school building but were generally low in downgradient areas (Weston 1998).

The other identified area of soil contamination was located adjacent to the school building outside of the original boiler room. This contamination was attributed to the 1978 fuel oil release from ruptured piping. An excavation at the time of the release showed visible fuel oil contamination emanating from underneath the school. Analytical data indicated that the contaminants were primarily total petroleum hydrocarbons at depths of 4 feet to 7 feet bgs beneath the parking lot. Contaminants appeared to be localized to the area immediately adjacent to the school.

Future leaching is not likely as the area is paved, thereby inhibiting leaching of soils via precipitation infiltration (KGS 2020).

3.2.4. Nature and Extent

Petroleum discharges to ground occurred at AOC 69W in 1972 and again in 1978, both times due to a failure in the piping from a heating oil UST. While a removal action in 1998 excavated the majority of the petroleum-contaminated soil, residual petroleum remained in the soil on-site. Once contaminants are released to the environment, they are subject to physical, chemical, and biological processes that influence their distribution in various environmental media.

3.2.4.1. EPH

EPH concentrations (specifically the C11-C22 aromatic carbon fraction) have decreased over time by one to two orders-of-magnitude since the data was collected in the early 2000s. Since November 2002, EPH has been detected above the Cleanup Goal established by the ROD of 200 µg/L in two monitoring wells (ZWM-99-22X in the former petroleum release area, and 69W-94-13 directly downgradient from the former petroleum release area). Over time, the EPH compounds may have sequestered within the soil organic matter, either as the original molecular structure or as the by-products of microbial utilization (KGS 2020). Concentrations in monitoring well 69W-94-13 have been less than the Cleanup Goal since October 2016, and well ZWM-99-22X has generally maintained concentrations slightly above the monitoring criterion since October 2008, but concentrations have been below the Cleanup Goal in four of the past six sampling events (October 2017, October 2020, October 2021, and November 2022 [**Table 3-1**]). All other monitoring wells sampled in accordance with the Main Post LTMMP have been below the Cleanup Goal for EPH since May 2002, with the exception of a single anomalous detection in October 2016 from well ZWM-95-18X where EPH has otherwise not been detected historically (**Table 3-1**).

3.2.4.2. Arsenic

Arsenic concentrations have generally remained above the Cleanup Goal established by the ROD of 10 µg/L since the start of LTM sampling (May 2000) in three monitoring wells (ZWM-99-22X in the former petroleum release area; 69W-94-13 and ZWM-99-23X downgradient from the former petroleum release area). Well ZWM-99-22X continues to have the highest detections of arsenic, with an average of 161 µg/L over the past 10 LTM sampling events (October 2013 to November 2022) compared to 56 µg/L in well 69W-94-13 and 19 µg/L in well ZWM-99-23X µg/L. Detections above the Cleanup Goal have also been observed in monitoring well ZWM-95-15X adjacent to Willow Brook (six out of 10 LTM events since October 2013, average concentration of 15 µg/L). All other monitoring wells sampled in accordance with the LTMMP have been below the Cleanup Goal for arsenic since November 2000, with the exception of two detections in October 2011 and October 2012 from well ZWM-01-25X, where arsenic has otherwise not been detected historically. A summary of arsenic concentrations from the November 2022 event is provided as **Figure 3-2.**

3.2.5. Fate and Transport

As presented in the 1998 RI, the primary route of contaminant migration at AOC 69W are releases of fuel oil to surface and subsurface soils then transport via leaching to groundwater. The release of fuel oil caused the historical EPH concentrations in groundwater and may have contributed to the observed concentrations of dissolved arsenic, iron, and manganese due to reducing geochemical conditions. While overall arsenic concentrations have remained consistent throughout the historical LTM sampling events, arsenic concentrations decrease from the petroleum release area to downgradient locations. **(Figure 3-2)**.

The correlation between ORP, DO, and concentrations of the site COCs have been examined historically, most recently in the 2020 FYR (KGS 2020). As indicated previously in **Section 3.2.4** of this SRI WP, historical concentrations of EPH and arsenic above their respective Cleanup Goal have been observed primarily in the former petroleum release area and immediately downgradient of the release area. Information on existing monitoring wells, including historical ORP and DO field measurements, is provided in **Table 3-1**. An average of

ORP and DO field measurements collected over the past 10 LTM sampling events is provided below in **Exhibit 3-1**:

Exhibit 3-1: Summary of Average Geochemical Conditions, October 2013 to November 2022

Well ID	ORP (mV)	DO (mg/L)	Geochemical Condition	Arsenic (µg/L)	Iron (µg/L)	Manganese (µg/L)
69W-94-13	-22.4	1.9	Moderately Reducing	56	5,825	1,429
69W-94-14	149.6	2.5	Oxidizing	1.7	137	214
69WP-08-01	-9.0	2.0	Moderately Reducing	1.4	7,180	426
69WP-13-01	-69.8	0.8	Reducing	--	--	193
ZWM-01-25X	75.8	3.2	Oxidizing	2.3	176	1,393
ZWM-01-26X	188.3	6.5	Oxidizing	--	--	--
ZWM-95-15X	44.9	1.5	Oxidizing	15	3,373	754
ZWM-95-17X	119	4.4	Oxidizing	--	--	--
ZWM-95-18X	159.6	4.6	Oxidizing	ND	162	114
ZWM-99-22X	-67.0	0.7	Reducing	161	16,400	1,154
ZWM-99-23X	7.5	1.3	Oxidizing	19	2,349	843
ZWM-99-24X	120.9	2.3	Oxidizing	1.9	271	50

Notes:
µg/L = micrograms per liter
mg/L = milligrams per liter
mV = millivolt
ND = not detected above laboratory reporting limits
-- = not sampled

Observations to date suggest that metals mobility in groundwater is controlled by the geochemical changes caused by the biodegradation of the fuel hydrocarbons (KGS 2020):

- Reducing conditions (negative ORP and DO < 1 mg/L) observed in the former petroleum release area (well ZWM-99-22X).
- Moderately reducing conditions (negative ORP or DO < 1 mg/L) in well 69W-94-13, the closest downgradient location to well ZWM-99-22X. This is consistent with historical EPH detections at these locations.
- With the exception of downgradient wells 69WP-08-01 and 69WP-13-01, oxidizing conditions (positive ORP and DO > 1 mg/L) exist at the remainder of monitoring wells monitored in accordance with the LTMMP.
- At wells 69WP-08-01 and 69WP-13-01, localized reducing or moderately reducing conditions exist, due to the observed native geology (historical peat layers) adjacent to Willow Brook, which may also explain the elevated concentrations of iron in these areas.

3.3. Potential Receptors and Exposure Pathways

Potential human and ecological receptors and exposure pathways were presented in the 1998 RI (ABB) based on the current and future land uses at AOC 69W and used to prepare human health and ecological risk assessments. The sections below present those assumptions.

3.3.1. Human Receptors and Exposure Pathways

The current land use for AOC 69W is educational purposes. It is anticipated that the foreseeable future land use will be consistent with current land use (VHB 1994). Therefore, land use assumptions used for the human health risk assessment (HHRA) prepared as part of the 1998 RI (ABB) remain the same.

Also consistent with the 1998 HHRA, potential current and future human receptors to groundwater may include site maintenance or utility workers. Future construction workers may be considered additional receptors in the event of site expansion or redevelopment.

The 1998 HHRA evaluated post-removal action conditions for surface soil and subsurface soil and pre-removal conditions for groundwater, sediment, and indoor air. Based on the conclusions of the risk assessment, there were no unacceptable human health risks associated with soils, sediment, groundwater discharge, or indoor air. The risk estimates presented in the risk assessment were worst-case estimates that were unlikely to be exceeded under conceivable land-use conditions. The only risks that exceeded USEPA thresholds were associated with the hypothetical use of groundwater as a source of residential drinking water (KGS 2020). However, as discussed previously, there are existing LUCs at AOC 69W the prohibit the use of groundwater for drinking water. In addition, LUCs were implemented to reduce/eliminate the direct contact threat of human exposure to remaining contaminated soils beneath and adjacent to the building/school.

Because there has been no change to underlying assumptions used to prepare the HHRA, no review of the HHRA is planned as part of the SRI.

3.3.2. Ecological Receptors and Exposure Pathways

A baseline ecological risk assessment (BERA) was prepared as part of the 1998 RI (ABB) to evaluate the actual and potential adverse effects to ecological receptors associated with exposure to contamination from AOC 69W. The BERA utilized surface soil, sediment, and groundwater data to evaluate potential risks to ecological receptors. Based on the conclusions of the ecological risk assessment, there are no unacceptable risks associated with site-related fuel oil contamination at AOC 69W (KGS 2020).

No review of the ecological risk assessment is planned as part of the SRI.

4. Supplemental Remedial Investigation Implementation

As presented in **Section 2.2**, the objectives of the AOC 69W SRI are to confirm the Army Protectiveness Statement in the 2020 Five-Year Review Report (KGS 2020) and address items specified in the USEPA Additional Work Requirements Table. Specifically, the objectives of the SRI are to:

- Collect sufficient and accurate site-specific data needed to accurately define/confirm the lateral and vertical extent of contamination
- Evaluate/identify current and potential human health risks
- Monitor attainment of ROD-specified RAOs and cleanup goals
- Assess short- and long-term protectiveness of the selected remedy.

To meet the SRI objectives, the study questions for this SRI are:

- What is the current lateral and vertical extent of the petroleum-related COC, EPH, in groundwater?
- What is the current lateral and vertical extent of the geochemical-related COCs, arsenic, iron, and manganese in groundwater?
- Are EPH, arsenic, iron, and manganese currently present in groundwater at concentrations above action levels and /or that present a current or potential human health risk?
- Is there a stable or decreasing trend of EPH, arsenic, iron, and manganese in groundwater?
- Are current reducing aquifer conditions associated with a petroleum release or are they naturally occurring?

This section presents the comprehensive project approach, methods, and operational procedures to be used for the investigations performed at AOC 69W at former Fort Devens. Detailed descriptions are presented in the AOC 69W QAPP Addendum (**Appendix A**). Proposed investigation locations are discussed below.

4.1. Proposed Activities

As discussed in **Section 3** of this Work Plan, historical groundwater data (**Table 3-1**) indicates that the extent of EPH and dissolved arsenic concentrations are well defined. EPH concentrations have exceeded the Cleanup Goal in one monitoring well since 2016 (ZWM-99-22X, located in the former petroleum release area). Elevated concentrations of dissolved arsenic have been detected historically, primarily at petroleum release area monitoring well ZWM-99-22X and downgradient monitoring wells 69W-94-13 and ZWM-99-23X.

As discussed in **Section 1.4.2** of this Work Plan, LTM groundwater data has been collected from varying monitoring wells at AOC 69W for 20 years. This SRI WP proposes sampling of all wells installed at the site, including several of which were previously eliminated from the monitoring program as part of Main Post LTMMP optimization (**Figure 4-1**). Sampling of all wells provides a snapshot of current conditions and will support the decision-making process. Data generated during the SRI, along with historical data, will be used to determine if the remedy is protective and answer the study questions established in **Section 2.2.1**.

To address the study questions for AOC 69W, the following activities are proposed:

- **To evaluate the current vertical extent of the analytes specified in the ROD for monitoring (arsenic, iron, manganese, and EPH)**, one VAP boring (69WVP-23-01) will be drilled adjacent to the petroleum release area monitoring well ZVM-99-22X (Figure 4-1). The need for a VAP at this location was identified to confirm vertical extent of arsenic and EPH in the petroleum release area.

- **To confirm the current lateral extent of analytes specified in the ROD for monitoring, arsenic and EPH**, all on-site monitoring wells and piezometers will be sampled for these parameters, with the addition of VPH to assist in the evaluation as to whether petroleum compounds remain. In addition, three new monitoring wells will be installed. Two of the wells (69W-23-01 and 69W-23-02) will be installed to the northwest of Willow Brook. The third well (69W-23-03) will be installed to the west of the petroleum release area. Two stream gauges (69WSG-23-01 and 69WSG-23-02) will also be installed in Willow Brook. The wells and staff gauges will be used to evaluate the potential for migration of arsenic to the west of the petroleum release area and/or beyond the brook (Figure 4-1).

- **To evaluate trends in the concentrations for analytes specified in the ROD for monitoring, arsenic and EPH**, the existing and new monitoring wells listed above will be sampled on a quarterly basis for a period of one year. A statistical trend analysis (Mann Kendall + Theil-Sen slope analysis) of the new and existing data will be performed upon the completion of the sampling.

- **To determine if current reducing aquifer conditions are associated with the historical petroleum releases or are naturally occurring**, groundwater samples will be analyzed for additional parameters (total and dissolved aluminum, TOC, sulfate, sulfide, nitrate, nitrite, and dissolved methane); the analytical results will be compared against the EPH and arsenic data, as well as the spatial location of the sampling location. As presented in detail in Section 2.2.3, the field water quality parameters (DO, ORP, specific conductance, temperature, turbidity, and pH) and laboratory geochemical data will be used to evaluate residual reducing potential in the aquifer and assess the potential for fine suspended particulates to influence other dissolved metals analyses (including iron, arsenic, and manganese). In addition, continuous soil logging will be performed during monitoring well installation to evaluate the presence or absence of a peat layer in the area.

- **To evaluate whether sorbed metals (arsenic, iron, and manganese) are present and in equilibrium with groundwater,** two soil samples will be collected from the saturated/proposed screen interval zones (i.e., within the top 10 feet of saturated soil) from each of the three proposed monitoring well locations, and from the corresponding interval at the proposed VAP location. Each soil sample will be submitted for an SPLP leach test via USEPA Method 1312 with analysis of arsenic, aluminum, iron, manganese, and pH on the leachate. The same samples will also be submitted for acid digestion via USEPA Method 3050B (coupled with EPA Method 6020A) for analysis of arsenic, aluminum, iron, and manganese. The SPLP-leachable arsenic will be compared with the groundwater arsenic in the same location, providing qualitative evidence for arsenic sorption potential**.**

Exhibit 4-1 presents the proposed groundwater sample locations and analytes. The proposed sample locations are shown on **Figure 4-1.**

Exhibit 4-1: AOC 69W Proposed Groundwater Sampling Locations and Laboratory Analyses

Location ID	Location Type	Location from Petroleum Release Area	Analyte List [b]						
			EPH/VPH	Total Al, As, Fe, Mn	Dissolved Al, As, Fe, Mn [a]	Sulfate / Sulfide	Nitrate/ Nitrite	TOC	Dissolved Methane
69WVP-23-01	VAP (proposed)	Former Release Area	X	X	X	X	X	X	X
69W-23-01	MW (proposed)	Downgradient	X	X	X	X	X	X	X
69W-23-02		Downgradient / Crossgradient	X	X	X	X	X	X	X
69W-23-03		Crossgradient	X	X	X	X	X	X	X
69W-94-12	MW (existing)	Downgradient	X	X	X	X	X	X	X
69W-94-13		Downgradient	X	X	X	X	X	X	X
69W-94-14		Downgradient	X	X	X	X	X	X	X
69WP-08-01		Downgradient	X	X	X	X	X	X	X
69WP-13-01		Downgradient	X	X	X	X	X	X	X
ZWM-01-25X		Downgradient	X	X	X	X	X	X	X
ZWM-01-26X		Downgradient / Crossgradient	X	X	X	X	X	X	X
ZWM-95-15X		Downgradient	X	X	X	X	X	X	X
ZWM-95-16X		Crossgradient	X	X	X	X	X	X	X
ZWM-95-17X		Upgradient	X	X	X	X	X	X	X
ZWM-95-18X		Downgradient	X	X	X	X	X	X	X
ZWM-99-22X		Former Release Area	X	X	X	X	X	X	X
ZWM-99-23X		Downgradient	X	X	X	X	X	X	X
ZWM-99-24X		Downgradient / Crossgradient	X	X	X	X	X	X	X
ZWP-95-01X		Downgradient / Crossgradient	X	X	X	X	X	X	X
ZWP-95-02X		Downgradient / Crossgradient	X	X	X	X	X	X	X

NOTES:
Al = aluminum
As = arsenic
EPH / VPH = extractable petroleum hydrocarbons / volatile petroleum hydrocarbons
Fe = iron
Mn = manganese
TOC – total organic carbon

a. Dissolved metals samples will be field-filtered.
b. Water quality parameters, including DO, ORP, specific conductance, temperature, turbidity, and pH, will be collected during sampling to assess the degree of dissolved particulates and oxidizing/reducing conditions.

4.2. Methodology

Field activities will be conducted in accordance with the following TGIs and SOPs:

- TGI – Ground Penetrating Radar
- TGI – Manual Water-Level Monitoring
- TGI – Well Installation
- TGI – Monitoring Well Development
- TGI – In-Situ and Ex-Situ Water Quality Parameters
- TGI – Sample Chain of Custody
- TGI – Investigation-Derived Waste Handling and Storage
- TGI – Groundwater and Soil Sampling Equipment Decontamination
- TGI – Soil Description
- TGI – Vertical Aquifer Profiling
- TGI – Soil Drilling and Sample Collection
- SOP – Low Stress (low flow) Purging and Sampling Procedure for the Collection of Groundwater Samples from Monitoring Wells

These TGIs are included in the AOC 69W QAPP Addendum (**Appendix A**). Additional details concerning field activities are provided below.

4.2.1. Site Preparation

Before any intrusive activities, the S-A JV will implement the following utility locating procedures:

- Notify the Massachusetts Digsafe System a minimum of 72-hours before any intrusive field work for underground utility clearance.
- Clear each drilling location of utilities with ground-penetrating radar.
- Conduct a detailed visual site inspection and review existing plans for possible utilities that potentially conflict with the planned activities.
- Use a soft dig method to a depth of 5 feet bgs to further clear the proposed locations before advancing any borings.

In addition, the Charter School will be notified of the planned field activities a minimum of 30 days before the start of intrusive activities.

S-A JV field personnel will complete the site-specific munitions and explosives of concern (MEC) awareness training with the Devens Fire Department before the start of field activities. Field personnel will also have current health and safety training as required by state/federal regulations, such as 40-hour Hazardous Waste Operations and Emergency Response (HAZWOPER) training. Personnel responsible for overseeing drilling operations will have at least 5 years of prior relevant drilling experience.

4.2.2. Soil Boring Installation and Vertical Aquifer Profiling

Continuous logging of overburden soils will be conducted using direct-push methods at the proposed VAP and monitoring well locations. An S-A JV field geologist will oversee the work and record soil lithology. Consistent with environmental investigation protocols, and because drilling is occurring in areas with historical petroleum impacts, soil will be screened for volatile organic compounds with a photoionization detector (PID) every 1 foot at the continuous logging locations. Soil descriptions will be recorded in accordance with the Unified Soil Classification System. The following will be recorded from each soil core at a minimum: depth interval, recovery, particle size, sorting, angularity/plasticity/dilatancy, principal and minor components, moisture, consistency/density, and color. When possible, the recovered soil cores will be photographed.

Soil samples will be collected from the proposed VAP location and analyzed for EPH; one sample from within the top two feet of the soil column, and one sample from the interval immediately above the water table. A third soil sample will be collected (if needed) from the interval with greatest apparent petroleum impacts and/or highest PID readings.

Additional soil samples will be collected from the saturated/proposed screen interval zones (i.e., within the top 10 feet of saturated soil) of the three proposed monitoring well locations, and from the corresponding interval at the proposed VAP location. Each soil sample will be submitted for an SPLP leach test via USEPA Method 1312 with analysis of arsenic, aluminum, iron, manganese, and pH on the leachate. The same samples will also be submitted for acid digestion via USEPA Method 3050B (coupled with EPA Method 6020A) for analysis of arsenic, aluminum, iron, and manganese.

Groundwater samples will be collected from the VAP location via a retractable well screen, which is advanced with 1-inch steel drilling rods (SP-22 or similar). The “top-down” approach will be used (i.e., samples collected as the borehole is drilled to minimize the potential for cross-contamination) starting at the water table; samples will be collected in 5-foot intervals for the first 15 feet, and then in 10-foot intervals for the remainder of the boring. A peristaltic or bladder pump setup with dedicated tubing will be used, and a minimum of three casing volumes will be purged prior to sample collection. It is anticipated that the VAP boring will extend to a total depth of 50 feet bgs, or until refusal is encountered (whichever comes first).

The VAP location will be abandoned using natural collapse and/or tremie-grout techniques, depending on borehole conditions after removal of drilling tools. All drilling will be completed by a licensed Massachusetts driller under the oversight of a JV geologist and will be conducted in accordance with all promulgated state and federal laws.

4.2.3. Monitoring Well Installation and Development

Monitoring wells will be installed using direct-push or hollow stem auger techniques, depending on the specific drilling location. Continuous soil logging will be performed during drilling. Monitoring wells will be constructed of 2-inch-diameter schedule 40 polyvinyl chloride (PVC) with 10-foot-long screen (10-slot size [0.010-inch]). Screen depths will be selected based on the observed depth to groundwater, and screens will be installed to “straddle” the water table.

Filter packs, seals, and surface completions will be completed consistent with Massachusetts guidance. The wells will be completed flush with the surface grade encased by a 2-foot by 2-foot concrete pad and secured using an 8-inch protective roadbox or 4-inch-diameter steel standpipe. Well construction details (included the materials used) will be recorded by an S-A JV field geologist. The measuring points and well labels will be marked with an indelible ink pen on both the inner and outer well casings or inside the roadbox lid. All drilling and well construction will be completed by a licensed Massachusetts driller under the oversight of a SERES-Arcadis JV geologist and will be conducted in accordance with all promulgated state and federal laws. All well locations will be surveyed by a licensed Massachusetts surveyor for northing, easting, and ground/top of casing elevations.

Each monitoring well will be developed using a submersible pump and surge block to remove fines and improve the hydraulic connection of the well with the native formation.

4.2.4. Groundwater Sampling and Water Level Measurements

In addition to the collection of groundwater samples from the VAP location (Section 4.2.2), groundwater samples will also be collected from newly installed monitoring wells and all existing monitoring wells and piezometers. Samples will be collected in accordance with the TGI. Groundwater sampling will be completed on a quarterly basis for one year (four sampling events), and a synoptic water level gauging event will be conducted prior to each sampling event to confirm groundwater flow direction. The events will include the staff gauges (69WSG-23-01 & -02) which will be useful in evaluating the interaction between surface water and groundwater.

To evaluate redox status and attenuation potential, samples from the VAP location and monitoring wells will be analyzed for the following additional parameters (in addition to EPH and dissolved arsenic, iron, and manganese identified in the Main Post LTMMP, as well as VPH (if present)):

- **Total and dissolved aluminum**, to assess the potential for presence of sub-0.45-micron particulates. Aluminum is anticipated to exhibit extremely low solubility at the observed groundwater pH. The presence of total aluminum would therefore indicate suspended particulates present in the groundwater sample, while the presence of dissolved aluminum correlated to total aluminum would indicate the presence of very fine (sub-0.45-micron) particulates.

- **Total arsenic, iron, and manganese**. Total arsenic will be collected as an additional line of evidence regarding potential for suspended particulates affecting COC concentrations. Total iron/manganese will be collected to evaluate redox status and arsenic attenuation potential via iron coprecipitation upon reoxidation.

- **TOC, sulfate, sulfide**, **nitrite, and nitrate,** to assess redox status and residual reducing potential. TOC will contribute to ongoing reducing potential by consuming dissolved oxygen (potentially limiting iron reoxidation and extending the timeframe for arsenic, iron, and manganese attenuation), while comparison of sulfate concentrations inside and outside of the historical petroleum hydrocarbon impacts may inform extent of historical sulfate reduction. If sulfate reduction has occurred, sulfide minerals in the formation may further extend time for attenuation of arsenic. Nitrate/nitrate samples will be used to further assess geochemical conditions as they relate to the potential for metals dissolution.

In addition to the above parameters, DO, ORP, specific conductance, temperature, turbidity, and pH, will be collected during sampling at each VAP location and monitoring well location. Field parameter stabilization requirements will be followed for each monitoring well location, and stabilization will be attempted at the VAP sampling locations.

4.2.5. Waste Management

Investigation-derived waste (IDW) generated during the proposed activities will include purged groundwater and drill cuttings, as well as general site refuse. IDW management procedures are presented in Worksheet #17-12 of the QAPP Addendum and will be managed in accordance with TGI – Investigation-Derived Waste Handling and Storage and previous waste management practices at Devens.

Drill cuttings generated during investigation activities will be spread on the ground surface adjacent to the site of generation. Groundwater generated (including drilling water, rinsate water, and well development water) will be discharged to the ground surface at the site of generation. If petroleum impacts/sheens are observed in any of the drill cuttings or purge water, the IDW will be containerized and transported to a central staging area for subsequent characterization and off-site disposal.

4.2.6. Surveying

All sampling locations will be surveyed for the location (northing and eastings), elevation of the ground surface, and measuring point elevation (for new monitoring wells and staff gauges). In locations where monitoring wells or staff gauges are not being installed, locations will be marked and/or staked after drilling activities have been completed to ensure the accuracy of the survey. Surveying will be measured to the nearest 0.1 foot horizontally and 0.01 foot vertically, and a reference point will be indicated by a notch or permanent marker. A Massachusetts-licensed surveyor will be contracted to perform surveying in accordance with the Massachusetts State Plane Coordinate System of the North American Datum of 1983 and vertically on the North American Vertical Datum of 1988. All measurement units will be in feet.

4.3. Risk Assessment

The 1998 HHRA concluded that there were no unacceptable human health risks associated with soils, sediment, groundwater discharge, or indoor air at AOC 69W. The only risks that exceeded USEPA thresholds were associated with the hypothetical use of groundwater as a source of residential drinking water (KGS 2020).

Because there has been no change to underlying assumptions used to prepare the HHRA and the BERA, no review of the HHRA or BERA is planned as part of the SRI.

5. Deliverables

Supplemental Remedial Investigation Report

After completion of the SRI field investigation, an SRI report will be prepared to present and evaluate the efficacy of the data for meeting the stated DQOs. The report will also include the following:

- Site description to include climate, topography, vegetation, geology, hydrology and hydrogeology, and natural resources.
- Site history and previous investigations.
- Description of the SRI field activities (i.e., groundwater sample collection).
- Results of the field activities.
- Nature and extent of contamination.
- Contaminant fate and transport.
- Findings and conclusions.
- Recommendations.

As appropriate, electronic deliverables (e.g., sample location data, analytical results) will be submitted to the Devens database. In addition, as appropriate, soil and geologic logs, cross sections, geophysical test results, laboratory data, data validation reports, and pertinent field data logs will be included as appendices to the SRI report.

6. Schedule

The actual and anticipated future project schedule is presented below in **Table 6-1**.

Table 6-1 Anticipated Project Schedule

Task	Date
Army Submits Draft AOC 69W Post-ROD Supplemental RI Work Plan to USEPA/MassDEP	11/22/21
USEPA/MassDEP Review of Draft AOC 69W Post-ROD Supplemental RI Work Plan	1/7/22
Suspension of Review by USEPA	1/20/22
Army Issues Response Letter to USEPA/MassDEP Comments on Draft AOC 69W Post-ROD Supplemental RI Work Plan	3/14/22
USEPA/MassDEP Review of Response Letter and USEPA Submits Remaining Comments on Draft AOC 69W Post-ROD Supplemental RI Work Plan (Extension Request Submitted)	4/15/22
USEPA Request for Submittal of Revised Draft AOC 69W Post ROD Supplemental RI Work Plan	4/20/22
Army Submits Revised Draft AOC 69W Post-ROD Supplemental RI Work Plan to USEPA/MassDEP	6/12/22
USEPA/MassDEP Review of Revised Draft AOC 69W Post-ROD Supplemental RI Work Plan	8/4/22
Army Issues Response Letter to USEPA/MassDEP Comments on Revised Draft AOC 69W Post-ROD Supplemental RI Work Plan	9/15/22
USEPA/MassDEP Review of Response Letter	2/1/23
Army Submits Draft Final AOC 69W Post-ROD Supplemental RI Work Plan to USEPA/MassDEP	3/3/23
USEPA/MassDEP Review of Draft Final AOC 69W Post-ROD Supplemental RI Work Plan	4/17/23
Army Submits Final Supplemental AOC 69W Post-ROD Supplemental RI Work Plan to USEPA/MassDEP	6/02/23
Field Work (tentative)	Summer 2023 – Summer 2024
Submit Draft Post-ROD Supplemental RI Report (pending field work)	Summer/Fall 2024

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Tables

Table 3-1
Historical Groundwater Monitoring Results
AOC 69W Supplemental Remedial Investigation Work Plan
Former Fort Devens Army Installation
Devens, Massachusetts

Analyte		EPH	Dissolved Metals			Field Parameters			
		C11-C22	Arsenic	Iron	Manganese	pH	SPC	ORP	DO
Unit		(µg/L)	(µg/L)	(µg/L)	(µg/L)	SU	µS/cm	mV	mg/L
Cleanup Goal*		200	10	NS	NS				
Monitoring Criteria**		NS	NS	9,100	375				
Well ID	Date								
69W-94-13	May-00	**690**	**54**	**9,800**	**2,300**	--	--	12	0.03
	Nov-00	**1,400**	**110**	**9,400**	**1,700**	--	--	-29	0.79
	May-01	**720**	**85**	7,700	**1,500**	--	--	-24	0.30
	Nov-01	**790**	**150**	**12,000**	**1,600**	--	--	-50	0.24
	May-02	**1,900**	**52**	**11,000**	**2,100**	--	--	7.0	2.9
	Nov-02	**290**	**130**	**20,000**	**2,400**	--	--	0.3	2.0
	May-03	87 U	**35**	**12,000**	**2,800**	--	--	41	0.25
	Oct-03	160	**69**	8,500	**4,100**	--	--	-23	0.48
	Apr-04	100 U	**27**	**10,000**	**2,500**	--	--	142	0.25
	Oct-04	110	**88**	7,400	**1,300**	--	--	124	0.32
	Jun-05	100 U	**56**	**11,000**	**3,000**	--	--	-15	0.62
	Nov-05	100 U	**60**	5,400	**1,600**	--	--	-120	0.30
	Jun-06	**209**	**69**	**15,000**	**2,600**	--	--	-23	0.12
	Oct-07	**311**	**142**	8,500	**1,120**	--	--	-160	0.16
	Oct-08	152	**73**	7,700	**1,940**	6.8	686	30	1.0
	Nov-09	**225**	**86**	**9,900**	**2,110**	6.5	964	-37	0.61
	Oct-10	**339**	**127**	8,400	**1,360**	6.5	631	-79	0.45
	Oct-11	**242**	**120**	**10,000**	**1,840**	6.6	891	-83	0.12
	Oct-12	**379**	**115**	8,100	**1,400**	6.7	652	-69	0.53
	Oct-13	**227**	**73**	6,600	**1,730**	6.7	850	-26	2.5
	Oct-14	**252**	**100**	**10,000**	**1,900**	6.5	520	-54	0.20
	Oct-15	175	**120**	**12,000**	**2,100**	6.6	1,800	-86	0.21
	Oct-16	**410**	**76**	**11,000**	**2,600**	6.9	1,340	-104	1.8
	Oct-17	100 U	**24**	1,000	320	6.6	1,400	140	2.7
	Oct-18	98	**35**	4,500	**1,600**	6.6	2,100	0.7	9.1
	Oct-19	77 J	**70**	7,400	**1,600**	6.6	2,400	-26	0.16
	Oct-20	50 J	**32**	3,300	**970**	6.6	1,100	-17	0.68
	Oct-21	71 U	**19**	1,500	**880**	6.6	1,750	-34	0.72
	Nov-22	95 U	**15**	950	**590**	6.5	1,010	-18	1.29
69W-94-14	May-00	110 U	8.3	1,300	300	--	--	118	0.64
	Nov-00	110 U	**12**	2,000	340	--	--	91	2.6
	May-01	100 U	5.0 U	520	**510**	--	--	114	6.1
	Nov-01	110 U	5.9	1,400	340	--	--	178	2.4
	May-02	100 U	4.5 J	1,100	320	--	--	134	2.8
	Nov-02	89 U	4.3 J	1,300	350	--	--	240	4.1
	May-03	89 U	2.2 J	550	200	--	--	181	5.1
	Oct-03	88 U	1.9 J	500	250	--	--	193	1.9
	Apr-04	120 U	5.0 U	660	360	--	--	243	0.64
	Oct-04	110 U	2.4 J	200	78	--	--	156	1.2
	Jun-05	110 U	2.6 J	690	140	--	--	94	0.78
	Nov-05	100 U	5.0 U	540	160	--	--	-41	2.5
	Jun-06	100 U	2.8 J	570	150	--	--	84	0.71
	Oct-07	102 U	5.0 U	120 U	126	--	--	83	1.9
	Oct-08	103 U	5.0 U	390	164	6.8	686	30	1.0
	Nov-09	106 U	5.0 U	320	177	4.9	559	343	1.0
	Oct-10	100 U	5.0 U	43 J	47	5.9	419	137	1.9
	Oct-11	100 U	3.0 J	50 U	29	6.0	196	80	1.4
	Oct-12	100 U	5.0 U	220	99	5.9	549	223	2.3
	Oct-13	100 U	5.0 U	5.0 U	10 U	5.8	615	154	3.8
	Oct-14	110 U	3.0 U	120	37 U	6.0	710	220	3.9
	Oct-15	100 U	4.0 U	100 U	19	5.8	900	170	3.3
	Oct-16	110 U	1.5 U	87	27	7.9	1,300	-87	3.1
	Oct-17	94 U	1.5 U	25 U	270	5.7	900	170	2.4
	Oct-18	71 U	3.8	910	320	5.7	1,200	100	0.36
	Oct-19	74 U	3.0 U	50 U	**1,200**	5.7	2,000	88	0.62
	Oct-20	71 U	3.0 U	50 U	19	5.9	740	290	3.3
	Oct-21	71 U	3.0 U	100	230	5.8	1,150	155	1.2
	Nov-22	65 U	3.0 U	39 J	27	6.0	1,140	236	3.1
69WP-08-01	Oct-08	--	--	--	174	5.7	485	-64	0.46
	Nov-09	--	--	--	89	5.8	670	135	3.9
	Oct-10	--	--	--	78	6.2	528	36	1.6
	Oct-11	--	--	--	**2,190**	6.0	419	-8.1	0.49
	Oct-12	--	5.0 U	1,800	**904**	6.1	458	-23	1.9
	Oct-13	--	2.0 J	2,900	237	5.9	677	131	5.1
	Oct-14	--	3.0 U	2,400	65	6.2	650	85	2.1
	Oct-15	--	4.0 U	5,000	78	6.3	860	-46	1.2
	Oct-16	--	1.5 U	7,100	79	6.7	470	-100	0.55
	Oct-17	--	1.5 U	4,900	33	6.4	1,200	62	1.4

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Historical Groundwater Monitoring Results
AOC 69W Supplemental Remedial Investigation Work Plan
Former Fort Devens Army Installation
Devens, Massachusetts

Analyte		EPH	Dissolved Metals			Field Parameters			
		C11-C22	Arsenic	Iron	Manganese	pH	SPC	ORP	DO
Unit		(µg/L)	(µg/L)	(µg/L)	(µg/L)	SU	µS/cm	mV	mg/L
Cleanup Goal*		200	10	NS	NS				
Monitoring Criteria**		NS	NS	9,100	375				
Well ID	Date								
69WP-08-01 (cont.)	Oct-18	--	3.0 U	6,000	35	6.2	1,400	1.0	7.0
	Oct-19	--	3.0 U	7,600	**1,300**	6.4	1,100	-19	0.35
	Oct-20	--	3.0 U	5,900	360	6.2	940	-27	0.84
	Oct-21	--	3.0 U	**11,000**	**670**	7.1	580	-113	0.01
	Nov-22	--	1.1 J	**19,000**	**1,400**	6.6	1,040	-64	1.04
69WP-13-01	Oct-13	--	--	--	235	6.3	513	-50	0.70
	Oct-14	--	--	--	49 U	6.3	700	-160	0.13
	Oct-15	--	--	--	72	6.3	1,000	-54	0.48
	Oct-16	--	--	--	140	6.7	470	-255	0.55
	Oct-17	--	--	--	62	6.6	620	21	0.79
	Oct-18	--	--	--	33	6.3	1,000	18	0.28
	Oct-19	--	--	--	88	6.3	1,100	-17	0.46
	Oct-20	--	3.0 U	**17,000**	240	6.1	730	-65	0.62
	Oct-21	--	--	--	42	6.4	730	-44	2.7
	Nov-22	--	--	--	**990**	6.4	990	-92	1.2
ZWM-01-25X	Nov-01	100 U	4.1 J	170	280	--	--	234	4.8
	May-02	100 U	5.0 U	100 U	61	--	--	147	6.8
	Nov-02	89 U	5.0 U	240	**1,000**	--	--	196	6.9
	May-03	88 U	2.3 J	59 J	89	--	--	219	6.5
	Oct-03	90 U	5.0 U	100 U	230	--	--	208	4.6
	Apr-04	100 U	5.0 U	19 J	140	--	--	601	4.2
	Oct-04	100 U	3.4 J	100 U	300	--	--	469	4.8
	Jun-05	100 U	5.0 U	38 J	140	--	--	202	4.0
	Nov-05	100 U	5.0 U	160	**490**	--	--	1.2	4.1
	Jun-06	102 U	3.0 J	520	**1,400**	--	--	230	1.6
	Oct-07	105 U	5.0	500	**3,210**	--	--	10	8.3
	Oct-08	103 U	2.3 J	190	**1,320**	6.1	290	165	1.3
	Nov-09	100 U	2.0 J	160	**5,830**	5.8	560	178	0.76
	Oct-10	100 U	5.0 U	80	**1,490**	6.1	540	162	2.5
	Oct-11	100 U	**13**	1,000	**2,820**	6.1	678	-21	0.40
	Oct-12	100 U	**19**	1,300	**2,540**	6.3	524	23	2.0
	Oct-13	100 U	5.0	250	**1,570**	6.2	510	68	4.4
	Oct-14	110 U	3.0 U	330	**435**	6.3	780	91	4.0
	Oct-15	100 U	4.0 U	100 U	**859**	6.1	930	61	2.0
	Oct-16	94 U	1.5 U	17 U	78	7.4	820	-77	5.4
	Oct-17	100 U	4.5	510	**590**	6.3	730	79	2.0
	Oct-18	71 U	2.0 J	130	**1,400**	5.9	1,400	91	0.46
	Oct-19	76 U	3.0 U	230	**6,200**	--	--	--	--
	Oct-20	82 U	2.9 J	200	**1,700**	6.0	820	130	3.3
	Oct-21	71 U	3.0 U	28 J	**540**	6.0	940	93	1.0
	Nov-22	72 U	3.0 U	50 U	**560**	6.1	880	146	6.2
ZWM-01-26X	Nov-01	100 U	5.0 U	100 U	58	--	--	252	4.8
	May-02	100 U	5.0 U	100 U	8.6 J	--	--	625	10
	Nov-02	100 U	5.0 U	100 U	15 U	--	--	290	6.0
	May-03	87 U	5.0 U	100 U	11 J	--	--	190	8.3
	Oct-03	88 U	5.0 U	100 U	85	--	--	231	2.3
	Apr-04	100 U	5.0 U	16 J	55	--	--	547	7.4
	Oct-04	110 U	5.0 U	100 U	25	--	--	207	3.0
	Jun-05	--	5.0 U	22 J	9.5 J	--	--	271	3.6
	Jun-06	--	--	--	--	--	--	412	1.8
	Oct-07	--	--	--	--	--	--	87	3.2
	Oct-08	--	--	--	--	5.8	240	192	1.4
	Nov-09	--	--	--	--	5.4	410	303	3.4
	Oct-10	--	--	--	--	5.8	422	120	4.3
	Oct-11	--	--	--	--	5.9	307	75	1.2
	Oct-12	--	--	--	--	5.8	484	223	3.6
	Oct-13	--	--	--	--	5.9	360	170	4.3
	Oct-21	--	--	--	--	6.0	670	136	7.7
	Nov-22	--	--	--	--	5.9	450	259	7.4
ZWM-95-15X	May-00	110 U	5.0 U	100 U	28	--	--	258	1.2
	Nov-00	110 U	7.9	5,100	**1,300**	--	--	38	1.7
	May-01	110 U	5.0 U	100 U	25	--	--	292	5.1
	Nov-01	110 U	**22**	4,300	100	--	--	29	0.47
	May-02	**1,400**	**36**	**11,000**	**1,500**	--	--	-23	2.9
	Nov-02	93 U	**40**	**12,000**	**2,200**	--	--	138	1.4
	May-03	85 U	5.0 U	470	**1,600**	--	--	167	2.8
	Oct-03	92 U	**16**	3,700	**970**	--	--	29	0.37

Table 3-1
Historical Groundwater Monitoring Results
AOC 69W Supplemental Remedial Investigation Work Plan
Former Fort Devens Army Installation
Devens, Massachusetts

	Analyte	EPH	Dissolved Metals			Field Parameters			
		C11-C22	Arsenic	Iron	Manganese	pH	SPC	ORP	DO
	Unit	(µg/L)	(µg/L)	(µg/L)	(µg/L)	SU	µS/cm	mV	mg/L
	Cleanup Goal*	200	10	NS	NS				
	Monitoring Criteria**	NS	NS	9,100	375				
Well ID	Date								
ZWM-95-15X (cont.)	Apr-04	88 U	7.7	**20,000**	**4,600**	--	--	132	0.47
	Oct-04	110 U	**30**	6,800	**980**	--	--	31	0.19
	Jun-05	100 U	5.0 U	450	**850**	--	--	177	1.2
	Nov-05	100 U	5.0 U	66	130	--	--	157	5.7
	Jun-06	101 U	5.0	420	**860**	--	--	115	1.3
	Oct-07	103 U	**16**	6,300	**1,230**	--	--	-20	1.0
	Oct-08	102 U	5.0 U	1,100	**438**	5.5	730	205	1.2
	Nov-09	108 U	5.0 U	1,900	**502**	5.6	1120	2.0	2.1
	Oct-10	100 U	**13**	5,000	**1,120**	5.9	606	45	0.47
	Oct-11	100 U	**41**	8,300	**1,010**	5.8	420	6.4	0.20
	Oct-12	100 U	**23**	7,400	**1,580**	5.8	395	33	0.19
	Oct-13	100 U	**17**	4,500	**1,280**	5.8	732	81	0.96
	Oct-14	100 U	**30**	7,000	**900**	5.9	280	24	0.48
	Oct-15	100 U	**19**	4,000	**840**	5.8	960	70	0.33
	Oct-16	100 J	3.7	180	17	7.5	86	-87	2.1
	Oct-17	94 U	10	550	220	6.1	420	100	0.68
	Oct-18	71 U	**18**	1,800	340	5.5	490	110	7.9
	Oct-19	74 U	**17**	2,300	**690 J**	5.8	1,300	54	0.42
	Oct-20	76 U	7.0	5,000	360	5.9	850	71	0.79
	Oct-21	70 U	**22**	5,500	**2,100**	6.8	670	-68	0.01
	Nov-22	65 U	8.9	2,900	**790**	5.8	1,190	94	1.7
ZWM-95-17X	May-00	100 U	5.0 U	220	15 U	--	--	244	4.8
	Nov-00	120 U	5.0 U	100 U	15 U	--	--	201	6.5
	May-01	110 U	5.0 U	100 U	15 U	--	--	253	7.5
	Nov-01	110 U	5.0 U	100 U	15 U	--	--	198	5.7
	May-02	100 U	5.0 U	100 U	15 U	--	--	538	6.7
	Nov-02	92 U	5.0 U	100 U	15 U	--	--	170	7.8
	May-03	85 U	2.0 J	100 U	15 U	--	--	164	8.3
	Oct-03	88 U	5.0 U	100 U	15 U	--	--	173	7.7
	Apr-04	120 U	5.0 U	20 J	1.9 J	--	--	350	8.5
	Oct-04	110 U	2.0 J	100 U	3.6 J	--	--	181	8.6
	Jun-05	100 U	5.0 U	25 J	2.3 J	--	--	209	7.9
	Jun-06	--	--	--	--	--	--	139	7.5
	Oct-07	--	--	--	--	--	--	109	5.4
	Oct-08	--	--	--	--	6.1	267	266	7.8
	Nov-09	--	--	--	--	6.1	351	248	9.0
	Oct-10	--	--	--	--	6.2	392	138	8.2
	Oct-11	--	--	--	--	6.3	461	227	8.0
	Oct-12	--	--	--	--	5.8	395	33	0.19
	Oct-13	--	--	--	--	6.4	272	135	8.70
	Oct-21	--	--	--	--	6.5	700	103	0.02
ZWM-95-18X	May-00	120 U	5.0 U	49 J	9.2 J	--	--	256	3.2
	Nov-00	110 U	5.0 U	100 U	15 U	--	--	237	7.5
	May-01	110 U	5.0 U	100 U	15 U	--	--	218	6.5
	Nov-01	100 U	5.0 U	100 U	4.4 J	--	--	313	5.4
	May-02	100 U	5.0 U	100 U	4.4 J	--	--	221	2.7
	Nov-02	96 U	5.0 U	100 U	15 U	--	--	275	7.2
	May-03	88 U	5.0 U	100 U	15 J	--	--	316	6.4
	Oct-03	92 U	5.0 U	100 U	5.5 J	--	--	206	8.0
	Apr-04	100 U	5.0 U	35 J	7.4 J	--	--	629	0.20
	Oct-04	110 U	5.0 U	17 J	6.3 J	--	--	392	5.5
	Jun-05	110 U	5.0 U	24 J	6.1 J	--	--	251	6.0
	Jun-06	111 U	5.0 U	50 U	10 U	--	--	226	6.5
	Oct-07	104 U	5.0 U	50 U	2.9 J	--	--	179	2.8
	Oct-08	102 U	5.0 U	50 U	10 U	5.8	526	294	5.4
	Nov-09	100 U	5.0 U	50 U	5.0 J	5.8	772	230	5.2
	Oct-10	100 U	5.0 U	50 U	10 U	6.0	618	163	4.1
	Oct-11	100 U	2.0 J	50 U	189	5.8	492	155	1.5
	Oct-12	100 U	5.0 U	50 U	90	6.0	521	265	3.6
	Oct-13	100 U	5.0 U	50 U	**540**	5.9	677	131	5.1
	Oct-14	110 U	3.0 U	50 U	200 U	6.0	700	240	6.2
	Oct-15	100 U	4.0 U	100 U	170	6.0	1,200	180	5.3
	Oct-16	**240**	1.5 U	17 U	12	6.1	715	-48	5.8
	Oct-17	94 U	1.5 U	25 U	29	6.0	1,000	210	2.3
	Oct-18	71 U	3.0 U	50 U	81	5.8	1,000	160	3.0
	Oct-19	77 U	3.0 U	1,400	66	5.9	1,200	200	7.7
	Oct-20	77 U	3.0 U	50 U	14	6.1	850	190	5.9

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Historical Groundwater Monitoring Results
AOC 69W Supplemental Remedial Investigation Work Plan
Former Fort Devens Army Installation
Devens, Massachusetts

Analyte		EPH	Dissolved Metals			Field Parameters			
		C11-C22	Arsenic	Iron	Manganese	pH	SPC	ORP	DO
Unit		(µg/L)	(µg/L)	(µg/L)	(µg/L)	SU	µS/cm	mV	mg/L
Cleanup Goal*		200	10	NS	NS				
Monitoring Criteria**		NS	NS	9,100	375				
Well ID	Date								
ZWM-95-18X (cont.)	Oct-21	71 U	3.0 U	50 U	110	6.5	700	103	0.02
	Nov-22	68 U	3.0 U	50 U	15	5.9	1,100	230	4.5
ZWM-99-22X	May-00	**2,500**	**150**	**21,000**	**2,000**	--	--	-46	0.03
	Nov-00	**1,400**	**130**	**14,000**	**1,800**	--	--	-30	0.52
	May-01	**2,100**	**230**	**25,000**	**2,300**	--	--	-64	0.37
	Nov-01	**370**	**140**	**16,000**	**2,400**	--	--	-26	0.52
	May-02	**620**	**86**	**13,000**	**2,000**	--	--	31	0.58
	Nov-02	**210**	**140**	**21,000**	**1,500**	--	--	-57	0.98
	May-03	**380**	**150**	**31,000**	**2,700**	--	--	-51	0.84
	Oct-03	**330**	**160**	**18,000**	**2,300**	--	--	-92	0.14
	Apr-04	**270**	**140**	**22,000**	**3,100**	--	--	13	0.20
	Oct-04	**400**	**140**	**15,000**	**1,900**	--	--	-111	0.53
	Jun-05	**320**	**120**	**24,000**	**3,400**	--	--	-58	0.21
	Nov-05	**280**	**120**	**16,000**	**3,900**	--	--	-61	0.58
	Jun-06	**627**	**159**	**28,000**	**3,700**	--	--	-37	0.18
	Oct-07	166	**244**	**12,000**	**3,120**	--	--	-151	0.45
	Oct-08	**356**	**223**	**24,000**	**3,790**	6.8	831	-32	0.60
	Nov-09	**276**	**408**	**16,000**	**2,660**	6.6	799	-142	2.3
	Oct-10	**209**	**343**	**12,000**	**1,750**	6.4	450	-79	0.15
	Oct-11	**327**	**367**	**21,000**	**2,160**	6.4	17	-81	0.30
	Oct-12	**308**	**299**	**16,000**	**1,120**	6.5	576	-101	0.18
	Oct-13	**286**	**233 J**	**15,000 J**	**998**	6.6	381	-64	1.2
	Oct-14	**332**	**172**	**20,000**	**1,280**	6.5	720	-100	0.17
	Oct-15	**354**	**125**	**21,000**	**1,440**	6.4	900	-89	0.20
	Oct-16	**210**	**150**	**18,000**	**960**	8.8	700	-110	2.1
	Oct-17	170	**190**	**24,000**	**1,200**	6.5	940	-42	0.16
	Oct-18	**230**	**150**	**19,000**	**1,500**	6.6	2,100	-48	0.26
	Oct-19	**220**	**150**	**10,000**	**1,100**	6.3	1,200	-27	0.39
	Oct-20	78 J	**130**	**13,000**	**910**	6.7	1,000	-34	0.51
	Oct-21	72 U	**140**	**11,000**	**1,300**	6.9	2,950	-81	0.91
	Nov-22	65 U	**170**	**13,000**	**850**	6.5	740	-75	1.4
ZWM-99-23X	May-00	170	**23**	8,000	**4,200**	--	--	67	0.39
	Nov-00	**520**	**70**	**11,000**	**3,600**	--	--	22	0.84
	May-01	**200**	**67**	**13,000**	**5,800**	--	--	15	0.44
	Nov-01	140	**55**	8,000	**1,500**	--	--	-23	1.5
	May-02	140	**15**	2,000	**550**	--	--	107	3.8
	Nov-02	90 U	**40**	6,500	**1,760**	--	--	18	2.7
	May-03	86 U	**27**	**11,000**	**5,300**	--	--	66	0.74
	Oct-03	87 U	**60**	7,900	**4,300**	--	--	19	0.26
	Apr-04	100 U	**44**	9,000	**2,500**	--	--	67	1.4
	Oct-04	110 U	**61**	7,400	**2,300**	--	--	7.6	0.23
	Jun-05	110 U	**46**	**13,000**	**5,200**	--	--	15	0.18
	Nov-05	100 U	**47**	8,600	**2,500**	--	--	0.7	1.0
	Jun-06	174	**56**	9,000	**2,700**	--	--	9.8	0.33
	Oct-07	107	**56**	5,800	**1,320**	--	--	-98	6.8
	Oct-08	80 J	**52**	6,500	**2,500**	6.5	480	58	0.52
	Nov-09	100 U	**62**	8,600	**3,080**	6.4	716	-62	0.62
	Oct-10	100 U	**15**	1,700	**523**	6.2	592	56	2.3
	Oct-11	100 U	**60**	5,500	**1,720**	6.5	575	-64	0.06
	Oct-12	100 U	**29**	3,000	**500**	6.5	383	-33	1.1
	Oct-13	100 U	**27**	2,800	**556**	6.6	420	-21	1.8
	Oct-14	100 U	**20**	2,500	**533**	6.6	600	-12	1.2
	Oct-15	100 U	**14**	1,800	**749**	6.3	880	-10	1.1
	Oct-16	110	7.7	1,500	**590**	8.6	420	-79	4.8
	Oct-17	96 U	**17**	2,600	**1,800**	6.4	1,100	29	0.14
	Oct-18	130	**39**	4,700	**1,600**	6.2	1,100	30	0.32
	Oct-19	73 U	**24**	3,500	**770**	6.3	1,200	6.5	0.31
	Oct-20	74 U	5.3	470	110	6.2	690	52	1.6
	Oct-21	71 U	**32**	2,800	**1,500**	6.2	960	25	0.68
	Nov-22	68 U	6.1	820	220	6.4	920	54	1.9
ZWM-99-24X	May-00	110 U	2.3 J	340	27	--	--	277	1.8
	Nov-00	100 U	5.0 U	100 U	12 J	--	--	195	1.7
	May-01	100 U	5.0 U	100 U	15 U	--	--	327	4.1
	Nov-01	100 U	5.0 U	100 U	14 J	--	--	276	2.9
	May-02	100 U	5.0 U	100 U	15 U	--	--	607	8.3
	Nov-02	86 U	5.0 U	100 U	15 U	--	--	226	4.8
	May-03	85 U	5.0 U	100 U	6.0 J	--	--	205	5.4

Table 3-1
Historical Groundwater Monitoring Results
AOC 69W Supplemental Remedial Investigation Work Plan
Former Fort Devens Army Installation
Devens, Massachusetts

Analyte		EPH	Dissolved Metals			Field Parameters			
		C11-C22	Arsenic	Iron	Manganese	pH	SPC	ORP	DO
Unit		(µg/L)	(µg/L)	(µg/L)	(µg/L)	SU	µS/cm	mV	mg/L
Cleanup Goal*		200	10	NS	NS				
Monitoring Criteria**		NS	NS	9,100	375				
Well ID	**Date**								
ZWM-99-24X (cont.)	Oct-03	90 U	5.0 U	100 U	31	--	--	191	0.37
	Apr-04	110 U	5.0 U	19 J	140	--	--	381	1.7
	Oct-04	110 U	1.7 J	100 U	8.7 J	--	--	412	0.65
	Jun-05	110 U	5.0 U	44 J	21	--	--	312	4.0
	Nov-05	110 U	5.0 U	25 J	22	--	--	20	0.30
	Jun-06	100 U	5.0 U	26 J	30	--	--	209	2.2
	Oct-07	110 U	5.0 U	80	10	--	--	72	1.4
	Oct-08	102 U	5.0 U	50 U	20	5.5	476	273	0.12
	Nov-09	111 U	5.0 U	50 U	8.9 J	5.8	561	178	0.76
	Oct-10	100 U	5.0 U	50 U	10 U	5.7	758	128	3.4
	Oct-11	100 U	5.0 U	50 U	8.0 J	5.8	405	126	0.31
	Oct-12	100 U	5.0 U	50 U	5.0 J	5.9	370	297	2.8
	Oct-13	100 U	3.0 J	50 U	10 U	5.7	620	160	3.9
	Oct-14	100 U	3.0 U	50 U	7.5 U	6.0	250	190	3.2
	Oct-15	100 U	4.0 U	100 U	15 U	5.6	880	210	2.2
	Oct-16	52 J	1.5 U	41	2.9	8.6	420	-79	4.8
	Oct-17	100 U	1.5 U	370	100	6.0	420	140	1.4
	Oct-18	89 J	3.4	700	68	5.6	250	70	0.78
	Oct-19	73 U	1.9 J	390	67	5.8	590	92	0.78
	Oct-20	74 U	3.0 U	120	39	5.8	470	200	3.3
	Oct-21	71 U	4.2	720	66	6.2	130	26	0.02
	Nov-22	65 U	3.0 U	21 J	92	5.6	530	200	2.5

24 = Above cleanup goal and/or monitoring criteria

Notes

1. '-- = Not analyzed
2. * = Cleanup Goal for arsenic is the MCL standard.
3. ** = Monitoring criteria for iron and manganese are background levels from the RI (Final Remediation Investigation Report, Area of Contamination (AOC) 69W, Devens, Massachusetts, HLA, 2000b).

Abbreviations:

µg/L = microgram per liter
µS/cm = microSiemen per centimeter
J = Estimated result
mg/L = milligram per liter
mV = millivolt
NS = no standard
ORP = oxidation-reduction potential
U = Non-detect

Table 3-2
Existing Monitoring Wells
AOC 69W Supplemental Remedial Investigation Work Plan
Former Fort Devens Army Installation
Devens, Massachusetts

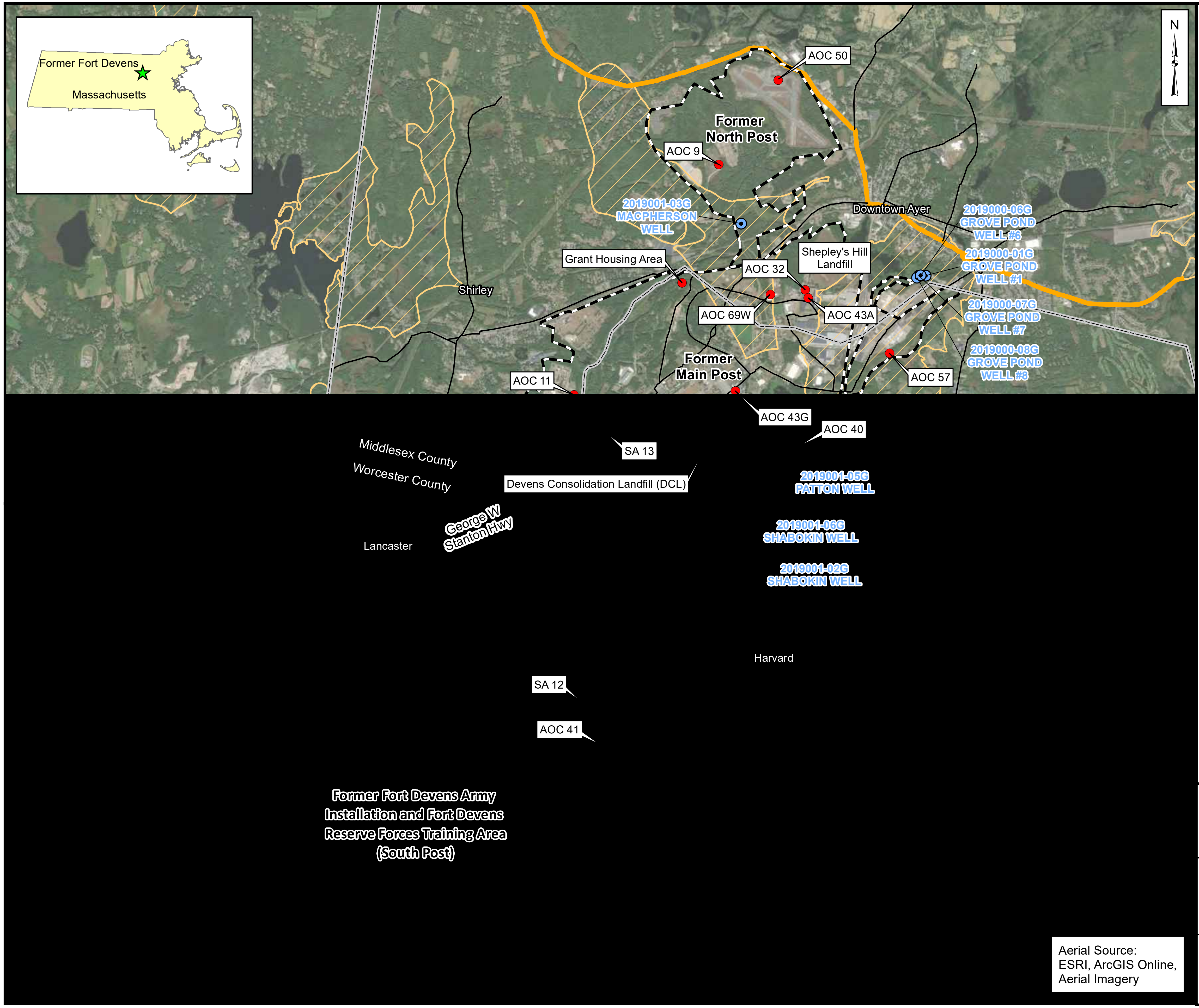
Location ID[1]	Location Description	LTM Sampling Rationale	Top of Casing Elevation	Ground Surface Elevation	Top of Screen Interval	Bottom of Screen Interval	Top of Screen Interval	Bottom of Screen Interval	DTW November 2022	GWE November 2022
			(ft NAVD88)	(ft NAVD88)	(ft BTOR)	(ft BTOR)	(ft NAVD88)	(ft NAVD88)	(ft BTOR)	(ft NAVD88)
69W-94-12	East of 69W-94-13.	LTM water level only.	228.14	225.65	3*	13*	--	--	9.53	218.61
69W-94-13	North of paved area near source area.	Source area well. Monitor for decrease in COC concentrations.	226.99	224.50	9.09	19.09	220.50	210.50	8.53	218.46
69W-94-14	Approx. 30 feet upgradient of Willow Brook wetlands.	Monitor for decrease in COC concentration and decrease in the potential for off-site migration.	227.22	224.73	5.49	15.49	221.73	211.73	9.48	217.74
69WP-08-01	Downgradient of ZWM-01-25X.	Sentry well point for manganese delineation.	NS	--	10*	13*	--	--	4.49	NS
69WP-13-01	Downgradient of 69WP-08-01.	Sentry well point for manganese delineation.	220.70	--	10*	13*	--	--	3.88	216.82
ZWM-01-25X	Downgradient well northeast of ZWM-95-15X.	Sentry well.	224.71	222.58	6.13	16.13	218.58	208.58	7.39	217.32
ZWM-01-26X	Northeast of ZWM-99-23.	LTM water level only.	226.81	224.36	6.45	16.45	220.36	210.36	8.82	217.99
ZWM-95-15X	Near former underground concrete vault.	Sentry well. Monitor for decrease in COC concentration and decrease in the potential for off-site migration.	225.01	222.14	8.74	18.74	219.14	209.14	7.45	217.56
ZWM-95-16X	Southeast of ZWM-99-22X, near loading dock.	LTM water level only.	227.58	228.21	5.67	15.67	221.91	211.91	8.01	219.57
ZWM-95-17X	Southeast of school.	Background well. Water level and quality parameters only.	237.83	235.27	14.76	24.76	223.07	213.07	16.35	221.48
ZWM-95-18X	Approx. 120 feet downgradient of the concrete vault.	Sentry well. Monitor for off-site migration.	222.15	219.93	7.44	17.44	216.93	206.93	5.50	216.65
ZWM-99-22X	Paved source area.	Replacement of destroyed well 69W-94-10. Monitor for decrease in COC concentrations.	226.72	226.89	4.66	14.66	222.09	212.09	7.71	219.01
ZWM-99-23X	Downgradient well east of Willow Brook and northeast of 69W-94-14.	Sentry well. Monitor for decrease in COC concentration and decrease in the potential for off-site migration.	225.08	223.40	6.63	16.63	220.40	210.40	7.33	217.75
ZWM-99-24X	Downgradient well east of Willow Brook and southwest of 69W-94-14.	Sentry well. Monitor for decrease in COC concentration and decrease in the potential for off-site migration.	225.85	222.83	8.54	18.54	220.33	210.33	7.69	218.16
ZWP-95-01X	Along Willow Brook, west of ZWM-99-24X.	LTM water level only.	226.04	223.63	12.41	14.41	213.63	211.63	7.88	218.16
ZWP-95-02X	West side of Willow Brook, northwest of ZWM-95-15X.	LTM water level only.	222.83	219.91	12.42	14.42	210.41	208.41	6.20	216.63

Notes:

1. * feet below ground surface

Notes:
AOC = Area of Contamination
COC = chemical of concern
ft = feet
ft BTOR = feet below top of riser
LTM = long-term monitoring
NAVD 88 = North American Vertical Datum of 1988
NS = not surveyed

Figures



Aerial Source:
ESRI, ArcGIS Online,
Aerial Imagery

AOC 69W Supplemental Remedial Investigation Work Plan
Former Fort Devens Army Installation
Devens, Massachusetts

Site Location
Former Fort Devens
Army Installation

SERES
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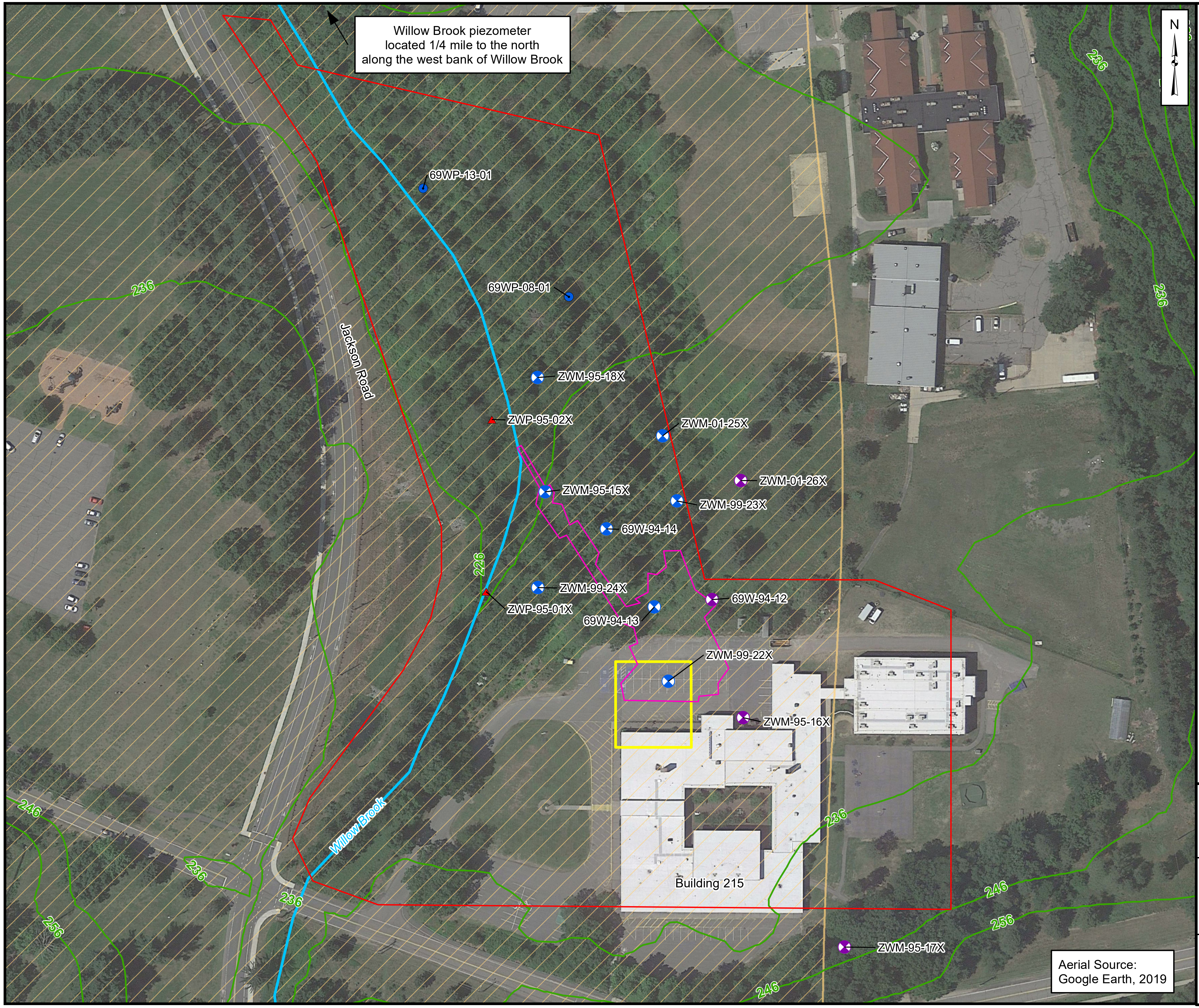
a joint venture

Figure
1-1



Legend

🟥	Parcel Boundary
●	LTM Sample Well
●	LTM Sample Well Point
●	LTM Well - Gauge Only
▲	LTM Piezometer
—	Surface Water Course
🟨	Excavated Soils Management Area
☐	Soil Excavation Limits (1997-1998)
⁄\⁄	Topographic Contour (Ft AMSL)
▨	MassDEP Zone II Wellhead Protection Area

ft AMSL = feet above mean sea level
LTM = long-term monitoring
MassDEP = Massachusetts Department of Environmental Protection

0 200 400
Feet

AOC 69W Supplemental Remedial Investigation Work Plan
Former Fort Devens Army Installation
Devens, Massachusetts

Site Layout
AOC 69W

SERES Engineering & Services, LLC
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Figure
1-2

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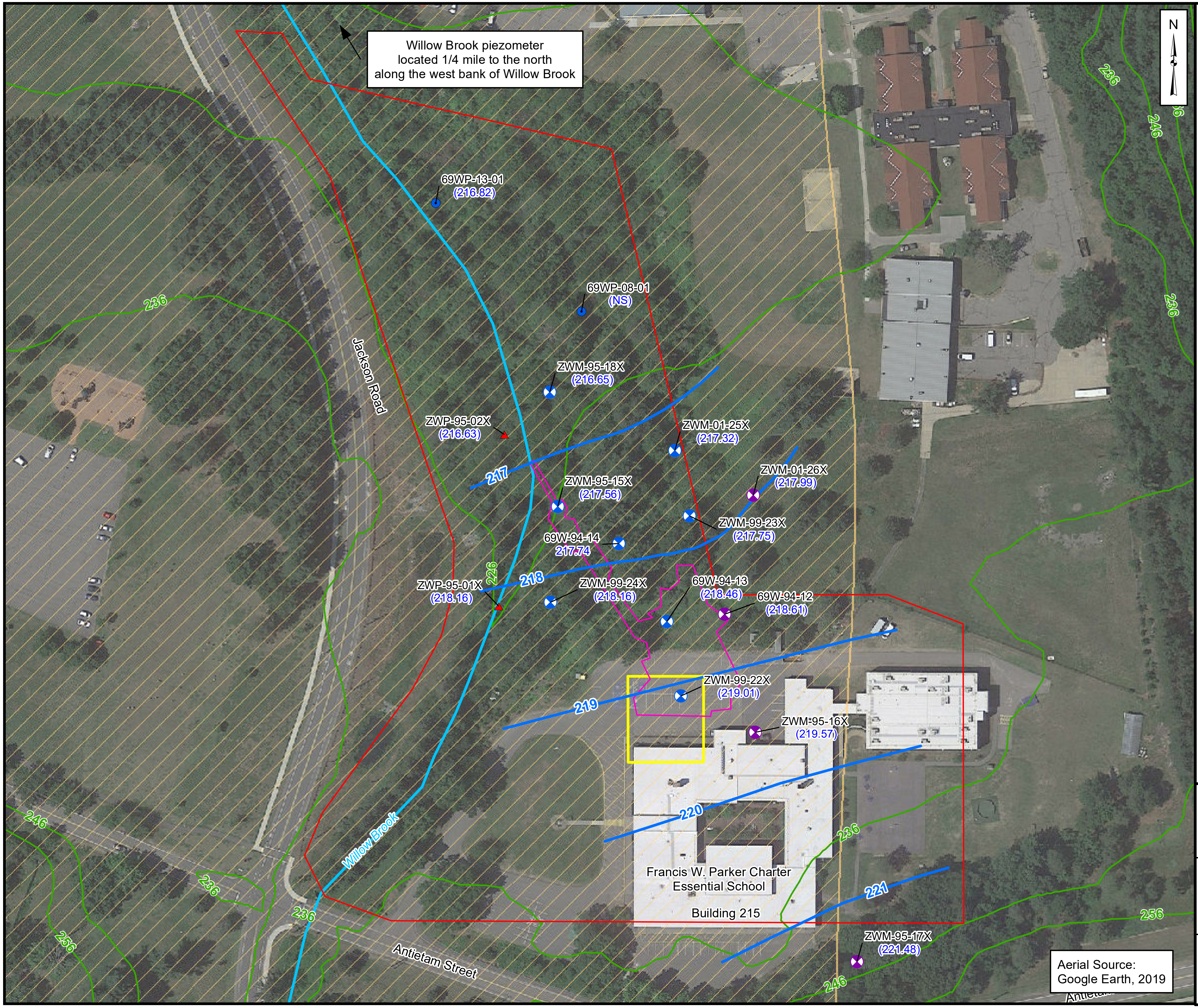

Legend

- Parcel Boundary (Parcel A15 Boundary)
- LTM Sample Well
- LTM Sample Well Point
- LTM Well - Gauge Only
- LTM Piezometer
- Surface Water Course
- Groundwater Elevation Contour (ft. NAVD88) (Contour Interval 1 ft.)
- Excavated Soils Management Area (ESMA)
- Soil Excavation Limits (1997-1998)
- Topographic Contour (ft AMSL)
- MassDEP Zone II Wellhead Protection Area
- (221.48) Groundwater Elevation (ft. NAVD88)

Note:
Boundaries and site features shown on the figure are approximate.
Historical site features digitized from historical site plan "Figure ES-1, RI Sampling Locations, AOC 69W" (Harding Lawson Associates, Inc. 1998)

AOC = area of contamination
ft AMSL = feet above mean sea level
LTM = long-term monitoring
MassDEP = Massachusetts Department of Environmental Protection
UST = underground storage tank
NS = not surveyed

0 200 400
Feet

AOC 69W Supplemental Remedial Investigation Work Plan
Former Fort Devens Army Installation
Devens, Massachusetts

Groundwater Elevation Contour Map
AOC69W
Fall 2022

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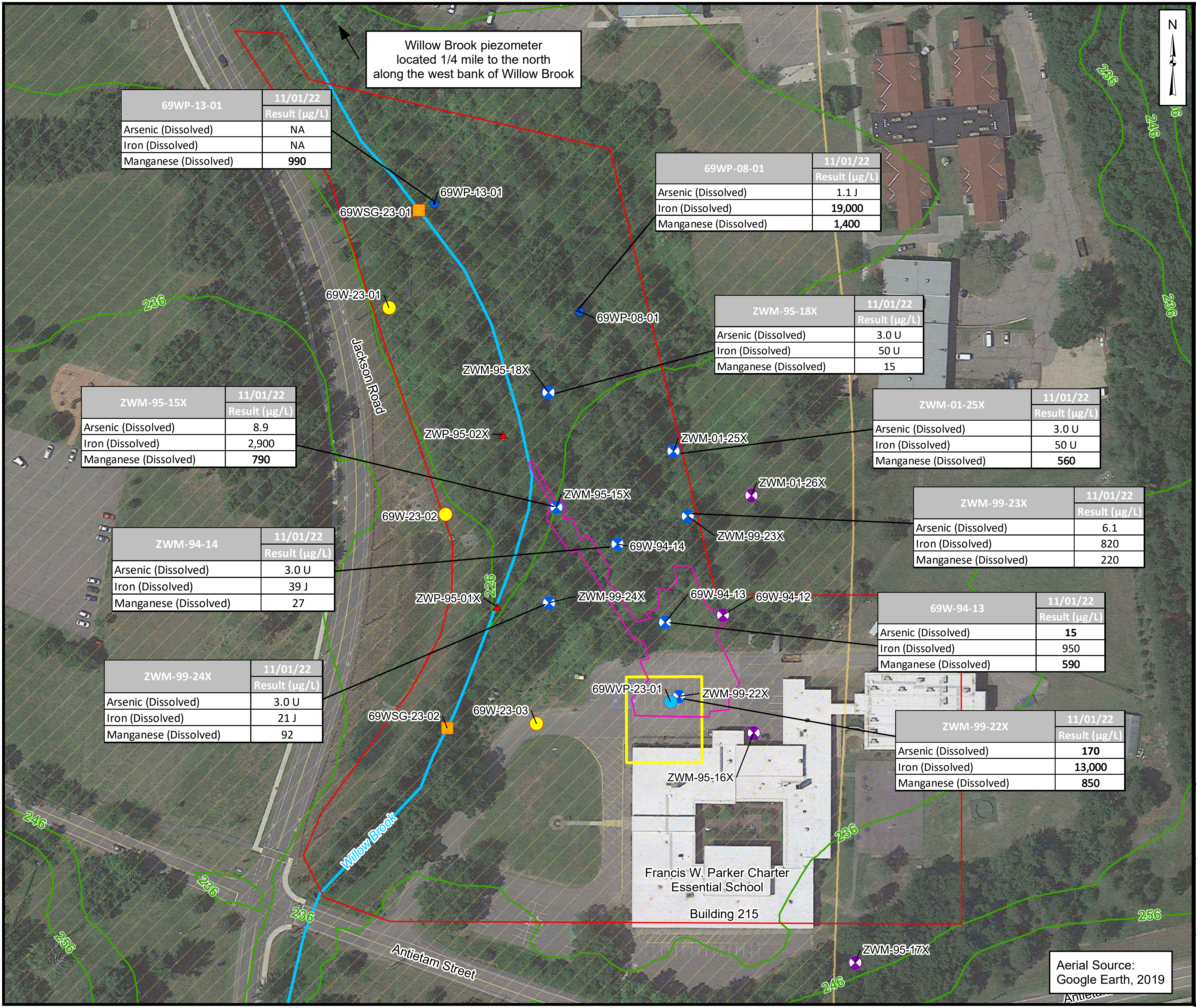
Figure
3-1

Path: T:_ENV\Devens_RFTA\Seed_Task_Order\MXDs\AOC69W Supp Rem Inv WP\Figure 3-1 - GW Elev Contour Map AOC69W.mxd

File: Figure 3-1 - GW Elev Contour Map AOC69W.mxd



69WP-13-01	11/01/22 Result (µg/L)
Arsenic (Dissolved)	NA
Iron (Dissolved)	NA
Manganese (Dissolved)	**990**

69WP-08-01	11/01/22 Result (µg/L)
Arsenic (Dissolved)	1.1 J
Iron (Dissolved)	**19,000**
Manganese (Dissolved)	**1,400**

ZWM-95-18X	11/01/22 Result (µg/L)
Arsenic (Dissolved)	3.0 U
Iron (Dissolved)	50 U
Manganese (Dissolved)	15

ZWM-95-15X	11/01/22 Result (µg/L)
Arsenic (Dissolved)	8.9
Iron (Dissolved)	2,900
Manganese (Dissolved)	**790**

ZWM-01-25X	11/01/22 Result (µg/L)
Arsenic (Dissolved)	3.0 U
Iron (Dissolved)	50 U
Manganese (Dissolved)	**560**

ZWM-99-23X	11/01/22 Result (µg/L)
Arsenic (Dissolved)	6.1
Iron (Dissolved)	820
Manganese (Dissolved)	220

ZWM-94-14	11/01/22 Result (µg/L)
Arsenic (Dissolved)	3.0 U
Iron (Dissolved)	39 J
Manganese (Dissolved)	27

69W-94-13	11/01/22 Result (µg/L)
Arsenic (Dissolved)	**15**
Iron (Dissolved)	950
Manganese (Dissolved)	**590**

ZWM-99-24X	11/01/22 Result (µg/L)
Arsenic (Dissolved)	3.0 U
Iron (Dissolved)	21 J
Manganese (Dissolved)	92

ZWM-99-22X	11/01/22 Result (µg/L)
Arsenic (Dissolved)	**170**
Iron (Dissolved)	**13,000**
Manganese (Dissolved)	**850**

Aerial Source:
Google Earth, 2019

Path: T:_ENV\Devens_RFTA\Seed_Task_Order\MXDs\AOC69W Supp Rem Inv WP\Figure 3-2 - Concentrations in Groundwater AOC69W.mxd

Legend

▭	Parcel Boundary (Parcel A15 Boundary)
⊗	LTM Sample Well
●	LTM Sample Well Point
⊗	LTM Well - Gauge Only
▲	LTM Piezometer
—	Surface Water Course
●	Proposed VAP Sampling Location
●	Proposed Monitoring Well Location
■	Proposed Stream Gauge Location
▭	Excavated Soils Management Area (ESMA)
▭	Soil Excavation Limits (1997-1998)
⁄\⁄	Topographic Contour (ft AMSL)
▨	MassDEP Zone II Wellhead Protection Area

Cleanup Goals (µg/L)	
Arsenic (Dissolved)	10
Monitoring Criteria (µg/L)	
Iron (Dissolved)	9,100
Manganese (Dissolved)	375

Note:
1. Bold concentrations indicate exceedances of Groundwater Cleanup Goals
2. AOC 69W lies within the MassDEP Zone II Wellhead protection Area for the MacPherson well

ft AMSL = feet above mean sea level
LTM = long-term monitoring
MassDEP = Massachusetts Department of Environmental Protection
U = not detected
J = estimated value
µg/L = micrograms per liter

0 200 400
Feet

AOC 69W Supplemental Remedial Investigation Work Plan
Former Fort Devens Army Installation
Devens, Massachusetts

Metals Concentrations in Groundwater
AOC69W
Fall 2022

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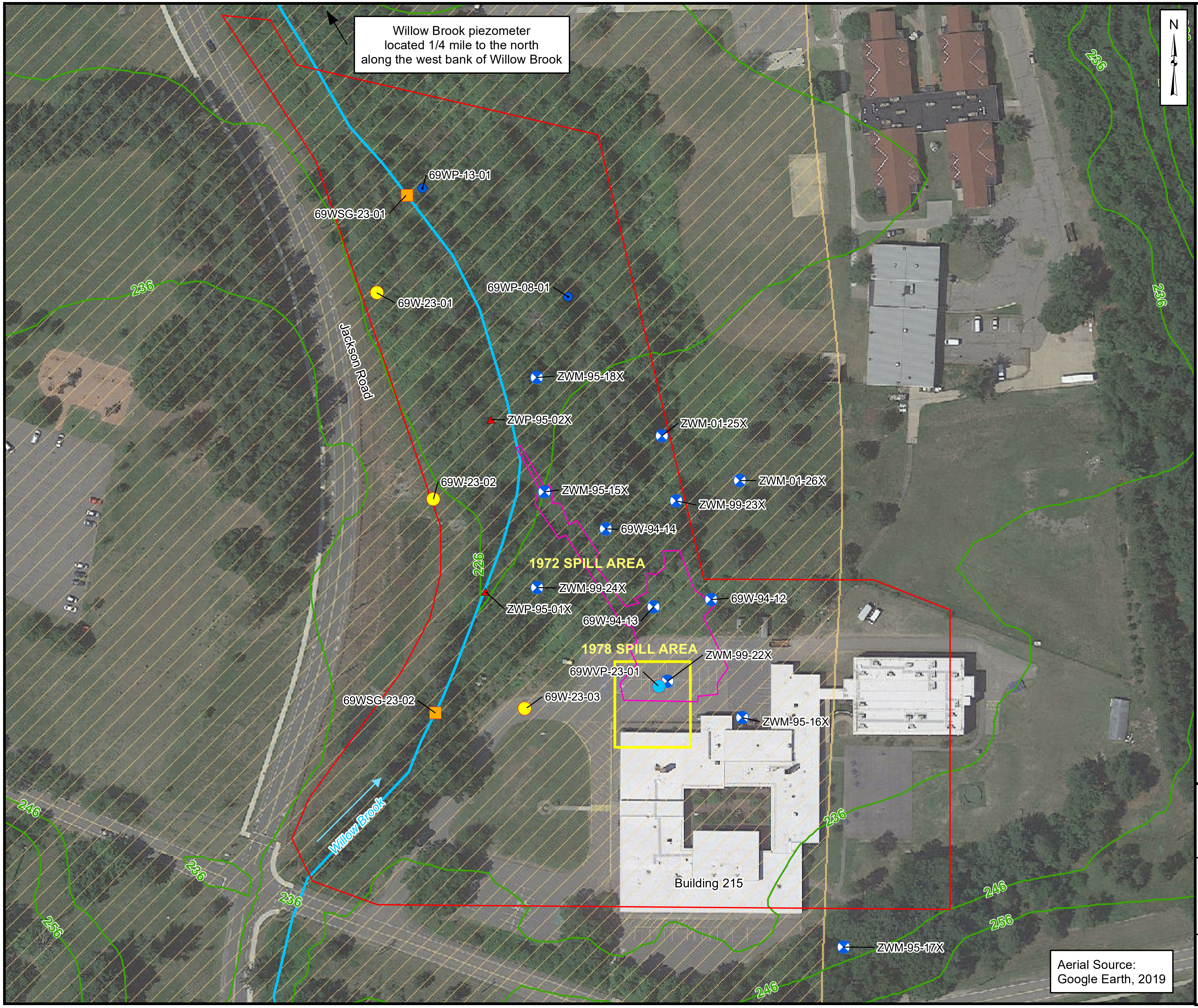
Figure
3-2

File: Figure 3-2 - Concentrations in Groundwater AOC69W.mxd



Aerial Source:
Google Earth, 2019

Legend

🟥	Parcel Boundary
⊗	LTM Sample Well (to be sampled)
●	LTM Sample Well Point (to be sampled)
▲	LTM Piezometer (to be sampled)
●	Proposed VAP Sampling Location
●	Proposed Monitoring Well Location
■	Proposed Stream Gauge Location
—	Surface Water Course
☐	Excavated Soils Management Area
☐	Soil Excavation Limits (1997-1998)
∧	Topographic Contour (ft AMSL)
▨	MassDEP Zone II Wellhead Protection Area

ft AMSL = feet above mean sea level
LTM = long-term monitoring
MassDEP = Massachusetts Department of Environmental Protection

0 200 400
Feet

AOC 69W Supplemental Remedial Investigation Work Plan
Former Fort Devens Army Installation
Devens, Massachusetts

Proposed Investigation Locations
AOC 69W

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Figure
4-1

Path: T:_ENV\Devens_RFTA\Seed_Task_Order\MXDs\AOC69W Supp Rem Inv WP\Figure 4-1 - Proposed Locations.mxd

File: Figure 4-1 - Proposed Locations.mxd

Appendix A

AOC 69W QAPP Addendum

VERSION 3

FINAL ADDENDUM

UNIFORM FEDERAL POLICY FOR QUALITY ASSURANCE PROJECT PLAN - ANNUAL LONG-TERM MONITORING AND MAINTENANCE PROGRAM

POST – RECORD OF DECISION SUPPLEMENTAL REMEDIAL INVESTIGATION – AOC 69W

FORMER FORT DEVENS ARMY INSTALLATION
DEVENS, MASSACHUSETTS

JUNE 2023

Contract No. W912WJ-19-D-0014
Task Order No. W912WJ-21-F-0060

Prepared For:

U.S. ARMY CORPS OF ENGINEERS, NEW ENGLAND DISTRICT
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Introduction

The SERES-Arcadis Joint Venture (JV), Limited Liability Company (LLC)[1] (hereafter referred to as the S-A JV) prepared this Draft Addendum to the Uniform Federal Policy for Quality Assurance Project Plan (UFP-QAPP) – Annual Long-Term Monitoring and Maintenance Program (QAPP Addendum) under Contract No. W912WJ-19-D-0014, Contract Delivery Order No. W912WJ-21-F-0060. This QAPP Addendum) is directed by and used in conjunction with the UFP-QAPP, Annual Long-Term Monitoring and Maintenance Program (LTMMP QAPP; SERES-Arcadis JV 2020) at the former Fort Devens Army Installation (Devens), located in Devens, Massachusetts (**Figure 1-1**). This QAPP Addendum provides detailed information on the execution of the field activities to be conducted as part of a Post – Record of Decision (ROD) supplemental remedial investigation (SRI) at a long-term-monitoring (LTM) site area of contamination (AOC) 69W at Devens.

All samples collected will be sent to the Eurofins Savannah laboratory for analysis. Results of the investigation will be used to confirm the Army Protectiveness Statement for AOC 69W in the 2020 Five-Year Review Report (KOMAN Government Solutions, LLC [KGS] 2020) by assessing the short- and long-term protectiveness of the ongoing remedial actions at the site. Environmental investigation at the former Fort Devens is governed by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); therefore, results of the SRI will be submitted to state and federal regulatory agencies for review as part of the CERCLA process.

UFP-QAPP worksheets are developed to systematically document the planning process, sampling rationale, sampling protocols, and quality assurance (QA)/quality control (QC) procedures included in the CERCLA investigation process.

Only Worksheets modified for the SRI are included in this QAPP Addendum.

Worksheet 2 provides cross-references to the location of CERCLA-required content within this QAPP Addendum that has been modified from the LTMMP QAPP. Elements of the LTMMP QAPP that were not modified and are not included in the QAPP Addendum are indicated as Not Applicable (NA). The LTMMP QAPP and this QAPP Addendum were developed with the understanding that unanticipated conditions may dictate a change in the plan as currently written.

Staff who will be participating in project and field efforts are required to read this plan and understand the objectives of the work to be performed, as well as the procedures to be used for conducting the field investigation, performing the laboratory analyses, and evaluating and reporting the data that are collected. In addition, key personnel are responsible for mentoring assigned staff in aspects of this QAPP Addendum potentially impacting their assigned work to ensure project activities are executed in accordance with the plan.

Project Goals

As stated above, the objective of the SRI is to confirm the Army Protectiveness Statements in the 2020 Five-Year Review Report (KGS 2020) by assessing the short- and long-term protectiveness of the ongoing remedial actions at the site. To support these objectives, the goals of the SRI field activities are to:

---

[1] The SERES-Arcadis JV is composed of protégé firm SERES Engineering & Services, LLC (SERES) and its mentor Arcadis U.S., Inc. (Arcadis).

- Confirm the current lateral and vertical extent of EPH, arsenic, iron, and manganese to assess contaminant distribution and possible off-site migration and assess concentration trends over time.
- Confirm the conceptual site model (CSM), including the residual petroleum remaining in groundwater and aquifer conditions (including reducing conditions and associated impacts on naturally occurring arsenic concentrations).

The objectives of this QAPP are to generate project data that are technically valid, legally defensible, and useful in meeting the project goals. The SRI will collect data sufficient to meet USACE and regulatory requirements and support remedial alternative decisions, if needed. The technical approach for the SRI is designed to achieve the data quality objectives (DQOs) listed in **Worksheet #11**.

The following attachments are provided to supplement the information presented in this QAPP Addendum:

Attachment A	Field Sampling Standard Operating Procedures
Attachment B	Laboratory Standard Operating Procedures

TABLE OF CONTENTS

LIST OF FIGURES

ATTACHMENTS

LIST OF ACRONYMS AND ABBREVIATIONS

1,4-DCB	1,4-dichlorobenzene
µg/L	microgram per liter
AAFES	Army Air Force Exchange Service
ABB	ABB Environmental Services, Inc.
AOC	area of contamination
Army	U.S. Army
bgs	below ground surface
BRAC	Base Realignment and Closure
BTEX	benzene, toluene, ethylbenzene, and xylenes
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
Charter School	Francis W. Parker Charter Essential School
CMR	Code of Massachusetts Regulations
CoC	chain-of-custody
COC	contaminant of concern
CSM	conceptual site model
Devens	Former Fort Devens Army Installation
DO	dissolved oxygen
DOC	dissolved organic carbon
DoD	Department of Defense
DQO	data quality objective
EDD	electronic database deliverable
EM	Engineer Manual
EPH	extractable petroleum hydrocarbons
ESD	Explanation of Significant Differences
FD	field duplicate
FS	feasibility study
HAZWOPER	Hazardous Waste Operations and Emergency Response
HGL	HydroGeoLogic, Inc.
HLA	Harding Lawson Associates
ICP-MS	inductively coupled plasma-mass spectrometry
JV	Seres-Arcadis JV
KGS	Koman Government Solutions, LLC
LLC	Limited Liability Company
LOD	limit of detection
LTM	long-term monitoring
LTMMP	Long-Term Monitoring and Maintenance Program
MassDEP	Massachusetts Department of Environmental Protection
MassDevelopment	Massachusetts Development and Finance Agency
MCP	Massachusetts Contingency Plan
µg/L	micrograms per liter
MS	matrix spike
MSD	matrix spike duplicate
NA	not applicable
NAVD 88	North American Vertical Datum of 1988
NFA	No Further Action
No.	Number
ORP	oxidation-reduction potential

PCB	polychlorinated biphenyl
PM	project manager
POC	point of contact
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
RG	remedial goal
RI	remedial investigation
ROD	Record of Decision
SOP	standard operating procedures
SPLP	synthetic precipitation leaching procedure
Sovereign	Sovereign Consulting, Inc.
TBD	to be determined
TGI	technical guidance instruction
TOC	total organic carbon
UFP-QAPP	Uniform Federal Policy for Quality Assurance Project Plans
U.S.	United States
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
UST	underground storage tank
VAP	vertical aquifer profile
VPH	volatile petroleum hydrocarbons
Weston	Roy F. Weston, Inc.

QAPP WORKSHEET #1 AND #2: TITLE AND APPROVAL PAGE

This worksheet identifies the principal points of contact for all organizations having decision authority in the project and documents their commitment to implement the UFP-QAPP. Signatories usually include the Project Manager (PM) and QA Manager, and individuals with approval or oversight authority. Signatures indicate that officials have reviewed the UFP-QAPP and concur with the implementation as written. It is the lead organization's responsibility to make sure all signatures are in place before work begins.

1. Project Identifying Information:
    a. Site name/project name: Former Fort Devens Army Installation (Devens), Supplemental Remedial Investigations
    b. Site location: Devens, Massachusetts
    c. Contract/work assignment number: Seres Engineering & Services, LLC - Arcadis U.S., Inc. Joint Venture (Seres-Arcadis JV) W912WJ-19D-0014, Task Order W912WJ-21-F-0060, Environmental Services and Remedial Action Operations for BRAC Legacy Sites – Former Fort Devens, Devens, Massachusetts
    d. Lead Organization: USEPA Region 1 and USACE
    e. Geographical Corps District: New England District
2. Department of Defense Organization(s):
    a. U.S. Army (Army), Base Realignment and Closure (BRAC)
        i. Name: Thomas Lineer
        ii. Title: BRAC Environmental Coordinator
    b. USACE, New England District
        i. Name: Penelope Reddy
        ii. Title: USACE PM
3. Contractor: SERES-Arcadis JV
    a. SERES-Arcadis JV PM
        i. Name: Andy Vitolins, Professional Geologist
        ii. Title: SERES-Arcadis JV PM
    b. SERES-Arcadis JV Corporate QA Manager
        i. Name: John Nocera, Professional Engineer
        ii. Corporate Quality Manager

4. Federal Regulatory Agency: USEPA Region I
5. State/Territory Regulatory Agency: Massachusetts Department of Environmental Protection (MassDEP)
6. Other Stakeholders:
    a. Massachusetts Development and Finance Agency (MassDevelopment)
    b. Restoration Advisory Board
    c. Local Residents and Businesses
7. Plans and reports from previous investigations in the following table:

2020	Five Year Review. Former Fort Devens Army Installation, Devens, Massachusetts	KGS
2015	Long Term Monitoring and Maintenance Plan – Former Fort Devens Army Installation and Sudbury Annex. March.	Sovereign Consulting Inc.(Sovereign)/HydroGeo Logic, Inc. (HGL)
2015	2015 Five-Year Review Report for Former Fort Devens Army Installation, BRAC Legacy Sites, Devens, Massachusetts.	KGS
1998	Remedial Investigation Report, Area of Contamination (AOC) 69W, Devens, Massachusetts, Vol. I and II. April.	ABB Environmental Services, Inc. (ABB).
1999	Record of Decision, Area of Contamination (AOC) 69W, Devens, Massachusetts.	Harding Lawson Associates (HLA)

Required UFP-QAPP elements that have been modified or are not included in the LTMMP QAPP are indicated in the table below with their location within this QAPP Addendum. Required UFP-QAPP elements that are included in the LTMMP QAPP and do not need modification for SRIs are indicated as "not applicable" (NA):

Worksheet #	**Required Information**	**Reference to Related Information**
A. Project Management and Objectives		
Documentation		
1	Title and Approval Page	Page 1
2	UFP-QAPP Identifying Information	Page 1
3	Distribution List	Page 5
4	Project Personnel Sign-Off Sheet	NA
Project Organization		
5	Project Organizational Chart	NA
6	Communication Pathways	NA
7	Personnel Responsibilities and Qualifications Table	NA
8	Special Personnel Training Requirements Table	NA
Project Planning/Problem Definition		

Worksheet #	**Required Information**	**Reference to Related Information**
9	Project Scoping Session Participants Sheet	NA
10	Problem Definition	Page 6
11	Project Quality Objectives/Systematic Planning Process Statements	Page 10
12	Measurement Performance Criteria Table	NA
13	Secondary Data and Limitations Table	NA
14	Summary of Project Tasks	Page 13
15	Reference Limits and Evaluation Table	Page 14
16	Project Schedule/Timeline Table	Page 13
B. Measurement/Data Acquisition		
Sampling Tasks		
17	Sampling Design and Rationale	Page 15
18	Sampling Locations and Methods/SOP Requirements Table Sample Location Map(s)	Page 19
19	Analytical Methods/SOP Requirements Table	Page 22
20	Field QC Sample Summary Table	Page 23
21	Project Sampling SOP References Table	Page 24
22	Field Equipment Calibration, Maintenance, Testing, and Inspection Table	NA
Analytical Tasks		
23	Analytical SOPs Analytical SOP References Table	Page 25
24	Analytical Instrument Calibration Table	NA
25	Analytical Instrument and Equipment Maintenance, Testing, and Inspection Table	NA
Sample Collection		
26	Sample Handling System, Documentation Collection, Tracking, Archiving and Disposal, and Custody SOPs Sample Handling Flow Diagram	NA
27	Sample Custody Requirements	NA
Quality Control Samples		
28	Laboratory QC Samples Table	Page 26
Data Management Tasks		
29	Project Documents and Records Table	NA
30	Analytical Services Table	Page 22
C. Assessment Oversight		

Worksheet #	**Required Information**	**Reference to Related Information**
31	Planned Project Assessments Table	NA
32	Assessment Findings and Corrective Action Responses Table	NA
33	QA Management Reports Table	NA
D. Data Review		
34	Verification (Step I) Process Table	NA
35	Validation (Steps IIa and IIb) Process Table	NA
36	Validation (Steps IIa and IIb) Summary Table	NA
37	Data Usability Assessment Table	NA

QAPP WORKSHEET #3: DISTRIBUTION LIST

QAPP Recipients	Title	Organization	Telephone Number	E-mail Address
Alex Lo	Program Manager	JV	(843) 388-7804	ahlo@seres-es.com
Andy Vitolins	PM	JV	(518) 461-3145	Andy.Vitolins@arcadis.com
John Nocera	Corporate Quality Control (QC) Manager	JV	(251) 405-4560	john.nocera@arcadis.com
Grey Coppi	Health and Safety Manager	JV	(732) 661-3851	grey.coppi@arcadis.com
Ian Martz	Field Operations Lead	JV	(978) 322-4526	ian.martz@arcadis.com
Theresa Cansler	Task Lead	JV	(518)528-8347	Theresa.cansler@arcadis.com
Jennifer Singer	Project Chemist	JV	(716) 667-6664	jennifer.singer@arcadis.com
Heather Levesque	Contract PM	JV	(619) 370-0374	halevesque@seres-es.com
Jerry Lanier	Laboratory PM	Eurofins TestAmerica - Savannah	(912) 250-0281	jerry.lanier@et.eurofinsus.com
Pei Geng	Data Validation PM	Laboratory Data Consultants, Inc (LDC)	(760) 827-1110	pgeng@lab-data.com
Penelope Reddy	PM	USACE	(978) 318-8160	penelope.reddy@usace.army.mil
Yixian Zhang	Project Chemist	USACE	(978) 318-8730	yixian.zhang@usace.army.mil
Tom Lineer	BRAC Environmental Coordinator	U.S. Army (Army)	(703) 545-2487	thomas.a.lineer.civ@mail.mil
Michael Daly	Remedial PM	USEPA Region I	(617) 918-1386	daly.mike@epa.gov
Joanne Dearden	Federal Sites Program	MassDEP	(617) 292-5788	joanne.dearden@state.ma.us

QAPP WORKSHEET #10: CONCEPTUAL SITE MODEL

10.1. AOC 69W Site Description and History

AOC 69W is located at the site of the former Fort Devens Elementary School (Building 215), the associated parking lot, and adjacent lawn extending approximately 300 feet northwest to Willow Brook (**Figure 1-1**).

In 1951, the Fort Devens Elementary School was built at the northeast corner of the intersection of Jackson Road and Antietam Street on the northern portion of the former Main Post. The school was operated and maintained by the Ayer School Department. The building was heated by an oil-fired boiler, and the heating oil was stored in a 10,000-gallon underground storage tank (UST) located in what is currently the school courtyard. In 1972, an addition to the school was built, forming the current school structure. The original building forms the east/southeast half of the present school. Although a new boiler room was constructed, the old boiler room remained operational. During construction of the addition, the original 10,000-gallon UST was removed, and a new 10,000-gallon UST was installed north of the school in the middle of the current parking lot. During the UST installation, the underground fuel line leading to the new boiler room was accidentally crimped, causing the pipe to leak approximately 7,000 to 8,000 gallons of No. 2 fuel oil to the ground. As a result of the fuel release, an oil recovery system was installed in the vicinity of the 10,000-gallon UST. The system consisted of underground piping connected to a buried 250-gallon concrete vault that acted as an oil/water separator. In 1978, underground fuel piping near the original boiler room failed at a pipe joint. Approximately 7,000 to 8,000 additional gallons of oil were released into the soil during the incident. Soil was excavated to locate the source of the release and approximately 2,600 gallons of residual oil was pumped from the oil recovery system. In 1993, the Ayer School Department closed the Fort Devens Elementary School because the facility was no longer needed (Roy F. Weston, Inc. [Weston] 1998). A historical site plan showing the Former Devens Elementary School and associated site features (boiler room, soil removal excavation area, former underground fuel line, former underground concrete vault) is provided in Appendix B of the AOC 69W Post – ROD SRI Workplan.

The former Fort Devens Elementary School was reopened in September 2000 as the Francis W. Parker Charter Essential School (Charter School), and currently occupies the site. The U.S. Army (Army) finalized the Findings of Suitable Transfer for AOC 69W in November 2006 and the property was formally transferred from Army ownership to MassDevelopment in August 2007.

10.2. Site Constituents of Concern

Petroleum discharges to ground occurred at AOC 69W in 1972 and again in 1978, both times due to a failure in the piping from a heating oil UST. While a removal action in 1998 excavated the majority of the petroleum-contaminated soil, residual petroleum remained in the soil on-site.

Table 10-1 AOC 69W Groundwater Monitoring Levels

Analyte	Original Screening	Current Action Levels (µg/L) [b]	Selection Basis
VPH			
C5-C8 Aliphatics	300	NA	MCP [b] (ROD)
C9-C12 Aliphatics	700	NA	MCP [b] (ROD)
C9-C10 Aromatics	200	NA	MCP [b] (ROD)
EPH			
C9-C18 Aliphatics	1,000	700	MCP [b] (ROD)
C19-C36 Aliphatics	5,000	14,000	MCP [b] (ROD)
C11-C22 Aromatics	200	200	MCP [b] (ROD)
Semivolatile Compounds			
Bis(2-eylhexyl)phthalate	6	NA	MCL (2000 LTMP)
Metals (dissolved)			
Arsenic	10.5 [c]	10	MCL (ROD)
Iron	9,100 [c]	9,100 [c]	Background [c] (2000 LTMP)
Manganese	291 [c]	375 [d]	MCL (2008 LTMP)

Note:
MCL =Maximum Contaminant Level (USEPA)
µg/L = micrograms per liter
a. Screening levels as noted in 2000 LTMP (HLA).
b. MCP 2021 https://www.mass.gov/regulations/310-CMR-4000-massachusetts-contingency-plan
c. Background concentrations determined from 10 wells at select locations on base (HLA 1998).
d. The 2008 LTM Plan (HGL) updated the cleanup goal for manganese to the approved MCL for a child.

The current LTM program for AOC 69W (Sovereign/HGL 2015) identifies the groundwater contaminants of concern (COCs) as EPH carbon fractions and arsenic, with the monitoring criteria based upon the lower of the MassDEP site-specific monitoring criteria or the Massachusetts Contingency Plan (MCP) GW-1 groundwater standard (310 Code of Massachusetts Regulations [CMR] 40 Subpart P). Manganese and iron (not identified as COCs in the AOC 69W Record of Decision (ROD) are monitored in the LTM program as indicators of degradation.

10.3 Key Physical Aspects of the Site

10.3.1 Site Groundwater Hydrology

The depth to groundwater at AOC 69W ranges from approximately 1-foot below ground surface (bgs) (adjacent to Willow Brook) to approximately 13 feet bgs (south/upgradient of the Charter School), with an average depth of approximately 6 feet bgs, Groundwater flow direction is predominately to the north-northwest. Vertical gradients have not been calculated historically, as there are no deep overburden wells at the site; however, the intermittent discharge to Willow Brook indicates the potential for locally upward gradients. Calculated groundwater flow velocities are consistent with the observed sandy soils with a maximum calculated flow velocity of 2 feet/day and a mean flow velocity of 0.7 feet/day (ABB 1998). AOC

69W is located within the delineated Zone II for the MacPherson production well located approximately 3,000 feet to the north, and downgradient of AOC 69W (KGS 2020).

10.3.2 Site Geology

The predominant soil type at AOC 69W consists of dark yellowish-brown fine to coarse sands, gravely sands, and silty sands. Explorations in the vicinity of Willow Brook and its associated wetlands revealed a 4- to 5-foot layer of dark grayish-brown, sandy silt overlying the sands. Organic material, believed to be from undisturbed native peat deposits, has been observed in the area north of the Charter School at a maximum depth of 4 feet bgs. Shallow subsurface soils beneath the Charter School and parking lot area consist of reworked native soils. During the remedial investigation in 1998, bedrock was not encountered in any of the soil borings or monitoring well installed at the site which reached depths of up to 25 feet (ABB 1998).

10.4 Primary Release Mechanism/Fate and Transport Consideration

As presented in the 1998 RI, the primary route of contaminant migration at AOC 69W are releases of fuel oil to surface and subsurface soils then transport via leaching to groundwater. The release of fuel oil caused the historical EPH concentrations in groundwater and observed concentrations of associated geochemical indicators of degradation (arsenic, iron, and manganese). While overall arsenic concentrations have remained consistent throughout the historical LTM sampling events, limited arsenic detections in downgradient areas demonstrates the attenuation of arsenic.

10.5 Study Questions

Specific study questions for AOC 69W and the proposed scope to address them include:

- What is the current lateral and vertical extent of the petroleum-related COC, EPH, in groundwater?
- What is the current lateral and vertical extent of the geochemical-related COCs (arsenic, iron, and manganese) in groundwater?
- Are EPH, arsenic, iron, and manganese currently present in groundwater at concentrations above action levels and /or that present a current or potential human health risk?
- Is there a stable or decreasing trend of EPH, arsenic, iron, and manganese in groundwater?
- Are current reducing aquifer conditions associated with a petroleum release or are they naturally occurring?

Using data collected during the SRI, the following questions will be asked:

- **Is there sufficient data to confirm the current lateral and vertical extent of the petroleum-related COC, EPH, in groundwater (i.e., are locations with samples exceeding screening criteria bounded by samples from locations not exceeding screening criteria)?**
    - If yes, no additional sampling is required during the SRI to confirm the current lateral and vertical extent of arsenic and EPH.
    - If no, collect additional data as needed.

- **Is there sufficient data to confirm the current lateral and vertical extent of the geochemical-related COCs, arsenic, iron, and manganese, in groundwater (i.e., are locations with samples exceeding screening criteria bounded by samples from locations not exceeding screening criteria)?**
    - If yes, no additional sampling is required during the SRI to confirm the current lateral and vertical extent of arsenic, iron, and manganese.
    - If no, collect additional data as needed.
- **Is there sufficient data to evaluate/identify current and potential human health risks? Are samples collected from locations representative of exposure scenarios evaluated?**
    - If yes, no additional sampling is required during the SRI.
    - If no, collect additional data as needed.
- **Does data indicate a stable or decreasing trend of EPH, arsenic, iron, or manganese in groundwater?**
    - If yes for a decreasing trend, no additional sampling is required, LTM remedy is protective, and the analyte may be recommended for reduced monitoring.
    - If yes for a stable trend below screening criteria, no additional sampling is required, LTM remedy is protective, and the analyte may be suitable for reduced monitoring or removal from LTM program.
    - If yes for a stable trend above screening criteria, additional sampling may be required, but the analyte may be suitable for reduced monitoring.
    - If no, LTM for the analyte will continue.
- **Is there sufficient data to determine if reducing aquifer conditions associated with a petroleum release are occurring?**
    - If yes, no additional sampling is required during the SRI.
    - If no, collect additional data as needed.

QAPP WORKSHEET #11: DATA QUALITY OBJECTIVES

The Data Quality Objectives (DQOs) are qualitative and quantitative statements that clarify study objectives, define the appropriate type of data, and specify the tolerable levels of potential decision errors that are used as the basis for establishing the quality and quantity of data needed to support decisions. The JV utilized the DQO guidelines established in the Data Quality Objectives Process for Hazardous Waste Site Investigations, *EPA QA/G-4 HW (January 2000) EPA/600/R-00/007* (USEPA 2000) to develop the DQOs for the SRI activities at Devens, as summarized in the tables below:

DQO	AOC 69W Former Fort Devens Elementary School Spill Site					
Problem Statement	**Project Goals**	**Information Inputs**	**Study Boundaries**	**Decision Rules**	**Performance Criteria**	**Plan for Obtaining Data**
Define the problem that necessitates this study	*Identify study questions*	*Identify data and information needed to answer study questions*	*Specify the spatial and temporal boundaries.*	*Define the conditions under which the data will be utilized.*	*Specify the limits on decision errors*	*Design an effective data collection strategy based on previous steps*
Is the remedy selected in the AOC 69W ROD still protective of human health?	1. What is the current lateral and vertical extent of the petroleum-related COC, EPH, in groundwater? 2. What is the current lateral and vertical extent of the geochemical-related COCs (arsenic, iron, and manganese) in groundwater? 3. Are EPH, arsenic, iron, and manganese currently present in groundwater at	The information inputs are required to accomplish the project goals are: • All information reviewed/gathered to date including historical information, the results of previous investigations, and previous remedial actions completed. • Analytical data from environmental media, specifically, groundwater samples.	The general areal boundary for the SRI is AOC 69W.	• All samples will be collected and analyzed in accordance with the LTMMP QAPP and QAPP Addendum technical guidance instruction (TGI) and Standard operating procedures (SOPs) documents to ensure that subsequent decisions are made based on valid data. • Presence/ absence of analytes will be based on the laboratory limits of detection (LODs) presented in the LTMMP QAPP in Worksheet #15.	The Data Usability Assessment Process will be used to limit decision errors based on field and analytical data. Project-specific MPCs, which are the criteria that collected data must meet to satisfy the DQOs, are presented in **Worksheet #12**.	The plan for obtaining the data necessary to meet the goals of the SRI is presented in **Section 4.0** of the AOC 69W Post-ROD SRI Work Plan

DQO	AOC 69W Former Fort Devens Elementary School Spill Site					
Problem Statement	**Project Goals**	**Information Inputs**	**Study Boundaries**	**Decision Rules**	**Performance Criteria**	**Plan for Obtaining Data**
	concentrations above action levels and /or that present a current or potential human health risk? 4. Is there a stable or decreasing trend of EPH, arsenic, iron, and manganese in groundwater? 5. Are current reducing aquifer conditions associated with a petroleum release or are they naturally occurring?					

Data previously collected during LTM field activities at the site have been reviewed, and the CSM and data screened against the DQOs established in the site-specific SRI Work Plan for the site. Data gaps to be addressed and the field investigation activities planned are discussed in **Worksheet #17**. The proposed sampling locations and analytical parameters are summarized in **Worksheet#18**. Standard operating procedures (SOPs) and technical guidance instruction (TGI) for field sampling and analytical procedures are summarized in **Worksheet #21** (*Field SOPs*). The field SOPs are provided in **Attachment A**.

Data generated from field activities will be documented using a digital data management approach to reduce the time needed for field data to be collected, reviewed, acted upon, and reported. Mobile technology and an enterprise platform will be used to collect and host the data. Digital data collection will include (but is not limited to) chain-of-custody (CoC) forms, field notes, groundwater sampling and gauging logs, and site photographs. In addition, notes from critical project meetings and telephone conversations will be filed. PDF copies of all field records will be stored electronically in the JV project network.

Laboratory data will be reported in analytical packages (produced in PDF format) that will, at a minimum, contain all necessary information to allow for validation in accordance with the USEPA Stage 2B as described in Guidance for Labeling Externally Validated Laboratory Analytical Data for Superfund Use (USEPA 2009) and U.S. Department of Defense (DoD) General Data Validation Guidelines (DoD, November 2019) (see **Worksheets #34 through #36** of the LTMMP QAPP). Electronic database deliverables (EDDs) will meet the requirements of Automated Data Review A1 and A3 files. All EDDs will be uploaded and stored on the Former Fort Devens electronic data management system portal. Field data and observations will be recorded in bound logbooks or electronically on sampling log sheets. Well stabilization parameters will be recorded on pre-printed field sheets.

USACE, USEPA, MassDEP, JV and stakeholders will use the data to support the project-specific decisions to be made, as outlined in **Worksheet #10**.

QAPP WORKSHEET #14 & 16: PROJECT TASKS AND SCHEDULE

The general project schedule, including the specific task/activity and the person or group responsible for execution is provided in the following table. The SRI schedule, including planning document preparation and field activities, report preparation, and meeting support, are presented in **Attachment B** of this QAPP. Note that the schedules are subject to updates and revisions based on field conditions.

Activity	Responsible Party	Deliverable(s)	Deliverable due date
DFW 1: Pre-Mobilization Activities			
Final Post-ROD SRI Work Plan and QAPP Addendum	Andy Vitolins *SERES-Arcadis JV PM*	Draft and Draft Final Work Plan and QAPP Addendum Submittals	One week after resolution of Draft Final Work Plan and QAPP Addendum comments.
DFW 2: Mobilization/Site Preparation			
Mobilization	Ian Martz *SERES-Arcadis JV Field Supervisor*	Field notes, Daily QC Report	Weekly submittals due Friday of the week following performance of the activity.
DFW 3: Environmental Data Collection			
Field Activities	Theresa Cansler *SERES-Arcadis JV Task Manager*	Data Package, including data validation summary	Twelve weeks after completion of field activities.
DFW 4: Final Report			
Draft Post-ROD SRI Report	Andy Vitolins *SERES-Arcadis JV PM*	Draft Post-ROD SRI Report	Approx. one year after completion of field activities.
Draft Final/Final Post-ROD SRI Report	Andy Vitolins *SERES-Arcadis JV PM*	Draft Final/Final Post-ROD SRI Report	45 days after receipt of Draft/Draft Final comment resolution.

QAPP WORKSHEET #15: REFERENCE LIMITS AND EVALUATION TABLE

Analyte	**CAS #**	**Laboratory Specific Reporting Limits**				**Precision (%) (RPD)**	**Recovery Limits (%) (LCS/MS/MSD)**	
		LOQ	**LOD**	**DL**	**Units**		**Low**	**High**
Metals by USEPA 3050B/6020B								
Aluminum	7429-90-5	10.0	5.00	2.10	mg/kg	20	78	124
Arsenic	7440-38-2	0.500	0.300	0.100	mg/kg	20	82	118
Iron	7439-89-6	25.0	10.0	3.50	mg/kg	20	81	124
Manganese	7439-96-5	1.00	0.300	0.120	mg/kg	20	85	116
SPLP Metals by USEPA 1312/6020B								
Aluminum	7429-90-5	200	100	35.0	µg/L	20	84	117
Arsenic	7440-38-2	5.00	3.00	0.860	µg/L	20	84	116
Iron	7439-89-6	100	75.0	26.0	µg/L	20	87	118
Manganese	7439-96-5	10.0	5.00	2.20	µg/L	20	87	115

Notes:
µg/L = micrograms per liter
CAS = Chemical Abstract Service
DL = detection limit
LCS = laboratory control sample
LOQ = limit of quantitation
LOD = limit of detection
mg/kg = milligrams per kilogram
MS = matrix spike
MSD = matrix spike duplicate
RPD = relative percent difference
SPLP = Synthetic Precipitation Leaching Procedure
USEPA = United States Environmental Protection Agency

QAPP WORKSHEET #17: SAMPLING DESIGN AND RATIONALE

Supplemental Remedial Investigation

As stated in the Introduction, the primary goal of the SRI field activities is to confirm the Army Protectiveness Statements for AOC 69W in the 2020 Five-Year Review Report (KGS 2020) by assessing the short- and long-term protectiveness of the ongoing remedial actions at each site.

17.1 Overall Investigation Approach Rationale

This worksheet describes the design for data collection and documents Step 7 of the DQO process. For each general field task, this section summarizes the data gap, the rationale for data collection, and the approach for filling the data gap. The general process for the investigation will consist of collection of sufficient groundwater data to confirm the lateral and vertical extent of contamination, assess contaminant distribution, and assess aquifer conditions (including reducing conditions and associated impacts on metals concentrations).

Groundwater sampling will be conducted in accordance with the following updated SOPs, which replace SOP-003 (Water Level Measurement), SOP-004 (Groundwater Sampling), SOP-005 (Field Decontamination Procedures), SOP-006 (Sample Handling, CoC Forms, and Shipping), and SOP-007 (Low-Flow Sampling) included with the LTMMP QAPP (see also **Worksheet #21**):

- **RI-SOP-03:** USEPA – *Low Stress (low flow) Purging and Sampling Procedure for the Collection of Groundwater Samples from Monitoring Wells*, (Rev #4, 19 September 2017)
- **RI-SOP-05:** SERES-Arcadis TGI – *Ground Penetrating Radar* (Rev #6, 8 February 2023)
- **RI-SOP-06:** SERES-Arcadis TGI – *Manual Water-Level and NAPL Monitoring* (JV; Rev #2, 5 April 2022)
- **RI-SOP-07:** SERES-Arcadis TGI – *In-Situ and Ex-Situ Water Quality Parameters – Surface Water and Groundwater* (Rev #1, 15 April 2022)
- **RI-SOP-08:** SERES-Arcadis TGI - *Sample Chain of Custody* (Rev #3, 28 March 2022)
- **RI-SOP-09:** SERES-Arcadis TGI - *Investigation-Derived Waste Handling and Storage* (Rev #1, 15 May 2020)
- **RI-SOP-10:** SERES-Arcadis TGI - *Groundwater and Soil Sampling Equipment Decontamination* (Rev#2, 14 June 2022)
- **RI-SOP-11:** SERES-Arcadis TGI - *Monitoring Well Development* (Rev #1, 12 April 2022)
- **RI-SOP-13:** SERES-Arcadis TGI - *Soil Description* (Rev #4, 14 June 2022)
- **RI-SOP-15:** SERES-Arcadis TGI – *Vertical Aquifer Profile (VAP) Sampling,* (Rev #2, 15 June 2022)
- **RI-SOP-16:** SERES-Arcadis TGI – *Monitoring Well Installation* (Rev #1, 23 June 2022)

- **RI-SOP-17:** SERES-Arcadis TGI – *Soil Drilling and Sample Collection* (Rev #2, 8 April 2022

17.1.1 Soil Boring Installation and Vertical Aquifer Profiling

Continuous logging of overburden soils will be conducted using direct-push methods at the proposed VAP and monitoring well locations. An S-A JV field geologist will oversee the work and record soil lithology. Consistent with environmental investigation protocols, and because drilling is occurring in areas with historical petroleum impacts, soil will be screened for volatile organic compounds with a photoionization detector (PID) every 1 foot at the continuous logging locations. Soil descriptions will be recorded in accordance with the Unified Soil Classification System. The following will be recorded from each soil core at a minimum: depth interval, recovery, particle size, sorting, angularity/plasticity/dilatancy, principal and minor components, moisture, consistency/density, and color. When possible, the recovered soil cores will be photographed.

Soil samples will be collected from the proposed VAP location and analyzed for EPH; one sample from within the top two feet of the soil column, and one sample from the interval immediately above the water table. A third soil sample will be collected (if needed) from the interval with greatest apparent petroleum impacts and/or highest PID readings.

Additional soil samples will be collected from the saturated/proposed screen interval zones (i.e., within the top 10 feet of saturated soil) of the three proposed monitoring well locations, and from the corresponding interval at the proposed VAP location. Each soil sample will be submitted for an SPLP leach test via USEPA Method 1312 with analysis of arsenic, aluminum, iron, manganese, and pH on the leachate. The same samples will also be submitted for acid digestion via USEPA Method 3050B (coupled with EPA Method 6020A) for analysis of arsenic, aluminum, iron, and manganese.

Groundwater samples will be collected from the VAP location via a retractable well screen, which is advanced with 1-inch steel drilling rods (SP-22 or similar). The “top-down” approach will be used (i.e., samples collected as the borehole is drilled to minimize the potential for cross-contamination) starting at the water table; samples will be collected in 5-foot intervals for the first 15 feet, and then in 10-foot intervals for the remainder of the boring. A peristaltic or bladder pump setup with dedicated tubing will be used, and a minimum of three casing volumes will be purged prior to sample collection. It is anticipated that the VAP boring will extend to a total depth of 50 feet bgs, or until refusal is encountered (whichever comes first).

The VAP location will be abandoned using natural collapse and/or tremie-grout techniques, depending on borehole conditions after removal of drilling tools. All drilling will be completed by a licensed Massachusetts driller under the oversight of a JV geologist and will be conducted in accordance with all promulgated state and federal laws.

17.1.2 Monitoring Well Installation and Development

Monitoring wells will be installed using direct-push or hollow stem auger techniques, depending on the specific drilling location. Continuous soil logging will be performed during drilling. Monitoring wells will be constructed of 2-inch-diameter schedule 40 polyvinyl chloride (PVC) with 10-foot-long screen

(10-slot size [0.010-inch]). Screen depths will be selected based on the observed depth to groundwater, and screens will be installed to "straddle" the water table.

Filter packs, seals, and surface completions will be completed consistent with Massachusetts guidance. The wells will be completed flush with the surface grade encased by a 2-foot by 2-foot concrete pad and secured using an 8-inch protective roadbox or 4-inch-diameter steel standpipe. Well construction details (included the materials used) will be recorded by an S-A JV field geologist. The measuring points and well labels will be marked with an indelible ink pen on both the inner and outer well casings or inside the roadbox lid. All drilling and well construction will be completed by a licensed Massachusetts driller under the oversight of a SERES-Arcadis JV geologist and will be conducted in accordance with all promulgated state and federal laws. All well locations will be surveyed by a licensed Massachusetts surveyor for northing, easting, and ground/top of casing elevations.

Each monitoring well will be developed using a submersible pump and surge block to remove fines and improve the hydraulic connection of the well with the native formation.

17.1.3 Groundwater Sampling and Water Level Measurements

In addition to the collection of groundwater samples from the VAP location, groundwater samples will also be collected from newly installed monitoring wells and all existing monitoring wells and piezometers. Samples will be collected in accordance with the TGI. Groundwater sampling will be completed on a quarterly basis for one year (four sampling events), and a synoptic water level gauging event will be conducted prior to each sampling event to confirm groundwater flow direction. The events will include the staff gauges (69WSG-23-01 & -02) which will be useful in evaluating the interaction between surface water and groundwater.

To evaluate redox status and attenuation potential, samples from the VAP location and monitoring wells will be analyzed for the following additional parameters (in addition to EPH and dissolved arsenic, iron, and manganese identified in the Main Post LTMMP):

- **Total and dissolved aluminum**, to assess the potential for presence of sub-0.45-micron particulates. Aluminum is anticipated to exhibit extremely low solubility at the observed groundwater pH. The presence of total aluminum would therefore indicate suspended particulates present in the groundwater sample, while the presence of dissolved aluminum correlated to total aluminum would indicate the presence of very fine (sub-0.45-micron) particulates.

- **Total arsenic, iron, and manganese**. Total arsenic will be collected as an additional line of evidence regarding potential for suspended particulates affecting COC concentrations. Total iron/manganese will be collected to evaluate redox status and arsenic attenuation potential via iron coprecipitation upon reoxidation.

- **TOC, sulfate, sulfide, nitrite, and nitrate**, to assess redox status and residual reducing potential. TOC will contribute to ongoing reducing potential by consuming dissolved oxygen (potentially limiting iron reoxidation and extending the timeframe for arsenic, iron, and manganese attenuation), while comparison of sulfate concentrations inside and outside of the historical petroleum hydrocarbon impacts may inform extent of historical sulfate reduction. If sulfate reduction has occurred, sulfide minerals in the formation may further extend time for attenuation of arsenic. Nitrate/nitrate samples will be used to further assess geochemical conditions as they relate to the potential for metals dissolution.

In addition to the above parameters, DO, ORP, specific conductance, temperature, turbidity, and pH, will be collected during sampling at each VAP location and monitoring well location. Field parameter stabilization requirements will be followed for each monitoring well location, and stabilization will be attempted at the VAP sampling locations.

QAPP WORKSHEET #18: SAMPLING LOCATIONS AND METHODS

Worksheet#17 describes the planned sampling for the SRI at AOC 69W. Sampling locations and analyses for the evaluation are summarized below.

Sampling Location	Sample Media /Sample Depth /Screening Interval (feet below ground surface)	Sample ID [a]	EPH +PAHs	Total Metals [a]	Dissolved Metals [b]	Sulfate, Sulfide, Nitrate, Nitrite, Methane	TOC	SPLP + Acid Digestion [C]	Sample Type	Sampling SOP Reference	Rationale for Sampling Location
Existing monitoring wells	Groundwater samples will be collected in accordance with the methodologies outlined in the LTMMP QAPP	69W-94-12(DDMMYY)	X	X	X	X	X		Discrete	RI-SOP-03, RI-SOP-06, RI-SOP-07, RI-SOP-08, RI-SOP-09, & RI-SOP-10	Downgradient
		69W-94-13(DDMMYY)									Downgradient
		69W-94-14(DDMMYY)									Downgradient
		69WP-08-01(DDMMYY)									Downgradient
		69WP-13-01(DDMMYY)									Downgradient
		ZWM-01-25X(DDMMYY)									Downgradient
		ZWM-01-26X(DDMMYY)									Downgradient / Crossgradient
		ZWM-95-15X(DDMMYY)									Downgradient
		ZWM-95-16X(DDMMYY)									Crossgradient
		ZWM-95-17X(DDMMYY)									Upgradient
		ZWM-95-18X(DDMMYY)									Downgradient
		ZWM-99-22X(DDMMYY)									Former Release Area
		ZWM-99-23X(DDMMYY)									Downgradient

Sampling Location	**Sample Media /Sample Depth /Screening Interval (feet below ground surface)**	**Sample ID [a]**	**EPH +PAHs**	**Total Metals [a]**	**Dissolved Metals [b]**	**Sulfate, Sulfide, Nitrate, Nitrite, Methane**	**TOC**	**SPLP + Acid Digestion [C]**	**Sample Type**	**Sampling SOP Reference**	**Rationale for Sampling Location**
		ZWM-99-24X(DDMMYY)									Downgradient / Crossgradient
		ZWP-95-01X(DDMMYY)									Downgradient / Crossgradient
		ZWP-95-02X(DDMMYY)									Downgradient / Crossgradient
New monitoring wells	Groundwater samples will be collected in accordance with the methodologies outlined in the LTMMP QAPP	69W-23-01 (DDMMYY)	**X**	**X**	**X**	**X**	**X**		Discrete	RI-SOP-03, RI-SOP-06, RI-SOP-07, RI-SOP-08, RI-SOP-09, & RI-SOP-10	downgradient
		69W-23-02 (DDMMYY)									downgradient / crossgradient
		69W-23-03 (DDMMYY)									crossgradient
Soil sampling	Soil samples will be collected from within the 10 feet of saturated soil	69W-23-01 (DDMMYY) to 69W-23-03 (DDMMYY)	**X**	**X**				**X**	Discrete	RI-SOP-8, RI-SOP-9, RI-SOP-10, RI-SOP-13, RI-SOP-17	See RI WP text
New VAP point	Groundwater samples will be collected in accordance with the methodologies outlined in the PFAS QAPP	69WVP-23-01 (DDMMYY)	**X**	**X**	**X**	**X**	**X**		Discrete	RI-SOP-03, RI-SOP-05, RI-SOP-06, RI-SOP-07, RI-SOP-08, RI-SOP-09, RI-SOP-10, RI-SOP-15	Former Release Area

Sampling Location	Sample Media /Sample Depth /Screening Interval (feet below ground surface)	Sample ID [a]	EPH +PAHs	Total Metals [a]	Dissolved Metals [b]	Sulfate, Sulfide, Nitrate, Nitrite, Methane	TOC	SPLP + Acid Digestion [C]	Sample Type	Sampling SOP Reference	Rationale for Sampling Location
Soil sampling	Soil samples will be collected from within the 10 feet of saturated soil	69WVP-23-01 (DDMMYY)	**X**					**X**	Discrete	RI-SOP-8, RI-SOP-9, RI-SOP-10, RI-SOP-13, RI-SOP-17	See RI WP text

NOTE:
NA = not analyzed
[a] = Total Metals= aluminum and arsenic.
[b] = Dissolved Metals= aluminum, iron, arsenic, and manganese. Dissolved samples will be field-filtered
[c] = SPLP and acid digestion will be completed for analysis of arsenic, aluminum, iron, manganese, and pH

QAPP WORKSHEET #19 AND 30: SAMPLE CONTAINERS, PRESERVATION AND HOLD TIMES

Matrix	**Analytical Group**	**Analytical / Preparation Method SOP Reference**	**Laboratory**	**Containers** (number, size, and type)	**Preservation Requirements** (chemical, temperature, light protected)	**Maximum Holding Time**[1] (preparation / analysis)
Soil	Metals	EPA 3050B/6020B (SOP SA-ME-051, SA-ME-074)	Eurofins Savannah	4-ounce plastic or glass soil jar	Cool ≤ 6 degrees Celsius (°C)	Digested and analyzed within 6 months of collection
SPLP	Metals	EPA 1312/6020B (SOP SA-EX-015, SA-ME-074)	Eurofins Savannah	4-ounce plastic or glass soil jar	Cool ≤ 6°C	Leach within 6 months of collection; analyze within 6 months of leach

QAPP WORKSHEET #20: FIELD QC SAMPLE QUANTITIES AND CONTROL FREQUENCIES

Matrix/ Analysis	**Estimated Parent Sample Quantity**[a]	**Field QC Sample**						**Laboratory QC Sample**				**Total**
		Field Duplicate		**Field Blank**		**Equipment Blank**		**Matrix Spike**		**Matrix Spike Duplicate**		
		Freq	**Number**	**Freq**	**Number**	**Freq**	**Number**	**Freq** [b]	**Number**	**Freq** [b]	**Number**	
Groundwater												
VPH/BTEX, EPH/PAHs	**80**	1/10	8	1/cooler	5	1/day	1	1/20	4	1/20	4	**102**
Metals - Total	**80**	1/10	8	NA	0	NA	0	1/20	4	1/20	4	**96**
Metals - Dissolved	**80**	1/10	8	NA	0	NA	0	1/20	4	1/20	4	**96**
Sulfate	**80**	NA	0	NA	0	NA	0	NA	0	NA	0	**80**
TOC	**80**	NA	0	NA	0	NA	0	NA	0	NA	0	**80**
Nitrate/Nitrite	**80**	NA	0	NA	0	NA	0	NA	0	NA	0	**80**
Methane	**80**	NA	0	NA	0	NA	0	NA	0	NA	0	**80**
Soil												
VPH/BTEX, EPH/PAHs	**12**	1/10	1	1/cooler	1	1/day	1	1/20	1	1/20	1	**17**
SPLP (Metals)	**4**	NA	0	NA	0	NA	0	NA	0	NA	0	**4**
Acid Digestion (Metals)	**4**	NA	0	NA	0	NA	0	NA	0	NA	0	**4**

Notes:

a. Sample quantities are approximate and assume four rounds of quarterly sampling.
b. Frequency for MS/MSD samples is 1 per 20 field samples, not including field blanks and field duplicates.

QC = quality control
NA = not applicable
*Field blanks and equipment blanks will be submitted concurrent with groundwater samples.

QAPP WORKSHEET #21: PROJECT SAMPLING SOP REFERENCES TABLE

The field SOPs associated with the project sampling are listed in the following table and provided in **Attachment A**.

SOP# or Reference	Title, Revision Date, and/or Number	Originating Organization	Equipment Type (if SOP provides different options)	Modified for Field Work? (Yes/No)
RI-SOP-03	Low Stress (low flow) Purging and Sampling Procedure for the Collection of Groundwater Samples from Monitoring Wells (Rev #4, 19 September 2017)	USEPA	NA	No
RI-SOP-05	Ground Penetrating Radar (Rev #6, 8 February 2023)	SERES-Arcadis JV	NA	No
RI-SOP-06	Manual Water-Level and NAPL Monitoring (Rev #2, 5 April 2022)	SERES-Arcadis JV	NA	No
RI-SOP-07	In-Situ and Ex-Situ Water Quality Parameters – Surface Water and Groundwater (Rev #1, 15 April 2022)	SERES-Arcadis JV	NA	No
RI-SOP-08	Sample Chain of Custody (Rev #3, 28 March 2022)	SERES-Arcadis JV	NA	No
RI-SOP-09	Investigation-Derived Waste Handling and Storage (Rev #1, 15 May 2020)	SERES-Arcadis JV	NA	No
RI-SOP-10	Groundwater and Soil Sampling Equipment Decontamination (Rev #2, 14 June 2022)	SERES-Arcadis JV	NA	No
RI-SOP-11	Monitoring Well Development (Rev #1, 12 April 2022)	SERES-Arcadis JV	NA	No
RI-SOP-13	Soil Description (Rev #4, 14 June 2022)	SERES-Arcadis JV	NA	No
RI-SOP-15	Vertical Aquifer Profiling (JV; Rev #2, 15 June 2022)	SERES-Arcadis JV	NA	No
RI-SOP-16	Monitoring Well Installation (JV; Rev #1, 23 June 2022).	SERES-Arcadis JV	NA	No
RI-SOP-17	Soil Drilling and Sample Collection (JV; Rev #2, 8 April 2022)	SERES-Arcadis JV	NA	No

QAPP WORKSHEET #23: ANALYTICAL STANDARD OPERATING PROCEDURE REFERENCES

SOP #	Title, Revision Date, and/or Number	Definitive or Screening Data	Matrix/ Analytical Group	Instrument	Organization Performing Analysis	Modified for Project Work? (Yes/No)
SA-EX-015	Toxicity Characteristic Leaching Procedure (TCLP) and Synthetic Precipitation Leaching Procedure (SPLP) (Methods: EPA 1311 and EPA 1312), Rev. 17, 9/27/2022	Definitive	SPLP Metals	Not applicable (NA) – sample preparation method	Eurofins Savannah	No
SA-ME-051	Soil Preparation Procedures for ICP and ICP/MS (Methods: EPA 3050B, EPA 3051A, and DI Leach by ASTM D3987-85), Rev. 16, 8/26/2022	Definitive	Metals	NA – sample preparation method	Eurofins Savannah	No
SA-ME-074	Elements by ICP-MS (Methods: EPA 200.8, EPA 6020A, and EPA 6020B), Rev. 16, 2/1/2023	Definitive	Metals	Inductively Coupled Plasma-Mass Spectrometry (ICP-MS)	Eurofins Savannah	No

QAPP WORKSHEET #28: LABORATORY QC SAMPLES TABLE

Matrix: Soil
Analytical Group: Metals
Analytical Method/SOP Reference: EPA 6020B / SA-ME-074

QC Sample	Frequency/ Number	Method/SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
Method Blank (MB)	1/ Preparatory Batch (20 samples)	No Target Compounds> ½ LOQ and greater than 1/10 the amount measured in any sample or 1/10 the regulatory limit (whichever is greater). Common lab contaminants: no analytes detected > LOQ.	If sufficient sample is available, reanalyze samples. Qualify data as needed. Report results if sample results >10x blank result or sample results ND.	Analyst	Accuracy/Bias-Contamination	No Target Compounds>1/2 LOQ
LCS	1/Preparatory Batch (20 samples)	QSM limits (if available) or current in-house limits if no QSM limits published.	If LCS has high bias, and samples non-detect, report with case narrative comment. If LCS has low bias, evaluate and reprepare and reanalyze the LCS and all samples in the associated prep batch for failed analytes, if sufficient sample material is available. Marginal exceedances allowed unless analyte is specified risk driver.	Analyst	Accuracy/Bias	QSM or Laboratory % Recovery / RPD Control Limits

QC Sample	Frequency/ Number	Method/SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
MS/MSD	1 pair/Preparatory Batch (20 samples)	Recovery: QSM limits (if available) or current in-house limits if no QSM limits published. RPD: RPD between MS and MSD ≤ 20%	If MS fails, consult project-specific DQOs and contact client to see if additional measures need to be taken. For specific analyte(s) in parent sample, apply J-flag if acceptance criteria are not met. If MS falls outside LCS limits, evaluate data to determine the source of the difference and to determine if there is a matrix effect or analytical error.	Analyst	Accuracy/Bias/ Precision	QSM or Laboratory % Recovery / RPD Control Limits
Dilution Test	One per preparatory batch if MS or MSD fails. Only applicable for samples with concentrations >50 x LOQ.	Five-fold dilution must agree within ± 10% of the original determination	If dilution test fails analyze post digestion spike.	Analyst	Accuracy/Bias/ Precision	NA
Post Digestion Spike Addition	When dilution test fails or analyte concentration of all samples < 50 x LOQ	Recovery within 80-120% of expected results	For specific analyte(s) in the parent sample, apply J-flag if acceptance criteria are not met.	Analyst	Accuracy/Bias	NA
Method of Standard Additions	When dilution test or post digestion spike fails and if required by the project	NA	NA	Analyst		NA

REFERENCES

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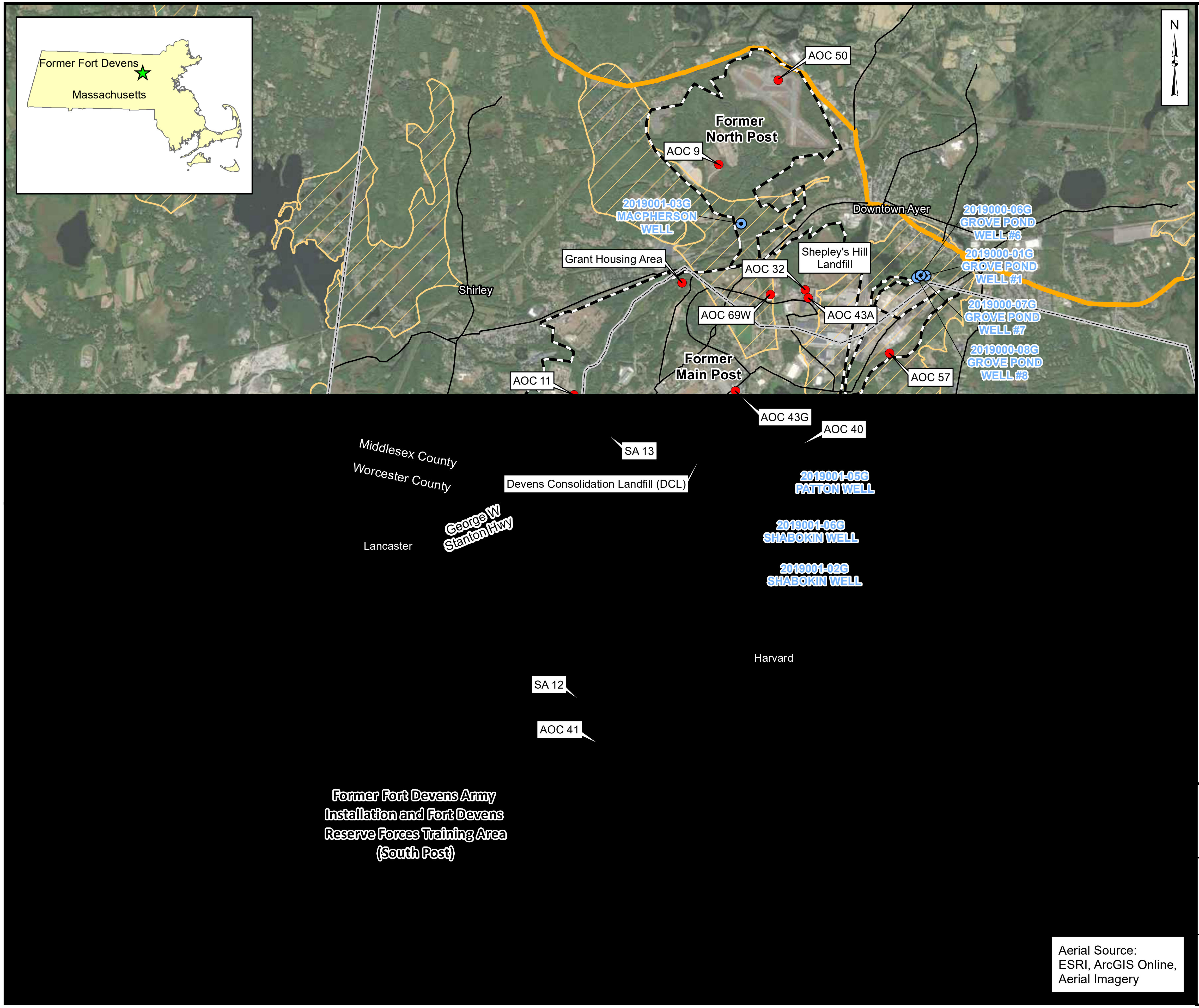
USEPA-New England, Region I, 2017. Low Stress (Low-Flow) Purging and Sampling Procedure for the Collection of Groundwater Samples from Monitoring Wells. September.

FIGURES



Aerial Source:
ESRI, ArcGIS Online,
Aerial Imagery

Legend

⬚	Former Fort Devens Boundary
●	Area of Contamination (AOC)
⦿	Water Supply Well
- - -	County Line
━	Highway
─	Major Road
▨	MassDEP Zone II Wellhead Protection Area

MassDEP = Massachusetts Department of Environmental Protection

0 1 2
Miles

AOC 69W Supplemental Remedial Investigation Work Plan
Former Fort Devens Army Installation
Devens, Massachusetts

Site Location
Former Fort Devens
Army Installation

SERES ARCADIS
a joint venture

Figure
1-1

ATTACHMENT A

FIELD SAMPLING SOPs

Appendix A

Field Standard Operating Procedures

U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION I

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

Quality Assurance Unit
U.S. Environmental Protection Agency – Region 1
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Prepared by:__________________________________ ____________
(Robert Reinhart, Quality Assurance Unit) Date

Approved by:__________________________________ ____________
(John Smaldone, Quality Assurance Unit) Date

Revision Page

Date	**Rev #**	**Summary of changes**	**Sections**
7/30/96	1	Finalized	
01/19/10	2	Updated	All sections
3/23/17	3	Updated	All sections
9/20/17	4	Updated	Section 7.0

Table of Contents

1.0 USE OF TERMS

Equipment blank: The equipment blank shall include the pump and the pump's tubing. If tubing is dedicated to the well, the equipment blank needs only to include the pump in subsequent sampling rounds. If the pump and tubing are dedicated to the well, the equipment blank is collected prior to its placement in the well. If the pump and tubing will be used to sample multiple wells, the equipment blank is normally collected after sampling from contaminated wells and not after background wells.

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

Indicator field parameters: This SOP uses field measurements of turbidity, dissolved oxygen, specific conductance, temperature, pH, and oxidation/reduction potential (ORP) as indicators of when purging operations are sufficient and sample collection may begin.

Matrix Spike/Matrix Spike Duplicates: Used by the laboratory in its quality assurance program. Consult the laboratory for the sample volume to be collected.

Potentiometric Surface: The level to which water rises in a tightly cased well constructed in a confined aquifer. In an unconfined aquifer, the potentiometric surface is the water table.

QAPP: Quality Assurance Project Plan

SAP: Sampling and Analysis Plan

SOP: Standard operating procedure

Stabilization: A condition that is achieved when all indicator field parameter measurements are sufficiently stable (as described in the “Monitoring Indicator Field Parameters” section) to allow sample collection to begin.

Temperature blank: A temperature blank is added to each sample cooler. The blank is measured upon receipt at the laboratory to assess whether the samples were properly cooled during transit.

Trip blank (VOCs): Trip blank is a sample of analyte-free water taken to the sampling site and returned to the laboratory. The trip blanks (one pair) are added to each sample cooler that contains VOC samples.

2.0 SCOPE & APPLICATION

The goal of this groundwater sampling procedure is to collect water samples that reflect the total mobile organic and inorganic loads (dissolved and colloidal sized fractions) transported through the subsurface under ambient flow conditions, with minimal physical and chemical alterations from sampling operations. This standard operating procedure (SOP) for collecting groundwater samples will help ensure that the project's data quality objectives (DQOs) are met under certain low-flow conditions.

The SOP emphasizes the need to minimize hydraulic stress at the well-aquifer interface by maintaining low water-level drawdowns, and by using low pumping rates during purging and sampling operations. Indicator field parameters (e.g., dissolved oxygen, pH, etc.) are monitored during purging in order to determine when sample collection may begin. Samples properly collected using this SOP are suitable for analysis of groundwater contaminants (volatile and semi-volatile organic analytes, dissolved gases, pesticides, PCBs, metals and other inorganics), or naturally occurring analytes. This SOP is based on Puls, and Barcelona (1996).

This procedure is designed for monitoring wells with an inside diameter (1.5-inches or greater) that can accommodate a positive lift pump with a screen length or open interval ten feet or less and with a water level above the top of the screen or open interval (Hereafter, the "screen or open interval" will be referred to only as "screen interval"). This SOP is not applicable to other well-sampling conditions.

While the use of dedicated sampling equipment is not mandatory, dedicated pumps and tubing can reduce sampling costs significantly by streamlining sampling activities and thereby reducing the overall field costs.

The goal of this procedure is to emphasize the need for consistency in deploying and operating equipment while purging and sampling monitoring wells during each sampling event. This will help to minimize sampling variability.

This procedure describes a general framework for groundwater sampling. Other site specific information (hydrogeological context, conceptual site model (CSM), DQOs, etc.) coupled with systematic planning must be added to the procedure in order to develop an appropriate site specific SAP/QAPP. In addition, the site specific SAP/QAPP must identify the specific equipment that will be used to collect the groundwater samples.

This procedure does not address the collection of water or free product samples from wells containing free phase LNAPLs and/or DNAPLs (light or dense non-aqueous phase liquids). For this type of situation, the reader may wish to check: Cohen, and Mercer (1993) or other pertinent documents.

This SOP is to be used when collecting groundwater samples from monitoring wells at all Superfund, Federal Facility and RCRA sites in Region 1 under the conditions described herein. Request for modification of this SOP, in order to better address specific situations at individual wells, must include adequate technical justification for proposed changes. All changes and modifications must be approved and included in a revised SAP/QAPP before implementation in field.

3.0 BACKGROUND FOR IMPLEMENTATION

It is expected that the monitoring well screen has been properly located (both laterally and vertically) to intercept existing contaminant plume(s) or along flow paths of potential contaminant migration. Problems with inappropriate monitoring well placement or faulty/improper well installation cannot be overcome by even the best water sampling procedures. This SOP presumes that the analytes of interest are moving (or will potentially move) primarily through the more permeable zones intercepted by the screen interval.

Proper well construction, development, and operation and maintenance cannot be overemphasized. The use of installation techniques that are appropriate to the hydrogeologic setting of the site often prevent "problem well" situations from occurring. During well development, or redevelopment, tests should be conducted to determine the hydraulic characteristics of the monitoring well. The data can then be used to set the purging/sampling rate, and provide a baseline for evaluating changes in well performance and the potential need for well rehabilitation. Note: if this installation data or well history (construction and sampling) is not available or discoverable, for all wells to be sampled, efforts to build a sampling history should commence with the next sampling event.

The pump intake should be located within the screen interval and at a depth that will remain under water at all times. It is recommended that the intake depth and pumping rate remain the same for all sampling events. The mid-point or the lowest historical midpoint of the saturated screen length is often used as the location of the pump intake. For new wells, or for wells without pump intake depth information, the site’s SAP/QAPP must provide clear reasons and instructions on how the pump intake depth(s) will be selected, and reason(s) for the depth(s) selected. If the depths to top and bottom of the well screen are not known, the SAP/QAPP will need to describe how the sampling depth will be determined and how the data can be used.

Stabilization of indicator field parameters is used to indicate that conditions are suitable for sampling to begin. Achievement of turbidity levels of less than 5 NTU, and stable drawdowns of less than 0.3 feet, while desirable, are not mandatory. Sample collection may still take place provided the indicator field parameter criteria in this procedure are met. If after 2 hours of purging indicator field parameters have not stabilized, one of three optional courses of action may be taken: a) continue purging until stabilization is achieved, b) discontinue purging, do not collect any samples, and record in log book that stabilization could not be achieved (documentation must describe attempts to achieve stabilization), c) discontinue purging, collect samples and provide full explanation of attempts to achieve stabilization (note: there is a risk that the analytical data obtained, especially metals and strongly hydrophobic organic analytes, may reflect a sampling bias and therefore, the data may not meet the data quality objectives of the sampling event).

It is recommended that low-flow sampling be conducted when the air temperature is above 32°F (0°C). If the procedure is used below 32°F, special precautions will need to be taken to prevent the groundwater from freezing in the equipment. Because sampling during freezing temperatures may adversely impact the data quality objectives, the need for water sample collection during months when these conditions are likely to occur should be evaluated during site planning and special sampling measures may need to be developed. Ice formation in the flow-through-cell will cause the monitoring probes to act erratically. A transparent flow-through-cell needs to be used to observe if ice is forming in the cell. If ice starts to form on the other pieces of the sampling equipment, additional problems may occur.

4.0 HEALTH & SAFETY

When working on-site, comply with all applicable OSHA requirements and the site's health/safety procedures. All proper personal protection clothing and equipment are to be worn. Some samples may contain biological and chemical hazards. These samples should be handled with suitable protection to skin, eyes, etc.

5.0 CAUTIONS

The following cautions need to be considered when planning to collect groundwater samples when the below conditions occur.

If the groundwater degasses during purging of the monitoring well, dissolved gases and VOCs will be lost. When this happens, the groundwater data for dissolved gases (e.g., methane, ethene, ethane, dissolved oxygen, etc.) and VOCs will need to be qualified. Some conditions that can promote degassing are the use of a vacuum pump (e.g., peristaltic pumps), changes in aperture along the sampling tubing, and squeezing/pinching the pump's tubing which results in a pressure change.

When collecting the samples for dissolved gases and VOCs analyses, avoid aerating the groundwater in the pump's tubing. This can cause loss of the dissolved gases and VOCs in the groundwater. Having the pump's tubing completely filled prior to sampling will avoid this problem when using a centrifugal pump or peristaltic pump.

Direct sun light and hot ambient air temperatures may cause the groundwater in the tubing and flow-through-cell to heat up. This may cause the groundwater to degas which will result in loss of VOCs and dissolved gases. When sampling under these conditions, the sampler will need to shade the equipment from the sunlight (e.g., umbrella, tent, etc.). If possible, sampling on hot days, or during the hottest time of the day, should be avoided. The tubing exiting the monitoring well should be kept as short as possible to avoid the sun light or ambient air from heating up the groundwater.

Thermal currents in the monitoring well may cause vertical mixing of water in the well bore. When the air temperature is colder than the groundwater temperature, it can cool the top of the water column. Colder water which is denser than warm water sinks to the bottom of the well and the warmer water at the bottom of the well rises, setting up a convection cell. "During low-flow sampling, the pumped water may be a mixture of convecting water from within the well casing and aquifer water moving inward through the screen. This mixing of water during low-flow sampling can substantially increase equilibration times, can cause false stabilization of indicator parameters, can give false indication of redox state, and can provide biological data that are not representative of the aquifer conditions" (Vroblesky 2007).

Failure to calibrate or perform proper maintenance on the sampling equipment and measurement instruments (e.g., dissolved oxygen meter, etc.) can result in faulty data being collected.

Interferences may result from using contaminated equipment, cleaning materials, sample containers, or uncontrolled ambient/surrounding air conditions (e.g., truck/vehicle exhaust nearby).

Cross contamination problems can be eliminated or minimized through the use of dedicated sampling equipment and/or proper planning to avoid ambient air interferences. Note that the use of dedicated sampling equipment can also significantly reduce the time needed to complete each sampling event, will promote consistency in the sampling, and may reduce sampling bias by having the pump's intake at a constant depth.

Clean and decontaminate all sampling equipment prior to use. All sampling equipment needs to be routinely checked to be free from contaminants and equipment blanks collected to ensure that the equipment is free of contaminants. Check the previous equipment blank data for the site (if they exist) to determine if the previous cleaning procedure removed the contaminants. If contaminants were detected and they are a concern, then a more vigorous cleaning procedure will be needed.

6.0 PERSONNEL QUALIFICATIONS

All field samplers working at sites containing hazardous waste must meet the requirements of the OSHA regulations. OSHA regulations may require the sampler to take the 40 hour OSHA health and safety training course and a refresher course prior to engaging in any field activities, depending upon the site and field conditions.

The field samplers must be trained prior to the use of the sampling equipment, field instruments, and procedures. Training is to be conducted by an experienced sampler before initiating any sampling procedure.

The entire sampling team needs to read, and be familiar with, the site Health and Safety Plan, all relevant SOPs, and SAP/QAPP (and the most recent amendments) before going onsite for the sampling event. It is recommended that the field sampling leader attest to the understanding of these site documents and that it is recorded.

7.0 EQUIPMENT AND SUPPLIES

A. Informational materials for sampling event

A copy of the current Health and Safety Plan, SAP/QAPP, monitoring well construction data, location map(s), field data from last sampling event, manuals for sampling, and the monitoring instruments' operation, maintenance, and calibration manuals should be brought to the site.

B. Well keys.

C. Extraction device

Adjustable rate, submersible pumps (e.g., centrifugal, bladder, etc.) which are constructed of stainless steel or polytetrafluoroethylene (PTFE, i.e. Teflon®) are preferred. PTFE, however, should not be used when sampling for per- and polyfluoroalkyl substances (PFAS) as it is likely to contain these substances.

Note: If extraction devices constructed of other materials are to be used, adequate information must be provided to show that the substituted materials do not leach contaminants nor cause interferences to the analytical procedures to be used. Acceptance of these materials must be obtained before the sampling event.

If bladder pumps are selected for the collection of VOCs and dissolved gases, the pump setting should be set so that one pulse will deliver a water volume that is sufficient to fill a 40 mL VOC vial. This is not mandatory, but is considered a “best practice”. For the proper operation, the bladder pump will need a minimum amount of water above the pump; consult the manufacturer for the recommended submergence. The pump’s recommended submergence value should be determined during the planning stage, since it may influence well construction and placement of dedicated pumps where water-level fluctuations are significant.

Adjustable rate, peristaltic pumps (suction) are to be used with caution when collecting samples for VOCs and dissolved gases (e.g., methane, carbon dioxide, etc.) analyses. Additional information on the use of peristaltic pumps can be found in Appendix A.
If peristaltic pumps are used, the inside diameter of the rotor head tubing needs to match the inside diameter of the tubing installed in the monitoring well.

Inertial pumping devices (motor driven or manual) are not recommended. These devices frequently cause greater disturbance during purging and sampling, and are less easily controlled than submersible pumps (potentially increasing turbidity and sampling variability, etc.). This can lead to sampling results that are adversely affected by purging and sampling operations, and a higher degree of data variability.

D. Tubing

PTFE (Teflon®) or PTFE-lined polyethylene tubing are preferred when sampling is to include VOCs, SVOCs, pesticides, PCBs and inorganics. As discussed in the previous section, PTFE tubing should not be used when sampling for PFAS. In this case, a suitable alternative such as high-density polyethylene tubing should be used.

PVC, polypropylene or polyethylene tubing may be used when collecting samples for metal and other inorganics analyses.

Note: If tubing constructed of other materials is to be used, adequate information must be provided to show that the substituted materials do not leach contaminants nor cause interferences to the analytical procedures to be used. Acceptance of these materials must be obtained before the sampling event.

The use of 1/4 inch or 3/8 inch (inside diameter) tubing is recommended. This will help ensure that the tubing remains liquid filled when operating at very low pumping rates when using centrifugal and peristaltic pumps.

Silastic tubing should be used for the section around the rotor head of a peristaltic pump. It should be less than a foot in length. The inside diameter of the tubing used at the pump rotor head must be the same as the inside diameter of tubing placed in the well. A tubing connector is used to connect the pump rotor head tubing to the well tubing. Alternatively, the two pieces of tubing can be connected to each other by placing the one end of the tubing inside the end of the other tubing. The tubing must not be reused.

E. The water level measuring device

Electronic ”tape”, pressure transducer, water level sounder/level indicator, etc. should be capable of measuring to 0.01 foot accuracy. Recording pressure transducers, mounted above the pump, are especially helpful in tracking water levels during pumping operations, but their use must include check measurements with a water level “tape” at the start and end of each sampling event.

F. Flow measurement supplies

Graduated cylinder (size according to flow rate) and stopwatch usually will suffice.

Large graduated bucket used to record total water purged from the well.

G. Interface probe

To be used to check on the presence of free phase liquids (LNAPL, or DNAPL) before purging begins (as needed).

H. Power source (generator, nitrogen tank, battery, etc.)

When a gasoline generator is used, locate it downwind and at least 30 feet from the well so that the exhaust fumes do not contaminate samples.

I. Indicator field parameter monitoring instruments

Use of a multi-parameter instrument capable of measuring pH, oxidation/reduction potential (ORP), dissolved oxygen (DO), specific conductance, temperature, and coupled with a flow-through-cell is required when measuring all indicator field parameters, except turbidity. Turbidity is collected using a separate instrument. Record equipment/instrument identification (manufacturer, and model number).

Transparent, small volume flow-through-cells (e.g., 250 mLs or less) are preferred. This allows observation of air bubbles and sediment buildup in the cell, which can interfere with the operation of the monitoring instrument probes, to be easily detected. A small volume cell facilitates rapid turnover of water in the cell between measurements of the indicator field parameters.

It is recommended to use a flow-through-cell and monitoring probes from the same manufacturer and model to avoid incompatibility between the probes and flow-through-cell.

Turbidity samples are collected before the flow-through-cell. A “T” connector coupled with a valve is connected between the pump’s tubing and flow-through-cell. When a turbidity measurement is required, the valve is opened to allow the groundwater to flow into a container. The valve is closed and the container sample is then placed in the turbidimeter.

Standards are necessary to perform field calibration of instruments. A minimum of two standards are needed to bracket the instrument measurement range for all parameters except ORP which use a Zobell solution as a standard. For dissolved oxygen, a wet sponge used for the 100% saturation and a zero dissolved oxygen solution are used for the calibration.

Barometer (used in the calibration of the Dissolved Oxygen probe) and the conversion formula to convert the barometric pressure into the units of measure used by the Dissolved Oxygen meter are needed.

J. Decontamination supplies

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

K. Record keeping supplies

Logbook(s), well purging forms, chain-of-custody forms, field instrument calibration forms, etc.

L. Sample bottles

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

N. Sample tags or labels

O. PID or FID instrument

If appropriate, to detect VOCs for health and safety purposes, and provide qualitative field evaluations.

P. Miscellaneous Equipment

Equipment to keep the sampling apparatus shaded in the summer (e.g., umbrella) and from freezing in the winter. If the pump's tubing is allowed to heat up in the warm weather, the cold groundwater may degas as it is warmed in the tubing.

8.0 EQUIPMENT/INSTRUMENT CALIBRATION

Prior to the sampling event, perform maintenance checks on the equipment and instruments according to the manufacturer's manual and/or applicable SOP. This will ensure that the equipment/instruments are working properly before they are used in the field.

Prior to sampling, the monitoring instruments must be calibrated and the calibration documented. The instruments are calibrated using U.S Environmental Protection Agency Region 1 *Calibration of Field Instruments (temperature, pH, dissolved oxygen, conductivity/specific conductance, oxidation/reduction [ORP], and turbidity),* March 23, 2017, or latest version or from one of the methods listed in 40CFR136, 40CFR141 and SW-846.

The instruments shall be calibrated at the beginning of each day. If the field measurement falls outside the calibration range, the instrument must be re-calibrated so that all measurements fall within the calibration range. At the end of each day, a calibration check is performed to verify that instruments remained in calibration throughout the day. This check is performed while the instrument is in measurement mode, not calibration mode. If the field instruments are being used to monitor the natural attenuation parameters, then a calibration check at mid-day is highly recommended to ensure that the instruments did not drift out of calibration. Note: during the day if the instrument reads zero or a negative number for dissolved oxygen, pH, specific conductance, or turbidity (negative value only), this indicates that the instrument drifted out of calibration or the instrument is malfunctioning. If this situation occurs the data from this instrument will need to be qualified or rejected.

9.0 PRELIMINARY SITE ACTIVITIES (as applicable)

Check the well for security (damage, evidence of tampering, missing lock, etc.) and record pertinent observations (include photograph as warranted).

If needed, lay out a sheet of clean polyethylene for monitoring and sampling equipment, unless equipment is elevated above the ground (e.g., on a table, etc.).

Remove well cap and if appropriate measure VOCs at the rim of the well with a PID or FID instrument and record reading in field logbook or on the well purge form.

If the well casing does not have an established reference point (usually a V-cut or indelible mark in the well casing), make one. Describe its location and record the date of the mark in the logbook (consider a photographic record as well). All water level measurements must be recorded relative to this reference point (and the altitude of this point should be determined using techniques that are appropriate to site's DQOs.

If water-table or potentiometric surface map(s) are to be constructed for the sampling event, perform synoptic water level measurement round (in the shortest possible time) before any purging and sampling activities begin. If possible, measure water level depth (to 0.01 ft.) and total well depth (to 0.1 ft.) the day before sampling begins, in order to allow for re-settlement of any particulates in the water column. This is especially important for those wells that have not been recently sampled because sediment buildup in the well may require the well to be redeveloped. If measurement of total well depth is not made the day before, it should be measured after sampling of the well is complete. All measurements must be taken from the established referenced point. Care should be taken to minimize water column disturbance.

Check newly constructed wells for the presence of LNAPLs or DNAPLs before the initial sampling round. If none are encountered, subsequent check measurements with an interface probe may not be necessary unless analytical data or field analysis signal a worsening situation. This SOP cannot be used in the presence of LNAPLs or DNAPLs. If NAPLs are present, the project team must decide upon an alternate sampling method. All project modifications must be approved and documented prior to implementation.

If available check intake depth and drawdown information from previous sampling event(s) for each well. Duplicate, to the extent practicable, the intake depth and extraction rate (use final pump dial setting information) from previous event(s). If changes are made in the intake depth or extraction rate(s) used during previous sampling event(s), for either portable or dedicated extraction devices, record new values, and explain reasons for the changes in the field logbook.

10.0 PURGING AND SAMPLING PROCEDURE

Purging and sampling wells in order of increasing chemical concentrations (known or anticipated) are preferred.

The use of dedicated pumps is recommended to minimize artificial mobilization and entrainment of particulates each time the well is sampled. Note that the use of dedicated sampling equipment can also significantly reduce the time needed to complete each sampling event, will promote consistency in the sampling, and may reduce sampling bias by having the pump's intake at a constant depth.

A. Initial Water Level

Measure the water level in the well before installing the pump if a non-dedicated pump is being used. The initial water level is recorded on the purge form or in the field logbook.

B. Install Pump

Lower pump, safety cable, tubing and electrical lines slowly (to minimize disturbance) into the well to the appropriate depth (may not be the mid-point of the screen/open interval). The Sampling and Analysis Plan/Quality Assurance Project Plan should specify the sampling depth (used previously), or provide criteria for selection of intake depth for each new well. If possible keep the pump intake at least two feet above the bottom of the well, to minimize mobilization of particulates present in the bottom of the well.

Pump tubing lengths, above the top of well casing should be kept as short as possible to minimize heating the groundwater in the tubing by exposure to sun light and ambient air temperatures. Heating may cause the groundwater to degas, which is unacceptable for the collection of samples for VOC and dissolved gases analyses.

C. Measure Water Level

Before starting pump, measure water level. Install recording pressure transducer, if used to track drawdowns, to initialize starting condition.

D. Purge Well

From the time the pump starts purging and until the time the samples are collected, the purged water is discharged into a graduated bucket to determine the total volume of groundwater purged. This information is recorded on the purge form or in the field logbook.

Start the pump at low speed and slowly increase the speed until discharge occurs. Check water level. Check equipment for water leaks and if present fix or replace the affected equipment. Try to match pumping rate used during previous sampling event(s). Otherwise, adjust pump speed until there is little or no water level drawdown. If the minimal drawdown that can be achieved exceeds 0.3 feet, but remains stable, continue purging.

Monitor and record the water level and pumping rate every five minutes (or as appropriate) during purging. Record any pumping rate adjustments (both time and flow rate). Pumping rates should, as needed, be reduced to the minimum capabilities of the pump to ensure stabilization of the water level. Adjustments are best made in the first fifteen minutes of pumping in order to help minimize purging time. During pump start-up, drawdown may exceed the 0.3 feet target and then "recover" somewhat as pump flow adjustments are made. Purge volume calculations should utilize stabilized drawdown value, not the initial drawdown. If the initial water level is above the top of the screen do not allow the water level to fall into the well screen. The final purge volume must be greater than the stabilized drawdown volume plus the pump’s tubing volume. If the drawdown has exceeded 0.3 feet and stabilizes, calculate the volume of water between the initial water level and the stabilized water level. Add the volume of the water which occupies the pump’s tubing to this calculation. This combined volume of water needs to be purged from the well after the water level has stabilized before samples are collected.

Avoid the use of constriction devices on the tubing to decrease the flow rate because the constrictor will cause a pressure difference in the water column. This will cause the groundwater to degas and result in a loss of VOCs and dissolved gasses in the groundwater samples.

Note: the flow rate used to achieve a stable pumping level should remain constant while monitoring the indicator parameters for stabilization and while collecting the samples.

Wells with low recharge rates may require the use of special pumps capable of attaining very low pumping rates (e.g., bladder, peristaltic), and/or the use of dedicated equipment. For new monitoring wells, or wells where the following situation has not occurred before, if the recovery rate to the well is less than 50 mL/min., or the well is being essentially dewatered during purging, the well should be sampled as soon as the water level has recovered sufficiently to collect the volume needed for all anticipated samples. The project manager or field team leader will need to make the decision when samples should be collected, how the sample is to be collected, and the reasons recorded on the purge form or in the field logbook. A water level measurement needs to be performed and recorded before samples are collected. If the project manager decides to collect the samples using the pump, it is best during this recovery period that the pump intake tubing not be removed, since this will aggravate any turbidity problems. Samples in this specific situation may be collected without stabilization of indicator field parameters. Note that field conditions and efforts to overcome problematic situations must be recorded in order to support field decisions to deviate from normal procedures described in this SOP. If this type of problematic situation persists in a well, then water sample collection should be changed to a passive or no-purge method, if consistent with the site's DQOs, or have a new well installed.

E. Monitor Indicator Field Parameters

After the water level has stabilized, connect the "T" connector with a valve and the flow-through-cell to monitor the indicator field parameters. If excessive turbidity is anticipated or encountered with the pump startup, the well may be purged for a while without connecting up the flow-through-cell, in order to minimize particulate buildup in the cell (This is a judgment call made by the sampler). Water level drawdown measurements should be made as usual. If possible, the pump may be installed the day before purging to allow particulates that were disturbed during pump insertion to settle.

During well purging, monitor indicator field parameters (turbidity, temperature, specific conductance, pH, ORP, DO) at a frequency of five minute intervals or greater. The pump's flow rate must be able to "turn over" at least one flow-through-cell volume between measurements (for a 250 mL flow-through-cell with a flow rate of 50 mLs/min., the monitoring frequency would be every five minutes; for a 500 mL flow-through-cell it would be every ten minutes). If the cell volume cannot be replaced in the five minute interval, then the time between measurements must be increased accordingly. Note: during the early phase of purging, emphasis should be put on minimizing and stabilizing pumping stress, and recording those adjustments followed by stabilization of indicator parameters. Purging is considered complete and sampling may begin when all the above indicator field parameters have stabilized. Stabilization is considered to be achieved when three consecutive readings are within the following limits:

Turbidity (10% for values greater than 5 NTU; if three Turbidity values are less than 5 NTU, consider the values as stabilized),
Dissolved Oxygen (10% for values greater than 0.5 mg/L, if three Dissolved Oxygen values are less than 0.5 mg/L, consider the values as stabilized),
Specific Conductance (3%),
Temperature (3%),
pH (± 0.1 unit),
Oxidation/Reduction Potential (±10 millivolts).

All measurements, except turbidity, must be obtained using a flow-through-cell. Samples for turbidity measurements are obtained before water enters the flow-through-cell. Transparent flow-through-cells are preferred, because they allow field personnel to watch for particulate build-up within the cell. This build-up may affect indicator field parameter values measured within the cell. If the cell needs to be cleaned during purging operations, continue pumping and disconnect cell for cleaning, then reconnect after cleaning and continue monitoring activities. Record start and stop times and give a brief description of cleaning activities.

The flow-through-cell must be designed in a way that prevents gas bubble entrapment in the cell. Placing the flow-through-cell at a 45 degree angle with the port facing upward can help remove bubbles from the flow-through-cell (see Appendix B Low-Flow Setup Diagram). Throughout the measurement process, the flow-through-cell must remain free of any gas bubbles. Otherwise, the monitoring probes may act erratically. When the pump is turned off or cycling on/off (when using a bladder pump), water in the cell must not drain out. Monitoring probes must remain submerged in water at all times.

F. Collect Water Samples

When samples are collected for laboratory analyses, the pump's tubing is disconnected from the "T" connector with a valve and the flow-through-cell. The samples are collected directly from the pump's tubing. Samples must not be collected from the flow-through-cell or from the "T" connector with a valve.

VOC samples are normally collected first and directly into pre-preserved sample containers. However, this may not be the case for all sampling locations; the SAP/QAPP should list the order in which the samples are to be collected based on the project's objective(s). Fill all sample containers by allowing the pump discharge to flow gently down the inside of the container with minimal turbulence.

If the pump's flow rate is too high to collect the VOC/dissolved gases samples, collect the other samples first. Lower the pump's flow rate to a reasonable rate and collect the VOC/dissolved gases samples and record the new flow rate.

During purging and sampling, the centrifugal/peristaltic pump tubing must remain filled with water to avoid aeration of the groundwater. It is recommended that 1/4 inch or 3/8 inch (inside diameter) tubing be used to help ensure that the sample tubing remains water filled. If the pump tubing is not completely filled to the sampling point, use the following procedure to collect samples: collect non-VOC/dissolved gases samples first, then increase flow rate slightly until the water completely fills the tubing, collect the VOC/dissolved gases samples, and record new drawdown depth and flow rate.

For bladder pumps that will be used to collect VOC or dissolved gas samples, it is recommended that the pump be set to deliver long pulses of water so that one pulse will fill a 40 mL VOC vial.

Use pre-preserved sample containers or add preservative, as required by analytical methods, to the samples immediately after they are collected. Check the analytical methods (e.g. EPA SW-846, 40 CFR 136, water supply, etc.) for additional information on preservation.

If determination of filtered metal concentrations is a sampling objective, collect filtered water samples using the same low flow procedures. The use of an in-line filter (transparent housing preferred) is required, and the filter size (0.45 µm is commonly used) should be based on the sampling objective. Pre-rinse the filter with groundwater prior to sample collection. Make sure the filter is free of air bubbles before samples are collected. Preserve the filtered water sample immediately. Note: filtered water samples are not an acceptable substitute for unfiltered samples when the monitoring objective is to obtain chemical concentrations of total mobile contaminants in groundwater for human health or ecological risk calculations.

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

G. Post Sampling Activities

If a recording pressure transducer is used to track drawdown, re-measure water level with tape.

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

Before securing the well, measure and record the well depth (to 0.1 ft.), if not measured the day before purging began. Note: measurement of total well depth annually is usually sufficient after the initial low stress sampling event. However, a greater frequency may be needed if the well has a “silting” problem or if confirmation of well identity is needed.

Secure the well.

11.0 DECONTAMINATION

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

The use of dedicated pumps and tubing will reduce the amount of time spent on decontamination of the equipment. If dedicated pumps and tubing are used, only the initial sampling event will require decontamination of the pump and tubing.

Note if the previous equipment blank data showed that contaminant(s) were present after using the below procedure or the one described in the SAP/QAPP, a more vigorous procedure may be needed.

Procedure 1

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

Flush the equipment/pump with potable water.

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

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

Optional - flush with isopropyl alcohol (pesticide grade; must be free of ketones {e.g., acetone}) or with methanol. This step may be required if the well is highly contaminated or if the equipment blank data from the previous sampling event show that the level of contaminants is significant.

Flush with distilled/deionized water. This step must remove all traces of alcohol (if used) from the equipment. The final water rinse must not be recycled.

Procedure 2

Steam clean the outside of the submersible pump.

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

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

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

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

12.0 FIELD QUALITY CONTROL

Quality control samples are required to verify that the sample collection and handling process has not compromised the quality of the groundwater samples. All field quality control samples must be prepared the same as regular investigation samples with regard to sample volume, containers, and preservation. Quality control samples include field duplicates, equipment blanks, matrix spike/matrix spike duplicates, trip blanks (VOCs), and temperature blanks.

13.0 FIELD LOGBOOK

A field log shall be kept to document all groundwater field monitoring activities (see Appendix C, example table), and record the following for each well:

Site name, municipality, state.

Well identifier, latitude-longitude or state grid coordinates.

Measuring point description (e.g., north side of PVC pipe).

Well depth, and measurement technique.

Well screen length.

Pump depth.

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

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

Pumping rate, drawdown, indicator parameters values, calculated or measured total volume pumped, and clock time of each set of measurements.

Type of tubing used and its length.

Type of pump used.

Clock time of start and end of purging and sampling activity.

Types of sample bottles used and sample identification numbers.

Preservatives used.

Parameters requested for analyses.

Field observations during sampling event.

Name of sample collector(s).

Weather conditions, including approximate ambient air temperature.

QA/QC data for field instruments.

Any problems encountered should be highlighted.

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

14.0 DATA REPORT

Data reports are to include laboratory analytical results, QA/QC information, field indicator parameters measured during purging, field instrument calibration information, and whatever other field logbook information is needed to allow for a full evaluation of data usability.

Note: the use of trade, product, or firm names in this sampling procedure is for descriptive purposes only and does not constitute endorsement by the U.S. EPA.

15.0 REFERENCES

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APPENDIX A

PERISTALTIC PUMPS

Before selecting a peristaltic pump to collect groundwater samples for VOCs and/or dissolved gases, (e.g., methane, carbon dioxide, etc.) consideration should be given to the following:

- The decision of whether or not to use a peristaltic pump is dependent on the intended use of the data.
- If the additional sampling error that may be introduced by this device is NOT of concern for the VOC/dissolved gases data's intended use, then this device may be acceptable.
- If minor differences in the groundwater concentrations could affect the decision, such as to continue or terminate groundwater cleanup or whether the cleanup goals have been reached, then this device should NOT be used for VOC/dissolved gases sampling. In these cases, centrifugal or bladder pumps are a better choice for more accurate results.

EPA and USGS have documented their concerns with the use of the peristaltic pumps to collect water sample in the below documents.

- "Suction Pumps are not recommended because they may cause degassing, pH modification, and loss of volatile compounds" *A Compendium of Superfund Field Operations Methods*, EPA/540/P-87/001, December 1987.
- "The agency does not recommend the use of peristaltic pumps to sample ground water particularly for volatile organic analytes" *RCRA Ground-Water Monitoring Draft Technical Guidance*, EPA Office of Solid Waste, November 1992.
- "The peristaltic pump is limited to shallow applications and can cause degassing resulting in alteration of pH, alkalinity, and volatiles loss", *Low-flow (Minimal drawdown) Ground-Water Sampling Procedures*, by Robert Puls & Michael Barcelona, April 1996, EPA/540/S-95/504.
- "Suction-lift pumps, such as peristaltic pumps, can operate at a very low pumping rate; however, using negative pressure to lift the sample can result in the loss of volatile analytes", USGS Book 9 Techniques of Water-Resources Investigation, Chapter A4. (Version 2.0, 9/2006).

APPENDIX B

SUMMARY OF SAMPLING INSTRUCTIONS

These instructions are for using an adjustable rate, submersible pump or a peristaltic pump with the pump's intake placed at the midpoint of a 10 foot or less well screen or an open interval. The water level in the monitoring well is above the top of the well screen or open interval, the ambient temperature is above 32°F, and the equipment is not dedicated. Field instruments are already calibrated. The equipment is setup according to the diagram at the end of these instructions.

1. Review well installation information. Record well depth, length of screen or open interval, and depth to top of the well screen. Determine the pump's intake depth (e.g., mid-point of screen/open interval).

2. On the day of sampling, check security of the well casing, perform any safety checks needed for the site, lay out a sheet of polyethylene around the well (if necessary), and setup the equipment. If necessary a canopy or an equivalent item can be setup to shade the pump's tubing and flow-through-cell from the sun light to prevent the sun light from heating the groundwater.

3. Check well casing for a reference mark. If missing, make a reference mark. Measure the water level (initial) to 0.01 ft. and record this information.

4. Install the pump's intake to the appropriate depth (e.g., midpoint) of the well screen or open interval. Do not turn-on the pump at this time.

5. Measure water level and record this information.

6. Turn-on the pump and discharge the groundwater into a graduated waste bucket. Slowly increase the flow rate until the water level starts to drop. Reduce the flow rate slightly so the water level stabilizes. Record the pump's settings. Calculate the flow rate using a graduated container and a stop watch. Record the flow rate. Do not let the water level drop below the top of the well screen.

If the groundwater is highly turbid or discolored, continue to discharge the water into the bucket until the water clears (visual observation); this usually takes a few minutes. The turbid or discolored water is usually from the well-being disturbed during the pump installation. If the water does not clear, then you need to make a choice whether to continue purging the well (hoping that it will clear after a reasonable time) or continue to the next step. Note, it is sometimes helpful to install the pump the day before the sampling event so that the disturbed materials in the well can settle out.

If the water level drops to the top of the well screen during the purging of the well, stop purging the well, and do the following:

> Wait for the well to recharge to a sufficient volume so samples can be collected. This may take a while (pump may be removed from well, if turbidity is not a problem). The project manager will need to make the decision when samples should be collected and the reasons recorded in the site's log book. A water level measurement needs to be performed and recorded before samples are collected. When samples are being collected, the water level must not drop below the top of the screen or open interval. Collect the samples from the pump's tubing. Always collect the VOCs and dissolved gases samples first. Normally, the samples requiring a small volume are collected before the large volume samples are collected just in case there is not sufficient water in the well to fill all the sample containers. All samples must be collected, preserved, and stored according to the analytical method. Remove the pump from the well and decontaminate the sampling equipment.

If the water level has dropped 0.3 feet or less from the initial water level (water level measure before the pump was installed); proceed to Step 7. If the water level has dropped more than 0.3 feet, calculate the volume of water between the initial water level and the stabilized water level. Add the volume of the water which occupies the pump's tubing to this calculation. This combined volume of water needs to be purged from the well after the water level has stabilized before samples are be collected.

7. Attach the pump's tubing to the "T" connector with a valve (or a three-way stop cock). The pump's tubing from the well casing to the "T" connector must be as short as possible to prevent the groundwater in the tubing from heating up from the sun light or from the ambient air. Attach a short piece of tubing to the other end of the end of the "T" connector to serve as a sampling port for the turbidity samples. Attach the remaining end of the "T" connector to a short piece of tubing and connect the tubing to the flow-through-cell bottom port. To the top port, attach a small piece of tubing to direct the water into a calibrated waste bucket. Fill the cell with the groundwater and remove all gas bubbles from the cell. Position the flow-through-cell in such a way that if gas bubbles enter the cell they can easily exit the cell. If the ports are on the same side of the cell and the cell is cylindrical shape, the cell can be placed at a 45-degree angle with the ports facing upwards; this position should keep any gas bubbles entering the cell away from the monitoring probes and allow the gas bubbles to exit the cell easily (see Low-Flow Setup Diagram). Note:

make sure there are no gas bubbles caught in the probes' protective guard; you may need to shake the cell to remove these bubbles.

8. Turn-on the monitoring probes and turbidity meter.

9. Record the temperature, pH, dissolved oxygen, specific conductance, and oxidation/reduction potential measurements. Open the valve on the "T" connector to collect a sample for the turbidity measurement, close the valve, do the measurement, and record this measurement. Calculate the pump's flow rate from the water exiting the flow-through-cell using a graduated container and a stop watch, and record the measurement. Measure and record the water level. Check flow-through-cell for gas bubbles and sediment; if present, remove them.

10. Repeat Step 9 every 5 minutes or as appropriate until monitoring parameters stabilized. Note: at least one flow-through-cell volume must be exchanged between readings. If not, the time interval between readings will need to be increased. Stabilization is achieved when three consecutive measurements are within the following limits:

Turbidity (10% for values greater than 5 NTUs; if three Turbidity values are less than 5 NTUs, consider the values as stabilized),
Dissolved Oxygen (10% for values greater than 0.5 mg/L, if three Dissolved Oxygen values are less than 0.5 mg/L, consider the values as stabilized),
Specific Conductance (3%),
Temperature (3%),
pH (± 0.1 unit),
Oxidation/Reduction Potential (±10 millivolts).

If these stabilization requirements do not stabilize in a reasonable time, the probes may have been coated from the materials in the groundwater, from a buildup of sediment in the flow-through-cell, or a gas bubble is lodged in the probe. The cell and the probes will need to be cleaned. Turn-off the probes (not the pump), disconnect the cell from the "T" connector and continue to purge the well. Disassemble the cell, remove the sediment, and clean the probes according to the manufacturer's instructions. Reassemble the cell and connect the cell to the "T" connector. Remove all gas bubbles from the cell, turn-on the probes, and continue the measurements. Record the time the cell was cleaned.

11. When it is time to collect the groundwater samples, turn-off the monitoring probes, and disconnect the pump's tubing from the "T" connector. If you are using a centrifugal or peristaltic pump check the pump's tubing to determine if the tubing is completely filled with water (no air space).

All samples must be collected and preserved according to the analytical method. VOCs and dissolved gases samples are normally collected first and directly into pre-preserved sample containers. However, this may not be the case for all sampling locations; the SAP/QAPP should list the order in which the samples are to be collected based on the project's objective(s). Fill all sample containers by allowing the pump discharge to flow gently down the inside of the container with minimal turbulence.

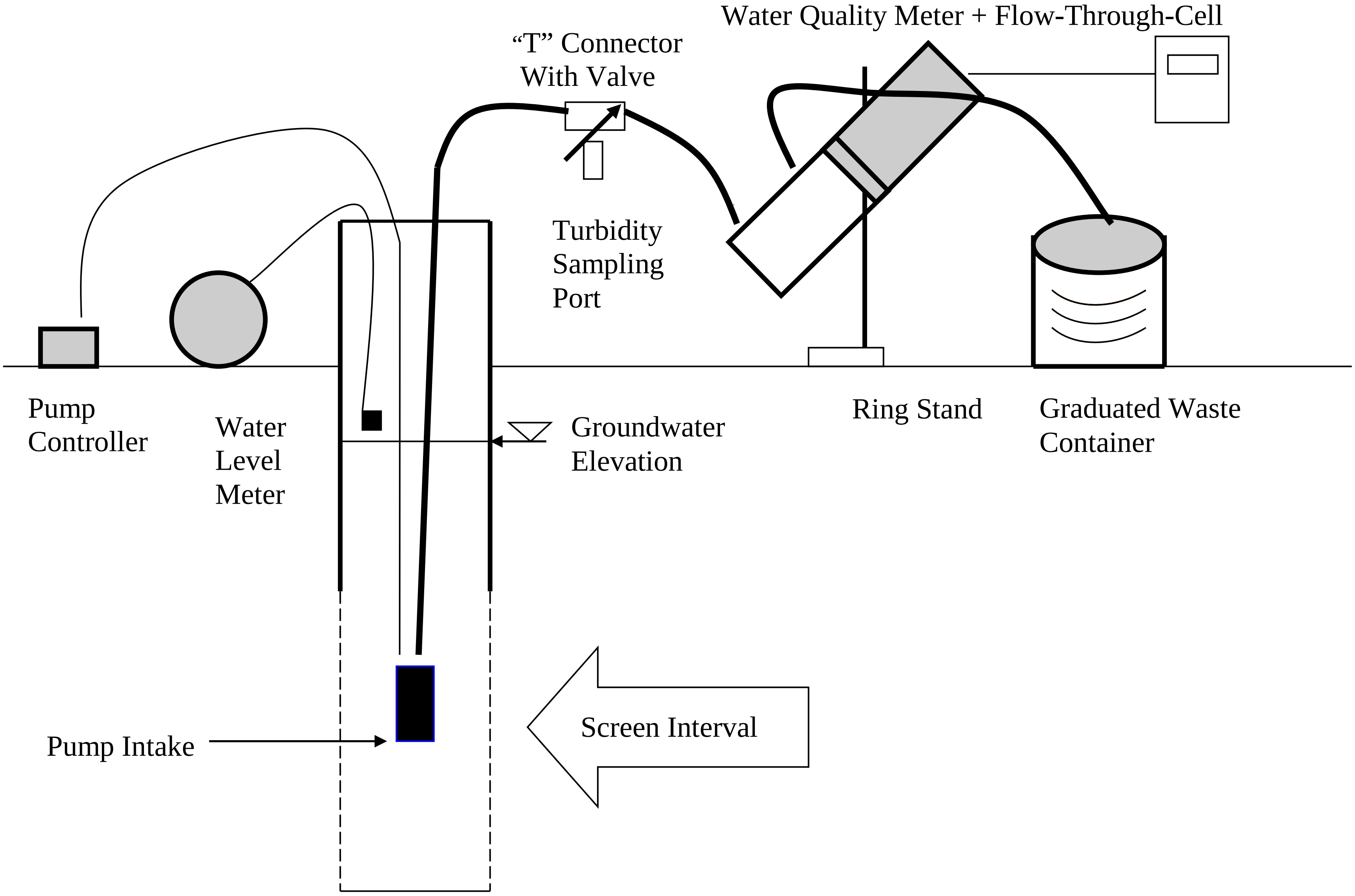
If the pump's tubing is not completely filled with water and the samples are being collected for VOCs and/or dissolved gases analyses using a centrifugal or peristaltic pump, do the following:

> All samples must be collected and preserved according to the analytical method. The VOCs and the dissolved gases (e.g., methane, ethane, ethene, and carbon dioxide) samples are collected last. When it becomes time to collect these samples increase the pump's flow rate until the tubing is completely filled. Collect the samples and record the new flow rate.

12. Store the samples according to the analytical method.

13. Record the total purged volume (graduated waste bucket). Remove the pump from the well and decontaminate the sampling equipment.

Low-Flow Setup Diagram



APPENDIX C

EXAMPLE (Minimum Requirements)

WELL PURGING-FIELD WATER QUALITY MEASUREMENTS FORM

Location (Site/Facility Name)________________________________
Well Number_________________ Date_________________________
Field Personnel____
Sampling Organization_______________________________________
Identify MP____

Depth to ________/_________ of screen
(below MP) top bottom
Pump Intake at (ft. below MP)_________
Purging Device; (pump type)___________
Total Volume Purged ________________

Clock Time 24 HR	Water Depth below MP ft	Pump Dial[1]	Purge Rate ml/min	Cum. Volume Purged liters	Temp. "C	Spec. Cond.[2] µS/cm	pH	ORP[3] mv	DO mg/L	Tur-bidity NTU	Comments
Stabilization Criteria					3%	3%	±0.1	±10 mv	10%	10%	

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

TGI – Ground Penetrating Radar

Rev: 6

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Version Control

Issue	Revision No.	Date Issued	Page No.	Description	Reviewed By
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Approval Signatures

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Brent Barker (Preparer) Date

Reviewed by: 1/8/2023

Gregory B. Byer

Gregory Byer (Subject Matter Expert) Date

1 Introduction

This Technical Guidance Instruction (TGI) is intended to provide general guidance on the use of ground penetrating radar systems for environmental, engineering, and other applications requiring detailed imaging of the subsurface. U.S. Army Corps of Engineers (1995) provides technical background regarding the applicability of ground penetrating radar. This guidance is intended to be used to provide Arcadis CPMs and technical staff with a uniform set of procedures either in cases where Arcadis is subcontracting the data collection and processing or in circumstances where the CPM and affiliated technical staff are participating in a ground penetrating radar survey led by designated Arcadis geophysical specialists. Whether the data collection and processing are being subcontracted or performed in-house, directed by geophysical specialists, in all cases the non-geophysical CPM and/or technical staff should consult with Arcadis geophysical specialists for survey design and scoping, data management and processing, and proper data interpretation procedures. It should be noted that it is commonplace to perform ground penetrating radar surveys as a part of a larger scope of work that may include other geophysical techniques such as seismic, electrical resistivity, magnetics, electromagnetics as well as direct observation (ground truthing) with drilling and borehole geophysics.

2 Intended Use and Responsibilities

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.

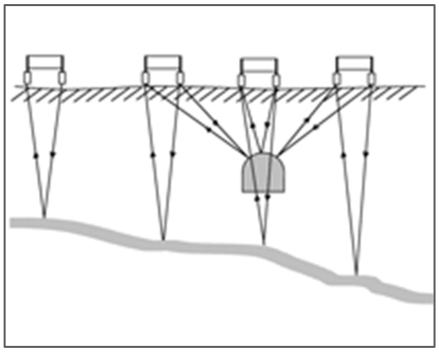
It is the responsibility of the Arcadis Certified Project Manager (CPM) to provide this document to the persons conducting services that fall under the scope and purpose of this procedure, instruction, and/or guidance. The Arcadis CPM will also ensure that the persons conducting the work falling under 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 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.

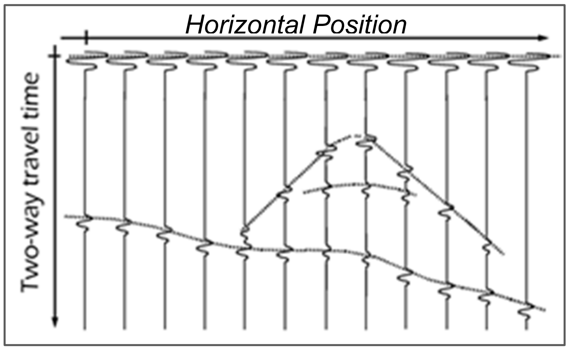
In following this document to execute the scope of work for a project, it may be necessary for staff to make professional judgment decisions to meet the project's scope of work based upon site conditions, staffing expertise, regulation-specific requirements, health and safety concerns, etc. Staff are 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.

3 Scope and Application

This Technical Guidance Instruction (TGI) document outlines the applications, limitations, and methodology for acquiring and interpreting subsurface data using ground penetrating radar (GPR). GPR is a non-invasive and non-destructive tool that transmits pulsed high frequency (generally between 100 and 1000 Megahertz [MHz]) electromagnetic waves into the ground and detects and records the energy returned to the surface with a frequency-matched receiver (see Table 1 for frequencies and applications). The transmitted pulse is reflected from boundaries that possess contrasting dielectric constants[1].



Field Data Collection with a pair of transmitter and receiver antennas moved laterally across the site



Resulting radargram with horizontal distance along the top and the two-wave travel time of the reflected radar pulses on the vertical axis

Reflections typically occur at lithologic contacts where there may be changes in water content and/or mineral composition. Table 2 contains examples of some geologic materials and their typical ranges of electromagnetic properties. Where subsurface materials have extremely high electrical conductivity and magnetic susceptibility including metal objects such as underground storage tanks (USTs), steel drums, and metallic utility pipes anomalously high amplitude reflections, as compared to geologic materials, are generally observed. Non-metallic pipes and utilities often produce weaker GPR reflections due to a lower contrast in dielectric constant between non-metallics and soil.

The two most common performance objectives GPR investigations are matching the survey design with the required depth of penetration and vertical and lateral resolution. For a given set of geologic conditions, both depth of penetration and vertical resolution are inversely related to the transmitter center frequency. The depth of penetration decreases with increasing frequency due to signal attenuation at higher frequencies. Vertical resolution is determined by the wavelength of the pulse. Since higher frequency will potentially yield better resolution, but a loss of total depth of penetration, a compromise in frequency selection may be the result. Conversely, a lower frequency will yield less vertical resolution while offering deeper penetration since attenuation will be lower. At some sites attenuation of the GPR signal may be the overriding limitation. As a rule, environments that are electrically conductive such where there is a high clay content or where the groundwater is groundwater high in total dissolved solids tend to offer the greatest signal attention and may be so severe as to limit the success of the GPR survey, regardless of frequency chosen. Environments with little or no clay minerals

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[1] Strength of reflection is determined by a contrast in GPR velocity (see Table 2). At an electrical conductivity of zero, the reflection coefficient is $(V_2 - V_1)/(V_2 + V_1)$, where V_1 and V_2 are the GPR velocities of Layer 1 and Layer 2

or soil moisture, frozen ground, or massive non-conductive rock offer the greatest success to GPR surveys. Table 2 provides the electrical conductivity of some common geologic materials.

Table 1. GPR Antenna Frequencies and Applications

Antenna Center Frequency (MHz)	Typical Applications
1000 or greater	Concrete studies (delaminations, condition of rebar, rebar dimensions, etc.), shallow void surveys (beneath pavement), bridge decking analysis, Subfloor utility investigations (floor drains, conduits, etc.)
500 to 1000	Ice and snow thickness mapping, forensics, search and rescue applications, shallow utility mapping
250 to 500	Search for underground storage tanks or other buried metals such as drums, utility mapping surveys, characterization of fill materials, search for excavations such as graves, roadway mapping, boring clearance work
100 to 250	Shallow geologic investigations, fracture mapping in rock quarries, stratigraphic analysis, fill and waste mapping
100 or less	Deep geologic investigations, permafrost investigations, glacial studies, mining applications

GPR units come in a number of configurations as shown below.

The most common type is a wheeled cart with both antennas in a closed housing (A-C). Low frequency antennas used for deep geologic work are generally large and are kept separate (D). Some units are designed to be towed with a skid plate (E). Units are also manufactured which contain multiple antenna pairs to increase data production (F). Positional control is usually managed using measuring tapes and ground markings, although it is also possible to gather the GPR data using a GPS unit (A). For most surveys where computer analysis is planned after the field activities, the data collection should be done in a methodical manner either in a series of parallel lines in a single direction or a grid of lines crossing at right angles to allow subsequent computer processing and analysis.

Table 2. Electromagnetic Properties of Earth Materials

Material	**ε (dimensionless)**	**σ (mS/m)**	**Velocity (m/ns)**	**Attenuation (db/m)**
Air	1	0	.3	0
Distilled Water	80	.01	.033	.002
Fresh Water	80	.5	.033	.1
Sea Water	80	3,000	.01	1,000
Dry Sand	3-5	.01	.15	.01
Wet Sand	20-30	.1-1	.06	.03-.3
Limestone	4-8	.5-2	.12	.4-1
Shales	5-15	1-100	.09	1-100
Silts	5-30	1-100	.07	1-100
Clays	5-40	2-1,000	.06	1-300
Granite	4-6	.01-1	.13	.01-1
Dry Salt	5-6	.01-1	.13	.01-1
Ice	3-4	.01	.16	.01
Metals	*	∞		∞

Table 1 Notes:

1. Intrinsic properties of earth materials at GPR frequencies are:
   ε = relative permittivity, also known as dielectric constant (dimensionless)
   σ = electrical conductivity in mS/m
2. Simplified equations for attenuation (a) and velocity (V) (at low loss) are:
   $V = (3 \times 10^8)/\varepsilon^{1/2}$
   $a = 1.69\sigma/\varepsilon^{1/2}$
3. mS/m = milliSiemens per meter | m/ns = meters per nanosecond | db/m = decibels per meter
4. Information Source: U.S. Army Corps of Engineers (1995)

4 Personnel Qualifications

GPR investigations should be conducted by qualified and experienced operators, such as an experienced field technician and/or geophysicist. The GPR operator should be experienced in evaluating data quality in the field and be able to adjust data acquisition procedures in response to variable site conditions in order to identify anomalies and resolve target features. Inexperienced Arcadis personnel directing or supervising GPR data acquisition or interpreting processed GPR data should seek appropriate guidance and technical peer review from qualified and experienced personnel available from the relevant members of the Subsurface Investigation Community of Practice.

5 Equipment List

The following equipment will be available, as required, during GPR surveys.

- Personal protective equipment (PPE), as required in the site Health and Safety Plan (HASP).
- Appropriate data collection forms (paper or electronic), field instructions, site plans, field notebook or tablet, spray paint or other means for ground marking of control grid, engineering tape measure, traffic cones or other visible markers for visual control of alignment.
- Specific GPR systems matched to project objectives and site conditions. There are a number of options; however, if Arcadis is self-performing the data collection, a geophysical specialist must be consulted prior to renting equipment (unless company owned) to assure that proper equipment and adequate familiarity with use of that equipment exists. Each manufacturer has their range of products, many of which are designed with specific applications in mind. In general, Arcadis will require that GPR data be stored and downloaded in digital format for later processing. Not all manufacturers offer data storage, and use of those GPR systems is discouraged. The most common acceptable GPR system manufactures include (not comprehensive and subject to change):
    - GSSI – https://www.geophysical.com
    - Sensors & Software – https://www.sensoft.ca
    - Mala - https://www.guidelinegeo.com/products/category/mala-ground-penetrating-radar-gpr/
- A primary and secondary antenna, of appropriate signal frequencies to match anticipated dimension and depth of objective(s). For example, it is good practice to have a 400-500 MHz antenna available at the project site if using a 200-250 MHz antenna in the event that conditions allow use of the higher frequency antenna as needed. Another example is if the lower frequency antenna is used as the primary reconnaissance antenna for mapping the entire site, and the higher frequency antenna is used for follow-up detailed mapping of select anomalous areas found with the lower frequency antenna. This second example is particularly relevant in the situation where the rate of travel of the GPR unit is limited by the memory buffer capacity of the unit (typically the demands on data streaming and store increase with antenna frequency).
- Optionally, a GPS unit which can be mounted to the GPR system for integration of GPS position into GPR data files (if option is available).
- Data processing software for use in the field and office. Generally, each GPR manufacturer has developed proprietary software to process their particular GPR system. Arcadis currently has licenses for Radan (GSSI), Ekko_Project (Sensors & Software), and Reflex (a general seismic and GPR processing program capable of converting most manufacturer-specific formats to industry standard formats). Other software for other GPR systems may be available for short term rental for specific projects. Note that GPR data processing is a highly specialized task and requires an experienced geophysical specialist to perform this task. The scope of GPR processing is beyond the scope of this TGI.

6 Cautions

The effectiveness of GPR is highly site-specific due to a number of possible types of interference and may be subject to the skill level of the operator in certain environments. Reliability and efficiency are enhanced when used in conjunction with other geophysical methods and/or direct observations. Soils with elevated electrical conductivity rapidly attenuate the radar energy, reducing the penetration depth and resolution. Clayey soils and saturated soils, particularly when high in dissolved solids, can significantly limit or even negate the applicability of GPR. Other potential interference sources include subsurface debris, rebar reinforced concrete, above ground, particularly overhead, reflective metal objects (cars, surface water, transmission lines, canopies, ceilings, etc.), and sources of electromagnetic signal (electrical generators, radio transmitters, etc.).

Both metallic and non-metallic utilities may be imaged by GPR under proper conditions. However, it should be noted that due to differences in the electromagnetic properties of materials (dielectric constant, see above), locating a non-metallic utility (e.g., plastic, vitrified clay tile, etc.) may be more difficult than a metallic pipe because of a low contrast in dielectric constant between non-metallics and soil. A general guideline for effective locating depth for utilities is 1-inch (2.5 cm) diameter of utility can be discerned for each foot (0.3 m) down to the maximum depth of penetration (highly site specific). For instance, one may expect to resolve a utility 10 inches (25 cm) in diameter at a depth of 10 feet (3 m) *if the maximum depth of penetration allows*. This is a general rule of thumb that can be applied to both metallic and non-metallic utilities but should be used cautiously as the type of material can affect the resolution. It is critical to perform initial testing to determine the total depth of penetration prior to beginning the methodical data collection process.

Also, the presence of reinforcing bar (rebar) in concrete can limit or negate the ability to resolve utilities present below the concrete. The resolution of smaller diameter pipes found within or just below the concrete may be completed masked by the strong reflections generated by the rebar.

Working inside of buildings can be especially challenging due the multiple surfaces (walls and ceilings) and fixtures above ground. The operator must know how to account for unwanted data artifacts. Generally, the GPR velocity in air is about 3 to 4 times faster than in the subsurface. For example, a metallic ceiling located 12 feet above the floor will appear in the GPR data at a position in the two-way travel time as a subsurface “depth” of about 3 to 4 feet. Remember, GPR records two-way travel time of the GPR pulse, which is converted to depth based on a measured or assumed GPR wave velocity.

Standing water is problematic. Typically, if a GPR unit is passed through a puddle of standing water a strong ringing response will be recorded, often obscuring subsurface information entirely.

7 Health and Safety Considerations

Minimize physical hazard exposure through use of proper PPE as prescribed in the HASP. Maintain awareness of other potential hazards associated with the physical location where the GPR investigation is being conducted and any ingress or egress conditions.

8 Procedure

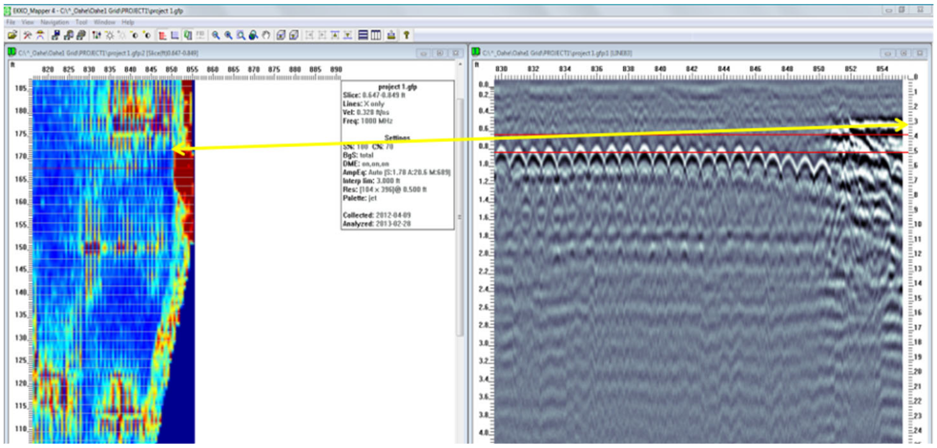
1. Become familiar with the details of the applicability and limitations of GPR.
2. Evaluate site-specific soil information to determine suitability of soils (clay content, saturation, TDS of groundwater) for GPR. In general, soils with greater than 35% clay content are considered restrictive, and soils with less than 10% clay content are considered favorable for reasonably deep penetration with GPR.
3. Evaluate meteorological information regarding recent or forecasted precipitation that could impact soil moisture content and GPR effectiveness. Standing water in paved areas is a condition that may limit or delay the GPR survey. Schedule GPR surveys appropriately.

4. Perform site reconnaissance in advance to identify potential sources of surface interference such as reinforced concrete, large metal objects, electrical equipment, overhead utilities, canopies, etc.
5. Consider complimentary technologies to supplement GPR and provide multiple lines of evidence. Geophysical technologies may include radio frequency tracing, magnetics, electromagnetic surveys, or electrical resistivity surveys. Direct observation (under proper health and safety guidance) is also an appropriate means of ground-truthing.
6. Employ only qualified and experienced GPR operators. For utility locating and mapping applications, the GPR operator should be specifically experienced in evaluating data quality and identifying anomalies in the field requiring variations in data acquisition procedures to positively interpret and locate targets of concern. If uncertain of a subcontractor's capabilities, consult with an Arcadis geophysical specialist.
7. Consider the depth and size of subsurface target features being sought with GPR. Attempt to match the signal frequency to the expected depth and size of the subsurface features. Change antenna as necessary for variable depths and sizes of target objects. Consider the selection of a primary and secondary choice of antennas and use multiple antennas as necessary. Test GPR at well-known, confirmed utility locations as means to verify depth of penetration. GPR wave velocity can also be confirmed by passing over a known utility, assuming it can be imaged.
8. Establish a reference grid over the area to be investigated and identify traverse locations in the field notebook or on a site plan map. It is preferable to perform a bidirectional grid. That is, lines collected both along the X and Y axes. The line separation should be a constant value based on the project objectives and the frequency of the GPR antenna. It is preferable to create a grid that has parallel base lines to minimize distance measurement errors.
9. Most GPR systems are equipped with an odometer to keep track of the distance moved. It is important to confirm the accuracy of the odometer calibration and adjust if necessary. This is done by laying out a measuring tape along a level, smooth surface and traversing a known distance. Recalibrate as needed.
10. Select and input a dielectric constant or average velocity into the GPR unit based on knowledge of the type of subsurface materials. Bear in mind that the dielectric constant or velocity is an approximation based on assumed subsurface materials and may vary based on the variability of the subsurface materials. The dielectric constant or velocity is necessary to estimate the depth of a target but should be considered an approximation not an absolute. Multiple passes over a known utility may be necessary using different dielectric constants before an accurate depth to a target can be estimated. Some manufacturers include the ability to perform hyperbola fitting to estimate dielectric constant or velocity from data collected in the field, and if this option is available, it should be used during initial testing.
11. Depending on the system and antenna frequency, the pace at which the GPR unit is moved along a traverse may affect the target resolution. It is recommended that an initial starting pace should be approximately 1.5 feet (0.5m) per second and modified if necessary, during field operations. Appropriate pacing can be determined in advance if the size of the smallest target is known.
12. Record GPR data while slowly pushing or pulling the antenna along each survey traverse. It is good practice to annotate periodic grid crossings using the system's ability to create fiducial markers. This is especially important for long traverses or locations where the ground surface is rough.
13. The data collection approach is generally one of two types.
    a. One approach, often used by utility location specialists, is to walk in a systematic pattern and mark out targets as they are found using paint or some other means. Once the area of interest is marked out, complete the survey by going back and storing key transects in the system memory for final reporting.

The locations of the final stored traverses should be properly surveyed either by high resolution GPS and/or triangulated using engineer tapes tied to known locations. This first approach is most appropriate for marking out USTs relatively simple utility patterns.

b. The second approach is applicable to mapping large areas, complex utility layouts, fill mapping, or other geologic objectives such as mapping a bedrock surface. In such circumstances the best practice is to layout a control grid and optionally using GPR mounted to the GPR system. The grid can either be a series of parallel lines at right angles to a known fabric, or if conditions are unknown, a bidirectional grid of lines at orthogonal orientations. It is important to start and end the GPR unit at marked out grid points and to keep good notes about the data collection process. Long lines should also be supplemented with fiducial marks at intermediate grid crossings. It is anticipated in this approach that data will be stored in memory and processed using appropriate GPR processing software as mentioned above.

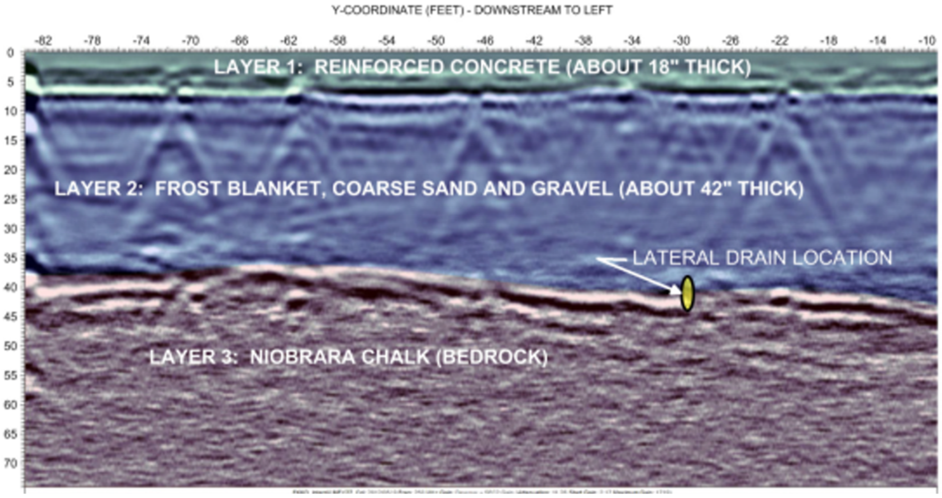
14. For projects where a complete grid of data is stored (13b above), the results may be interpreted either as a series of horizontal slice maps or 3-dimensional data sets. Most contemporary software has the capability of digitizing discrete objects or horizons on a line-by-line basis, after which the interpretations can be exported to a vector drawing format such as DXF or SHP files in the form of 3D points and polylines. Below are examples of GPR outputs.



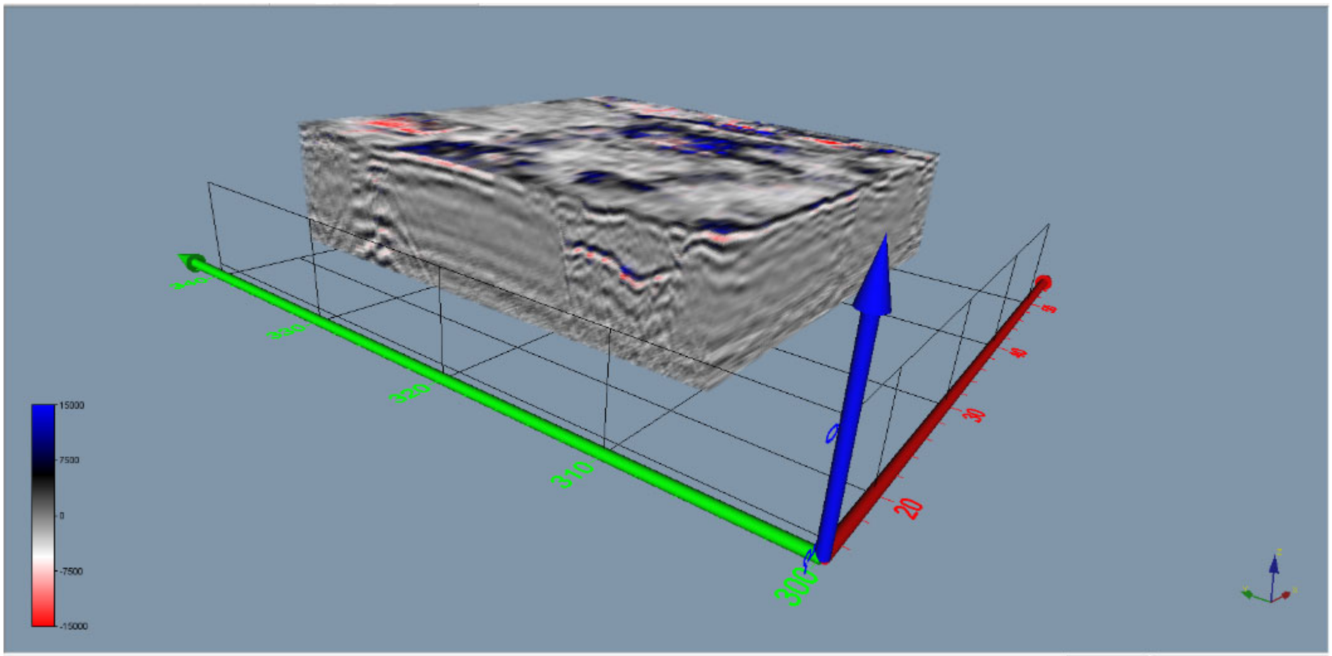
project 1.gfp
Slice: 0.647-0.849 ft
Lines: X only
Vel: 0.328 ft/ns
Freq: 1000 MHz

Settings
SN: 100 CN: 70
BgS: total
DME: on,on,on
AmpEq: Auto [S:1.78 A:20.6 M:689]
Interp lim: 3.000 ft
Res: [104 x 396]@ 0.500 ft
Palette: jet

Collected: 2012-04-09
Analyzed: 2013-02-28



GPR Example 2. GPR vertical section imaging fill sand and bedrock beneath a concrete slab (250 MHz antenna).



GPR Example 3. 3D GPR image showing two vertical sections and horizontal slice at a crossing of a waste burial pit (250 MHz antenna).

9 Waste Management

GPR is a non-invasive procedure and should not result in the generation of derived wastes. Any trash or rubbish generated during the course of field activities should be disposed of in a proper trash receptacle.

10 Data Recording and Management

Digital data collection is the Arcadis standard using available FieldNow® applications that enable real-time, paperless data collection, entry, and automated reporting. Paper forms should only be used as backup to FieldNow® digital data collection and/or as necessary to collect data not captured by available FieldNow® applications. The Field Now® digital form applications follow a standardized approach, correlate to most TGIs and are available to all projects accessible with a PC or capable mobile device. Once the digital forms are saved within FieldNow®, the data is instantly available for review on a web interface. This facilitates review by project management team members and SMEs enabling error or anomalous data detection for correction while the staff are still in the field. Continual improvements of FieldNow® applications are ongoing, and revisions are made as necessary in response to feedback from users and subject matter experts.

During GPR data collection, the GPR data files are stored in a memory within the manufacture's data logging computer. Generally, each traverse of the GPR unit is stored as a separate, uniquely named file. Often the file naming scheme either encodes the geometric information related to the data grid or a sequential naming scheme. Accurate note taking should be performed to assure that file names are properly associated with the grid notations. At periodic points during the GPR survey, it is best practice to download and backup the GPR data files to a company laptop and at least daily to copy the GPR data files and field notes to a secure SharePoint drive on the Arcadis system.

11 Quality Assurance

The following quality control procedures should be observed:

- Seek appropriate input prior to conducting a GPR survey to identify site-specific features (soil conditions/sources of interference) that may impact data acquisition.
- Operate all equipment in accordance with manufacturer's instructions and recommended procedures. Record all system components (Unit, antennae frequency, etc.) information in the field book or a pre-made field form.
- Regardless of which data collection approach is taken, data quality should always be checked in the field to identify factors that may require adjustment to the data acquisition procedures. Make appropriate adjustments to data acquisition methods to achieve survey objectives, as feasible.
- It is recommended that the operation and performance of the GPR equipment is field checked (if possible) by locating existing underground utilities or structures of known depth, size, and construction. These characteristics should be similar to that of unidentified target objects.
- Data interpretation should undergo peer review by appropriate qualified and experienced personnel.

12 References

U.S. Army Corps of Engineers (1995). Geophysical Exploration for Engineering and Environmental Investigations, Engineering Manual (EM) 1110-1-1802.

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TGI - Manual Water-Level and NAPL Monitoring

Rev: 2

Rev Date: April 5, 2022

Version Control

Issue	Revision No.	Date Issued	Page No.	Description	Reviewed By
0	0	October 11, 2018	All	Updated and re-written as TGI	Marc Killingstad Everett H. Fortner III
1	1	May 8, 2020	All	Updated and added NAPL gauging	Marc Killingstad Everett H. Fortner III Andy Pennington
2	2	April 5, 2022	All	Formatting and Revisions	Martha Wulftange

Approval Signatures

Prepared by:		4/5/2022
	Everett H. Fortner III, PG (Preparer)	Date
Reviewed by:		4/5/2022
	Marc Killingstad (Subject Matter Expert)	Date

1 Introduction

This TGI describes the equipment, field procedures, materials, and documentation procedures to measure and record water-levels using an electronic water-level probe or an oil-water level indicator. This TGI also describes procedures for measuring in-well thicknesses of non-aqueous phase liquid (NAPL), both light and/or dense (LNAPLs and DNAPLs, respectively).

2 Intended Use and Responsibilities

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 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, regulation-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.

3 Scope and Application

The objective of this Technical Guidance Instruction (TGI) is to describe procedures to measure and record water-levels (groundwater and surface-water) using manual water-level meters. Water levels may be measured using an electronic water-level probe or an oil-water level indicator from established reference points (e.g., top of casing). Reference points must be surveyed to evaluate fluid level elevations relative to a vertical datum (e.g., North America Vertical Datum of 1988 [NAVD88] relative to sea level). This TGI also describes procedures for measuring in well thickness of NAPL and DNAPLs.

Surface water-levels can be measured from stilling wells or fixed points (bridges, walls, etc.) and measuring from an established point of reference using a water-level meter. In some cases, surface water water-levels may be determined from a graduated stream gauge, attached to a pole located in open water with known elevation, without the use of a water-level meter.

The use of pressure transducers or other automated devices for the collection of groundwater elevation data will be subject of *TGI – Water-Level Monitoring using Pressure Transducers and TGI – Water-Level Measurements using Sonic Meters.*

4 Personnel Qualifications

Arcadis field sampling 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 regulations, such as 40-hour HAZWOPER training and/or OSHA HAZWOPER site supervisor training. Arcadis personnel will also have current training as specified in the Health and Safety Plan (HASP) which may include first aid, cardiopulmonary resuscitation (CPR), Blood Borne Pathogens (BBP) as needed. In addition, Arcadis field sampling 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. The HASP and other documents will identify other training requirements or access control requirements.

5 Equipment List

The following field equipment is suggested for water-level measurements:

- Site-specific Health and Safety Plan (HASP)
- Appropriate personal protective equipment (PPE) as specified in the HASP
- Electronic water-level indicator graduated in 0.01 ft. increments
- Electronic oil-water (interface) level indicator graduated in 0.01 ft. increments, if necessary
- Non-phosphate laboratory soap (Alconox or equivalent), brushes, clean buckets or clean wash tubs.
- Distilled or de-ionized (required for some sites) water for equipment decontamination
- Photoionization detector (PID) and/or organic vapor analyzer (optional)
- 150-foot measuring tape (or sufficient length for the maximum site depth requirement) – if required for total depth measurements of deeper wells
- Solvent (methanol/acetone/isopropyl alcohol) rinse – optional
- Spray bottle for solvent - optional
- Plastic drop cloth (e.g. Weatherall Visqueen) to place beneath the buckets or tubs to reduce potential for contamination of the tape or probe
- Tools and/or keys required for opening wells
- Well construction summary table and/or well construction logs
- Summary table of previous water-level measurements
- Field notebook and/or smart device (phone or tablet) or appropriate field forms (see Attachment 1).
- Indelible ink pen

6 Cautions

Electronic water-level indicators and oil-water interface probes may sometimes produce false-positive readings. For example, if the inside casing surface of the well or stilling tube has condensation above the water level, then an electronic water-level probe may produce a signal by contacting the sidewall of the well, rather than the true water-level surface. For accuracy, 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 (three or more times). Additionally, some wells may be constructed with a sump. If local/regional groundwater levels have declined such that the water-level is below the base of the well screen, a sump may still contain water and provide an erroneous measurement. Therefore, possessing and comparing measurements with a well construction summary table or well construction log is recommended for proper reporting.

If the presence of a NAPL is known or suspected within specific wells, do not use an electronic water- level indicator. Use an oil-water interface probe instead. If NAPL presents ignition or explosion hazards, an intrinsically safe oil-water interface probe is required to be used with grounding and following the manufacturer's instructions.

If the NAPL is known to be very viscous or problematic to gauge, the data quality will require additional consideration prior to measuring. Staff will consider the data quality objectives for the gauging activity – e.g., if quantifying NAPL thickness is necessary, or if assessing the presence/absence is sufficient.

Alternate NAPL measurement methods (such as using drop pipes or temporary coatings for down-well equipment) may be considered.

When measuring total well depths with an electronic water-level indicator, the measurement must have a correction factor applied for post processing or completed at the time of measurement that is equal to the length of the probe beneath the circuit closing electrodes (if applicable to the instrument). This is necessary because the tape distance markings are referenced to the electrode, rather than the end of the probe. Some newer instruments do not have an offset electrode and this correction factor is needed. In addition, total depth measurements are difficult with wells that have large water columns due to buoyancy issues. In addition, the total depth measurement will include notes that indicate a soft or hard bottom if recognized during the measurement.

Ensure that the type of electronic water-level indicator is compatible with the depth and diameter of the wells to be measured. Some smaller piezometers or larger diameter well stilling tubes will accommodate only smaller diameter probes.

7 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 oil. Other potential hazards include pressurized wells, stinging insects that may inhabit well heads, other biologic hazards (e.g. ticks in long grass/weeds around well head), and potentially the use of sharp cutting tools (scissors, knife). Appropriate personal protective equipment (PPE) will be worn during these activities. Only use non-toxic peppermint oil spray for stinging insect nests. Open well caps slowly and keep face and body away to allow to vent any built-up pressure. Field personnel will thoroughly review client-specific health and safety requirements, which may preclude the use of fixed/folding-blade knives.

Obtaining measurements from active pumping wells requires knowledge of the construction and design, as the indicator probe and tape can become intertwined within down-well equipment (such as pump impellers) causing a serious health and safety hazard and equipment damage. Ensure that stilling wells have a perforated end and capped bottom to inhibit tape from extending into the downhole pump depth. If a stilling tube is not present or the still tube construction is not known, determine a conservative “not to exceed” measurement depth based on the top of pump depth with an added safety factor. If all information is not known, a water-level will not be taken from the pumping well until clarification on depths are available.

8 Procedure

Calibration procedures and groundwater level measurement procedures for electronic water-level indicators and oil-water indicators are described in the sections below. Calibration documentation can berequested from the rental or manufacturer.

Calibration Procedures

If the indicator requires length and markings verification is required by project data quality plan or other reasons, then the following steps may be used:

- Measure the lengths between each increment marker on the indicator with a measuring tape. The appropriate length of indicator measuring tape, suitable to cover the depth range for the wells of interest, will be checked for accuracy.
- If the indicator measuring tape is inaccurate, the probe will require to be sent back to the manufacturer or rental company. If a replacement can’t immediately be available, then an offset can be measured to correct the measurements.
- If multiple water-level indicators and/or oil-water interface probes are being used for an event, calibration of the multiple devices will be required by measuring a water-level at a single well contemporaneously with all indicators to be used and calculated correction factors provided for data processing (typical corrections are small and range from 0.01 to 0.03 foot).
- Equipment calibration will be recorded in the field logbook and/or smart device.

Water-Level Measurement Procedures

The general procedures to be followed for the collection of fluid level measurements and well depths from the monitoring wells are as follows:

- Check that the water-level/oil-water level indicator battery is functional, before mobilization and prior to each work day (e.g., turn power on and check that meter sounds when probe is lowered into a bucket of water – note that water-level meters will not work with low-electrical-conductivity liquids such as distilled water).
- Record instrument make, model, serial number, and (if present) Arcadis ID number in the field form or electronic field form.
- Don disposable nitrile gloves. Decontaminate the water-level/oil-water indicator, any attached tape and the spool with laboratory-grade soap and distilled water (see Initial Decontamination Procedures below). The spool requires caution with cleaning as it is not water-proof and can be damaged during cleaning.

- The top of the monitoring well will be cleaned with a clean rag to prevent loose particulate matter from falling into the well.
- Perform a well inspection (note that a well inspection form may be required to be filled out along with a photo to document the conditions).
- Place clean plastic sheeting on the ground next to the well.
- Unlock and/or open the monitoring well cover while standing upwind from the well (note that some wells may be under pressure and precaution should be taken with opening well caps – see Section 6).
- Measure the volatile organics present in the monitoring well head space with a PID and record the PID reading (if applicable and requirement for the site).
- Allow the water-level in the well to equilibrate with atmospheric pressure for a few minutes (check previous field forms or field books for equilibration time, if noted).
- Locate the measuring reference point that correlates to the survey point on the well casing. If one is not found, make a reference point by notching the highest and/or north point on the inner casing (or outer if an inner casing is not present) or mark with a permanent mark. All downhole measurements will be taken from the reference point. Document any changes or new reference point addition.
- Measure to the nearest 0.01 foot and record the height of the inner well casing and outer protective casing to ground level (note that some well pads are raised and are not at true ground surface).
- Lower the indicator probe into the center of the well until contact with the water surface is indicated by either an audible alarm or light. The sensitivity of the probe may need adjustment if the alarm or light is not strong signal. Use and install a tape guide (available from some manufacturers) to help with accuracy and provide protection with damaging the measurement tape. If a tape guide is not available, make sure that the tape does rub on the inner or outer casing which could fray and damage the tape.
- If an oil-water interface probe is being used to measure depth and thickness of NAPL, lower the interface probe into the center of the well until a contact with the NAPL surface is indicated by either audible alarm or light. The sensitivity of the probe may need adjustment if the alarm or light is not strong signal. To gauge the water level in a well which contains LNAPL (LNAPL-water interface), advance the interface probe past the LNAPL-water interface until the probe produces a solid audible alarm indicating water. While slowly retrieving the probe upward, the equipment will produce a different tone when the LNAPL-water interface is reached (typically this is a multiple alarm sound or flashing light). This level should represent the depth to water. The depth indicating the bottom of the water column and top of DNAPL layer, if any, is indicated by the multiple alarm signal or flashing light emitted by the interface probe.
- Hold the tape at the measuring point and repeat the measurement two more times.
- Read and record measurement to the nearest 0.01 foot. Check the measurement with previous measurements, if available, and note any anomalies/discrepancies; if significant, contact the project staff.

- Measure and record total depth of well (see Total Depth Measurement Procedures below); note that measurement of total depth is not always performed at wells containing LNAPL or DNAPL, in order to reduce decontamination of the instrument and reduce potential exposure to NAPL.
- Record all measurements (with date and time collected to the nearest minute) and note any inconsistencies/anomalies and relevant observations in the field notebook and/or smart device or appropriate field forms.
- Follow decontamination procedure outlined below before measuring subsequent wells (see
- Decontamina*tion after Water Level and Total Depth Measurements* below).
- Replace cap and lock the well when all activities are completed.

Total Depth Measurement Procedures

- Weighted tape or electronic water-level indicator can be used to measure the total well depth.
- Follow initial procedures noted above in Water-Level Measurements above.
- Lower indicator probe (or tape) until weighted end is resting on the bottom of the well. Raise indicator slowly until there is no slack in the tape. Gently estimate the bottom of the well by slowly raising and lowering the indicator: great care should be taken to avoid damaging the sensor on the probe. The operator may find it easier to allow the weight to touch bottom and then detect the 'tug' on the tape while lifting the weight off the well bottom.
- Because of tape buoyancy and weight effects encountered in deep wells with long water columns, it may be difficult to determine when the probe is in contact the bottom of the well and sediment in the bottom of the well can also make it difficult to determine total depth. Care must be taken in these situations to ensure accurate measurements.
- If total depth measurements are to be collected during low-flow sampling events, the measurement will be made only after low-flow sampling has been completed or at least 12 hours prior to initiating sample collection from the well, in order to minimize: 1) mixing of the stagnant water at the top of the well column with potential formation water underneath; and/or 2) agitation and subsequent entrainment of possible sediment collected at the well bottom).
- Read and record measurement to the nearest 0.1 foot. Please refer to the note regarding total depth measurements described in Section 5 Cautions above.
- Follow decontamination procedure outlined below before gauging the next well (see Decontaminationafter *Water Level, NAPL Level, and Total Depth Measurements* below).

Initial Decontamination

- Note that there may be project specific decontamination procedure documents that will be followed in lieu of the below procedures.
- Set up a decontamination station consisting of three clean buckets (e.g., 5-gallon buckets). The buckets should not be used to containerize purge water; they will be used for decontamination purposes only.
- Fill the first bucket with one gallon of distilled water (use deionized water if metals are a contaminant at the site) and add non-phosphate laboratory-grade soap. Fill the second bucket

with distilled water (use deionized water if metals are a contaminant at the site) and leave the third bucket empty. Place the drop cloth underneath.

- Unwind the entire tape from the spool into a bucket with non-phosphate laboratory-grade soap and distilled water; Brush the tape carefully to remove dirt and possible contamination, using a brush dedicated to the wash bucket.
- Carefully brush all dirt of the spool and wipe down with a soapy cloth or paper towel.
- Transfer the tape into the second bucket containing rinse water. Carefully brush the tape using a second brush, dedicated to the rinse bucket. Lift the tape out of the bucket and allow rinse water to drip off the tape.
- Transfer the tape to the third bucket. Wind the tape onto the spool while wiping excess water off the tape using a paper towel.

Decontamination after Water Level, NAPL Level, and Total Depth Measurements

- Set up a decontamination station consisting of three clean buckets, fill according to the initial decon procedure.
- Unwind the only the length of tape used for gauging from the spool into a bucket with laboratory-grade soap and distilled water. Brush the tape carefully to remove dirt and possible contamination, using a brush dedicated to the wash bucket.
- Continue as described above.
- Extra care should be taken to clean the probe after a total depth measurement. All sediment or dirt needs to be removed during decontamination.
- If an oil-water interface probe is used to gauge NAPL, a solvent may be necessary to remove all NAPL residue. After decontaminations steps above, use a spray bottle filled with chosen solvent (ex. isopropyl alcohol) and spray across all surfaces of the tape. Use paper towels to wipe off solvent and/or residue. This step may be repeated if necessary.

Notes:

- Collect equipment blanks if required by the work plan (minimum 1 per 20 samples or 1 per sampling event).
- Prepare new wash solution and rinse water when necessary (e.g., every 10 to 20 wells). The spent wash and rinse solution should be discharged according to site practices.
- The decontamination station may be expanded by adding extra rinse and/or detergent stations (i.e., solvent wash station) to the set up. The addition of more stations depends on the requirements of the work plan or the site-specific Field Sampling and Quality Assurance Plan and outlined in the project field plan or kick-off meeting.
- Small crates or washtubs are a possible substitute for the buckets. In any case, it is recommended to use containers with a lid.

9 Waste Management

Decontamination fluids, PPE, and other disposable equipment will be properly stored on site in labeledcontainers and disposed of properly. Be certain that waste containers are properly labeled and documented in the field log book. Review *TGI – Investigation Derived Waste Handling and Storage*, foradditional information and state- or client-specific requirements.

10 Data Recording and Management

Digital data collection is the Arcadis standard using available FieldNow® applications that enable real-time, paperless data collection, entry, and automated reporting. Paper forms should only be used as backup to FieldNow® digital data collection and/or as necessary to collect data not captured by available FieldNow® applications. The Field Now® digital form applications follow a standardized approach, correlate to most TGIs and are available to all projects accessible with a PC or capable mobile device. Once the digital forms are saved within FieldNow®, the data is instantly available for review on a web interface. This facilitates review by project management team members and SMEs enabling error or anomalous data detection for correction while the staff are still in the field. Continual improvements of FieldNow® applications are ongoing, and revisions are made as necessary in response to feedback from users and subject matter experts.

If paper forms are used, fluid level measurements as well as all relevant observations should be documented in the field logbook, field forms and/or PDA as appropriate. The following information must be documented:

- Well or location identification;
- Measurement time;
- Total well depth or depth of the water body at the location;
- Depth to water and, where necessary, depth to NAPL.

Once all the data has been collected and recorded, all notes/forms/data must be uploaded to the appropriate project directory on the Arcadis server, and an email should be sent to the Task Manager and/or Technical Lead for notification. A summary of the work completed that day and any relevant observations noted (such as well inspections) during the daily activities as well as copies of the data mentioned above should be included with the email. The appropriate team member will review the datafor accuracy and provide feedback.

11 Quality Assurance

Suggested quality control measures are below; project teams may implement some or all of these at their discretion and based on project data quality needs.

- As described in the detailed procedure, the electronic water-level meter and/or oil-water interfaceprobe can be calibrated prior to use versus an engineer’s rule to ensure accurate length demarcations on the tape or cable. The results will be recorded.
- Measurements will be completed three times, with the final measurement recorded.
- Fluid interface measurements will be verified by gently raising and lowering the instrument through each interface to confirm repeatable results.

- Field notes will be reviewed by the project team once the field data has been delivered.

12 References

Cunningham, W.L., and Schalk, C.W., comps., 2011. *Groundwater technical procedures of the U.S.Geological Survey: U.S. Geological Survey Techniques and Methods 1–A1, 151 pp*.

U.S. Environmental Protection Agency, 2013. *SESD Operating Procedure, Groundwater level and WellDepth Measurement.* January 29.

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TGI - In-Situ and Ex-Situ Water Quality Parameters – Surface Water and Groundwater

Rev: 1

Rev Date: April 15, 2022

Version Control

Issue	Revision No.	Date Issued	Page No.	Description	Reviewed By
	0	October 16, 2018	All	Updated and re-written as TGI (in-situ and ex-situ adaptation)	Marc Killingstad
	1	April 15, 2022	All	Review and update to include surface water turbidity sensors	Shannon Dunn / Marc Killingstad

Approval Signatures

Prepared by: 4/15/2022

Chris Shepherd

Chris Shepherd, PG Date

Reviewed by: 4/15/2022

Marc Killingstad (Subject Matter Expert) Date

1 Introduction

This Technical Guidance Instruction (TGI) describes methods used to measure water quality parameters in surface water as well as groundwater both in-situ and ex-situ.

2 Intended Use and Responsibilities

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3 Scope and Application

Water quality parameters (e.g., turbidity, specific conductivity, pH, and temperature) of natural waters are usually measured in the field. The temperature, pH, specific conductivity, dissolved oxygen (DO), and oxidation reduction potential (ORP) and turbidity of water will be measured in-situ or ex-situ with amultiparameter water quality meter (i.e., multimeter).

Conductivity is the ability of a solution to pass an electric current. This current is carried by inorganic dissolved solids. The measurement is useful to quantify the chemical purity of the water relative to the amount of dissolved solids in a solution. Generally, temperature-compensated conductivity, termed specific conductivity, is measured by a water quality meter. Specific conductivity can also be used to estimate total dissolved solids (TDS) in solution (grams per liter or g/L) by multiplying the specific conductivity (measured in milli-siemens per centimeter or mS/cm) by 0.65 or a matrix specific factor, which assumes that sodiumchloride is a reasonable surrogate for the dissolved solids in solution.

Measuring the concentration of DO in water is an important component in evaluating the quality of naturalas well as contaminated waters. The effects of wastes on rivers/streams, the suitability of water for fish and other organisms, as well as the effects of remediation efforts, can often be ascertained from the DO content. Dissolved oxygen levels generally range from 5 to 9 milligrams per liter (mg/L) when measured inwater that is in equilibrium with air, depending on the temperature and barometric pressure; however, levels may be lower in a ‘reducing’ environment where anoxic conditions exist in water (e.g., gasoline plume undergoing bioremediation). DO is measure in both mg/L and percent.

The measurement from an ORP sensor represents the net status of all the oxidation and reduction reactions in the sample being measured. Positive results indicate an oxidizing environment while negativeresults indicate a reducing environment. ORP is determined by measuring the potential of a chemically- inert electrode which is immersed in the solution. The sensing electrode potential is read relative to the reference electrode of the pH probe and the value is presented in millivolts (mV).

ORP meter results can indicate possible contamination and can be particularly useful if it is known that one component of the sample is primarily responsible for the observed value. For example, excess chlorine in a sample will result in a large positive ORP value while the presence of hydrogen sulfide willresult in a large negative ORP value. Together with pH, temperature, and knowledge of the dominant species in a sample, ORP results help predict the oxidation state of ions in solution and whether certainreactions may take place.

Temperature readings will be taken at each water sampling location to assist understanding the water quality as well as compensating measurements. A thermometer is typically part of the multimeter. If not,a temperature probe or thermometer will be used.

Turbidity is a measure of the relative clarity of water. It is an optical measurement of the amount of light scattered in the water. Turbidity is often used as a proxy for the amount of suspended particles in the water. Turbidity is typically reported in nephelometric turbidity units (NTUs) or Formazin Nephelometric Units (FNUs).

Refer to the appropriate TGI(s) for surface water sampling and/or groundwater sampling, if applicable. In addition, the water quality instruments should be cleaned in accordance the manufacturers specifications and the *TGI for Groundwater and Soil Sampling Equipment Decontamination* and all investigative derived wastes (IDW) should be managed in accordance with project plans.

4 Personnel Qualifications

Arcadis field sampling 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 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, the sampling team 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 sampling 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. Additionally, the field sampling 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.

5 Equipment List

The following materials, as required, will be available during field measurement of water qualityparameters:

- Site-specific HASP and health and safety documents identified in the HASP (e.g., job safetyassessments [JSAs])
- Field Implementation Plan (FIP) that includes site map with sampling locations, well constructionrecords (table or logs), sampling plan, and prior sampling records (if available)
- Field notebook, pen(s) (indelible ink) and/or smart device (smart phone or tablet, see Section 10)
- Field laptop / smart device / data manager, as appropriate
- Water Quality Measurement Log (**Attachment 1**) or smart device with a digital form; alternatively, the surface water sampling or groundwater sampling form may be used, if appropriate.
- Water Quality Meter Calibration Log (**Attachment 2**)
- Appropriate personal protective equipment (PPE) (e.g., latex or nitrile gloves, safety glasses, etc.) asspecified in the HASP
- Traffic cones, delineators, and caution tape as appropriate for securing the work area as specified inthe Traffic Safety Plan (TSP)
- Well key(s), as needed
- Photoionization detector (PID), flame ionization detector (FID) or other air monitoring equipment, asneeded, in accordance with the HASP
- Plastic sheeting (e.g., Weatherall Visqueen) or other clean surface to prevent sampling equipment from coming in contact with potentially contaminated surfaces, as needed
- Multiparameter (temperature/pH/specific conductivity/ORP/turbidity/DO) water quality meter or sondewith flow-through cell (as appropriate) plus reader and protective housing, for example:
    - YSI Professional Plus Multiparameter Instrument
    - YSI EX01 or EX02 Multiparameter Sonde
    - Horiba W-22 XD Multiparameter Instrument
    - Hydrolab DS5 Multiprobe and Display

- Turbidity meter (e.g., Lamotte 1974) and sample vessels, as required by FIP or QAPP.
    - Some multiparameter meters have a turbidity sensor; however, the team must verify the sensor will meet the data quality objectives in the FIP or QAPP.
- Operation manual(s) for meter(s)
- Water quality meter extension cable (as needed for in-situ readings of wells)
- Standard solutions for calibration, check expiration dates
- Multimeter maintenance kit and extra DO membranes if using amperometric DO probe
- Extra batteries for the various instruments and/or charging cables
- Electronic water-level indicator (e.g., Solinist Model 101) or oil/water interface probe with 0.01-foot accuracy), as needed
- Tape measure, as needed
- Cleaning equipment (buckets, distilled or deionized water, cleansers appropriate for removingexpected chemicals of concern, paper towels), as needed.

6 Cautions

NOTE: *Proper operation and maintenance are very important for a functioning meter and accuratereadings. Carefully follow manufacturer's instructions for operation (including down-hole use), maintenance, and calibration as each manufacturer's instructions will vary. Some meters require periodic manufacturer calibration.*

Verify the meters meet the project data quality objectives in the FIP and QAPP. In some cases, it may be necessary to use a separate turbidity meter (nephelometer) or higher accuracy and precision meter(s) if the measurements are intended to be used for compliance purposes.

Verify the meter is intended for in-situ measurements (i.e., can be fully submerged in water) and that all necessary parts are available prior tofield mobilization. Check and record the expiration dates of calibration fluids. Verify that calibration readings are reasonableand correspond to previous calibration readings when available. Expired or contaminated calibration fluids may result in erroneous results. If accurate measurements of TDS are required, site-specific calibration will be necessary in accordance with the manufacturer's specifications.

When taking measurements in the field, verify that readings make sense and compare to historicalreadings when possible. See Section 3.

7 Health and Safety Considerations

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

Appropriate personal PPE will be worn at all times in line with the task and the site-specific HASP. Also, at a minimum, wear latex gloves and safety glasses when working with calibration solutions.

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.

Access to wells and some surface water bodies may expose field personnel to hazardous materials such as contaminated groundwater ornon-aqueous phase liquid (NAPL) (e.g., oil). Other potential hazards include pressurized wells, stinging insects that may inhabit well heads, other biologic hazards (e.g. ticks in long grass/weeds around wellhead), and potentially the use of sharp cutting tools (scissors, knife)—open well caps slowly and keep face and body away to allow to vent any built-up pressure; 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 working near surface water bodies, it may be necessary to use personal flotation devices and/or use additional safety measures. Consult with the HASP and JSA for site- and task-specific health and procedures.

If working at a site with hazardous levels of volatile organic compounds, headspace and/or breathingzone readings will be measured prior to working at/in the well, in accordance with the HASP.

8 Procedures

This Procedures Section is divided into:

- General Procedures – calibration, operation, and maintenance procedures that apply to all methods and meters
- Calibration – general calibration procedures for:
    - Multimeter
    - Separate turbidity meter, if required
- Operation – general measurement operations for:
    - Ex-situ measurements
        - Multimeter
        - Separate turbidity meter, if required
    - In-situ measurements (downhole/well or submerged applications)
- Maintenance
    - Multimeter
    - Turbidity meter

8.1 General Procedures

The following, general procedures apply to most instruments regardless of whether measuring in-situ or ex-situ. For groundwater, most measurement are conducted ex-situ (i.e., not within the groundwater well/aquifer). It is also possible to use in-situ measurements for some parameters and ex-situ measurements for other parameters. If in-situ measurements are carried out, a special probe and/or cables are required.

- Read through all relevant procedures before field implementation and familiarize yourself with the equipment
- Verify all equipment is present and the instrument is fully functioning prior to field mobilization, if possible
  - Check batteries/power levels
- The meter(s) should be cleaned prior to each use in accordance with cleaning and decontamination procedures as specified in the FIP or QAPP and in accordance with the instruction manual.
  - Most meters can only handle light washing with a mild soap and warm water.
  - After cleaning the sensors should be soaked in distilled/deionized water and then rinsed in distilled/deionized water. The recommended soaking periods vary depending on the sensor (see Section 8.2)
  - It is recommended that you temporarily store the probes in distilled/deionized water uses between measurements as some probes like conductivity require long soaking periods (see Section 8.2).
- The meter will be calibrated following the manufacturer's instructions as calibration steps vary bymanufacturer
  - Probes should be rinsed with a small amount of the calibration solution and then discard that used solution prior to calibration, if applicable. This will reduce cross-contamination of the calibration solution during calibration
  - Two or three-point calibrations are preferred over single point calibrations, where applicable. See Section 8.2 and should be selected based on expected water quality
  - Verify calibration solutions, if applicable, are not expired
  - Caution: calibration solutions should not be reused as it can cross-contaminate the solution unless authorized by the QA/QC manager
  - Ensure the sensor is completely submerged in the calibration solution, if applicable
  - Calibration information will be recorded in the calibration log (Attachment 2) and the field notebook
  - More frequent calibration may be necessary in harsh conditions or per project plans
  - Barometric verification or calibration may be required for some instruments
- The meter will be operated following the manufacturer's instructions
- Multimeters can be operated in-situ (down-hole, in water, etc.) or ex-situ (water is transferred to container for measurement)
  - Ex situ operation is described in Section 8.3.1
  - In situ operation is described in Section 8.3.2
- The meter will be maintained according to the manufacturer's instructions
  - Maintenance information will be recorded in the field notebook or instrument log
  - Manufacturer recalibration or replacement probes may be required on a routine basis
  - Additional details for pH, conductivity, temperature, dissolved oxygen, and turbidity maintenance

are presented in section 8.4 Maintenance below

    - More frequent maintenance (probe replacement, sensor reconditioning, etc.) may be necessary in harsh conditions or per project plans

- A replacement meter and probes will be available onsite or ready for overnight shipment, as necessary
- Store the meters in accordance with manufacturer's specifications
    - Most multi-meter sensors should be stored with a small amount of water in the cap to keep it moist but not saturated/submerged.

The complete procedures are described in Section 8.2 through 8.4.

8.2 Calibration

8.2.1 Multimeter Calibration

1) Connect cables from meter to reader
2) Check probes and ensure they are clean
3) Switch on instrument and allow to warm-up, warm up may take from 5 to 15 minutes depending on the instrument and sensors used
4) Check battery life and replace, if needed
5) Adjust date/time, if needed
6) Soak all probes in distilled or de-ionized water for at least 5 minutes (some probes may requirelonger soak times, see below and manufacturer instructions) and then shake off excess liquid
    i. NOTE: *If the probes are recently reconditioned or have slight build-up, allow for longer soaking period*
7) Navigate to calibration display/mode; enable auto stabilization feature, if appropriate
8) **pH Calibration** – when in use, the pH meter will be calibrated daily, at a minimum.
    a. Connect electrode (if applicable) or remove protective cap from electrode
    b. Rinse end of electrode in distilled/deionized water and shake off excess water
    c. Measure and record temperature of buffer solutions
    d. Immerse pH electrode in pH buffer 7.00, set the temperature to that of the buffer 7.00, andallow sufficient time for the electrode to stabilize
    e. Adjust the calibration for the correct readout and temperature
    f. Confirm/press the calibration button
    g. Remove electrode from buffer and rinse with distilled/deionized water
    h. Immerse pH electrode in buffer 4.00, set the temperature control to that of the buffer 4.00,and allow sufficient time for the electrode to stabilize

    i. Adjust the calibration for the correct readout and temperature
    j. Confirm/press the calibration button
    k. Rinse electrode with distilled/deionized water
    l. A pH 10 calibration will also be performed if high pH (>9) is anticipated, following manufacturers procedures
    m. The pH meter is calibrated

9) **Conductivity Calibration** – when in use, the conductivity meter will be calibrated daily, at aminimum.

    a. Conductivity is generally measured in specific conductivity (temperature compensated),verify with the FIP/work plan
    b. Soak the probe in distilled/deionized water for at least 30 minutes
    c. Remove the probe from the water and fling out drops clinging inside
    d. Immerse the probe to or beyond the vent holes in a beaker containing 1.413 mS/cmstandard solution for freshwater measurements or a standard with a higher concentration for marine water, and gently agitate vertically to remove entrapped air
    e. Repeat Steps 3 and 4 at least once more
    f. Press calibration button

10) **Temperature calibration** – temperature will be verified according to FIP/work plan, if applicable.

11) **Dissolved Oxygen (DO) calibration** – when in use, the DO meter will be calibrated daily usingthe air calibration method or less frequently if using an optical sensor (see below).

    a. Preparation
        i. Polarographic sensor – periodically recondition sensor, replace fluids, and Teflon®membrane, per manufacturer, and air bubbles should not be present
        ii. Galvanic sensor – Periodically recondition sensor, replace fluids, and membrane,per manufacturer, and air bubbles should not be present
        iii. Optical sensor – Per manufacturer, most will only require field checks and maintenance, however, weekly checks are recommended to verify the accuracy, ata minimum
    b. Obtain a barometric pressure reading from a daily weather report or from the instrument,as required by instrument
    c. Keep instrument upright and vent cap/cover while retaining a small amount of clean water(do not cover probes) for non-optical sensors only
    d. Allow 5 to 15 minutes for optimum probe stabilization and polarization, for non-optical sensors (reading will range between 5 to 9 mg/L depending on temperature and barometricpressure)
    e. Press calibration button if reading is more than 2% from the standard

12) **Oxidation reduction potential (ORP) calibration** – when in use, the ORP meter will becalibrated daily, if required.
    a. Rinse the probe in distilled/deionized water
    b. Remove the probe from the water and fling out drops clinging inside
    c. Immerse the probe in the ORP solution. Gently agitate vertically to remove entrapped air.
    d. Adjust calibration target based on temperature in accordance with manufacturer and calibration solution guide
    e. Allow the sensor to equilibrate to solution
    f. Press calibration button if reading is more than 2% from the standard
13) **Turbidity, if used** – when in use, turbidity sensor will be checked daily and calibrated weekly, at aminimum
    a. Verify with the FIP/work plan if the turbidity sensor will be used and the proper units (NTU, FNU, etc.)
    b. Gently clean the sensor to remove and sediments or buildup and then rinse the sensor with distilled/deionized water one to two times
    c. Remove the probe from the water and fling out drops clinging inside
    d. Next do a final rinse with the calibration solution starting with lower calibration solution and dispose of the used solution.
    e. Immerse the probe in the calibration cup with the guard. It is important to calibrate with the guard on or verify the cup is designed to match the guard as turbidity measurements are affected by the dimensions and reflectivity of the guard. Verify the there are no air bubbles.
    f. Repeat Steps c, d, and e at least once more with higher turbidity calibration solutions
    g. Press calibration button
14) Adjust the instrument to READ or LOGGING mode, per instruction manual and project plans; theinstrument is now ready for use
15) Record the calibration on the field form or smart device.

8.2.2 Turbidity Meter Calibration (if required)

When in use, the turbidity meter will be checked daily and calibrated weekly. The turbidity meter will be calibrated per steps below:

1) Switch on instrument and allow time to warm-up
2) Check battery life and replace, if needed
3) Turbidity sample tubes will always be washed prior to use, but not the calibration standard tubes,using a mild detergent to remove any dirt or fingerprints that could bias the results
4) Dry the outside of the sample turbidity tubes with a clean, lint-free cloth or disposable wipe (non-scratch)

andallow the turbidity tubes to air-dry in an inverted position to prevent dust from entering the tube,as allowable (but, not the calibration standard tubes)—dirt or fingerprints can lead to inaccurateresults.

5) Wipe the 1 NTU standard and place in the chamber after aligning the arrows (manufacturer dependent)

6) Place the light shield over the turbidity standard and allow the meter to stabilize

7) Press the read and/or CAL button, per instructions

8) Repeat steps 3 thru 5 above

9) Adjust to READ mode and the instrument is now ready for use

10) Record the calibration and/or verification in the calibration log.

8.3 Operation

Water quality parameters can be measured ex-situ or in-situ in accordance with the FIP/work plan. The operating procedures for each method are described below. It is also possible to collect a depth-specific water sample from a well or water body for ex-situ measurement.

8.3.1 Ex-situ Operation

For ex-situ operation one or two representative water samples will be collected from the well or surface water body for measurement using the required meters. If two representative samples are collected, both values for each parameter should be reported, however, the average of the two results should be used as the final value.

8.3.1.1 Multimeter

1) Fill two 100-mL plastic clean, disposable containers or cleaned beakers with water from the sample

2) Insert the probe into the first beaker immersing all sensors and allow to stabilize (2 minutes atminimum)

3) Record readings

   a. Temperature – in degrees Celsius or Fahrenheit

   b. pH – in standard units between 0 and 14, in 0.01 increments

   c. Specific conductivity – in mS/cm or micro siemens per centimeter (uS/cm)

   d. DO – in mg/L and percent (will typically read between 0 and 15 mg/L)

   e. ORP – in millivolts (mV; will typically read between -1,400 mV and + 1,400 mV), if required

   f. Turbidity, if used – in NTU or NFU

4) Rinse probe off with distilled/deionized water

5) Repeat Steps 2 thru 4 for the other beaker, if applicable

6) Record results on the water quality measurement log and/or in field notebook - the average will bethe actual result, after stabilization if two samples are used

7) Rinse probe off with distilled/deionized water

NOTE: *If a flow through cell is used during sampling, a single reading can be obtained from the multimeter during each step of the wells purging in accordance with TGI - Low FlowGroundwater Purging and Sampling.*

8.3.1.2 Turbidity Meter, if needed

1) Fill the two cleaned, manufacturer provided sample tubes with water from the sample
    a. If using a flow through cell, it is recommended to collect the turbidity samples before the flow through cell
2) Wipe off and dry the outside of the sample turbidity tubes with a clean, lint-free cloth ordisposable wipe
3) Insert the first sample tube and close the cover
4) Push the READ button
5) Record turbidity reading in NTUs (0 to 1,100 NTUs)
    a. If readings are over the instrument limit, a single 2X dilution can be run by mixing thesample with equal parts distilled or de-ionized water and gently mixing
    b. The resulting value will need to be doubled (for example, if the diluted reading is 750 NTUs, the estimated turbidity would be 750 x 2 = 1,500 NTUs. Diluted samples will bequalified as estimated)
6) Repeat steps 2 thru 5 with the second sample tube
7) Log the results on the water quality measurement log and/or in field notebook - the average willbe the actual result
8) Rinse sample tubes with distilled/deionized water.

NOTE: *If a flow through cell is used during low flow groundwater sampling, a single reading can be obtained from the multimeter during each step of the wells purging in accordance with TGI - Low FlowGroundwater Purging and Sampling. The turbidity sample is recommended to be collected prior to passing through the flow through cell.*

8.3.2 In-situ Operation

1) Connect extension cable and protective housing to meter
2) Measure water level from reference point
3) Lay out plastic sheeting as needed to keep the multimeter clean
4) Clean multimeter and cable per decontamination procedures and instruction manual and rinse with distilled/deionized water using caution, as most meters can only handle light washing with amild soap and warm water
5) Organize work area to prevent dirt or objects from falling in the well
6) Measure and mark extension cable at planned measurement intervals in accordance with the FIP
7) Slowly lower the probe into the well or water body to the desired measurement interval usingcaution to prevent rubbing of cable on the well and minimize water and sediment disturbance

8) Allow readings to stabilize (typically 1 to 3 minutes)
    a. For many instruments, the instrument may need to be slowly oscillated up and down a fewinches to circulate water around the probes
9) Record readings
    a. Temperature – in degrees Celsius or Fahrenheit
    b. pH – in standard units between 0 and 14, in 0.01 increments
    c. Specific conductivity – in mS/cm or uS/cm
    d. DO – in mg/L and percent (will typically read between 0 and 15 mg/L)
    e. ORP – in mV (will typically read between -1,400 mV and +1,400 mV), if required
    f. Turbidity, if used – in NTU or NFU
10) Repeat steps 4 through 9 to complete targeted in-situ measurements
11) Record results on the water quality measurement log or smart device
12) Slowly retrieve the multimeter
13) Clean multimeter and cable per decontamination procedures and instruction manual and rinse with distilled/deionized water using caution, as most meters can only handle light washing with amild soap and warm water

8.4 Maintenance

8.4.1 Multimeter

1) After use, the meter will be inspected and maintained according to the manufacturer's specifications and the inspection/maintenance activities will be recorded in the field notebook
2) Keep records of usage, maintenance, calibration, problems, and repairs
3) Recharge/replace batteries on a regular basis
4) Store meters or electrodes in protective casing when not in use
5) DO membranes will be stored moist, unless specified otherwise by manufacturer
6) Focused probe cleaning may be necessary in accordance with the operation manual and may be needed more frequently in harsh conditions
7) A replacement meter will be available onsite or ready for rapid delivery/shipment
8) Periodic manufacturer calibration may be necessary per operation manual and/or field plans.

8.4.2 Turbidity Meter, if used

1) Recharge battery on a regular basis

2) Store in protective casing when not in use
3) Keep records of usage, maintenance, calibration, problems, and repairs
4) After use, the meter will be inspected with results recorded in the field notebook
5) Keep sample tubes clean inside and out replacing them when they become scratched or etchedand avoid handling the tubes in the region where the light beam enters them.
6) Clean lens periodically per instruction manual
7) Turbidity meter will be sent back to the manufacturer for service when needed

9 Waste Management

IDW, including 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 (or equivalent), FSP, and/or IDW management guidance document.

10 Data Recording and Management

Digital data collection is the Arcadis standard using available FieldNow® applications that enable real-time, paperless data collection, entry, and automated reporting. Paper forms should only be used as backup to FieldNow® digital data collection and/or as necessary to collect data not captured by available FieldNow® applications. The FieldNow® digital form applications follow a standardized approach, correlate to most TGIs and are available to all projects accessible with a PC or capable mobile device. Once the digital forms are saved within FieldNow®, the data is instantly available for review on a web interface. This facilitates review by project management team members and SMEs enabling error or anomalous data detection for correction while the staff are still in the field. Continual improvements of FieldNow® applications are ongoing, and revisions are made as necessary in response to feedback from users and subject matter experts.

Management of the original documents from the field will be completed in accordance with the site- specific QAPP. Records generated as a result of this TGI will be controlled and maintained in the projectrecord files in accordance with project requirements.

In general, documentation of the following information is required:

- Calibration – calibration information will be recorded on a calibration form, field log, or electronicdevice per project plans
    - Meter manufacturer and model
    - Serial number
    - Calibration personnel
    - Calibration date/time
    - Standard value, initial and final reading
    - Observations, if applicable

- Readings - data will be recorded on a field log, sampling form, or electronic device per projectplans
    - Instrument model
    - Measurement date/time
    - Field personnel
    - Weather
    - Measurement location and depth, if applicable
    - Source of water (surface water, groundwater, etc.)
    - In-situ vs ex-situ measurement method
    - Value of readings and average reading, if applicable
    - Units of readings
    - Key observations

All records will be provided to the project manager and retained in the project files. Any maintenanceneeds will be communicated to the project manager promptly.

11 Quality Assurance

Quality assurance procedures will be conducted in accordance with the Arcadis Quality ManagementSystem or the site-specific QAPP. Refer to the QAPP or FIP/sampling plan/work plan for the frequency of calibrations.

12 References

Not applicable.

13 Attachments

Attachment A - Water Quality Measurement Log

Attachment B - Water Quality Meter Calibration Log

Attachment A

Water Quality Measurement Log

WATER QUALITY MEASUREMENT LOG

Page______of _______

GENERAL INFORMATION

Date ________________________

Project No ________________________

Site Name ________________________

Site Location ________________________

Site/Well No. ________________________

Weather ________________________

Sample Personnel ________________________

Sample ID ________________________

Start reading time ________________________

End reading time ________________________

MEASUREMENT DATA

Measuring Point (MP) description ________________

Depth to Water (ft)/Time ________________

Well Screen Interval (ft) ________________

Casing Diameter (in) ________________

Meters calibrated (Y/N) ________________

☐ Surface Water or ☐ Groundwater

Instrument model/serial no. ________________

Instrument model /serial no. 2 ________________

☐ In-situ ☐ Ex-situ reading

(see calibration log, if applicable)

Water Quality Parameters

Time	**Depth**	**pH**	**Spec. Cond.**	**Temp**	**DO**		**ORP**	**Turbidity**	**Observations**
	(ft)	**(S.U.)**	**(mS/cm or uS/cm)**	**(°C or °F)**	**(mg/L)**	**(%)**	**(mV)**	**(NTU)**	**(Odor, clarity, etc., if applicable)**

REMARKS

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Attachment B

Water Quality Meter Calibration Log

ARCADIS Design & Consultancy for natural and built assets

WATER QUALITY METER CALIBRATION LOG

PROJECT NAME	
PROJECT NO.	
MODEL(s)	
SERIAL #(s)	
SAMPLER	
DATE	

TURBIDITY CALIBRATION

CAL. READING		CAL. READING		CAL. RANGE	TIME
(LOT #)		(LOT #)			
(EXP. DATE)		(EXP. DATE)			
PRE-CAL. / POST-CAL		PRE-CAL. / POST-CAL			
/		/		☐ WITHIN RANGE	
/		/		☐ WITHIN RANGE	
/		/		☐ WITHIN RANGE	
/		/		☐ WITHIN RANGE	

MULTIMETER CALIBRATION

AUTOCAL SOLUTION (Y / N)		CAL. READING	CAL. RANGE	TIME	CALIBRATION RANGES (1)	
(LOT #)						
(EXP. DATE)						
PARAMETER	LOT / EXP. DATE	PRE-CAL. / POST-CAL				
☐ pH		/	☐ WITHIN RANGE		pH	± 0.2 S.U.
☐ CONDUCTIVITY		/	☐ WITHIN RANGE		COND	± 1% OF CAL. STANDARD
☐ ORP		/	☐ WITHIN RANGE		ORP	± 25 mV
☐ DO		/	☐ WITHIN RANGE		DO	Atmospheric
☐ TURBIDITY		/	☐ WITHIN RANGE		TURB	± 5% OF CAL. STANDARD
☐		/	☐ WITHIN RANGE			
☐		/	☐ WITHIN RANGE			

(1) CALIBRATION RANGES ARE SPECIFIC TO THE MODEL OF THE WATER QUALITY METER

NOTES:

SIGNED DATE

CHECKED BY DATE

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TGI – Sample Chain of Custody

Rev: 3

Rev Date: March 28, 2022

Version Control

Issue	Revision No.	Date Issued	Page No.	Description	Reviewed By
	0	April 19, 2017	All	Re-write to COC only	Richard Murphy
	1	May 23, 2017	4,7,9	Add: Guidance on use of previous version of TGI. Add: Info on COCs for multiple shipping containers Modify: Move letter i. to letter m. and change to "when appropriate"	Peter Frederick
	2	April 29, 2020	4, 11	Remove obsolete link	Lyndi Mott
	3	December 28, 2022	All	Updated Arcadis format Added to 6c. Collection time between COC and container must match. Added to 6o. Add name of overnight courier when relinquishing samples. Updated reference documents and added internet links.	Lyndi Mott

Approval Signatures

Prepared by: 3/28/2022

Lyndi Mott (Preparer) Date

Reviewed by: Dennis K. Capria 3/28/2022

Dennis Capria (Chain of Custody Reviewer) Date

Reviewed by: 12/22/2021

Lyndi Mott (Subject Matter Expert) Date

1 Introduction

This Technical Guidance Instruction (TGI) provides the procedure for Arcadis field personnel for required documentation during the collection of environmental field samples and transfer of custody to a laboratory. It provides direction for completion of the Chain of Custody form that must accompany collected field samples for analysis by a laboratory.

2 Intended Use and Responsibilities

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 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, regulation-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.

3 Scope and Application

This TGI describes the general Chain of Custody (COC) procedures and guidance instructions for samples collected from project sites that are relinquished from Arcadis’ possession.

COC is defined as the maintenance of an unbroken record of possession of an item from the time of its collection through some analytical or testing procedure. COC is typically documented by a written record of the collection, possession, and handling of samples collected from a project location. Each sample will be tracked by a documented record that efficiently documents the individuals who were responsible for the sample during each successive transfer of that sample to various recipients beyond Arcadis’ possession. This information can be used to legally establish the integrity of the samples and therefore the analytical results derived from the samples. This information can be used in addition to other records and documentation regarding the samples, such as field forms, field logs, and photographs.

A sample is considered under custody if:

- It is in your possession; or
- It is in your view, after being in your possession; or
- It was in your possession and then you then locked it up to prevent tampering; or
- It is in a designated secure area.

Continued use of previous version of TGI:

Although not recommended, Arcadis program-, project-, and client-teams may be able to use the previous version of this TGI provided that it meets all of the quality expectations of Arcadis and client and meets applicable regulatory requirements. It is up to the program, project, and/or client-team leader to determine whether it is appropriate to adopt the current TGI or to continue using the previous version.

However, all new work not associated with the previous version of this TGI must be performed with the current version of the TGI.

When adopting this new TGI, users of the previous versions must be aware that specific handling, packing, and shipping procedures and guidance has been removed and that those should be addressed within program or project plans (e.g., Quality Assurance Project Plans (QAPP), Work Plans, Sampling and Analysis Plans (SAPs), etc.) or in a more detailed TGI specific to that sampling activity, whether related to media, constituent/analyte, client, state, etc.

In addition, adopting this new TGI will require users to refer to the Arcadis Department of Transportation (DOT) Safety Program for procedures and guidance on the determination and handling, packing, and shipping of samples that are or may be considered hazardous materials.

4 Personnel Qualifications

Arcadis personnel performing work under the purview of this TGI will have received appropriate training and have field experience regarding the collection of samples from project locations. Arcadis personnel will have all other applicable and appropriate training relevant to the sampling work and project site.

5 Equipment List

The following list provides materials that may be required for each COC. Project reporting and documentation requirements must be reviewed with the CPM prior to execution of work. Additional materials, tools, equipment, etc. may be required, and project staff are required to verify with the CPM and/or Technical Expert what specific equipment is required to complete the COC.

- Indelible ink pen (preferably either black or blue ink);
- COC form **(Appendix A)** from either Arcadis, laboratory receiving and analyzing the samples, or other applicable and appropriate entity for the work performed;
- When appropriate, such as for litigation or expert testimony work, custody seals or tape.

6 Cautions

One way in which the law tries to ensure the integrity of evidence is by requiring proof of the chain of custody by the party who is seeking to introduce a particular piece of evidence.

A proper chain of custody requires three types of affirmations: (1) affirmation that a sample is what it purports to be (for example, soil collected from a specified location and depth); (2) affirmation of continuous possession by each individual who has had possession of the sample from the time it is collected until the time it is analyzed or held by a laboratory; and (3) affirmation by each person who has had possession that sample remained in substantially the same condition and not contaminated or affected by outside influences from the moment one person took possession until the moment that person released the evidence into the custody of another (for example, affirmation that the sample was stored in a secure location where no one but the person in custody had access to it).

Proving chain of custody is necessary to "lay a foundation" for the samples in question, by showing the absence of alteration, substitution, or change of condition.

Ensure that appropriate sample containers with applicable preservatives, coolers, and packing material are planned for and provided at the site at the time of sample collection.

Understand the offsite transfer requirements of the samples 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.

An Arcadis employee appropriately trained at the correct level of internal hazardous materials/DOT)shipping must complete an Arcadis shipping determination to address applicable DOT and International Air Transport Association (IATA) 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.

The person relinquishing possession of the samples or other member of the project team should contact the final recipient of the samples to confirm receipt and review any special provisions on the COC or questions that they may have.

7 Health and Safety Considerations

Follow the health and safety procedures outlined in the project/site Health and Safety Plan (HASP) as well as other applicable H&S requirements, such as:

- Arcadis Hazardous Material/DOT handling, packaging, and shipping training
- Project site-specific H&S training
- Client-specific H&S training
- Constituent-specific H&S training
- Media-specific H&S training

8 Procedure

Collected samples must be uniquely identified, and properly documented, containerized, labeled with unique identifier, possessed in a secure manner during remainder of sampling event, packaged, and shipped to recipient laboratory.

Sample Identification

The method of sample identification depends on the type of measurement or analyses performed. In some cases, in-situ measurements of existing conditions and/or sample location must be made during sample collection.

These data will be recorded directly on field forms, logbooks, or other project record data sheets used to permanently retain this information for the project file. Examples of location identification information includes: latitude/longitudinal measurements, compass directions, well number, building number, floor number, room name, or proximity to a site feature unique to the site. Examples of in-situ measurements are pH, temperature, conductivity, flow measurement, or physical condition of the media being sampled. Physical samples collected are identified by a unique identifying number or code on a sample tag or label. These physical samples are removed from the sample location and transported to a laboratory for analyses.

In some cases, before samples are placed into individual containers and labeled as individual samples, samples may be separated into portions depending upon the analytical methods and required duplicate or triplicate analyses to be performed.

When completing a COC for samples, personnel must complete the following:

1. Written COCs must be completed with indelible ink (preferably either black or blue colored ink).
2. Written COCs must be completed using legible printed writing, and not cursive writing.
3. All entry fields on the COC form must be completed. If information is not applicable for a specific entry field, personnel will either put “N/A” or use a strike-out line or dash like “-----------“ to indicate no applicable information is needed for that field.
4. Use of quotation marks or lines/down arrows to represent repetitive/duplicative text in similar fields.
5. Regardless of the type or specific COC form, the following pertinent information must be provided on the COC form:
    a. Arcadis project number
    b. Arcadis project name
    c. Project location, including street address, city, state, building number, providing as much detail as appropriate
    d. Recipient laboratory contact and sample receiving shipping location information
    e. Entities’/persons’ contact information for who will be receiving analytical results
    f. Name of sampler, i.e., person collecting sample and relinquishing possession of samples to the next entity in the chain of custody
    g. Date of sample collection
    h. If appropriate for the sample media, contaminant/constituent of concern, or analytical method, document time of sample collection using standard military time
    i. Sample analytical method(s)

j. Turnaround time required for analyses and/or reporting

k. Instructions to laboratory regarding handling, timing, analyses, etc. as applicable and appropriate.

l. Printed name and signature of the individual person who collected the samples and relinquishing possession of the samples

m. If appropriate or when documentation of the specific sample collection method will influence how the laboratory handles, prepares, or analyzes the samples, document the sample collection methodology used for collecting the samples (e.g., ASTM D5755)

6. The following additional specific information will be entered on the COC form, regardless of what type of COC is being used:

   a. Unique Sample Identifier – The sample identifier (ID) must be unique to the individual sample it is applied to. The information in which the sample ID conveys is determined by the CPM, Technical Expert, and/or other project team members in advance of sample collection so that sample identification is consistently applied for the project. The sample nomenclature may be dictated by a specific client, program, or project database and require unique identification for each sample collected for the project. Consult with the CPM and/or Technical Expert for additional information regarding sample identification.

   The sample ID could convey specific information regarding the sample to aid personnel in recognizing what the sample represents, or they may be arbitrary so as to facilitate the anonymity of the sample location, media, constituent of concern, project site, etc.

   Examples of unique identifiers include:

      1. 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.

      2. Sample names may also use the abbreviations “FB,” “TB,” “FD” and “DUP” as prefixes or suffixes to indicate that the sample is a field blank, trip blank, or field duplicate, respectively.

   b. List the date of sample collection. All indicated dates must be formatted using either mm/dd/yy (e.g., 03/07/09) or mm/dd/yyyy (e.g., 03/07/2009).

   c. List the local 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. The time listed on the COC form must match the sample collection time on the sample container(s).

   d. Samples should be indicated to be either “Grab” or “Composite”. Grab samples are collected from only one unique location at one specific point in time.

   e. Composite samples are a group of individual samples that are combined for analysis in their totality. Composite samples need to be documented if they are either collected from a number of different locations over a broader area to be representative of the entire area being sampled, or if they are representative of a single location over an extended period of time.

f. If used, preservatives for the individual sample will be noted.

g. The requested analytical method(s) that the samples are being analyzed for must be indicated. As much detail, as necessary, should be presented to allow the analytical laboratory to properly analyze the samples. For example, polychlorinated biphenyl (PCB) analyses may be represented by entering "EPA Method 8082 – PCBs" or "EPA PLM 600-R93-116." In cases where multiple analytical methods and/or analytical parameters are required for an individual sample, each method should be indicated for the sample (e.g., EPA 8082/8260/8270 or EPA PLM/400-point count).

h. If there are project-specific sample analytes to be reported, they should be specifically listed for each individual sample (e.g., 40 CFR 264 Appendix IX).

i. The total number of containers for each analytical method requested should be documented. This information may be included under the parameter or as a total for the sample.

j. When necessary, note which samples should be used for site specific matrix spikes in the Remarks or Comments field.

k. Indicate special project-specific requirements pertinent to the handling, shipping, or analyses. 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).

l. Indicate turnaround time (TAT) required for samples on COC. If individual samples have differing TATs, the different TATs for each sample or groups of samples must be clearly indicated.

m. Provide contact name and phone number in the event that problems are encountered when samples are received at the laboratory. The person relinquishing possession of the samples or other member of the project team should contact the final recipient of the samples to confirm receipt and review any special provisions on the COC or questions that they may have.

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

o. The "Relinquished By" field must contain the signature of the Arcadis person who relinquished custody of the samples to the next entity in the chain of custody, which may be another person, the shipping courier, or the analytical laboratory. If a courier, enter the shipping courier in the "Received by" such as FedEx. The date/time relinquished should be when the person signs the COC and seals the cooler or shipping container for pick-up by the shipping courier.

p. Dates and times must be indicated using the following format:

   1) Date: either mm/dd/yy e.g., 01/01/17 OR mm/dd/yyyy e.g., 01/01/2017

   2) Time: use military format, e.g., 9:30 a.m. is 0930 and 9:30 p.m. is 2130

q. The "Received By" section is signed by sample courier or laboratory representative who received the samples from the sampler. The laboratory will sign upon laboratory receipt from the overnight courier service.

7. When more than one page of the COC form is required to complete the total number of samples, use as many sheets as necessary to accurately and clearly, document the samples and information. Some COCs may have a standard first page/cover page, and subsequent pages may not contain all the detailed fields as

the first page/cover page. Ensure that any subsequent pages convey all of the necessary and pertinent information for each individual sample as required in this procedure document.

8. Pages of the COC must retain a page count of the total number of pages; e.g., Page 1 of 3, Page 2 of 3, Page 3 of 3.
9. Upon completing the COC forms, forward the original signed COC with the sample package. Ensure that the original COC form is secured with the sample package so that it remains with the physical samples for the duration of transport and handling to its final destination and ensure that the COC form will not be become damaged or rendered unreadable due to sample breakage/leakage if stored inside the sample shipping container or outside influences if COC is stored in an outside plastic pouch to the container.
10. If you've collected enough samples that would require more than one container to ship them all to the same laboratory or location, then each separate/individual container that contains any number of samples must have a separate COC representing only those samples contained within that specific container. For example, if you have 3 total shipping containers for all of your samples, you must have a total of 3 separate, individual COCs for each of the 3 containers representing only those samples in their representative container. Thus, every container holding samples must have its own, individual COC.
11. If electronic chain of custody (eCOC) forms are utilized, ensure that the requirements of this procedure and guidance instructions are followed to the extent possible. Verify that proper signature and COC procedures are maintained with the CPM and/or Technical Expert when using eCOC.

9 Waste Management

Not Applicable.

10 Data Recording and Management

The original signed COC shall be submitted with the samples. Copies of COC records will be transmitted to the CPM or designee at the end of each day unless otherwise directed by the CPM. 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 client- and project-specific requirements and Arcadis policies, the most stringent will apply.

The option to use the Electronic Chain of Custody (eCOC) form in conjunction with the appropriate sample application(s) may be available through the FieldNow® program but is currently limited to a select list of approved analytical laboratories. Use of the eCOC application is intended to reduce common transcription errors both by field staff and laboratory staff on a conventional handwritten paper COC. Once the eCOC form is completed and approved on the field tablet by field staff, a PDF version of the form is automatically emailed to each assigned team member. In addition, a dedicated or mobile printer is recommended for printing a hard copy of the completed eCOC to be included in each sample cooler to meet laboratory requirements.

11 Quality Assurance

COC forms will be legibly completed in accordance with this procedure and guidance instruction document, as well as other applicable and appropriate project documents such as SAP, Quality QAPP, Work Plan, or other project guidance documents.

COC records will be reviewed by the CPM or their appropriate designee for completeness and accuracy to the applicable requirements. Non-conformances will be noted and corrected in a timely manner on the copies retained by Arcadis as well as contacting the ultimate receiving entity for correction to the originally signed COC in their possession.

12 References

Arcadis Transportation Safety Program requirements, procedures, and guidance instructions.

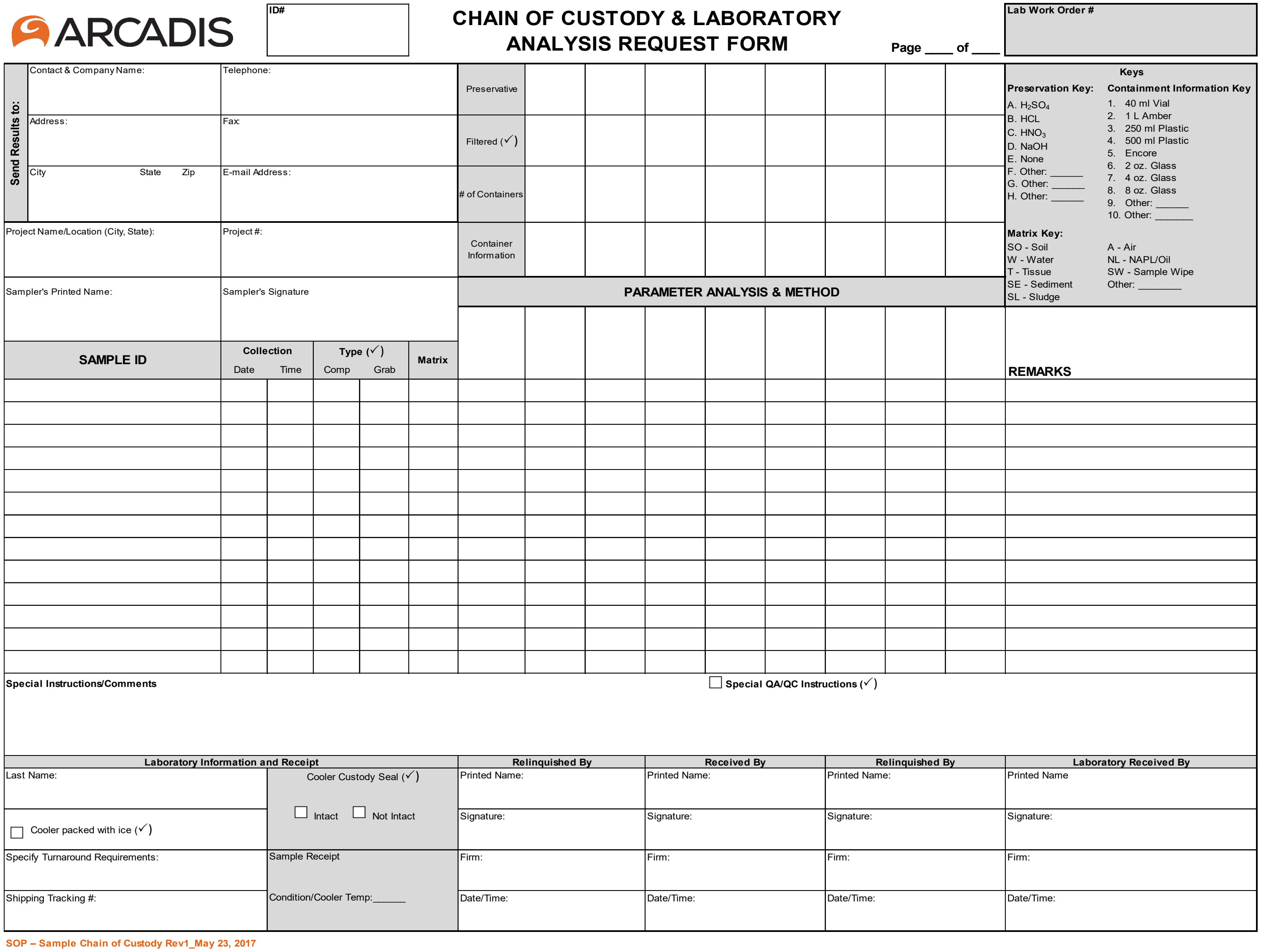
EPA Samplers' Guide – Contract Laboratory Program Guidance for Field Samplers, EPA document EPA-540-R014-013 October 2014 https://www.epa.gov/sites/default/files/2015-03/documents/samplers_guide.pdf.

EPA Region III – Sample Submission Procedures for the Office of Analytical Services and Quality Assurance (OASQA) Laboratory Branch revision 14.0 October 18, 2018, https://www.epa.gov/sites/default/files/2018-12/documents/sample-submission-procedures-rev14.pdf.

EPA Region IV Science and Ecosystem Support Division Operating Procedure for Sample and Evidence Management May 25, 2016, https://www.epa.gov/sites/default/files/2015-06/documents/Sample-and-Evidence-Management.pdf.

Attachment A

Chain of Custody and Laboratory Analysis Request Form



ID#

CHAIN OF CUSTODY & LABORATORY ANALYSIS REQUEST FORM

Page ____ of ____

Lab Work Order #

Send Results to:	Contact & Company Name:	Telephone:	Preservative							
	Address:	Fax:	Filtered (✓)							
	City State Zip	E-mail Address:	# of Containers							
Project Name/Location (City, State):		Project #:	Container Information							
Sampler's Printed Name:		Sampler's Signature	**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: ______

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

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

Special Instructions/Comments

☐ **Special QA/QC Instructions (✓)**

Laboratory Information and Receipt		**Relinquished By**	**Received By**	**Relinquished By**	**Laboratory Received By**
Last 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:	Firm:	Firm:
Shipping Tracking #:	Condition/Cooler Temp:______	Date/Time:	Date/Time:	Date/Time:	Date/Time:

SOP – Sample Chain of Custody Rev1_May 23, 2017

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ARCADIS Design & Consultancy for natural and built assets

TGI - INVESTIGATION-DERIVED WASTE HANDLING AND STORAGE

Rev #: 1

Rev Date: May 15, 2020

VERSION CONTROL

Revision No	Revision Date	Page No(s)	Description	Reviewed by
0	February 23, 2017	ALL	Conversion from SOP to TGI	Ryan Mattson / Peter Frederick
1	May 15, 2020	ALL	Updated to reflect regulatory changes	

APPROVAL SIGNATURES

Prepared by: Derrick Maurer 02/23/2017

Derrick Maurer Date:

Technical Expert Reviewed by: 05/15/2020

Ryan Mattson (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

The objective of this Technical Guidance Instruction (TGI) is to describe the procedures to manage investigation-derived wastes (IDW), both hazardous and nonhazardous, generated during site activities, which may include, but are not limited to: drilling, trenching/excavation, construction, demolition, monitoring well sampling, soil sampling, decontamination and remediation. For the purposes of this TGI, IDW is considered to be discarded materials which are defined as solid waste by United States Environmental Protection Agency (EPA) standard 40 CFR § 261.2 (which may include liquids, solids, or sludges). IDW may include soil, groundwater, drilling fluids, decontamination liquids, as well as contaminated personal protective equipment (PPE), sorbent materials, construction and demolition debris, and disposable sampling materials. Hazardous or uncharacterized IDW will be collected and staged at the point of generation. Quantities small enough to be containerized in 55-gallon drums will be taken to a designated temporary onsite storage area (discussed in further detail under Drum Storage) pending characterization and disposal. IDW materials will be characterized using process knowledge and appropriate laboratory analyses to determine the waste classification and evaluate proper safe handling and disposal methods.

This TGI describes the necessary equipment, field procedures, materials, regulatory references, and documentation procedures necessary for proper handling and storage of IDW up to the time it is properly transported from the project site and disposed. The procedures included in this TGI for handling and temporary storage of IDW are based on the EPA's guidance document *Guide to Management of Investigation Derived Wastes* (USEPA, 1992). IDW is assumed to be contaminated with the site constituents of concern (COCs) until analytical evidence indicates otherwise. IDW will be managed to ensure the protection of human health and the environment and will comply with all applicable or relevant and appropriate requirements (ARAR). Although not comprehensive, the following laws and regulations on Hazardous Waste Management should be considered as potential ARAR. It is the Arcadis Certified Project Manager (CPM) and/or designated Technical Expert to determine which laws and regulations, at all levels of government, are applicable to each project site and activity falling under this TGI.

Federal Laws and Regulations

- Resource Conservation and Recovery Act (RCRA) 42 USC § 6901-6987.
- Federal Hazardous Waste Regulations 40 CFR § 260-265

Department of Transportation (DOT) Hazardous Materials Transportation 49 CFR

Occupational Safety and Health Administration (OSHA) Regulations 29 CFR

State Laws and Regulations

- To be determined based on location of site and location of treatment, storage, and/or disposal facility (TSDF) to be utilized.

Regional, County, Municipal, and Local Regulations

- To be determined based on location of site and location of treatment, storage, and/or disposal facility (TSDF) to be utilized.

Initial Storage

Pending characterization, IDW will be temporarily stored appropriately within each area of contamination (AOC). Under RCRA, "storage" is defined as the "holding of hazardous waste for a temporary period, at the end of which the hazardous waste is treated, disposed of, or stored elsewhere" (40 CFR § 260.10). The onsite waste staging area will be in a secure and controlled area. Uncharacterized wastes are considered potentially hazardous wastes and must be stored in DOT approved packaging. Liquid wastes must be stored in DOT approved closed head drums or other approved containers (e.g., portable tank containers) that are compatible with the type of material stored therein. Solid materials must be stored in DOT approved open head drums where practicable. Larger quantities of solid IDW can be containerized in bulk containers (such as in a roll-off box). Soil from large excavation projects may be managed in stockpiles with within the AOC and does not need to be containerized until exiting the AOC.

Characterization

Waste characterization can either be based on generator knowledge, such as using historical process knowledge and safety data sheets (SDS), or can be based upon characterization sampling analytical results. IDW typically is not characterized using SDS as it is a mixture of aged chemicals and environmental media. Historical process knowledge should be used to determine if the IDW is a listed hazardous waste (40 CFR § 261.31-33). If the IDW is not a listed hazardous waste, waste characterization can be completed by laboratory analysis of representative samples of the IDW. The laboratory used for waste characterization analysis must have the appropriate state and federal accreditations and may be required to be pre-approved by the Client. IDW will be classified as RCRA hazardous or non-regulated under RCRA based on the waste characterization determination.

If IDW is characterized as RCRA hazardous waste, RCRA and DOT requirements must be followed for packaging, labeling, transporting, storing, and record keeping as described in 40 CFR § 262 and 49 CFR § 171-178. Waste material classified as RCRA nonhazardous may be handled and disposed of as nonhazardous waste in accordance with applicable federal, state, and local regulations.

Storage Time Limitations

Containerized hazardous wastes can be temporarily stored for a maximum of 90 calendar days from the accumulation start date for a large quantity generator or a maximum of 180 calendar days from the accumulation start date for a small quantity generator. Wastes classified as nonhazardous may be handled and disposed of as nonhazardous waste and are not subject to storage time limitations.

This is TGI may be modified by the CPM and/or Technical Expert for a specific project or client program, as required, dependent upon client requirements, site conditions, equipment limitations, or limitations imposed by the procedure. The resulting procedure employed to execute the work 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 the CPM and/or Technical Expert as soon as practicable, and if approved to be performed, be documented.

3 PERSONNEL QUALIFICATIONS

Arcadis field sampling personnel will have current regulatory- and Arcadis-required health and safety training including 40-hour HAZWOPER training, site supervisor training, site-specific training, first aid, and cardiopulmonary resuscitation (CPR), as needed. Personnel handling and packaging hazardous waste and performing hazardous waste characterizations must have RCRA hazardous waste management training per 40 CFR § 264.16. Additional state-specific hazardous waste management training is required in certain states (i.e., California).

Although not common practice, in certain situations Arcadis personnel may sign waste profiles and/or waste manifests on a case by case basis for clients, provided the appropriate agreement is in place between Arcadis and the client documenting that Arcadis is not the generator, but is acting as an authorized representative of the generator. Arcadis personnel who sign waste profiles and/or waste manifests will have both current RCRA hazardous waste management training per 40 CFR § 264.16 and current DOT hazardous materials transportation training per 49 CFR § 172.704. Arcadis field personnel will also comply with client-specific training. In addition, Arcadis field sampling personnel will be knowledgeable in the relevant processes, procedures, and Technical Guidance Instructions (TGIs) and possess the demonstrated required skills and experience necessary to successfully complete the desired field work. The project health and safety plan (HASP) and other documents will identify other training requirements or access control requirements.

4 EQUIPMENT LIST

The Following Materials, as required, will be available for IDW handling and Storage:

- Appropriate personal protective equipment as specified in the Site Health and Safety Plan (HASP)
- DOT approved containers
- Hammer
- Leather gloves
- Drum dolly
- Appropriate drum labels (outdoor waterproof self-adhesive)
- Portable tank container
- Appropriate labeling, packing, chain-of-custody forms, and shipping materials as determined by the CPM and/or Technical Expert.
- Indelible ink and/or permanent marking pens
- Plastic sheeting
- Appropriate sample containers, labels, and forms
- Stainless-steel bucket auger
- Stainless steel spatula or knife
- Stainless steel hand spade
- Stainless steel scoop
- Digital camera
- Field logbook

5 CAUTIONS

Filled drums can be very heavy, become unbalanced, or spill its contents. Therefore, use appropriate moving techniques and equipment for safe handling. Similar media (e.g. soils with other soils; or liquids with other liquids) will be stored in the same drums to aid in sample analysis and disposal. Drum lids must be secured to prevent rainwater from entering the drums and leakage during movement. Drums containing solid material may not contain any free liquids. Waste containers stored for extended periods of time may be subject to deterioration. Drum Over Packs may be used as secondary containment. All drums must be visually inspected for condition to ensure that they are in good condition without visible evidence of rusting, holes, breakage, etc., to prevent potential leakage and facilitate subsequent disposal. All drum lids must be verified as having a properly functioning secured lid prior to use.

6 HEALTH AND SAFETY CONSIDERATIONS

As determined by the site’s known and suspected hazards, appropriate PPE must be worn by all field personnel within the designated work area. Exposure air monitoring may be required during certain field activities as required in the Site Health and Safety Plan. If soil excavation in areas with potentially hazardous contaminants is possible, contingency plans will be developed to address the potential for encountering gross contamination or non-aqueous phase liquids. All excavation activities shall be in compliance with OSHA standard 29 CFR 1926.651 Excavations, and any other applicable regulations.

Arcadis field personnel and subcontractors will be trained in and perform their work in compliance with all applicable federal, state, and local health and safety regulations as well as Arcadis' HASP and applicable Client health and safety requirements.

7 PROCEDURE

Specific waste temporary storage and handling procedures to be used are dependent upon the type of generated waste, including type of media (e.g. soils or free liquids) and constituents of concern. For this reason, IDW can be stored in a secure location onsite in separate 55-gallon storage drums, where solids can be stockpiled onsite (if nonhazardous) and purge water may be stored in portable tank containers. Waste materials such as broken sample bottles or equipment containers and wrappings will be stored in 55-gallon drums unless they were not in contact with sample media.

Management of IDW

Minimization of IDW should be considered by the project team during all phases of the project. Site managers may want to consider techniques such as replacing solvent based cleaners with aqueous-based cleaners for decontamination of equipment, reuse of equipment (where it can be properly decontaminated), limitation of traffic between exclusion and support zones, and drilling methods and sampling techniques that minimize the generation of waste. Alternative drilling and subsurface sampling methods may include the use of small diameter boreholes, as well as borehole testing methods such as a core penetrometer or direct push technique instead of coring.

Drum Storage

Drums containing hazardous waste will be stored in accordance with the requirements of 40 CFR 265 Subpart I (for containers) and 265 Subpart DD (for containment buildings). All 55-gallon drums will be stored at a secure, centralized onsite location that is readily accessible for vehicular pick-up. Drums confirmed as, or assumed to contain hazardous waste will be stored over an impervious surface provided with secondary spill containment. The storage location will, for drums containing liquid, have a containment system that can contain at least the larger of 10% of the aggregate volume of staged materials or 100% of the volume of the largest container. Drums will be closed during storage and be in good condition in accordance with the Guide to Management of Investigation-Derived Wastes (USEPA, 1992).

Hazardous Waste Determination

Waste material must be characterized to determine if it meets any of the federal definitions of hazardous waste as required by 40 CFR § 262.11. If the waste does not meet any of the federal definitions, it must then be established if any state-specific or local-specific hazardous waste criteria exist/apply.

Generator Status

Once hazardous waste determination has been made, the generator status will be determined. Large quantity generators (LQG) are generators who generate more than 1,000 kilograms of hazardous waste in a calendar month. Small quantity generators (SQG) of hazardous waste are generators who generate greater than 100 kilograms but less than 1,000 kilograms of hazardous waste in a calendar month. Very small quantity generators (VSQG) are generators who generate less than 100 kilograms of hazardous waste per month. Please note that a generator status may change from month to month and that a notice of this change is usually required by the generator's state agency.

Accumulation Time for Hazardous Waste

A LQG may accumulate hazardous waste on site for 90 calendar days or less without a permit and without having interim status, provided that such accumulation is in compliance with requirements in 40 CFR § 262.17. A SQG may accumulate hazardous waste on site for 180 calendar days or less without a permit or without having interim status, subject to the requirements of 40 CFR § 262.16. VSQG requirements are found in 40 CFR § 262.14. NOTE: The federal VSQG and SQG provisions may not be recognized by some states (e.g., California and Rhode Island). State-specific and local-specific regulations must be reviewed and understood prior to the generation of hazardous waste.

Satellite Accumulation of Hazardous Waste Satellite accumulation (SAA) will mean the accumulation of as much as fifty-five (55) gallons of hazardous waste, or the accumulation of as much as one quart of acutely hazardous waste, in containers at or near any point of generation where the waste initially accumulates, which is under the control of the operator of the process generating the waste, without a permit or interim status and without complying with the requirements of 40 CFR § 262.15 and without any storage time limit, provided that the generator complies with 40 CFR § 262.15.

Once more than 55 gallons of hazardous waste accumulates in SAA, the generator has three days to move this waste into storage.

Storage recommendations for hazardous waste include:

- Ignitable or reactive hazardous wastes must be >50 feet from the property line per 40 CFR § 265.176 (LQG generators only).
- Hazardous waste should be stored on a concrete slab (asphalt is acceptable if there are no free liquids in the waste).
- Drainage must be directed away from the accumulation area.
- Area must be properly vented.
- Area must be secure.

Drum/Container Labeling

Drums will be labeled on both the side and lid of the drum using a permanent marking pen. Old drum labels must be removed to the extent possible, descriptions crossed out should any information remain, and new labels affixed on top of the old labels. Other containers used to store various types of waste (e.g., polyethylene tanks, roll-off boxes, end-dump trailers, etc.) will be labeled with an appropriate "Waste Container" or "Testing in Progress" label pending characterization. Drums and containers will be labeled as follows:

- Appropriate waste characterization label (Pending Analysis, Hazardous, or Nonhazardous)
- Waste generator's name (e.g., client name)
- Project Name
- Name and telephone number of Arcadis project manager
- Composition of contents (e.g., used oil, acetone 40%, toluene 60%)
- Media (e.g., solid, liquid)
- Accumulation start date

- Drum number of total drums as reconciled with the Drum Inventory maintained in the field log book.

IDW containers will remain closed except when adding or removing waste. Immediately upon beginning to place waste into the drum/container, a “Waste Container” or “Pending Analysis” label will be filled out to include the information specified above, and affixed to the container. Once the contents of the container are identified as either non-hazardous or hazardous, the following additional labels will be applied.

- Containers with waste determined to be non-hazardous will be labeled with a green and white "Nonhazardous Waste" label over the "Waste Container" label.
- Containers with waste determined to be hazardous will be stored in an onsite storage area and will be labeled with the "Hazardous Waste" label and affixed over the "Waste Container" label.

The ACCUMULATION DATE for the hazardous waste is the date the waste is first placed in the container and is the same date as the date on the "Waste Container" label. DOT hazardous class labels must be applied to all hazardous waste containers for shipment offsite to an approved disposal or recycling facility. In addition, a DOT proper shipping name will be included on the hazardous waste label. The transporter should be equipped with the appropriate DOT placards. However, placarding or offering placards to the initial transporter is the responsibility of the generator per 40 CFR § 262.33.

Inspections and Documentation

All IDW will be documented as generated on a Drum Inventory Log maintained in the field log book. The Drum Inventory will record the generation date, type, quantity, matrix and origin (e.g., Boring-1, Test Pit 3, etc.) of materials in every drum, as well as a unique identification number for each drum. The drum inventory will be used during drum pickup to assist with labeling of drums. The drum storage area and any other areas of temporarily staged waste, such as soil/debris piles, will be inspected weekly. The weekly inspections will be recorded in the field notebook or on a Weekly Inspection Log. Digital photographs will be taken upon the initial generation and drumming/staging of waste, and final labeling after characterization to document compliance with labeling and storage protocols, and condition of the container. Evidence of damage, tampering or other discrepancy should be documented photographically.

Emergency Response and Notifications

Specific procedures for responding to site emergencies will be detailed in the HASP. If the generator is designated as a LQG, a Contingency Plan will need to be prepared to include emergency response and notification procedures per 40 CFR § 265 Subpart D. In the event of a fire, explosion, or other release which could threaten human health outside of the site or when Client or Arcadis has knowledge of a spill that has reached surface water, Client or Arcadis must immediately notify the National Response Center (800-424-8802) in accordance with 40 CFR § 262.265. Other notifications to state and/or other local regulatory agencies may also be necessary.

Drilling Soil Cuttings and Muds

Soil cuttings are solid to semi-solid soils generated during trenching activities, subsurface soil sampling, or installation of monitoring wells. Depending on the drilling method, drilling fluids known as "muds" may be used to remove soil cuttings. Drilling fluids flushed from the borehole must be directed into a settling section of a mud pit. This allows reuse of the decanted fluids after removal of the settled sediments. Soil cuttings will be labeled and stored in 55-gallon drums with bolt-sealed lids.

Excavated Solids

Excavated solids may include, but are not limited to: soil, fill, and construction and demolition debris. Prior to permitted treatment or offsite disposal, potentially hazardous excavated solids may be temporarily stockpiled onsite as long as the stockpile remains in the same AOC from where it was excavated. Potentially hazardous excavated solids removed from the AOC must be immediately containerized in labeled drums or closable top roll-offs lined with 9-mil polyvinyl chloride (PVC) sheeting and are subject to LQG storage time limits. Nonhazardous excavated solids can be stockpiled either inside or outside of the AOC, do not have to be containerized and are not subject to hazardous waste regulations. Potentially hazardous excavated solids must not be mixed with nonhazardous excavated solids. All classes of excavated solid stockpiles should be maintained in a secure area onsite. At a minimum, the floor of the stockpile area will be covered with a 20-mil high density polyethylene liner that is supported by a foundation or at least a 60-mil high density polyethylene liner that is not supported by a foundation. The excavated material will not contain free liquids. The owner/operator will provide controls for windblown dispersion, run-on control, and precipitation runoff. The run-on control system will prevent flow onto the active portion of the pile during peak discharge from at least a 25-year storm and the run-off management system will collect and control at least the water volume resulting from a 24-hour, 25-year storm (USEPA, 1992). Additionally, the stockpile area will be inspected on a weekly basis and after storm events. Individual states may require that the stockpile be inspected/certified by a licensed professional engineer. Stockpiled material will be covered with a 6-mil polyvinyl chloride (PVC) liner or sprayed dust control product. The stockpile cover will be secured in place with appropriate material (concrete blocks, weights, etc.) to prevent the movement of the cover.

Decontamination Solutions

Decontamination solutions are generated during the decontamination of personal protective equipment and sampling equipment. Decontamination solutions may range from detergents, organic solvents and acids used to decontaminate small field sampling equipment to steam cleaning rinsate used to wash heavy field equipment. These solutions are to be labeled and stored in closed head drums compatible with the decontamination solution. Decontamination procedures, including personnel and field sampling equipment, must comply with applicable Arcadis procedural documents.

Disposable Equipment

Disposable equipment includes personal protective equipment (e.g., tyvek coveralls, gloves, booties and APR cartridges) and disposable sampling equipment such as trowels or disposable bailers. If the media sampled exhibits hazardous characteristics per results of waste characterization sampling, contaminated disposable equipment will also be disposed of as a hazardous waste. If compatible with the original IDW waste stream (i.e., the IDW is a solid and the disposal equipment is a solid), the disposable equipment can be combined with the IDW. If these materials are not compatible (i.e., the IDW is a liquid and the disposal equipment is a solid), the disposable equipment will be stored onsite in separate labeled 55-gallon drums. Uncontaminated or decontaminated disposable equipment can be considered nonhazardous waste.

Purge Water

Purge water includes groundwater generated during well development, groundwater sampling, or aquifer testing. The volume of groundwater generated will dictate the appropriate storage procedure. Monitoring well development and groundwater sampling may generate three well volumes of groundwater or more. This volume will be stored in labeled 55-gallon drums. Aquifer tests may generate significantly greater volumes of groundwater depending on the well yield and the duration of the test. Therefore, large-volume portable polyethylene tanks will be considered for temporary storage pending groundwater-waste characterization.

Purged Water Storage Tank Decontamination and Removal

The following procedures will be used for inspection, cleaning, and offsite removal of storage tanks used for temporary storage of purge water. These procedures are intended to be used for rented portable tanks such as Baker Tanks or Rain for Rent containers. Storage tanks will be made of inert plastic materials. The major steps for preparing a rented tank for return to a vendor include characterizing the purge water, disposing of the purge water, decontaminating the tank, final tank inspection, and mobilization. Decontamination and inspection procedures are described in further detail below.

- Tank Cleaning: Most vendors require that tanks be free of any visible sediment and water before returning, a professional cleaning service may be required. Each specific vendor should be consulted concerning specific requirements for returning tanks.
- Tank Inspection: After emptying the tank, purged water storage tanks should be inspected for debris, chemical staining, and physical damage. The vendors require that tanks be returned in the original condition (i.e., free of sediment, staining and no physical damage).

8 WASTE MANAGEMENT

Soil/Solids Characterization

Waste characterization will be conducted in accordance with waste hauler, waste handling facility, and local/state/federal requirements. In general, RCRA hazardous wastes are those solid wastes determined by a Toxicity Characteristic Leaching Procedure (TCLP) test or to contain levels of certain toxic metals, pesticides, or other organic chemicals above specific applicable regulatory agency thresholds. If the one or more of 40 toxic compounds listed in Table I of 40 CFR § 261.24 are detected in the sample at levels above the maximum unregulated concentrations, the waste must be characterized as a toxic hazardous waste. Wastes can also be considered “listed” hazardous waste depending on site-specific processes.

Composite soil samples will be collected at a frequency of one sample per 250 cubic yard basis for stockpiled soil or one per 55-gallon drum per different waste stream for containerized. A four-point composite sample will be collected per 250 cubic yards of stockpiled material and for each drum waste stream. Sample and composite frequencies may be adjusted in accordance with the waste handling facility’s requirements and may be reduced for large volumes of waste with consistent properties. Waste characterization samples will be considered valid for consistent waste streams for a period of 1 year. Waste characterization samples may be analyzed for the TCLP volatile organic compounds (VOCs), TCLP semi-volatile organic compounds (SVOCs), TCLP RCRA metals, and polychlorinated biphenyls (PCBs), as well as reactivity and flammability (flashpoint). Additional samples may be collected and analyzed by the laboratory on a contingency basis. Site-specific constituents of concern including pesticides may require additional sampling. Please note that state- or local-specific regulations may require a different or additional sampling approaches.

Wastewater Characterization

Waste characterization will be conducted in accordance with the requirements of the waste hauler, waste handling facility, and local/state/federal governments. In general, purge water should be analyzed by methods appropriate for the known contaminants, if any, that have been historically detected in the monitoring wells. Samples will be collected and analyzed in accordance with the requirements of the waste disposal facility. Wastewater characterization samples may be analyzed for TCLP volatile organic compounds (VOCs), TCLP semi-volatile organic compounds (SVOCs), TCLP RCRA metals, and polychlorinated biphenyls, as well as corrosivity (pH), reactivity and flammability (flashpoint). Additional samples may be collected and analyzed by the laboratory on a contingency basis. Site-specific constituents of concern including pesticides may require additional sampling. Please note that state- and/or local-specific regulations may require different or additional sampling approaches.

Sample Handling and Shipping

All samples will be appropriately labeled, packed, and shipped, and the chain-of-custody will be filled out in accordance with current Arcadis sample chain of custody, handling, packing, and shipping procedures and guidance instructions.

It should be noted that additional training is required for packaging and shipping of hazardous and/or dangerous materials. Please refer to the current Arcadis training requirements related to handling and shipping of samples, shipping determinations, and hazardous materials.

Preparing Waste Shipment Documentation (Hazardous and Nonhazardous)

Waste profiles will be prepared by the Arcadis CPM and forwarded, along with laboratory analytical data to the Client for approval/signature. The Client will then return the profile to Arcadis who will then forward to the waste removal contractor for preparation of a manifest. The manifest will be reviewed by Arcadis prior to forwarding to the Client for approval. Upon approval of the manifest, the Client will return the original signed manifest directly to the waste contractor or to the Arcadis CPM for forwarding to the waste contractor. Arcadis personnel may sign waste profiles and/or waste manifests on a case by case basis for clients, provided the appropriate agreement is in place between Arcadis and the client documenting that Arcadis is not the generator, but is acting as an authorized representative of the generator.

Final drum labeling and pickup will be supervised by an Arcadis representative who is trained and experienced with applicable waste labeling procedures. The Arcadis representative will have a copy of the drum inventory maintained in the field book and will reconcile the drum inventory with the profile numbers on the labels and on the manifest. Different profile numbers will be generated for different matrices or materials in the drums. For example, the profile number for drill cuttings will be different than the profile number for purge water. When there are multiple profiles it is critical that the proper label, with the profile number appropriate to a specific material be affixed to the proper drums. A copy of the Arcadis drum inventory will be provided to the waste transporter during drum pickup and to the facility receiving the waste.

9 DATA RECORDING AND MANAGEMENT

Waste characterization sample handling, packing, and shipping procedures will be documented in accordance with relevant Arcadis procedures and guidance instructions as well as applicable client and/or project requirements, such as a Quality Assurance Project Plan or Sampling and Analysis Plan. Copies of the chain-of-custody forms will be maintained in the project file. Arcadis should photograph or maintain a copy of any hazardous waste manifest signed on behalf of Client in the corresponding office DOT record file.

10 QUALITY ASSURANCE

The CPM or APM will review all field documentation once per week for errors or omissions as compared to applicable project requirements including but not limited to: the proposal/scope of work, QAPP, SAP, HASP, etc. Deficiencies will be noted, tracked, and resolved. Upon correction, they will be noted for project documentation.

11 REFERENCES

United States Environmental Protection Agency (USEPA). 1992. Guide to Management of Investigation-Derived Wastes. Office of Remedial and Emergency Response. Hazardous Site Control Division. January 1992.

TGI – Groundwater and Soil Sampling Equipment Decontamination

Rev: 2

Rev Date: June 14, 2022

Version Control

Issue	Revision No.	Date Issued	Page No.	Description	Reviewed By
	0	February 23, 2017	All	Conversion from SOP to TGI	Cassandra McCloud / Pete Frederick
	1	May 8, 2020	4, 5	Added note regarding use of Liquinox and 1,4-Dioxane	Marc Killingstad
	2	June 14, 2022	All	Conversion to new TGI format and minor edits.	Kevin Engle / Marc Killingstad

Approval Signatures

Prepared by: 6/14/2022

Name (Preparer) Date

Reviewed by: 6/14/2022

Marc Killingstad (Subject Matter Expert) Date

1 Introduction

This document is intended to provide guidance to staff performing decontamination procedures at project sites. The content in this document describes the intended use, scope and application, personnel qualifications, equipment, cautions, health and safety considerations, procedures, waste management, data recording and management, and quality assurance of decontamination procedures.

2 Intended Use and Responsibilities

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 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, regulation-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.

3 Scope and Application

Decontamination is performed on sampling equipment prior to sample collection to ensure that the 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 could interfere with laboratory analysis for analytes of interest. Sampling equipment must be appropriately cleaned prior to use for sampling or coming into contact with environmental media to be sampled and following completion of the sampling event prior to shipment or storage. The effectiveness of the decontamination procedure should be verified by collecting and analyzing equipment blank samples.

The sampling equipment cleaning procedures described herein includes pre-field, in the field, and post- field cleaning of sampling equipment which may be conducted at an established equipment decontamination area (EDA) on site, as appropriate and necessary. Sampling equipment that may require decontamination at a given site include 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 each sample collected, and prior to placing sampling equipment in protective cases, or containers for transport. Cleaning procedures for sampling equipment should be monitored by collecting equipment blank samples as required in project work plans, field sampling plans, quality assurance project plans (QAPP), or other pertinent project documents. Dedicated and/or single-use (i.e., not to be re-used) sampling equipment will not require decontamination.

4 Personnel Qualifications

Arcadis field sampling 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 regulations, such as 40-hour hazardous waste operations and emergency response (HAZWOPER) training and/or Occupational Safety and Health Administration (OSHA) HAZWOPER site supervisor training. Arcadis personnel will also have current training as specified in the Health and Safety Plan (HASP) which may include first aid, cardiopulmonary resuscitation (CPR), Blood Borne Pathogens (BBP) as needed. In addition, Arcadis field sampling personnel will be knowledgeable in the relevant processes, procedures, and Technical Guidance Instructions (TGIs) and possess the demonstrated required skills and experience necessary to successfully complete the desired field work. The project HASP and other documents will identify other training requirements or access control requirements.

5 Equipment List

The equipment required for equipment decontamination is presented below. Note that certain contaminants may require specific materials be used that are not captured in this list. Always review project and contaminant specific TGIs or work plans to ensure proper equipment is utilized. Note for per- and polyfluoroalkyl substances (PFAS) see *TGI – Per- and Polyfluoroalkyl Substances (PFAS) Field Sampling Guide*.

- Health and safety equipment, including appropriate personal protective equipment (PPE), as required in the site HASP
- Deionized water that meets the analytical criteria for deionized water with no detectable constituents above the reporting limits for the methods to be used and analytes being analyzed for. Deionized water is used for inorganics, and organic-free water for volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), pesticides, etc.
- Non-phosphate detergent such as Alconox® or, if sampling for phosphorus or phosphorus- containing compounds, Liquinox (or equivalent). NOTE: Liquinox has shown to provide false positives for 1,4-Dioxane and should not be used at sites where that may be a constituent of concern (COC).
- Tap water
- Rinsate collection plastic containers

- Department of Transportation (DOT)-approved waste shipping container(s), as specified in the work plan, field sampling plan, or regulatory requirements if decontamination waste is to be shipped for disposal
- Brushes
- Large heavy-duty garbage bags
- Spray bottles
- (Optional) – Isopropyl alcohol (free of ketones) or methanol. These can be wipes or diluted with water (usually 1part isopropyl/methanol to 10 parts water) if a spray is needed.
- Airtight, sealable plastic baggies, such as Ziploc®-type
- Plastic sheeting

6 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. Ensure all rinse materials do not adversely affect sample collection efficiency or analytical results.

Store decontaminated equipment in a clean, dry environment. Do not store near combustion engine exhausts. Properly containerize equipment to ensure cross-contamination doesn't happen from other uncontaminated surfaces or equipment.

If equipment is damaged to the extent that decontamination is uncertain due to cracks, gouges, crevices, 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 regarding hazardous materials will be performed by a DOT-trained individual for cleaning materials shipped by Arcadis.

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.

7 Health and Safety Considerations

Review the safety data sheets (SDS) for the cleaning agents and materials used in decontamination. If solvent is used during decontamination, use appropriate PPE and 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 and bystanders. Follow health and safety procedures outlined in the HASP.

8 Procedure

A designated area will be established to clean sampling equipment in the field prior to and following sample collection. Equipment cleaning areas will be set up within or adjacent to the specific work area, but not at a location that expose equipment to contamination (i.e., exposed to combustion engine exhaust). Detergent solutions will be prepared in clean containers for use in equipment decontamination. Decontaminated equipment will be handled by workers wearing clean gloves, properly changed to prevent cross-contamination. The procedures detailed in this section provide an overview of common decontamination techniques. Additional steps may be required based on the type of contaminant present or client/site requirements.

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. NOTE: Liquinox® has shown to provide false positives for 1,4-Dioxane and will not be used at sites where that may be a COC.
3. If equipment is very dirty, precleaning gross debris with a brush and tap water may be necessary.
4. If non-aqueous phase liquids are present, the use of isopropyl alcohol (free of ketones) or methanol is recommended. Cloth wipes or diluted solution can be used to remove the non-aqueous phase liquids that are hard to remove with detergent solution in step 2. Consult with project manager if non-aqueous phase liquids are present onsite and design an appropriate decontamination procedure that includes step 4.
5. Rinse with deionized water.

Decontaminating Submersible Pumps

Submersible pumps may be used during well development, groundwater sampling, or other investigative activities. The pumps must 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 container filled with potable water. The pump will be be flushed with deionized water as the last step prior to use. The pump will run long enough to effectively flush the pump housing and hose (unless new, disposable hose is used). Disconnect the pump from the power source before handling. The pump and hose will be placed on or in clean polyethylene sheeting to avoid contact with the ground surface.

9 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).

10 Data Recording and Management

Digital data collection is the Arcadis standard using available FieldNow® applications that enable real-time, paperless data collection, entry, and automated reporting. Paper forms should only be used as backup to FieldNow® digital data collection and/or as necessary to collect data not captured by available FieldNow® applications. The Field Now® digital form applications follow a standardized approach, correlate to most TGIs and are available to all projects accessible with a PC or capable mobile device. Once the digital forms are saved within FieldNow®, the data is instantly available for review on a web interface. This facilitates review by project management team members and SMEs enabling error or anomalous data detection for correction while the staff are still in the field. Continual improvements of FieldNow® applications are ongoing, and revisions are made as necessary in response to feedback from users and subject matter experts.

Equipment cleaning and decontamination will be noted during project documentation. Information will include the type of equipment cleaned, the decontamination location, specific procedures utilized, solvents and/or cleaning agents used, source of water, and deviations or omissions from this TGI.

Unusual field conditions should be noted if there is potential to impact the efficacy 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 project documentation. Records will be maintained for solvents used in decontamination, including lot number and expiration date.

Containers with decontamination fluids will be labeled.

11 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 (or organic-free water, for organic analyses) over the clean and dry tools and collecting the 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 as specified in the sampling and analysis plan. Equipment blanks are collected per equipment set, which represents all the tools needed to collect a specific sample.

12 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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TGI – Monitoring Well Development

Rev: 1

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Version Control

Issue	Revision No.	Date Issued	Page No.	Description	Reviewed By
	0	4/24/2017	All	Re-written as TGI	Marc Killingstad
	1	4/12/2022	All	Updated to new format and some minor content changes	Marc Killingstad

Approval Signatures

Prepared by: 4/12/2022

Jay Erickson (Preparer) Date

Reviewed by: 4/12/2022

Marc Killingstad (Subject Matter Expert) Date

1 Introduction

This Technical Guidance Instruction (TGI) covers the development of screened wells used for obtaining representative groundwater information and samples from granular aquifers (i.e., monitoring wells).

Note: This TGI only applies to monitoring well development and not remediation (injection/extraction) well development.

2 Intended Use and Responsibilities

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3 Scope and Application

The objectives of monitoring well development are:

1. Repair damage to the borehole wall from drilling that can include clogging, smearing or compaction of aquifer materials;
2. Remove fine-grained sediment from the formation and filter pack that may result in high turbidity levels in groundwater samples;
3. To re-sort formation and filter pack material adjacent to the well screen;

4. To recover any drilling fluids (if used) that may affect the permeability of the formation and filter pack or alter the water quality around the well; and
5. To optimize the well efficiency and hydraulic communication between the well screen and the formation.

Successful monitoring well development is dependent on the following:

1. Hydrostratigraphy – Permeable formations containing primarily sand and gravel are more easily developed due to lower percentages of silt and clay material. Water in permeable formations can be moved in and out of the screen and/or through the formation easier than in less permeable deposits.
2. Well Diameter – Development tooling including brushes, surge blocks, pumps and jetting tools are more readily available for wells 4 inches in diameter and greater.
3. Well Design – Wells with filter packs and screens designed to match the formation through the analysis of formation sieve samples are easier to develop. An important aspect to well design is to minimize the size of the annular space between the formation and well screen. Adequate room must be allowed for the proper installation of well materials, but not too large as to prevent/reduce communication with the surrounding formation.
4. Drilling Methods – Different drilling methods result in varying amount of borehole damage and, therefore, impact the degree to which development will be successful.

Well development methods for monitoring wells include the following:

1. Bailing – Use of a bailer to remove water and sediment from the well casing. This technique does little to remove fines from the filter pack and may lead to bridging of sediment since the flow is in only one direction, toward the well screen. The most effective use of bailing during monitoring well development is in conjunction with other methods (e.g., surging/swabbing) to remove fines accumulated in the monitoring well between cycles of other development methods.
2. Pumping/over pumping – Use of a pump to remove water and sediment from the well casing, over pumping involves pumping the well at a rate that exceeds the design capacity of the well. Similar to bailing, this technique does little to remove fines from the filter pack and may lead to bridging of sediment since the flow is in only one direction, toward the well screen. Small diameter monitoring wells have the additional constraint on pump size and flow rates which further limit the effectiveness of this methodology.
3. Backwashing (rawhiding) – Consists of starting and stopping a pump intermittently to produce rapid pressure changes in a well. This method can produce better results than pumping alone since the procedure involves movement of the water in and out of the screen and formation. However, in many cases the surging action is not rigorous enough to fully develop the well and might be considered the final phase of development after a more rigorous method has been used. Again, small diameter monitoring wells have the additional constraint on pump size and flow rates which further limit the effectiveness of this methodology.
4. Surging/swabbing – Use of a mechanical surge block or swabbing tool to operate like a piston with an up and down motion. The downstroke causes a backwash action that breaks up bridged sediment and the upstroke pulls the dislodged sediment into the well. This method works well for both small and large diameter monitoring wells. Care should be taken on the downstroke so as not to force fines back into the formation, frequent pumping/purging during surging help to keep fines out of the well. Double surge blocks are recommended, and this is typically the most effective method for development of monitoring wells.

5. Jetting – Use of a tool fitted with nozzles that direct streams of water horizontally into well screens at high velocity. Due to the size of the tooling, this method is better suited for wells 4 inches in diameter and larger. The method is also more effective with wire-wrapped/continuous slot screens due to the increased open area. Jetting requires specialized equipment and concurrent pumping to prevent reintroducing fines into the filter pack. Additionally, depending on the configuration of the tool, jetting may require subsequent surging/pumping to remove fines dislodged in the filter pack and formation. Typically, jetting is not a preferred option for new well development but may be effective as part of a re-development/rehabilitation effort.

For most situations, surging/swabbing coupled with bailing or pumping to remove dislodged materials is recommended.

Final well development for properly designed and constructed monitoring wells may begin after the annular seal materials have been installed and allowed to cure, since these wells are designed to retain approximately 90% of the filter pack material. This cure time is typically at least 24 to 48 hours after the sealing materials have been installed.

This TGI is meant to provide a general guide for proper development of newly installed monitoring wells.

A site-specific field implementation plan (FIP) for well installation and development detailing the specific methods and tools is strongly recommended to provide site-specific instruction and guidance.

4 Personnel Qualifications

Generally, 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, and/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 specified in the Health and Safety Plan (HASP) which may include first aid, cardiopulmonary resuscitation (CPR), Blood Borne Pathogens (BBP) as needed. In addition, Arcadis field sampling 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. The HASP and other documents will identify other training requirements and access control requirements.

The designated Field Manager is responsible for periodic observation of field activities and review of field generated documentation associated with this TGI. The Field Manager is also responsible for implementation of corrective action if problems occur (e.g., retraining personnel, additional review of work plans and TGIs, variances to QC sampling requirements, issuing non-conformances, etc.).

Prior to mobilizing to the 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)/field sampling plan/work plan, Quality Assurance Project Plan (QAPP), HASP, historical information, and other relevant site documents.

Field personnel assigned to install and develop monitoring wells are responsible for completing their tasks in accordance with the specifications outlined in this TGI and other appropriate and relevant guidelines.

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.

5 Equipment List

Required equipment depends on the selected method and should be detailed in the site-specific FIP; however, the following are typically required.

- Approved site-specific Health and Safety Plan (HASP)
- Approved site-specific FIP which will include site map, well construction information/borehole information, and development plan
- Personal protective equipment (PPE) and health and safety equipment, as required by the HASP
- Field notebook and/or smart device (phone or tablet)
- Cleaning/decontamination equipment
    - Non-phosphate laboratory soap (Alconox or equivalent), brushes, clean buckets or clean wash tubs—new buckets or tubs will be purchased if it cannot be determined if the presentitems are clean
    - Distilled or de-ionized water for equipment decontamination
- Monitoring well keys
- Water-level meter
- Down-hole multiparameter water quality sonde (e.g., YSI)
- Plastic sheeting (e.g., Weatherall Visqueen) to protect all down-hole sampling equipment fromcontact with potential sources of contamination
- Well development forms/logs
- Well construction logs/diagrams
- Weighted tape (of sufficient length for maximum site depth)
- Turbidity meter
- Camera
- Watch/timing device

6 Cautions

Different USEPA regions and/or state regulatory agencies may stipulate deviations from this document. It is the responsibility of the Project Team (Project Manager and Technical Lead) to be fully aware of the requirements from the applicable regulatory framework.

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/field sampling plan/work plan scope and objectives is strongly recommended prior to mobilization to ensure that the field work will be effectively and efficiently executed.

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 Certified Project Manager (CPM) and/or Project Hydrogeologist must be notified, and the CPM 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 CPM 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

7 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.

Appropriate 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.

Access to well locations may expose field personnel to hazardous materials such as contaminated groundwater or NAPL (e.g., petroleum hydrocarbons, chlorinated solvents). Other potential hazards include pressurized wells, stinging insects that may inhabit well heads, other biological hazards (e.g., ticks in long grass/weeds around wellhead), and potentially the use of sharp cutting tools (scissors, knife). Open well caps slowly and keep face and body away while allowing to vent any built-up pressure to vent. 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.

Do not enter confined spaces unless following appropriate confined space entry procedures specified in the HASP.

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

8 Procedure

As indicated above, for most monitoring wells, gentle surging coupled with bailing or pumping to remove dislodged sediment is recommended.

8.1 Preliminary Well Development

After installation of the primary filter pack around the monitoring well screen, preliminary well development is recommended be performed to ensure that the filter pack settles and does not bridge within the annular space. The preliminary well development steps are as follows:

1. Measure and record depth to water, total depth of well, and depth to top of the sand pack in the annulus.
2. Use steel or weighted bailer to remove any fines that have accumulated in the bottom of the well.
3. Lower an appropriately sized double-surge block into the screened portion of the well on a rigid pipe or high-density tubing and gently cycle up and down to force water in and out of the screen slots and formation. A two-foot throw is recommended (use tape or chalk marks on the pipe or tubing); however, the entire length of well screen must be gently surged.
4. Start above the screen and gently surge over two-foot intervals while working down to the screen bottom.

NOTE: Care must be taken not to surge the well too aggressively at this point as the casing is not well-supported and damage could occur. The objective is to create enough surging action to settle the primary filter pack and provide some preliminary removal of accumulated materials before final development.

NOTE: If possible, ensure that the developer surges the block upward faster than downward to pull the fines out of the filter pack, instead of forcing them back in (and allowing for proper settlement).

5. Monitor the total depth of the well periodically during surging to ensure that we are not pulling excessive amounts of filter pack through the screen and remove any debris accumulated in the well with a weighted bailer or pump.
6. Re-measure the top of the sand in the annulus to see if more sand pack is necessary. Remove any fines that have accumulated out of the well using a submersible pump or weighted bailer.

NOTE: If the monitoring well was drilled using mud rotary drilling methodology or if significant fines were encountered during the well installation, consider adding a commercially available ‘mud’ dispersant (e.g., AQUA-CLEAR PFD, Nu Well 220, etc.) as part of the preliminary development. This will help to break up the ‘skin’ along the borehole wall created by either the drilling fluid or smearing during drilling and assist in final development. Follow manufacturer’s directions for dosing, and the mixture should be worked through the entire saturated screen interval by gently surging or brushing.

8.2 Final Well Development

After sufficient time has passed to allow for proper curing of the well seal/grout (i.e., 24 to 48 hours), final well development can be performed. Final well development steps are as follows:

1. Don appropriate PPE (as required by the site-specific 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 logbook. It is recommended to use a weighted tape for the total well depth measurement.
6. The depth to the bottom of the well should be sounded and then compared to the completion form or construction diagram for the well. Any discrepancies should be reported immediately to the CPM and/or Project Hydrogeologist. If sand or sediment is present inside the well, it should first be removed by bailing. Do not insert bailers, pumps, or surge blocks into the well if obstructions, parting of the casing, or other damage to the well is suspected. Instead report the conditions to the CPM and/or Project Hydrogeologist and obtain approval to continue or cease well development activities.

NOTE: If the monitoring well was drilled using mud rotary drilling methodology or if significant fines were encountered during the well installation, it is recommended that a commercially available 'mud' dispersant (e.g., AQUA-CLEAR PFD, Nu Well 220, etc.) be included as part of the final well development to effectively break up the 'skin' along the borehole wall created by either the drilling fluid or smearing during drilling.

Per manufacturer's instructions, the general procedure for adding dispersant is as follows:

- *i. Determine volume of water in screen area and double the calculated volume to account for water in gravel pack and formation interface*
- *ii. Once the water volume is determined, calculate the required treatment volume of dispersant need per manufacturer's recommendations*
- *iii. Mix thoroughly before introducing into well*
- *iv. The preferable application method utilizes a tremie line with the product applied into the screened area*
- *v. Mixture should be thoroughly blended in well, then agitated via surging/swabbing/brushing repeatedly (e.g., every two hours) for a period of up to 24 hours*
- *vi. The dispersant should sit for at least 6 to 8 hours or overnight before continuing well development activities*

7. After allowing the dispersant to sit for the required time (if dispersant is used), start the mechanical development by lowering an appropriately sized double-surge block (or similar) into the well on a rigid pipe or high-density tubing.
    - i. Surging should start above the screen to reduce the possibility of "sand-locking" the surge block. Initial surging should be with a long stroke and at a slow rate (20 to 25 strokes per minute)
    - ii. After surging above the screen, the well should be cleaned via bottom-loading bailer, submersible pump, or inertia pump tubing with check valve to the bottom of the well

   iii. Begin surging at the lower end of the screen, gradually working upward, surging in 2-ft intervals until the entire screen has been developed.
   iv. Surge the well a minimum of 10 throws per 2-ft screen interval.
   v. Each interval may require several surge cycles to achieve the best development.
   vi. The entire length of well screen must be surged.
   vii. Ensure that the developer surges the block upward faster than downward to pull the fines out of the filter pack, instead of forcing them back in (and allowing for proper settlement)
   viii. measure total depth of the well periodically during surging to ensure that excessive amounts of sediment are not being pulled through the screen. Remove any debris accumulated in the well via simultaneous airlifting (if a combined tool is available) or with bailing/pumping.

8. After completing a cycle of surging, lower a bottom-loading bailer, submersible pump, or inertia pump tubing with check valve to the bottom of the well and gently bounce 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 contact at the bottom of the well feels solid. Alternatively, measurement of the well depth with a weighted tape 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 for a minimum of two cycles 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/bailing.
    i. Where pumping is used, measure and record the pre-pumping water level.
    ii. Operate the pump at a relatively constant rate
    iii. Measure the pumping rate using a calibrated container and stopwatch, and record the pumping rate in the field log book
    iv. Measure and record the water level in the well at least once every 5 minutes during pumping
    v. Record any relevant observations in terms of color, visual level of turbidity, sheen, odors, etc.
    vi. Pump or bail until termination criteria specified in the site-specific FIP are reached
    vii. Record the total volume of water purged from the well

NOTE: The FIP may also specify a maximum turbidity requirement for completion of development. Unless otherwise specified the maximum turbidity should be 50 NTUs or less

11. While developing, take periodic water level measurements (at least one every five minutes) to determine if drawdown is occurring and record the measurements on the Well Development Log.
12. While developing, calculate the rate at which water is being removed from the well. Record the volume on the Well Development Log.
13. While developing, water is also periodically collected directly from the well or bailer discharge and readings taken of the indicator parameters: pH, specific conductance, and temperature. Development is

considered complete when the indicator parameters have stabilized (i.e., three consecutive pH, specific conductance, and temperature readings are within tolerances specified in the project work plans or within 10% if not otherwise specified), the extracted water is clear and free of fine sediment and most importantly, when acceptable volume of water has been removed and/or a sufficient amount of surging has been performed.

14. In certain instances, for slow recharging wells, the parameters may not stabilize. In this case, well development is considered complete when minimal amounts of fine-grained sediments are recovered, and an acceptable volume of water has been removed.
15. 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.
16. Contain all development water in appropriate containers.
17. When complete, secure the lid back on the well.
18. Place disposable materials in plastic bags for appropriate disposal and decontaminate reusable, downhole pump components and/or bailer

9 Waste Management

Investigation-Derived Waste (IDW), including purge water and decontamination liquids, will be stored on site in appropriately labeled containers and disposed of properly. Disposable materials will be stored and disposed of separately. 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., water, PPE). Waste will be managed in accordance with the *TGI – Investigation-Derived Waste Handling and Storage*, the procedures identified in the FIP/field sampling plan/work plan 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.

10 Data Recording and Management

Digital data collection is the Arcadis standard using available FieldNow® applications that enable real-time, paperless data collection, entry, and automated reporting. Paper forms should only be used as backup to FieldNow® digital data collection and/or as necessary to collect data not captured by available FieldNow® applications. The Field Now® digital form applications follow a standardized approach, correlate to most TGIs and are available to all projects accessible with a PC or capable mobile device. Once the digital forms are saved within FieldNow®, the data is instantly available for review on a web interface. This facilitates review by project management team members and SMEs enabling error or anomalous data detection for correction while the staff are still in the field. Continual improvements of FieldNow® applications are ongoing, and revisions are made as necessary in response to feedback from users and subject matter experts.

All well development activities will be documented on appropriate log forms as well as in a proper field notebook and/or PDA. Additionally, all documents (and photographs) should 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 well development activities; development method(s); observations of purge water color, turbidity, odor, sheen, etc.; purge rate; and water levels before, during, and after pumping.

Management of the original documents from the field will be completed in accordance with the site-specific QAPP. Records generated as a result of this TGI will be controlled and maintained in the project record files in accordance with project requirements.

Development activities will be documented on appropriate field logs as well as in a proper field notebook. All field data will be recorded digitally or with 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. Any deviations or omissions from this TGI should be documented.

Initial field logs and forms will be transmitted to the Arcadis CPM and/or Technical Lead at the end of each day unless otherwise directed by the CPM. The field team leader retains copies of the field documentation.

11 Quality Assurance

Quality assurance procedures will be conducted in accordance with the Arcadis Quality ManagementSystem or the site-specific QAPP. Refer to the QAPP or FIP/sampling plan/work plan for specific requirements.

12 References

American Society for Testing Materials (ASTM), Designation D5521-05. *Standard Guide for Development of Ground-Water Monitoring Wells in Granular Aquifers*. American Society for Testing Materials. West Conshohocken, Pennsylvania.

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TGI – Soil Description

Rev: 4

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Version Control

Issue	Revision No.	Date Issued	Page No.	Description	Reviewed By
	0	May 20, 2008	17	Original SOP	Joe Quinnan Joel Hunt
	1	September 2016	15	Updated to TGI	Nick Welty Patrick Curry
	2	February 16, 2018	15	Updated descriptions, attachments and references in text	Nick Welty Patrick Curry
	3	April 15, 2022		Minor description edits, intro of grain-size K analysis, revised boring log template	Matt McCaughey Patrick Curry
	4	June 14, 2022		Updated date on cover page and header. Updated revision number from 3 to 4. Updated reference throughout document from ASTM D2488-06 to ASTM D-2488.17 . Change “25% silt and clay; 15% pebbles” to “20% silt and 20% clay” on page 10 of 23. Updates made to Section 8.2.1 Changed reference to Appendix B to Appendix A	

Approval Signatures

Prepared by: 6/14/2022

Matthew C. McCaughey

Matthew C. McCaughey, PG (Preparer) Date

Reviewed by: 6/14/2022

Patrick Curry, PG (Subject Matter Expert) Date

1 Introduction

This Arcadis Technical Guidance Instruction (TGI) describes proper soil description procedures based on visual inspection and testing of soil cores and samples. This document 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.

2 Intended Use and Responsibilities

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 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, regulation-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.

3 Scope and Application

This TGI should be followed for unconsolidated material unless there is an established client-required specific procedure or regulatory-required specific procedure. In cases where there is a required specific procedure, 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 procedure, additional information required by this TGI should be included in field notes with client approval.

This TGI incorporates elements from various standard systems such as ASTM D-2488-17, Unified Soil Classification System, Burmister and Udden 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 TGI includes the following attachments:

- **Attachment A –** Field Soil Description Guide
- **Attachment B –** Particle Size System Comparison
- **Attachment C –** Description of Logging Terms
- **Attachment D –** Blank Boring Log
- **Attachment E –** Completed Boring Log

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

4 Personnel Qualifications

Soil descriptions should only be performed by Arcadis personnel or authorized sub-contractors with a degree in geology or a geology-related discipline. Field personnel will complete training on the Arcadis soil description TGI in the office and/or in the field under the guidance of an experienced field geologist with at least 2 years of prior experience applying the Arcadis soil description method.

5 Equipment List

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

- Field book, field forms or digital devices to record soil descriptions
- Field book for supplemental notes
- This TGI for Soil Descriptions and any project-specific procedure, guidance, and/or instructional documents (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
- 4-ounce glass jars with lids (for collecting soil core samples)
- Personal protective equipment (PPE), as required by the HASP
- Digital camera

- Folding table

6 Cautions

Drilling and drilling-related hazards including subsurface utilities are discussed in other procedure documents 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.

7 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.

8 Procedure

8.1 General Procedures

- 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, acetate sleeves for direct push, bagged core for sonic drilling, etc.
- 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.
- Set up boring log field sheet.
  - Determine the proper units of measure. Drillers in both the US and Canada generally work in feet due to equipment specifications. Field geologists typically record drilling depths, core recovery, and sample intervals in feet and grain size in millimeters
  - Use the Arcadis standard boring log form (**Attachment D**). *Note that as of April 2022, several digital logging applications are available through the FieldNow™ program and the Fulcrum app. A future revision of this TGI, likely in early 2023, will emphasize digital logging methods and field boring log forms will no longer be acceptable. FieldNow is discussed further in Section 10.*
  - The boring log template includes a graphic log of the primary soil texture to support quick visual evaluation of grain size. The purpose of the graphic log is to quickly assess relative soil permeability. Note, for poorly sorted soils (e.g., glacial till), the principal component may not correlate to permeability of the sample. In this case, the geologist should use best judgement to graph overall soil type consistent with relative soil permeability. For example, for a dense sand/silt/clay till, the graphic log would reflect the silt/clay, rather than sand.

  - Record depths along the left-hand side at a standard scale to aid in the use of this tool.
- Examine each soil core (this is different than examining each sample selected for laboratory analysis) and record the soil conditions in accordance with guidelines provided in Section 8.2.
- At the end of the boring, record the amount of drilling fluid used (if applicable) and the total depth logged.
- At a minimum, a written or digital boring log should be prepared with the following information:
  - Describe type of surface material (asphalt, grass, topsoil, gravel, etc.)
  - Describe the type of fill or non-native soils and estimated depth to native soils
  - Record sample intervals (soil cores, environmental and/or geotechnical samples)
  - Describe soil conditions in accordance with this TGI
  - Record moisture content and estimated depth to water table or saturated zone
  - Record the total depth and document why drilling was stopped (refusal, target depth achieved, etc.)

8.2 Soil Description Procedures

The standard soil description order is presented below.

- Depth
- PRIMARY TEXTURE
- Principal and Minor Components with Descriptors
  - % Modifiers and grain size fraction
  - Angularity for coarse sand and larger particles
  - Consistency or Density
  - Plasticity for silt and clay
  - Dilatancy for silt and silt-sand mixtures
- Sorting
- Moisture Content
- Color
- Notes

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

- 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.
- 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., 36/60 for 36 inches recovered from 5-ft [60-inch] sampling interval).
- Thickness of each stratum measured sequentially from the top of recovery to the bottom of recovery.
- 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 36/60 bottom 12 inches of core 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: SAND, fine; 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 class differs from the next larger 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 Soil Description Field Guide (**Attachment A**) that shows Udden-Wentworth scale or by measuring with a ruler.

The following table summarized the modified Udden-Wentworth Scale for grain size classification. Note that gravel is a size category encompassing the granule, pebble, cobble, and boulder size classes.

Udden-Wentworth Scale (Modified by Arcadis, 2008)

Size Category	**Size Class**	**Millimeters**	**Inches**	**Standard Sieve #**
Gravel (Cobble)	Boulder	256 – 4096	10.08+	
	Large cobble	128 - 256	5.04 -10.08	
	Small cobble	64 - 128	2.52 – 5.04	
Gravel (Pebble)	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

Sand	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
Fines	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	0.00002 – 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.

Sieve and hydrometer grain-size analysis can be used to vet the visual description, as well as used to estimate hydraulic conductivity. Lab or field sieve analysis is advisable to characterize the variability and facies trends within each hydrostratigraphic unit. It is recommended that sieve-hydrometer analysis be performed on representative samples from each soil type to estimate the fraction of each grain size category using ASTM D422 Standard Test Method for Particle-Size Analysis of Soils. If desired sieve sizes can be specified to follow the Udden-Wentworth classification (U.S. Standard sieve 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.

Several empirical formulas provide a reliable means of estimating hydraulic conductivity (K) from grain-size distribution data, provided that the formation does not contain abundant fines that result in cohesive or plastic behavior or include cobble-sized grains (Payne et al. 2008). Grain-size analysis can help bracket the permeability of hydrostratigraphic units (HSUs) and identify order-of-magnitude spatial variations in K. Arcadis has completed modifications to the Excel-based program HydroGeoSieveXL (Devlin 2015) to process sieve data quickly and estimate K. The tool calculates estimated K values from grain-size data using 15 different empirical formulas. A decision matrix then selects which of the formulas is relevant for the soil type and calculates an average K.

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% small to medium pebbles would be “PEBBLES, small to medium”; or the principal component in a sample that was 20% fine sand, 30% medium sand and 25% coarse sand would be “SAND, fine to coarse” or for a sample that was 40% silt and 45% clay the principal component would be “CLAY and SILT”.

The boring log form (**Appendix D**) includes a graphic log to visually illustrate a relative estimate of soil permeability. To use the graphic log, place an ‘X’ or shade the appropriate column for the primary soil texture. If the soils have a high percentage of a secondary soil texture (i.e., when the ‘and’ modifier’ is used), it’s acceptable to mark off the appropriate column for the secondary soil texture in this instance. However, care should be used to avoid marking off the columns for other minor soil textures because doing so will make it difficult to determine the relative soil permeability of the poorly sorted soils.

As noted above, for poorly sorted soils such as glacial till, the principal component may not correlate to permeability of the sample. In this case, the geologist should use best judgement to graph overall soil type consistent with relative soil permeability.

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, 20% silt and 20% clay – there are two identified minor components: silt and clay.

Include a standard modifier to indicate percentage of minor components (see particle size table) and the same descriptors that would be used for a principal component. An example of minor constituents with modifiers include: some silt and clay, low plasticity; little medium to large pebbles, sub-round.

8.2.1 Secondary Descriptors

The following are the descriptors used outside of the principal and minor components. Note that plasticity should be provided as a descriptor for clay and clay mixtures. Dilatancy should be provided for silt and silt mixtures. Angularity should be provided as a descriptor for pebbles and coarse sand.

Angularity. Describe the angularity for coarse sand and larger particles in accordance with the table below (ASTM D-2488-17). Figures showing examples of angularity are available in ASTM D2488-17 and the Arcadis Soil Description Field Guide (**Appendix A**).

Description	Criteria
Angular	Particles have sharp edges and relatively plane sides with unpolished surfaces
Sub-Angular	Particles are like angular description but have rounded edges
Sub-Rounded	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-2488-17).

- As in the dilatancy test (described 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
Non-plastic	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-2488-17).

- 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

Note that silt and silt-sand mixtures will be non-plastic and display dilatancy. Clay mixtures will have some degree of plasticity but do not typically react to dilatancy testing. Therefore, the tests outlined above can be used to differentiate between silt-dominated and clay-dominated soils.

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:

Description	Criteria
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).

Consistency or Density. This can be determined by standard penetration test (SPT) blow counts (ASTM D-1586) obtained when using hollow-stem auger drilling methods and a split spoon sampling device. Otherwise, some field tests are available as outlined below. When drilling with hollow-stem augers and split-spoon sampling, the SPT blow counts and N-value is used to estimate density. The N-value is the blows per foot for the 6” to 18” interval. For example, for a 24-inch split spoon soil core, the recorded blows per 6-inch interval are: 4/6/9/22. Since the second interval is 6” to 12”, 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. In recent years, more common drilling methods include rotary-sonic or direct push. When blow counts are not available, density is determined using a thumb test. Note however, the thumb test only applies to fine-grained soils.

Fine-grained soil – Consistency

Description	Criteria	Blow Counts (6-12 to 12-18-inch split spoon interval)
Very soft	Easily penetrated several inches by thumb	N-value < 2
Soft	Easily penetrated one inch by thumb	N-value 2-4
Medium Stiff	Indented about ½ inch with much effort	N-value 5-8
Stiff	Indented with ¼ inch with great effort	N-value 9-15
Very Stiff	Readily indented by thumbnail	N-value 16-30
Hard	Indented by thumbnail with difficulty	N-value > than 30

Coarse-grained soil – Density

Description	Criteria	Blow Counts (6-12 to 12-18-inch split spoon interval)
Very loose	Density classification of coarse-grained soils is only required when blow counts from standard penetration tests are performed during hollow-stem auger drilling	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

Moisture Content. Moisture content should be described for each soil sample in accordance with the table below (percentages should not be used unless determined in the laboratory). *Note that some drilling methods (e.g., sonic) can compress and dry out the sample during drilling. Therefore, it can be difficult to determine if a sample is saturated, or merely moist. In this case, care should be taken to try and determine a static water level within the borehole by measuring depth to water through the drill casing, if possible.*

Description	Criteria
Dry	Absence of moisture, dry to touch, dusty
Moist	Damp but no visible water
Wet	Visibly free water

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.

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 only used for special soil conditions, such as caliche environments.
- Origin, if known (Lacustrine; Fill; etc.).

8.3 Example of Soil Descriptions

The standard generic description order is presented below.

- Depth
- PRIMARY TEXTURE
- Principal and Minor Components with Descriptors
  - % Modifiers and grain size fraction
  - Angularity for coarse sand and larger particles
  - Consistency or Density
  - Plasticity for silt and clay
  - Dilatancy for silt and silt-sand mixtures
- Sorting
- Moisture Content
- Color
- Notes

10-15 feet CLAY, trace silt, trace small to very large pebbles, subround to subangular up to 2" diameter; medium to high plasticity, stiff, moist, dark grayish brown (10YR 4/2). NOTE: Lacustrine; laminated 0.1 to 0.2" thick, laminations brownish yellow (10YR 4/3).

10 -15 feet SAND, medium to very coarse, little granules to medium pebbles, subround to subangular, trace silt; poorly sorted, wet, grayish brown (10YR5/2).

Unlike the first example where a density of cohesive soils could be estimated, this rotary-sonic 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.

9 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.

10 Data Recording and Management

10.1 Digital Data Collection Process Overview

Digital data collection is the Arcadis standard using available FieldNow® applications that enable real-time, paperless data collection, entry, and automated reporting. Paper forms should only be used as backup to FieldNow® digital data collection and/or as necessary to collect data not captured by available FieldNow® applications. The Field Now® digital form applications follow a standardized approach, correlate to most TGIs and are available to all projects accessible with a PC or capable mobile device. Once the digital forms are saved within FieldNow®, the data is instantly available for review on a web interface. This facilitates review by project management team members and SMEs enabling error or anomalous data detection for correction while the staff are still in the field. Continual improvements of FieldNow® applications are ongoing, and revisions are made as necessary in response to feedback from users and subject matter experts.

10.2 Digital Data Collection Tools for Soil Descriptions

Arcadis is transitioning from the use of paper forms to a digital soil description logging process using web-based FieldNow applications accessible on field tablets and smart phones. Company-wide roll out of a FieldNow application for soil descriptions is targeted by the end of 2022.

Paper forms are included in Revision 3 (April 2022) of this Soil Description TGI. Specifically, a blank boring log and completed boring log are provided in **Attachment D** and **Attachment E**. Additional guidance and examples of the digital data collection tools for soil descriptions will be provided in the next revision to this TGI.

10.3 Additional Guidance

The general logging scheme for soil descriptions is described in this document. Depending on project data quality objectives, specific soil description parameters that are not applicable to project goals may be omitted at the project manager’s discretion. In any case, use of consistent procedures 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. Photographs should include a ruler or common object for scale. Photo location, depth and orientation must be recorded in the daily log or logbook and a label showing this information in the photo is useful.

For projects involving soil logging and soil sampling, the soil sample should be recorded on the Arcadis boring log form and the field logbook based on Data Quality Objectives for the task/project.

11 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.

12 References

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

ASTM D-2488-17, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)

ASTM D422, 63rd Edition, 1972 - Standard Test Method for Particle-Size Analysis of Soils.

Devlin, J.F. 2015. HydroGeoSieve XL: an Excel-based tool to estimate hydraulic conductivity from grain-size analysis. Hydrogeology Journal, DOI 10.1007/s10040-015-1255-0.

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

Payne, F. C., Quinnan, J. A., & Potter, S. T. 2008. Remediation Hydraulics. Boca Raton: FL: CRC Press.

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.

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.”

NIOSH Pocket Guide to Chemical Hazards.

Attachment A

Soil Field Reference Guide

The purpose of this attachment is to present a field reference guide for use during soil logging. Field staff are encouraged to bring a laminated copy of this reference guide into the job site.

ON THE ORIGINAL DRAWING.
USE TO VERIFY FIGURE
REPRODUCTION SCALE

SOIL DESCRIPTION FIELD GUIDE (APRIL, 2022; REV. 3.0)

ARCADIS Design & Consultancy for natural and built assets

FINE-GRAINED SOILS

Description	Criteria
	Descriptor - Plasticity
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.
	Descriptor - Dilatancy
No Dilatancy	No visible change when shaken or squeezed.
Slow	Water appears slowly on the surface of soil during shaking and does not disappear or disappears slowly when squeezed.
Rapid	Water appears quickly on surface of soil during shaking and disappears quickly when squeezed.
Minor Components with Descriptors	
	Moisture
Dry	Absence of moisture, dry to touch, dusty.
Moist	Damp but no visible water.
Wet	Visible free water; soil is usually below the water table. (Saturated)
	Consistency
Very soft	N-value < 2 or easily penetrated several inches by thumb.
Soft	N-value 2-4 or easily penetrated 1 inch by thumb.
Medium stiff	N-value 5-8 or indented about 1/2 inch by thumb with great effort.
Stiff	N-value 9-15 or indented about 1/4 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.
Color using Munsell	
Geologic Origin (if known)	
Other	

EXAMPLE OF SOIL DESCRIPTION AND PHOTO

10-15 feet CLAY, trace silt, trace small to very large pebbles, subround to subangular up to 2" diameter; medium to high plasticity, stiff, moist, dark grayish brown (10YR 4/2). NOTE: Lacustrine; laminated 0.1 to 0.2" thick, laminations brownish yellow (10YR 4/3).

DESCRIPTION ORDER

Depth Interval
PRIMARY TEXTURE (e.g., SAND)
Principal and Minor Components with Descriptors:
- % Modifiers and grain size fraction
- Angularity coarse sand and larger
- Consistency or Density
- Plasticity for silt and clay
- Dilatancy for silt and silt-sand

Sorting for granular sediments
Moisture Content
Color
Other NOTES

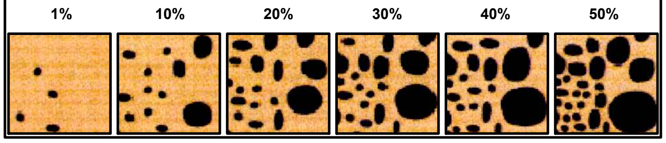
MINOR COMPONENTS % MODIFIERS

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

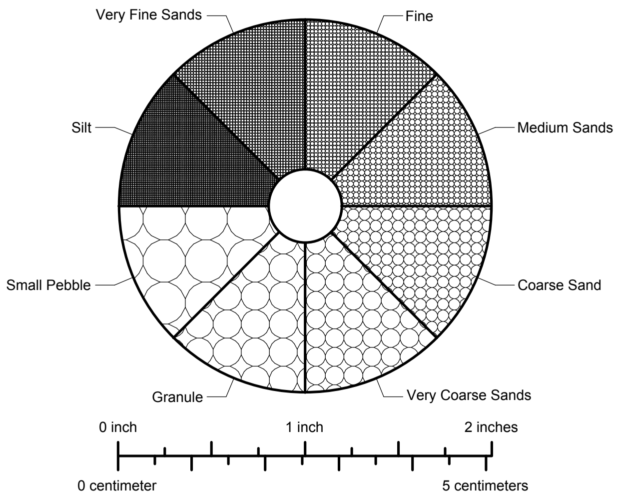
UDDEN-WENTWORTH SCALE

Fraction	Sieve Size	Grain Size	Approximate Scale
Boulder		256 - 4096 mm	Larger than volleyball
Large Cobble		128 - 256 mm	Softball to volleyball
Small Cobble		64 - 128 mm	Pool ball to softball
Very Large Pebble		32 - 64 mm	Pinball to pool ball
Large Pebble		16 - 32 mm	Dime size to pinball
Medium Pebble		8 - 16 mm	Pencil eraser to dime size
Small Pebble	No. 5+	4 - 8 mm	Pea size to pencil eraser
Granule	No. 10 - 5	2 - 4 mm	Rock salt to pea size
Very Coarse Sand	No. 18 - 10	1 - 2 mm	See field gauge card
Coarse Sand	No. 35 -18	0.5 - 1 mm	See field gauge card
Medium Sand	No. 60 - 35	0.25 - 0.5 mm	See field gauge card
Fine Sand	No. 120 - 60	0.125 - 0.25 mm	See field gauge card
Very Fine Sand	No. 230 - 120	0.0625 - 0.125 mm	See field gauge card
Silt and Clay. See SOP for description of fines	Not Applicable	<0.0625 mm	Analyze by pipette or hydrometer

PARTICLE PERCENT COMPOSITION ESTIMATION



GRAPH FOR DETERMINING SIZE OF PARTICLES



FOR COARSE-GRAINED SOILS

Description	Criteria
	Descriptor - Angularity
Angular	Particles have sharp edges and relatively planar sides withunpolished surfaces.
Subangular	Particles are similar to angular but have rounded edges.
Subround	Particles have nearly planar sides but have well-roundedcorners and edges.
Round	Particles have smoothly curved sides and no edges.
Minor Components with Descriptors	
	Sorting **Cu= d60/d10**
Well Sorted	Near uniform grain-size distribution Cu= 1 to 3.
Poorly Sorted	Wide range of grain size Cu= 4 to 6.
	Moisture
Dry	Absence of moisture, dry to touch, dusty.
Moist	Damp but no visible water.
Wet	Visible free water; soil is usually below the water table. (Saturated)
	Density
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 using Munsell	
Geologic Origin (if known)	
Other	
	Cementation
Weak Cementation	Crumbles or breaks with handling or little finger pressure.
Moderate Cementation	Crumbles or breaks with considerable finger pressure.
Strong Cementation	Will not crumble with finger pressure.
	Reaction with Dilute HCl Solution (10%)
No Reaction	No visible reaction.
Weak Reaction	Some reaction, with bubbles forming slowly.
Strong Reaction	Violent reaction, with bubbles forming immediately.

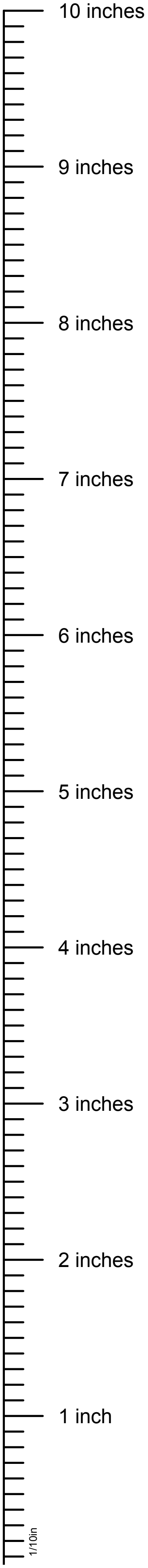
EXAMPLE OF SOIL DESCRIPTION AND PHOTO

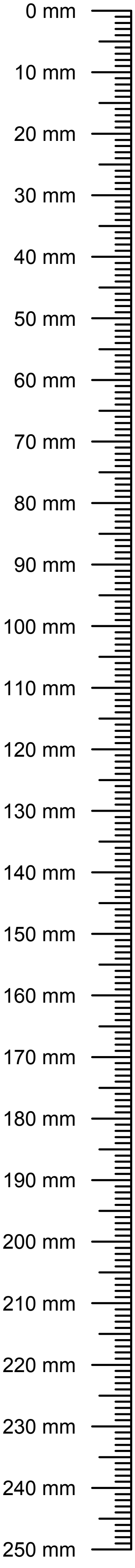
10 -15 feet SAND, medium to very coarse, little granules to medium pebbles, subround to subangular, trace silt; poorly sorted, wet, grayish brown (10YR 5/2).

ON THE ORIGINAL DRAWING.
USE TO VERIFY FIGURE
REPRODUCTION SCALE

SOIL DESCRIPTION FIELD GUIDE (APRIL, 2022; REV. 3.0)

ARCADIS Design & Consultancy for natural and built assets





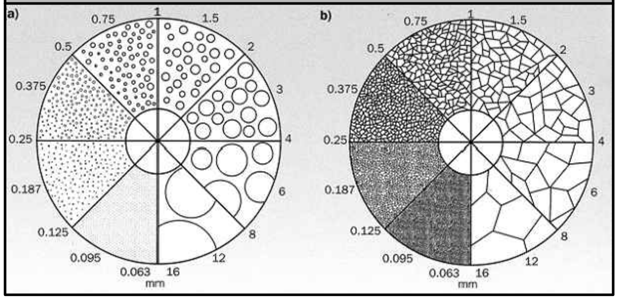
VARIATIONS IN SOIL STRATIGRAPHY

Term	Thickness of Configuration
Parting	0 - to 1/16-inch thickness.
Seam	1/16 - to 1/2-inch thickness.
Layer	1/2 - to 12-inch thickness.
Stratum	> 12-inch thickness.
Pocket	Small erratic deposit, usually less than 1 foot in size.
Varved Clay	Alternating seams or layers of sand, silt, and clay (laminated).
Occasional	≤ 1 foot thick.
Frequent	> 1 foot thick.

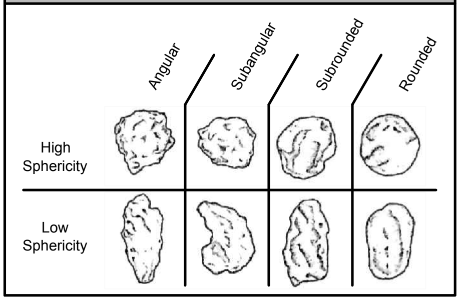
SOIL STRUCTURE DESCRIPTIONS

Term	Description
Homogeneous	Same color and appearance throughout.
Laminated	Alternating layers < 1/4 inch thick.
Stratified	Alternating layers ≥ 1/4 inch thick.
Lensed	Inclusions of small pockets of different materials, such as lenses of sand scattered through a mass of clay; note thickness.
Blocky	Cohesive soil can be broken down into small angular lumps, which resist further breakdown.
Fissured	Breaks along definite planes of fracture with little resistance to fracturing.
Slickensided	Fracture planes appear to be polished or glossy, sometimes striated.

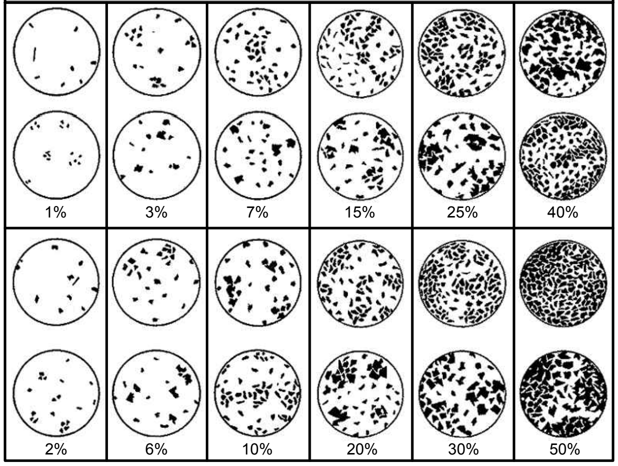
GRAPH FOR DETERMINING SIZE OF PARTICLES



ANGULARITY CHART



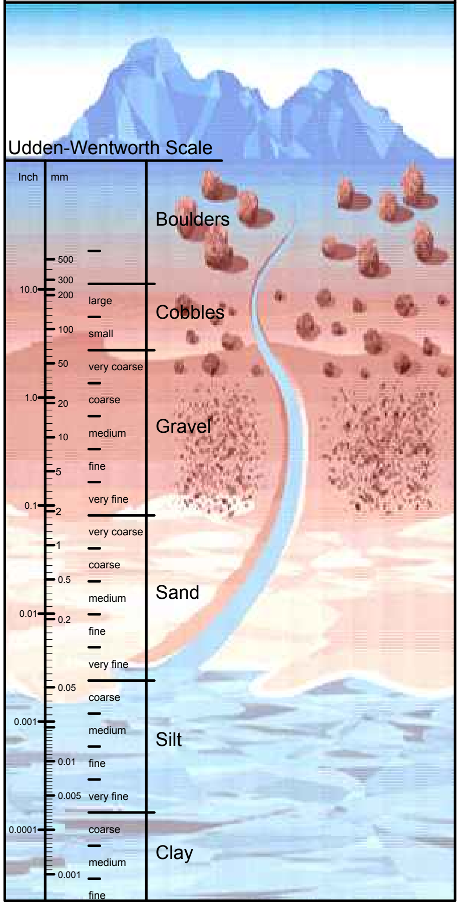
PARTICLE PERCENT COMPOSITION ESTIMATION



SETTLING TABLE (SILT/CLAY)

Diameter of Particle (mm)	<0.625	<0.031	<0.016	<0.008	<0.004	<0.002	<0.0005
Depth of Withdrawal (cm)	10	10	10	10	5	5	3
Time of Withdrawal	hr:min:sec	hr:min:sec	hr:min:sec	hr:min:sec	hr:min:sec	hr:min:sec	hr:min:sec
Temperature (Celsius)							
20	00:00:29	00:01:55	00:07:40	00:30:40	00:61:19	04:05:00	37:21:00
21	00:00:28	00:01:52	00:07:29	00:29:58	00:59:50	04:00:00	
22	00:00:27	00:01:50	00:07:18	00:29:13	00:58:22	03:54:00	
23	00:00:27	00:01:47	00:07:08	00:28:34	00:57:05	03:48:00	
24	00:00:26	00:01:45	00:06:58	00:27:52	00:55:41	03:43:00	33:56:00
25	00:00:25	00:01:42	00:06:48	00:27:14	00:54:25	03:38:00	
26	00:00:25	00:01:40	00:06:39	00:26:38	00:53:12	03:33:00	
27	00:00:24	00:01:38	00:06:31	00:26:02	00:52:02	03:28:00	
28	00:00:24	00:01:35	00:06:22	00:25:28	00:50:52	03:24:00	31:00:00
29	00:00:23	00:01:33	00:06:13	00:24:53	00:49:42	03:10:00	
30	00:00:23	00:01:31	00:06:06	00:24:22	00:48:42	03:05:00	

SORTING



Attachment B

Particle Size System Comparison

The purpose of this attachment is to illustrate how the Udden-Wentworth particle sizes and descriptive terms compares to other particle size systems.

When in the field, it is a customary practice to compare current soil descriptions to historical soil boring logs for reference purposes. When reviewing boring logs prepared by others, field staff should first note the particle size system used and recognize these particle size systems may differ. This will avoid confusion when cross referencing between historical and new boring logs and when reviewing existing geologic cross-sections.

For example, a well-sorted sand with grain sizes ranging from 1 to 2 mm should be classified as a very coarse sand by the Udden-Wentworth system. As shown in this attachment, the same particle size would be classified as a medium sand by the United Soil Classification System. The later system has fewer particle size grades and in general, is less descriptive than the Udden-Wentworth system.

PARTICLE SIZE SYSTEM COMPARISON

System Name | **Used By** | **Grain size distribution in millimeters (mm)**

Udden-Wentworth — **Remediation Geologists and Engineers**

								Pebbles				Cobbles	
		V. Fine	Fine	Medium	Coarse	V. Coarse	Granule	Small	Medium	Large	V. Large	Small	Large
CLAY	SILT	SAND					GRAVEL						

0.039 0.065 0.125 0.25 0.5 1 2 4 8 16 32 64 128 256

1/16 1/8 1/4 1/2

United Soil Classification System — **Geotechnical Engineers**

		Fine	Medium	Coarse	Fine	Coarse	
CLAY	SILT	SAND			GRAVEL		COBBLE

0.074 0.42 2 4.75 19 75 300

U.S. Dept. of Agriculture — **Soil Scientists**

		V. Fine	Fine	Medium	Coarse	V. Coarse	
CLAY	SILT	SAND					GRAVEL

0.002 0.05 0.10 0.25 0.5 1 2 75

Remediation Hydraulics 2008, page 195): The Udden-Wentworth scale is preferred "...because the geometric progression of grain-size diameter also reflects relationships that are important when considering the erosion and deposition of sediments during the depositional process. The correlation between increasing grain size and degree of sorting and permeability is the most important, as permeability structure is responsible for the mobile and immobile porosity within aquifer systems. "

Attachment C

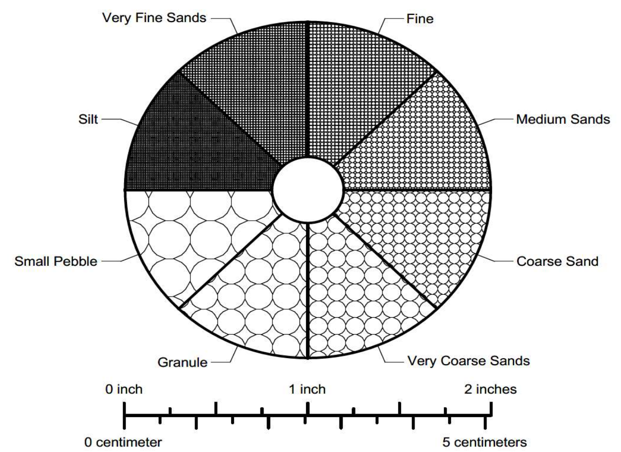
Description of Soil Logging Terms

The purpose of this attachment is to concisely define the soil logging terms used when filling out boring logs. During report preparation, project staff could use this sheet as an index placed in front of the completed boring logs. Also, it can serve as a supplemental reference sheet during field activities.

Description of Logging Terms

Note: Soil descriptions based on Arcadis Technical Guidance and Instructions (TGI) procedures. Key terms defined below.

GRAPH FOR DETERMINING SIZE OF PARTICLES



Udden Wentworth Soil Sizes

Boulder	> 256 mm
Large Cobble	128 to 256 mm
Small Cobble	64 to 128 mm
Very Large Pebble	32 to 64 mm
Large Pebble	16 to 32 mm
Medium Pebble	8 to 16 mm
Small Pebble	4 to 8 mm
Granule	2 to 4 mm
Very Coarse Sand	1 to 2 mm
Coarse Sand	0.5 to 1 mm
Medium Sand	0.25 to 0.5 mm
Fine Sand	0.125 to 0.25 mm
Very Fine Sand	0.062 to 0.12 mm
Silt/Clay	<0.065 mm

Primary Texture *(e.g. CLAY, SILT, SAND, GRANULE, PEAT, MUCK, FILL, etc.)*
List particle size with the highest percentage per sample interval (e.g. SAND)
Always CAPITALIZE the primary texture
Follow primary texture with a comma followed by grain-size descriptors, etc.

Minor Texture

And	(36 to 50%)
Some	(21 to 35%)
Little	(10 to 20%)
Trace	(>10%)

Angularity

Angular	Sharp edges
Sub-Angular	Rounded edges
Sub-Rounded	Well-rounded
Rounded	Smooth curved edges

Sand Density (Blow Counts/ft)

Very Loose	0-4
Loose	5-10
Medium Dense	11-30
Dense	31-50
Very Dense	<50

Silt/Clay Consistency (Blow Counts/ft)

Very Soft	0-2,	thumb easily penetrates several inches
Soft	3-4,	thumb easily penetrates one inch
Medium Stiff	5-8,	thumb indents 0.5 in. with much effort
Stiff	9-15,	thumb indents 0.25 in. with great effort
Very Stiff	16-30,	thumbnail is readily intended

Sorting

Well Sorted	1 to 3 Particle Sizes
Poorly Sorted	4+ Particle Sizes

Moisture Content

Dry	Dry to touch
Moist	No visible water
Wet	Visible free water

Plasticity (for silts and clays)

Non-Plastic	3 mm thread can not be rolled
Low Plasticity	3 mm thread can barely be rolled
Medium Plasticity	3 mm thread can easily and quickly rolled, but not rerolled
High Plasticity	3 mm thread can be rolled slowly, but can be rerolled

Dilatancy (for silts and silt-sand mixtures)

None	No visible change in the specimen
Slow	Water appears slowly during shaking / disappears slowly or not at all upon squeezing
Rapid	Water appears quickly during shaking / disappears quickly upon squeezing

Example Description

10 -15 feet SAND, medium to very coarse, little granules to medium pebbles, subround to subangular, trace silt; poorly sorted, wet, grayish brown (10YR5/2).

Attachment D

Blank Boring Log

The purpose of this attachment is to present a blank field form for use during soil logging. A digital version (Microsoft Excel) of this field form is available from the authors (upon request). If project specific modifications to this boring log template are warranted, please contact the Site Investigation Community of Practice leader for further assistance.

BORING LOG

ARCADIS

Boring ID: ____________________

Permit ID: ____________________

Site Address: ____________________

City, State: ____________________

Drilling Co: ____________________

Driller: ____________________

Drilling Method: ____________________

Boring Status: ____________________

Project Name: ______________________________

Date Started: ____________________

Date Completed: ____________________

Total Depth: ____________________

Depth to Water: ____________________

Hole Diameter: ____________________

Core Device: ____________________

Drilling Fluid: ____________________

Page: ________/________

Ground Elevation: ____________________

Vertical Datum: ____________________

Northing: ____________________

Easting: ____________________

Horizontal Datum: ____________________

Prepared by: ____________________

Reviewed by: ____________________

Drilling Information				**Graphical Log for Primary Texture**											**Soil Description (Udden-Wentworth System)**	**Field Notes**
Drilling Depth (ft bgs)	**Core Interval (ft)**	**Core Recovery (inches)**	**Vapor Reading (ppm)**	**Fines**		**Sand**					**Gravel**				Depth Interval (ft), PRIMARY TEXTURE, Principal and Minor Components with Descriptors (% modifiers and grain size fraction, angularity for coarse sand and larger, consistency/density, plasticity for silt and clay, dilatancy for silt/silt-sand); Sorting, Moisture Content, Color. NOTES: *Texture Modifiers: Trace (<10%), Little (10 to 20%), Some (21 to 35%), And (36 to 50%)*	Driller's Observations, Geologic Formation, Field Screening Results, Sample Interval etc.
				clay	silt	very fine	fine	medium	coarse	very coarse	granule	pebble	cobble	boulder		

BORING LOG

Boring ID: ________________ **Project Name:** ________________________ **Page:** _____/_____

Drilling Information				Graphical Log for Primary Texture											Soil Description (Udden-Wentworth System)	Field Notes
				Fines		Sand					Gravel					
Drilling Depth (ft bgs)	Core Interval (ft)	Core Recovery (inches)	Vapor Reading (ppm)	clay	silt	very fine	fine	medium	coarse	very coarse	granule	pebble	cobble	boulder	Depth Interval (ft), PRIMARY TEXTURE, Principal and Minor Components with Descriptors (% modifiers and grain size fraction, angularity for coarse sand and larger, consistency/density, plasticity for silt and clay, dilatancy for silt/silt-sand); Sorting, Moisture Content, Color. NOTES: *Texture Modifiers: Trace (<10%), Little (10 to 20%), Some (21 to 35%), And (36 to 50%)*	Driller's Observations, Geologic Formation, Field Screening Results, Sample Interval etc.

Attachment E

Completed Boring Log

The purpose of this attachment is to provide an example of a completed boring log for reference purposes to field staff. The example provided is for a soil boring completed outside the waste mass of a closed municipal landfill near Baltimore, Maryland. The objective of the drilling program was to determine the depth to groundwater to determine the appropriate depth interval to install a soil gas monitoring well and groundwater monitoring well across the first water-bearing zone. The site geology consists of unconsolidated sediments of the Mid-Atlantic Coastal Plain, specifically the Upper Patapsco formation. These sediments were deposited in a moderate gradient fluvial environment during the Cretaceous period. The landfill was constructed into a regional clay confining unit.

BORING LOG

Boring ID:	MW-08	**Project Name:**	Acme Landfill	**Page:**	1 / 1
Permit ID:	MD-PG-100	**Date Started:**	7/18/2018	**Ground Elevation:**	50.5 ft
Site Address:	100 Landfill Road	**Date Completed:**	7/18/2018	**Vertical Datum:**	NAVD 88, feet
City, State:	Baltimore, Maryland	**Total Depth:**	35 ft below ground	**Northing:**	123456.79
Drilling Co:	Earth Matters	**Depth to Water:**	19 ft below ground	**Easting:**	123456.79
Driller:	Rod E. Piper	**Hole Diameter:**	2-inch	**Horizontal Datum:**	NAD 83 feet, MD State
Drilling Method:	Direct-push/hollow-stem	**Core Device:**	5-foot macrocore sampler	**Prepared by:**	Sandy Pebbles
Boring Status:	completed as well	**Drilling Fluid:**	none	**Reviewed by:**	Clay Brown

Drilling Information				**Graphical Log for Primary Texture**											**Soil Description (Udden-Wentworth System)**	**Field Notes**
				Fines		**Sand**					**Gravel**					
Drilling Depth (ft bgs)	**Core Interval (ft)**	**Core Recovery (inches)**	**VOC Vapor Reading (ppm)**	clay	silt	very fine	fine	medium	coarse	very coarse	granule	pebble	cobble	boulder	Depth Interval (ft), PRIMARY TEXTURE, Principal and Minor Components with Descriptors (% modifiers and grain size fraction, angularity for coarse sand and larger, consistency/density, plasticity for silt and clay, dilatancy for silt/silt-sand); Sorting, Moisture Content, Color. NOTES: *Texture Modifiers: Trace (<10%), Little (10 to 20%), Some (21 to 35%), And (36 to 50%)*	Driller's Observations, Geologic Formation, Field Screening Results, Sample Interval etc.
0 to 1	0-5	43.2/60	< 1												0-0.5 ft, topsoil with organics	Grass covered area
1 to 2			< 1				X								0.5-5 ft, SAND, fine, trace silt, trace pebble, round; poorly sorted, moist, yellowish brown (7.5 YR 5/8). NOTE: some cementation, does not react with HCl	continuous macro-core logging
2 to 3			< 1				X									
3 to 4			< 1				X									cemented sand @3.6-4 ft
4 to 5			< 1				X									
5 to 6	5-10	40.8/60	< 1				X	X	X						5-10 ft, SAND, fine to coarse, round to subround; well sorted, moist, light to strong brown (7.5 YR 6/4 to 7.5 YR 5/6).	
6 to 7			< 1				X	X	X							
7 to 8			< 1				X	X	X							
8 to 9			< 1				X	X	X							
9 to 10			< 1				X	X	X							
10 to 11	10-15	36/60	< 1				X	X	X						10-12.5 ft, same as above with trace silt	
11 to 12			< 1				X	X	X							
12 to 13			< 1				X	X	X							
13 to 14			< 1				X	X	X						12.5 to 15 ft, same as above, color change to pink (7.5 YR 7/3) and reddish yellow (7.5YR 6/8)	
14 to 15			< 1				X	X	X							
15 to 16	15-20	55.2/60	< 1						X	X					15-18.9 ft, SAND, coarse to very coarse, round to subround; well sorted, moist, strong brown (7.5YR 5/6) to reddish yellow (7.5YR 6/6)	
16 to 17			< 1						X	X						
17 to 18			< 1						X	X						
18 to 19			< 1		X	X	X								18.9-22.7 ft, SAND, very fine to fine, and SILT, coarse to very coarse, poorly sorted, wet, light gray (7.5YR 7/1)	water table encountered @ 18.9 ft
19 to 20			< 1		X	X	X									
20 to 21	20-25	36/60	< 1		X	X	X									
21 to 22			< 1		X	X	X									
21 to 23			< 1		X	X	X									
23 to 24			< 1	X	X										22.7-25 ft, CLAY and SILT, high plasticity, soft to stiff at 25 ft, dry to moist, light gray (2/5YR 7/1) w/ red mottling (2.5YR 4/6)	Middle Patapsco Confining Unit
24 to 25			< 1	X	X											
25 to 26	25-30	30/60	< 1	X	X										25-31.1 ft, CLAY and SILT, high plasticity, stiff; dry to moist, light gray (2/5YR 7/1) with red mottling (2.5YR 4/6)	
26 to 27			< 1	X	X											
27 to 28			< 1	X	X											
28 to 29			< 1	X	X											
29 to 30			< 1	X	X											
30 to 31	30-35 ft	60/60	< 1	X	X											
31 to 32			< 1		X											
32 to 33			< 1		X											
33 to 34			< 1		X										31.1-35 ft, SILT, low plasticity, high dilatancy; wet, gray (7.5YR 7/1)	End of direct-push boring @ 35 ft
34 to 35			< 1		X											

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TGI – Vertical Aquifer Profile (VAP) Sampling

Rev: 2.0

Rev Date: June 15, 2022

Version Control

Issue	Revision No.	Date Issued	Page No.	Description	Reviewed By
	0	June 22, 2018	All	Original SOP	Joe Quinnan
	1	May 11, 2020	Multiple	Added content to Personnel Qualifications, references to Geoprobe SP-16 and SP-22, Attachment 3, and updated references /formatting	Marc Killingstad
	2	June 15, 2022	Multiple	Combined with PFAS-specific VAP TGI and dye/tracer procedures.	Patrick Curry

Approval Signatures

Prepared by:		6/15/2022
	Patrick Curry (Preparer)	Date
Reviewed by:		6/15/2022
	Marc Killingstad (Subject Matter Expert)	Date

1 Introduction

This Arcadis Technical Guidance Instruction (TGI) describes proper vertical aquifer profile (VAP) sampling procedures using a variety of methods and approaches. This document has been developed to emphasize drilling and sampling procedures used to collect groundwater samples from boreholes installed via direct push technology (DPT), hollow stem auger (HSA), and rotary-sonic (sonic) methods and includes the use of visible tracer in drilling fluid to obtain representative samples during vertical profiling.

2 Intended Use and Responsibilities

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 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, regulation-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.

3 Scope and Application

Vertical aquifer profile (VAP) borings are typically advanced via DPT, HSA, or sonic drilling techniques to collect single or multiple depth-discrete groundwater samples using low-flow or grab sampling methodologies. This can be combined with retrieval of continuous soil cores and lithologic logging, as well as collection of single or multiple depth-discrete dry and saturated soil samples.

When possible, co-locate or bias VAP groundwater sampling intervals towards potential discrete transport zones (and target slow advection zones when feasible) as indicated by soil logging observations or permeability measurements (e.g., point slug tests, Geoprobe® hydraulic profiling tool [HPT] [preferred], Waterloo APS™ [alternate]). Permeability measurements coupled with contaminant concentration allows estimationof relative flux and mass discharge to evaluate potential risk to downgradient receptors. In the absence ofpermeability measurements, field soil lithological logging observations may be used to interpret hydrostratigraphy and select sampling intervals.

The intent of this TGI is to provide VAP instructions including specific considerations for per- and polyfluoroalkyl substances (PFAS) due to their unique chemical and physical properties, low detection limits, and regulatory standards. It also covers 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.

Multiple VAP samples can be collected through temporary wells, drilling rod tooling (e.g., Geoprobe® Screen Point 16 [SP-16]/Screen Point 22 [SP-22] Groundwater Samplers or SP-60 Sonic Groundwater Sampler or Cascade’s Sonic Push-Ahead or Packer Isolation Groundwater Profilers) or via combined hydraulic profiling and sampling tools (e.g., Geoprobe® HPT-Groundwater Sampling System [HPT-GWS] or Waterloo APS™). They can be analyzed quickly via on-site mobile lab or expedited off-site fixed lab analysis to provide adaptive high-resolution quantitative groundwater concentration data. The vertical frequency of groundwater sampling within a formation will be determined relative to the scale of variability demonstrated in site hydrostratigraphy and outlined in the FIP/Work Plan. Thin aquifers with transport zones only tens of feet thick (or less) can be sampled at intervals as close as 3 to 5 feet. In aquifers with transport zones substantially thicker (e.g., more than 50 feet), sample spacing of 5 to 20 feet may be adequate. It is important to note that field data be evaluated to verify that sampling intervals provide sufficient resolution to meet data quality objectives (DQOs) (See **Section 7**).

4 Personnel Qualifications

In general, VAP activities will be performed by persons who have been trained in proper drilling and sampling procedures under the guidance of an experienced field geologist, engineer, or technician. Arcadis personnel overseeing, directing, or supervising VAP activities shall have previous related experience (minimum of 2 years) in drilling and groundwater sampling. Drilling subcontractors will need current applicable drilling licenses.

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 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 mobilization, the field team 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)/field sampling plan, Quality Assurance Project Plan (QAPP), HASP, historical information, and other relevant site documents.

Arcadis field sampling 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. Additionally, the 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.

5 Equipment List

The following equipment and materials must be available for VAP sampling

- Site plan with proposed sampling locations
- Relevant work plan (or equivalent)
- Health and Safety Plan (HASP)
- Field Tablet with appropriate Fulcrum app for logging groundwater sampling.
- NOTE: *As of June 2022, several digital logging applications are available through the FieldNow™ program and the Fulcrum app. A future revision of this TGI, likely in early 2023, will emphasize digital logging methods and groundwater sampling. FieldNow™ is discussed further in Section 10.*
- Appropriate health and safety equipment, as specified in the site HASP
  - Drilling Equipment
  - Drill rig (to be provided by drilling subcontractor). Type (e.g., roto-sonic, direct push) to be determined based on site-specific details
  - Traffic cones, delineators, caution tape, and/or fencing as appropriate for securing the work area,if not provided by the drillers

    NOTE: *Prior to mobilizing to the site, Arcadis personnel will contact the drilling subcontractor or in-house driller (as appropriate) to confirm that appropriate sampling equipment will be provided in quantities capable of achieving estimated target depths. Typical equipment/materials providedby the driller could include*

    - Acetate or plastic liners
    - Appropriate length of drilling rods and tooling
    - Drilling and sampling equipment decontamination materials,
    - Decontamination pad materials, if required. See **Section 6.3** below for more information
- Sampling Equipment
  - Appropriate groundwater sampling equipment (e.g., disposable bailers for volumetric sampling,peristaltic pump for shallow groundwater sampling, submersible bladder pump for deeper sampling). Refer to *the TGI – Low-Flow Groundwater Purging and Sampling Procedures for Monitoring Wells* (Arcadis 2020a) for necessary equipment
  - Direct push groundwater samplers (e.g., Geoprobe® SP-22) or roto-sonic sampling devices (e.g.,Cascade Push Ahead/Packer Isolation Groundwater Profiler or Geoprobe® SP-60 Sonic Groundwater Sampler) (to be provided by drilling subcontractor)
  - Appropriate soil sampling equipment (e.g., stainless steel spatulas, knife, metal trowel)

- Dedicated plastic sheeting (preferably high-density polyethylene [HDPE]) or other clean surface toprevent sample contact with the ground
- Multi-parameter water quality probe (e.g., conductivity, temperature, pH, dissolved oxygen,oxidation reduction potential, and turbidity meter)
- Water level meter
- Appropriate sample containers and labels
    - Labeled sample bottles: see the *TGI – Poly- and Perfluorinated Alkyl Substances (PFAS)Field Sampling Guidance* (Arcadis 2017a) for PFAS-specific considerations
    - Ziplock-style bags to hold ice and samples
    - Appropriate blanks (field reagent blanks supplied by the laboratory)
    - Packing and shipping materials
    - Chain-of-Custody (COC) Forms; see the *Sample Chain of Custody* for reference (Arcadis2017b)
    - Appropriate transport bottles (coolers) with ice and appropriate labeling, no blue ice

- Decontamination Equipment
    - Equipment cleaning materials: see the *TGI – Poly- and Perfluorinated Alkyl Substances (PFAS)Field Sampling Guidance* (Arcadis 2017a) or the *TGI – Groundwater and Soil Sampling Equipment Decontamination* (Arcadis 2020b) as applicable
    - Drum labels as required for investigation derived waste handling: see the *TGI – Investigation-Derived Waste Handling and Storage* for details (Arcadis 2017c)
- Documentation/Field Notes
    - Electronic data collection device (smart phone or tablet) as applicable
    - Pens, pencils, and/or Sharpie® brand pens for writing
    - Digital camera
    - Any other appropriate field forms
- Tracer Equipment (as needed)
    - 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)

  - 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
  - Flashlight or other portable lighting device
  - Blue ice (for tracer dye samples)

6 Cautions

Field activities associated with borehole advancement and VAP groundwater sampling will be performed in accordance with the HASP, a copy of which will be present on site during such activities. Field staff (including subcontractors) will be aware of and understand the associated physical and health hazards.

6.1 Utility Clearance

The appropriate drilling authorities will be contacted and a site visit for public utility line clearance at the proposed boring locations will be conducted at least 72 hours prior to work commencing. As applicable, utility maps will be reviewed during field reconnaissance of the proposed investigation locations to determine if any are co-located with public utility lines. Arcadis will also contract an independent geophysical survey company to verify that proposed boring locations are not co-located with existing underground utility/substructure features, as necessary. Arcadis will clear locations with soft dig methods to assess the presence of underground utilities as necessary.

See the *Utility Location and Clearance Arcadis Health and Safety Standard* (Arcadis 2020c) for reference.

6.2 PFAS-Specific General Sampling Considerations

This section provides a summary of methods and procedures applicable to the collection of environmental samples for field screening or laboratory analysis during PFAS site characterization activities. In general, sampling techniques used for PFAS site characterization are consistent with conventional sampling techniques used in the environmental industry, but special consideration is made regarding PFAS-containing materials and cross-contamination potential. For example, Teflon™ and other fluoropolymer containing materials are found in pumps, tubing, and sample storage containers and, therefore, will be avoided if possible (Department of Environment Regulation [DER], Western Australia 2016; New Hampshire Department of Environmental Services [NHDES] 2016). Certain field documentation materials such as waterproof paper or field books, adhesive paper products, and some writing utensils (grouped as non-Sharpie® markers) are also prohibited items during PFAS sampling (DER 2016; NHDES 2016).

Attachment 1 (Tables 1 and 2) provides recommendations for PFAS Site Investigation equipment. Table 1 provides a summary of materials that have been approved for site investigation; this list is expected to grow longer as industry experience increases. Table 2 provides a summary of field equipment and materials that have available testing information and/or industry knowledge regarding PFAS cross-contamination potential, and it is recommended that these materials be prohibited for samplecollection. For materials that are suspected of containing and/or retaining PFAS, these recommendations are considered preliminary and subject to change.

Given the extremely low detection limits associated with PFAS analysis and the many potential sources of trace levels of PFAS, field personnel are typically advised to err on the side of caution by strictly following field wear guidelines and decontamination procedures as specified in the *TGI - Poly- and Perfluorinated Alkyl Substances (PFAS) Field Sampling Guidance* (Arcadis 2022).The most important consideration during PFAS related VAP sampling is to prevent contact between sample media and suspect PFAS sources.

6.3 PFAS-Specific Groundwater Sampling

The potential presence of material containing PFAS in equipment that may come into contact with the target water sample must be evaluated as part of the sample planning process to maintain sample integrity. For example, low-flow sampling with a peristaltic pump will be conducted using silicone or HDPE tubing; Teflon™ tubing is prohibited (DER 2016). If a bladder pump is used to collect samples, the bladder and other internal parts (e.g., check balls, O-rings, compression fittings) will not contain Teflon™, and bladder and O-rings will be changed between samples (DER 2016).

Note that if high concentrations of PFAS related to Class B firefighting foams are expected in a groundwater sample, it has been recommended to collect and shake a small portion of the sample at the time of sample collection (USACE 2016; Arcadis 2017a). If foaming is noted within the sample, it indicates elevated concentrations of PFAS may be present and the sample will be proactively diluted at the laboratory prior to analysis, and the foaming will be noted on the sample COC form. It is recommended to collect sampling equipment blanks following foam observation to confirm the effectiveness of decontamination procedures.

6.4 Use of Tracer in Drilling Fluid

Field staff (including subcontractors) will be aware of tracer hazards and understand the associated health hazards. Please be sure to read the SDS (included as Attachment 2) for fluorescein dye. Note that some individuals can experience a mild allergic reaction to skin contact with fluorescein. Protective gloves will be worn during dye handling and mixing activities, and rinse bottles will be readily available for washing affected areas in case of accidental contact.

7 Health and Safety Considerations

To ensure the safety of the field personnel, field activities associated with VAP will be performed in accordance with a site-specific HASP, a copy of which will be present on site during such activities. Review all site-specific and procedural hazards as they are provided in the HASP and review relevant Job SafetyAnalysis (JSA) documents in the field each day prior to beginning work.

Appropriate personal protective equipment (PPE) will be always worn in line with the task and the site-specific HASP. Verify staff has required health and safety training and personal protection equipment in accordance with the HASP and JSAs. At a minimum, all staff will have level D PPE with chemical resistant gloves.

8 Procedure

The specific procedure for advancing VAP borings will be developed after careful review and consideration of project DQOs and clearly detailed in the FIP/Work Plan. Typically, VAP borings are conducted in boreholes adjacent to soil borings previously completed to develop stratigraphic and relative permeability profiles of the aquifer to determine sampling depth intervals that target transport zones. Prior boreholes typically consist of soil borings with detailed soil descriptions or Geoprobe® HPT borings. The primary advantage of completing stratigraphic/permeability profiles in advance of VAP sampling is to gain an understanding of hydrofacies trends to ensure that the most appropriate intervals and sampling methods are used. For sonic or HSA drilling, VAP samples are typically collected from the same borehole as soil samples. In the absence of a co-located boring, sample depth intervals can be determined based upon lithologic logging of soil cores, either from a separate adjacent borehole or from the same borehole. HPT drilling will be completed consistent with the *TGI – Geoprobe Hydraulic Profiling Tool (HPT)* (Arcadis 2022a), and soil lithologic logging will be performed in accordance with *TGI – Soil Description* (Arcadis 2022b).

NOTE: *Waterloo APS™ can be utilized as an alternative to HPT to provide permeability profiles, but it is more time consuming than HPT; therefore, it is not considered the preferred tool for permeability profiling.*

8.1 Direct Push Vertical Aquifer Profile Sampling

Direct push tooling is ideal for shallow unconsolidated aquifers and requires minimal water for drilling, reducing the potential for sample dilution/cross-contamination. For sites with shallow groundwater in unconsolidated formations (e.g., at less than 100 feet bgs), the typical approach is to collect VAP groundwater samples nominally every 5 to 10 feet with a bias to the more permeable transport zones.

When a zone of interest is identified, either by using permeability measurements (preferred) or logging soil, a screen point sampling device such as Geoprobe® SP-16 or SP-22 (see **Attachment 3**) can be driven to the target interval and the screen opened to collect a groundwater sample. In poorly sorted aquifers with appreciable amounts of silt, VAP sampling from an adjacent borehole after completing initial permeability profiling (e.g., Geoprobe® HPT or point slug tests) is typically more efficient and cost effective. In the absence of permeability profiling tools (e.g., HPT), VAP sampling can be performed based on soil lithological observations alone, either from a separate borehole or in the same borehole. However, VAP sample collection can be more efficient when conducted from an adjacent borehole, particularly if a bottom-up sampling approach is used. See Section 8.1.1.

Combined permeability profiling and sampling tools such as the Geoprobe® HPT-GWS (or Waterloo APS™ as an alternate) can be used to collect groundwater samples based on permeability measurements from the same borehole at deeper depths where the process is more cost-effective; otherwise at shallower depths, separate permeability profiling prior to VAP sampling is preferred. This is most effective in well-sorted sand and gravel when small volumes are required for analysis, since these tools provide limited volumes for purging and sample collection. Use of these combined tools (HPT-GWS or Waterloo APS™) for PFAS sites is not recommended because low detection and regulatory thresholds for PFASs require more extensive purging to decontaminate the sampling equipment (i.e., insufficient data are available to confirm the volume of purging required to eliminate cross-contamination with PFAS).

It is recommended that DPT drilling for VAP sampling be completed using a dual-tube drilling approach. An outer casing is advanced with the screen point sampling device to limit the potential for cross-contamination between sampling intervals. Pre-calculated volume purging and monitoring for water quality parameter stabilization can be performed consistent with low-flow sampling to help determine when purge water is representative of the groundwater formation.

There are two general methods for completing VAP sampling: bottom-up and top-down. With bottom-up sampling, a greater purge volume is required to ensure a representative groundwater sample; however, the overall time savings is significant relative to top-down sampling, where more time is required per borehole to lower the tooling, retract it, and decontaminate it between subsequent sampling intervals. However, the top-down method minimizes any potential for cross-contamination and is the preferred approach for PFAS projects due to the low detection limits and regulatory levels associated with PFASs.

8.1.1 Bottom-Up VAP Sampling

Bottom-up VAP sampling involves advancing dual-tube direct push casing to the deepest target depth with either a solid drive tip (without collecting soil cores) or acetate liners for collection of continuous soil cores to provide a lithological log for the entire boring. This is followed by lowering the groundwater sampling screen through the outer casing to the bottom of the borehole and collecting multiple VAP groundwater samples at different depths as the casing and screen is retracted up the borehole.

Using this approach, the external casing is retracted to allow borehole collapse around the sampling screen while isolating it from the section above that is still covered by the external casing.

NOTE: *Bottom-up VAP sampling is not recommended when there is a potential for dense non-aqueous phase liquid (DNAPL), the highest concentrations are expected to be at the bottom of the formation, or the borehole goes through multiple confining units. Bottom-up is not recommended for PFAS sampling due to potential cross-contamination concerns associated with lack of decontamination between sample intervals.*

The advantages of this approach are: (1) when combined with soil core collection, groundwater sampling depth intervals can be pre-selected based on lithologic observations to target the transport zones, especially in the absence of any co-located permeability measurements, and (2) the entire process is much more time-efficient per borehole as the sampling equipment is not pulled, decontaminated, and then drilled to the next interval. However, additional purging (i.e., 3to 5 casing volumes) is required to assure a representative groundwater sample. Bottom-up sampling also does not allow for post-grouting of the borehole since when the groundwater sampling device is pulled up to the next VAP sampling interval, the sidewalls of the open borehole below collapse.

8.1.2 Top-Down VAP Sampling

Top-down VAP sampling involves advancing dual-tube direct push casing with either a solid drive tip (without collecting soil cores) or a plastic liner for soil core retrieval from target depth interval followed by lowering the screen point sampling screen to target depth and pulling up the outer casing to expose the screen. After purging and sample collection, the screen point device is pulled back up and decontaminated. A solid drive tip or plastic liner is lowered back into the borehole and the entire assembly is then advanced to the next depth interval. Thus, top-down sampling requires pulling the tooling after each sample interval, decontaminating the tooling, re-setting the groundwater sampler, and advancing the tooling to the next planned interval.

The advantages of this approach are that it allows grouting of the borehole from the bottom of the borehole and reduces the potential for cross-contamination from adjacent sampling intervals.

The primary disadvantage is that the entire process is much less time-efficient per borehole since the tooling must be retracted and re-advanced every time.

NOTE: *Top-down is the preferred method for PFAS VAP sampling.*

8.2 Sonic Drilling VAP Sampling

For sites with deep unconsolidated aquifers, bedrock/weathered bedrock, or otherwise challenging drilling conditions (e.g., presence of dense tills, caliche, cobbles), sonic drilling will be necessary to complete VAP. Like direct push, groundwater profilers can be used with sonic rigs to collect multiple depth-discrete groundwater samples biased towards transport zones based on soil lithological cores. The configuration of individual samplers varies based on their manufacturer by different drilling contractors (e.g., Cascade Push Ahead/Packer Isolation Groundwater Profiler or Geoprobe® SP-60).

The overall strategy of sonic drilling VAP sampling is consistent with direct push VAP sampling; however, drilling with sonic or some rotary methods can require the introduction of drilling fluid/water that can potentially affect the integrity of the groundwater sample. If possible, sonic drilling for VAP borings will be conducted without the use of drilling water. If, for example, the geology is known for flowing sands or VAP is required deep below the water table, drilling water will be used to keep the core barrel free inside the outer drill casing. In this case it is recommended that a visible dye be used to spike the drilling water to assist with purging of the VAP interval. The VAP interval is then purged until the visible dye is no longer visible, or less the 10% of the starting concentration. For more on drilling with visible dye, see Section 8.2.3. Sonic VAP sampling is typically performed in a top-down manner using either a push ahead sampling device or a packer system.

8.2.1 Push-Ahead Groundwater Profiler

Push-ahead groundwater sampling devices are available through Cascade Drilling and other sonic drillers and consists of a stainless-steel sheathed “screen” threaded to the base of the sonic drill rod. The device is driven ahead of the sonic casing into the undisturbed formation to the prescribed sample depth interval. Once the point is at the specified interval, the threaded portion between the profiler and rod is partially unthreaded to expose the water ports to allow native formation water to enter the profiler. A groundwater sample is then obtained using either a stainless-steel bailer or pump with tubing depending on the DQOs. The interval is typically purged until relatively free of fine-grained material.

The disadvantage of using this device is that groundwater samples are obtained from undisturbed native formation with unknown soil lithology, so sampling is conducted “blind”. Therefore, it is recommended that a pre-existing lithological log from an adjacent borehole is used to determine sampling depth intervals.

8.2.2 Packer Isolation Groundwater Profiler

Packer Isolation groundwater profilers (e.g., Packer Isolation groundwater profiler from Cascade, Geoprobe ® SP-60 Sonic Groundwater Profiler) work by driving the casing over the soil core, retrieving the soil core barrel, and then lowering a stainless screen and packer assembly to the base of the sonic casing. The sonic outer casing is then extracted to expose the screen to the formation, and the packer is inflated within the casing above the screen to isolate the screened interval from any water that might be above the packer in the sonic casing. A groundwater sample can then be collected from the screen.

The biggest advantage of this device is that groundwater sampling depth intervals can be determined based on lithological logs obtained from the same borehole.

A disadvantage is that a large volume of purge water may need to be removed to clear the borehole of water introduced from above.

8.2.3 Drilling with Visible Dye

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 drill casing(s).

Typically, if groundwater sampling is performed during drilling, the purge volume to be removed is at least as much 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 or possible.

To ensure that groundwater samples accurately represent groundwater quality of the surrounding formation and are not significantly influenced by unrecovered drilling fluid, fluorescein dye can be added to the drilling water to visually confirm when unimpacted native groundwater enters the borehole and can be sampled.

The target concentration of dye is approximately 20 mg/L, which is greater than two (2) orders of magnitude above its visual threshold (approximately 0.1 mg/L) and over five (5) orders of magnitude above its typical laboratory detection limit (less than 0.001 mg/L). Once the drilling tool has been advanced to the prescribed 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 sent for fluorescein analysis. The fluorescein data can then be used to calculate a correction factor to be applied to COC analytical results.

8.2.3.1 Set-Up Procedures

a. <u>Dye Batch Preparation</u>

- 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 is also recommended 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 a 50 mL graduated cylinder for use in preparing the visual standard discussed below.
- Collect four (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 a 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 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.

8.2.3.2 Drilling Procedures

- Fresh drilling water from the dyed drilling water batch tank will be used during drilling operations. In general, a positive head will 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 will be sampled for chlorine and pH at the start of the project. Chlorine, if present in detectable quantities, will consume fluorescein; therefore, wait a period of at least four (4) hours between dye addition and sampling (and use) of the drilling fluid. Below pH values of about 5, fluorescein will have 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, use 1-millimeter (mm) thick black plastic to cover the tank during the day to minimize photodegradation of the tracer batch water.
- After tracer addition, each batch of drilling fluid will be sampled at least once for fluorescein.
- At the end of the day, any excess tracer batch water can be stored for use on 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.

8.2.3.3 Purging and Sampling Procedures

- After a groundwater sampling interval is reached, purging and screening-level groundwater sampling will be performed.
- The target sample interval will be purged using a pump, and 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 the following two conditions is met:

  1) 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.

     a. 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.

OR

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

     a. 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

     b. Also, a sample of the purge water will be collected in a 40 mL unpreserved VOA; 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 (see Section 8.2.3.4).

- 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.

8.2.3.4 Calculation of Correction Factor

- If the purge water does not reach the 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.

8.3 Boring Abandonment

Upon completion, each top-down borehole is backfilled with bentonite grout from the terminal end of the boring upward. The top portion of each boring is sealed with asphalt or concrete to match the existing grade. Each bottom-up borehole is typically abandoned by the collapse as the rods are retraced.

Borehole abandonment requirements in some geographies dictate top-down sampling; this should be verified in advance of work and outlined in the FIP/Work Plan. See also *TGI for Monitoring Well and Borehole Decommissioning.*

9 Waste Management

Investigation derived waste (IDW) (e.g., soil cuttings and decontamination water generated during cleaning procedures) will be collected and contained on site in appropriate containers: see the *TGI – Investigation- Derived Waste Handling and Storage* for details (Arcadis 2020d). All IDW generated during field activities will be placed in Department of Transportation approved containers, sealed, and labeled. Containerized IDW will be stored on site until it is profiled and subsequently transported to an approved facility for disposal or recycling.

Personal protective equipment (e.g., gloves, disposable clothing, disposable equipment) resulting from personnel cleaning procedures and soil sampling activities will be placed in plastic bags. These bags will be transferred into appropriately labeled containers for appropriate disposal.

Waste manifests for all IDW suspected to have come into contact with PFAS will clearly note the potential presence of PFAS.

Additional IDW sampling and management details will be provided in the site-specific FIP/Work Plan/QAPP addendum and will be consistent with applicable client and state requirements.

10 Data Recording and Management

Digital data collection is the Arcadis standard using available FieldNow® applications that enable real-time, paperless data collection, entry, and automated reporting. Paper forms should only be used as backup to FieldNow® digital data collection and/or as necessary to collect data not captured by available FieldNow® applications. The Field Now® digital form applications follow a standardized approach, correlate to most TGIs and are available to all projects accessible with a PC or capable mobile device. Once the digital forms are saved within FieldNow®, the data is instantly available for review on a web interface. This facilitates review by project management team members and SMEs enabling error or anomalous data detection for correction while the staff are still in the field. Continual improvements of FieldNow® applications are ongoing, and revisions are made as necessary in response to feedback from users and subject matter experts.

The supervising field lead will be responsible for documenting drilling events and for recording all relevant information in a clear and concise format. The record of drilling events will include (at a minimum):

- Start and finish drilling dates
- Project name and location
- Project number, client, and site location
- VAP boring number and depths
- Depth to water
- Type of VAP performed and associated tools
- Core barrel size
- Names of contractor's drillers, inspectors, or other people onsite
- Weather conditions

Field staff will ensure COC Forms are properly completed and will verify which analytes (including PFAS analytes) are required for analysis and note on the COC.

Waterproof field books must not be used for field notes. Instead, it's recommended that field notes be on loose paper on Masonite, plastic, or aluminum clip boards and/or electronic data collection tablets (as required). Other requirements for field notes include:

- Keep field notes, writing implements, and electronic data collection tablets away from samples and sampling materials; and,
- Do not write on sampling bottles unless they are closed.

11 Quality Assurance

In general, the following quality assurance and quality control (QA/QC) samples will be collected:

- Equipment blanks
- Field duplicates
- Field (i.e., reagent) blanks

- Matrix spike/matrix spike duplicate

Details on QC sampling requirements (e.g., frequency of collection, types of QA/QC samples) are provided in the QAPP and/or FIP/Work Plan. Additionally, detailed procedures related to equipment and field (i.e., reagent) blank sample collection are outlined in the *TGI for Equipment and Reagent Blank Sample Collection for PFAS Analysis*.

In general, equipment blanks should be collected from every piece of downhole equipment that could come into contact with soil or groundwater during sample collection. This includes the profiling tools (e.g., Geoprobe® SP-16, Geoprobe® SP-22, Geoprobe® SP-60, Cascade Packer Isolation Groundwater Profiler).

To avoid cross-contamination during drilling and sampling, reusable equipment such as hand tools will be cleaned using a non-phosphate soap free of VOCs, double-rinsed in potable water, and allowed to air dry prior to re-use. Drive casings and other drilling equipment will be steam cleaned or replaced with new equipment between boreholes. The drilling equipment will be cleaned in an area designated by the supervising engineer or geologist that is located outside of the work zone.

Prior to initiating field activities, water sources to be used during drilling activities will be sampled to verify those sources are PFAS-free to the extent possible.

Refer to quality control requirements for the project to ensure that appropriate quality assurance and quality control (QA/QC) samples are collected. When collecting QA/QC samples, the same guidelines apply as when collecting regular samples – specifically that:

- Samples will be collected in laboratory-supplied HDPE bottles
- Bottle caps must remain in the hand of the sampler until replaced on the bottle
- Labels must be completed after the caps have been placed back on each bottle
- Samples must be stored in appropriate transport bottles (coolers) with ice (Ziplock-type bags for use as ice containers) with appropriate labeling
- Do not use blue ice except for shipping fluorescein samples
- Store PFAS samples in a separate cooler from other types of samples

11.1 Equipment Blanks (if relevant)

QA/QC sampling typically includes daily collection of equipment blanks using the laboratory-supplied water, or in the case of PFAS sampling, “PFAS-free” water. For peristaltic pump tubing, laboratory supplied water will be poured into a clean HDPE sample bottle and then pumped through new HDPE tubing using the peristaltic pump (with new silicone tubing). Equipment blanks will also be collected from the water used by drillers, as well as any downhole tooling to ensure absence of any cross-contamination. Drilling water sources must be submitted for analysis of all COCs before work commences for VAP as discussed above. See *also TGI for Poly- and Perfluorinated Alkyl Substances (PFAS) Potable Water Sampling Guidance*.

11.2 Field Duplicates

QA/QC sampling typically includes the collection of one field duplicate for every 10 or 20 samples collected. Each duplicate sample will be collected immediately after the initial sample of which it is a duplicate into a separate laboratory-provided sample bottle. Do not indicate to the laboratory which sample the duplicate replicates (i.e., it will be given a blind reference on the COC and sample name such as "Dup 1").

11.3 Field Blanks

QA/QC sampling for typically includes the submission of one laboratory supplied field blank per day. The reagent field blank sample is brought to the site in a laboratory-supplied sample bottle. Field staff transfer the laboratory-supplied reagent blank to an empty sample bottle. This reagent fieldblank will be placed in the same cooler as the other PFAS samples.

11.4 Matrix Spikes (optional in some cases)

QA/QC sampling includes submitting a sample to be used as a matrix spike if the project requires it. If a separate sample bottle is required, an additional sample will be collected immediately after the initial sample of which it is a duplicate into a separate laboratory-supplied sample bottle.

11.5 Laboratory Analytical QA/QC

- Internal laboratory QA/QC will consist of one laboratory blank and one laboratory control sample (or blank spike) per batch of samples, and additional QA/QCs as indicated by the laboratory QA/QC procedures. Isotope dilution will be used for quantification with isotope-labeled surrogate standards, as available.
- For groundwater and surface water samples, extract the entire groundwater and surface water sample and at least two sampling bottle solvent rinsates for analysis to increase sample accuracy. Avoid sub-sampling an aliquot of the sample bottle.
- Soil samples will be analyzed in their entirety or thoroughly homogenized before extraction and analysis.
- As part of the internal QA/QC, relative percent difference will be calculated between samples and corresponding field or laboratory duplicates. The laboratory quality assurance portion of the laboratory certificates will be reviewed to verify that all calculations/recoveries were within acceptable limits as established by the laboratory method.
- In January 2017, the U.S. Department of Defense and U.S. Department of Energy Quality Systems Manual (QSM) 5.1 (U.S. Department of Defense 2017) was finalized and introduced laboratory guidance for the measurement of PFAS in matrices other than drinking water. This guidance is not a detailed procedural method such as an U.S. Environmental Protection Agency method, but it does recommend best practices around the analysis of PFAS. Laboratories are not required to comply with QSM 5.1 until 2019, although the recommendations around PFAS analysis are similar to what most laboratories are already implementing. Arcadis recommends that any request for PFAS analysis in

groundwater or soil should specifically reference the need to comply with Table B-15 in the QSM 5.1 (i.e., Per- and Polyfluoroalkyl Substances (PFAS) Using Liquid Chromatography Tandem Mass Spectrometry (LC/MS/MS) With Isotope Dilution or Internal Standard Quantification in Matrices Other Than Drinking Water); however, this list can be modified to support project specific deliverables.

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ATTACHMENT 1

Table 1 and Table 2: PFAS Investigation Material Recommendations

Table 1: Summary of Acceptable Sampling Equipment and Materials for PFAS Site Investigations

Sampling Materials	Additional Considerations	References
Water Sampling Materials		
High density polyethylene (HDPE) or silicone tubing materials	--	DER 2016; USACE 2016; NHDES 2016; MassDEP 2017
HDPE HydraSleeves™	Low density polyethylene (LDPE) HydraSleeves™ are not recommended	USACE 2016; MassDEP 2017
Drilling and Soil Sampling Materials		
PFAS-free drilling fluids	--	DER 2016
PFAS-free makeup water	Confirm PFAS-free water source via laboratory analysis prior to investigation	--
Acetate liners	For use in soil sampling	USACE 2016
Sample Containers and Storage		
HDPE sample containers with HDPE lined lids for soil and water samples	Laboratory should provide; whole bottle analysis of aqueous samples combined with a solvent rinse of bottle is recommended	DER 2016, MassDEP 2017
Ice contained in plastic (polyethylene) bags (double bagged)	--	DER 2016; USACE 2016; NHDES 2016; MassDEP 2017
Field Documentation		
Sharpie®	--	NHDES 2016; USACE 2016; MassDEP 2017
Ball point pens	--	MassDEP 2017
Standard paper and paper labels	--	DER 2016; USACE 2016; NHDES 2016; MassDEP 2017
Decontamination		
Water-only decontamination	Confirm PFAS-free water source via laboratory analysis prior to investigation	DER 2016
Alconox®, Liquinox® or Citranox® followed by deionized water or PFAS-free water rinse	Alconox® known to contain trace levels of 1,4-dioxane	NHDES 2016; USACE 2016; MassDEP 2017
Methanol, isopropanol, or acetone	Special health and safety precautions are necessary	UNEP 2015; USACE 2016

Note: This list is considered preliminary and additional materials may be added as additional information becomes available. Project teams are expected to follow a methodical evaluation process of materials to be used and confirm acceptance prior to implementation of field activities.

Table 2: Summary of Equipment and Materials Not Recommended for PFAS Site Investigations.

Sampling Materials	Known PFAS-Containing Materials	Suspected PFAS-Containing Materials	Materials with Potential to Retain PFASs	References
Water Sampling Materials				
Teflon® or polytetrafluoroethylene (PTFE)-containing or coated field equipment (e.g., tubing, bailers, tape, plumbing paste)	x			DER 2016; USACE 2016; NHDES 2016; MassDEP 2017
Passive diffusion bags			x	MassDEP 2017
LDPE HydraSleeves ™			x	USACE 2016; MassDEP 2017
Water particle filters			x	MassDEP 2017
Drilling and Soil Sampling Materials				
Aluminum foil			x	DER 2016; USACE 2016; NHDES 2016; MassDEP 2017
Drilling fluid containing PFASs	x	x		DER 2016
Sample Containers and Storage				
Glass sample containers with lined lids			x	DER 2016; USACE 2016; NHDES 2016; MassDEP 2017
LDPE containers and lined lids			x	USACE 2016
Teflon® or PTFE- lined lids on containers (e.g., sample containers, rinsate water storage containers)	x			DER 2016; USACE 2016; NHDES 2016; MassDEP 2017
Reusable chemical or gel ice packs (e.g., BlueIce®)		x		DER 2016; USACE 2016; NHDES 2016; MassDEP 2017
Field Documentation				
Self-sticking notes and similar office products (e.g., 3M Post-it-notes)		x		DER 2016; USACE 2016; NHDES 2016; MassDEP 2017
Waterproof paper, notebooks, and labels	x			DER 2016, MassDEP 2017
Non-Sharpie® markers		x		NHDES 2016
Decontamination				
Some detergents and decontamination solutions (e.g., Decon 90® Decontamination Solution)	x	x		DER 2016; NHDES 2016; MassDEP 2017

Note: For materials that are suspected of containing PFASs, or have the potential to retain PFASs, project specific considerations may provide adequate justification for use during the field event. For example, further evaluation may be conducted in the form of pre-field equipment blank sample analysis.

ATTACHMENT 2

Safety Data Sheet (SDS) Fluorescein

SAFETY DATA SHEET (SDS)
REVISION DATE: 03/03/2016

HUE CORPORATION

Color your everything, may your Hue come true

SECTION I. IDENTIFICATION OF THE SUBSTANCE/MIXTURE AND OF THE COMPANY/UNDERTAKING

PRODUCT IDENTIFIER:

PRODUCT NAME ……………………… **HUE URANINE CONC** (Also known as Fluorescein)
PRODUCT NUMBER ………………… 1-C8-073PC
COLOR INDEX NAME ………………. ACID YELLOW 073
COLOR INDEX NO ……..……………… 45350
C. A. S. # ………………………………. 518-47-8
CHEMICAL FAMILY……………………. XANTHENE

INTENDED USE OF THE PRODUCT:

FELT TIP, MARKER INKS, WATER BASED COATINGS AND LEAK DETECTION

NAME, ADDRESS AND TELEPHONE OF RESPONSIBLE PARTY:

HUE CORPORATION	TELEPHONE	714-389-3130
P.O. BOX 509	FAX	714-389-9731
TUSTIN, CA 92781	EMAIL	SUPPORT@HUECORPORATION.COM

EMERGENCY TELEPHONE NUMBER:

CHEMTREC (USA)	1-800-424-9300
CHEMTREC (OUTSIDE USA)	1-703-527-3887

SECTION 2. HAZARD(S) IDENTIFICATION

CLASSIFICATION OF THE SUBSTANCE OR MIXTURE:

GHS-US
ACUTE TOX. - INHALATION (CATEGORY 5)
EYE DAM./IRRITATION (CATEGORY 2B)
SKIN CORR./IRRITATION (CATEGORY 3)

GHS LABELING:

HAZARD PICTOGRAMS (GHS-US):	NO SYMBOL
SIGNAL WORD	WARNING
HAZARD STATEMENT(S)	H333 - MAY BE HARMFUL IF INHALED H320 - CAUSES EYE IRRITATION H316 - CAUSES MILD SKIN IRRITATION
PRECAUTIONARY STATEMENTS	P305 + 351 + P338 - IF IN EYES: RINSE CAUTIOUSLY WITH WATER FOR SEVERAL MINUTES. REMOVE CONTACT LENSES IF PRESENT AND EASY

TO DO. CONTINUE RINSING.
P337 + P313 - IF EYE IRRITATION OCCURS/PERSISTS:
GET MEDICAL ADVICE AND ATTENTION.
P261 - AVOID BREATHING DUST/FUMES/GAS/MIST/VAPORS/SPRAY
P264 - WASH FACE THOROUGHLY AFTER HANDLING.
P322 + P313 - IF SKIN IRRITATION OCCURS: GET MEDICAL ADVICE/ ATTENTION.
P304 + 312 - IF INHALED: CALL A POISON CENTER/DOCTOR/PHYSICIAN IF YOU FEEL UNWELL

OTHER HAZARDS	NO DATA AVAILABLE
UNKNOWN ACUTE TOXICITY	NO DATA AVAILABLE

SECTION 3. COMPOSITION / INFORMATION ON INGREDIENTS

DESCRIPTION OF MIXTURE: PROPRIETARY MIXTURE OF DYES.

SUBSTANCE:

NAME	C.A.S.#	WEIGHT 100%	GHS-US CLASSIFICATION
ACID YELLOW 073	518-47-8	100%	ACUTE TOX. - INHALATION (CATEGORY 5) EYE DAM./IRRITATION (CATEGORY 2B) SKIN CORR./IRRITATION (CATEGORY 3)

SECTION 4. FIRST AID MEASURES

FIRST AID MEASURES GENERAL:

INHALATION:	REMOVE TO FRESH AIR. IF BREATHING IS DIFFICULT, GIVE OXYGEN AND GET IMMEDIATE MEDICAL ATTENTION.
SKIN:	WASH WITH MILD SOAP AND WATER. IF IRRITATION OCCURS GET MEDICAL ATTENTION. IF CLOTHING IS CONTAMINATED, RE-MOVE AND WASH BEFORE REUSE.
EYES:	FLUSH EYES WITH WATER FOR AT LEAST 15 MINUTES, HOLDING EYELIDS APART FOR THOROUGH IRRIGATION. GET IMMEDIATE MEDICAL ATTENTION.
INGESTION:	INDUCE VOMITING - SEEK IMMEDIATE MEDICAL ATTENTION.

MOST IMPORTANT SYMPTOMS AND EFFECTS, ACUTE AND DELAYED:

THIS PRODUCT IS NOT HAZARDOUS AS DEFINED BY HAZARDOUS COMMUNICATION STANDARD. HOWEVER, AS WITH ALL CHEMICAL; HANDLE WITH CARE, AVOID EYE AND SKIN CONTACT, AVOID INHALATION OF DUSTS OR VAPORS. WASH THOROUGHLY AFTER HANDLING. KEEP CONTAINERS CLOSED.

SECTION 5. FIRE-FIGHTING MEASURES

EXTINGUISHING MEDIA:

WATER, DRY CHEMICAL, CARBON DIOXIDE, FOAM.

SPECIAL HAZARDS ARISING FROM SUBSTANCE OR MEDIA:

FIREFIGHTERS SHOULD BE EQUIPPED WITH SELF-CONTAINED BREATHING APPARATUS TO GUARD AGAINST POTENTIALLY TOXIC AND IRRITATING FUMES. AVOID DUSTING. DUST CAN FORM EXPLOSIVE MIXTURES WITH AIR.

PROTECTION/ADVICE FOR FIREFIGHTER(S):

BE EQUIPPED WITH SELF-CONTAINED BREATHING APPARATUS AND PROTECTIVE CLOTHING.

SECTION 6. ACCIDENTAL RELEASE MEASURES

PERSONAL PRECAUTIONS:

REMOVE PERSONS FROM DANGER AREA.

ENVIROMENTAL PRECAUTIONS:

AVOID ANY UNCONTROLLED RELEASE OF MATERIAL. DO NOT EMPTY INTO DRAINS OR THE AQUATIC ENVIRONMENT.

EMERGENCY PROCEDURES:

NO ADDITIONAL INFORMATION

METHODS AND MATERIALS FOR CONTAMINENT AND CLEANING UP:

WHERE SPILLS ARE POSSIBLE, A COMPREHENSIVE SPILL RESPONSE PLAN SHOULD BE DEVELOPED AND IMPLEMENTED. AVOID ANY UNCONTROLLED RELEASE OF MATERIAL.

UTILIZE RECOMMENDED PROTECTIVE CLOTHING AND EQUIPMENT (SEE SECTION 8).
SPILLS SHOULD BE SWEPT UP USING AN ABSORBENT DUST CONTROL PRODUCT AND PLACED IN CONTAINERS. SPILL AREA CAN BE WASHED WITH WATER. COLLECT WATER FOR APPROVED DISPOSAL.
IN THE EVENT OF UNCONTROLLED RELEASE OF THIS MATERIAL, THE USER SHOULD DETERMINE IF THE RELEASE IS REPORTABLE UNDER APPLICABLE LAWS AND REGULATIONS.

SECTION 7. HANDLING AND STORAGE

PRECAUTIONS FOR SAFE HANDLING:

HANDLE WITH CARE. AVOID OVER EXPOSURE. USE NIOSH/OSHA APPROVED RESPIRATOR, WORK GLOVES, AND CLOTHING. WASH AFTER HANDLING. SENSITIVE INDIVIDUALS MAY EXPERIENCE RESPIRATORY ALLERGIES. MAY CAUSE SKIN IRRITATION. USE WITH LOCAL VENTILATION.

CONDITIONS FOR SAFE STORAGE, INCLUDING ANY INCOMPATIBILITIES:

USE PROCESS ENCLOSURES, LOCAL EXHAUST VENTILATION OR OTHER ENGINEERING CONTROLS TO KEEP AIRBORNE LEVELS BELOW RECOMMENDED EXPOSURE LIMITS.

KEEP AWAY FROM HEAT. KEEP AWAY FROM SOURCES OF IGNITION.

KEEP AWAY FROM STRONG OXIDIZING AND REDUSING AGENTS.

SPECIFIC END USES:

FELT TIP, MARKER INKS, WATER BASED COATINGS AND LEAK DETECTION

SECTION 8. EXPOSURE CONTROLS /PERSONAL PROTECTION

CONTROL PARAMETERS:

INGREDIENTS WITH LIMIT VALUES THAT REQUIRE MONITORING AT THE WORKPLACE - NOT REQUIRED

EXPOSURE CONTROLS:

APPROPRIATE ENGINEERING CONTROLS - THE USUAL PRECAUTIONARY MEASURES ARE TO BE ADHERED TO WHEN HANDLING CHEMICALS.

PERSONAL PROTECTIVE EQUIPMENT:

HAND PROTECTION	WEAR IMPERMEABLE RUBBER OR PLASTIC GLOVES
EYE PROTECTION	TIGHTLY SEALED SAFETY GOGGLES OR FULL FACE SIDE SHIELDS.
SKIN AND BODY	APRON, COVERALLS AND NON-LEATHER SOLED WORK SHOES. WASH DYE CONTAMINATED CLOTHES AND SKIN WITH MILD SOAP AND DETERGENTS.
RESPIRATORY	WEAR OSHA/NIOSH APPROVED DUST MASK/RESPIRATOR
HYGIENE MEASURES	HANDLE IN ACCORDANCE WITH GOOD INDUSTRIAL HYGIENE AND SAFETY PRACTICES. WASH HANDS AFTER HANDLING MATERIAL.
OTHER PROTECTION	DELUGE SAFETY SHOWER AND EYE WASH STATION SHOULD BE LOCATED NEAR WORK AREA.

SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

INFORMATION ON BASIC PHYSICAL AND CHEMICAL PROPERTIES :

APPEARANCE, COLOR, ODOR	YELLOW POWDER, NO ODOR
pH	8.0 - 9.0
MELTING POINT/FREEZING POINT	ND
INITIAL BOILING POINT/BOILING RANGE	0.00
FLASHPOINT	NORMALLY STABLE, NOT COMBUSTIBLE NOR FLAMMABLE
EVAPORATION RATE	NO DATA
FLAMMABILITY (SOLID,GAS)	NORMALLY STABLE, NOT COMBUSTIBLE NOR FLAMMABLE
UPPER EXPLOSIVE LIMITS	NA
LOWER EXPLOSIVE LIMITS	NA
VAPOR PRESSURE	NA
VAPOR DENSITY	NA
RELATIVE DENSITY	NA
SOLUBILITY IN WATER	SOLUBLE
PARTITION COEFFICIENT N-OCTANOL/WATER	NO DATA

AUTO-IGNITION TEMPERATURE	NO DATA
DECOMPOSITION TEMPERATURE	NO DATA
VISCOSITY, DYNAMIC	NO DATA
VISCOSITY, CINEMATIC	NO DATA
EXPLOSIVE PROPERTIES	N/A
OXIDIZING PROPERTIES	NA
OTHER INFORMATION	NA

SECTION 10. STABILITY AND REACTIVITY

CHEMICAL STABILITY	STABLE UNDER NORMAL STORAGE AND HANDLING CONDITIONS.
CONDITIONS TO AVOID	OXIDIZING & REDUCING AGENTS MAY DESTROY COLOR.
INCOMPATIBLE MATERIALS	OXIDIZING & REDUCING AGENTS MAY DESTROY COLOR.
HAZARDOUS DECOMPOSITION PRODUCTS	- CO, CO2, OXIDES OF NITROGEN AND OTHER POTENTIALLY TOXIC FUMES.

SECTION 11. TOXICOLOGICAL INFORMATION

TOXICOLOGICAL EFFECTS :

ORAL (ANIMAL	GREATER THAN 7,000 MG/KG - RAT
DERMAL (ANIMAL)	NA
EFFECTS TO EYES (ANIMAL)	EYES - RABBIT, NOT IRRITATING
SKIN IRRITATION (ANIMAL)	SKIN - RABBIT, SLIGHT IRRITANT

SKIN CORROSION/IRRITATION	NOT CLASSIFIED
SERIOUS EYE DAMAGE/IRRITATION	CAUSES EYE IRRITATION
RESPIRATORY OR SKIN SENSITIZATION	NOT CLASSIFIED
GERM CELL MUTAGENICITY	NOT CLASSIFIED
CARCINOGENICITY	NOT CLASSIFIED
REPRODUCTIVE TOXICITY	NOT CLASSIFIED
SPECIFIC TARGET ORGAN TOXICITY (SINGLE EXPOSURE)	MAY CAUSE DROWSINESS OR DIZZINESS.
ASPIRATION HAZARD	NOT CLASSIFIED
INHALATION	MAY CAUSE DROWSINESS OR DIZZINESS.
EYE CONTACT	CAUSES SERIOUS EYE IRRITATION.
INGESTION	INGESTION MAY CAUSE NAUSEA, VOMITING AND DIARRHEA

SECTION 12. ECOLOGICAL INFORMATION

TOXICITY	NA
PERSISTENCE AND DEGRADABILITY	NA
BIOACCUMULATIVE POTENTIAL	NA
MOBILITY IN SOIL	LC-50 (LETHAL CONCENTRATION) UG = MICROGRAMS/LITER CHANNEL CATFISH - 2,267,000 UG/LITER RAINBOW TROUT - 1,372,000 UG/LITER BLUEGILL - 3,433,000 UG/LITER
OTHER ADVERSE EFFECTS	NA

SECTION 13. DISPOSAL CONSIDERATION

WASTE DISPOSAL RECOMMENDATION :

EMPTY BAGS THOROUGHLY. CARRY OUT THE PROPER RECYLING, REUSAGE OR DISPOSAL. PLEASE REFER TO THE RELEVANT EU REGULATIONS, IN PARTICULAR THE GUIDELINES/DECISIONS OF THE COUNCIL REGARDING HANDLING OF WASTES (E.G. 75/442/EEC, 91/689/EEC, 94/67/EC, 94/904/EC) AS IMPLEMENTED IN NATIONAL REGULATIONS.

REGIONAL RECOMMENDATION :

BURY OR INCINERATE ACCORDANCE WITH FEDERAL, STATE AND LOCAL REGULATIONS.

CONTAINERS SHOULD NOT BE REUSED WITHOUT PROFESSIONAL CLEANING AND RECONDITIONING. OBSERVE ALL LABELED SAFEGUARDS UNTIL CLEANED, RECONDITIONED OR DESTROYED.

PLEASE REFER TO SECTION 8 (EXPOSURE CONTROLS /PERSONAL PROTECTION) OF THIS SDS.

SECTION 14. TRANSPORTATION INFORMATION

UN NUMBER	NONE
UN PROPER SHIPPING NAME	NONE

DEPARTMENT OF TRANSPORTATION (DOT) : NOT HAZARDOUS FOR TRANSPORTATION

TRANSPORT HAZARD CLASS(ES)

HAZARD LABLES (DOT) :

PACKING GROUP (DOT)	NA
DOT SPECIAL PROVISIONS	NA

ADDITIONAL INFORMATION:

OVERLAND TRANSPORT	NONE
TRANSPORT BY SEA	NONE
AIR TRANSPORT	NONE
DOT QUANTITY LIMITATIONS PASSENGER AIRCRAFT	NA
DOT QUANTITY LIMITATIONS CARGO AIRCRAFT	NA

SECTION 15. REGULATORY INFORMATION

US FEDERAL REGULATIONS:

THE SUBSTANCES IS LISTED ON UNITED STATES TSCA (TOXIC SUBSTANCE CONTROL ACT) INVENTORY.

US STATE REGULATIONS:

NONE

CHEMICAL IDENTITY:

518-47-8	TSCA	DSL	NDSL	EINECS	ELINCS	ENCS	CHINA	KECL	PICCS	AICS
	X	-	-	-	-	-	-	-	-	-

TSCA STATUS	IN COMPLIANCE
E C CLASSIFICATION	(67/548/EEC - 88/379/EEC) N/A
EINECS NUMBER	
REACH CLASSIFICATION	
R PHRASES	
ADDITIONAL REGULATORY INFORMATION	

SECTION 16. OTHER INFORMATION

INDICATION OF CHANGES:

NA

OTHER INFORMATION:

NA

GHS FULL TEXT PHRASES:

MAY BE HARMFUL IF INHALED	H333
CAUSES EYE IRRITATION	H320
CASUES MILD SKIN IRRITATION	H316

	HEALTH	FLAMMABILITY	REACTIVITY	PERSONAL PROT
H. M. I. S. CLASSIFICATION:	1	0	0	D

HMIS CODE: **4** - SEVERE HAZARD, **3** - SERIOUS HAZARD, **2** - MODERATE HAZARD, **1** - SLIGHT HAZARD, **0** - MINIMAL HAZARD

SAFETY DATA SHEET (SDS)
REVISION DATE: 03/03/2016

ATTACHMENT 3

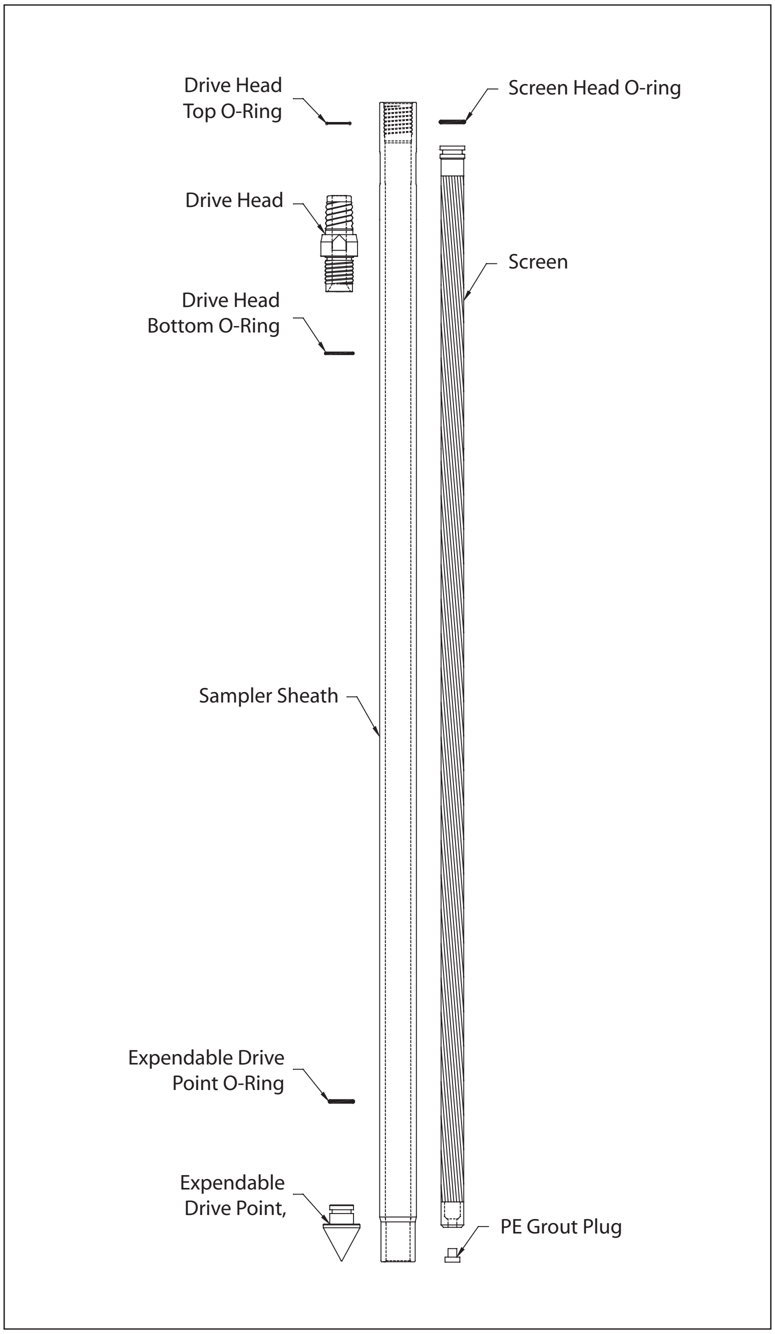
SOPs Geoprobe® Screen Point 16 and Screen Point 22 Groundwater Samplers

GEOPROBE® SCREEN POINT 16 GROUNDWATER SAMPLER

STANDARD OPERATING PROCEDURE

Technical Bulletin No. MK3142

PREPARED: November, 2006



GEOPROBE® SCREEN POINT 16 GROUNDWATER SAMPLER PARTS

Geoprobe® and Geoprobe Systems®, Macro-Core® and Direct Image® are Registered Trademarks of Kejr, Inc., Salina, Kansas

Screen Point 16 Groundwater Sampler is manufactured under U.S. Patent 5,612,498

1.0 OBJECTIVE

The objective of this procedure is to drive a sealed stainless steel or PVC screen to depth, deploy the screen, obtain a representative water sample from the screen interval, and grout the probe hole during abandonment. The Screen Point 16 Groundwater Sampler enables the operator to conduct abandonment grouting that meets American Society for Testing and Materials (ASTM) Method D 5299 requirements for decommissioning wells and borings for environmental activities (ASTM 1993).

2.0 BACKGROUND

2.1 Definitions

Geoprobe®: A brand name of high quality, hydraulically powered machines that utilize both static force and percussion to advance sampling and logging tools into the subsurface. The Geoprobe® brand name refers to both machines and tools manufactured by Geoprobe Systems®, Salina, Kansas. Geoprobe® tools are used to perform soil core and soil gas sampling, groundwater sampling and monitoring, soil conductivity and contaminant logging, grouting, and materials injection.

Screen Point 16 (SP16) Groundwater Sampler: A direct push device consisting of a PVC or stainless steel screen that is driven to depth within a sealed, steel sheath and then deployed for the collection of representative groundwater samples. The assembled SP16 Sampler is approximately 51.5 inches (1308 mm) long with an OD of 1.625 inches (41 mm). Upon deployment, up to 41 inches (1041 mm) of screen can be exposed to the formation. The Screen Point 16 Groundwater Sampler is designed for use with 1.5-inch probe rods and machines equipped with the more powerful GH60 Hydraulic Hammer. Operators with GH40 Series hammers may chose to use this sampler in soils where driving is difficult.

Rod Grip Pull System: An attachment mounted on the hydraulic hammer of a direct push machine which makes it possible to retract the tool string with extension rods or flexible tubing protruding from the top of the probe rods. The Rod Grip Pull System includes a pull block with rod grip jaws that are bolted directly to the machine. A removable handle assembly straddles the tool string while hooking onto the pull block to effectively grip the probe rods as the hammer is raised. A separate handle assembly is required for each probe rod diameter.

2.2 Discussion

In this procedure, the assembled Screen Point 16 Groundwater Sampler (Fig. 2.1A) is threaded onto the leading end of a Geoprobe® probe rod and advanced into the subsurface with a Geoprobe® direct push machine. Additional probe rods are added incrementally and advanced until the desired sampling interval is reached. While the sampler is advanced to depth, O-ring seals at each rod joint, the drive head, and the expendable drive point provide a watertight system. This system eliminates the threat of formation fluids entering the screen before deployment and assures sample integrity.

Once at the desired sampling interval, extension rods are sent downhole until the leading rod contacts the bottom of the sampler screen. The tool string is then retracted approximately 44 inches (1118 mm) while the screen is held in place with the extension rods (Fig. 2.1B). As the tool string is retracted, the expendable point is released from the sampler sheath. The tool string and sheath may be retracted the full length of the screen or as little as a few inches if a small sampling interval is desired.

There are three types of screens that can be used in the Screen Point 16 Groundwater Sampler. Two of the these, a stainless steel screen with a standard slot size of 0.004 inches (0.10 mm) and a PVC screen with a standard slot size of 0.010 inches (0.25 mm), are recovered with the tool string after sampling. The third screen is also manufactured from PVC with a standard slot size of 0.010 inches (0.25 mm), but is designed to be left downhole when sampling is complete. This disposable screen has an exposed screen length of approximately 43 inches (1092 mm). The two screens that are recovered with the sampler both have an exposed screen length of approximately 41 inches (1041 mm).

(continued on following page)

An O-ring on the head of the stainless steel screens maintains a seal at the top of the screen. As a result, any liquid entering the sampler during screen deployment must first pass through the screen. PVC screens do not require an O-ring because the tolerance between the screen head and sampler sheath is near that of the screen slot size.

The screens are constructed such that flexible tubing, a mini-bailer, or a small-diameter bladder pump can be inserted into the screen cavity. This makes direct sampling possible from anywhere within the saturated zone. A removable plug in the lower end of the screens allows the user to grout as the sampler is extracted for further use.

Groundwater samples can be obtained in a number of ways. A common method utilizes polyethylene (TB25L) or Teflon® (TB25T) tubing and a Check Valve Assembly (GW4210). The check valve (with check ball) is attached to one end of the tubing and inserted down the casing until it is immersed in groundwater. Water is pumped through the tubing and to the ground surface by oscillating the tubing up and down.

An alternative means of collecting groundwater samples is to attach a peristaltic or vacuum pump to the tubing. This method is limited in that water can be pumped to the surface from a maximum depth of approximately 26 feet (8 m). Another technique for groundwater sampling is to use a stainless steel Mini-Bailer Assembly (GW41). The mini-bailer is lowered down the inside of the casing below the water level where it fills with water and is then retrieved from the casing.

The latest option for collecting groundwater from the SP16 sampler is to utilize a Geoprobe® MB470 Series Mechanical Bladder Pump (MBP)*. The MBP may be used to meet requirements of the low-flow sampling protocol (Puls and Barcelona 1996, ASTM 2003). Through participation in a U.S. EPA Environmental Technology Verification study, it was confirmed that the MB470 can provide representative samples (EPA 2003).

**The Mechanical Bladder Pump is manufactured under U.S. Patent No. 6,877,965 issued April 12, 2005.*

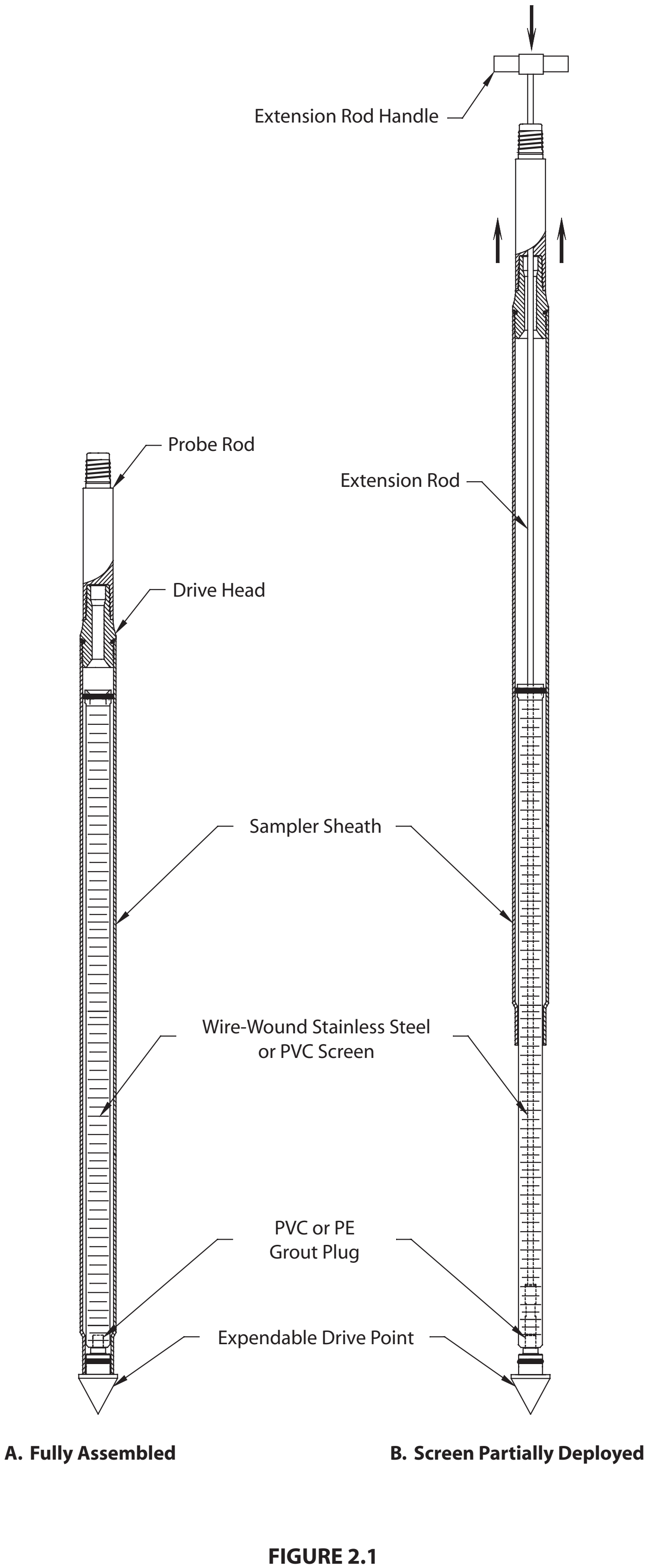


FIGURE 2.1
Screen Point 16 Groundwater Sampler

3.0 TOOLS AND EQUIPMENT

The following tools and equipment can be used to successfully recover representative groundwater samples with the Geoprobe® Screen Point 16 Groundwater Sampler. Refer to Figures 3.1 and 3.2 for identification of the specified parts. Tools are listed below for the most common SP16 / 1.5-inch probe rod configurations. Additional parts for optional rod sizes and accessories are listed in Appendix A.

SP16 Sampler Parts	**Part Number**
SP16 Sampler Sheath	15187
SP16 Drive Head, 0.5-inch bore, 1.5-inch rods*	18307
SP16 O-ring Service Kit, 1.5-inch rods *(includes 4 each of the O-ring packets below)*	15844
O-rings for Top of SP16 Drive Head, 1.5-inch rods only (Pkt. of 25)	*15389*
O-rings for Bottom of SP16 Drive Head (Pkt. of 25)	*13196*
O-rings for GW1520 Screen Head (Pkt. of 25)	*GW1520R*
O-rings for SP16 Expendable Drive Point (Pkt. of 25)	*GW1555R*
Screen, Wire-Wound Stainless Steel, 4-Slot*	GW1520
Grout Plugs, PE (Pkg. of 25)	GW1552K
Expendable Drive Points, steel, 1.625-inch OD (Pkg. of 25)*	GW1555K
Screen Point 16 Groundwater Sampler Kit, 1.5-inch Probe Rods *(includes 1 each of: 15187, 18307, 15844, GW1520, GW1535, GW1540, GW1555K, and GW1552K)*	15770

Probe Rods and Probe Rod Accessories	**Part Number**
Drive Cap, 1.5-inch probe rods, threadless, (for GH60 Hammer)	12787
Pull Cap, 1.5-inch probe rods	15090
Probe Rod, 1.5-inch x 60-inch*	11121

Extension Rods and Extension Rod Accessories	**Part Number**
Screen Push Adapter	GW1535
Grout Plug Push Adapter	GW1540
Extension Rod, 60-inch*	10073
Extension Rod Coupler	AT68
Extension Rod Handle	AT69
Extension Rod Jig	AT690
Extension Rod Quick Link Coupler, pin	AT695
Extension Rod Quick Link Coupler, box	AT696

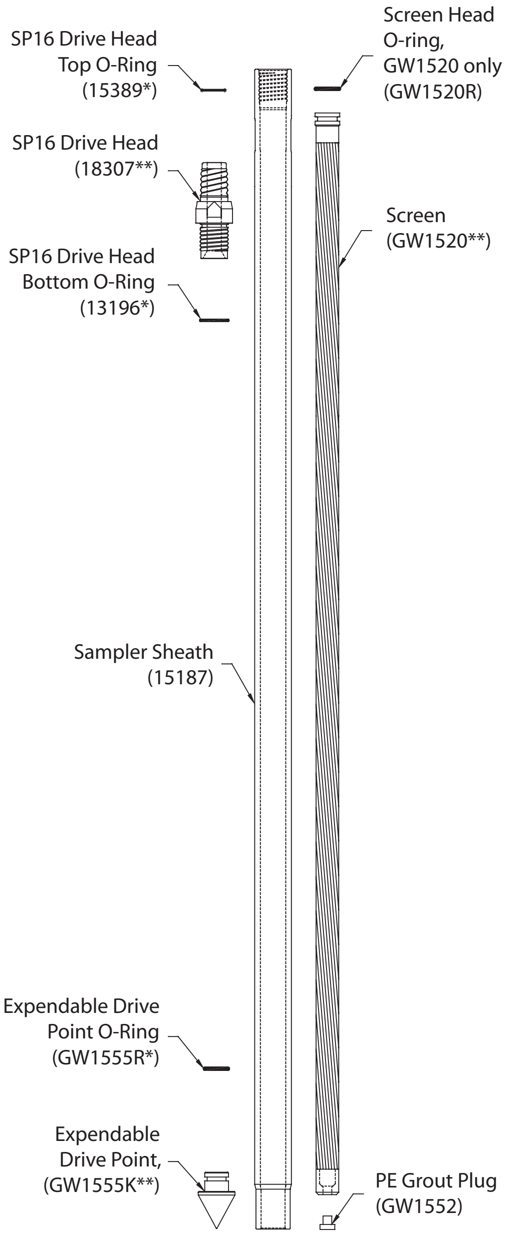
Grout Accessories	**Part Number**
Grout Nozzle, for 0.375-inch OD tubing	GW1545
High-Pressure Nylon Tubing, 0.375-inch OD / 0.25-inch ID, 100-ft. (30 m)	11633
Grout Machine, self-contained*	GS1000
Grout System Accossories Package, 1.5-inch rods	GS1015

Groundwater Purging and Sampling Accessories	**Part Number**
Polyethylene Tubing, 0.375-inch OD, 500 ft.*	TB25L
Check Valve Assembly, 0.375-inch OD Tubing*	GW4210
Water Level Meter, 0.438-inch OD Probe, 100 ft. cable*	GW2000
Mechanical Bladder Pump**	MB470
Mini Bailer Assembly, stainless steel	GW41

Additional Tools	**Part Number**
Adjustable Wrench, 6.0-inch	FA200
Adjustable Wrench, 10.0-inch	FA201
Pipe Wrenches	NA

* See Appendix A for additional tooling options.

** Refer to the Standard Operating Procedure (SOP) for the Mechanical Bladder Pump (Technical Bulletin No. MK3013) for additional tooling needs.



* Included in the SP16 O-ring Service Kit (15844)
** Part numbers show most common tool configuration. See Appendix A for alternative parts.

FIGURE 3.1
SP16 Sampler Parts

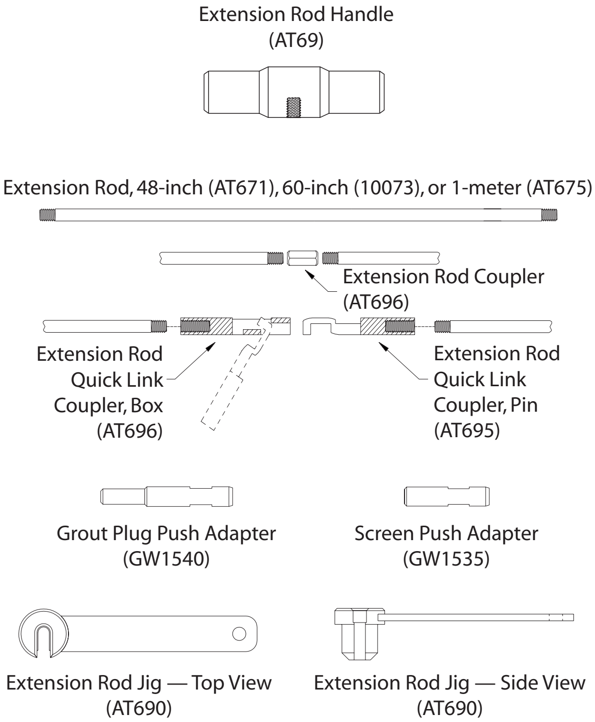


FIGURE 3.2
Geoprobe® Extension Rods and Accessories

4.0 OPERATION

4.1 Basic Operation

The SP16 sampler utilize a stainless steel or PVC screen which is encased in an alloy steel sampler sheath. An expendable drive point is placed in the lower end of the sheath while a drive head is attached to the top. O-rings on the drive head and expendable point provide a watertight sheath which keeps contaminants out of the system as the sampler is driven to depth.

Once the sampling interval is reached, extension rods equipped with a screen push adapter are inserted down the ID of the probe rods. The tool string is then retracted up to 44 inches (1118 mm) while the screen is held in place with the extension rods. The system is now ready for groundwater sampling. When sampling is complete, a removable plug in the bottom of the screen allows for grouting below the sampler as the tool string is retrieved.

4.2 Sampler Options

The Screen Point 15 and Screen Point 16 Groundwater Samplers are nearly identical. Subtle differences in the design of the SP16 sampler make it more durable than the earlier SP15 system. Operators of GH60-equipped machines should always utilize SP16 tooling. Operators of machines equipped with GH40 Series hammers may also choose SP16 tooling when sampling in difficult probing conditions.

A 1.75-inch OD Expendable Drive Point (17066K) and Disposable PVC Screen (16089) provide two useful options for the SP16 sampler. The 1.75-inch drive point may be used when soil conditions make it difficult to remove the sampler after driving to depth. The disposable PVC screen may be left downhole after sampling (when regulations permit) to eliminate the time required for screen decontamination.

4.3 Decontamination

In order to collect representative groundwater samples, all sampler parts must be thoroughly cleaned before and after each use. Scrub all metal parts using a stiff brush and a nonphosphate soap solution. Steam cleaning may be substituted for hand-washing if available. Rinse with distilled water and allow to air-dry before assembly.

4.4 SP16 Sampler Assembly (Figure 4.1)

Part numbers are listed for a standard SP16 sampler using 1.5-inch probe rods. Refer to Page 6 for screen and drive head alternatives.

1. Place an O-ring on a steel expendable drive point (GW1555K). Firmly seat the expendable point in the necked end of a sampler sheath (15187).

2. Install a PE Grout Plug (GW1552) in the bottom end of a Wire-wound Stainless Steel Screen (GW1520). Place a GW1520R O-ring in the groove on the top end of the screen.

3. Slide the screen inside of the sampler sheath with the grout plug toward the bottom of the sampler. Ensure that the expendable point was not displaced by the screen.

4. Install a bottom O-ring (13196) on a Drive Head (18307 or 15188). Thread the drive head into the sampler sheath using an adjustable wrench if necessary to ensure complete engagement of the threads. Attach a Drive Cap (12787 or 15590) to the top of the drive head.

   NOTE: The 18307 drive head should be used whenever possible as the smaller 0.5-inch ID provides a greater material cross-section for increased durability.

Sampler assembly is complete.

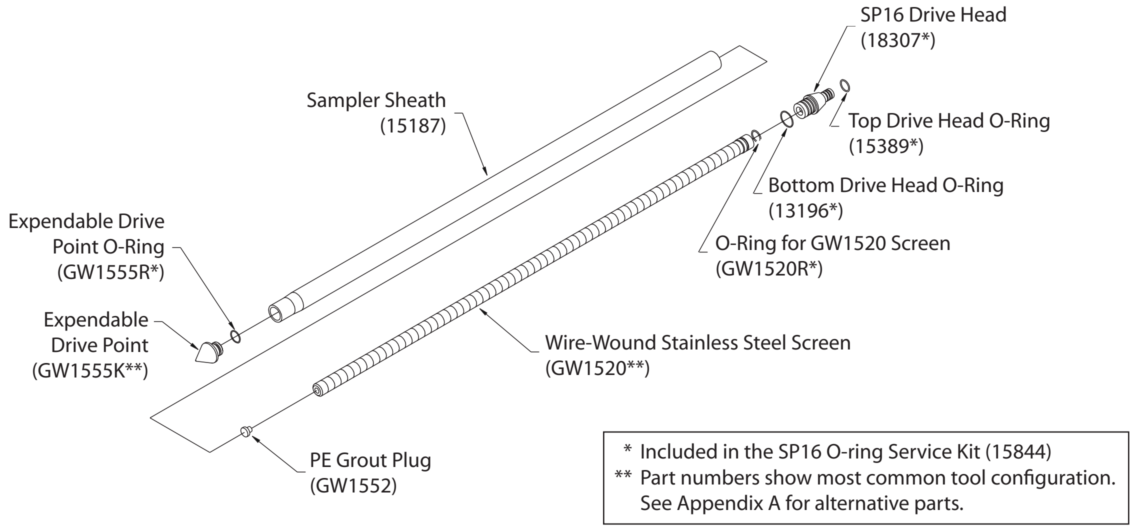


FIGURE 4.1
Screen Point 16 Groundwater Sampler Assembly

4.5 Advancing the SP16 Sampler

To provide adequate room for screen deployment with the Rod Grip Pull System, the probe derrick should be extended a little over halfway out of the carrier vehicle when positioning for operation.

1. Begin by placing the assembled sampler (Fig. 2.1.A) in the driving position beneath the hydraulic hammer of the direct push machine as shown in Figure 4.2.

2. Advance the sampler with the throttle control at slow speed for the first few feet to ensure that the sampler is aligned properly. Switch to fast speed for the remainder of the probe stroke.

3. Completely raise the hammer assembly. Remove the drive cap and place an O-ring in the top groove of the drive head. Distilled water may be used to lubricate the O-ring if needed.

   Add a probe rod (length to be determined by operator) and reattach the drive cap to the rod string. Drive the sampler the entire length of the new rod with the throttle control at fast speed.

4. Repeat Step 3 until the desired sampling interval is reached. Approximately 12 inches (305 mm) of the last probe rod must extend above the ground surface to allow attachment of the puller assembly. A 12-inch (305 mm) rod may be added if the tool string is over-driven.

5. Remove the drive cap and retract the probe derrick away from the tool string.

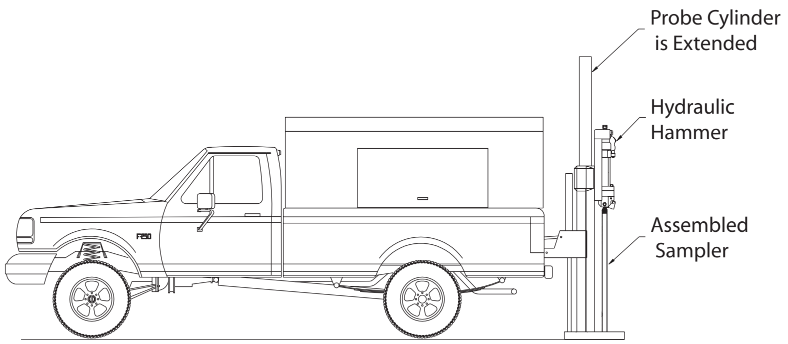


FIGURE 4.2
Screen Point 16 Groundwater Sampler in Driving Position

4.6 Screen Deployment

1. Thread a screen push adapter (GW1535) on an extension rod of suitable length (AT671, 10073, or AT675). Attach a threaded coupler (AT68) to the other end of the extension rod. Lower the extension rod inside of the probe rod taking care not to drop it down the tool string. An extension rod jig (AT690) may be used to hold the rods.

2. Add extension rods until the adapter contacts the bottom of the screen. To speed up this step, it is recommended that Extension Rod Quick Links (AT695 and AT696) are used at every other rod joint.

3. Ensure that at least 48 inches (1219 mm) of extension rod protrudes from the probe rod. Thread an extension rod handle (AT69) on the top extension rod.

4. Maneuver the probe assembly into position for pulling.

5. Raise (pull) the tool string while physically holding the screen in place with the extension rods (Fig. 4.3.B). A slight knock with the extension rod string will help to dislodge the expendable point and start the screen moving inside the sheath.

   Raise the hammer and tool string about 44 inches (1118 cm) if using a GW1520 or GW1530 screen. At this point the screen head will contact the necked portion of the sampler sheath (Fig. 4.3.C.) and the extension rods will rise with the probe rods. Use care when deploying a PVC screen so as not to break the screen when it contacts the bottom of the sampler sheath.

   The Disposable Screen (16089) will extend completely out of the sheath if the tool string is raised more than 45 inches (1143 mm). Measure and mark this distance on the top extension rod to avoid losing the screen during deployment.

6. Remove the rod grip handle, lower the hammer assembly, and retract the probe derrick. Remove the top extension rod (with handle) and top probe rod. Finally, extract all extension rods.

7. Groundwater samples can now be collected with a mini-bailer, peristaltic or vacuum pump, tubing bottom check valve assembly, bladder pump, or other acceptable small diameter sampling device.

   When inserting tubing or a bladder pump down the rod string, ensure that it enters the screen interval. The leading end of the tubing or bladder pump will sometimes catch at the screen head giving the illusion that the bottom of the screen has been reached. An up-and-down motion combined with rotation helps move the tubing or bladder pump past the lip and into the screen.

4.7 Abandonment Grouting for GW1520 and GW1530 Screens

The SP16 Sampler can meet ASTM D 5299 requirements for abandoning environmental wells or borings when grouting is conducted properly. A removable grout plug makes it possible to deploy tubing through the bottom of GW1520 and GW1530 screens. A GS500 or GS1000 Grout Machine is then used to pump grout into the open probe hole as the sampler is withdrawn. The following procedure is presented as an example only and should be modified to satisfy local abandonment grouting regulations.

1. Maneuver the probe assembly into position for pulling. Attach the rod grip puller to the top probe rod. Raise the tool string approximately 4 to 6 inches (102 to 152 cm) to allow removal of the grout plug.

2. Thread the Grout Plug Push Adapter (GW1540) onto an extension rod. Insert the adapter and extension rod inside the probe rod string. Add extension rods until the adapter contacts the grout plug at the bottom of the screen. Attach the handle to the top extension rod. When the extension rods are slightly raised and lowered, a relatively soft rebound should be felt as the adapter contacts the grout plug. This is especially true when using a PVC screen.

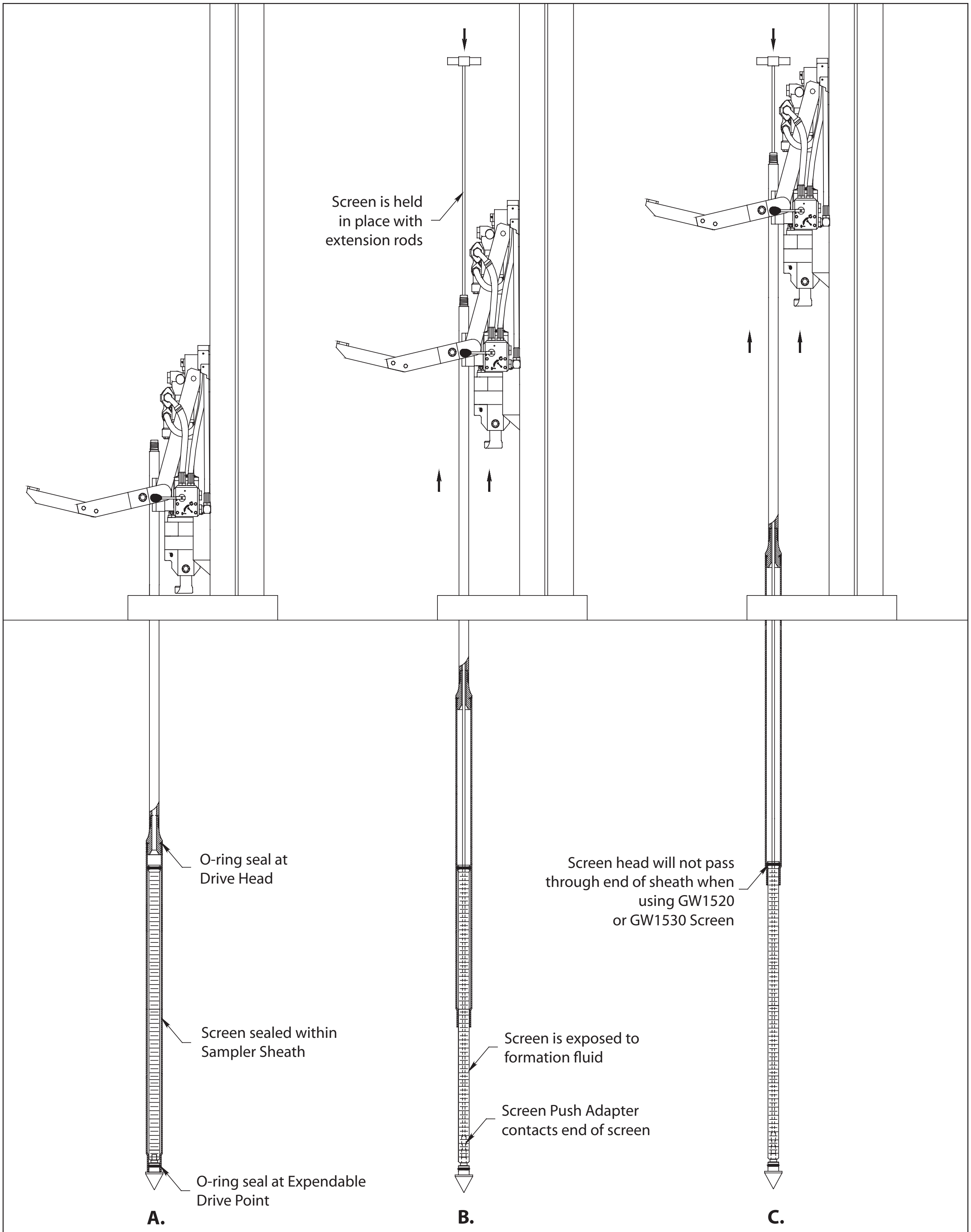


FIGURE 4.3
Screen Deployment for SP16 Sampler

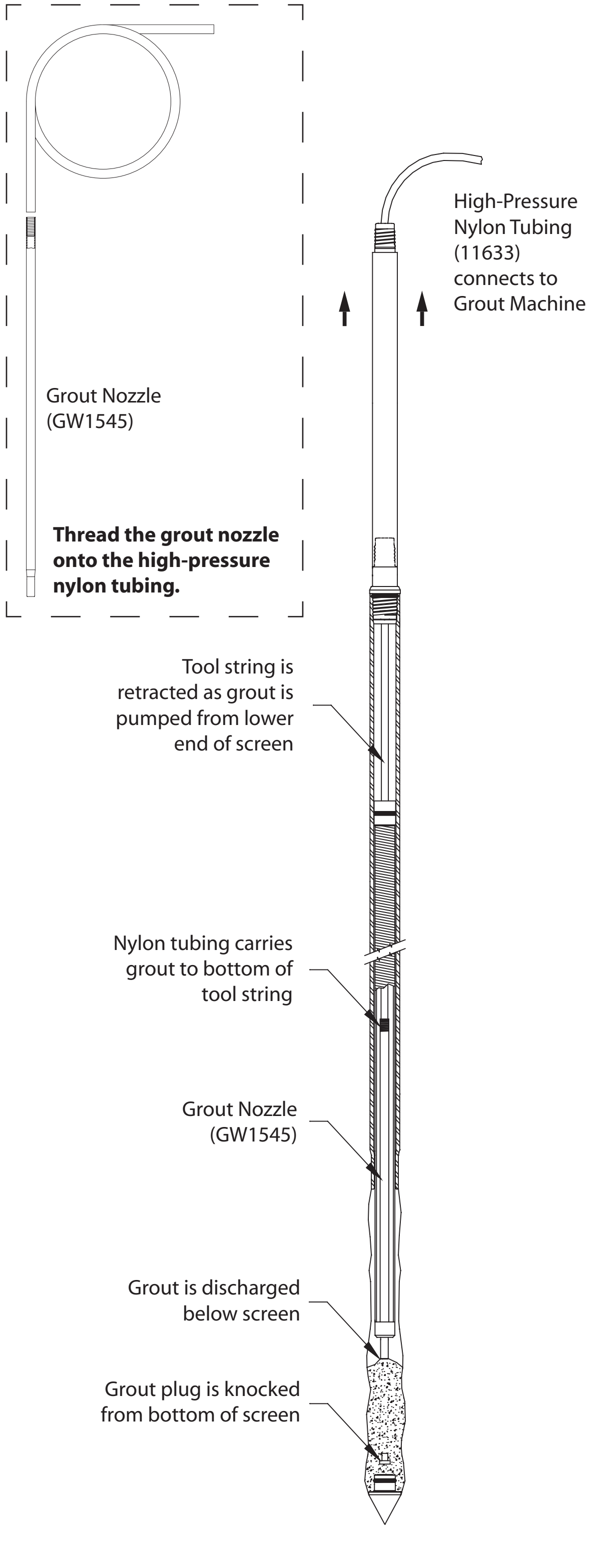


FIGURE 4.4
Grouting the SP16 Sampler With a GW1520 or GW1530 Screen

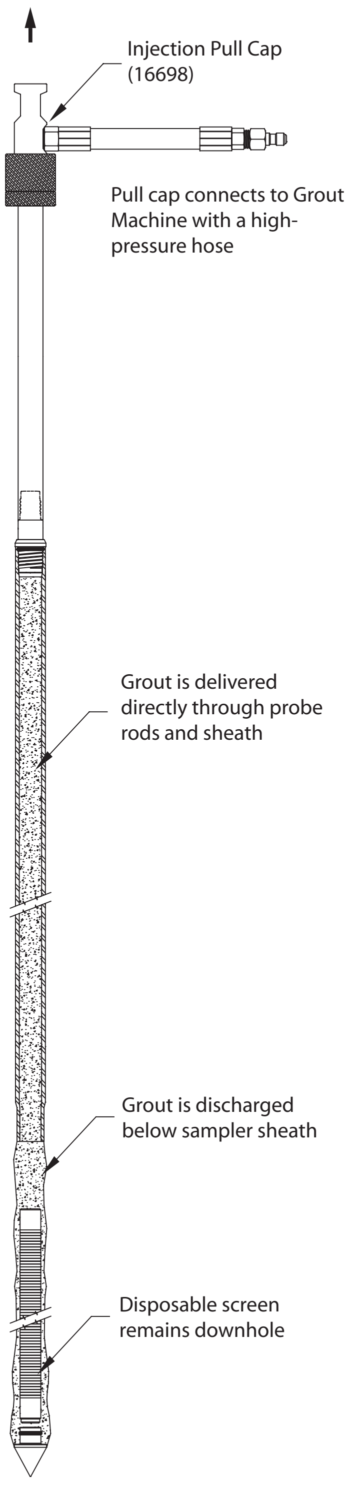


FIGURE 4.5
Grouting the SP16 Sampler With a 16089 Disposable Screen

3. Place a mark on the extension rod even with the top of the probe rod. Apply downward pressure on the extension rods and push the grout plug out of the screen. The mark placed on the extension rod should now be below the top of the probe rod. Remove all extension rods.

   Note: When working with a stainless steel screen, it may be necessary to raise and quickly lower the extension rods to jar the grout plug free. When the plug is successfully removed, a metal-on-metal sensation may be noted as the extension rods are gently "bounced" within the probe rods.

4. A Grout Nozzle (GW1545) is now connected to High-Pressure Nylon Tubing (11633) and inserted down through the probe rods to the bottom of the screen (Fig. 4.4). It may be necessary to pump a small amount of clean water through the tubing during deployment to jet out sediments that settled in the bottom of the screen. Resistance will sometimes be felt as the grout nozzle passes through the drive head. Rotate the tubing while moving it up-and-down to ensure that the nozzle has reached the bottom of the screen and is not hung up on the drive head.

   Note: *All probe rods remain strung on the tubing as the tool string is pulled. Provide extra tubing length to allow sufficient room to lay the rods on the ground as they are removed. An additional 20 feet is generally enough.*

5. Operate the grout pump while pulling the first rod with the rod grip pull system. Coordinate pumping and pulling rates so that grout fills the void left by the sampler. After pulling the first rod, release the rod grip handle, fully lower the hammer, and regrip the tool string. Unthread the top probe and slide it over the tubing placing it on the ground near the end of the tubing.

6. Repeat Step 5 until the sampler is retrieved. Do not bend or kink the tubing when pulling and laying out the probe rods. Sharp bends create weak spots in the tubing which may burst when pumping grout. Remember to operate the grout pump only when pulling the rod string. The probe hole is thus filled with grout from the bottom up as the rods are extracted.

7. Promptly clean all probe rods and sampler parts before the grout sets up and clogs the equipment.

4.8 Abandonment Grouting for the 16089 Disposable Screen

ASTM D 5299 requirements can also be met for the SP16 samplers when using the 16089 disposable screen. Because the screen remains downhole after sampling, the operator may choose either to deliver grout to the bottom of the tool string with nylon tubing or pump grout directly through the probe rods using an Injection Pull Cap (16698). A GS500 or GS1000 Grout Machine is needed to pump grout into the open probe hole as the sampler is withdrawn. The following procedure is presented as an example only and should be modified to satisfy local abandonment grouting regulations.

1. Maneuver the probe assembly into position for pulling with the rod grip puller.

2. Thread the screen push adapter onto an extension rod. Insert the adapter and extension rod inside the probe rod string. Add extension rods until the adapter contacts the bottom of the screen. Attach the handle to the top extension rod.

3. The disposable screen must be extended at least 46 inches (1168 mm) to clear the bottom of the sampler sheath. Considering the length of screen deployed in Section 4.7, determine the remaining distance required to fully extend the screen from the sheath. Mark this distance on the top extension rod.

4. Pull the tool string up to the mark on the top extension rod while holding the disposable screen in place.

   The screen is now fully deployed and the sampler is ready for abandonment grouting. Apply grout to the bottom of the tool string during retrieval using either flexible tubing (as described in Section 4.7) or an injection pull cap (Fig. 4.5). This section continues with a description of grouting with a pull cap.

5. Remove the rod grip handle and maneuver the probe assembly directly over the tool string. Thread an Injection Pull Cap (16698) onto the top probe rod and close the hammer pull latch over the top of the pull cap.

6. Connect the pull cap to a Geoprobe® grout machine using a high-pressure grout hose.

7. Operate the pump to fill the entire tool string with grout. When a sufficient volume has been pumped to fill the tool string, begin pulling the rods and sampler while continuing to operate the grout pump. Considering the known pump volume and sampler cross-section, time tooling withdrawal to slightly "overpump" grout into the subsurface. This will ensure that all voids are filled during sampler retrieval.

   The grouting process can lubricate the probe hole sufficiently to cause the tool string to slide back downhole when disconnected from the pull cap. Prevent this by withdrawing the tool string with the rod grip puller while maintaining a connection to the grout machine with the pull cap.

4.9 Retrieving the Screen Point 16 Sampler

If grouting is not required, the Screen Point 16 Sampler can be retrieved by pulling the probe rods as with most other Geoprobe® applications. The Rod Grip Pull System should be used for this process as it allows the operator to remove rods without completely releasing the tool string. This avoids having the probe rods fall back downhole when released during the pulling procedure. A standard Pull Cap (15164) may still be used if preferred. Refer to the Owner's Manual for your Geoprobe® direct push machine for specific instructions on pulling the tool string.

5.0 REFERENCES

American Society of Testing and Materials (ASTM), 2003. D6771-02 Standard Practice for Low-Flow Purging and Sampling for Wells and Devices Used for Ground-Water Quality Investigations. ASTM, West Conshocken, PA. (www.astm.org)

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Puls, Robert W., and Michael J. Barcelona, 1996. Ground Water Issue: Low-Flow (Minimal Drawdown) Ground Water Sampling Procedures. EPA/540/S-95/504. April.

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Appendix A
ALTERNATIVE PARTS

The following parts are available to meet unique soil conditions. See section 3.0 for a complete listing of the common tool configurations for the Geoprobe® Screen Point 16 Groundwater Sampler.

SP16 Sampler Parts and Accessories	**Part Number**
SP16 Drive Head, 0.625-inch bore, 1.5-inch rods	15188
Expendable Drive Points, aluminum, 1.625-inch OD (Pkg. of 25)	GW1555ALK
Expendable Drive Points, steel, 1.75-inch OD (Pkg. of 25)	17066K
Screen, PVC, 10-Slot	GW1530
Screen, Disposable, PVC, 10-Slot	16089

Groundwater Purging and Sampling Accessories	**Part Number**
Polyethylene Tubing, 0.25-inch OD, 500 ft.	TB17L
Polyethylene Tubing, 0.5-inch OD, 500 ft.	TB37L
Polyethylene Tubing, 0.625-inch OD, 50 ft.	TB50L
Check Valve Assembly, 0.25-inch OD Tubing	GW4240
Check Valve Assembly, 0.5-inch OD Tubing	GW4220
Check Valve Assembly, 0.625-inch OD Tubing	GW4230
Water Level Meter, 0.375-inch OD Probe, 100-ft. cable	GW2001
Water Level Meter, 0.438-inch OD Probe, 200-ft. cable	GW2002
Water Level Meter, 0.375-inch OD Probe, 200-ft. cable	GW2003
Water Level Meter, 0.438-inch OD Probe, 30-m cable	GW2005
Water Level Meter, 0.438-inch OD Probe, 60-m cable	GW2007
Water Level Meter, 0.375-inch OD Probe, 60-m cable	GE2008

Grouting Accessories	**Part Number**
Grout Machine, auxiliary-powered	GS500

Probe Rods, Extension Rods, and Accessories	**Part Number**
Probe Rod, 1.5-inch x 1-meter	17899
Probe Rod, 1.5-inch x 48-inch	13359
Drive Cap, 1.5-inch rods (for GH40 Series Hammer)	15590
Rod Grip Pull Handle, 1.5-inch Probe Rods (for GH40 Series Hammer)	GH1555
Extension Rod, 48-inch	AT671
Extension Rod, 1-meter	AT675

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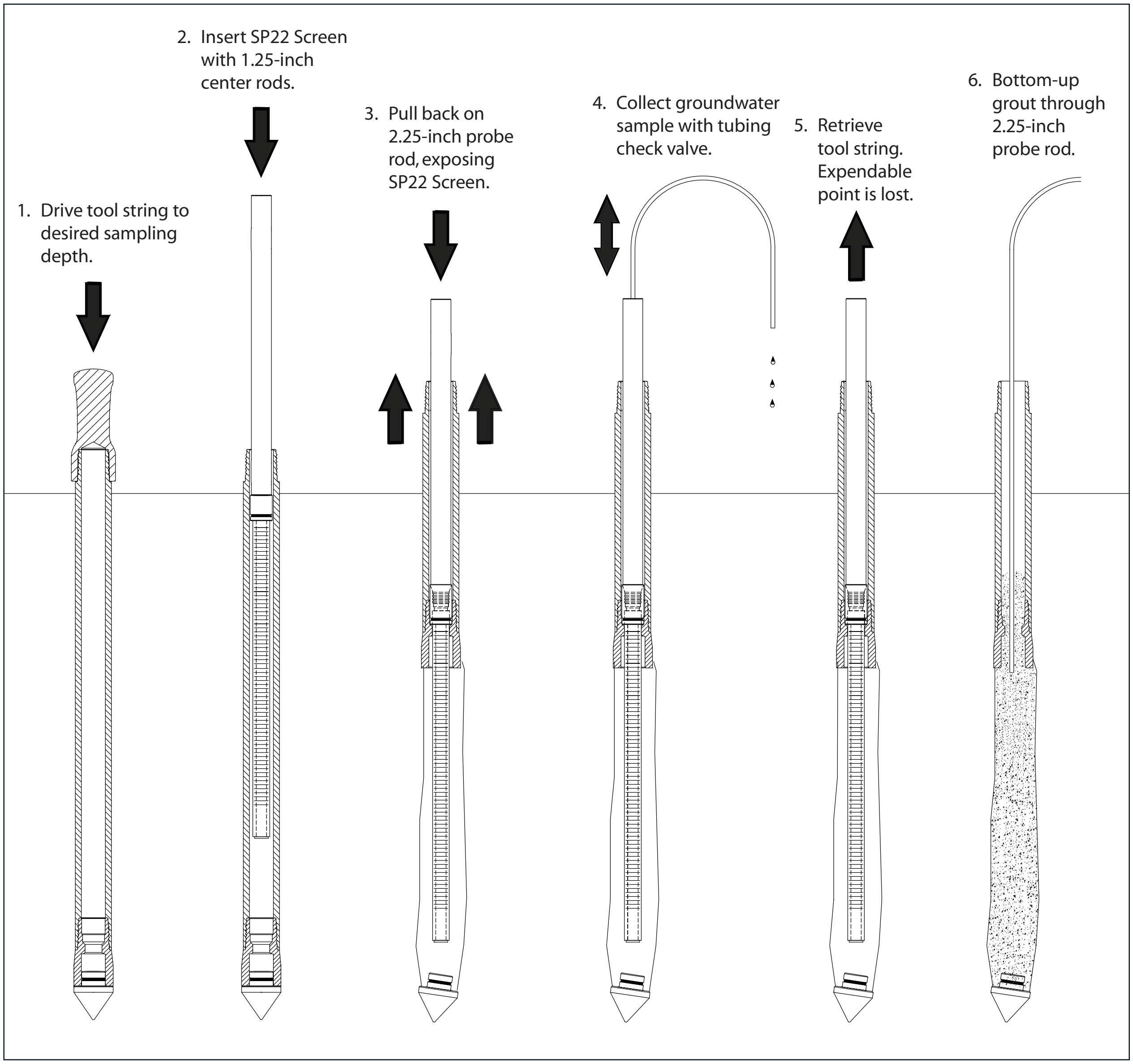
GEOPROBE® SCREEN POINT 22 GROUNDWATER SAMPLER

STANDARD OPERATING PROCEDURE

Technical Bulletin No. MK3173

PREPARED: April 2010



OPERATION OF THE GEOPROBE® SCREEN POINT 22 GROUNDWATER SAMPLER

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Screen Point 22 Groundwater Sampler is manufactured under U.S. Patent 5,612,498

1.0 OBJECTIVE

The objective of this procedure is to deploy a stainless steel or PVC screen at depth, obtain a representative water sample from the screen interval, and grout the probe hole during abandonment. The Screen Point 22 Groundwater Sampler enables the operator to conduct abandonment grouting that meets American Society for Testing and Materials (ASTM) Method D 5299 requirements for decommissioning wells and borings for environmental activities (ASTM 1993).

2.0 BACKGROUND

2.1 Definitions

Geoprobe®: A brand name of high quality, hydraulically powered machines that utilize static force and percussion or rotation to advance sampling and logging tools into the subsurface. The Geoprobe® brand name refers to both machines and tools manufactured by Geoprobe Systems®, Salina, Kansas. Geoprobe® tools are used to perform activities such as soil core and soil gas sampling, groundwater sampling and monitoring, soil conductivity and contaminant logging, grouting, and materials injection.

Screen Point 22 (SP22) Groundwater Sampler: A direct push device consisting of a PVC or stainless steel screen that is lowered (post-run) to depth within a sealed string of steel probe rods and then deployed for the collection of representative groundwater samples. Upon deployment, up to 48 inches (1219 mm) of screen can be exposed to the formation. There is also an optional 12-inch screen that can be used. The Screen Point 22 Groundwater Sampler is designed for use with 2.25-inch probe rods and machines equipped with the more powerful GH60 and GH80 series hydraulic hammers. Operators with GH40 series hammers may choose to use this sampler in soils where driving is easier.

Rod Grip Pull System: An attachment mounted on the hydraulic hammer of a direct push machine which makes it possible to retract the tool string with probe rods or flexible tubing protruding from the top of the probe rods. The Rod Grip Pull System includes a pull block with rod grip jaws that are bolted directly to the machine. A removable handle assembly straddles the tool string while hooking onto the pull block to effectively grip the probe rods as the hammer is raised. A separate handle assembly is required for each probe rod diameter.

2.2 Discussion (Fig. 2.1)

In this procedure, 2.25-inch probe rods are advanced into the subsurface with a Geoprobe® subsurface machine (Fig. 2.1, Step 1). While the tool string is advanced to depth, O-ring seals at each rod joint, the expendable point holder, and the expendable drive point provide a watertight system. This eliminates the threat of formation fluids entering the screen before deployment and assures sample integrity.

Once the leading end of the 2.25-inch probe rods reaches the desired sampling interval, an SP22 screen is lowered to the bottom of the rods using a string of either 1.25-inch outside diameter (OD) light-weight center rods, 1.25-inch probe rods, or 0.75-inch schedule 40 flush-thread PVC riser (Fig. 2.1, Step 2). The 2.25-inch rods are then retracted while the SP22 screen is held in place with the 1.25-inch rods or PVC riser (Fig 2.1, Step 3). As the 2.25-inch tool string is retracted, the expendable point is released from the expendable point holder. The tool string and expendable point holder may be retracted the full length of the screen or as little as a few inches if a small sampling interval is desired.

The SP22 Sampler can also be used with the Geoprobe® DT22 system. (Fig. 2.2)

(continued on following page)

Expendable Drive Points

The SP22 system utilizes an SP22 Expendable Point Holder (33764) and standard 2.45-inch (62-mm) OD steel Expendable Drive Points for 2.25-inch probe rods (AT2015K). Extended Shank Expendable Drive Points (19442) are available for soft soil conditions where standard points may be advanced out of the point holder during percussion. A third option is to use a part number 43128 SP22 Expendable Point Holder along with 1.625-inch (41-mm) steel Expendable Drive Points (GW1555K). These smaller drive points are more economical to purchase and ship, but must not be used with GH80 Series Hydraulic Hammers as they may not stay seated during percussion.

Screens

Two types of screens have been developed for use in the Screen Point 22 Groundwater Sampler - a stainless steel screen with a standard slot size of 0.004 inches (0.10 mm) and a PVC screen with a standard slot size of 0.010 inches (0.25 mm). These screens are available in nominal 48- and 12-inch lengths. Effective screen lengths for the 48- and 12-inch PVC screens are 48 inches (1219 mm) and 12 inches (305 mm), while 48- and 12-inch stainless steel screens have effective screen lengths of 43 inches (1092 mm) and 14 inches (356 mm) respectively. Both types of screens are recovered with the tool string after sampling.

The SP22 PVC Screen Head Adapter (37871) provides yet another screen option for the SP22 sampler. Using this adapter, a section of slotted 0.75-inch Schedule 40 PVC pipe may be lowered through the 2.25-inch probe rods using a string of flush-threaded 0.75-inch Schedule 40 PVC Riser. An SP22 PVC Screen Plug (38968) is installed in the leading end of the slotted pipe prior to use. The slotted pipe may be cut and the screen plug installed to provide custom screen lengths .

An O-ring is located at the top of each stainless screen and on the screen adapters. When a screen is deployed, this O-ring maintains a seal between the top of the screen and the inner wall of the probe rods or expendable point holder as indicated in Figure 2.1. As a result, any liquid entering the tool string must first pass through the screen.

Screens are constructed such that equipment can be inserted into the screen cavity for sample collection as noted in the following section and illustrated in Figure 2.1, Step 4. This makes direct sampling possible from anywhere within the saturated zone.

The inner rod string and screen are generally removed prior to grouting through the 2.25-inch rod string as shown in Figure 2.1, Steps 5-6. However, a removable plug in the lower end of the screens allows for grouting through flexible tubing extending out the bottom of the screen as with the Geoprobe® SP15/16 Groundwater Samplers if desired.

Sample Collection

Groundwater samples can be obtained from the SP22 screen in a number of ways. A common method utilizes 0.375-inch OD polyethylene (TB25L) or Teflon® (TB25T) tubing and a check valve assembly. The check valve (with check ball) is attached to one end of the tubing and inserted down the casing until it is immersed in groundwater. Water is then pumped through the tubing and to the ground surface by oscillating the tubing up and down.

An SP22 Check Valve Assembly (37893) is recommended if sampling through 1.25-inch light-weight center rods. The SP22 Check Valve Assembly is approximately 20 inches long to enable it to pass through the stepped diameters at each rod joint that may cause problems for other, shorter check valves.

An alternative means of collecting groundwater samples is to attach a peristaltic or vacuum pump to tubing that is inserted through the inner rods to within the SP22 screen. This method is limited in that water can be pumped to the surface from a maximum depth of approximately 26 feet (8 m). Another technique for groundwater sampling is to use a stainless steel Mini-Bailer Assembly (GW41). The mini-bailer is lowered down the inside of the casing below the water level where it fills with water and is then retrieved from the casing.

The latest option for collecting groundwater from the SP22 Sampler is to utilize a Geoprobe® MB470 Series Mechanical Bladder Pump (MBP)*. The MBP may be used to meet requirements of the low-flow sampling protocol (Puls and Barcelona 1996, ASTM 2003). Through participation in a U.S. EPA Environmental Technology Verification study, it was confirmed that the MB470 can provide representative samples (EPA 2003).

**The Mechanical Bladder Pump is manufactured under U.S. Patent No. 6,877,965 issued April 12, 2005.*

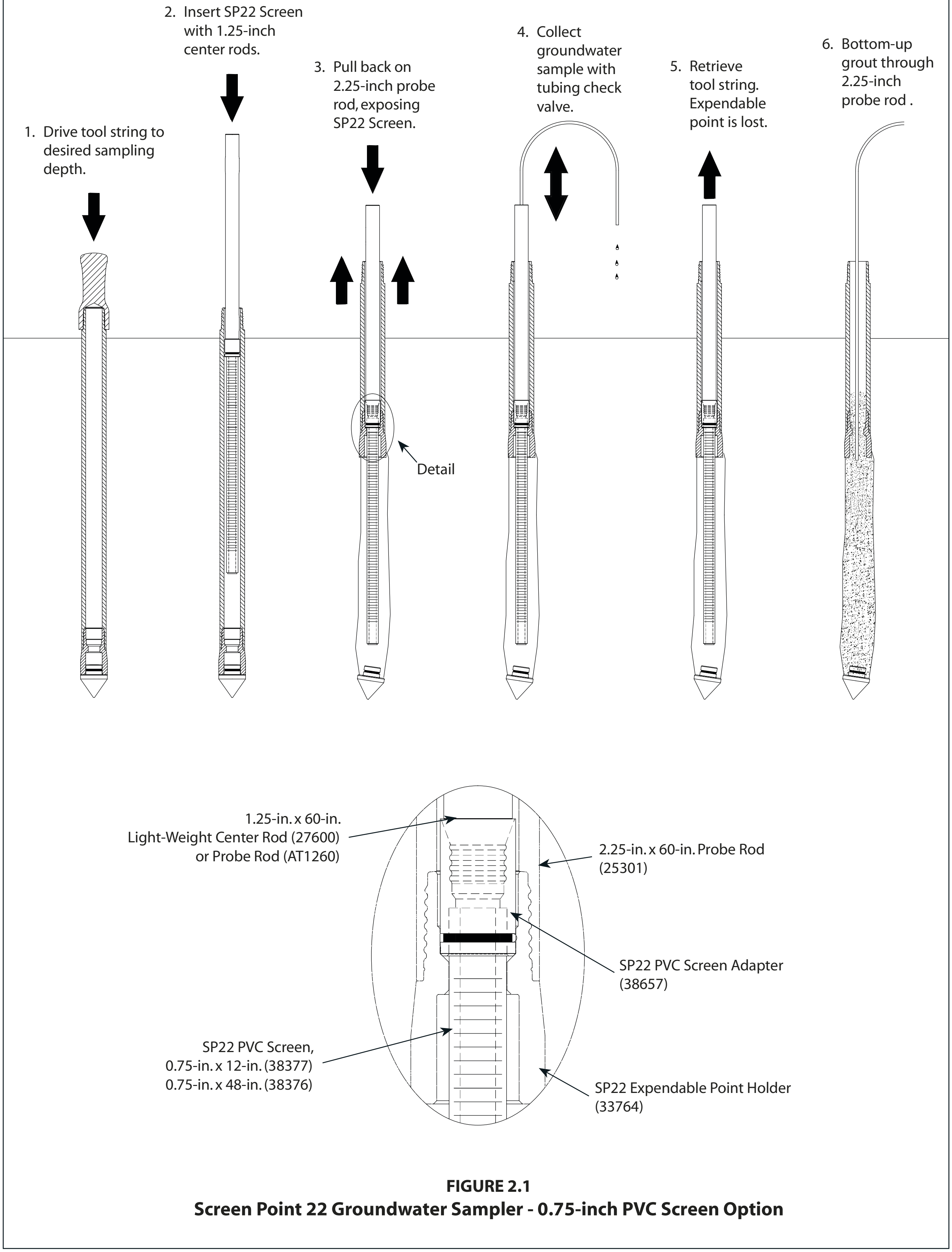

FIGURE 2.1

Screen Point 22 Groundwater Sampler - 0.75-inch PVC Screen Option

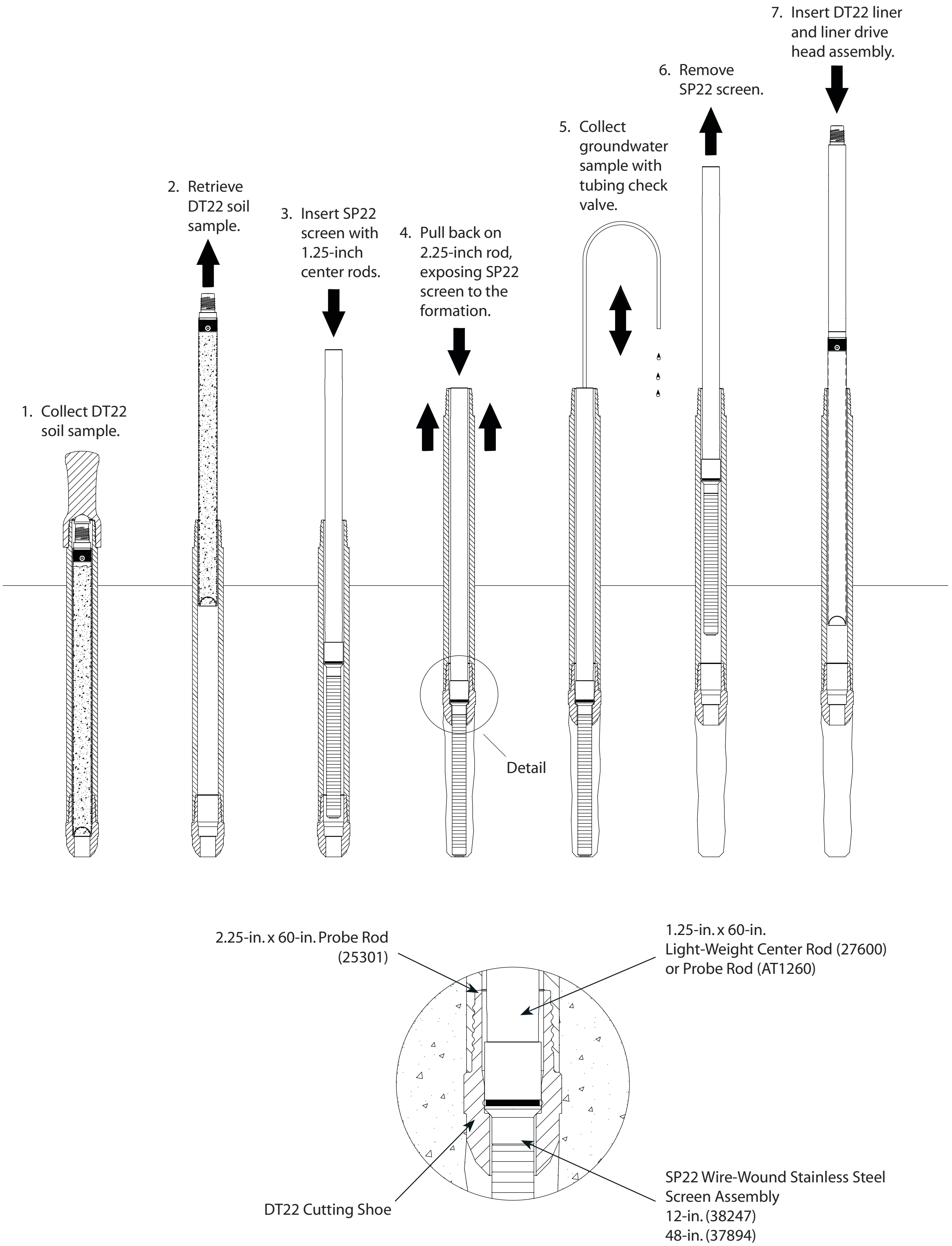

FIGURE 2.2

Screen Point 22 Groundwater Sampler Operation with DT22 Sampling System

3.0 TOOLS AND EQUIPMENT

The following tools and equipment can be used to successfully recover representative groundwater samples with the Geoprobe® Screen Point 22 Groundwater Sampler. Refer to Figures 3.1 and 3.2 for identification of the specified parts. Tools are listed below for the most common SP22 / 2.25-inch probe rod configurations. Additional rod sizes and accessories are available. Contact Geoprobe Systems® for information regarding tools and equipment options.

SP22 Sampler Parts	**Part Number**
SP22 Screen, Wire-Wound Stainless Steel, 4-Slot (48-in.)	37894
SP22 Screen, Wire-Wound Stainless Steel, 4-Slot (12-in.)	38247
Grout Plugs, PE (Pkg. of 25)	GW1552K
SP22 Screen, PVC, 10-Slot, 0.75-in. x 48-in.	38376
SP22 Screen, PVC, 10-Slot, 0.75-in. x 48-inch, Kit (includes 2 each of 38376 and 38429)	*38664*
SP22 Screen, PVC, 10-Slot, 0.75-in. x 12-in.	38377
SP22 Screen, PVC, 10-Slot 0.75-in. x 12-in., Kit (includes 2 each of 38377 and 38429)	*38667*
SP22 PVC Screen Plug	38968
SP22 PVC Screen Plug Kit (includes 10 of 38968)	*38530*
SP22 PVC Screen Adapter, 0.75-in. PVC x 1.25-in. Probe Rod Box	38657
SP22 PVC Screen Head Adapter, 0.75-in. (for flush-threaded 0.75-in. Schedule 40 PVC)	37871
SP22 O-ring Kit (Pkg. of 10 O-rings for SP22 PVC screen adapters and stainless steel screens)	37853
O-rings, 0.75-in. PVC Riser (Pkg. of 25)	GW4401R
SP22 Expendable Point Holder, 2.25-in. Probe Rods, AT2045K and 19442 Points	33764
SP22 Expendable Point Holder, 2.25-in. Probe Rods, GW1555 Points*	43128

Outer Casing (2.125-inch Probe Rods) and Inner Rod String	**Part Number**
Probe Rod, 2.25-in. x 60-in.	25301
Expendable Drive Points, Steel, 2.45-in. OD (Pkg. of 25)	AT2015K
Expendable Drive Points, Steel, 2.45-in. OD, extended shank	19442
Expendable Points, steel, 1.625-in. OD (Pkg. of 25)*	GW1555K
Drive Cap, 2.25-in. Probe Rods, Threadless, (for GH60 and GH80 Series Hammers)	31530
O-Rings, 2.25-in. Probe Rods (Pkg. of 25)	AT2100R
Rod Grip Handle, 2.25-in. Probe Rods, (for GH60 and GH80 Series Hammers)	29385
Light-Weight Center Rod, 1.25-in. x 60-in.	27600
Probe Rod, 1.25-in. x 60-in.	AT1260
O-ring, 1.25-in. rods (Pkg. of 25)	AT1250R
Rod Grip Handle, 1.25/1.5-in. Rods, (for GH60 and GH80 Series Hammers)	15554
PVC Riser, 0.75-in. Schedule 40 x 60-inch	11747
PVC Pipe, 0.75-in. Schedule 40 x 60-inch, 10-Slot	17474

Grout Accessories	**Part Number**
High-Pressure Nylon Tubing, 0.375-in. OD / 0.25-in. ID, 100-ft. (30 m)	11633
Grout Machine, Auxiliary-Powered	GS2200
Grout System Accessories Package, 2.25-in. rods	GS1015

Groundwater Purging and Sampling Accessories	**Part Number**
Polyethylene Tubing, 0.375-in. OD, 500 ft.	TB25L
Check Valve Assembly, 0.375-in. OD Tubing x 20 in. Long	37893
Water Level Meter, 0.438-in. OD Probe, 100 ft. cable	GW2000
Mechanical Bladder Pump**	MB470
Mini Bailer Assembly, Stainless Steel	GW41

* Not for use with GH80 Series Hydraulic Hammers

** Refer to the Standard Operating Procedure (SOP) for the Mechanical Bladder Pump (Technical Bulletin No. MK3013) for additional tooling needs.

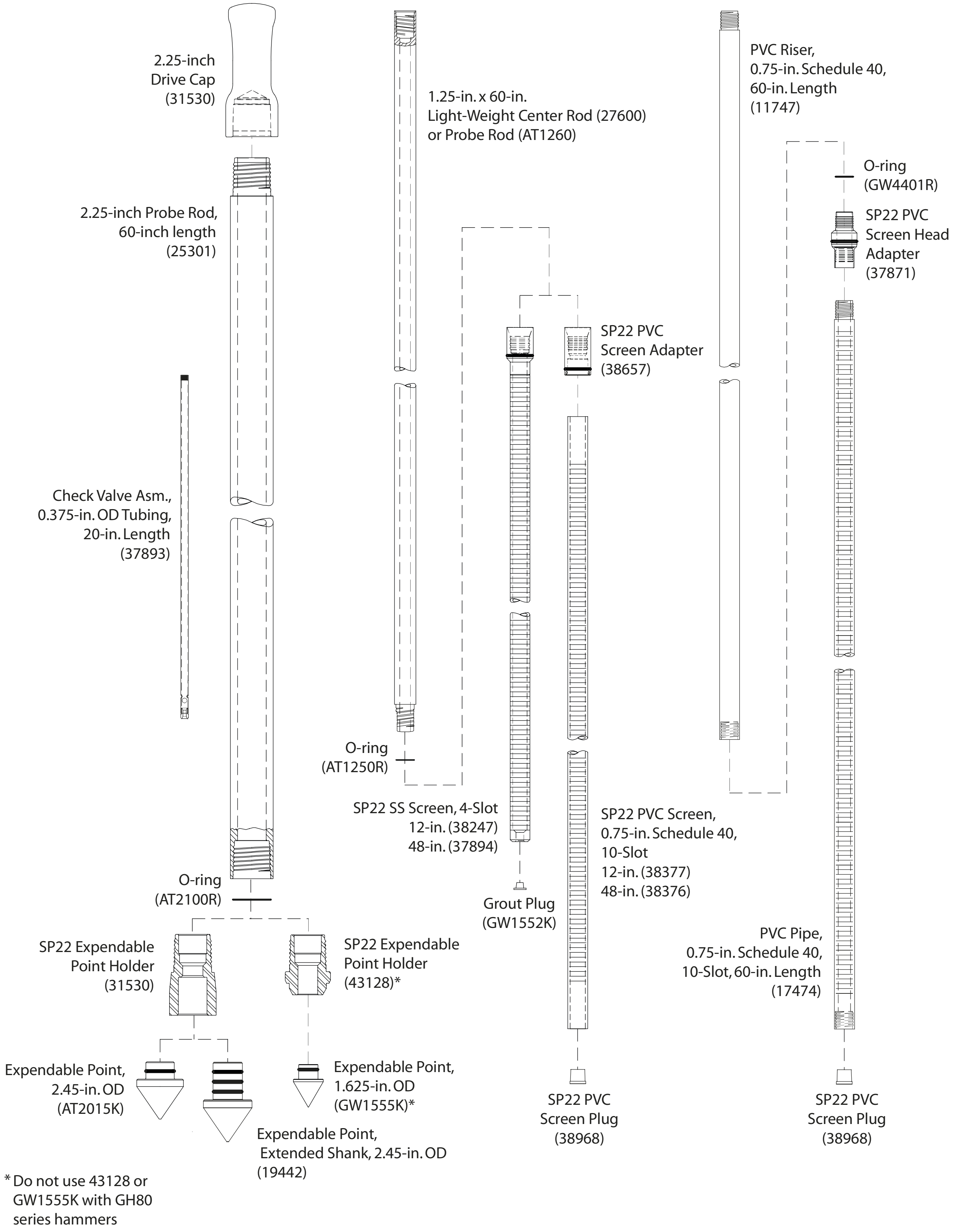

FIGURE 3.1
SP22 Sampler Parts

4.0 OPERATION

4.1 Basic Operation

The SP22 Sampler utilizes a stainless steel or PVC screen which is lowered (post-run) through an alloy steel 2.25-inch OD probe rod tool string. An expendable drive point is placed in an expendable point holder on the leading 2.25-inch probe rod prior to advancement (Fig. 4.1). This expendable point is removed and stays in the subsurface as the rods are pulled back to exposes the SP22 screen. O-rings on the probe rods ,the expendable point holder, and the expendable drive point provide a watertight tool string which keeps contaminants out of the system as the 2.25-inch rods are driven to depth in preparation for installation of the SP22 screen.

Once the sampling interval is reached with the 2.25-inch probe rods, the stainless steel or PVC screen is lowered through the rods using 1.25-inch probe rods, 1.25-inch light-weight center rods, or 0.75-inch PVC riser pipe. The 2.25-inch tool string is then retracted while the screen is held in place with the inner rods or riser. The system is now ready for groundwater sampling. When sampling is complete, the inner rods and screen are removed for grouting during retrieval or the 2.25-inch rods. Alternatively, a removable plug is located in the bottom of the screens to allow grouting directly through the inner tool string with high-pressure tubing during retrieval.

4.2 Decontamination

In order to collect representative groundwater samples, all sampler parts must be thoroughly cleaned before and after each use. Scrub all metal parts using a stiff brush and a nonphosphate soap solution. Steam cleaning may be substituted for hand-washing if available. Rinse with distilled water and allow to air-dry before assembly.

4.3 Lead Rod Assembly (Fig. 4.1)

1. Place an O-ring on the expendable point holder.
2. Thread expendable point holder into the 2.25-inch probe rod.
3. Place an O-ring on a steel expendable drive point.
4. Firmly seat the expendable point in the expendable point holder.
5. Place 2.25-inch Drive Cap (31530) on the top of the 2.25-inch probe rod. The lead rod assembly is now ready to be driven to depth.

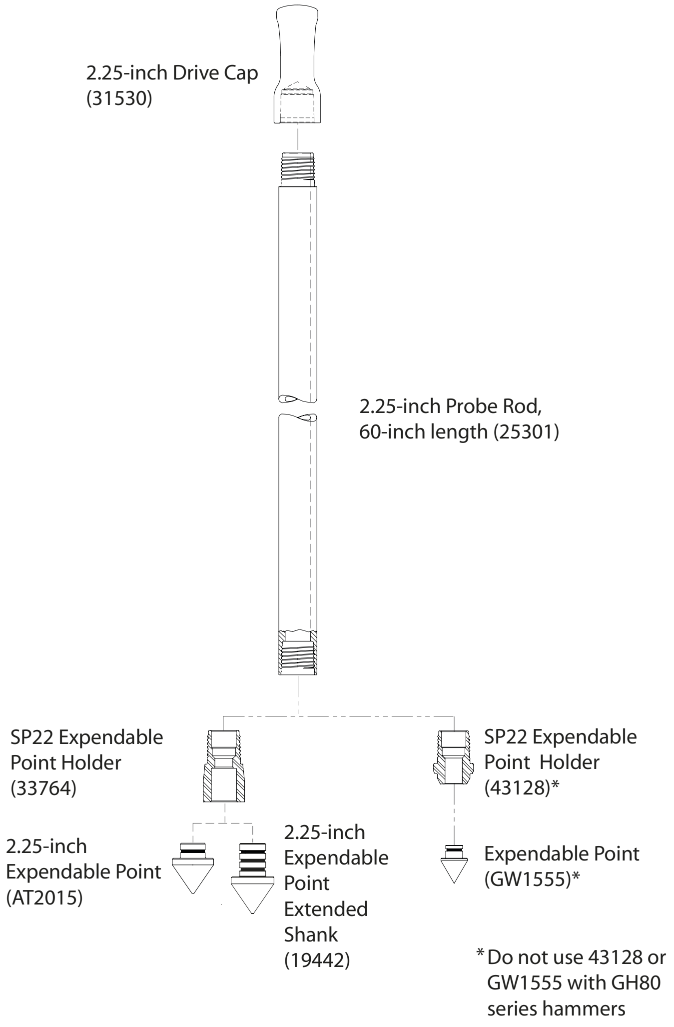

FIGURE 4.1
Lead Rod Assembly for the SP22 Groundwater Sampler

4.4 Advancing the Tool String (Fig. 4.2, step 1)

To provide adequate room for screen deployment with the Rod Grip Pull System, the probe derrick should be extended a little over halfway out of the carrier vehicle when positioning for operation.

1. Drive first 2.25-inch probe rod (as assembled in section 4.3).

2. Advance the tool string at a slow speed for the first few feet to ensure that the string is aligned properly.

3. Completely raise the hammer assembly. Remove the drive cap and place an O-ring in the top groove of the driven probe rod. Distilled water may be used to lubricate the O-ring if needed.

   Add a probe rod (length to be determined by operator) and reattach the drive cap to the rod string. Drive the tool string the entire length of the new rod.

4. Repeat Step 3 until the desired sampling interval is reached. Approximately 12 inches (305 mm) of the last probe rod must extend above the ground surface to allow attachment of the puller assembly. A 12-inch (305 mm) rod may be added if the tool string is over-driven.

5. Remove the drive cap and retract the probe derrick away from the tool string.

4.5 Screen Deployment (Fig 4.2, step 2 - 4)

1. Attach an SP22 stainless steel or PVC screen to a 1.25-inch probe rod, 1.25-inch light-weight center rod, or 0.75-inch fiush-thread PVC riser using an SP22 PVC Screen Adapter (38657) or SP22 PVC Screen Head Adapter (37871) as shown in Figure 3.1. Note that the 38657 screen adapter is connected to the SP22 PVC screen using the setscrews provided with the adapter.

and lower it into the driven casing.

2. Lower the screen into the 2.25-inch probe rod casing and add rods or riser until the screen head contacts the bottom of the tool string.

3. Ensure that at least 48 inches (1219 mm) of rods or riser protrudes from the top 2.25-inch probe rod.

4. Maneuver the probe assembly into position for pulling.

5. Raise (pull) the outer 2.25-inch tool string while physically holding the screen in place with the inner 1.25-inch rods or 0.75-inch riser. A slight knock with the inner tool string will help to dislodge the expendable point and start the screen moving inside the probe rod.

   Raise the hammer and outer tool string to expose the desired length of screen. The inner rods will begin raising with the outer rods when the screen adapter contacts the necked portion of the expendable point holder or DT22 Cutting Shoe. Use care when deploying a PVC screen so as not to break the screen when it contacts the expendable point.

6. Remove the rod grip handle, lower the hammer assembly, and retract the probe derrick. Remove the top 2.25-inch probe rod.

7. Groundwater samples can now be collected with a mini-bailer, peristaltic or vacuum pump, tubing bottom check valve assembly, bladder pump, or other acceptable small diameter sampling device.

   When inserting tubing or a bladder pump down the rod string, ensure that it enters the screen interval. The leading end of the tubing or bladder pump will sometimes catch at the screen head giving the illusion that the bottom of the screen has been reached. An up-and-down motion combined with rotation helps move the tubing or bladder pump past the lip and into the screen.

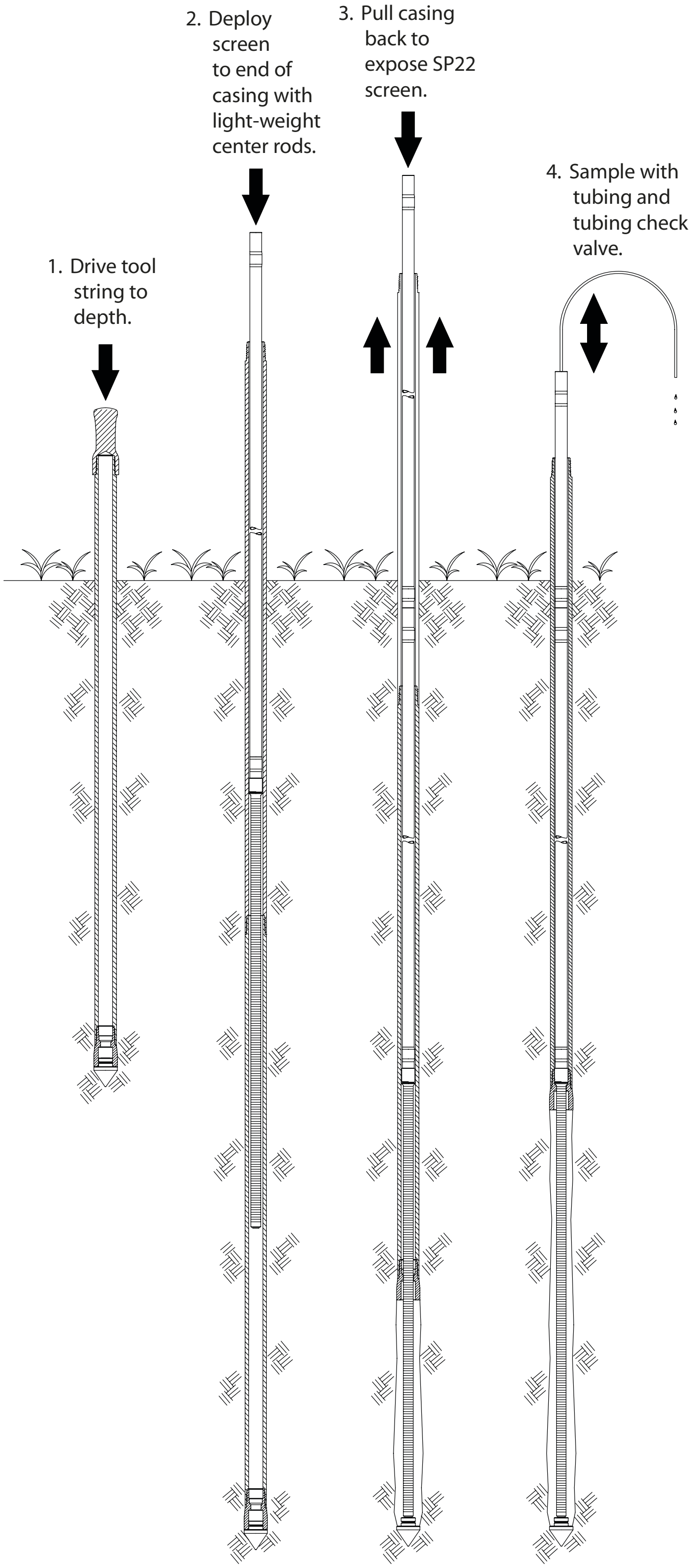

FIGURE 4.2

Screen Deployment for SP22 Sampler

4.6 Abandonment Grouting for SP22 Screens

The SP22 Sampler can meet ASTM D 5299 requirements for abandoning environmental wells or borings when grouting is conducted properly. A removable grout plug makes it possible to deploy tubing through the bottom of the SP22 screens, but the easiest method is to remove the inner string of rods; including the SP22 screen. A Grout Machine is then used to pump grout into the open probe hole as the outer casing is withdrawn. The following procedure is presented as an example only and should be modified to satisfy local abandonment grouting regulations. (Figure 4.3)

1. Maneuver the probe assembly into position for pulling.

2. High-Pressure Nylon Tubing (11633) is inserted down through the probe rods through the bottom of the expendable point holder (Fig. 4.3).

Note: *All probe rods remain strung on the tubing as the tool string is pulled. Provide extra tubing length to allow sufficient room to lay the rods on the ground as they are removed. An additional 20 feet is generally enough.*

3. Operate the grout pump while pulling the first rod with the rod grip pull system. Coordinate pumping and pulling rates so that grout fills the void left by the sampler. After pulling the first rod, release the rod grip handle, fully lower the hammer, and regrip the tool string. Unthread the top probe and slide it over the tubing placing it on the ground near the end of the tubing.

4. Repeat Step 5 until the tool string is retrieved. Do not bend or kink the tubing when pulling and laying out the probe rods. Sharp bends create weak spots in the tubing which may burst when pumping grout. Remember to operate the grout pump only when pulling the rod string. The probe hole is thus filled with grout from the bottom up as the rods are extracted.

5. Promptly clean all probe rods and sampler parts before the grout sets up and clogs the equipment.

4.7 Retrieving the Screen Point 22 Sampler

If grouting is not required, the Screen Point 22 Sampler can be retrieved by pulling the probe rods as with most other Geoprobe® applications. The Rod Grip Pull System should be used for this process as it allows the operator to remove rods without completely releasing the tool string. This avoids having the probe rods fall back downhole when released during the pulling procedure. A standard Pull Cap (33622) may still be used if preferred. Refer to the Owner's Manual for your Geoprobe® direct push machine for specific instructions on pulling the tool string.

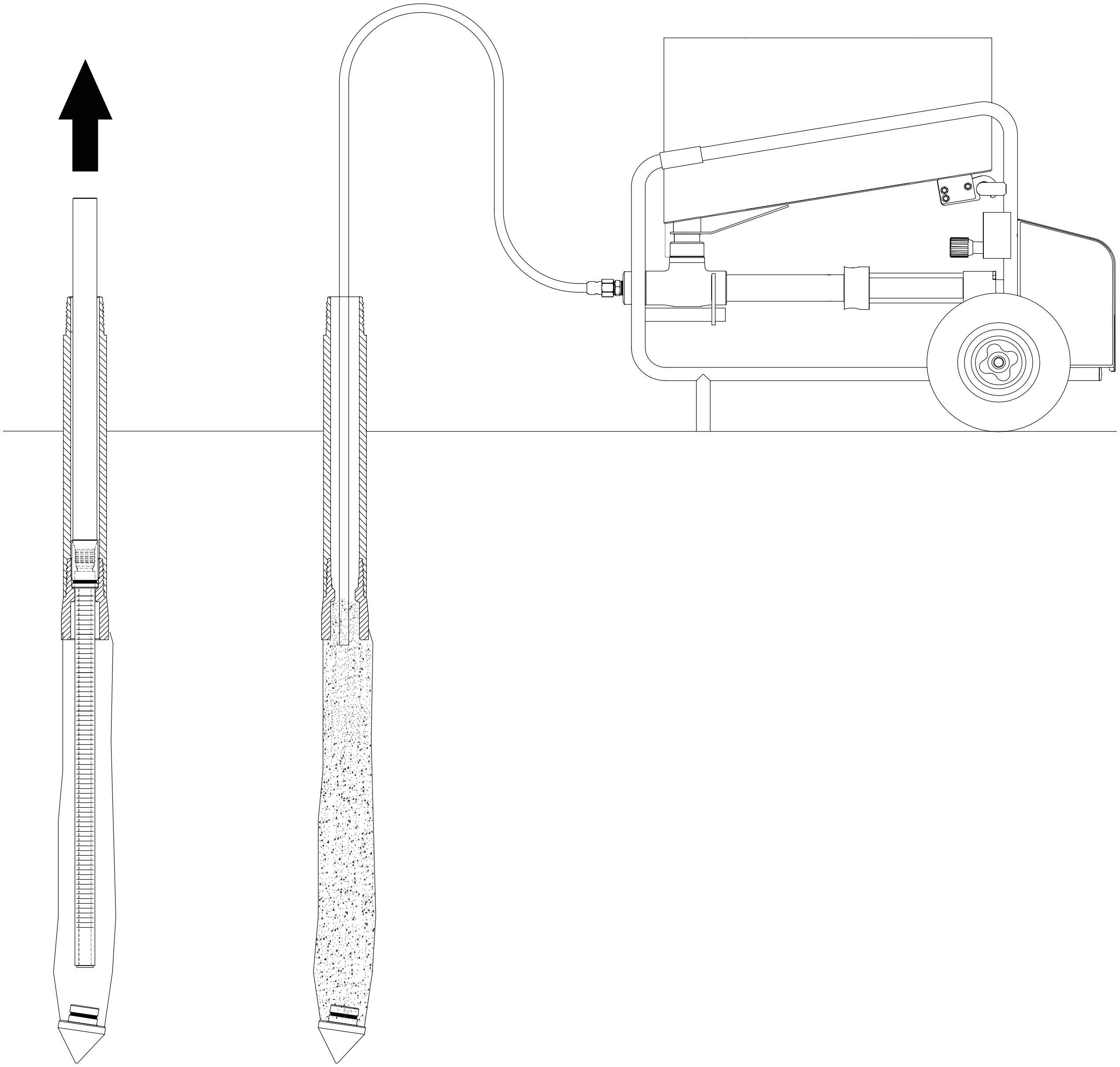

FIGURE 4.3
Abandonment Grouting for the SP22 Sampler

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TGI – Monitoring Well Installation

Rev: 1

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Version Control

Issue	Revision No.	Date Issued	Page No.	Description	Reviewed By
	0	4/24/2017	All	Re-written as a TGI	Marc Killingstad Peter C. Frederick
	1	6/23/2022	All	Put into new template format, reviewed and made minor revisions	Whitney Plasket Marc Killingstad

Approval Signatures

Prepared by: Whitney L Plasket 4/7/2022

Whitney Plasket Date

Reviewed by: 4/7/2022

Marc Killingstad Date

1 Introduction

This Technical Guidance Instruction (TGI) describes methods used to install groundwater monitoring wells in unconsolidated aquifers. It is assumed that the monitoring well to be installed has been properly designed, including sizing of the filter pack and screen, the length of the screen, total depth of the well, material strength and compatibility and surface completion. Typical monitoring wells are constructed of manufactured screen and engineered filter pack and are generally suitable for formations with granular materials having a grain size distribution with up to 50% passing a #200 sieve and up to 20% clay-sized material. Monitoring wells installed in formations finer than this may not be able to produce turbidity free water.

2 Intended Use and Responsibilities

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 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, regulation-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.

3 Scope and Application

The monitoring well installation procedures set forth herein are consistent with the approach and methods presented in the American Society of Testing and Materials (ASTM) *D5092 – Standard Practice for Design and Installation of Groundwater Monitoring Wells* (ASTM D5092). As such, following this TGI in combination with proper well design (see appropriate TGI and/or consult with appropriate subject matter expert), well development (see appropriate TGI), groundwater sampling procedures (see appropriate TGI), and well maintenance and rehabilitation (see appropriate TGI and/or consult with appropriate subject matter expert), will result in a monitoring well suitable for: (1) collection of groundwater samples representative of the surrounding formation and free of artificial turbidity; (2) measurement of accurate groundwater levels; and (3) hydraulic testing of formation sediments immediately adjacent to the open interval of the well to assess hydraulic properties (e.g., slug testing).

Monitoring well boreholes in unconsolidated (overburden) materials are often drilled using the hollow-stem auger drilling method; however, other drilling methods are also suitable for installing overburden monitoring wells and may be appropriate given site-specific geologic conditions or project objectives. These methods include drive-and-wash, spun casing, rotosonic (sonic), 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 to be installed within consolidated materials such as fractured bedrock are commonly drilled using air rotary, water-rotary (coring or tri-cone roller bit), or sonic drilling methods. For guidance when installing monitoring wells in consolidated materials, please consult the appropriate subject matter expert and, if available, the applicable guidance document.

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, project objectives, and cost. Consultation with the appropriate subject matter expert is also strongly recommended.

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.

Coated bentonite pellets are generally not recommended because of potential chemical incompatibilities between the coating material and groundwater chemistry.

Specifications of materials to be installed in the borehole will be obtained prior to mobilizing onsite. These materials generally include:

- Well casing (length, material, and diameter);
- Well screen (length, material, diameter, and slot size);
- Grout (typically neat cement grout, which is 5-6 gallons of water per 94 lb. bag of Portland Type I/II cement *with no bentonite* but, as applicable, up to 5% bentonite can be added);
- Filter pack (filter pack type and fine sand seal type, as applicable); and
- Bentonite (type, as applicable/needed, non-coated pellets or tablets are generally preferred over chips).

Well materials will be inspected and, if needed, cleaned, or replaced prior to installation. The field task manager or field team lead will communicate with the drilling company ahead of time to make sure the materials meet the required specification for well construction.

NOTE: If installing monitoring wells for per- and polyfluoroalkyl substances please refer to *TGI for Per- and Polyfluoroalkyl Substances (PFAS) Field Sampling Guide*.

4 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 field implementation plan (FIP)/task-specific work plan, 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 well installation activities will have a minimum of 1 year of previous environmental monitoring well installation experience. Field employees with less than six months of experience will be accompanied by a supervisor (as described above) to ensure that proper well installation 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 particularly the selected drilling method/rig.

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. Field sampling is typically performed for soil or bedrock characterization as part of monitoring well installation; therefore, field personnel will have undergone in-field training in soil or bedrock description and sample collection methods, as described in *TGI for Soil Drilling and Sample Collection, TGI for Bedrock Core Collection and Description, and TGI for Soil Description*.

5 Equipment List

The following materials may be required during soil boring and monitoring well installation activities:

- Site Plan with proposed soil boring/well locations;
- Field Implementation Plan (FIP)/Work Plan that includes site map with proposed well locations, well construction details (tabulated and drawings) which will include well casing material and size, well screen material and size, length of screen, target depth and screen interval, filter pack material, development methods, and previous boring logs (as available);
- Field Sampling Plan (FSP), and site-specific 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 FIP/work plan or other appropriate project documents;
- Appropriate sample containers and labels;
- Drum labels as required for investigation derived waste handling;
- 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);
- Engineer's tape/measuring wheel;
- Weighted tape;
- Disposable bailers;
- Forms/notes:
    - Tablet with digital forms
    - Field notebook
    - Chain-of-custody forms
    - Digital camera (or smart phone with camera);
    - Appropriate field forms, consider including a photo of the well head and a Google Earth map showing the well location.

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 is necessary to ensure that the materials provided will meet the project objectives. Equipment/materials typically provided by the driller could include:

- Drilling equipment required by the ASTM standard guidance document D1586, when performing split-spoon sampling;
- Disposable plastic liners (when drilling with direct-push equipment);
- Drums for investigation derived waste (IDW);
- Equipment to move IDW drums, if required;
- Drilling and sampling equipment decontamination materials;
- Decontamination pad materials, if required;

- Traffic cones, delineators, caution tape, and/or fencing as appropriate for securing the work area, if required; and
- Well construction materials.

6 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 Arcadis standard for proper utility clearance protocol.
- Prior to beginning field work, contact the project technical team (including Project Hydrogeologist) to ensure that all field procedures, logistics (e.g., access issues, health and safety issues, communication network, schedules, etc.), and objectives are clearly understood by all team members.
- 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 to 3 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 and well seal materials. Determine whether the oversight agency has any such requirements prior to finalizing the drilling and well installation plan. If installing a monitoring well into consolidated sediments, refer to regulatory agency rules regarding casing.
- The maximum screen length may also be dictated by regulatory agencies. If installing a monitoring well with greater than a 10-ft screen, refer to regulatory agency rules regarding screen length.
- If dense non-aqueous phase liquids (DNAPL) are known or expected to exist at the site, refer to the project specific documents for additional details regarding drilling and well installation to reduce the potential for inadvertent DNAPL remobilization. Similarly, if light non-aqueous phase liquids (LNAPLs) are 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 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. Consider testing of water supply as necessary.
- Similarly, consider the 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 or are corrosive to metal well materials, and some remedial technologies are incompatible with certain materials of construction. If questions arise, contact the CPM and Project Hydrogeologist/Technical Lead to discuss.
- Specifications of materials used for backfilling the borehole will be obtained, reviewed, and approved to meet project quality objectives. Bentonite is not recommended where DNAPLs are likely to be present or in groundwater with high salinity. In these situations, neat cement grout is preferred.
- As noted above, coated bentonite pellets are not recommended for monitoring well construction, as the coating could impact the water quality in the completed well.

- Heat of hydration during neat cement grout curing must be considered to avoid damage to PVC well materials. The annular space for a typical monitoring well is small enough that heat of hydration should not create excessive temperature increases which may damage PVC well material. However, washouts in the borehole can lead to thick accumulations of grout which can produce enough heat during curing to weaken and potentially damage PVC casing. If heat of hydration is a concern, contact the Project Hydrogeologist/Technical Lead to address the issue.
- Similarly, it is imperative that backfill volumes (filter pack and well seal) be estimated and then closely monitored to ensure that materials are not 'lost' to the formation. If estimated volumes do not reasonably match actual volumes, contact the Project Hydrogeologist/Technical Lead to address the issue.

7 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. The HASP may require that the drilling company provide their own HASP and/or Job Safety Analyses (JSAs).

The HASP will be followed, as appropriate, to ensure the safety of field personnel. Review all site-specific and procedural hazards as they are provided in the HASP, and review Job SafetyAnalysis (JSA) documents in the field each day prior to beginning work.

Prior to drilling, utility clearance must be performed (see Section 6). Appropriate personal protective equipment (PPE) must always be worn in accordance with the task and the HASP.

Working outside at sites with suspected contamination may expose field personnel to hazardous materials such as contaminated groundwater or 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 useof fixed/folding-blade knives and use appropriate hand protection.

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

8 Procedure

The procedures for installing groundwater monitoring wells are presented below:

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

1. Prior to monitoring well installation, determine the expected volumes of filter pack and seal materials including grout (neat cement or cement-bentonite) and bentonite (if applicable).
2. Locate boring/well location, establish work zone, and set up sampling equipment decontamination area.
3. During well installation, record construction details, measurements, and tabulate materials used (e.g., screen and riser footages; filter pack volume; bags of cement/sand; volume of grout; etc.) in the field notebook as well as appropriate field forms.

4. Advance boring to desired depth.
    a. Collect soil and/or bedrock samples at appropriate interval(s), document, and store samples for laboratory analysis as specified in the FIP/Work Plan.
    b. Decontaminate equipment between samples in accordance with the *TGI for Groundwater and Soil Sampling Equipment Decontamination* or if installing monitoring wells for per- and polyfluoroalkyl substances please refer to *TGI for Per- and Polyfluoroalkyl Substances (PFAS) Field Sampling Guide* for both sampling and decontamination guidance.
    c. A common sampling method that produces high-quality soil samples with relatively little soil disturbance is described in *ASTM D1586 – Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils* (ASTM D1586). Split-spoon samples are obtained during drilling using hollow-stem auger, drive-and-wash, spun casing, and fluid/mud rotary.
    d. Sonic 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.
    e. Dual-rotary removes cuttings by compressed air or water/mud and allow only a general assessment of geology.
5. Describe each soil sample as outlined in *TGI for Soil Description* and document descriptions in the field notebook and/or field tablet or field forms and photo document the samples. It should be noted that electronic logs must be 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 boring advancement, document all drilling events in field notebook or field forms, 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 sonic, dual-rotary, or direct-push methods are used.
6. Before installing a screen, it is important to confirm that the borehole has been advanced into the targeted saturated zone. This is particularly important for wells installed to monitor the water table and/or the shallow saturated zone, as the capillary fringe may cause soils above the water table to appear saturated. If one or more previously installed monitoring wells exist nearby, use the depth to water at such well(s) to estimate the water-table depth at the new borehole location.

    NOTE: *To verify that the borehole has been advanced into the saturated zone, it is necessary to measure the water level in the borehole. For boreholes drilled without using water (e.g., hollow-stem auger, cable-tool, air rotary, air hammer), verify the presence of groundwater (and/or LNAPL, if applicable) in the borehole using an electronic water level meter, oil-water interface probe, or a new/decontaminated bailer. For boreholes drilled using water (e.g., drive and wash, spun-casing with roller-bit wash, sonic, or water rotary with core or roller bit), monitor the water level in the borehole as it re-equilibrates to the static level.*

    In low-permeability units like clay, fine-grained glacial tills, shale, and other bedrock formations, it may be necessary to wait overnight to allow the water level to equilibrate. Document depth to water in the borehole on the appropriate field forms and field notebook. If there are questions concerning the depth of the well/screen interval, consult with the project technical lead prior to finalizing well depth/screen interval. To the extent practicable, ensure that the depth of the well below the apparent water table is deep enough so that the installed well can monitor groundwater year-round, accounting for seasonal water-table fluctuations. When in doubt, err on the side of slightly deeper well installation.

7. Upon completing the borehole to the desired depth, if a screened well construction is required, install the monitoring well by lowering the screen and casing assembly through the augers or casing. Monitoring wells typically will be constructed of 2-inch-diameter (although sometimes 4-inch), flush-threaded PVC or stainless steel slotted or wire wrapped 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, according to the well design as outlined in the FIP/Work Plan. The screen length and other construction details will be specified in the FIP/Work Plan based on regulatory requirements and specific monitoring objectives. Monitoring well screens are usually 5 to 10 feet long, but the screen length will depend on the purpose for the well and the objectives of the groundwater investigation and will (in most cases) be determined prior to the field mobilization.

   NOTE: *The slot size and filter pack gradation will be predetermined in the Work Plan (or equivalent) or FSP and based on site-specific grain-size analysis (sieve analysis) or other geologic considerations or monitoring objectives. Consult the Project Hydrogeologist and/or subject matter expert if there are questions/concerns regarding the filter pack and slot size specified. If the screen slot size and filter pack have not been based on site-specific grain-size analysis, consider collecting soil samples during well installation so future wells can be properly designed.*

   NOTE: *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 may be backfilled with filter pack during placement around the well screen.*

8. A blank riser will extend from the top of the screen to the level specified in the FIP/Work Plan (e.g., approximately 2.5 feet above grade if a stick up or just below grade where a flush-mounted monitoring well is specified).

   NOTE: *For wells greater than 50 feet deep, placement of centralizers may be desired to assist in centering the monitoring well in the borehole during installation. Refer to the FIP/Work Plan and/or consult with the Project Hydrogeologist/Technical Lead.*

9. When the monitoring well assembly has been set, using a tremie place the washed silica filter pack in the annular space from the bottom of the boring to a height above the top of the screen as specified in the FIP/Work Plan (typically placed to at least 2 feet above the top of the well screen). The filter pack will be placed, and drilling equipment extracted in increments until the top of the sand pack is at the appropriate depth.

   NOTE: *It is very important to verify that the expected volume of filter pack matches with the actual amount placed. There can be differences due to irregularities in the borehole geometry. Washout of the borehole will result in the need for greater than calculated well materials. If a difference of more than 10% is noted, consult with the Project Hydrogeologist/Technical Lead. The filter pack will be consistent with the screen slot size and the soil particle size in the screened interval, as specified in the FIP/Work Plan.*

10. After placement of the filter pack, preliminary well development is recommended be performed to ensure that the filter pack settles and does not bridge within the annular space and to remove any fines accumulated in the well during installation. This typically entails gently surging the entire well screen to prevent filter pack material bridging and to settle the filter pack prior to well seal installation. For recommended procedures, please refer to the *TGI for Monitoring Well Development*. Monitor the placement of the filter pack (e.g., with a weighted tape measure) and, as necessary during preliminary development (i.e., settlement), add filter pack to ensure proper thickness/height above screen is attained.

11. Depending on the project-specific requirements and applicable federal/state/local regulations, a well seal comprised of either fine sand or hydrated bentonite will then be placed in the annular space above the filter pack, typically at a minimum of 2 feet thick—follow the specifications outlined in the FIP/Work Plan). If non-hydrated bentonite is used, allow sufficient time for hydration to occur (typically a minimum of 30 minutes, but follow manufacturer's recommendations and/or specifications outlined in the FIP/Work Plan). Potable water may be added to hydrate the bentonite if the seal is above the water table. Monitor the placement of the fine sand/bentonite seal (e.g., with a weighted tape measure).

    NOTE: *Coated bentonite pellets are generally not recommended for monitoring well construction because of potential chemical incompatibilities between the coating material and groundwater chemistry.*

12. During the extraction of the augers or casing, a neat cement or cement/bentonite grout will be placed in the annular space from the well seal to a depth as specified in the FIP/Work Plan (e.g., approximately 2 ft. below groundwater surface). It is recommended that grout be placed with a tremie pipe. Ensure that seal materials are mixed at the proper ratios with water following manufacturer's recommendations.

    NOTE: *If it is necessary to install a monitor well into a permeable zone below a confining layer (i.e., confined conditions), 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 may be considered.*

    In this case, the borehole is advanced approximately 3 to 5 feet into the top of the confining layer (depending upon the thickness of the confining layer), and a permanent casing (typically PVC 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 (1) 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; (2) 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 (3) 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. Refer to the FIP/Work Plan, Project Hydrogeologist, and/or subject matter expert for the completion of non-standard monitoring wells, including telescopic wells.

13. Install the monitoring well surface completion as specified in FIP/Work Plan. Typical completions are 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 will slope gently away from the casing to promote drainage away from the well.

14. When an above-grade completion is used, the 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 riser will be sealed using an unvented, expandable locking plug.

15. Monitoring wells will be labeled as specified in the FIP/Work Plan. If not specified, use indelible ink or paint with the appropriate designation on both the inner and outer well casings and/or inside of the curb box lid. If called for, mark a consistent measuring point by cutting a V in the PVC casing or marking the measuring point in black.
16. After completing the well installation, lock the well, clean the area, and dispose of materials in accordance with the procedures outlined in Section 9 below.
17. After completing well installation, finalize documentation and follow data management procedures outlined in Section 10 below.
18. For final well development guidance and procedures, please refer to the *TGI for Monitoring Well Development.*

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 and 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. 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.

If direct-push drilling has been determined to be a viable method for site conditions and project objectives, 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 FIP/Work Plan. Samples will be collected using dedicated, disposable, plastic liners. Collect and describe samples in accordance with the procedures outlined in Steps 4 and 5 above. Collect samples for laboratory analysis as specified in the FIP/Work Plan.
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 filter pack, well seal, and neat cement/cement-bentonite grout will be installed as described, where applicable, in Steps 9 through 12 above.
4. Install surface completion (protective steel casing or flush-mount), as appropriate and as described in Steps 13 through 15 above.
5. After completing the well installation, lock the well, clean the area, and dispose of materials in accordance with the procedures outlined in Section 9 below.
6. After completing well installation, finalize documentation and follow data management procedures outlined in Section 10 below.

Driven Well Point Installation

If specified in the FIP/Work Plan, well points installed by pushing or driving using a drilling rig or direct-push rig (or hand-driven where possible) will typically 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. Refer to the FIP/Work Plan and/or consult with the Project Hydrogeologist/Technical Lead and/or subject matter expert for specific guidance on drive point installation procedures/specifications.

9 Waste Management

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 (or equivalent), FSP, and/or IDW management guidance document.

Investigative-Derived Waste (IDW) generated during drilling activities, including soil and excess drilling fluids (if used), and decontamination liquids, will be stored on site in appropriately labeled containers and disposed of properly. Disposable materials will be stored and disposed of separately. 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 for Investigation-Derived Waste Handling and Storage,* the procedures identified in the FIP/work plan 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.

10 Data Recording and Management

Digital data collection is the Arcadis standard using available FieldNow® applications that enable real-time, paperless data collection, entry, and automated reporting. Paper forms should only be used as backup to FieldNow® digital data collection and/or as necessary to collect data not captured by available FieldNow® applications. The Field Now® digital form applications follow a standardized approach, correlate to most TGIs and are available to all projects accessible with a PC or capable mobile device. Once the digital forms are saved within FieldNow®, the data is instantly available for review on a web interface. This facilitates review by project management team members and SMEs enabling error or anomalous data detection for correction while the staff are still in the field. Continual improvements of FieldNow® applications are ongoing, and revisions are made as necessary in response to feedback from users and subject matter experts.

If not using FieldNow®, all well drilling/installations activities will be documented on appropriate field/log forms as well as in a proper field notebook and/or Personal Digital Assistant (PDA) and/or tablet. All field data will be recorded digitally or with 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. Any deviations or omissions from this TGI will be documented.

Additionally, all documents (and photographs) should 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 well installation activities, soil descriptions, well construction specifications (screen and riser material and diameter, sump length, screen length and slot size, riser length, filter pack type and volume, type of well seal (fine sand or bentonite seal) and volume, type and volume of grout (neat cement or cement-bentonite), and other materials used.

Management of the original documents from the field will be completed in accordance with the site-specific QAPP. Records generated as a result of this TGI will be controlled and maintained in the project record files in accordance with project requirements.

Initial field logs and forms will be transmitted to the Arcadis CPM and/or Technical Lead at the end of each day unless otherwise directed by the CPM. The field team leader retains copies of the field documentation.

Locations of newly installed wells will be documented photographically and/or on a site sketch. If appropriate, a measuring wheel, engineer’s tape, or handheld GPS will be used to determine approximate distances from key site features or estimated coordinates.

The well location, ground surface elevation, and inner and outer casing elevations will be surveyed using the method specified in the FIP/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 (NGVD)of 1929 or North American Vertical Datum (NAVD) of 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 NGVD of 1929 or the NAVD of 1988. A permanent mark will be placed on top of the inner casing to mark the point for water-level measurements.

11 Quality Assurance

Quality assurance procedures will be conducted in accordance with the Arcadis Quality Management System or the site-specific QAPP. Refer to the QAPP or FIP/sampling plan/work plan for specific requirements.

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. All well construction materials will be inspected and cleaned (as necessary) prior to well installation.

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.

12 References

American Society for Testing Materials (ASTM) D5092 - *Standard Practice for Design and Installation of Ground Water Monitoring Wells*. American Society for Testing Materials. West Conshohocken, Pennsylvania.

American Society of Testing and Materials (ASTM) D1586 - *Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils*. American Society for Testing Materials. West Conshohocken, Pennsylvania.

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TGI – Soil Drilling and Sample Collection

Rev: #2

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Version Control

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	0	October 11, 2018	All	Updated and re-written as a TGI	Marc Killingstad
	1	May 12, 2020	None	Review – no changes necessary	Marc Killingstad
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Approval Signatures

Prepared by: 4/8/2022

Chris Shepherd (Preparer) Date

Reviewed by: 4/8/2022

Marc Killingstad (Subject Matter 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. All deviations or omissions should be documented.

2 Intended Use and Responsibilities

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3 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 or weakly consolidated 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*. For per- and polyfluoroalkyl substances (PFASs) drilling and soil sampling procedures, please refer to: *TGI – PFAS-Specific Drilling and Monitoring Well Installation, TGI – Per- and Polyfluoroalkyl Substances (PFAS) Field Sampling Guide*, and *TGI – Equipment and Reagent Blank Sample Collection for PFAS Analysis*.

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: direct-push, 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 rock 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, targeted chemicals, 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, undisturbed cores, 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). Some lubricants (e.g., vegetable oil-based lubricants) may be acceptable, if the constituents won't interfere with the analyses.

4 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.

5 Equipment List

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

- Site-specific HASP and health and safety documents identified in the HASP
- FIP/work plan that includes site map with proposed boring locations, fieldsampling 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
- Including but not limited to disposable chemical resistant gloves and Level D PPE
- 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/soil screening equipment, asneeded, in accordance with the HASP or workplan
- Sampling equipment:
- Drilling equipment required by *ASTM D1586*, when performing split-spoon sampling including clean sample sleeves
- Disposable plastic liners, when drilling with direct-push equipment
- Stainless steel hand auger and stainless-steel spade if using manual methods
- Appropriate soil sampling equipment (e.g., stainless steel spatulas/spoons/bowls, knife)
- Sealable plastic bags (e.g., Ziploc®)

- Air-tight sample containers and 8-oz. glass Mason jars or driller's jars
- Aluminum foil
- 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)
- Sample labels
- Indelible ink pens
- Engineer's ruler or survey rod
- Plastic sheeting (e.g., Weatherall Visqueen)
- Appropriate transport containers (coolers) with ice and appropriate labeling, packing, and shipping materials
- Decontamination equipment (buckets, distilled or deionized water, cleansers appropriate for removing expected chemicals of concern, paper towels) in accordance with the *TGI for Groundwater and Soil Sampling Equipment Decontamination*
- Forms/notes:
    - Tablet with digital forms, etc., if appropriate
    - 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

6 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 in accordance with the work plan, client requirements, and Arcadis guidance. See appropriate guidance forproper 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 uponcompletion 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. Sample container threads should be wiped down with a clean, nonabrasive material (e.g., paper towels) to better ensure the sample container is properly sealed. Be careful not to over-tighten lids with Teflon® liners or septa. Over-tightening can impair the integrity of the seal and cancause 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.*

7 Health and Safety Considerations

The HASP will be followed, as appropriate, to ensure the safety of field personnel. Review all site-specific and procedural hazards as they are provided in the HASP, and review Job SafetyAnalysis (JSA) documents in the field each day prior to beginning work.

Prior to drilling, utility clearance must be performed (see Section 5). Appropriate personal protective equipment (PPE) will be worn at all times in line with the task and thesite-specific HASP.

Working outside at sites with suspected contamination may expose field personnel to hazardous materials such as contaminated groundwater or 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 useof fixed/folding-blade knives and use appropriate hand protection.

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

8 Procedure

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

8.1 Drilling Procedures

8.1.1 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.
    a. Verify utilities were cleared (see Section 5) and use soft dig technique to clear borehole, if applicable
    b. Clean sampling equipment in accordance with the FIP/work plan prior to drilling
2. Advance boring to target depth:
    a. Collect soil samples at appropriate interval as specified in the FIP/work plan (or equivalent) using the appropriate tooling (e.g., split-barrel sampler) and sample containers
        i. Split-barrel or drive-ahead samples are obtained during drilling
        ii. A common sampling method that produces high-quality soil samples with relatively littlesoil disturbance is described in *ASTM D1586 – Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils* (ASTM D1586).
    b. Always change disposable gloves before handling the sampling equipment
    c. Collect, document, and store samples for laboratory analysis as specified in the FIP/work plan (or equivalent; see below for additional details on sample collection procedures)
    d. Field screen samples as specified in the FIP/work plan (or equivalent; see below for additional details on field screening procedures)
    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. The core is retrieved by vibrating the soil/rock into a separate core bag, typically in 5-foot or 10-foot increments. The soil cores may consolidate or expand during retrieval, depending on soils, etc.
    f. Dual-rotary removes cuttings by compressed air or water/mud and allow only a

generalassessment of geology unless separate coring tools and techniques are used

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

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-barrels)
   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
   e. If soils are screened with a PID/FID or another instrument, document the measurement in accordance with the work plan
4. The drilling contractor will be responsible for obtaining accurate and representative samples, informing the supervising Arcadis geologist of changes in drilling pressure, drilling penetration rates, and keeping a separategeneral 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, construction materials that may have been used as fill, etc.
   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 in accordance with the work plan
   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

8.1.2 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 samplingsoil (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 notprovide a cased boring and which limits tremie-grouting from the bottom up.

Direct-push drilling can generally achieve target depths 100 feet or less depending on the site geology. The known or expected site conditions (e.g., presence of NAPL) will be evaluated when selecting the typeof direct-push sampling system to be employed.

1. Find/identify boring location, establish work zone, and set up sampling equipment decontamination area
    a. Verify utilities were cleared (see Section 5) and use soft dig technique to clear borehole, if applicable
    b. Clean sampling equipment in accordance with the FIP/work plan prior to drilling
2. Advance soil boring to target depth.
    a. Collect soil samples at appropriate interval as specified in the FIP/work plan (or equivalent) using clean/disposable sampling equipment (plastic liners)
    b. Always change disposable gloves before handling the sampling equipment
    c. Collect, document, and store samples for laboratory analysis as specified in theFIP/work plan (or equivalent; see below for additional details on sample collection procedures)
    d. Field screen samples as specified in the FIP/work plan (or equivalent; see below for additional details on field screening procedures)
3. Decontaminate equipment between samples in accordance with the FIP/work plan (or equivalent)
4. 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*)

8.1.3 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) and transfer to the appropriate, laboratory-supplied container
    c. Collect, document, and store samples for laboratory analysis as specified in the FIP/work plan (or equivalent; see below for additional details on sample collection procedures)
    d. Field screen samples as specified in the FIP/work plan (or equivalent; see below for additional details on field screening procedures)
6. Decontaminate equipment between samples in accordance with the FIP/work plan (orequivalent)
7. 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*)

8.2 Field Screening Procedures

8.2.1 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. PIDs and FIDs require calibration in accordance with the work plan(s) and manufacturer’s specifications and PIDs should be calibrated based on the target chemicals. The PID employs an ultraviolet lamp to measure VOCs and the ionizationenergy (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 canbe 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 clean, gloved hand. Such readings will be obtained at several locations along the lengthof 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 (see below). After warming, the cover is removed, the foil is pierced withthe PID or FID probe, and a reading is obtained.

Prior to usage, the PID or FID must be calibrated according to the manufacturer's specifications at a minimum frequencyof once per day prior to collecting PID or FID readings. The PID will be calibrated to a benzene-related compound (isobutylene) or other appropriate gas, 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 form.

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.

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

For the second method, a representative portion of the sample will be placed in a pre-cleaned air-tight 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 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 approximately4ºC until screening can be performed.

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

1. Samples will be taken to a warm workspace and allowed to equilibrate to room temperature for atleast one hour.
2. Prior to measuring the soil vapor headspace concentration, the container will be shaken.
3. The headspace of the sample will then be measured directly from the container by piercingthe 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.

8.2.2 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-barrel samplers or direct-push samplers will be collected continuously ahead of the auger, drill casing/rods, or probe rods. Upon opening each split-barrel sampler or direct-push plastic liner sleeve, the soil will immediately be evaluated for the presence of visible NAPL and odors. If suspected NAPL is immediately visible in the sample, its depth will benoted.

Additionally, the soil will be screened for the presence of organic vapors using a PID or FID, in accordance with the work plan, if applicable. During screening, the soil will be split open using a clean spatula or knife and the PID or FID probe will be placedin the opening and covered with a clean, 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 permillion (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 should be added in accordance with the work plan, and the soil and dye will be manually mixed for approximately 30 to 60 seconds and smeared in the dish tocreate 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 in accordance with the work plan
  - 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 ofwater, 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. Further, these tests will only be performed if specified in the work plan(s).*

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, if applicable*.

8.3 Soil Sample Collection for Laboratory Procedures

If not specifically identified in the FIP/work plan, 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 or staining)
3. The relative levels of total VOCs based on field screening measurements
4. The judgment of the field coordinator
5. Moisture content or relative position with regard to apparent groundwater table/saturation

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 analyses, a sufficient amount of the remaining soil willthen 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 samplers 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 and PFAS analysis will NOT be homogenized or composited and will be collected asdiscrete 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 shovelor 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 four 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 orhomogenized sample
6. Place composite or homogenized sample into specified containers
7. Remaining material will be disposed of in accordance with project requirements and applicableregulations
8. Sample containers will be labeled with sample identification number, date, and time of collection andplaced 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).

8.4 Soil Boring Abandonment

All soil borings need to be abandoned in accordance with ***TGI for Monitoring Well and Soil Boring Decommissioning***. See Attachment E of the TGI for specifics.

9 Waste Management

Investigative-Derived Waste (IDW) generated during drilling activities, including soil and excess drilling fluids (if used), and decontamination liquids, will be stored on site in appropriately labeled containers and disposed of properly. Disposable materials will be stored and disposed of separately. 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/work plan 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.

10 Data Recording and Management

Digital data collection is the Arcadis standard using available FieldNow® applications that enable real-time, paperless data collection, entry, and automated reporting. Paper forms should only be used as backup to FieldNow® digital data collection and/or as necessary to collect data not captured by available FieldNow® applications. The Field Now® digital form applications follow a standardized approach, correlate to most TGIs and are available to all projects accessible with a PC or capable mobile device. Once the digital forms are saved within FieldNow®, the data is instantly available for review on a web interface. This facilitates review by project management team members and SMEs enabling error or anomalous data detection for correction while the staff are still in the field. Continual improvements of FieldNow® applications are ongoing, and revisions are made as necessary in response to feedback from users and subject matter experts.

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 digitally or with 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. Any deviations or omissions from this TGI should be documented.

Initial field logs and chain-of-custody records will be transmitted to the Arcadis CPM and Technical Lead at the end of each day unless otherwise directed by the CPM. The field teamleader 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.

11 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.

12 References

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

13 Attachments

Attachment 1. Soil Boring Log Form

Attachment 1

Soil Boring Log Form

BORING LOG

ARCADIS

Boring ID: ____________
Permit ID: ____________
Site Address: ____________
City, State: ____________
Drilling Co: ____________
Driller: ____________
Drilling Method: ____________
Boring Status: ____________

Project Name: ____________
Date Started: ____________
Date Completed: ____________
Total Depth: ____________
Depth to Water: ____________
Hole Diameter: ____________
Core Device: ____________
Drilling Fluid: ____________

Page: ____________
Ground Elevation: ____________
Vertical Datum: ____________
Northing: ____________
Easting: ____________
Horizontal Datum: ____________
Prepared by: ____________
Reviewed by: ____________

Drilling Information				Primary Texture											Soil Description (Udden-Wentworth System)	Field Notes
Drilling Depth (ft bgs)	Core Interval (ft)	Core Recovery (inches)	PID Reading (ppm)	Fines		Sand					Gravel				Depth interval (ft), Moisture, PRIMARY TEXTURE, Modifier/Minor Texture, Sorting, Angularity, Consistency, Plasticity, Color - Only Record Sand Density with Standard Penetration Tests Minor Texture Modifiers: Trace (<10%), Little (10 to 20%), Some (21 to 35%), And (36 to 50%)	Driller's Observations, Particle Size Percentages, Geologic Formation, Field Screening Results, Sample Interval etc.
				clay	silt	very fine	fine	medium	coarse	very coarse	granule	pebble	cobble	boulder		

BORING LOG

ARCADIS

Boring ID: ____________ **Project Name:** ____________ **Page:** ____ / ____

Drilling Information				Primary Texture											Soil Description (Udden-Wentworth System)	Field Notes
				Fines		Sand					Gravel					
Drilling Depth (ft bgs)	Core Interval (ft)	Core Recovery (inches)	PID Reading (ppm)	clay	silt	very fine	fine	medium	coarse	very coarse	granule	pebble	cobble	boulder	Depth interval (ft), Moisture, PRIMARY TEXTURE, Modifier/Minor Texture, Sorting, Angularity, Consistency, Plasticity, Color - Only Record Sand Density with Standard Penetration Tests Minor Texture Modifiers: Trace (<10%), Little (10 to 20%), Some (21 to 35%), And (36 to 50%)	Driller's Observations, Particle Size Percentages, Geologic Formation, Field Screening Results, Sample Interval etc.

BORING LOG

ARCADIS

Boring ID: ____________ **Project Name:** ____________ **Page:** ___/___

Drilling Information				Primary Texture											Soil Description (Udden-Wentworth System)	Field Notes
				Fines		Sand					Gravel				Depth interval (ft), Moisture, PRIMARY TEXTURE, Modifier/Minor Texture, Sorting, Angularity, Consistency, Plasticity, Color - Only Record Sand Density with Standard Penetration Tests Minor Texture Modifiers: Trace (<10%), Little (10 to 20%), Some (21 to 35%), And (36 to 50%)	Driller's Observations, Particle Size Percentages, Geologic Formation, Field Screening Results, Sample Interval etc.
Drilling Depth (ft bgs)	Core Interval (ft)	Core Recovery (inches)	PID Reading (ppm)	clay	silt	very fine	fine	medium	coarse	very coarse	granule	pebble	cobble	boulder		

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ATTACHMENT B

LABORATORY SOPs

SOIL PREPARATION PROCEDURES FOR ICP AND ICP/MS

(Methods: EPA 3050B, EPA 3051A and DI Leach by ASTM D3987-85)

Approvals (Signature/Date):

Adriana Geiger	08/12/2022
Adriana Geiger Department Manager	Date
Kimberly Chamberlain	08/12/2022
Kimberly Chamberlain Quality Assurance Manager / Technical Director / Environmental Health & Safety Coordinator	Date

Facility Distribution No. ____1______ **Distributed To: LIMS File System Shares**

1.0 Scope and Application

This SOP gives the procedures for the digestion soil samples for the determination of total metals prior to analysis by ICP (SOP SA-ME-070: *Elements by ICP*) or ICP/MS (SOP SA-ME-074: *Elements by ICP/MS)*.

Note: The routine matrix for this procedure is soil; however, this procedure may be adapted to accommodate other matrices as outlined in Section 16.1.

A complete target analyte list, the reporting limits (RL), the method detection limits (MDL), and the accuracy and precision criteria associated with this procedure are provided in the LIMS Method Limit Groups (MLGs).

This SOP was written by and for Eurofins Savannah laboratory.

2.0 Summary of Method

EPA 3050B:
A known weight (approximately 1 g) of the well-mixed sample is transferred to a suitable digestion vessel. The sample is digested with aliquots of nitric acid and hydrogen peroxide to break down the organics present in the sample. After the sample has been digested, as evidenced by a clear, pale yellow digestate, HCl is added to give an approximate acid concentration of 10% HCl and 5% HNO_3. Then the sample digest is diluted to 100 mL with reagent water.

A smaller weight of sample may be digested and the sample brought to a final volume that is proportional to the 1 g sample to 100 mL final volume ratio. For example, if 0.50 g is digested, the final volume of the digestate must be 50 mL to achieve the same reporting limits.

Note: For silica samples for EPA 6010C or EPA 6010D, solid samples are extracted with reagent water using a DI Leach procedure and then filtered. The filtered solid extracts are analyzed by ICP.

EPA 3051A:

A known weight (approximately 0.5 g) of the well mixed sample is transferred to a microwave vessel. Concentrated nitric acid and hydrochloric acid is added to the vessel, the vessel is sealed and heated in the microwave for a specified amount of time. After cooling, the contents are diluted, filtered and allowed to settle then analyzed by the appropriate method.

This SOP is based on the following methods: SW-846 Method 3050B and 3051A. Silica soil preparation guidance is taken from ASTM Method D3987-85.

3.0 Definitions

Refer to the Glossary Section of the *Quality Assurance Manual* (QAM) for a complete listing of applicable definitions and acronyms.

4.0 Interferences

4.1 Procedural Interferences

4.1.1 Interferences may be caused by contaminants in solvents, reagents, glassware, and other sample processing apparatus and can make identification and/or quantification of the target analytes difficult.

4.1.2 All sample collection containers are single-use disposable containers which limits the potential for contamination. All non-disposable labware must be scrupulously cleaned in accordance with the posted Labware Cleaning Instructions in attachment 5 to ensure it is free from contaminants and does not contribute artifacts.

4.1.3 High purity reagents and solvents are used to help minimize interference problems. Hydrochloric acid, hydrogen peroxide, and nitric acid must be verified prior to use in accordance with the Eurofins Environment Testing America Solvent Lot Testing Program (NDSC-QA-SOP46704: *Acid and Solvent Testing and Approval Program*).

4.1.4 Instrument and/or method blanks are routinely used to demonstrate all reagents and apparatus are free from interferences under the conditions of the analysis.

4.2 Matrix Interferences

4.2.1 Matrix interferences may be caused by contaminants that are co-extracted from the sample matrix.

4.2.2 Interfering contamination may occur when a sample containing low concentrations of analytes is analyzed immediately following a sample containing relatively high concentrations of analytes. As such, samples known to be clean should be analyzed first. To prevent carryover into subsequent samples, analysis of reagent blanks may be needed after the analysis of a sample containing high concentrations of analytes.

5.0 Safety

Employees must abide by the policies and procedures in the Eurofins Environmental Health and Safety Manual (EHSM), the Eurofins Savannah Addendum to the EHSM, and this document.

This procedure may involve hazardous materials, operations, and equipment. This SOP does not purport to address all of the safety problems associated with its use. It is the responsibility of the user to follow appropriate safety, waste disposal, and health practices under the assumption that all samples and reagents are potentially hazardous.

The analyst must protect himself/herself from exposure to the sample matrix. Many of the samples that are tested may contain hazardous chemical compounds or biological organisms. The analyst must, at a minimum, wear protective clothing (lab coat), eye protection (safety glasses or face shield), disposable nitrile or latex gloves, and closed-toe, nonabsorbent shoes when handling samples.

5.1 Specific Safety Concerns or Requirements

Nitric and hydrochloric acids are extremely hazardous as oxidizers, corrosives, poisons, and are reactive. Inhalation of the vapors can cause coughing, choking, irritation of the nose, throat, and respiratory tract, breathing difficulties, and lead to pneumonia and pulmonary edema. Contact with the skin can cause severe burns, redness, and pain. Nitric acid can cause deep ulcers and staining of the skin to a yellow or yellow-brown color. These acid vapors are irritating and can cause damage to the eyes. Contact with the eyes can cause permanent damage. Procedures that utilize the addition of concentrated acids must be performed under a fully functioning fume hood.

Samples that contain high concentrations of carbonates or organic matter, or samples that are at elevated pH can react violently when acids are added. Acids must be added to samples under a hood to avoid splash/splatter hazards and/or possibly toxic vapors that will be given off when the samples are acidified.

Hydrogen peroxide is a strong oxidizer that can cause a fire when it comes into contact with materials. Contact with the skin or eyes can cause irritation and burns.

The reagent combination (9 mL nitric acid to 3 mL hydrochloric acid) used in EPA 3051A results in greater pressures than those resulting from the use of only nitric acid. These higher pressures necessitate the use of vessels having higher pressure capabilities (30 atm or 435 psi).

The outer layers of microwave vessels are frequently not as acid or reagent resistant as the liner material. In order to retain the specified performance and safety requirements, these outer layers must not be chemically degraded or physically damaged. Routine examination of the vessel materials is necessary to ensure their safe use.

The microwave uses sealed containers with pressure relief devices. Temperature is the important variable controlling the reaction. Pressure is needed to attain elevated temperatures, but must be safely contained. Some digestion vessels constructed from certain fluorocarbons may crack, burst, or explode in the unit under certain pressures. Only vessels approved by the manufacturer of the microwave system being used are considered acceptable.

When acids, such as nitric and hydrochloric, are used to effect sample digestion in microwave units in open vessel(s) or sealed vessel(s), there is the potential for any released acid vapors to corrode the safety devices that prevent the microwave magnetron from shutting off when the door is opened. This can result in operator exposure to microwave energy. Use of a laboratory-grade microwave equipment system with isolated and corrosion resistant safety devices to prevent this from occurring.

5.2 Primary Materials Used

The following is a list of the materials used in this procedure, which have a serious or significant hazard rating, and a summary of the primary hazards listed in their MSDS/SDS.

Note: This list does not include all materials used in the procedure. A complete list of materials used in this procedure can be found in the Reagents and Standards Section and the Equipment and Supplies Section of this SOP

Employees must review the information in the MSDS/SDS for each material before using it for the first time or when there are major changes to the MSDS/SDS. Electronic copies of MSDS/SDS can be found using the "Login/MSDSonline" link on the EETA homepage.

Material	Hazards	Exposure Limit[1]	Signs and Symptoms of Exposure
Hydrochloric Acid[2]	Corrosive Poison	5 ppm Ceiling	Inhalation of vapors can cause coughing, choking, inflammation of the nose, throat, and upper respiratory tract, and in severe cases, pulmonary edema, circulatory failure, and death. Can cause redness, pain, and severe skin burns. Vapors are irritating and may cause damage to the eyes. Contact may cause severe burns or permanent eye damage.
Nitric Acid[2]	Corrosive Oxidizer Poison	2 ppm TWA 4 ppm STEL	Nitric acid is extremely hazardous; it is corrosive, reactive, an oxidizer, and a poison. Inhalation of vapors can cause breathing difficulties and lead to pneumonia and pulmonary edema, which may be fatal. Other symptoms may include coughing, choking, and irritation of the nose, throat, and respiratory tract. Can cause redness, pain, and severe skin burns. Concentrated solutions can cause deep ulcers and stain skin a yellow or yellow-brown color. Vapors are irritating and may cause damage to the eyes. Contact may cause severe burns and permanent eye damage.
Hydrogen Peroxide	Corrosive Oxidizer	1 ppm TWA	Danger! Strong oxidizer. Contact with other material may cause a fire. Corrosive. Light sensitive. May be harmful if swallowed. May cause central nervous system effects. Eye contact may result in permanent eye damage. May cause severe respiratory tract irritation with possible burns. Causes eye and skin irritation and possible burns. May cause severe digestive tract irritation with possible burns.

[1] Exposure limit refers to the OSHA regulatory exposure limit.

[2] Always add acid to water to prevent violent reactions.

6.0 Equipment and Supplies

6.1 Equipment and Instrumentation

Top-loading Balance - Verify in accordance with SOP SA-AN-100: *Laboratory Support Equipment (Verification and Use)*

Thermometers - Verify in accordance with SOP SA-AN-100: *Laboratory Support Equipment (Verification and Use)*

Digestion Block - capable of maintaining a sample temperature of 95±5°C – The temperature of the digestion block must be monitored and recorded for each batch. The temperature is measured using an external thermometer placed in a digestion vessel containing reagent water.

Microwave - Performance requirements necessitate the microwave decomposition system to sense the temperature to within ±2.5 °C and automatically adjust the microwave field output power within 2 seconds of sensing. Temperature sensors should be accurate to ±2°C (including the final reaction temperature of 175±5°C). Temperature feedback control provides the primary performance mechanism for the method.

Microwave Vessels - Microwave transparent and reagent resistant materials such as fluorocarbon polymers (examples are PFA or TFM) to contain samples. The internal volume of the vessel should be at least 45 mL, and the vessel must be capable of withstanding pressures of at least 30 atm (435 psi), and capable of controlled pressure relief.

Agitation/Leaching Equipment – capable of holding the sample containers and rotating around a central axis at 23-35 rpm.

6.2 Lab Supplies

- 0.45 um Syringe Filters and syringes

- Disposable watch glasses

6.3 Volumetric Labware

Volumetric Containers – various sizes; Class A, where applicable. Verify in accordance with SOP SA-AN-100: *Laboratory Support Equipment (Verification and Use)*. Refer to Attachment 5 for Labware Cleaning Procedures.

Volumetric Labware	Volume	Type (Quantitative / Qualitative)	Use	Verification Frequency	Laboratory Verification Criteria
Eppendorf-Style Pipettes	Various	QUANTITATIVE	Standard Preparation and Spiking	Initially, prior to first use, then quarterly thereafter (Daily for DOD)	Accuracy = 2% Precision = 1%
Digestion Tubes	50-100 mL	QUANTITAIVE	Final Sample Volumes	None (if purchased w/ COA attesting Class A criteria)	None (if purchased w/ COA attesting Class A criteria)
Pump-Style Pipettes	Various	Qualitative	To deliver acids	Initially, upon 1st use	Accuracy = 10% Precision = 10%

6.4 Sample Collection Containers

All sample collection containers are single-use disposable containers which limits the potential for contamination.

The routine sample collection containers supplied by the laboratory are:

4oz plastic or glass soil jar – purchased with Certificate of Analysis attesting to purity.

7.0 Reagents and Standards

7.1 Expiration Dates

Expiration dates (time from initial use or receipt to final use) for standard and reagent materials must be set according to the guidance in this SOP. **Note:** These are maximum expiration dates and are not to be considered an absolute guarantee of standard or reagent quality. Sound judgment must be used when deciding whether to use a standard or reagent. If there is doubt about the quality of a standard or reagent material, a new material must be obtained or the standard or reagent material verified. Data quality must not be compromised to extend a standard's life.

The expiration date of any standard or reagent must not exceed the expiration date of the standard or reagent that was used to prepare it.

7.2 Reagents

Reagents must be prepared and documented in accordance with SOP SA-AN-041: *Reagent and Standard Materials Procedures.*

Hydrochloric acid, hydrogen peroxide, and nitric acid must be verified prior to use in accordance with the Eurofins Environment Testing America Solvent Lot Testing Program (NDSC-QA-SOP46704: *Acid and Solvent Testing and Approval Program*).

7.2.1 Blank Matrix – Teflon chips or equivalent. Used for the preparation of soil QC samples.
LIMS Name: P_TEFLONCH_xxxxx
Storage: Room Temperature
Expiration:
Unopened: Manufacturer's expiration date
Opened: 5 years from date opened

7.2.2 Laboratory Reagent Water – ASTM Type II – Laboratory Generated DI water; the conductivity must be checked daily in accordance with SOP SA-AN-100: *Laboratory Support Equipment (Verification and Use)*.

7.2.3 Nitric acid (HNO_3) – reagent grade (Macron Chemicals)
LIMS Name: ME_HNO3_XXXX
Storage: room temperature in the acid cabinet. Store in a cool, dry, ventilated storage area with acid resistant floors and good drainage. Store away from sunlight, heat, water, and incompatible materials. Stable under ordinary conditions of use and storage.
Expiration:
Unopened: Manufacturer's expiration date or 5 years, whichever is sooner
Opened: Manufacturer's expiration date or 5 years, whichever is sooner

7.2.5 Hydrochloric acid (HCl) – reagent grade (JT Baker)
LIMS Name: ME_HCL_XXXX
Storage: room temperature in the acid cabinet. Store in a cool, dry, ventilated storage area with acid resistant floors and good drainage. Store away from sunlight, heat, water, and incompatible materials. Stable under ordinary conditions of use and storage.
Expiration:
Unopened: Manufacturer's expiration date or 5 years, whichever is sooner.
Opened: Manufacturer's expiration date or 5 years, whichever is sooner.

7.2.7 Hydrogen peroxide (H_2O_2), 30% – reagent grade.
LIMS Name: ME_PEROX_XXXX
Storage: refrigerated between 0°C and 6°C. Separate from incompatibles.
Expiration:
Unopened: Manufacturer's expiration date
Opened: Manufacturer's expiration date

7.3 <u>Standards</u>

Standards must be prepared and documented in accordance with SOP SA-AN-041: *Reagent and Standard Materials Procedures.* Certificates of analysis or purity must be received with all purchased standards, and scanned and attached in LIMS.

7.3.1 Stock Standards – purchased from CPI, Inorganic Ventures, or equivalent vendor, at the concentrations listed below.

Aluminum – 10000 mg/L; LIMS Reagent Name: Alspx10000
Antimony – 1000 mg/L; LIMS Reagent Name: Sbcpi1000
Arsenic – 1000 mg/L; LIMS Reagent Name: Ascpi1000
Barium – 1000 mg/L; LIMS Reagent Name: Bacpi1000

Beryllium – 1000 mg/L; LIMS Reagent Name: Becpi1000
Boron – 1000 mg/L; LIMS Reagent Name: Bcpi1000
Cadmium – 1000 mg/L; LIMS Reagent Name: Cdcpi1000
Calcium – 10000 mg/L; LIMS Reagent Name: Caspx10000
Chromium – 1000 mg/L; LIMS Reagent Name: Crcpi1000
Cobalt – 1000 mg/L; LIMS Reagent Name: Cocpi1000
Copper – 1000 mg/L; LIMS Reagent Name: Cucpi1000
Iron – 10000 mg/L; LIMS Reagent Name: Fecpi10000
Lead – 1000 mg/L; LIMS Reagent Name: Pbcpi1000
Magnesium – 10000 mg/L; LIMS Reagent Name: Mgspx10000
Manganese – 1000 mg/L; LIMS Reagent Name: Pbcpi1000
Mercury – 1000 mg/L; LIMS Reagent Name: Hgspex1000
Molybdenum – 1000 mg/L; LIMS Reagent Name: Mocpi1000
Nickel – 1000 mg/L; LIMS Reagent Name: Nicpi1000
Potassium – 10000 mg/L; LIMS Reagent Name: Kcpi10000
Selenium – 1000 mg/L; LIMS Reagent Name: Secpi1000
Silver – 1000 mg/L; LIMS Reagent Name: Agcpi1000
Sodium – 10000 mg/L; LIMS Reagent Name: Nacpi10000
Strontium – 1000 mg/L; LIMS Reagent Name: SrABS1000
Thallium – 1000 mg/L; LIMS Reagent Name: Tlcpi1000
Tin – 1000 mg/L; LIMS Reagent Name: Sncpi1000
Titanium – 1000 mg/L; LIMS Reagent Name: Ticpi1000
Vanadium – 1000 mg/L; LIMS Reagent Name: Vcpi1000
Zinc – 1000 mg/L; LIMS Reagent Name: Zncpi1000

Storage: room temperature. Store away from sunlight, heat, water, and incompatible materials.
Expiration: opened and unopened containers are given the manufacturer's expiration date

7.3.2 Silica/Silicon Standards

Silicon (Si) stock solutions are usually purchased for this procedure. The following conversion is used to adjust any volumes or concentrations appropriately:

$$Si = \frac{SiO_2}{2.14}$$

7.3.2.1 Stock SiO_2 Standard, 10000 mg/L Si / 21400 mg/L SiO_2 – purchased from CPI.
LIMS Name: Sicpi10000_xxxxx
Storage: Store at room temperature in a cool, dry, ventilated storage area with acid resistant floors and good drainage. Store away from sunlight, heat, water, and incompatible materials.
Expiration: This standard must be used by the manufacturer's expiration date.

Silicon (Si) stock solutions are usually purchased for this procedure. The following conversion is used to adjust any volumes or concentrations appropriately:

$$Si = \frac{SiO_2}{2.14}$$

7.3.2.2 Intermediate SiO_2 Standard, 467 mg/L Si /1000 mg/L SiO_2 – Add 20 mL to 30 mL of reagent water to a clean, plastic 100 mL volumetric flask. Add the volume of the Stock SiO_2 Standard given in the table below to the volumetric flask. Dilute to volume with reagent water. Store the standard at room temperature. This standard must be used by its parent standard's expiration date or within 6 months of preparation, whichever comes first.

Element	Parent Concentration (mg/L)	Volume Added (mL)	Final Volume (mL)	Final Concentration (mg/L)
Silica (SiO_2) [Silicon (Si)]	21400 [10000]	4.67	100	1000 [467]

LIMS Name: P_SiO2_INT_xxxxx
Storage: Store in a cool, dry, ventilated storage area with acid resistant floors and good drainage. Store away from sunlight, heat, water, and incompatible materials.
Expiration: Prepare this solution every 180 days (6 months) or sooner as needed or required. The expiration date must not exceed the expiration date of any of the components.

7.3.5 Spiking Solution 1 – Add approximately 50 mL reagent water to a clean 100 mL volumetric flask. Add 2 mL of concentrated nitric acid and 0.5 mL of concentrated hydrochloric acid to the volumetric flask. The standard will have an acid concentration of 2% HNO_3 and 0.5% HCl when diluted to volume.

Add the volumes of the stock standards given in the following table to the volumetric flask:

Element	Parent Concentration (mg/L)	Volume Added (mL)	Final Volume (mL)	Final Concentration (mg/L)
Aluminum (Al)	10000	5	100	500
Antimony (Sb)	1000	5		5
Arsenic (As)	1000	1		10
Barium (Ba)	1000	1		10
Beryllium (Be)	1000	0.5		5
Boron (B)	1000	2		20
Cadmium (Cd)	1000	0.5		5
Calcium (Ca)	10000	5		500
Chromium (Cr)	1000	1		10
Cobalt (Co)	1000	0.5		5
Copper (Cu)	1000	1		10

Iron (Fe)	10000	5		500
Lead (Pb)	1000	5.0		50
Magnesium (Mg)	10000	5		500
Manganese (Mn)	1000	5		50
Molybdenum (Mo)	1000	1		10
Nickel (Ni)	1000	1		10
Potassium (K)	10000	5		500
Selenium (Se)	1000	1		10
Sodium (Na)	10000	5		500
Strontium (Sr)	1000	1		10
Thallium (Tl)	1000	0.4		4.0
Tin (Sn)	1000	2		20
Titanium (Ti)	1000	1		10
Vanadium (V)	1000	1		10
Zinc (Zn)	1000	1		10

Dilute to volume with reagent water.

LIMS Name: MS_LCS1_wk_xxxxx
Storage: room temperature Expiration: 6 months of preparation or sooner based on the manufacturer's expiration date.

7.3.6 Spiking Solution 2 – Add approximately 50 mL reagent water to a clean 100 mL volumetric flask. Add 10 mL of concentrated hydrochloric acid to the volumetric flask. The standard will have an acid concentration of 10% HCl when diluted to volume.

Add the volumes of the stock standards given in the following table to the volumetric flask:

Element	Parent Concentration (mg/L)	Volume Added (mL)	Final Volume (mL)	Final Concentration (mg/L)
Mercury (Hg)	1000	0.05	100	0.5

Dilute to volume with reagent water.
LIMS Name: MS_lcs2_wk_xxxxx
Storage: room temperature
Expiration: 28 days of preparation or sooner based on the manufacturer's expiration date.

7.3.7 Spiking Solution 3 – Add approximately 50 mL reagent water to a clean 100 mL volumetric flask. Add 10 mL of concentrated hydrochloric acid to the volumetric flask. The standard will have an acid concentration of 10% HCl when diluted to volume.

Add the volumes of the stock standards given in the following table to the volumetric flask:

Element	Parent Concentration (mg/L)	Volume Added (mL)	Final Volume (mL)	Final Concentration (mg/L)
Silver (Ag)	1000	0.5	100	5

Dilute to volume with reagent water.
LIMS Name: MS_Ag_LCS_SPKxxxxx
Storage: room temperature
Expiration: 6 months of preparation or sooner based on the manufacturer's expiration date.

8.0 Sample Collection, Preservation, Shipment, and Storage

8.1 Soil Samples

Soil samples are routinely collected in 4oz plastic or glass soil containers.

Samples must be iced at the time of collection and maintained at 0-6°C (less than 6°C but not frozen) until the time of digestion/leaching. Samples for mercury must be digested/leached and analyzed within 28 days of collection. All other samples must be digested and analyzed within 6 months of collection. Digestates may be stored at room temperature until the time of analysis.

9.0 Quality Control

SOP SA-QA-017: *Evaluation of Batch QC Data* and the SOP Summary in Attachment 3 provide requirements for evaluating QC data.

9.1 Batch QC

A digestion batch consists of up to 20 environmental samples and the associated QC items. The default QC items performed for each digestion batch are: a method blank, a laboratory control sample (LCS), a matrix spike (MS), and a matrix spike duplicate (MSD) or sample duplicate (SD).

The routine container supplied for this method 4 oz (soil) container. Using EPA 3050B 1 g is required for digestion. It is unlikely that insufficient sample would be provided to meet the batch QC frequency. If insufficient sample is provided, reduced sample initial weights may be used to achieve the required batch matrix spike frequency; however, the minimum extraction weight to be used for the matrix spike samples is 0.5 g.

Note: Final volumes and spike amounts must be adjusted to compensate for these reduced initial volumes.

Note: Unless the client has specified which sample to use as the matrix spike, the matrix spike must be selected at random from the samples in the batch. Field QC (e.g., equipment blanks, trip blanks, and field blanks) must not be used for MS/MSD unless specifically requested to do so by the client or unless there is insufficient sample available for performing MS/MSD using an actual field sample.

If there is insufficient sample to perform the required matrix spike(s) and/or sample duplicates, the LCS must be prepared in duplicate (i.e., LCS/LCSD). An NCM must be initiated on all affected samples to denote this situation. Insufficient sample is defined as receiving less than a total of 2 g.

Batch QC must meet the criteria given in Attachment 3 of this SOP.

9.2 Instrument QC

The instrument QC requirements for the analytical procedures associated with this digestion procedure are given in SOP SA-ME-070: *Elements by ICP* or SOP SA-ME-074: *Elements by ICP/MS.*

9.3 Corrective Action for Out-of-Control Data

When the quality control parameters do not meet the criteria set forth in this SOP, corrective action must be taken in accordance with SOP SA-QA-005: *Preventive and Corrective Action Procedures* the QC Summary Table in Attachment 3. SOP SA-QA-005 provides contingencies for out-of-control data and gives guidance for exceptionally permitting departures from approved policies and procedures. Nonconformance Memos must be initiated to document all instances where QC criteria are not met and all departures from approved policies and procedures.

10.0 Procedure

10.1 Sample Preparation

10.1.1 EPA 3050B Sample Preparation

10.1.1.1 Remove the samples from the refrigerator and allow them to come to room temperature.

10.1.1.2 Soil samples must be homogenized prior to preparation in accordance with SOP SA-QA-015: *Homogenization, Compositing, and Segregation of Samples*.

10.1.1.3 Weigh 1.0-1.2 g (wet weight) of each homogeneous sample into a 100 mL digestion vessel. The lab may weigh a larger aliquot equal to 1.00 g of sample on a dry weight basis, if required.

Note: A smaller weight of sample may be digested and the sample brought to a final volume that is proportional to the 1 g sample to 100 mL final volume ratio. For example, if 0.50 g is digested, the final volume of the digestate must be 50 mL to achieve the same reporting limits; if 0.1 g is digested, the final volume of the digestate must be 10mL. If the sample weight to final volume ratio is less than 1:100, the reporting limits will be higher than those listed in the LIMS MLGs. Adjust the volumes of spikes and reagents proportionately to compensate for the sample weight/final volume. For example, if 0.5 g is digested, use ½ of the spike and reagent volumes listed above.

10.1.1.4 Add 5 mL of reagent water, 5 mL of concentrated HNO_3, and 2.5 mL of HCL to each digestion vessel and swirl the vessel to mix the contents. Perform this step under a fume hood.

10.1.1.5 Place the digestion vessels on the digestion block and cover with a watchglass. The water in the digestion block must be 95°C +/- 5°C. Carefully heat the covered vessel until a gentle reflux is achieved. The sample is not heated to boiling; that is, bubbles are not formed in the liquid in the bottom of the digestion vessel. The sample/acid solution is refluxing when the liquid evaporates and drops of liquid condense on the sides of the digestion vessel and fall back into the digestion vessel. Do not allow the samples to boil. Reflux for 10-15 minutes.

NOTE: To verify temperature of the hotblock, a digestion tube filled with DI water must be placed at random locations across each block used for digestion. This position must be changed daily. A single thermometer is transferred from block to block and a minimum of 10 minutes allowed for the thermometer to equilibrate before taking the reading. This temperature reading, uncorrected and corrected, is then recorded in the batch information.

10.1.1.6 Remove the digestion vessels from the digestion block, and allow them to cool to room temperature. Add 5 mL of concentrated HNO_3 to each sample. Return the covered digestion vessels to the digestion block. Carefully heat the covered digestion vessels until a gentle reflux is achieved. Reflux the samples for at least 30 minutes. Do not allow the samples to boil.

If brown fumes are given off during reflux, remove the vessels from the digestion block, allow to cool, add a second 5 mL portion of HNO_3, and reflux (covered) for at least 30 more minutes. Repeat this step until no brown fumes are given off.

10.1.1.7 Evaporate the covered sample digestate to approximately 5 mL without boiling or heat for 2 hours without boiling. Do not allow the bottom of the digestion vessels to go dry during the evaporation. Remove the samples from the digestion block, and allow the samples to cool to room temperature before continuing onto the next step.

Note: If the sample is still warm when the 30% hydrogen peroxide (H_2O_2) is added in the next step, the sample may "boil over" and the entire process must be started over.

10.1.1.8 Add 2 mL of reagent water to each digestion vessel. Slowly and carefully add 3 mL of 30% H_2O_2 to each digestion vessel. It is very important to add the hydrogen peroxide slowly to prevent loss of sample due to vigorous effervescence. Return the covered digestion vessels to the digestion block, and heat until the effervescence subsides. Cool the digestion vessels after the effervescence subsides.

10.1.1.9 Continue to add 30% H_2O_2 in 1-3 mL aliquots to the sample digestate until the effervescence is minimal or until the general appearance of the digestate is unchanged. Warm the covered sample digestate after each addition of H_2O_2 on the digestion block.

Note: Do not add more than 10 mL of hydrogen peroxide to each sample.

10.1.1.10 After the last addition of peroxide, return the covered samples to the digestion block and reduce the volume of the digestate to approximately 5 mL without boiling or heat for 2 hours without boiling and without allowing the bottom of the digestion vessel to go dry. Remove samples, allow to cool, and add 10 mL of concentrated HCl to each sample digestate. Return the covered digestion vessels to the digestion block, and reflux the sample digestates for 10-15 minutes.

10.1.1.11 Remove samples from the digestion block, allow to cool, and wash down the inside of the digestion vessels with reagent water. Carefully rinse the watch glass into the digestion vessel with reagent water. Dilute the sample digestate to 100 mL with reagent water.

10.1.2 EPA 3051A - Microwave Sample Preparation

10.1.2.1 Remove the samples from the refrigerator and allow them to come to room temperature.

10.1.2.2 Soil samples must be homogenized prior to preparation in accordance with SOP SA-QA-015: *Homogenization, Compositing, and Segregation of Samples*.

10.1.2.3 Weigh 0.45 g- 0.50 g (wet weight) of each homogeneous sample into a microwave tube. No more than 0.50 g may be used in the vessel.

10.1.2.4 Add approximately 9 mL of concentrated Nitric acid and 3 mL of Hydrochloric acid to the vessel.

10.1.2.5 Place the digestion tube into the carousel. Place the carousel into the microwave.

10.1.2.6 Select program US EPA 3051 A to begin digestion process.

10.1.2.7 At the end of the microwave program, allow the vessels to cool. The analyst should determine if the vessels have maintained their seal through the digestion process by monitoring the liquid level inside the vessel before and after digestion as well as inspecting the seal threads of the cap and vessel.

10.1.2.8 Carefully uncap the vessels in a hood and quantitatively transfer the sample to a 50 mL volumetric digestion tube using reagent water to carefully rinse the vessel into the collection container. Dilute the sample digestate to 50 mL with reagent water.

10.1.2.9 If the digested sample contains particulates which may clog nebulizers or interfere with injection of the sample into the instrument, the sample may be centrifuged to allow the sample to settle or filtered.

Centrifugation - Centrifugation at 2,000 - 3,000 rpm for 10 min is usually sufficient to clear the supernatant.

Settling - If undissolved material, such as SiO_2, TiO_2 or other refractory oxides remain, allow the sample to stand until the supernatant is clear. Allowing a sample to stand overnight will usually accomplish this. If it does not, centrifuge or filter the sample.

Filtering - If necessary, the filtering apparatus must be thoroughly cleaned and pre-rinsed with dilute (approximately 10% V/V) nitric acid. Filter the sample through qualitative filter paper into a second acid-cleaned container.

10.1.3 Silica (DI Leach) Sample Preparation

Solid and waste samples for silica are extracted by performing a DI leaching procedure. **Note:** Any QC samples which need the DI leach procedure (i.e. LCS, MS/MSD, IDOCs/CDOCs, MDL studies, etc.) need to be appropriately spiked prior to the leaching procedure.

10.1.3.1 Remove the samples from the refrigerator and allow them to come to room temperature.

10.1.3.2 Soil samples must be homogenized prior to preparation in accordance with SOP SA-QA-015: *Homogenization, Compositing, and Segregation of Samples*.

10.1.3.3 To a 125 mL plastic container weigh a 4.5-5.5 g portion of homogenized sample.

Note: Different initial weights may be used as long as the extraction fluid to sample ratio remain the same.

10.1.3.4 Add 100 mL of reagent water to each sample container (or a volume equal to 20 times the weight of the samples used).

10.1.3.5 Agitate (leach) continuously for 18 ± 2 hours at 23-35 rpm.

10.1.3.6 After the extraction period, allow the sample to settle and filter a portion for analysis through a 0.45 um filter. The sample may be allowed to settle, centrifuged, decanted, or filtered through coarse filter paper before the final filtration to remove the solid phase. The method blank and laboratory control sample must be treated the same as the samples (i.e., same volumes and same number of filter pads) so that an adequate background, contamination, and recovery checks can be made.

10.2 QC Sample Preparation

10.2.1 EPA Method 3050B QC Sample Preparation

10.2.1.1 Method Blank – Weigh a 1.0-1.2 g aliquot of blank matrix into a labeled digestion vessel and prepare as listed in Section 10.1.1.

10.2.1.2 Laboratory Control Sample – Weigh a 1.0-1.2 g aliquot of blank matrix into a labeled digestion vessel, add 1.0 mL of each spiking solution (Spike I, Spike 2 and Spike 3) and prepare as listed in Section 10.1.1.

10.2.1.3 Matrix Spike / Matrix Spike Duplicate – Weigh out 2 separate 1.0-1.2 g aliquots of the sample chosen for the matrix spike into a labeled digestion vessel. Add 1.0 mL of each spiking solution (Spike I, Spike 2, and Spike 3) and prepare as listed in Section 10.1.1.

10.2.2 EPA Method 3051A QC Sample Preparation

10.2.2.1 Method Blank – Weigh a 0.45-0.50 g aliquot of blank matrix into a labeled digestion tube and prepare as listed in Section 10.1.2.

10.2.2.2 Laboratory Control Sample – Weigh a 0.45-0.50 g aliquot of blank matrix into a labeled digestion tube, add 0.5ml of each spiking solution (Spike I, Spike 2 and Spike 3) and prepare as listed in Section 10.1.2.

10.2.2.3 Matrix Spike / Matrix Spike Duplicate – Weigh out 2 separate 0.45-0.50 g aliquots of the sample chosen for the matrix spike into a labeled digestion vessel. Add 0.5ml of each spiking solution (Spike I, Spike 2, and Spike 3) and prepare as listed in Section 10.1.2.

10.2.3 Silica (DI Leach) QC Sample Preparation

10.2.3.1 Method Blank – Weigh a 4.5-5.5 g aliquot of blank matrix into a labeled 125 mL plastic container and continue as outlined in Section 10.1.3.

10.2.3.2 Laboratory Control Sample – Weigh a 4.5-5.5 g aliquot of blank matrix into a labeled 125 mL plastic container, add 1.0 mL of the SiO_2 Intermediate Standard and continue as outlined in Section 10.1.3.

10.2.3.3 Matrix Spike / Matrix Spike Duplicate – Weigh out 2 separate 4.5-5.5 g aliquots of the sample chosen for the matrix spike into a labeled 125 mL plastic container. Add 1.0 mL of the SiO_2 Intermediate Standard and continue as outlined Section 10.1.3.

10.3 Analysis

The analytical procedures associated with this digestion procedure are given in SOP SA-ME-070: *Elements by ICP* or SOP SA-ME-074: *Elements by ICP/MS.*

11.0 Calculations / Data Reduction

11.1 Data Reduction

Data must be evaluated in accordance with SOP SA-QA-002: *Data Generation and Review*.

The data reduction procedures associated with this digestion procedure are given in SOP SA-ME-070: *Elements by ICP* or SOP SA-ME-074: *Elements by ICP/MS.*

11.1.1 Historical Data

Many of the laboratory's clients submit samples for repeat monitoring purposes. Prior to analysis, verify LIMS Worksheet Notes and/or use the Historical Data Tracker feature to determine if historical data is available for review.

11.1.2 Chemical Relationships

When available, the following chemical relationships must be evaluated for each sample. If these relationships are not met, the Department Manager must be contacted immediately.

- Total Results are $\geq$ Dissolved results (e.g. metals)

11.2 Calculations

The calculations for the determination of metals by ICP and ICP/MS are given in the associated analytical SOPs (SOP SA-ME-070 or SOP SA-ME-074).

12.0 Method Performance

12.1 Reporting Limit Verification (RLV/LOQ)

At a minimum, RLVs must be performed initially upon method set-up in accordance with SOP SA-QA-007: *Determination and Verification of Detection and Reporting Limits*.

RLVs must be performed quarterly.

12.2 Method Detection Limit (MDL) Study

The method detection limits (MDL) is defined as the minimum measure concentration of a substance that can be reported with 99% confidence that the measured concentration is distinguishable from the method blank results. The current MDLs associated with this procedure are given in the Method Limit Group (MLG) in LIMS.

At a minimum, MDL Studies must be performed initially upon method set-up in accordance with SOP SA-QA-007: *Determination and Verification of Detection and Reporting Limits*.

12.3 Method Detection Limit Verification (MDLV/LOD)

At a minimum, MDLVs must be performed initially upon method set-up in accordance with SOP SA-QA-007: *Determination and Verification of Detection and Reporting Limits*.

For analytes and methods certified by DOD ELAP and Texas, MDLVs must be performed quarterly.

Note: MDLVs are not required for non-routine analytes provided results are not reported below the RL (i.e., MDL equals RL in LIMS).

12.4 QC Limit Generation, Control Charting, and Trend Analysis

The control limits for the batch QC items (LCS and MS/MSD) for this procedure are specified in the reference method and cannot be broadened; therefore, the laboratory defaults to the method-defined limits and does not utilize in-house or laboratory-derived limits for the evaluation of batch QC items.

Although the laboratory must default to the method-defined QC limits, control charting is a useful tool and is performed to assess analyte recoveries over time to evaluate trends. Control charting must be performed periodically (at a minimum annually) in accordance with SOP SA-QA-017: *Evaluation of Batch QC Data.*

12.5 Demonstrations of Capability

Initial and continuing demonstration of capability must be performed in accordance with SOP SA-QA-006*: Training Procedures.*

Prior to performing this procedure unsupervised, each new analyst who performs this analysis must demonstrate proficiency per method/analyte combination by successful completion of an initial demonstration of capability. The IDOC is performed by the analysis of 4 consecutive laboratory QC check samples spiked at 1–4x the RL/LOQ that meet the method criteria for accuracy and precision. The IDOC must be documented and routed to the QA Department for filing.

Annual continuing demonstrations of capability (CDOCs) are also required per analyst per method/analyte combination. The CDOC requirement may be met by the consecutive analysis of four LCS all in the same batch, by the analysis of four LCS analyzed in four consecutive batches (in different batches on different days), via acceptable results on a PT study, or analysis of client samples with statistically indistinguishable results when compared to another certified analyst. The CDOC must be documented and routed to the QA Department for filing.

12.6 Training Requirements

All training must be performed and documented in accordance with SOP SA-QA-006: *Training Procedures*.

Note: The SOPs listed in the Reference/Cross-Reference Section are applicable to this procedure. All employees performing this procedure must also be trained on these SOPs, and/or have a general understanding of these procedures, as applicable.

13.0 Pollution Control

It is Eurofins Savannah's policy to evaluate each method and look for opportunities to minimize waste generated (e.g., examining recycling options, ordering chemicals based on quantity needed, preparing reagents based on anticipated usage and reagent stability, etc.). Employees must abide by the policies in Section 13 of the Environmental Health and Safety Manual.

This procedure has been evaluated for opportunities to minimize the waste generated. Where reasonably feasible, pollution control procedures have been incorporated.

14.0 Waste Management

Waste management practices must be conducted consistent with all applicable federal, state, and local rules and regulations. All waste (i.e., excess reagents, samples, and method process wastes) must be disposed of in accordance with Section 9 of the Eurofins Savannah Addendum to the EHSM. Waste description rules and land disposal restrictions must be followed.

14.1 Waste Streams Produced by the Method

The following waste streams are produced when this method is carried out:

- Excess soil and solid samples – Transfer RCRA hazardous and non-hazardous samples to waste department for disposal via yardbox. The samples must be transferred in LIMs to the designated yardbox. PCB or Foreign Soil samples must be disposed per waste stream with waste coordinator.

- Acidic sample digestions – Neutralize before disposal into drain/sewer system.

- Excess oil samples – Transfer to waste department for storage/disposal.

- Neutralize the standard by passing with sodium bicarbonate before transferring the waste to the RCRA aqueous hazardous waste drum.

- All other metals standards may be disposed, using copious amounts of water, down a sink that flows to the neutralization pit.

15.0 References / Cross-References

- SOP SA-AN-041: *Reagent and Standard Materials Procedures*
- SOP SA-AN-100: *Laboratory Support Equipment (Verification and Use)*
- SOP SA-QA-002: *Data Generation and Review*
- SOP SA-QA-005: *Preventive and Corrective Action Procedures*

- SOP SA-QA-006*: Training Procedures*
- SOP SA-QA-007: *Determination and Verification of Detection and Reporting Limits (RLs, MDLs, and IDLs)*
- SOP SA-QA-015: *Homogenization, Compositing, and Segregation of Samples*
- SOP SA-QA-017: *Evaluation of Batch QC Data*
- SOP SA-ME-070: *Elements by ICP*
- SOP SA-ME-074: *Elements by ICPMS*
- NDSC-QA-SOP46704: *Acid and Solvent Testing and Approval Program*
- Eurofins Savannah Quality Assurance Manual
- Eurofins Environmental Health and Safety Manual
- Eurofins Savannah Addendum to the Environmental Health and Safety Manual
- *Test Methods for Evaluating Solid Waste*, Third Edition, SW-846; EPA Office of Solid Waste and Emergency Response: Washington, DC. (including Updates III and IV)
    - Method 3050B Revision 2: *Acid Digestion of Sediments, Sludges, and Soils*.
    - Method 3051A Revision 1, February 2007 : *Microwave Assisted Acid Digestion of Sediments, Sludges, Soils and Oils.*
- ASTM Method D3987-85: *Shake Extraction for Solid Waste with Water*

16.0 Method Modifications/Clarifications

16.1 Incorporation of Other Matrices

16.1.1 This procedure may be modified to analyze other matrices (e.g., wipe, waste, tissue, and filter samples) based on the needs of the client. This will need to be arranged by the Project Manager at the initiation of the project.

16.1.2 Wipe, waste, filter, and tissue matrices are non-routine, and the laboratory is not currently NELAC certified for these matrices. The laboratory uses its routine soil RLs (converted for initial and final volumes, etc.) and soil QC limits to evaluate wipe, waste, filter, and tissue samples. Soil DOCs can be used to satisfy analyst demonstrations of capability for these types of non-routine matrices. Teflon chips, Ottawa sand, or equivalent is used as the blank matrix for these non-routine matrices unless specifically requested otherwise by the project.

16.1.3 Waste samples may be collected in 8 oz plastic soil jars. However, it should be noted that an alternate container may be required as some organic wastes (oils) may not be conducive to plastic. Tissue samples may be collected in 8 oz plastic soil jars or plastic bags. Wipes and filters may be collected in a variety of different containers.

16.1.4 Wipe, waste, and filter samples must be iced at the time of collection and maintained at 0-6°C (less than 6°C but not frozen) until the time of digestion/leaching. Samples for mercury must be digested/leached and analyzed within 28 days of collection. All other samples must be digested and analyzed within 6 months of collection. Digestates may be stored at room temperature until the time of analysis.

16.1.5 Tissue samples must be iced at the time of collection and maintained at -10°C to -20°C for up to 6 months. Samples for mercury must be digested/leached and analyzed within 28 days of thawing. All other samples must be digested and analyzed within 6 months of thawing. Digestates may be stored at room temperature until the time of analysis.

16.1.6 Wipe, waste, filter, and tissue matrices are prepared in the same manner as soil samples with the following exceptions:

- The initial amount for wipe or filter samples is 1 wipe or 1 filter.
- The initial amount for tissue and waste samples is 1.0-1.2 g.

16.2 Other Considerations

16.2.1 As allowed by EPA 3050B, an alternative determinative technique has been employed for samples analyzed by ICP/MS. The preparation procedures in the method are identical for ICP and ICP/MS samples up to the addition of concentrated HCl. SW-846 Method 3050B only requires this step for samples to be analyzed by ICP. The laboratory has adopted this procedure for both ICP and ICP/MS samples. All field samples and quality control samples (including MDLs, DOCs, and PT samples) have been prepared using this alternative technique.

16.2.2 The analyte list in Section 1.0 of EPA 3050B and EPA 3051A has been expanded to include all analytes currently performed by the laboratory.

16.2.3 EPA 3050B requires only a method blank, matrix spike, and matrix spike duplicate with each preparation batch; however, the analytical methods also require the analysis of a laboratory control sample taken through the entire preparation process. For this reason the laboratory includes the LCS as part of the required batch QC for SW-846 Method 3050B. The analytical methods also allow a sample duplicate to be performed in lieu of a matrix spike duplicate. The laboratory's procedures allow for this option; however, the MSD is performed as the default.

16.2.4 EPA 3050B requires a method blank be analyzed prior to use of nitric acid, hydrochloric acid, and hydrogen peroxide with results less than the MDL for all analytes of interest. The laboratory does not perform this analysis in advance. The vendor certificate of analysis is reviewed and approved prior to use. Method blanks are also analyzed with each batch as a check on the cleanliness of the reagents.

16.2.6 EPA 3050B includes information on performing an alternate digest to obtain better recoveries for antimony. The laboratory has adjusted its default procedure to incorporate additional HNO_3 at the beginning of the digestion process to accommodate this analyte.

16.2.7 Although not a SW-846 requirement, the laboratory requires that soil samples be submitted on ice to satisfy other state, regulatory and/or client requirements.

16.2.8 EPA 3050B specifies 2 decimal places for sample weights (i.e. 0.01 g) whereas EPA 3051A specifies 3 decimal places for sample weights (i.e. 0.001 g). The balances currently in use have a 2 place max. All samples are prepped using these balances; therefore, the lab has adopted a 2 decimal place measurement for sample weights.

17.0 Attachments

The following Tables, Diagrams, and/or Validation Data are included as Attachments:

Attachment 1: SOP Summary
Attachment 2: Sample Collection, Preservation, and Holding Time Table
Attachment 3: QC Summary
Attachment 4: Instrument Maintenance and Troubleshooting
Attachment 5: Labware Cleaning Procedures

Attachment 1: SOP Summary

Sample Preparation Summary

EPA Method 3050B: A known weight (approximately 1 g) of the well-mixed sample is transferred to a suitable digestion vessel. The sample is digested with aliquots of nitric acid and hydrogen peroxide to break down the organics present in the sample. After the sample has been digested, as evidenced by a clear, pale yellow digestate, HCl is added to give an approximate acid concentration of 10% HCl and 5% HNO_3. Then the sample digest is diluted to 100 mL with reagent water.

A smaller weight of sample may be digested and the sample brought to a final volume that is proportional to the 1 g sample to 100 mL final volume ratio. For example, if 0.50 g is digested, the final volume of the digestate must be 50 mL to achieve the same reporting limits.

EPA Method 3051A: A known weight (approximately 0.5 g) of the well mixed sample is transferred to a microwave vessel. Concentrated nitric acid and hydrochloric acid is added to the vessel, the vessel is sealed and heated in the microwave for a specified amount of time. After cooling, the contents are diluted, filtered and allowed to settle then analyzed by the appropriate method.

Silica samples for EPA Method 6010C: Solid samples are extracted with reagent water using a DI Leach procedure and then filtered. The filtered solid extracts are analyzed by ICP.

Attachment 2: Sample Collection, Preservation, and Holding Time Table

Matrix	Routine Container	Routine Sample Size	Minimum Sample Size	Chemical Preservation	Thermal Preservation	Dechlorination Agent	Holding Time[1]
Soil	4 oz or 8 oz soil jar	1 g 5 g (Silica)	0.5 g 2.5 g (Silica)	None	<0-6°C	None	6 months (except for Hg which is 28 days)

[1] Inclusive of digestion and analysis.

Attachment 3: QC Summary

QC Item	Frequency	Criteria	Corrective Action
Batch Definition	Up to 20 field samples, prepared together w/in 24-hour time period	Not Applicable	Not Applicable
Method Blank (MB)	One per batch	Refer to analytical SOP	Refer to analytical SOP
Lab Control Sample (LCS)	One per batch	Refer to analytical SOP	Refer to analytical SOP
Lab Control Sample Duplicate (LCSD)	One per batch, if insufficient sample provided for MS/MSD/SD	Refer to analytical SOP	Refer to analytical SOP
Matrix Spike (MS)	One per batch	Refer to analytical SOP	Refer to analytical SOP
Matrix Spike Duplicate (MSD) Or Sample Duplicate (SD)	One per batch	Refer to analytical SOP	Refer to analytical SOP
Initial Demonstration of Capability (IDOC)	Initially, per analyst, per method/analyte combination	Refer to SOP SA-QA-006 Spiked at 1-4x the RL/LOQ	Refer to SOP SA-QA-006 (Unsupervised work cannot begin until acceptable IDOC is obtained.)
Continuing Demonstration of Capability (CDOC)	Annually, per analyst, per method/analyte combination	Refer to SOP SA-QA-006	Re-perform CDOC
Reporting Limit Verification (RLV)	Upon method/instrument set-up, per analyte/method/matrix combination. Quarterly thereafter for DOD ELAP.	Refer to SOP SA-QA-007	Refer to SOP SA-QA-007

QC Item	Frequency	Criteria	Corrective Action
Method Detection Limit Study (MDL Study)	Upon method/instrument set-up	Refer to SOP SA-QA-007	Refer to SOP SA-QA-007
MDL Verification (MDLV/LOD)	Upon method/instrument set-up, per analyte/method/matrix combination. Then quarterly thereafter for DOD ELAP.	Refer to SOP SA-QA-007	Refer to SOP SA-QA-007

Attachment 4: Instrument Maintenance and Troubleshooting

Instrument Labeling

Each instrument must be labeled with its name or ID (e.g., MSA, ICP-D, etc.). Additionally, non-operational instruments must be isolated from service or marked as being out of service. Each piece of equipment has an “Operational / Not Operational” sticker that is used for this purpose.

Maintenance Log

A maintenance log must be established for each piece of equipment used in the laboratory. All maintenance that is performed on the instrument must be recorded in the log including:

- Type of maintenance performed
  (**Note:** This includes preventative/routine maintenance; non-routine maintenance; maintenance performed by an external vendor; updates to software versions; etc.)
- Analyst or technician performing the maintenance
- Date the maintenance was performed
- Detailed explanation of the reason for the maintenance
- Resolution of the problem and return to control
- All service calls from instrument representatives

Preventive Maintenance

Refer to the instrument manufacturer’s guides for trouble-shooting items.

The temperature of the hot plate or digestion block must be monitored with each batch. If the temperature required for sample preparation cannot be maintained, the heating device must be removed from service and repaired or replaced.

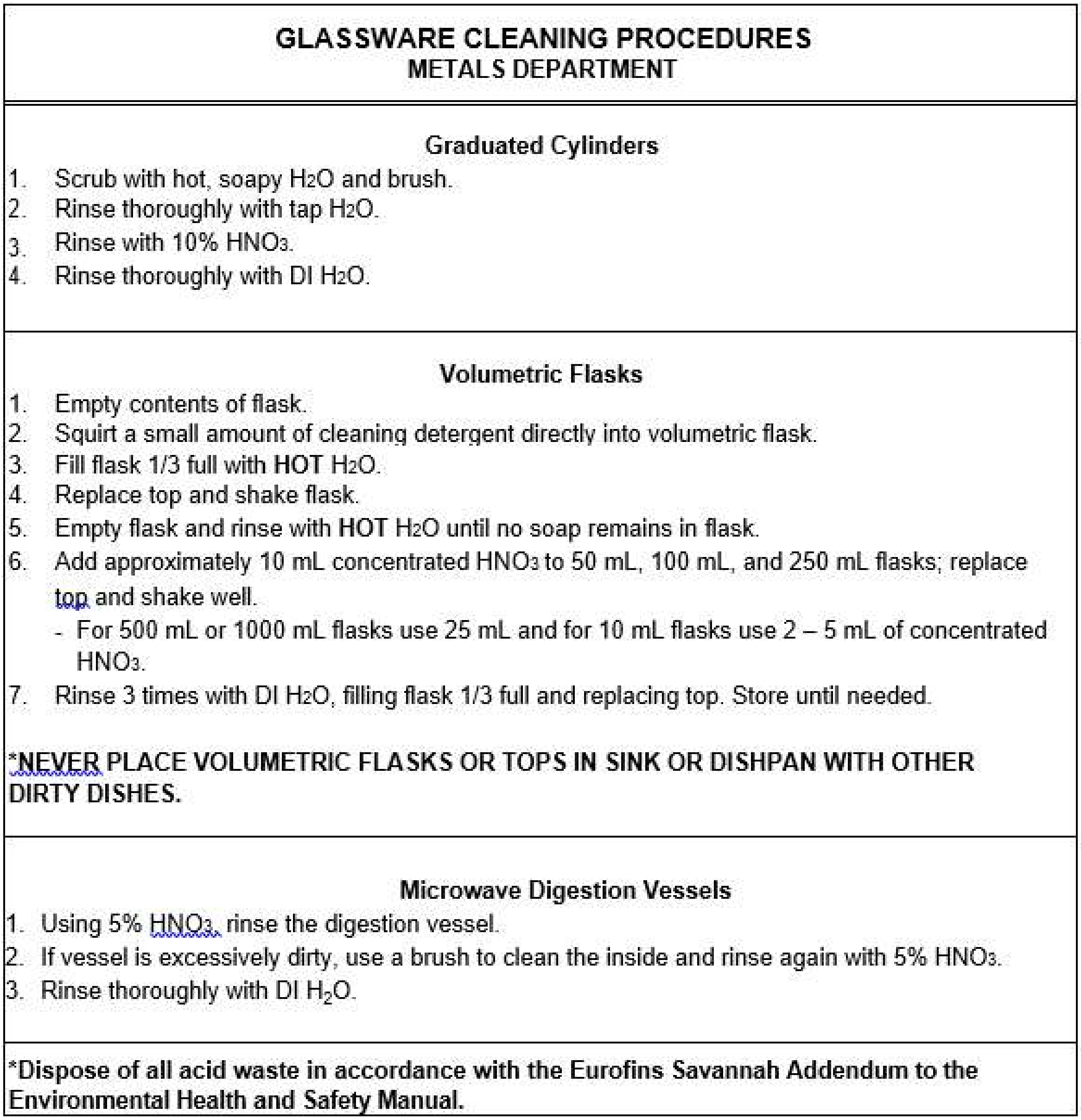
Troubleshooting

Troubleshooting should be documented as outlined above. If possible, troubleshooting is best performed in a step-wise manner to systematically isolate instrument components. Refer to the instrument manufacturer’s guides for specific information and strategies. Enlist assistance from technical and/or department management as needed.

Contingency Plan

In general, the laboratory has at least one backup unit for each critical unit. In the event of instrument failure, portions of the sample load may be diverted to duplicate instrumentation, the analytical technique switched to an alternate approved technique (such as manual colorimetric determination as opposed to automated colorimetric determination), or samples shipped to another properly certified or approved Eurofins location.

Attachment 5: Labware Cleaning Procedures



GLASSWARE CLEANING PROCEDURES
METALS DEPARTMENT

Graduated Cylinders

1. Scrub with hot, soapy H_2O and brush.
2. Rinse thoroughly with tap H_2O.
3. Rinse with 10% HNO_3.
4. Rinse thoroughly with DI H_2O.

Volumetric Flasks

1. Empty contents of flask.
2. Squirt a small amount of cleaning detergent directly into volumetric flask.
3. Fill flask 1/3 full with **HOT** H_2O.
4. Replace top and shake flask.
5. Empty flask and rinse with **HOT** H_2O until no soap remains in flask.
6. Add approximately 10 mL concentrated HNO_3 to 50 mL, 100 mL, and 250 mL flasks; replace top and shake well.
   - For 500 mL or 1000 mL flasks use 25 mL and for 10 mL flasks use 2 – 5 mL of concentrated HNO_3.
7. Rinse 3 times with DI H_2O, filling flask 1/3 full and replacing top. Store until needed.

***NEVER PLACE VOLUMETRIC FLASKS OR TOPS IN SINK OR DISHPAN WITH OTHER DIRTY DISHES.**

Microwave Digestion Vessels

1. Using 5% HNO_3, rinse the digestion vessel.
2. If vessel is excessively dirty, use a brush to clean the inside and rinse again with 5% HNO_3.
3. Rinse thoroughly with DI H_2O.

***Dispose of all acid waste in accordance with the Eurofins Savannah Addendum to the Environmental Health and Safety Manual.**

FME023:08.09.22:5

18.0 Revision History

Summary of Changes for Revision 16:

- Added process and procedures to EPA 3051A to SOP.
- Added safety concerns to microwave to Section 5.1.
- Added requirements to utilize a watch glass during the digestion process.
- Updated section 10.1.1.7 and 10.1.1.10that digests may be taken to a volume of 5mL or digested for 2 hours.
- Revised IDOC criteria in Section 12.5. ANAB Audit 2022.

Summary of Changes for Revision 15B:

- Removed references to TestAmerica from document due to change in legal entity.
- Revised definition of MDL to match definition is SOP SA-QA-007.

Summary of Changes for Revision 15A:

- Added Vendor name to Hydrochloric and Nitric Acid reagents.
- Revised Attachment 2 for sample containers.

Summary of Changes from Revision 15:

- Minor editorial, grammatical, and/or formatting changes made.
- Updated SOP signatories to reflect current responsibilities and titles.
- Updated company name where applicable.
- Replaced references of TALS to LIMS.
- Updated section 14.1 for current disposal practices.

TOXICITY CHARACTERISTIC LEACHING PROCEDURE (TCLP) AND SYNTHETIC PRECIPITATION LEACHING PROCEDURE (SPLP)

(Methods: EPA 1311 and EPA 1312)

Approvals (Signature/Date):

09/13/2022

Emma Ogletree — Date
Department Manager

Kimberly Chamberlain

09/13/2022

Kimberly Chamberlain — Date
Quality Assurance Manager / Environmental Health & Safety Coordinator

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1.0 Scope and Application

1.1 This SOP gives the procedures for the determination of the mobility of certain analytes in water, soil, and waste samples by the Toxic Characteristic Leaching Procedure (TCLP) or the Synthetic Precipitation Leaching Procedure (SPLP).

The Toxicity Characteristic (TC) of a sample is established by determining the concentrations of 8 metals and 31 organic chemicals. The TC - along with corrosivity, reactivity, and ignitability - is one criteria used to determine whether a sample can be classified as a hazardous waste. A sample is considered to be toxic and therefore hazardous if, after performing the TCLP procedure, the sample leachate contains any of the analytes listed in Attachment 5 at a concentration greater than or equal to the regulatory limit. The TCLP procedure is a sample preparation procedure used to simulate the leaching of a sample by a mildly acidic aqueous solution such as what might be expected from municipal landfill.

This SOP also describes the application of the Synthetic Precipitation Leaching Procedure (SPLP) which simulates the leaching that would occur if a sample was disposed in a landfill and exposed only to percolating rain water. The list of analytes for SPLP may extend beyond the toxicity characteristic compounds shown in Attachment 5. With the exception of the use of a modified extraction fluid, the SPLP and TCLP protocols are essentially equivalent. Where slight differences exist between the SPLP and TCLP, they are distinguished within this SOP.

1.2 The results obtained by these procedures are highly dependent on the pH of the extracting solution, the length of time that the sample is exposed to the extracting solution, the temperature during extraction, and the particle size/surface area of the sample. These parameters must be carefully controlled.

1.3 The target analytes that are determined on the leachate vary from state to state. In general, the concentration of the target analytes in the leachate will be evaluated against the groundwater limits of the various states and regulatory agencies. The reporting limits are based on the individual samples as well as the individual analysis techniques; however, the sample is determined to be hazardous if it contains any analyte at levels greater than or equal to the regulatory limits.

1.4 If a total analysis of the sample (i.e., that following preparation and analysis via the laboratory's routine, non-TCLP/SPLP procedures) demonstrates that individual analytes are not present in the sample, or that they are present but at such low concentrations that the appropriate regulatory levels could not possibly be exceeded, the TCLP procedure may not need to be performed. Consultation with the client is required at this point to determine whether leaching is required.

Volatile organic analysis of the leachate obtained using a bottle extraction, normally used for extractable organics and metals can be used to demonstrate that the sample is hazardous, but only the Zero Headspace Extraction (ZHE) procedure may be used to demonstrate that the concentration of volatile organic compounds is below regulatory limits.

1.5 This procedure is applicable to liquid, solid, and multiphase waste samples. The reporting limits (RL), and the accuracy and precision criteria associated with this procedure are provided in the LIMS Method Limit Groups (MLGs).

Attachment 5 contains the regulated (routine) target analytes and the associated preparation and analytical SOPs.

1.5 This SOP was written by and for Eurofins Savannah laboratory.

2.0 Summary of Method

2.1 The sample is initially visually evaluated for percent solids. If a liquid sample contains less than 0.5% dry, solid material, the sample is filtered, and the liquid phase after filtration is defined as the TCLP/SPLP leachate

If the sample is 100% solid, the particle size is reduced, if necessary, and the sample is extracted with twenty times the weight of the solid material in extraction fluid for 18 hours (+/- 2 hours.).

If the percent solid is greater than 0.5%, the solid and liquid phases must be separated. The liquid phase is collected and refrigerated until the time of extraction and analysis. The particle size of the remaining solid phase must be reduced, if necessary, and the solid phase is extracted with twenty times the weight of the solid phase in extraction fluid for 18 hours (+/-2 hours).

The TCLP extraction fluid is chosen based on the target analytes and the type of sample. The SPLP extraction fluid is chosen based on the region of the country where the sample site is located, if the sample is a solid.

After the leaching process has been completed, the leachate is collected.

If the sample was separated into a liquid and solid material, the leachates are evaluated for compatibility. If compatible, the liquid leachate is combined with the liquid phase from the solids determination. If the leachate is not compatible with the liquid phase, the leachate is collected and refrigerated until the time of extraction and analysis.

2.2 The leachate or combined leachate/liquid phase is extracted/digested by the procedure appropriate to the target compounds. Section 10.3 lists the appropriate methods and SOPs for the extraction or digestion and analysis of the liquid phase, or leachate. If the liquid phase from the solids determination is not compatible with the leachate, the samples (the leachate sample and the liquid phase sample) are analyzed individually, and a weighted average is used to determine the total concentration of the contaminants.

2.3 The extract or digestate is analyzed using the appropriate analytical procedure. The result from the analysis is compared to the regulatory limit to determine if the waste sample exhibits hazardous characteristics.

Note: It is unlikely that a sample that is a non-aqueous liquid, or contains a non-aqueous liquid phase, will be able to meet the regulatory threshold limits.

2.4 This SOP is based on the following methods: SW-846 Methods 1311 (TCLP) and 1312 (SPLP).

3.0 Definitions

Refer to the Glossary Section of the *Quality Assurance Manual* (QAM) for a complete listing of applicable definitions and acronyms.

Extraction Fluid – the aqueous liquid used to leach the analytes from the sample matrix.

Leachate – the liquid portion of a sample that passes through a 0.6um filter in the initial evaluation of the percent solids, or the liquid that passes through a 0.6um filter after the sample has been subjected to the TCLP/SPLP procedure.

Liquid Phase – the portion of the sample that passes through the 0.6-0.8um filter when subjected to a pressure of 50psi.

Percent Solids – the percentage of sample remaining on the 0.6um filter after the sample is subjected to a pressure of 30psi. Oily or viscous materials, although they appear to be liquids, are part of the solids if they do not pass through the filter. **NOTE: This is not the same as the percent solids used to report samples on a "dry-weight basis".**

Regulatory Threshold Limit – the concentration of analyte in the TCLP leachate at which the sample is deemed hazardous.

Solid Phase – the solids that remain on the 0.6-0.8um filter when subjected to a pressure of 50psi. Material that appears to be liquid but does not pass through the filter is deemed to be part of the solid portion of the sample.

SPLP – synthetic precipitation leaching procedure

TCLP – toxicity characteristic leaching procedure

ZHE – zero headspace extraction

4.0 Interferences

4.1 Procedural Interferences

4.1.1 Interferences may be caused by contaminants in solvents, reagents, glassware, and other sample processing apparatus and can make identification and/or quantification of the target analytes difficult.

Note: The extraction vessels must not be rinsed with acids or solvents that will interfere with the analysis of the target compounds. The extraction vessels must be stored in an area that is free from contamination, and the extraction procedure must take place in an area that is free from contamination.

4.1.2 All sample collection containers are single-use disposable containers which limits the potential for contamination. All non-disposable labware must be scrupulously cleaned in accordance with the posted Labware Cleaning Instructions to ensure it is free from contaminants and does not contribute artifacts.

4.1.3 High purity reagents and solvents are used to help minimize interference problems. Hydrochloric acid, nitric acid, and sulfuric acid must be verified prior to use in accordance with the Eurofins Environment Testing Solvent Lot Testing Program.

4.1.4 Instrument and/or method blanks are routinely used to demonstrate all reagents and apparatus are free from interferences under the conditions of the analysis.

4.2 Matrix Interferences

4.2.1 Matrix interferences may be caused by contaminants that are co-extracted from the sample matrix. The sample may require cleanup or dilution prior to analysis to reduce or eliminate the interferences. Refer to the applicable preparatory or analytical SOP for more details.

4.2.2 Interfering contamination may occur when a sample containing low concentrations of analytes is analyzed immediately following a sample containing relatively high concentrations of analytes. As such, samples known to be clean should be analyzed first. To prevent carryover into subsequent samples, analysis of reagent blanks may be needed after the analysis of a sample containing high concentrations of analytes.

4.2.3 Interferences encountered in the analysis of the leachate of the sample are discussed in the appropriate analytical SOP. (Section 10.3)

5.0 Safety

Employees must abide by the policies and procedures in the Eurofins Environmental Health and Safety Manual (EHSM), the Eurofins Savannah Addendum to the EHSM, and this document.

This procedure may involve hazardous materials, operations, and equipment. This SOP does not purport to address all of the safety problems associated with its use. It is the responsibility of the user to follow appropriate safety, waste disposal, and health practices under the assumption that all samples and reagents are potentially hazardous.

The analyst must protect himself/herself from exposure to the sample matrix. Many of the samples that are tested may contain hazardous chemical compounds or biological organisms. The analyst must, at a minimum, wear protective clothing (lab coat), eye protection (safety glasses or face shield), disposable latex or nitrile gloves, and closed-toe, nonabsorbent shoes when handling samples.

5.1 Specific Safety Concerns or Requirements

All samples must be treated as if they are hazardous. The analyst must protect himself/herself from exposure to the sample matrix. Many of the samples that are tested may contain hazardous chemical compounds or biological organisms. The analyst must wear protective clothing (lab coat or apron), eye protection (glasses or face shield), and disposable gloves when handling samples.

Reagent water must be used as the leaching fluid for SPLP cyanide samples and TCLP cannot be performed on cyanide samples, as it requires acidic leaching fluids. If cyanide-containing samples are leached under acidic conditions hydrogen cyanide gas could be formed.

Acetic acid is a corrosive. Contact with concentrated acetic acid can cause damage to the skin and eyes. Inhalation of concentrated vapors may cause damage to the lining of the nose, throat, and lungs.

Nitric and hydrochloric acids are extremely hazardous as oxidizers, corrosives, poisons, and are reactive. Inhalation of the vapors can cause coughing, choking, irritation of the nose, throat, and respiratory tract, breathing difficulties, and lead to pneumonia and pulmonary edema. Contact with the skin can cause severe burns, redness, and pain. Nitric acid can cause deep ulcers, and staining of the skin to a yellow or yellow-brown color. These acid vapors are irritating and can cause damage to the eyes. Contact with the eyes can cause permanent damage. Concentrated acid must be used under a fully functioning fume hood.

Sodium hydroxide is a severe corrosive. Contact with the skin can cause irritation or severe burns and scarring. Contact with the eyes can cause irritation, burns, permanent vision impairment or even blindness.

Sulfuric acid is a strong oxidizer and is a corrosive. It will react violently when combined with organic compounds, possibly producing fire. Inhalation can cause irritation of the nose, throat, mucus membranes, and upper respiratory tract. Contact with the eyes can cause blurred vision, redness, pain, and even blindness.

5.2 Primary Materials Used

The following is a list of the materials used in this procedure, which have a serious or significant hazard rating, and a summary of the primary hazards listed in their MSDS/SDS.

Note: This list does not include all materials used in the procedure. A complete list of materials used in this procedure can be found in the Reagents and Standards Section and the Equipment and Supplies Section of this SOP

Employees must review the information in the MSDS/SDS for each material before using it for the first time or when there are major changes to the MSDS/SDS. Electronic copies of MSDS/SDS can be found using the “MSDS Online” button on the Oasis homepage, on the EH&S webpage on Oasis, and on LIMS File System Shares.

Material	Hazards	Exposure Limit[1]	Signs and Symptoms of Exposure
Acetic Acid	Corrosive Poison Flammable	10ppm TWA	Contact with concentrated solution may cause serious damage to the skin and eyes. Inhalation of concentrated vapors may cause serious damage to the lining of the nose, throat, and lungs. Breathing difficulties may occur.
Hydrochloric Acid	Corrosive Poison	5ppm Ceiling	Inhalation of vapors can cause coughing, choking, inflammation of the nose, throat, and upper respiratory tract, and in severe cases, pulmonary edema, circulatory failure, and death. Can cause redness, pain, and severe skin burns. Vapors are irritating and may cause damage to the eyes. Contact may cause severe burns and permanent eye damage.
Nitric Acid	Corrosive Oxidizer Poison	2ppm TWA 4ppm STEL	Nitric acid is extremely hazardous; it is corrosive, reactive, an oxidizer, and a poison. Inhalation of vapors can cause breathing difficulties and lead to pneumonia and pulmonary edema, which may be fatal. Other symptoms may include coughing, choking, and irritation of the nose, throat, and respiratory tract. Can cause redness, pain, and severe skin burns. Concentrated solutions cause deep ulcers and stain skin a yellow or yellow-brown color. Vapors are irritating and may cause damage to the eyes. Contact may cause severe burns and permanent eye damage.
Sodium Hydroxide	Corrosive	$2 mg/m^3$ Ceiling	Severe irritant. Effects from inhalation of dust or mist vary from mild irritation to serious damage of the upper respiratory tract, depending on severity of exposure. Symptoms may include sneezing, sore throat or runny nose. Contact with skin can cause irritation or severe burns and scarring with greater exposures. Causes irritation of eyes, and with greater exposures it can cause burns that may result in permanent impairment of vision, even blindness.
Sulfuric Acid	Corrosive Oxidizer Dehydrator Poison Carcinogen	$1 mg/m^3$ TWA	Inhalation produces damaging effects on the mucous membranes and upper respiratory tract. Symptoms may include irritation of the nose and throat, and labored breathing. Symptoms of redness, pain, and severe burn can occur. Contact can cause blurred vision, redness, pain and severe tissue burns. Can cause blindness.

[1] Exposure limit refers to the OSHA regulatory exposure limit.

Note: Always add acid to water to prevent violent reactions.

TWA – the time-weighted average exposure limit: the maximum average concentration of a chemical in air for a normal 8-hour working day and 40-hour week
Ceiling – the concentration that should not be exceeded at any time
STEL – short-term exposure limit: the maximum average concentration to which workers can be exposed for a short period (usually 15 minutes)

6.0 Equipment and Supplies

6.1 Equipment and Instrumentation

pH Meter – accurate to 0.05 pH units. Calibrate each day of use in accordance with Attachment 6.

Top-loading Balance – accurate to 0.01g. Verify in accordance with SOP SA-AN-100: *Laboratory Support Equipment (verification and Use)*

Thermometers – Verify in accordance with SOP SA-AN-100: *Laboratory Support Equipment (verification and Use)*

Laboratory Oven – for determination of percent solids and baking of ZHE extraction vessels.

Magnetic Stir Plate

Stir Bars

Water Bath

Rotator– Capable of holding several extraction vessels and ZHE units and rotating samples continuously at a rate of 30RPM ± 2RPM.

Filtration Device to filter the leachate after the TCLP/SPLP for SVOC/metals/cyanide; stainless steel; 1L capacity.

NIST-traceable digital timer - Verify in accordance with SOP SA-AN-100: *Laboratory Support Equipment (verification and Use)*

ZHE Extraction Vessels – 500mL vessel capable of maintaining zero headspace during the extraction procedure. The vessel must allow for the initial liquid/solid phase separation and final leachate filtration while maintaining zero headspace conditions.

Note:
- The ZHE vessels must be numbered, and the ZHE designation recorded on the preparation log. This will aid in tracking high level samples and help to prevent or minimize contamination of the ZHE vessels.
- ZHE vessels must not be segregated for use for QC samples (i.e., fluid blanks).
- The units must be rotated such that each is used for fluid blank preparation every 20 extractions.
- Heavily contaminated extractors must be removed from service until it can be demonstrated that a fluid blank taken through the entire leaching procedure produces an acceptable blank with no target analytes detected above the RL.

IDEX Micropump Model DP415A – for the addition of the extraction fluid to the ZHE vessels

6.2 Volumetric Labware

Volumetric Containers and Dispensers – various sizes; Class A, where applicable. Verify in accordance with SOP SA-AN-100: Laboratory Support Equipment (Verification and Use).

Volumetric Labware	Volume	Type (Quantitative / Qualitative)	Use	Verification Frequency	Laboratory Verification Criteria
Graduated Cylinders (Class A)	Various	QUANTITATIVE	Extraction Fluid Measurement	None (Class A)	None (Class A)
Plastic Carboy	Various	Qualitative	Preparing/Storage of TCLP Fluid	None*	None

*pH is verified to determine accurate preparation.

Non-ZHE Extraction Vessels (for SVOC/Metals/Cyanide)

SVOC and SVOC/Metals/Cyanide – Glass bottle with a volume of approximately 2L size. Two containers are used per sample . The glass container must be free from the target analytes when subjected to the TCLP.

Metals/Cyanide only – Plastic bottle with a volume of approximately 2L. The plastic container must be free from the target analytes when subjected to the TCLP.

Non-ZHE Filter Media (for SVOC/Metals/Cyanide) – Binderless glass fiber filters, 0.6-0.8um pore size; purchased from Whatman (catalog number 1810-142)

ZHE Filter media – Whatman GC/F, 90mm diameter, 0.70um pore size

6.3 Laboratory Supplies

Tedlar bag – 1-liter; for collection of ZHE leachates

Detergent –Bar Maid or equivalent, used for washing non-disposable labware

6.4 Sample Collection Containers

All sample collection containers are single-use disposable containers which limits the potential for contamination.

Refer to Attachment 5 for default sample collection containers. All sample collection containers supplied by the laboratory are purchased with Certificate of Analysis attesting to purity.

7.0 Reagents and Standards

7.1 Expiration Dates

Expiration dates (time from initial use or receipt to final use) for standard and reagent materials must be set according to the guidance in this SOP. Note: These are maximum expiration dates and are not to be considered an absolute guarantee of standard or reagent quality. Sound judgment must be used when deciding whether to use a standard or reagent. If there is doubt about the quality of a standard or reagent material, a new material must be obtained or the standard or reagent material verified. Data quality must not be compromised to extend a standard's life.

The expiration date of any standard or reagent must not exceed the expiration date of the standard or reagent that was used to prepare it.

Unless listed elsewhere in this SOP, the expiration dates given below apply.

7.1.1 The expiration date for unopened standards and reagents is the manufacturer's expiration date.

7.1.2 The expiration date for opened stock reagents is the manufacturer's expiration date or 5 years from the date opened, whichever is sooner.

7.1.3 The expiration date for prepared reagents is 6 months from the date prepared or the expiration date of the parent reagent, whichever is sooner.

7.2 Reagents

Reagents must be prepared and documented in accordance with SOP SA-AN-041: *Reagent and Standard Materials Procedures.*

Hydrochloric acid, nitric acid, and sulfuric acid must be verified prior to use in accordance with the Eurofins Environment Testing-Solvent Lot Testing Program.

7.2.1 Purchased Reagents

7.2.1.1 Laboratory Reagent Water – ASTM Type I that does not contain the target compounds above the reporting limit. Reagent water is used as the extraction fluid for SPLP Cyanide. (SPLP Extraction fluid #3)

7.2.1.2 Sodium Hydroxide (NaOH) – reagent grade
Storage: Room temperature

7.2.1.3 Sulfuric Acid (H_2SO_4) – concentrated, reagent grade
Storage: Room temperature

7.2.1.4 Glacial Acetic Acid (CH_3COOH) – reagent grade
Storage: Room temperature – Do not store with other acids.

7.2.1.5 Nitric Acid (HNO_3) – reagent grade
Storage: Room temperature – Away from incompatibles.

7.2.1.6 Hydrochloric Acid (HCl) – reagent grade
Storage: Room temperature – Away from incompatibles.

7.2.1.7 TCLP Fluid 1 Concentrate- Part number HP-P100 from Environmental Express
Storage: Room temperature

7.2.2 Prepared Reagents

7.2.2.1 Non-ZHE Prepared Reagents (for SVOC/Metals/Cyanide)

7.2.2.1.1 Sodium Hydroxide (1N) – Dissolve 40.0g of NaOH in 800mL of reagent water contained in a 1L volumetric flask. Dilute to volume with reagent water and mix thoroughly.
Storage: Transfer to a glass container equipped with a Teflon-lined cap.

Note: Do not store basic solutions in volumetric glassware equipped with ground glass joints.

7.2.2.1.2 Nitric Acid (approx. 1N) – Transfer about 800mL of reagent water to a 1-L volumetric flask. Slowly and carefully add 70mL of concentrated HNO_3 to the 1-L volumetric flask. Dilute to volume with reagent water and mix thoroughly by inverting the flask. This solution is used for cleaning the glass fiber filters when the waste is evaluated for metals. Prepare this reagent in a fully functioning fume hood.
Storage: Room temperature

Note: Solutions that contain HNO_3 must be prepared under a hood.

7.2.2.1.3 Sulfuric Acid/Nitric Acid Mixture (60/40) – Cautiously mix 32.6mL sulfuric acid with 26.7mL of nitric acid. Prepare this reagent in a fully functioning fume hood.
Storage: Room temperature

7.2.2.1.4 TCLP Extraction Fluid # 1 - Dilute 200mls of concentrated mix in DI water for a final volume of 10L. The resulting pH should be 4.93. Multiple containers may be used to make large volumes of Extraction Fluid. Verify the pH of this fluid each day prior to use, and record the pH and lot on the LIMS worksheet. pH of fluid must be 4.93 ± 0.05.
Storage: Room temperature

7.2.2.1.5 TCLP Extraction Fluid #2 – Transfer 5.7mL of glacial acetic acid to a 1-L volumetric flask and dilute to volume with reagent water. The pH of this fluid should be 2.88 ± 0.05. Verify the pH of this fluid each day prior to use, and record the pH and lot on the LIMS worksheet.
Storage: Room temperature

7.2.2.1.6 SPLP Extraction Fluid #1 – Add small volumes of the 60/40 Sulfuric Acid/Nitric Acid mixture to reagent water until the pH is 4.20 ± 0.05. This extraction fluid is used for soils collected from sites east of the Mississippi River and for all wastes and wastewaters. Verify the pH of this fluid each day prior to use, and record the pH and lot on the LIMS worksheet.
Storage: Room temperature

7.2.2.1.7 SPLP Extraction Fluid #2 – Add small volumes of the 60/40 Sulfuric Acid/Nitric Acid mixture to reagent water until the pH is 5.00 ± 0.05. This extraction fluid is used for soils collected from sites west of the Mississippi River. Prepare this reagent in a fully functioning fume hood. Verify the pH of this fluid each day prior to use, and record the pH and lot on the LIMS worksheet.
Storage: Room temperature

7.2.2.2 ZHE Prepared Reagents (for VOC)

7.2.2.2.1 VOA Reagent Water – DI Water is used as the extraction fluid for SPLP volatiles (ZHE SPLP Extraction Fluid #1.)
Storage: Room temperature

7.3 Standards

With the exception of the pH buffers used to calibrate the pH meter (as indicated in Attachment 6), there are no standards associated with this procedure.

The calibration and spiking standards used for the preparation and analysis of the leachate produced by the TCLP/SPLP are given in the appropriate preparation and analytical SOPs (Section 10.3).

8.0 Sample Collection, Preservation, Shipment, and Storage

Attachment 2 provides a summary of the sample collection, preservation, shipment, and storage conditions associated with this procedure.

Samples must be iced at the time of collection and maintained at 4°C (less than 6°C but not frozen) until the time of leaching. Leachates must be stored at 4°C (less than 6°C but not frozen) until the time of preparation. Extracts/digestates must be stored at 4°C (less than 6°C but not frozen) until the time of analysis. Samples must be leached, extracted/digested, and analyzed within the timeframe given in Attachment 2.

9.0 Quality Control

SOP SA-QA-017: *Evaluation of Batch QC Data* and the SOP Summary in Attachment 3 provide requirements for evaluating QC data.

9.1 Batch QC

A leachate batch consists of up to 20 environmental samples and the associated QC items. The minimum QC item required for each leachate batch is a leachate blank which is designated as LB.

The minimum leachate volumes required for extraction/digestion are listed in the table below.

Parameter/Analysis	**Leach Type**	**Minimum Leachate Volume Required for Sample (mL)**	**Minimum Leachate Volume Required for MS/MSD* (mL)**	**Preparation SOP**
Metals (6010 or 6020) and Mercury (7470A)	TCLP	100	300	SA-ME-050
Metals (6010 or 6020) and Mercury (7470A)	SPLP	100	500	SA-ME-050
BNAs (8270)	TCLP	200	400	SA-EX-030
BNAs (8270)	SPLP	1000	3000	SA-EX-030
Pesticides (8081B)	TCLP	20	40	SA-EX-030
Pesticides (8081B)	SPLP	1000	3000	SA-EX-030
Herbicides (8151A)	TCLP	10	20	SA-SG-065
Herbicides (8151A)	SPLP	1000	3000	SA-SG-065
Cyanide (9010/9012)	SPLP	100	300	SA-GE-040

* If the minimum leachate volume listed in this column is not available, there is insufficient sample to perform the required matrix spike(s). If there is insufficient sample volume to perform the required matrix spike(s), an NCM must be initiated on all affected samples to denote this situation.

Note: Additionally a matrix spike (MS) and a matrix spike duplicate (MSD) must be performed on a leached sample per analytical method per leachate batch. The matrix spikes must be spiked after the TCLP or SPLP procedure has been completed and prior to sample preservation. For example, if samples are leached for EPA 8081B analysis, upon EPA 3510C extraction an MS/MSD must be prepared on one of the leached samples. If there is insufficient sample to perform the MS/MSD, an NCM must be initiated to denote this situation.

Additional QC requirements are addressed in the associated preparation and analytical SOPs.

Prior to sample analysis, leachate samples are prepared in the same manner as water samples. Refer to the SOPs in the previous table for specifics on the leachate preparation process

Batch QC must meet the criteria given in Attachment 3 of this SOP.

9.2 Instrument QC

This section is not applicable to this SOP. Refer to Attachment 6 for further information on the pH meter.

9.3 Corrective Action for Out-of-Control Data

When the quality control parameters do not meet the criteria set forth in this SOP, corrective action must be taken in accordance with SOP SA-QA-005: *Preventive and Corrective Action Procedures* and the QC Summary Table in Attachment 3. SOP SA-QA-005 provides contingencies for out-of-control data and gives guidance for exceptionally permitting departures from approved policies and procedures. Nonconformance Memos must be initiated to document all instances where QC criteria are not met and all departures from approved policies and procedures.

10.0 Procedure

This procedure consists of multiple steps. The first step is a preliminary evaluation and characterization of the sample which includes: minimum leachate volume determination; % Solids determination; extraction fluid determination; particle size reduction; container selection.

Note: The preliminary evaluation must be performed on a minimum 100gm aliquot.
Note: This aliquot may not undergo the TCLP extraction.

After the preliminary evaluation, sample preparation and addition of the fluid occurs; then tumbling/leaching; followed by recombination of phases and filtration.

These steps can be further categorized SVOC/Metals/CN (i.e., non-ZHE) versus Volatiles (i.e., ZHE) procedures. Additionally, the SPLP procedure incorporates a different type of leaching fluid than TCLP.

Non-ZHE soil samples must be homogenized prior to preparation and particle size reduction in accordance with SOP SA-QA-015: *Compositing, Homogenization, and Segregation of Samples*. If the sample contains an oil material, paint or has oil and water material with the appearance of multiple layers, consult with the Project Manager. Analysis of the material as a total may be appropriate for the matrix.

Note: Due to the potential loss of the volatile target analytes, homogenization procedures are not employed for ZHE samples.

10.1 Procedures for Non-ZHE Samples (SVOCs, Metals, and Cyanide)

10.1.1 Minimum Leachate Volume Determination

The minimum volume of leachate required for each analysis is provided in the table below:

Parameter	Leach Type	Minimum Leachate Volume Required for Sample (mL)	Minimum Leachate Volume Required for MS/MSD (mL)
BNAs	TCLP	200	400
BNAs	SPLP	1000	3000
Cyanide	SPLP	100	300
Herbicides	TCLP	10	20
Herbicides	SPLP	1000	3000
Metals and Mercury	TCLP	100	300
Metals and Mercury	SPLP	100	500
Pesticides	TCLP	20	40
Pesticides	SPLP	1000	3000

10.1.2 % Solids Determination

Note: To ensure all required information is captured, the data from the % Solids determination is recorded in the LIMS Worksheet and in a supplemental Excel Spreadsheet.

10.1.2.1 Remove the samples from the storage refrigerator, and allow them to come to room temperature.

Note: The sample is considered 100% solid if it will obviously yield no liquid when subjected to pressure filtration. If sample is 100% solid, then proceed to Section 10.1.5 for particle size reduction, if necessary. If the sample is liquid or multi-phasic, liquid/solid separation is required to determine % solids, as outlined in Section 10.1.5

10.1.2.2 Scan the samples requiring % Solids Determination into the preparation batch in LIMS.

10.1.2.3 Record the weight of a filter pad in grams on the worksheet tab of the LIMS batch in the field called “FilterWeight” and as “Filter Weight” on the spreadsheet.

10.1.2.4 Place the filter pad on the filtration device and complete assembly of the device.

10.1.2.5 Weigh the empty container that will receive the filtrate and record the weight in the field called “FiltrateTareWeight”.

10.1.2.6 Add a minimum of 100gm of sample in a beaker and record the weight as "SubsampleGrossWeight".

Note: Do not tare the balance after beaker is placed on the scale. Need to record the weight of the beaker and sample.

10.1.2.7 Transfer the sample in the beaker to the filtration device. Weigh the beaker after transfer and record as "*SubSampleTare*".

Note: It is recommended that the 100g aliquot be allowed to settle to facilitate filtration.

10.1.2.8 Calculate the weight of sample added to the filtration device (i.e., "*SubSampleNet*") as follows:

$$W_{sample} = W_1 - W_2$$

Where:

W_1 = weight of beaker + sample (i.e., "*SubSampleGross*")
W_2 = weight of beaker after sample has been added to filter ("*SubSampleTare*")

10.1.2.9 Place the top on the filtration device and clamp it into place. Place the pre-weighed receiving container under the filtration device.

10.1.2.10 Attach the air line to the filtration vessel and gradually increase the pressure in 10psi increments while collecting the liquid that is filtered out in the receiving container. Gradually increase the pressure until the pressure in the filtration device is 50psi. Continue the pressure filtration for 2-5 minutes until no further liquid is filtered out of the sample.

10.1.2.11 The material on the filter is defined as the solid phase. The filtrate is defined as the liquid phase.

Note: If a sample does not filter, the sample will be defined as a solid.

10.1.2.12 Slowly release the pressure in the filtration vessel. After the pressure has returned to atmospheric pressure (i.e., no further pressure released from the vessel), remove the top of the filtration device.

10.1.2.13 Remove the filter with the wet solids from the filtration device.

10.1.2.14 Dry the filter in the oven at 100°C +/-20°C for approximately 1 hour. Remove the filter from the oven and allow it to cool.

Weigh the filter and record the weight as "*Weight of Wet Solids*" in the LIMS Worksheet.

If the % Solids is less than 0.5% as determined in Section 10.1.2.17, then proceed to Section 10.1.3.

If the % Solids is greater than 0.5%, repeat the drying step and re-weigh the filter. If the two weights do not agree within 1%, perform additional dryings and weighing until consecutive weights agree within 1%. Record the last two successive weights in the spreadsheet as outlined in Section 10.1.2.16.

10.1.2.15 Determine the % Solids using the spreadsheet located on the Public_QA Drive.

10.1.2.16 Enter the "*SubSampleNetWeight"* from Section 10.1.2.8, the filter weight from Section 10.1.2.3 and the filter + particulate weights from Section 10.1.2.14.

10.1.2.17 Calculate the percent dry solids as follows:

$$precent\ dry\ solids = \frac{W_{p2} - W_{p1}}{W_{sample}} \otimes 100$$

Where:
W_{p2} = weight of filter pad and dry solids
W_{p1} = weight of filter pad
W_{sample} = weight of sample added to filtration device

10.1.2.18 If the percent solids is <0.5%, the sample is considered to be a liquid. Filter enough volume of the sample for all analytical methods. Refer to Section 10.1.1 for the volumes required.

10.1.2.19 Weigh the collection container and leachate. Record this weight in the worksheet of the LIMS batch in the field called *"FiltrateGrossWeight*".

10.1.2.20 The liquid obtained by filtering the sample to collect the solid fraction must be retained until the leaching procedure is completed. Transfer the liquid phase to a glass or plastic container and store at 0-6°C until the process is completed. A plastic container may be used if <u>only</u> metals are being evaluated and the liquid phase is aqueous. The liquid phase will be combined with the leachate, if compatible.

10.1.2.21 For samples containing >0.5%, but less than 99.5%, dry solids, use the % Solids information to determine the sample size required for filtration as outlined in Attachment 7. Notify the Project Manager of the sample requirements before proceeding with preparation.

10.1.2.22 A minimum of 105g of solids is required to proceed (i.e., 5g for the extraction fluid determination and 100g for the leaching process).

For example, if a sample contains 1% solids, a minimum of 10,000g of sample would have to be filtered to produce 100g of solids (i.e., 10,000g x 0.01 = 100g).

If sufficient sample is available to proceed after the Department Manager or Project Manager has been consulted, filter a larger aliquot of waste to produce enough solids (i.e., 105g), to determine the extraction fluid to use and to perform the leaching process on the solids portion. Proceed to Section 10.1.3 for fluid determination.

10.1.3 Extraction Fluid Type Determination - TCLP

10.1.3.1 The determination of which extraction fluid to use is based on the buffering capacity of the solid portion of the waste sample.

10.1.3.2 Perform particle size reduction, if necessary, and weigh 5.0g of the solid portion of the sample from the solids determination or 5.0g of a sample that contains no obvious free liquids into a 100ml disposable beaker.

Record this weight in the field called "*EFD_SampleWeight*".

10.1.3.3 Add 96.5mL of reagent water to the cup. Add a magnetic stir bar to the cup, and stir the sample on a magnetic stir plate for 5 minutes.

10.1.3.4 Measure the pH of the sample. Record this pH in the "*EFD_InitialpH*" field.

10.1.3.5 If the pH of the solid sample is less than or equal to 5, TCLP Extraction Fluid #1 is used.

10.1.3.6 If the pH of the solid sample is greater than 5, add 3.5mL of 1.0N HCl to the sample and swirl the sample for 30 seconds. Place a watchglass on the beaker and place the container in a water bath maintained at 50°C. Allow the sample to equilibrate to 50°C and remain in the waterbath for 10 minutes.

10.1.3.7 After 10 minutes at 50°C +/- 2°C, remove the sample from the waterbath and allow the sample to cool to room temperature.

10.1.3.8 Measure the pH of the solid sample. Record this pH in the "*EFD_SecondpHCheck*" check field. If the pH is less than or equal to 5.0, TCLP Extraction Fluid #1 is used. If the pH is greater than 5.0, TCLP Extraction Fluid #2 is used.

10.1.3.9 Denote which fluid (i.e., 1 or 2) is utilized in the LIMS Worksheet in the field called "*Extraction Fluid Used*".

10.1.4 Extraction Fluid Type Determination - SPLP

SPLP Extraction Fluid #1 is used for soils collected from sites east of the Mississippi River and for all wastes and wastewaters. The 1312E LIMS method is used for these types of samples.

SPLP Extraction Fluid #2 is used for soils collected from sites west of the Mississippi River. The 1312W LIMS Method is used for these types of samples.

SPLP Extraction Fluid #3 (i.e., reagent water) is used as the extraction fluid for cyanide

10.1.5 Particle Size Reduction

10.1.5.1 The solid portion of the sample must be evaluated for particle size. This may be accomplished by passing the solid portion through a 9.5mm sieve or by measuring the particle size of the solid with a ruler.

10.1.5.2 If the particle size is greater than 9.5mm, the solid portion is prepared for extraction fluid determination and extraction by crushing, cutting, or grinding the waste. The vessels used for homogenizing the sample must be compatible with the type of analysis and should not contribute to contamination. For example, plastic bags may be used to homogenize samples for metals only but must not be used for semivolatiles.

Note: Samples that require particle size reduction must be denoted via an NCM.

10.1.6 Container Selection

Based on the analysis methods requested, determine which container type will be used. For samples requiring SVOC methods only, glass containers are used. For samples requiring metals methods only, plastic containers are used. If SVOC and metals are required, then glass containers are used. Denote which container type is used in the comments section of the LIMS worksheet in the preparation batch.

10.1.7 Preparation of the Leachate Blank

The leachate blank is prepared using the same fluid used for the samples as determined in Section 10.1.3 and Section 10.1.4. The blank is designated in the preparation batch as “LB”. If both TCLP Fluid 1 and TCLP Fluid 2 are required for sample preparation, then a TCLP Fluid 1 leachate blank and a TCLP Fluid 2 leachate blank must be prepared.

Leachate blanks must be performed in the same type of container (i.e., plastic or glass) as the associated samples in the batch. If both glass and plastic containers are tumbled/leached together, then two fluid blanks must be prepared and reported – one in glass, and one in plastic.

Note: If, due to the nature of the sample matrix, field samples are not tumbled/leached and only require filtration, then a filtration blank must be prepared using the applicable TCLP/SPLP Fluid.

10.1.8 Minimum Extraction Volume Determination

A minimum of 100g must be utilized for extraction. If insufficient volume is available, consult the department manager, supervisor and/or project manager.

Determine the volume of the appropriate extraction fluid to add to the containers using the equation below:

$$\text{Volume of extraction fluid (mL)} = W_{solids} \times 20$$

Where:

W_{solids} = weight of solids portion of sample added to extraction vessel (g)

Document the volume of fluid utilized in the LIMS worksheet as *“Final Amount”.*

Note: If 100g of sample is not available, the volume of extraction fluid utilized must be adjusted according to the above formula. An NCM must be initiated to denote this adjustment.

10.1.9 Leaching/Tumbling Procedures

10.1.9.1 Weigh out the solid material into a jar of weigh boat. A minimum of 100g and 2000mL of extraction fluid must be utilized.

Note: Each gram of solid material requires 20mL of extraction fluid, as determined using the equation below; therefore, tumbling of additional sample material may be required:

$$\text{Weight of Sample(g)} = \frac{\text{Volume(mL) of Combined Liqud/Leachate to support analyses}}{20 mL/g}$$

For example, if 2700mL extraction fluid is needed to support the analyses requested, then a minimum of 135g of solid is necessary to produce the leachate for the analysis.

Note: Due to regulatory requirements, the analyst must start with a minimum of 100g of sample. If less than 100g of sample is available, the PM must be contacted for approval to proceed with preparation. An NCM must be initiated to denote this situation.

10.1.9.2 Add the volume of the appropriate extraction fluid, equal to 20 times the weight of the solid portion of the sample added to the extraction vessel, using the equation from Section 10.1.9.1 above. If weight of sample used is outside 95 gm to 105 gm, then the fluid volume used in the process must be adjusted.

10.1.9.3 Place the cap on the extraction vessel and seal the cap with Teflon tape. Place the extraction vessel into the rotary extraction device and rotate the sample at 30RPM for 18 ± 2 hours. Record observed rotation time on the LIMS worksheet daily prior to use.

10.1.9.4 The temperature must be maintained at 23°C +/- 2°C (i.e., 20.5°C to 25.4°C) during the extraction. Record the uncorrected and corrected temperature of the room at the beginning and end of rotation on the LIMS worksheet. In addition, the minimum and maximum temperatures observed during the rotation period must be recorded.

Note: Pressure may develop in the extraction vessel as the sample is rotated. Stop the extraction after a short time and vent each sample. Some types of samples, e.g., those with high carbonates, may develop significant pressure after a short period of time, especially if TCLP Fluid #2 is used.

10.1.9.5 After the extraction period is over, remove the samples from the rotation device. Place the samples in an upright position and allow the solids to settle for approximately 1 hour. This will facilitate the filtration of the leachate.

10.1.9.6 Samples with % Solids Equal to 100% or <0.5%

If the sample contains a very low level of solids, and the solids filtered from the sample were heated to determine the percent dry solids, a new aliquot of the waste sample must be used to prepare the leachate. If the sample contains less than 0.5% solids, the filtered liquid is the leachate. Set up the filtration device and filter the leachate through the 0.7um filter pad. Collect the leachate in the appropriate container. Measure and record the pH of the leachate as the final leachate pH in LIMS.

10.1.10 Filtration and Phase Re-Combination

Set up the filtration device and filter the leachate through the 0.7um filter pad. Collect the filtrate in a glass container for SVOC or plastic bottles for metals. Measure and record the pH of the filtrate as the *"FinalLeachatepH*" in LIMS.

- If the sample contained no liquid phase, then the filtrate is the TCLP extract.

- If a sample is multiphasic or has a soil and water fraction, determine if the leachate and the liquid phase (if any) are compatible by placing 1mL of each liquid into the same small container. Note if leachate and liquid phase combine or separate.

- If the leachate and the liquid phase separate, they are not compatible and must be prepared and analyzed separately. The final results are based on a weighted average of the results of the analysis of the leachate and the result from the analysis of the liquid phase. Refer to Section 11.2.3 for more information.

- If the leachate and the liquid phase combine, they are compatible, and the entire leachate and the entire liquid phase are combined prior to preparation and analysis. The final results are based on the analysis of the combined sample. Refer to Section 11.2.2 for more information.

- If the leachate is difficult to filter, filter only enough of the leachate to support the required analyses. The filter may be changed, if clogged, to facilitate the filtration.

Combine the leachate and liquid portion of the sample, using the same proportion of each fraction. For example, if one half of the volume of the leachate is filtered, it is combined with one half of the volume of the liquid portion of the sample. If one fourth of the volume of the leachate is filtered, it is combined with one fourth of the volume of the liquid portion of the sample, etc.

10.1.11 Storage and Sample Transfer

The leachate, liquid, or leachate/liquid combination must be preserved and stored in the same manner as a routine field sample.

Note: If metals are being determined on the sample, then the Metals Preparation Analyst must transfer a portion to a labeled plastic container and acidify with nitric acid to pH<2. Matrix spiking must occur prior to preservation. This step of the process is performed by the Metals Department, and is captured via the PRESERV_CHK method.

10.2 <u>Procedures for ZHE Samples (Volatiles)</u>

10.2.1 Particle Size Reduction

10.2.1.1 The particle size of the sample must be evaluated before the sample is introduced into the ZHE. If the sample particle size diameter is less than 1cm, no particle-size reduction is required. Most soils will not require particle size reduction. The particle size may be verified by measuring the size of the sample particles with a ruler or by passing thru a 9.5mm particle sieve.

If required, the particle-size reduction must take place just before the sample is introduced into the ZHE. The sample must be cooled to 0-6°C prior to particle size reduction, and exposure to the atmosphere must be minimized. The particle size may be reduced by crushing, grinding, or cutting the sample. The sample transfer and size reduction steps should be done quickly to minimize the loss of VOC.
NCM must be initiated to denote that particle size reduction was performed.

10.2.2 Percent Solids Determination

The ZHE filtration apparatus cannot accurately determine percent solids less than 5%. If an extraction is to be performed solely for volatile organic compounds and the percent solids concentration is obviously greater than 5% upon visual observation, proceed to Section 10.4.2.

10.2.3 Leachate Blank Procedures

The leachate blank is prepared using the same fluid used for the samples.

Note: If, due to the nature of the sample matrix, field samples are not tumbled/leached and only require filtration, then a filtration blank must be prepared using the applicable TCLP/SPLP Fluid.

Note: Each unit must be used as a leachate blank per every 20 extractions. Use the logbook to determine which unit to select for use as the leachate blank. Record the date and the batch number each unit was used.

10.2.4 Sample Extraction/Tumbling

10.2.4.1 Assemble up the ZHE units. The cylinder is identified with alpha characters. Record the ID of the units utilized in the worksheet section of the LIMS Worksheet.

10.2.4.2 If the % solid determined in section 10.1.2 is <0.5% add 100mls of waste to the ZHE apparatus. Assemble the filter paper between the two metal screens and close the ZHE. Connect the top plate and seal the unit. Gently apply pressure in small increments to a maximum of 50 psi. Attach the Tedlar bag to the valve and open the valve. This filtrate is the TCLP leachate and is processed for analysis.

10.2.4.3 If the % solid determined in section 10.1.2 is >0.5%, the volume of waste to be added to the ZHE is determined by the following equation. The material left in the ZHE is defined as the solid phase and the filtrate is the liquid phase. The sample is filtered to obtain a filtrate from the liquid phase and then the remaining solid material is leached utilizing TCLP fluid.

Note: The ZHE unit has a maximum capacity of 500mls. Therefore, if the %Solid is >0.5%, but less than 5 %, then charge the ZHE with 500mls of waste. If the % Solid is >5%, then use the equation below to determine the sample volume to be charged in the ZHE. This will result in 25gm of solid material left in the ZHE filters.

Weight of sample to charge the ZHE = (25g/% solids) x 100

10.2.4.4 The determined weight from section 10.2.4.3 is added to the ZHE and filter assembled on top of the waste. The unit is sealed. The pre-weighed tedlar bag is attached to the ZHE. Pressure is slowly applied in 10psi units until a maximum of 50psi is reached. The liquid obtained is the filtrate.

With the unit still closed, calculate the volume of TCLP fluid needed for extraction based on the calculated weight of soil material that should be in the ZHE filters based on the % solids section 10.2.4.6. Add the TCLP fluid to the ZHE unit. This extract is defined as the TCLP leachate. Proceed with leaching process as defined in sections 10.2.4.6 thru 10.2.4.11.

Volume of extraction fluid= 20 x % solids x weight of waste filtered / 100

For example, a % solid of 1 would require 100mls of TCLP fluid as a theoretical weight of 10gm of material would be inside the filters.

10.2.4.5 If the sample is 100% solid, then a 25gm aliquot is utilized. A minimum of 25gm must be used. If insufficient volume is available, the project manager must approve using a reduced volume an NCM must be generated.

Transfer the portion of the waste sample to the assembled vessel. Place the material between the piston base and metal screens housing the filter paper.

Note: Some samples may have very low densities, e.g. fabric samples, cardboard, or fly ash. The analyst will have to estimate the maximum weight of sample to allow the use of the maximum amount of extraction fluid without overfilling the ZHE vessel. A general guideline is to err on the low side to ensure sufficient room in the extraction vessel for the waste sample and extraction fluid.

Initiate an NCM to denote that a reduced volume of sample was utilized due to matrix.

10.2.4.6 Calculate the volume (V_{exf}) of extraction fluid in mL that is to be added to the ZHE as follows:

$$V_{exf} = (W_{sample} - (W_{s2} - W_{s1})) \times 20$$

Where:

W_{sample} = weight of sample added to the ZHE
W_{s2} = weight of the syringe and the liquid phase of the sample
W_{s1} = weight of the syringe

Note: The volume of extraction fluid added to the ZHE is twenty times the weight of the solid portion of the sample. If less than 25gm of sample was used, then the fluid volume will be adjusted and denoted with an NCM.

10.2.4.7 Assemble the ZHE unit and weigh out 25gm of the sample. Add the sample to the ZHE. Assemble the screens and seal the ZHE unit. Measure the appropriate volume of extraction fluid with a Class A volumetric flask and transfer the fluid into the sealed ZHE vessel with the micropump. Pressurize the unit to 50psi and record the initial pressure in the LIMS worksheet.

The temperature of the room must be maintained at 23°C +/- 2°C (i.e., 20.5°C to 25.4°C) during the leaching step. Reset the Min and Max on the digital thermometer prior to starting the rotator. The minimum and maximum temperatures observed during the rotation period must be recorded as uncorrected and corrected at the end of the rotation period.

10.2.4.8 Rotate the samples for 18 +/- 2 hours. Document the start time and end times in the preparation batch information tab.

Using a NIST-traceable digital timer, count the number of rotations observed over a 1-minute time period. Record the rotation and the timer ID on the batch information.

NOTE: The rotation must be within 30RPM +/- 2RPM.

10.2.4.9 After the leaching period has finished, stop the rotators and record the min and max temps from the room thermometer in the batch information screen. Let the rotators sit in the upright position for a minimum of 15 minutes to allow the material to settle.

Attach batch labels to the tedlar bags. Place a tedlar bag on the scale and tare the weight. Attach the tedlar bag to the ZHE with transfer tubing and open the bag.

Check the pressure gauge of the ZHE to make sure the apparatus did not leak during the tumble. Add this pressure reading to the appropriate field in the LIMS batch. Attach the nitrogen line to the ZHE and apply pressure until all the TCLP fluid has been transferred to the Tedlar bag.

Weigh filled Tedlar bag to determine final volume of sample and record this as LeachVolume in the worksheet of the LIMS batch. Transfer the tedlar bags to the volatile sample refrigerator on the 3rd floor.

Disassemble and clean ZHE units. Refer to the Labware Cleaning Posting for cleaning instructions.

10.2.4.10 If the sample waste has a liquid portion (from the solids determination) and a leachate, determine if the liquid and leachate are compatible by adding a small volume of each to a small vial.

If the liquid and leachate mix, combine the liquid and leachate and analyze. Any combination of volumes (liquid phase and leachate) that maintains the ratio of the leachate to the liquid phase may be used for convenience.

Calculate the ratio of liquid to leachate using the following equation.

$$Ratio = \frac{V_1}{V_{exf}}$$

Where:
V_1 = volume of liquid (mL) (Assume density is 1.0)
V_{exf} = volume of extraction fluid added to ZHE (mL)

Alternatively, combine the entire leachate with the liquid, preserve, store, and analyze an aliquot.

If the liquid and leachate are not compatible (do not mix), analyze them separately and combine the results arithmetically ~~(~~Section 11).

11.0 Analysis

The leachate preparation and analysis procedures are given in the following SOPs:

Category	Preparation Method	Analysis Method	Preparation SOP	Analysis SOP
Metals (no Mercury)	EPA 3010 EPA 3050	EPA 6010 EPA 6020	Waters and Soils: SA-ME-050 Wastes: SA-ME-051	SA-ME-070 or SA-ME-074
Mercury	Waters and Soils: EPA 7470 Wastes: EPA 7471	Waters and Soils: EPA 7470 Wastes: EPA 7471	SA-ME-028	SA-ME-028
Cyanide	EPA 9012	EPA 9012	SA-GE-040	SA-GE-040
Base/Neutral Acids	EPA 3510	EPA 8270	SA-SM-033	SA-SM-033
Chlorinated Herbicides	EPA 8151	EPA 8151	SA-SG-065	SA-SG-065
Chlorinated Pesticides	EPA 3510	EPA 8081	SA-EX-030	SA-SG-045
Volatiles	EPA 5030B	EPA 8260	SA-VO-001	SA-VO-004

11.0 Calculations / Data Reduction

11.1 Data Reduction

Data must be evaluated in accordance with SOP SA-QA-002: *Data Generation and Review*.

11.1.1 Historical Data

Many of the laboratory's clients submit samples for repeat monitoring purposes. Prior to analysis, verify LIMS Notes and/or use the Historical Data Tracker feature to determine if historical data is available for review.

11.2 Calculations

11.2.1 The procedures for the qualitative and quantitative evaluation of the analysis of the leachate for the target compounds are given in the appropriate analytical SOPs. (Section 10.3)

11.2.2 The following calculations are used to determine the volume of liquid phase and solid phase leachate that are combined to maintain the proper ratio if the entire liquid phase is not combined with the entire solid phase leachate.

11.2.2.1 Determine the volumes of the liquid phase (V_1) and solid phase leachate (V_2) in the weight (W, nominally 100g) of waste initially evaluated for percent solids.

$$V_1 = W \otimes \left(1 - \frac{percentsolids}{100}\right)$$

Assuming a density of 1g/mL

$$V_2 = W \otimes percentsolids \otimes 20$$

11.2.2.2 Calculate the percentage of the liquid phase (%LP) and the leachate from the solids phase (%LSP) if entire volumes were combined:

$$\%LP = \left(\frac{V_1}{V_1 + V_2}\right) \otimes 100$$

$$\%LSP = \left(\frac{V_2}{V_1 + V_2}\right) \otimes 100$$

11.2.2.3 Calculate the volume of liquid phase and leachate from the solid phase to combine to produce a given volume (FV) of the combined fractions:

$$Volumeof\ liquid\ phase(mL) = \frac{\%LP}{100} \otimes FV$$

$$Volumeof\ leachatefrom\ solid\ phase(mL) = \frac{\%LSP}{100} \otimes FV$$

11.2.2.4 Combine the calculated volumes in a labeled container, preserve as required, and store as given in Attachment 2.

11.2.3 If the liquid and leachate are analyzed separately, the results are combined mathematically as follows:

$$Final\mathrm{Re}sult, mg/L = \frac{C_1V_1 + C_2V_2}{V_1 + V_2}$$

Where:

C_1 = concentration of liquid phase (mg/L)
V_1 = volume of liquid phase (L)
C_2 = concentration of leachate from the solid phase (mg/L)
V_2 = volume of leachate from the solid phase (L)

12.0 Method Performance

12.1 Reporting Limit Verification (RLV)

Reporting limits verifications as outlined in SOP SA-QA-007: *Determination and Verification of Reporting and Detection Limits* are not applicable to this procedure.

12.2 Method Detection Limit Study (MDL)

Method detection limits as generated in accordance with 40CFR Part 136 Appendix B are not applicable to this procedure.

Note: The laboratory may use the water MDL values converted for TCLP initial and final volumes to obtain MDL values for the TCLP procedure.

12.3 Method Detection Limit Verification (MDLV)

Method detection limit verifications as generated in accordance with 40CFR Part 136 Appendix B are not applicable to this procedure.

Note: The laboratory may use the water MDLV values converted for TCLP initial and final volumes to obtain MDLV (i.e., LOD) values for the TCLP procedure.

12.4 QC Limit Generation, Control Charting, and Trend Analysis

The control limits for the batch QC items (LCS, MS/MSD) for this procedure are not specified by the reference method; therefore, the laboratory defaults to in-house and/or laboratory-derived limits for the evaluation of batch QC items.

Control charting is a useful tool and is performed to assess analyte recoveries over time to evaluate trends. Control charting must be performed periodically (at a minimum annually) in accordance with SOP SA-QA-017: *Evaluation of Batch QC Data.*

12.5 Demonstrations of Capability

Initial and continuing demonstration of capability must be performed in accordance with SOP SA-QA-006*: Training Procedures.*

Prior to performing this procedure unsupervised, each new analyst who performs this analysis must demonstrate proficiency per method/analyte combination by successful completion of an initial demonstration of capability. The IDOC is accomplished via observation and verification of the employee’s technique coupled with preparation of an acceptable fluid blank.

Annual continuing demonstrations of capability (CDOCs) are also required per analyst per method/analyte combination. The CDOC requirement is typically accomplished via acceptable results on a PT study. The CDOC must be documented and routed to the QA Department for filing.

12.6 Training Requirements

All training must be performed and documented in accordance with SOP SA-QA-006: *Training Procedures*.

Note: The SOPs listed in the Reference/Cross-Reference Section are applicable to this procedure. All employees performing this procedure must also be trained on these SOPs.

13.0 Pollution Control

It is Eurofins Savannah's policy to evaluate each method and look for opportunities to minimize waste generated (e.g., examining recycling options, ordering chemicals based on quantity needed, preparing reagents based on anticipated usage and reagent stability, etc.). Employees must abide by the policies in Section 13 of the Environmental Health and Safety Manual and the Savannah Addendum to the EHSM.

This procedure has been evaluated for opportunities to minimize the waste generated. Where reasonably feasible, pollution control procedures have been incorporated.

14.0 Waste Management

Waste management practices must be conducted consistent with all applicable federal, state, and local rules and regulations. All waste (i.e., excess reagents, samples, and method process wastes) must be disposed of in accordance with Section 9 of the Eurofins Savannah Addendum to the EHSM. Waste description rules and land disposal restrictions must be followed.

14.1 Waste Streams Produced by the Method

The following waste streams are produced when this method is carried out:

- Excess aqueous samples, acidic aqueous samples, and extracts- Neutralize non-hazardous samples before disposal into drain/sewer. Transfer hazardous samples to the waste department for disposal.

- Excess soil and solid samples –Transfer RCRA hazardous and non-hazardous samples to waste department for disposal via incineration in the yardbox. Samples characterized as PCB Hazardous or Foreign Soils must be transferred to the waste department for drumming.

- TCLP extracts: Dispose of according to instructions in the analytical SOPs. (Section 10.3)

15.0 References / Cross-References

- SOP SA-AN-100: *Laboratory Support Equipment (Verification and Use)*
- SOP SA-AN-041: *Reagent and Standard Materials Procedures*
- SOP SA-QA-002: *Data Generation and Review*
- SOP SA-QA-005: *Preventive and Corrective Action Procedures*
- SOP SA-QA-006*: Training Procedures*
- SOP SA-QA-007: *Determination and Verification of Detection and Reporting Limits*
- SOP SA-QA-015: *Homogenization, Compositing, and Segregation of Samples*
- SOP SA-QA-017: *Evaluation of Batch QC Data*
- Eurofins Savannah Quality Assurance Manual
- Eurofins Environmental Health and Safety Manual
- Eurofins Savannah Addendum to the Environmental Health and Safety Manual
- *Test Methods for Evaluating Solid Waste, Third Edition*; U.S. EPA Office of Solid Waste and Emergency Response: Washington, DC, November, 1992.
    - Method 1311, Revision 0: *Toxicity Characteristic Leaching Procedure;* July 1992
    - Method 1312, Revision 0: *Synthetic Precipitation Leaching Procedure;* September 1994

16.0 Method Modifications and Clarifications

16.1 The laboratory does not perform method detection limit studies for this procedure. Values are not reported below the routine reporting limit associated with each analytical procedure.

16.2 The laboratory defaults to its routine liquid control limits for evaluation of TCLP and SPLP samples.

16.3 Other matrices may be incorporated into this procedure upon client request.

16.4 EPA Method 1312 does not address the holding time for cyanide analysis. Therefore, the laboratory has incorporated a default holding time as listed in Attachment 2.

16.5 EPA 1311 and EPA 1312 define the temperature required during rotation as 23 +/- 2°C. The thermometers utilized to monitor the room temperature are digital units and display temperatures to the 0.1 degree. As such, the laboratory allows a room temperature of 20.5°C to 25.4°C during rotation.

17.0 Attachments

The following Tables, Diagrams, and/or Validation Data are included as Attachments:

Attachment 1: SOP Summary
Attachment 2: Sample Collection, Preservation, and Holding Time Table
Attachment 3: QC Summary
Attachment 4: Instrument Maintenance and Troubleshooting
Attachment 5: TCLP Levels for Non-Volatile and Semi-Volatile Analytes
Attachment 6: pH Procedure
Attachment 7: Weight needed to filter to give 100g of solids and the total volume
Attachment 8: TCLP Flow Chart

Attachment 1:
SOP Summary

Sample Preparation and Analysis Summary

The sample is initially evaluated for percent solids. If a liquid sample contains less than 0.5% dry, solid material, the sample is filtered, and the liquid phase after filtration is defined as the TCLP/SPLP leachate. If the percent solids is greater than 0.5%, the solid and liquid phases must be separated. The liquid phase is collected and refrigerated until the time of extraction and analysis. The particle size of the remaining solid phase must be reduced, if necessary, and the solid phase is extracted with twenty times the weight of the solid phase in extraction fluid for 18 hours (+/-2 hours).

The TCLP extraction fluid is chosen based on the target analytes and the type of sample. The SPLP extraction fluid is chosen based on the region of the country where the sample site is located, if the sample is a solid.

After the leaching process has been completed, the leachate is collected, and, if compatible, is combined with the liquid phase from the solids determination. If the leachate is not compatible with the liquid phase, the leachate is collected and refrigerated until the time of extraction and analysis.

The leachate or combined leachate/liquid phase is extracted/digested by the procedure appropriate to the target compounds. Section 10.3 lists the appropriate methods and SOPs for the extraction or digestion and analysis of the liquid phase, or leachate. If the liquid phase from the solids determination is not compatible with the leachate, the samples (the leachate sample and the liquid phase sample) are analyzed individually, and a weighted average is used to determine the total concentration of the contaminants.

The extract or digestate is analyzed using the appropriate analytical procedure. The result from the analysis is compared to the regulatory limit to determine if the waste sample exhibits hazardous characteristics.

Note: It is unlikely that a sample that is a non-aqueous liquid, or contains a non-aqueous liquid phase, will be able to meet the regulatory threshold limits.

Attachment 2:

Sample Collection, Preservation, and Holding Time Table

Fraction	Sample Bottle Type & Preservation	Sample Storage	Holding Time to Leach[2]	Leachate Bottle Type & Preservation[3]	Leachate Storage	Holding Time to Prep[4]	Holding Time to Analysis
SVOC	Glass container; minimum headspace	Refrigerated at 4°C[1]	14 days	1L glass container w/ Teflon cap	Refrigerated at 4°C[1]	7 days	40 days from prep
ME (includes Hg)	Glass or plastic container; minimum headspace	Refrigerated at 4°C[1]	28 days	500mL plastic container; preserved with 1mL HNO_3 to pH <2	Refrigerated at 4°C[1]	28 days	28 days from leach
ME (no Hg)	Glass or plastic container; minimum headspace	Refrigerated at 4°C[1]	6 months	500mL plastic container; preserved with 1mL HNO_3 to pH <2	Refrigerated at 4°C[1]	6 months	6 months from leach
CN	Glass or plastic container; minimum headspace	Refrigerated at 4°C[1]	14 days	500mL plastic container; preserved with NaOH	Refrigerated at 4°C[1]	14 days	14 days from leach
VOA	Glass VOA vial; no headspace	Refrigerated at 4°C[1]	14 days	Tedlar bag w/ no headspace;	Refrigerated at 4°C[1]	NA	14 days from leach

[1] <0-6°C, but not frozen
[2] From sample collection to leaching
[3] Sample preservation must be performed by the analytical department upon receipt of the leachate. The sample chosen as the MS/MSD must be spiked prior to preservation.
[4] From sample leaching to preparation

Attachment 3:
QC Summary

QC Item	Frequency	Criteria	Corrective Action
Batch Definition	Up to 20 field samples, prepared together, within a 24-hour time period	Not Applicable	Not Applicable
Method/Fluid Blank	One per batch, in each Extraction Fluid used	result <RL	Evaluate according to SOP SA-QA-017
Initial Demonstration of Capability (IDOC)	Initially, per analyst, per method/analyte combination	E-training; SOP Competency Exam; and Fluid Blank <RL	Unsupervised work cannot begin until successful IDOC has been obtained.
Continuing Demonstration of Capability (CDOC)	Annually, per analyst, per method/analyte combination	Fluid Blank < RL; or Acceptable PT	Re-perform CDOC. Perform refresher training, if necessary.

Attachment 4:
Instrument Maintenance and Troubleshooting

Instrument Labeling

Each instrument must be labeled with its name or ID (e.g., MSA, ICP-D, etc.). Additionally, non-operational instruments must be isolated from service or marked as being out of service. Each piece of equipment has an "Operational / Not Operational" sticker that is used for this purpose.

Maintenance Log

A maintenance log must be established for each piece of equipment used in the laboratory.

All maintenance performed must be recorded in the logbook in real time. Items to be captured include:

- Type of maintenance performed (Note: This includes preventative/routine maintenance; non-routine maintenance; maintenance performed by an external vendor; updates to software versions; etc.)
- Name of person performing the maintenance
- Date the maintenance was performed
- Detailed explanation of the reason for any non-routine maintenance (i.e., the source of the problem)
- Resolution of the problem (i.e., the Return to Control)

Note: All maintenance performed by external service providers should be accompanied by work orders, etc., which need to be scanned and filed with the associated instrument records.

Note: Monthly review of maintenance logbooks is required.

Preventive Maintenance

Inspect the extractor motor and bearings. The motor and bearings are considered normal if there is no observable wear and tear on the extractor and the rate of rotation can be maintained. Note any unusual wear in the maintenance log and notify the Department Manager immediately.

Rotator– Capable of holding several extraction vessels and rotating samples continuously at a rate of 30RPM ± 2RPM. The extractor must be maintained at 23°C (i.e., 20.5°C to 25.4°C) during the leaching process. The rotation device must be verified for the correct RPM with each extraction and documented in the analytical batch information.

Inspect the ZHE extractor bodies, fittings, and o-rings after each use. Replace any part that will not hold pressure under the test conditions or remove from service until repaired.

Troubleshooting

Troubleshooting should be documented as outlined above. If possible, troubleshooting is best performed in a step-wise manner to systematically isolate instrument components. Refer to the instrument manufacturer's guides for specific information and strategies. Enlist assistance from technical and/or department management as needed.

Contingency Plan

An extensive spare parts inventory is maintained for routine repairs. Since instrumentation is standardized throughout the laboratory network, spare parts and components can be readily exchanged among the network.

In general, the laboratory has at least one backup unit for each critical unit. In the event of instrument failure, portions of the sample load may be diverted to duplicate instrumentation, the analytical technique switched to an alternate approved technique (such as manual colorimetric determination as opposed to automated colorimetric determination), or samples shipped to another properly certified or approved Eurofins location.

Attachment 5:
TCLP Levels for Non-Volatile and Semi-Volatile Analytes

Fraction	Analysis Method	Preparation SOP	Analysis SOP	Analyte	Regulatory Threshold Limit (mg/L)	Matrix Spike Level (mg/L)
Metals	EPA 6010 EPA 6020	Soil and Water: SA-ME-050 Waste: SA-ME-051	SA-ME-070 SA-ME-074	Arsenic	5.0	20
				Barium	100.0	20
				Cadmium	1.0	0.50
				Chromium	5.0	0.20
				Lead	5.0	5.0
				Selenium	1.0	20
				Silver	5.0	0.50
Mercury	Soil and Water: EPA 7470A Waste: EPA 7471B	SA-ME-028	SA-ME-028	Mercury	0.2	0.10
Base/Neutral Acids	EPA 8270	SA-EX-030	SA-SM-033	o-Cresol	200.0	0.50
				m-Cresol	200.0	0.50
				p-Cresol	200.0	0.50
				Cresol (Total)	200.0	
				1,4-Dichlorobenzene	7.5	0.50
				2,4-Dinitrotoluene	0.13	0.50
				Hexachlorobenzene	0.13	0.50
				Hexachlorobutadiene	0.5	0.50
				Hexachloroethane	3.0	0.50

Fraction	Analysis Method	Preparation SOP	Analysis SOP	Analyte	Regulatory Threshold Limit (mg/L)	Matrix Spike Level (mg/L)
				Nitrobenzene	2.0	0.50
				Pentachlorophenol	100.0	0.50
				Pyridine	5.0	0.50
				2,4,5-Trichlorophenol	400.0	0.50
				2,4,6-Trichlorophenol	2.0	0.50
Chlorinated Herbicides	EPA 8151A	SA-SG-065	SA-SG-065	2,4-D	10.0	0.10
				2,4,5-TP (Silvex)	1.0	0.10
Volatiles	EPA 8260	SA-VO-001	SA-VO-004	Benzene	0.5	0.50
				Carbon tetrachloride	0.5	0.50
				Chlorobenzene	100.0	0.50
				Chloroform	6.0	0.50
				1,2-Dichloroethane	0.5	0.50
				1,1-Dichloroethylene	0.7	0.50
				Methyl ethyl ketone	200.0	0.50
				Tetrachloroethene	0.7	0.50
				Trichloroethylene	0.5	0.50
				Vinyl chloride	0.2	0.50

The matrix spike level is the concentration of the sample after the spiking solution has been added (the theoretical or true concentration).

Attachment 6:
pH Meter Procedure

pH Meter Use

Ensure that the pH meter has warmed up and that pH is the selected mode of operation. Rinse the electrode with DI water. Place an aliquot of the item to be measured (i.e., field sample, QC sample, or buffer solution) into a beaker with a Teflon-coated stir bar. Immerse the electrode in the sample ensuring that it does not come in contact with the stir bar. Allow the solution to stir slowly while the measurement is being made.

After the reading has stabilized, record the pH to the nearest 0.01 pH unit.

After all measurements have been made, return the electrode to the 7 buffer solution or electrode storage solution and set the meter to “standby.” The meter should be left “on” when not in use.

Pour fresh pH buffer solution from the stock bottle each day. Do not reuse the solution over multiple days.

pH Meter Calibration

The pH meter must be calibrated prior to first use and when the daily verification fails to meet criteria. In order to bracket the range of use of the pH meter (and accommodate the varying TCLP Fluid pH values) the pH meter must be calibrated using pH 2.0, 4.0, and 7.0 and 10 buffer solutions. The lot numbers of the pH buffers must be recorded in the LIMS Worksheet.

Note: The buffers should be at the same temperature of the samples.

- Rinse the electrode with DI water and with the buffer.
- Place the electrode in the buffer. When reading is stable, set the meter to the pH value of the buffer.
- Repeat until all 4 pH buffers have been measured.
- Record the date of meter calibration and slope within each LIMS batch.

pH Meter Verification

The pH meter must be verified daily using pH 2.0, 4.0, 7.0, and 10 buffer solutions. Compare the meter’s reading of each buffer’s pH to the actual value. Each buffer’s reading must be within 0.05 pH units from the actual value, to be acceptable. If the verification of pH is not within 0.05 pH units of expected value, re-calibration of the meter is required.

Note: Record the lot numbers of the buffers, the nominal pH, and the measured pH in the batch summary for each LIMS batch.

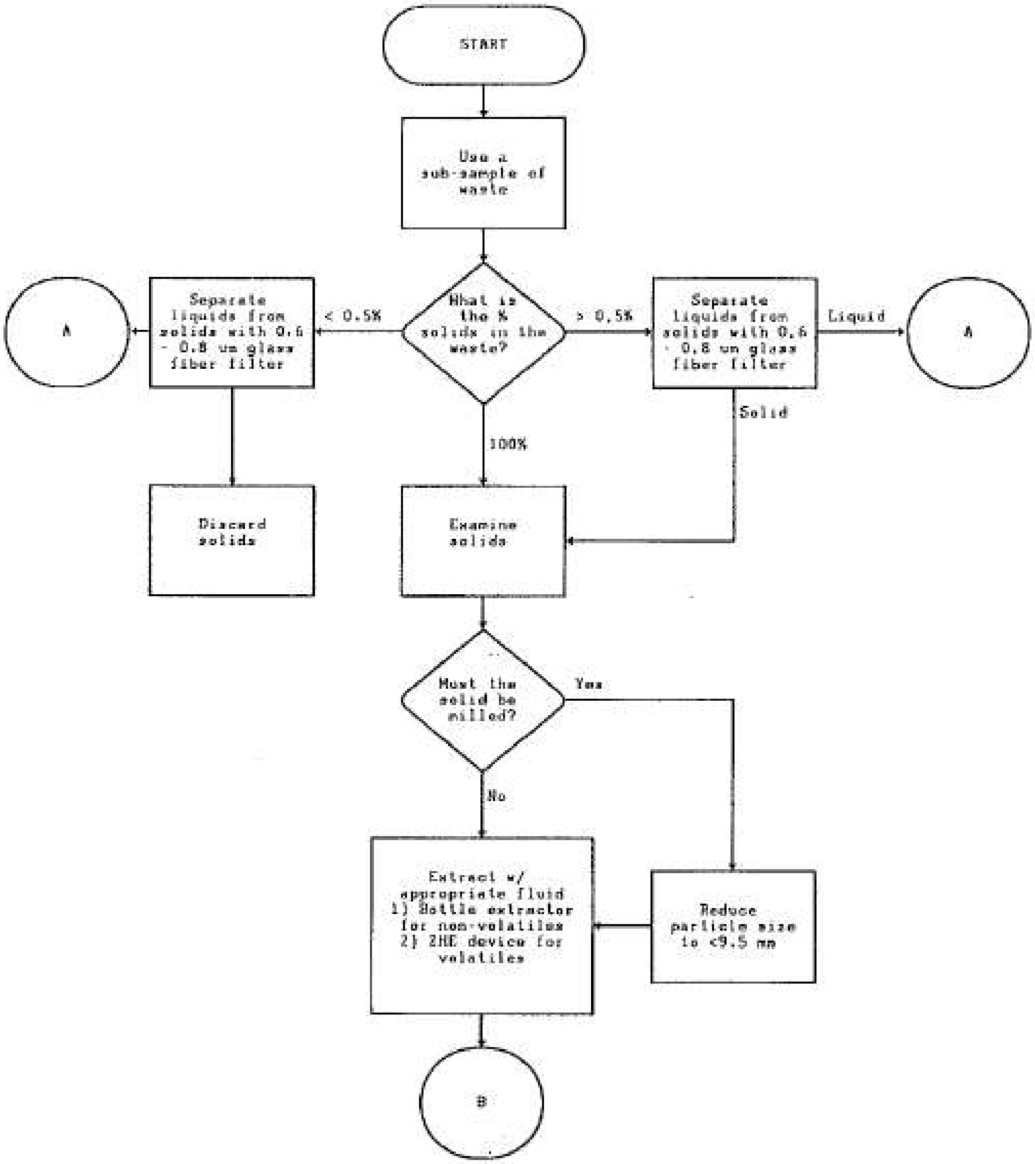
Attachment 7:
Weight Needed to Filter to Give 100g of Solids and the Total Volume

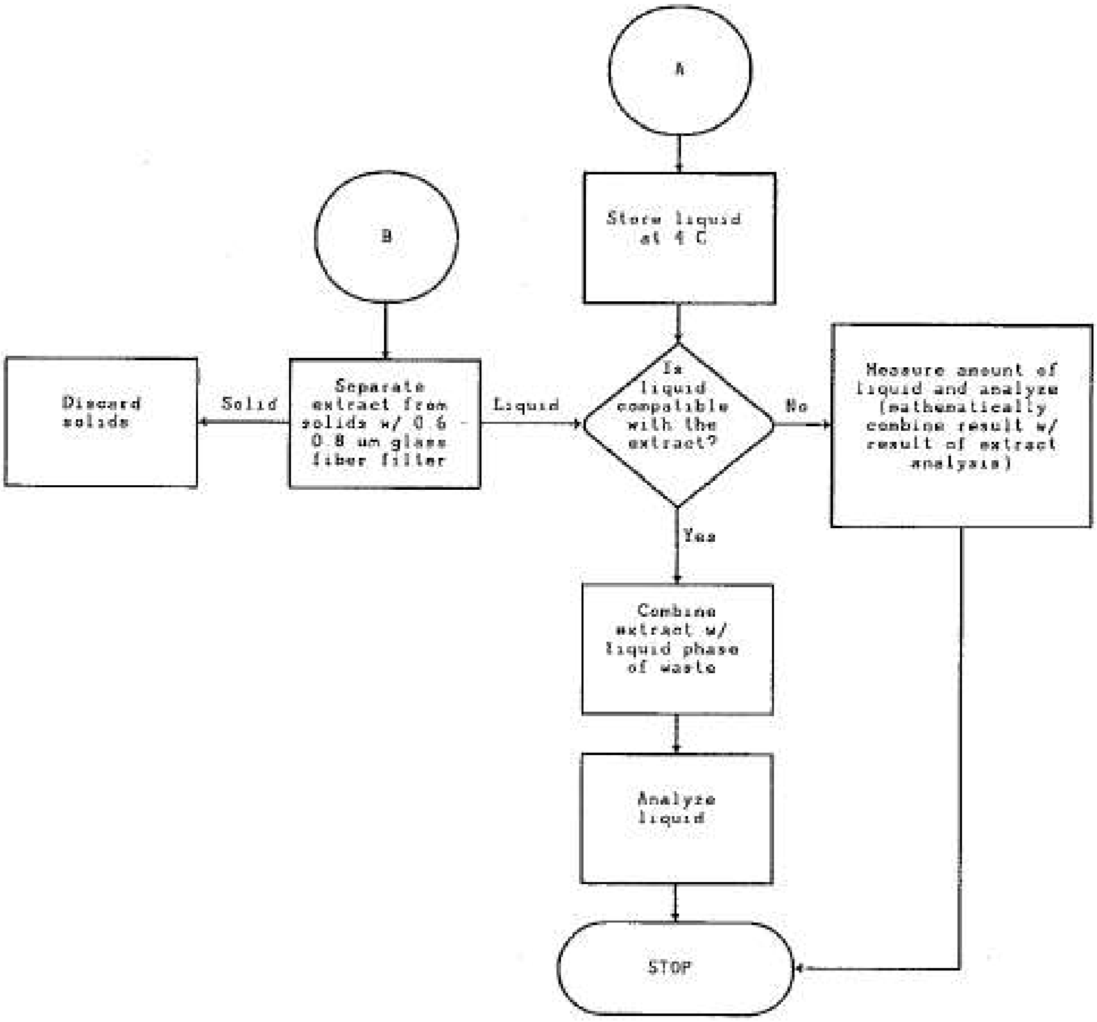
Percent Solids	Liquid (g)	Weight to filter to give 100g of solids (g)	Leachate (mL)	Liquid Phase (g)	Total Volume (mL)	Total Volume (L)
100	0	NA	2000	0	2000	2
90	10	111.11	2000	11.11	2011.11	2.01
80	20	125	2000	25	2025	2.02
70	30	142.85	2000	42.85	2042.85	2.04
60	40	166.66	2000	66.66	2066.66	2.06
50	50	200	2000	100	2100	2.1
40	60	250	2000	150	2150	2.15
30	70	333.33	2000	233.33	2233.33	2.23
20	80	500	2000	400	2400	2.4
10	90	1000	2000	900	2900	2.9
5	95	2000	2000	1900	3900	3.9
1	99	10000	2000	9900	11900	11.9
0.5	99.5	20000	2000	19900	21900	21.9
<0.5	>99.5	filter enough to obtain sufficient volume to support tests	NA	NA	NA	NA

Attachment 8:
TCLP Flowchart

METHOD 1311

TOXICITY CHARACTERISTIC LEACHATE PROCEDURE




A
Store liquid at 4 C
B
Discard solids
Solid
Separate extract from solids w/ 0.6 - 0.8 um glass fiber filter
Liquid
Is liquid compatible with the extract?
No
Measure amount of liquid and analyze (mathematically combine result w/ result of extract analysis)
Yes
Combine extract w/ liquid phase of waste
Analyze liquid
STOP

Revision History

Summary of Changes for Revision 17:
- Removed references to TestAmerica due to a change in legal entity.

Summary of Changes for Revision.
- Added micropump to section 6.1.
- Updated section 10.2.4.7 that the micropump is utilized to deliver the fluid to the ZHE units. Environmental Standards Audit 2021

Summary of Changes from Previous Revision:

- Minor editorial, grammatical, and/or formatting changes made.
- Removed references to Non-ZHE rotators and ZHE rotators from the SOP. New rotators are in use that hold both Non-ZHE and ZHE containers.
- Added to section 10.1.9.2 guidance on when to adjust fluid volume based on weight of the sample.
- ZHE units with pressure gauges have been purchased. Edits to section 10.2.4.7 on the addition of extraction fluid and pressurization requirements.
- Added to section 10.2.4.11 the requirement to document the final pressure of the ZHE unit in LIMS.

ELEMENTS BY ICP-MS

(Methods: EPA 200.8, EPA 6020A, and EPA 6020B)

Approvals (Signature/Date):

01/18/2023

Emma Ogletree — Date
Department Manager

Kimberly Chamberlain — 01/18/2023

Kimberly Chamberlain — Date
Quality Assurance Manager

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Facility Distribution No. _____1_____ **Distributed To:_TALS File System Shares**

1.0 Scope and Application

This SOP gives the procedures for the determination of various metals by inductively coupled plasma mass spectrometry (ICP-MS).

Note: The routine matrices for this procedure are waters and soils; however, this procedure may be adapted to accommodate other matrices as outlined in Section 16.1.

A complete target analyte list, the reporting limits (RL), the method detection limits (MDL), and the accuracy and precision criteria associated with this procedure are provided in the TALS Method Limit Groups (MLGs).

This SOP was written by and for Eurofins Savannah laboratory.

2.0 Summary of Method

Prior to analysis by ICP-MS, the sample must be solubilized or digested using the sample preparation method appropriate to the matrix. Sample digestates are aspirated and nebulized into a spray chamber. A stream of argon gas carries the sample aerosol through the innermost of three concentric tubes and injects it into the middle of the donut-shaped plasma. The sample elements are dissociated, atomized, and excited to a higher energy level. The ions that are produced are entrained in the plasma gas and introduced, by means of an interface, into a mass spectrometer. The ions are sorted according to their mass to charge ratios and quantified with a channel mass spectrometer.

This SOP is based on the following methods: EPA Method 200.8, EPA Method 6020A, and EPA Method 6020B.

3.0 Definitions

Refer to the Glossary Section of the *Quality Assurance Manual* (QAM) for a complete listing of applicable definitions and acronyms.

4.0 Interferences

4.1 Procedural Interferences

4.1.1 Interferences may be caused by contaminants in solvents, reagents, glassware, and other sample processing apparatus and can make identification and/or quantification of the target analytes difficult.

4.1.2 All sample collection containers are single-use disposable containers which limits the potential for contamination. All non-disposable labware must be scrupulously cleaned in accordance with the posted Labware Cleaning Instructions to ensure it is free from contaminants and does not contribute artifacts.

4.1.3 High purity reagents and solvents are used to help minimize interference problems. Hydrochloric acid and nitric acid must be verified prior to use in accordance with the Eurofins Environment Testing Solvent Lot Testing Program.

4.1.4 Instrument and/or method blanks are routinely used to demonstrate all reagents and apparatus are free from interferences under the conditions of the analysis.

4.2 Matrix Interferences

4.2.1 Matrix interferences may be caused by contaminants that are co-extracted from the sample matrix. The sample may require cleanup such as filtration or dilution prior to analysis to reduce or eliminate the interferences.

4.2.2 Interfering contamination may occur when a sample containing low concentrations of analytes is analyzed immediately following a sample containing relatively high concentrations of analytes. As such, samples known to be clean should be analyzed first. To prevent carryover into subsequent samples, analysis of reagent blanks may be needed after the analysis of a sample containing high concentrations of analytes.

4.2.3 Isobaric elemental interferences in the ICP-MS are caused by isotopes of different elements forming atomic ions with the same nominal mass-to-charge ratio (m/z) as the target analyte. These can be managed by the selection of an alternate isotope or by the use of elemental interference equations. Most isobaric interferences that could affect the ICP-MS analysis for elements in this SOP have been identified. The basic elemental interference equations are based on natural isotopic abundances. The most precise coefficients for an instrument must be determined from the ratio of the net isotope signals that are observed for a known standard solution at a concentration sufficient to produce suitable counting statistics.

4.2.4 Physical interferences are effects associated with the sample nebulization and transport processes as well as ion-transmission efficiencies. Changes in viscosity can cause significant inaccuracies, especially in samples containing high concentrations of dissolved solids or high acid concentrations. These changes in matrix can cause significant signal suppression or enhancement. Dissolved solids can deposit on nebulizer tips and interface cones (reducing the orifice size and the instrument’s performance). Internal standards can be used to correct for physical interferences if they are carefully matched to the analyte so that both elements react similarly to the matrix changes.

4.2.5 Memory interferences can occur when analytes from a previous sample contribute to signals measured from subsequent samples. The memory effects can result from analyte deposition of sample on the sample tubing, joints, nebulizer, spray chamber, torch, and/or interface cones. Routine maintenance on the sample introduction system is necessary in order to minimize the memory interferences. The memory effects must be taken into account when setting up a suitable rinse times. The evaluation of a minimum of three replicate integrations will help to determine memory problems.

5.0 Safety

Employees must abide by the policies and procedures in the Eurofins Environmental Health and Safety Manual (EHSM), the Eurofins Savannah Addendum to the EHSM, and this document.

This procedure may involve hazardous materials, operations, and equipment. This SOP does not purport to address all of the safety problems associated with its use. It is the responsibility of the user to follow appropriate safety, waste disposal, and health practices under the assumption that all samples and reagents are potentially hazardous.

The analyst must protect himself/herself from exposure to the sample matrix. Many of the samples that are tested may contain hazardous chemical compounds or biological organisms. The analyst must, at a minimum, wear protective clothing (lab coat), eye protection (safety glasses or face shield), disposable gloves, and closed-toe, nonabsorbent shoes when handling samples.

5.1 Specific Safety Concerns or Requirements

Nitric and hydrochloric acids are extremely hazardous as oxidizers, corrosives, poisons, and are reactive. Inhalation of the vapors can cause coughing, choking, irritation of the nose, throat, and respiratory tract, breathing difficulties, and lead to pneumonia and pulmonary edema. Contact with the skin can cause severe burns, redness, and pain. Nitric acid can cause deep ulcers, and staining of the skin to a yellow or yellow-brown color. These acid vapors are irritating and can cause damage to the eyes. Contact with the eyes can cause permanent damage.

Samples that contain high concentrations of carbonates or organic matter, or samples that are at elevated pH can react violently when acids are added. Acids must be added to samples under a hood to avoid splash/splatter hazards and/or possibly toxic vapors that will be given off when the samples are acidified.

5.2 Primary Materials Used

The following is a list of the materials used in this procedure, which have a serious or significant hazard rating, and a summary of the primary hazards listed in their MSDS/SDS.

NOTE: This list does not include all materials used in the procedure. A complete list of materials used in this procedure can be found in the Reagents and Standards Section and the Equipment and Supplies Section of this SOP

Employees must review the information in the MSDS/SDS for each material before using it for the first time or when there are major changes to the MSDS/SDS. Electronic copies of MSDS/SDS can be found using the “MSDS” button on the Oasis homepage, on the EH&S webpage on Oasis, and via TALS File System Shares.

Material	Hazards	Exposure Limit[1]	Signs and Symptoms of Exposure
Hydrochloric Acid[2]	Corrosive Poison	5ppm Ceiling	Inhalation of vapors can cause coughing, choking, inflammation of the nose, throat, and upper respiratory tract, and in severe cases, pulmonary edema, circulatory failure, and death. Can cause redness, pain, and severe skin burns. Vapors are irritating and may cause damage to the eyes. Contact may cause severe burns and permanent eye damage.
Nitric Acid[2]	Corrosive Oxidizer Poison	2ppm TWA 4ppm STEL	Nitric acid is extremely hazardous; it is corrosive, reactive, an oxidizer, and a poison. Inhalation of vapors can cause breathing difficulties and lead to pneumonia and pulmonary edema, which may be fatal. Other symptoms may include coughing, choking, and irritation of the nose, throat, and respiratory tract. Can cause redness, pain, and severe skin burns. Concentrated solutions cause deep ulcers and stain skin a yellow or yellow-brown color. Vapors are irritating and may cause damage to the eyes. Contact may cause severe burns and permanent eye damage.
[1]Exposure limit refers to the OSHA regulatory exposure limit.			
[2]Always add acid to water to prevent violent reactions.			

6.0 Equipment and Supplies

6.1 Equipment and Instrumentation

Agilent 7700 / 7900 (or equivalent) equipped with an Octopole Reaction System (ORS). The ORS is a small enclosed chamber that can be pressurized with a collision/reaction gas and mounted on-axis to the quadrapole for high ion transmission. The reaction gases used are:

Helium (UHP grade) - reduces both matrix based interferences, such as chlorides, and simple plasma based interferences, such as argon oxide or the doubly charged argon argon+, attributed from the argon plasma.

Hydrogen (UHP grade) - reduces the intense plasma-based interferences which the helium mode may not be efficient enough to correct for, such as argon hydride, argon gas, or argon oxide.

The ORS corrects for most of the interferences associated with a non-collision cell ICP-MS, but there are a few analytes that are evaluated in a “no gas” or normal mode that still require an interference equation. They are typically:

Cd 111: (1 * 111) - (0.00124 * 95)
Sn 115: (1 * 115) - (118 * 0.016)
Pb 208: (1 * 206) + (1 * 207) + (1 * 208)

If analyzing drinking water samples in "normal" mode only (no collision or reaction gas), then the following interference equations are recommended by the EPA. These equations are guidelines and can differ from instrument to instrument.

As 75: (1 * 75) - [(3.127 * 77) - (0.815 * 82)]
Cd 111: (1 * 111) - [(1.073 * 108) - (0.712 * 106)]
Pb 208: (1 * 206) + (1 * 207) + (1 * 208)
Mo 98: (1 * 98) - (0.146 * 99)
V 51: (1 * 51) - [(3.127 * 53) - (0.113 * 52)]
In 115: (1 * 115) - (0.016 * 118)

Data System: Chemstation and TALS are used to acquire, store, reduce, and output ICP mass spectral data. This software has the capability of processing stored ICP-MS data. The software allows for the calculation of concentrations of analytes using the calibration curve.
A Master Equipment Listing is maintained by the Quality Assurance Department. This listing contains information regarding software and firmware for all equipment utilized in the laboratory.

6.2 Volumetric Containers and Dispensers
All volumetric labware must be verified in accordance with SOP SA-AN-100: *Laboratory Support Equipment (Verification and Use).* Refer to Attachment 10 for Labware Cleaning Procedures.

Volumetric Labware	Volume	Type (Quantitative / Qualitative)	Use	Verification Frequency	Laboratory Verification Criteria
Autosampler Vials	50mL	Qualitative	Holding sample on instrument	None	None
Eppendorf-Style Mechanical Pipettes	Various	QUANTITATIVE	Preparing Dilutions, Standard and Reagent Preparation and Spiking	Quarterly (Daily for DOD)	Accuracy = 2% Precision = 1%
Volumetric Flasks (Class A)	Various	QUANTITATIVE	Preparing Dilutions, Standard and Reagent Preparation	None (Class A)	None (Class A)

6.3 Lab Supplies

Argon gas supply and appropriate fittings

Cooling water supply

Hydrogen gas (UHP)

Helium gas (UHP)

Detergent – Citranox or comparable cleaner, used for washing non-disposable labware.

Filters – 0.45um syringe filters, used to filter samples for dissolved metals in the lab. Also used to remove particulates from sample digestions.

6.4 Sample Collection Containers

All sample collection containers are single-use disposable containers which limits the potential for contamination.

The routine sample collection containers supplied by the laboratory are:

Waters:
Total Metals:
250mL plastic with nitric acid – purchased with Certificate of Analysis attesting to purity.
Dissolved Metals:
250mL plastic – purchased with Certificate of Analysis attesting to purity.

Soils:
8oz plastic soil jar – purchased with Certificate of Analysis attesting to purity.

7.0 Reagents and Standards

7.1 Expiration Dates

Expiration dates (time from initial use or receipt to final use) for standard and reagent materials must be set according to the guidance in this SOP. Note: These are maximum expiration dates and are not to be considered an absolute guarantee of standard or reagent quality. Sound judgment must be used when deciding whether to use a standard or reagent. If there is doubt about the quality of a standard or reagent material, a new material must be obtained or the standard or reagent material verified. Data quality must not be compromised to extend a standard's life.

The expiration date of any standard or reagent must not exceed the expiration date of the standard or reagent that was used to prepare it.

7.2 Reagents

Reagents must be prepared and documented in accordance with SOP SA-AN-041*: Reagent and Standard Materials Procedures.*

Hydrochloric acid and nitric acid must be verified prior to use in accordance with the Eurofins Environment Testing Solvent Lot Testing Program.

Laboratory Reagent Water – ASTM Type II or better; water from the Modulab filtration system (i.e., ASTM Type II) should be used as the default.

Nitric Acid (HNO_3) - trace metal grade.

Storage: Store in a cool, dry, ventilated storage area with acid resistant floors and good drainage. Store away from sunlight, heat, water, and incompatible materials. Stable under ordinary conditions of use and storage.
Expiration: Manufacturer's expiration date

Hydrochloric Acid (HCl) - trace metal grade.

Storage: Store in a cool, dry, ventilated storage area with acid resistant floors and good drainage. Store away from sunlight, heat, water, and incompatible materials. Stable under ordinary conditions of use and storage.

Expiration: Manufacturer's expiration date

7.3 Standards

Standards must be prepared and documented in accordance with SOP SA-AN-041*: Reagent and Standard Materials Procedures.* Certificates of analysis or purity must be received with all purchased standards, and scanned and attached in TALS.

7.3.1 Calibration Stock Standards

The following individual analytes are purchased at the concentrations listed:

Aluminum – 10000mg/L
Antimony – 1000mg/L
Arsenic – 1000mg/L
Barium – 1000mg/L
Beryllium – 1000mg/L
Boron – 1000mg/L
Cadmium – 1000mg/L
Calcium – 10000mg/L
Chromium – 1000mg/L
Cobalt – 1000mg/L
Copper – 1000mg/L
Iron – 10000mg/L
Lead – 1000mg/L
Lithium – 1000 mg/L
Magnesium – 10000mg/L
Manganese – 1000mg/L
Mercury – 1000mg/L
Molybdenum – 1000mg/L
Nickel – 1000mg/L
Potassium – 10000mg/L
Selenium – 1000mg/L
Silver – 1000mg/L
Sodium – 10000mg/L
Strontium – 1000mg/L
Thallium – 1000mg/L
Tin – 1000mg/L
Titanium – 1000mg/L
Vanadium – 1000mg/L
Zinc – 1000mg/L
Uranium – 1000ug/L
Thorium – 1000ug/L

Storage: room temperature
Expiration: opened and unopened containers are given the manufacturer's expiration date

7.3.2 Initial Calibration Verification Stock Standards

The following individual analytes are routinely purchased from Absolute standards (this standard must be purchased from a vendor different than the vendor of the calibration standards) at the concentrations listed:

Aluminum – 10000mg/L
Antimony – 1000mg/L
Arsenic – 1000mg/L
Barium – 1000mg/L
Beryllium – 1000mg/L
Boron – 1000mg/L
Cadmium – 1000mg/L
Calcium – 10000mg/L
Chromium – 1000mg/L
Cobalt – 1000mg/L
Copper – 1000mg/L
Iron – 10000mg/L
Lead – 1000mg/L
Lithium – 1000 mg/L
Magnesium – 10000mg/L
Manganese – 1000mg/L
Mercury – 100mg/L
Molybdenum – 1000mg/L
Nickel – 1000mg/L
Potassium – 10000mg/L
Selenium – 1000mg/L
Silver – 1000mg/L
Sodium – 10000mg/L
Strontium – 1000mg/L
Thallium – 1000mg/L
Tin – 1000mg/L
Titanium – 1000mg/L
Vanadium – 1000mg/L
Zinc – 1000mg/L
Uranium – 1000ug/L
Thorium – 1000ug/L

Storage: room temperature
Expiration: opened and unopened containers are given the manufacturer’s expiration date

7.3.3 Interference Check Standard

A/B Stock Standards:

Solution Component	**Concentration Solution A (mg/L)**	**Concentration Solution B (mg/L)**
Aluminum (Al)	1000	
Calcium (Ca)	1000	
Iron (Fe)	1000	
Magnesium (Mg)	1000	
Sodium (Na)	1000	
Phosphorus (P)	1000	
Potassium (K)	1000	
Sulfur (S)	1000	
Carbon (C)	2000	
Chloride (Cl)	10000	
Molybdenum (Mo)	20	
Titanium (Ti)	20	
Arsenic (As)		10
Cadmium (Cd)		10
Chromium (Cr)		10
Cobalt (Co)		10
Copper (Cu)		10
Manganese (Mn)		10
Nickel (Ni)		10
Silver (Ag)		10
Zinc (Zn)		10

Storage: room temperature
Expiration: opened and unopened containers are given the manufacturer's expiration date

7.3.4 Internal Standard Stock Standard

The following elements are used as the internal standards: Bi, In, Li6, Sc, Tb, Y, Ho, and Ge. A mixed standard containing all elements is purchased from a vendor at a concentration of 10mg/L.

Storage: room temperature
Expiration: opened and unopened containers are given the manufacturer's expiration date

7.3.5 Prepared Standards

Refer to Attachment 7 for information on prepared standards.

8.0 Sample Collection, Preservation, Shipment, and Storage

8.1 Water Samples

8.1.1 Total Metals

Water samples are routinely collected in 250mL plastic containers containing 3mL of a 1:3 nitric acid preservative. The preservative should be sufficient to achieve a sample pH of less than 2.

Although no temperature preservation is required, samples are routinely iced at the time of collection at 0-6°C (less than 6°C but not frozen). Samples are stored at room temperature until the time of digestion. Samples must be digested and analyzed within 6 months of collection, unless mercury is requested. Samples for mercury analysis must be digested and analyzed within 28 days of sample collection. Digestates are stored at room temperature until the time of analysis.

NCMs must be initiated for samples collected in improper containers and containing improper or insufficient preservatives.

8.1.2 Dissolved Metals

Water samples for dissolved metals are routinely filtered at the time of sampling and collected in 250mL plastic containers containing 3mL of a 1:3 nitric acid preservative. The preservative should be sufficient to achieve a sample pH of less than 2.

Note: If the sample is to be filtered in the laboratory, the sample must be collected in 250mL plastic container with no preservatives. Once filtered, the laboratory will add nitric acid to obtain a pH of less than 2. Unpreserved water samples that are to be filtered in the laboratory must be iced at the time of collection at 0-6°C (less than 6°C but not frozen). The samples must be kept refrigerated until the time of filtration and preservation.

> **Note:** The reference methods state that filtration must occur immediately; therefore, if the laboratory is requested to filter the samples - as opposed to a field filtration - appropriate narration must be included in the final report to denote this method deviation.

Although no temperature preservation is required when the samples are preserved with nitric acid, samples are routinely iced at the time of collection at 0-6°C (less than 6°C but not frozen). Samples are stored at room temperature until the time of digestion. Samples must be digested and analyzed within 6 months of collection, unless mercury is requested. Samples for mercury analysis must be digested and analyzed within 28 days of sample collection. Digestates are stored at room temperature until the time of analysis.

NCMs must be initiated for samples collected in improper containers and containing improper or insufficient preservatives.

8.2 Soil Samples

Soil samples are routinely collected in 8oz plastic soil containers.

Samples must be iced at the time of collection and maintained at 0-6°C (less than 6°C but not frozen) until the time of digestion and analysis. Samples must be digested and analyzed within 6 months of collection, unless mercury is requested. Samples for mercury analysis must be digested and analyzed within 28 days of sample collection. Digestates are stored at room temperature until the time of analysis.

9.0 Quality Control

SOP SA-QA-017: *Evaluation of Batch QC Data* and the SOP Summary in Attachment 3 provide requirements for evaluating QC data.

9.1 Batch QC

9.1.1 EPA 200.8 – Drinking Water

A digestion batch consists of up to 20 environmental samples and the associated QC items digested together within a 24 hour period.

The minimum QC items required for each digestion batch are: a method blank, a laboratory control sample (LCS), a low-level LCS (LLCS), a matrix spike (MS) to be performed on a minimum of 10% of samples or one per batch – whichever is greater, and a matrix spike duplicate (MSD).

This frequency equates to the following:

- For a batch of 10 or fewer samples, the minimum QC items are a method blank, an LCS, an LLCS, 1 matrix spike, and 1 matrix spike duplicate.
- For a batch of 11-20 samples, the minimum QC items are a method blank, an LCS, an LLCS, 1 matrix spike (from sample 1-10), another matrix spike (from sample 11-20), and a matrix spike duplicate.

The routine container supplied for this method is a 250mL container. 50mL is required for digestion. Reduced sample initial volumes may be necessary to achieve the required batch matrix spike frequency; however, the minimum digestion volume to be used for the matrix spike samples is 25mL. Note: Final volumes and spike amounts must be adjusted to compensate for these reduced initial volumes.

If there is insufficient sample volume to perform the required matrix spike(s), the LCS must be prepared in duplicate (i.e., LCSD). An NCM must be initiated on all affected samples to denote this situation. Insufficient sample volume is defined as receiving less than a total of 100mL.

Note: If an LCS and LCSD are performed, both QC items must be evaluated and reported. Acceptable recoveries (as well as %RPD) for both LCS and LCSD are required.

The sample preparation and digestion procedures are listed in the following SOPs:

Matrix	SOP
Aqueous samples	SA-ME-050

Batch QC must meet the criteria given in Attachment 3 of this SOP.

9.1.2 EPA 200.8 – Clean Water Act

An extraction batch consists of up to 20 environmental samples and the associated QC items extracted together within a 24 hour period.

The minimum QC items required for each extraction batch are: a method blank, a laboratory control sample (LCS), a matrix spike (MS) to be performed on a minimum of 10% of samples or one per batch – whichever is greater, and a matrix spike duplicate (MSD).

This frequency equates to the following:

- For a batch of 10 or fewer samples, the minimum QC items are a method blank, an LCS, 1 matrix spike, and 1 matrix spike duplicate.
- For a batch of 11-20 samples, the minimum QC items are a method blank, an LCS, 1 matrix spike (from sample 1-10), another matrix spike (from sample 11-20), and a matrix spike duplicate.

The routine container supplied for this method is a 250mL container. 50mL is required for extraction. Reduced sample initial volumes may be necessary to achieve the required batch matrix spike frequency; however, the minimum extraction volume to be used for the matrix spike samples is 25mL. Note: Final volumes and spike amounts must be adjusted to compensate for these reduced initial volumes.

If there is insufficient sample volume to perform the required matrix spike(s), the LCS must be prepared in duplicate (i.e., LCSD). An NCM must be initiated on all affected samples to denote this situation. Insufficient sample volume is defined as receiving less than a total of 100mL.

Note: If an LCS and LCSD are performed, both QC items must be evaluated and reported. Acceptable recoveries (as well as %RPD) for both LCS and LCSD are required.

The sample preparation and digestion procedures are listed in the following SOPs:

Matrix	SOP
Aqueous samples	SA-ME-050

Batch QC must meet the criteria given in Attachment 3 of the associated analytical SOP.

9.1.3 EPA 6020A and EPA 6020B

A digestion batch consists of up to 20 environmental samples and the associated QC items. The minimum QC items required for each digestion batch are: a method blank, a laboratory control sample (LCS), a matrix spike (MS), and a matrix spike duplicate (MSD) or a sample duplicate.
If there is insufficient sample to perform the MS/MSD or sample duplicate, an NCM must be initiated on all affected samples to denote this situation.

The routine container supplied for this method is a 250mL container. 50mL is required for digestion. Reduced sample initial volumes may be necessary to achieve the required batch matrix spike frequency; however, the minimum digestion volume to be used for the matrix spike samples is 25mL. Note: Final volumes and spike amounts must be adjusted to compensate for these reduced initial volumes.

If there is insufficient sample volume to perform the required matrix spike(s), the LCS must be prepared in duplicate (i.e., LCSD). An NCM must be initiated on all affected samples to denote this situation. Insufficient sample volume is defined as receiving less than a total of 100mL.

Note: If an LCS and LCSD are performed, both QC items must be evaluated and reported. Acceptable recoveries (as well as %RPD) for both LCS and LCSD are required.

The sample preparation and digestion procedures are listed in the following SOPs:

Matrix	**SOP**
Water samples	SA-ME-050
Soil samples	SA-ME-051

Batch QC must meet the criteria given in Attachment 3 of this SOP.

9.2 <u>Instrument QC</u>

9.2.1 Initial Calibration (ICAL)

The instrument must be calibrated daily in accordance with SOP SA-QA-016: *Evaluation of Calibration Curves.* This SOP provides requirements for establishing the calibration curve and gives the applicable formulas.

Instrument calibration is performed daily by analyzing a series of known standards. The methods require the calibration curve to consist of a minimum of a single standard and a blank; however, a multi-point calibration is used for all analytes. Readback is evaluated when standards are recalculated as samples and the calculated results compared with the true concentration

Refer to Attachment 7 for the standard preparation instructions. Other standard concentrations may be used provided they support the reporting limit and are fully documented in accordance with SOP SA-AN-041.

Tabulate the concentrations and corresponding responses for each analyte. Establish a calibration curve by plotting the concentration along the x-axis and the corresponding response along the y-axis.

EPA 6020A:

If a multi-point calibration is used, a minimum of five (5) points is required and the The regression coefficient/coefficient of determination (r^2) of the regression curve must be greater than 0.998 for the initial calibration curve to be acceptable

- Low-Level Readback: For a multi-point calibration, the low level standard should be within +/-30% of the true value. For a single point calibration, a standard at or below the reporting level is analyzed and should recover within +/- 20% of the true value.
- Mid-Level Readback: or a multi-point calibration, the low level standard should quantitate within +/- 10% of the true value. For a single point calibration, a standard from the same source as the calibration standard is analyzed and should recover with +/- 10% of the true value.

EPA 6020B:

If a multi-point calibration is used, a minimum of five (5) points is required and the The regression coefficient/coefficient of determination (r^2) of the regression curve must be greater than 0.998 for the initial calibration curve to be acceptable.

- Low-Level Readback: For a multi-point calibration, the low level standard should be within +/-20% of the true value. For a single point calibration, a standard at or below the reporting level is analyzed and should recover within +/- 20% of the true value.
- Mid-Level Readback: or a multi-point calibration, the low level standard should quantitate within +/- 10% of the true value. For a single point calibration, a standard from the same source as the calibration standard is analyzed and should recover with +/- 10% of the true value.

EPA 200.8

If a multi-point calibration is used, a minimum of five (5) points is required and the The regression coefficient/coefficient of determination (r^2) of the regression curve must be greater than 0.998 for the initial calibration curve to be acceptable.

Readback Criteria: Low-Level must be within 50% of true value and all others within 30% of true value.

DODQSM V5:

If a multi-point calibration is used, a minimum of five (5) points is required and the The regression coefficient/coefficient of determination (r^2) of the regression curve must be greater than 0.99 for the initial calibration curve to be acceptable

9.2.2 Second Source Initial Calibration Verification (ICV)

Each calibration curve must be verified initially – prior to any sample analyses – in accordance with SOP SA-QA-016 with a standard obtained from a second source.

The ICV must be within +/-10% to be acceptable.

Refer to Attachment 7 for the standard preparation instructions. Another standard concentration may be used provided it is mid-level and fully documented in accordance with SOP SA-AN-041.

9.2.3 Initial Calibration Blank (ICB) / Continuing Calibration Blank (CCB)

The instrument must be shown to be free from contamination by the analysis of calibration blanks. Initial calibration blanks are analyzed at the beginning of each analytical run immediately following the ICV. Continuing calibration blanks are analyzed every 10 analyses immediately following each CCV.

Initial and continuing calibration blanks must be <1/2RL to be acceptable.

9.2.4 Continuing Calibration Verification (CCV)

The initial calibration curve must be verified before and after every 10 analyses with a mid-level standard.

The CCV must be within +/-10% to be acceptable.

DODQSM V5:

The CCV must be analyzed after every 10 field samples and at the end of the sequence. All analytes must be within +/- 10% of the true value.

A LLCV must be analyzed daily. All analytes must be within +/-20% of the true value. LLCV should be less than equal to the LOQ. If the concentration of the lowest calibration standard is less than or equal to the LOQ, then the standard must be re-quantified against the calibration curve as the LLCV.

Corrective Action: Immediately analyze two additional CCVs. If both pass, samples by be reported. If either fails or if two CCVs cannot be run, perform corrective actions and repeat CCV(s) and analysis of all associated samples. Recalibration may be necessary.

Refer to Attachment 7 for the standard preparation instructions. Another standard concentration may be used provided it is mid-level and fully documented in accordance with SOP SA-AN-041.

9.2.5 Interference Check Standard (ICSA and ISCAB)

The purpose of the Interference Check Standard is to prove that the instrument software is adequately correcting for common interferences through the use interelement correction factors. This check must be performed at the beginning of each analysis run. The concentrations of the target analytes must be within 20% of the true concentrations to be acceptable. The analyst must pay particular attention to false positives and false negatives for elements not present in the interference check solutions. Unspiked analytes should be less than two times the RL.

Note: The vendor has acknowledged trace impurities in the ICSA and ICSAB solution for the following analytes: Cadmium, Cobalt, Chromium, Strontium, Lead, and Manganese. As such, the presence of these analytes is not indicative of a matrix interference.

9.2.6 Internal Standard (ISTD)

This procedure utilizes internals standards. See Attachment 7 for the concentrations and masses of the internal standard elements.

The internal standard solution is added to all standards, samples, and QC items by way of a peristaltic pump, a "T" connector, and a mixing coil at the instrument. The solution used is 1mg/L for each of the internal standard elements. Other concentrations may be used provided it is mid-level and fully documented in accordance with SOP SA-AN-041.

9.2.6.1 EPA 200.8

The response of the internal standard in all samples and QC items must be within 60-125% of the response of the internal standard in the calibration blank. If the response is outside this range, flush the instrument with rinse blank and re-analyze the calibration blank. If the responses are within limits, re-analyze the samples at a dilution of 2.

9.2.6.2 EPA 6020A and EPA 6020B

The response of the internal standard in all samples and QC items must not fall outside 30-150% of the response of the internal standard in the initial calibration blank. If the response is outside this range for instrument QC, terminate the analysis, correct the problem, and re-calibrate. If the response is outside this range for samples, re-analyze the sample at a dilution of 5.

9.2.6.3 DODQSM V5

The response of the internal standard in every field sample, standard and QC sample must be within 30-120% of the intensity of the IS in the initial calibration blank.

9.2.7 Post Digestion Spike (PDS)

A post-digestion spike is performed on one sample per analytical batch to determine if matrix interferences are present. This post-digestion spike is evaluated if the serial dilution fails or if the analyte concentration is not at least 50 times the instrument detection limit. This should be the same sample selected for the serial dilution in Section 9.2.7.

9.2.7.1 Transfer 10mL of a digestate to a suitable vial.

9.2.7.2 Spike the sample with 20uL of the ICP-MS Calibration Stock Standard.

9.2.7.3 Analyze the spiked aliquot and an un-spiked aliquot (the un-spiked may have been analyzed previously and does not need to be reanalyzed).

9.2.7.4 Calculate the percent recovery of the post digestion spike as follows:

$$\%REC = \frac{C_{ps} - C_s}{C_2} \times 100$$

Where: C_{ps} = concentration of post digestion spike (ug/L)
C_s = concentration of un-spiked sample (ug/L)
C_2 = theoretical concentration of spike (ug/L)
(Refer to Attachment 7)

9.2.7.5 Evaluate the recovery using the following decision matrix. Limits for post digestion spikes are 80-120%.

Result of Post Digestion Spikes	Action
Within 80-120% limits	None
>120% recovery	Repeat analysis. Remake spiking solutions, re-spike, and reanalyze. Reanalyze un-spiked sample.
<80% recovery but >50% recovery	1) Dilute and re-spike. Elevate RL accordingly (for all associated samples). 2) Spike and evaluate all associated samples. 3) Spike and evaluate all associated samples by single point MSA. 4) Qualify all associated samples.
<50% recovery	Dilute digestate and repeat spike. ***Treat all samples associated with spike in the same manner as the spiked sample (i.e., spike or dilute samples).*** If recoveries are not 80-120%, analyze all associated samples by single point MSA. Note – high level of target analytes may inhibit spike recovery. Consult the supervisor in events where high levels of targets appear to be interfering.

Note: The >50% recovery of the post digestion spike is a benchmark below which samples may be biased high if corrected for spike recovery.

9.2.7.6 The post digestion spike and the method of standard additions must not be applied to samples analyzed at a dilution that produces a significant negative response. The analyst must use good judgment when evaluating data where the sample response is negative. Where a significant negative response is present, the digestate should be diluted and reanalyzed to determine the extent of the matrix interferences. If necessary, adjust the interference corrections and reanalyze the samples.

9.2.8 Single Point Method of Standard Additions (MSA)

The Method of Standard Additions (MSA) is performed for TCLP samples and when the post-digestion spike is less than 50%. Perform the MSA as follows:

Two identical aliquots of the sample digest, V_x, are taken. One aliquot is spiked with a solution of known concentration, C_s. The second aliquot is analyzed un-spiked (the small volume of standard added to the spiked sample should be disregarded). The concentration of both aliquots is measured and the sample concentration, C_x, is calculated as follows:

$$C_x = \frac{S_2 V_s C_s}{(S_1 - S_2) V_x}$$

Where: S_1 = absorbance or concentration of the spiked aliquot
S_2 = absorbance or concentration of the un-spiked aliquot
Vs = volume of spike solution

Example:	Sample concentration (S_2):	523ug/L.
	Spike solution concentration (C_s):	50,000ug/L
	Volume of spike solution (V_s):	0.10mL
	Volume of sample aliquots (V_x):	10mL
	Spiked sample concentration (S_1):	951ug/L

C_x = [(523)*(0.10)*(50,000)] / [(951-523)*10)] = [2,615,000]/[4280] = 611 ug/L

9.2.9 Dilution Test (Serial Dilution)

A 1/5 dilution is prepared and analyzed on one sample per batch to determine if matrix interferences are present.

9.2.9.1 Select a sample digestate that contains one or more target analytes at concentrations greater than 50 times the method detection limit.

9.2.9.2 Dilute the digestate by a factor of 5, and analyze the dilution using the same procedures used for the un-diluted aliquot.

9.2.9.3 Compare the results of the diluted and un-diluted aliquots of sample digestate.

9.2.9.4 If the results of the dilution are within +/-10% of the results of the undiluted sample, no matrix interference is present. If the results differ by greater than +/-10%, matrix interference should be suspected.

9.2.10 Determination of Linear Range of the ICP-MS

If the instrument is not calibrated over its entire linear range for a particular element, a linear range standard must be analyzed daily to validate the linear range.

9.2.10.1 The ICSA solution is utilized as a linear range standard for those elements included in the solution. For elements not contained in the ICSA solution, a linear range standard must be prepared and analyzed.

9.2.10.2 Prepare the standard at concentrations that are expected to define the linear range of the instrument. The calibration standards and the linear range standards must be matrix matched; that is, they have the same percentage of hydrochloric and nitric acids.

9.2.10.3 Analyze the standard(s) after the initial calibration is validated.

9.2.10.4 Compare the concentration of the linear range standard with its true concentration using the following equation:

$$PercentDiference = \left| \frac{Ccal - Ctrue}{Ctrue} \right| \otimes 100$$

Where:
C_{cal} = concentration determined from analysis
C_{true} = true concentration of the standard

If the percent difference is less than or equal to 10%, the linear range is confirmed at that concentration. If the percent difference is greater than 10%, repeat the analysis with a lower concentration. For elements validated in this manner, data may be reported up to 90% of that linear range before a dilution is required.

9.3 Corrective Action for Out-of-Control Data

When the quality control parameters do not meet the criteria set forth in this SOP, corrective action must be taken in accordance with SOP SA-QA-005: *Preventive and Corrective Action Procedures* the QC Summary Table in Attachment 3. SOP SA-QA-005 provides contingencies for out-of-control data and gives guidance for exceptionally permitting departures from approved policies and procedures. Nonconformance Memos must be initiated to document all instances where QC criteria are not met and all departures from approved policies and procedures.

10.0 Procedure

10.1 Sample Preparation

The sample preparation procedures are given in the following SOPs:

Matrix	SOP #
Aqueous Samples	SA-ME-050
Soil Samples	SA-ME-051

10.2 QC Sample Preparation

The QC sample preparation procedures are given in the following SOPs:

Matrix	SOP #
Aqueous Samples	SA-ME-050
Soil Samples	SA-ME-051

10.3 Analysis

10.3.1 Instrument Operating Conditions

The instrument conditions listed in this SOP are provided for guidance purposes. The actual conditions used by the laboratory may be slightly different from those listed here and must be documented in the instrument maintenance log, data system, and/or run log.

Instrument maintenance must be performed in accordance with Attachment 4 of this SOP. Turn the ICP-MS on and initiate the tune screen. Start the tune screen to allow the instrument to become thermally stable before analyzing the calibration standards. While the instrument is warming up, if the sample and skimmer cones are new or have been cleaned, aspirate the interference check solution (or similar solution) for about 15 minutes to pre-condition the cones.

Aspirate a 1ppb solution containing Lithium 7, Cesium, Yttrium, and Thallium.

An autotune using the “Start Up” function is performed before every calibration. This autotune process will optimize the following:

- Torch Axis
- EM
- Plasma Correction
- Resolution / Axis
- Performance Report
- P/A (Pulse to Analog)

The performance report should be reviewed and should meet the following conditions:

- Sensitivity: should yield counts greater than 1500 for Li7 and 2500 for Y and Tl
- Precision: should be less than 10% RSD of 200 replicates
- Oxides: must be less than 3% as CeO
- Doubly charged ions: must be less than 10%

10.3.1.2 Analyze the calibration standards and calibrate the ICP-MS in accordance with SOP SA-QA-016: *Evaluation of Calibration Curves.*

10.3.2 Internal Standard (ISTD)

Prior to analysis, internal standards must be added to all standards, samples, and QC items. The concentration of the internal standard must be the same in all calibration samples, field samples, and QC samples. The internal standard solution is added at the time of analysis by using a peristaltic pump, a “T” connection, and a mixing coil that is inserted in the sample uptake line before the instrument’s nebulizer. The concentration of the internal standard solution is listed in Attachment 7 of this document.

10.3.3 Initial and Continuing Calibration Verifications

Calibrate the instrument using the standards and criteria described given in Section 9.2. Once the calibration has been established and verified with an ICV in accordance with Section 9.2, sample analysis may proceed.

Verify the calibration curve with a continuing calibration verification using the standards and criteria described given in Section 9.2.

10.3.4 Sample Analysis

The samples/digestates must be analyzed using the same procedures as those used for the calibration standards.

Note: It is the laboratory’s default procedure to analyze soil samples and non-drinking water samples at a dilution factor of 5. The dilution is prepared immediately preceding analysis by diluting 2mL of digestate to a 10mL final volume. These dilution factors are captured by adjusting the default final volume in the Method Limit Groups. Reporting limits and MDLs have been elevated accordingly.

The default procedure is to include QC items (method blank, LCS, MS/MSD, and SD) in determining the maximum number of samples in the sequence.

10.3.5 Example Analytical Sequence

Analytical Sequence for samples immediately following an initial calibration:

Description	Comments
Blank	
Initial Calibration	Lowest standard is at or below the RL
ICV	Second Source
ICB	
Samples & Batch QC Items	RL Check Standard, ICSA, ICSAB, up to 7 additional analyses.
CCV	
CCB	
Samples & Batch QC Items	Up to 10 analyses, including QC.
CCV	
CCB	

Analytical Sequence for samples not immediately following an initial calibration:

Description	Comments
CCV	
CCB	
Samples & Batch QC Items	ICSA, ICSAB (minimum of every 12 hours) Up to 8 additional analyses.
CCV	
CCB	
Samples & Batch QC Items	Up to 10 analyses, including QC.
CCV	
CCB	

Note: For EPA 6020A and EPA 6020B, if the analysis run proceeds for more than 12 hours after the preceding ICSA/ICSAB pair, the analyst must repeat the analysis of the ICSA and ICSAB solutions.

The “up to 10 analyses” includes analysis of all analytical and batch QC items with the exception of the CCV and CCB analyses.

11.0 Calculations / Data Reduction

11.1 Data Reduction

Data must be evaluated in accordance with SOP SA-QA-002: *Data Generation and Review*.

11.1.1 Dilutions

If the concentration of a sample is above the calibration range (or linear range for single point curves) of the instrument the sample digestate must be diluted and reanalyzed.

11.1.2 Historical Data

Many of the laboratory’s clients submit samples for repeat monitoring purposes. Prior to analysis, verify TALS Worksheet Notes to determine if historical data is available for review.

11.1.3 Chemical Relationships

When available, the following chemical relationships must be evaluated for each sample. If these relationships are not met the Supervisor must be contacted immediately.

- Total Results are $\geq$ Dissolved results (e.g. metals)

11.1.4 Drinking Water Compliance Evaluation

Public water suppliers (PWS) are governed by EPA-specified Maximum Contaminant Levels (MCL) above which indicates noncompliance. Many analytes also have a Maximum Contaminant Level Goal (MCLG), which is often lower than the MCL. The MCLs and MCLGs associated with this procedure are given in Attachment 8.

11.2 Calculations

11.2.1 The calculations associated with batch QC determinations are given in SOP SA-QA-017. Applicable calculations include accuracy (% recovery) and precision (%RPD).

11.2.2 The calculations associated with initial and continuing calibrations and are given in SOP SA-QA-016. Applicable calculations include determination for: calibration factor, standard deviation, relative standard deviation, relative response factor, and relative standard deviation.

11.2.3 The calculation to determine final concentration is given as follows:

Regression Curve:

$$FinalConcentration = CONC_{Sample} \otimes \frac{F}{I \times dw} \otimes D$$

Where:

CONC$_{Sample}$= Concentration of the sample
F = Final volume/weight
I = Initial volume/weight
D = Dilution factor
dw = % Solids decimal equivalent

Note: All dry weight corrections are performed automatically in TALS.

Note: This calculation assumes all applicable unit correction factors are applied.

12.0 Method Performance

12.1 Reporting Limit Verification (RLV)

At a minimum, RLVs must be performed initially upon method set-up in accordance with SOP SA-QA-007: *Determination and Verification of Detection and Reporting Limits*.

For analytes and methods certified by DOD ELAP, RLVs must also be performed quarterly thereafter. For analytes and methods certified by NELAC, RLVs must also be performed annually thereafter. Exceptions may be made for project-specific non-routine analytes.

12.1.1 Lower Limit of Quantitation Check (QCS)

EPA 6020A and EPA 6020B require a Lower Limit of Quantitation Check (LLQC) to be performed after establishing the reporting limit and on an as needed basis to demonstrate sensitivity. As such, the laboratory requires a Low-Level LCS (spiked at the reporting limit) to be performed annually, at a minimum. The recovery of the LLCS must be within 70-130% of the true value, or the reporting limit must be re-evaluated and elevated accordingly.

12.2 Method Detection Limit (MDL) Study

The MDL is the lowest concentration that can be detected for a given analytical method and sample matrix with 99% confidence that the analyte is present. MDLs reflect a calculated (statistical) value determined under ideal laboratory conditions in a clean matrix and may not be achievable in all environmental matrices. The current MDLs associated with this procedure are given in the Method Limit Group (MLG) in TALS.

At a minimum, MDL Studies must be performed initially upon method set-up in accordance with SOP SA-QA-007: *Determination and Verification of Detection and Reporting Limits*.

Note: MDL Studies are not required for non-routine analytes provided results are not reported below the RL (i.e., MDL equals RL in TALS).

12.3 Method Detection Limit Verification (MDLV)

At a minimum, MDLVs must be performed initially upon method set-up in accordance with SOP SA-QA-007: *Determination and Verification of Detection and Reporting Limits*.

For analytes and methods certified by DOD ELAP, MDLVs must also be performed quarterly thereafter. For analytes and methods certified by NELAC, MDLVs must also be performed annually thereafter.

Note: MDLVs are not required for non-routine analytes provided results are not reported below the RL (i.e., MDL equals RL in TALS).

12.4 Determination of the Instrument Detection Limit (IDL)

The instrument detection limit (IDL) is the concentration of analyte that can be statistically distinguished from the background noise of the instrument. The IDL limit must be determined quarterly, at a minimum, for each analyte in accordance with SOP SA-QA-007: *Determination and Verification of Detection and Reporting Limits.*

The IDL for EPA 6020A and EPA 6020B is defined as three times the standard deviation of seven replicate analyses of a blank solution analyzed over three non-consecutive days. The IDL for EPA 200.8 is defined as the concentration equivalent to the analyte signal which is equal to three times the standard deviation of a series of eight replicate measurements of the calibration blank signal at the selected mass (es). The IDL may be elevated above the background noise (blank levels). The current IDL associated with this procedure is given in the Equipment Limit Group (ELG) in TALS.

12.5 QC Limit Generation, Control Charting, and Trend Analysis

The control limits for the batch QC items (LCS and MS/MSD) for this procedure are specified in the reference method and cannot be broadened; therefore, the laboratory defaults to the method-defined limits and does not utilize in-house or laboratory-derived limits for the evaluation of batch QC items.

Although the laboratory must default to the method-defined QC limits, control charting is a useful tool and is performed to assess analyte recoveries over time to evaluate trends. Control charting must be performed periodically (at a minimum annually) in accordance with SOP SA-QA-017: *Evaluation of Batch QC Data.*

12.6 Demonstrations of Capability

Initial and continuing demonstration of capability must be performed in accordance with SOP SA-QA-006*: Training Procedures.*

Prior to performing this procedure unsupervised, each new analyst who performs this analysis must demonstrate proficiency per method/analyte combination by successful completion of an initial demonstration of capability. The IDOC is performed by the analysis of 4 consecutive LCSs that meet the method criteria for accuracy and precision. The IDOC must be documented and routed to the QA Department for filing.

Annual continuing demonstrations of capability (CDOCs) are also required per analyst per method/analyte combination. The CDOC requirement may be met by the consecutive analysis of four LCS all in the same batch, by the analysis of four LCS analyzed in four consecutive batches (in different batches on different days), via acceptable results on a PT study, or analysis of client samples with statistically indistinguishable results when compared to another certified analyst. The CDOC must be documented and routed to the QA Department for filing.

12.7 Training Requirements

All training must be performed and documented in accordance with SOP SA-QA-006: *Training Procedures*.

Note: The SOPs listed in the Reference/Cross-Reference Section are applicable to this procedure. All employees performing this procedure must also be trained on these SOPs, and/or have a general understanding of these procedures, as applicable.

13.0 Pollution Control

It is Eurofins Savannah's policy to evaluate each method and look for opportunities to minimize waste generated (e.g., examining recycling options, ordering chemicals based on quantity needed, preparing reagents based on anticipated usage and reagent stability, etc.). Employees must abide by the policies in Section 13 of the Environmental Health and Safety Manual (EHSM) and the Savannah Addendum to the EHSM.

This procedure has been evaluated for opportunities to minimize the waste generated. Where reasonably feasible, pollution control procedures have been incorporated.

14.0 Waste Management

Waste management practices must be conducted consistent with all applicable federal, state, and local rules and regulations. All waste (i.e., excess reagents, samples, and method process wastes) must be disposed of in accordance with Section 9 of the Eurofins Savannah Addendum to the EHSM. Waste description rules and land disposal restrictions must be followed.

14.1 Waste Streams Produced by the Method

The following waste streams are produced when this method is carried out:

- Excess aqueous samples – Dispose according to characterization on the sample disposal sheets. Neutralize non-hazardous samples before disposal into drain/sewer. Transfer hazardous samples (identified on disposal sheets) to the waste department for disposal.

- Excess soil and solid samples – Dispose according to characterization on sample disposal sheets. Transfer non-hazardous samples to TCLP container for characterization in hazardous waste department. Transfer hazardous samples (identified on disposal sheets) to waste department for disposal.

- Acidic sample digestions – Neutralize before disposal into drain/sewer system.

Dispose of all metals standards with concentrations exceeding the TCLP threshold limits as a RCRA aqueous hazardous waste. The TCLP constituents and the respective threshold limits are:

Analyte	Disposal Limit (mg/L)
Arsenic	5.0
Barium	100
Cadmium	1.0
Chromium	5.0
Lead	5.0
Selenium	1.0
Silver	5.0
Mercury	0.20

Neutralize the standard by passing with sodium bicarbonate before transferring the waste to the RCRA aqueous hazardous waste drum.

All other metals standards may be disposed, using copious amounts of water, down a sink that flows to the neutralization pit.

15.0 References / Cross-References

- SOP SA-AN-100: *Laboratory Support Equipment (Verification and Use)*
- SOP SA-AN-041: *Reagent and Standard Materials Procedures*
- SOP SA-QA-002: *Data Generation and Review*
- SOP SA-QA-005: *Preventive and Corrective Action Procedures*
- SOP SA-QA-006*: Training Procedures*
- SOP SA-QA-007: *Determination and Verification of Detection and Reporting Limits*
- SOP SA-QA-015: *Homogenization, Compositing, and Segregation of Samples*
- SOP SA-QA-016: *Evaluation of Calibration Curves*
- SOP SA-QA-017: *Evaluation of Batch QC Data*
- Eurofins Savannah Quality Assurance Manual
- Eurofins Environmental Health and Safety Manual
- Eurofins Savannah Addendum to the Environmental Health and Safety Manual
- *Methods for Chemical Analysis of Water and Waste*; U.S EPA Office of Research and Development: Cincinnati, OHIO, March 1983.
- *Test Methods for Evaluating Solid Waste, Third Edition*; U.S. EPA Office of Solid Waste and Emergency Response: Washington, D.C., November 1986 (Revision III and IV).
  - SW-846 Chapter 3, Revision 3: Inorganic Analytes, December 1996
  - SW-846 Method 6020A, Revision 1: Inductively Coupled Plasma – Mass Spectrometry, February 2007
  - SW-846 Chapter 3, Revision 4: Inorganic Analytes, February 2007
  - SW-846 Method 6020B, Revision 2: Inductively Coupled Plasma – Mass Spectrometry, July, 2014
- *Methods for the Determination of Metals in Environmental Samples*; US EPA Office of Research and Development. Washington, DC, May 1994.
- EPA Method 200.8, Revision 5.4: Determination of Trace Elements in Waters and Wastes by Inductively Coupled Plasma – Mass Spectrometry, 1994

16.0 Method Modifications

16.1 Incorporation of Other Matrices

This procedure may be modified to analyze other matrices (e.g., wipe, waste, tissue, filter, and TCLP/SPLP leachate samples) based on the needs of the client. This will need to be arranged by the Project Manager at the initiation of the project.

Wipe, waste, filter, and tissue matrices are non-routine, and the laboratory is not currently NELAC certified for these matrices. The laboratory uses its routine soil RLs (converted for initial and final volumes, etc.) and soil QC limits to evaluate wipe, waste, filter, and tissue samples. Soil DOCs can be used to satisfy analyst demonstrations of capability for these types of non-routine matrices. The laboratory uses its routine soil RLs (converted for initial and final volumes, etc.) and soil QC limits to evaluate TCLP/SPLP leachate samples. Water DOCs can be used to satisfy analyst demonstrations of capability for TCLP/SPLP matrices. Teflon chips, Ottawa sand, or equivalent is used as the blank matrix for wipes, wastes, filters, and tissues unless specifically requested otherwise by the project.

16.1.1 Collection and Handling Procedures for Non-Routine Matrices

Waste samples may be collected in 8oz plastic soil jars; however, it should be noted that an alternate container may be required as some organic wastes (oils) may not be conducive to plastic. Tissue samples may be collected in 8oz plastic soil jars. Wipes and filters may be collected in a variety of different containers.

Wipe, waste, and filter samples must be iced at the time of collection and maintained at 0-6°C (less than 6°C but not frozen) until the time of digestion/leaching. Samples for mercury must be digested/leached and analyzed within 28 days of collection. All other samples must be digested and analyzed within 6 months of collection. Digestates may be stored at room temperature until the time of analysis.

Tissue samples must be iced at the time of collection and maintained at -10°C to -20°C for up to 6 months. Samples for mercury must be digested/leached and analyzed within 28 days of thawing. All other samples must be digested and analyzed within 6 months of thawing. Digestates may be stored at room temperature until the time of analysis.

Wipe, waste, filter, and tissue matrices are prepared in the same manner as soil samples with the following exceptions:

- The initial amount for wipe or filter samples is 1 wipe or 1 filter.
- The initial amount for tissue and waste samples is 1.0-1.2g.

Once the TCLP/SPLP extraction procedure has been performed, the TCLP/SPLP leachate must be transferred to a 500mL plastic container and preserved with 1.0mL nitric acid to a pH <2. Preserved TCLP/SPLP leachates are stored at room temperature until the time of digestion. The leachate sample must be digested within 6 months of completion of the TCLP/SPLP extraction. Digestates are stored at room temperature until the time of analysis and must be analyzed within 6 months of completion of the TCLP/SPLP extraction.

16.1.2 Preparation and Analytical Procedures for Non-Routine Matrices

Wipe, waste, filter, and tissue samples are prepared in the same manner as routine soil samples as outlined in SOP SA-ME-051. TCLP/SPLP matrices are prepared in the same manner as routine water samples as outlined in SOP SA-ME-050. Refer to the applicable preparation SOPs for more information.

Wipe, waste, filter, tissue, and TCLP/SPLP matrices are analyzed in the same manner as routine samples as outlined in this SOP.

16.2 Other Considerations

16.2.1 EPA 6020A and 6020B note to use gold as a preservative for mercury; however, the laboratory has not implemented this preservative. The instrument manufacturer's recommendations do not include this reagent if HCl is used in standards and samples. Additionally, initial method validation did not indicate this preservative was necessary to prevent carryover as intended by the method.

16.2.3 EPA 200.8 requires the regression coefficient (r^2) of the regression curve to be greater than 0.995 for the initial calibration curve to be acceptable. EPA 6020A requires the r^2 of the regression curve to be greater than 0.998 for the initial calibration curve to be acceptable. The laboratory has adopted the 0.998 criteria for all three methods.

16.2.4 The EPA Manual for the Certification of Laboratories Analyzing Drinking Water requires a LFB at the MRL to be performed each day. The laboratory meets this requirement by preparing an LCS at the RL in each EPA 200.8 batch of drinking water samples. The EPA DW Manual does not specify criteria for the low-level LCS; therefore, the laboratory defaults to qualitative identification.

16.12 There is no method-defined batch precision requirement for EPA 200.8. The EPA does require precision for all samples analyzed under the Clean Water Act, and the laboratory routinely performs an MSD to support clients who require precision to be reported. If insufficient sample volume is provided to perform the MS/MSD, the laboratory performs the LCS in duplicate (i.e., LCS/LCSD).

16.13 It is the laboratory's default procedure to analyze samples at a dilution factor of 5. The dilution is prepared immediately preceding analysis by diluting 2mL of digestate to a 10mL final volume. These dilution factors are captured by adjusting the default final volume in the Method Limit Groups. Reporting limits and MDLs have been elevated accordingly.

16.2.5 The reference methods state that, for dissolved metals analysis, filtration must occur in the field. The laboratory may be requested to filter the samples upon receipt. If this occurs, then appropriate narration must be included in the final report to denote this method deviation.

16.2.6 EPA has acknowledged there is an error in the EPA 6020A reference method regarding the ISTD criteria (in one section the lower limit is listed as 30%, and in another section it is listed as 70%). The laboratory has adopted a lower limit of 30%, as is consistent with EPA Method 6020B. Additionally, there is no upper limit specified in the reference method. The laboratory has adopted an upper limit of 150% to ensure corrective action is taken when extremely high ISTD recovery is noted in samples.

17.0 Attachments

The following Tables, Diagrams, and/or Validation Data are included as Attachments:

Attachment 1: SOP Summary
Attachment 2: Sample Collection, Preservation, and Holding Time Table
Attachment 3: QC Summary
Attachment 4: Instrument Maintenance and Troubleshooting
Attachment 5: Analysis Masses, Internal Standards, and Tune Steps
Attachment 6: Element-specific Masses and Concentrations
Attachment 7: Standard Preparation
Attachment 8: Drinking Water MCLGs and MCLs
Attachment 9: Hardness Calculation Work Instruction
Attachment 10: Glassware Cleaning Procedures

Attachment 1:
SOP Summary

Sample Preparation Summary

Prior to analysis by ICP-MS, the sample must be solubilized or digested using the sample preparation method appropriate to the matrix.

Samples should be prepared according to the appropriate matrix-specific SOP.

Matrix	SOP
Aqueous Samples	SA-ME-050
Soil Samples	SA-ME-051

Sample Analysis Summary

Sample digestates are aspirated and nebulized into a spray chamber. A stream of argon gas carries the sample aerosol through the innermost of three concentric tubes and injects it into the middle of the donut-shaped plasma. The sample elements are dissociated, atomized, and excited to a higher energy level. The ions that are produced are entrained in the plasma gas and introduced, by means of an interface, into a mass spectrometer. The ions are sorted according to their mass to charge ratios and quantified with a channel mass spectrometer.

Analytical Sequence

Analytical Sequence for samples immediately following an initial calibration:

Description	Comments
Blank	
Initial Calibration	Lowest standard is at or below the RL
ICV	Second Source
ICB	
Samples & Batch QC Items	RL Check Standard, ICSA, ICSAB, up to 7 additional analyses.
CCV	
CCB	
Samples & Batch QC Items	Up to 10 analyses, including QC.
CCV	
CCB	

Analytical Sequence for samples not immediately following an initial calibration:

Description	Comments
CCV	
CCB	
Samples & Batch QC Items	ICSA, ICSAB Up to 8 additional analyses.
CCV	
CCB	
Samples & Batch QC Items	Up to 10 analyses, including QC.
CCV	
CCB	

Note: For EPA 6020A, if the analysis run proceeds for more than 12 hours after the ICSA/ICSAB pair, the analyst must repeat the analysis of the ICSA and ICSAB solutions.

The "up to 10 analyses" includes analysis of all analytical and batch QC items with the exception of the CCV and CCB analyses.

Attachment 2:
Sample Collection, Preservation, and Holding Time Table

Matrix	Routine Sample Container	Routine Sample Size	Minimum Sample Size	Dechlorination Agent	Chemical Preservation	Thermal Preservation	Holding Time[2]
Water	250mL plastic	50mL	25mL	Not Applicable	3mL 1:3 HNO3, to pH<2	Not Applicable	Mercury: 28 days Other Metals: 6 months
Soil	8oz plastic soil jar	1.0g	0.5g	Not Applicable	Not Applicable	0-6 °C[1]	Mercury: 28 days Other Metals: 6 months

[1] Samples are collected on ice and maintained at <6 °C with no frozen samples.

[2] Inclusive of digestion and analysis.

Note: If dissolved metals are requested, the sample must be filtered prior to the acid being added to the sample.

Attachment 3:
QC Summary

QC Item	Frequency	Criteria	Corrective Action
Initial Calibration: minimum 1 standard and 1 blank	Daily	Correlation $\geq$0.998 (for multipoint curves)	Recalibrate
Initial Calibration Verification Standard (ICV)	At the beginning of the analysis	Within ±10%	Recalibrate
Continuing Calibration Verification Standard (CCV)	At the beginning and end of the analysis, and every 10 samples	Within ±10% of the true value	Terminate the analysis, fix the problem and reanalyze the previous 10 samples.
Interference Check Standards (ICSA/ICSAB)	At the beginning of an analysis run	± 20% of the true values Unspiked analytes should be less than two times the RL.	Terminate the analysis, correct the problem, recalibrate, and reanalyze all samples since the last ICS that was in control.
Calibration Blank (ICB/CCB)	After ICV and every CCV	<½ RL	Terminate the analysis, correct problem and reanalyze the previous 10 samples
Internal Standard	All samples and QC items	Refer to Section 9.2.5	Refer to Section 9.2.5
Batch Definition	Digested together w/in 24-hr timeframe; not to exceed 20 field samples	Not Applicable	Not Applicable
Method Blank	One per batch	|result|<RL DOD requires |result|<½ RL	Redigest and reanalyze batch
Laboratory Control	One per batch	TALS MLG	Redigest and reanalyze batch

QC Item	Frequency	Criteria	Corrective Action
Sample (LCS)			
Laboratory Control Sample Duplicate (LCSD)	One per batch, if insufficient sample provided for MS/MSD	TALS MLG	Redigest and reanalyze batch
Low-Level Laboratory Control Sample (LLCS) – spiked at the RL	EPA 200.8 DW: One per batch of 20 samples or less	Qualitatively identified	If the “regular” LCS meets criteria, initiate NCM and report data If the “regular” LCS does not meet criteria, redigest and reanalyze batch
Lower Limit of Quantitation Check (LLQC) – spiked at the RL	EPA 6020A / EPA 6020B: Annually, at a minimum, and as needed thereafter	EPA 6020A: 70-130% EPA 6020B: 80-120%	Re-evaluate RL and elevate accordingly
Matrix Spike (MS)	EPA 200.8: 10% of samples prepared; i.e., 2 separate matrix spikes per batch of twenty samples EPA 6020A: 5% of samples prepared; i.e., 1 matrix spike per batch of twenty samples	TALS MLG	Flag and report data
Matrix Spike Duplicate (MSD) or Sample Duplicate (SD)	EPA 200.8 (Clean Water Act), EPA 6020A: One MSD or sample duplicate per batch of twenty samples or less	TALS MLG	Flag and report data
Serial Dilution	One per batch of twenty	Refer to Section 9.2.7	Refer to Section 9.2.7

QC Item	Frequency	Criteria	Corrective Action
(1/5 Dilution)	samples or less		
Post Digestion Spike (PDS)	One per batch of twenty samples or less	Refer to Section 9.2.6	Refer to Section 9.2.6
Reporting Limit Check Solution	EPA 200.8 and EPA 6020B: At the beginning of analysis run EPA 6020B: At beginning and end of analysis run.	EPA 200.8: Recovery +/-50% of the true concentration (if the instrument is not calibrated at or below the RL) EPA 6020A: 70-130% of the true concentration (if the instrument is not calibrated at or below the RL). EPA 6020B: 80-120% of the true concentration (if the instrument is not calibrated at or below the RL).	Stop the analysis, fix the problem and reanalyze the affected samples.
Initial Demonstration of Capability (IDOC)	Initially, per analyst, per analyte/method/matrix combination	Refer to SOP SA-QA-006	Refer to SOP SA-QA-006 Note: Unsupervised work must not begin until acceptable IDOC is obtained.
Continuing Demonstration of Capability (CDOC)	Annually, per analyst, per analyte/method combination	Refer to SOP SA-QA-006	Refer to SOP SA-QA-006
Reporting Limit	Upon method/instrument set-up,	Refer to SOP SA-QA-007	Refer to SOP SA-QA-007

QC Item	Frequency	Criteria	Corrective Action
Verification (RLV)	per analyte/method/matrix combination. Then quarterly thereafter (for DOD ELAP) or annually thereafter (for NELAC)		
Method Detection Limit Study (MDL Study)	Upon method/instrument set-up, per analyte/method/matrix combination	Refer to SOP SA-QA-007	Refer to SOP SA-QA-007
MDL Verification (MDLV)	Upon method/instrument set-up, per analyte/method/matrix combination. Then quarterly thereafter (for DOD ELAP) or annually thereafter (for NELAC)	Refer to SOP SA-QA-007	Refer to SOP SA-QA-007

Attachment 4:
Instrument Maintenance and Troubleshooting

Instrument Labeling

Each instrument must be labeled with its name or ID (e.g., MSA, ICP-D, etc.). Additionally, non-operational instruments must be isolated from service or marked as being out of service. Each piece of equipment has an "Operational / Not Operational" sticker that is used for this purpose.

Maintenance Log

A maintenance log must be established for each piece of equipment used in the laboratory.

All maintenance that is performed on the instrument must be recorded in the log including:

- analyst or technician performing the maintenance
- date the maintenance was performed
- detailed explanation of the reason for the maintenance
- resolution of the problem and return to control
- all service calls from instrument representatives

Preventive Maintenance

Refer to the instrument manufacturer's guides for trouble-shooting items.

LABORATORY EQUIPMENT PREVENTIVE MAINTENANCE SCHEDULE								
EQUIPMENT ITEM	Service Interval							SERVICE LEVEL
	D	W	M	Q	SA	A	AN	
Cones							X	Clean, as needed.
Intake							X	Wipe down as needed.
Lenses							X	Clean or replace as needed.
Nebulizer							X	Clean, as needed.
Pump Oil							X	Replace as needed.
Pump Tubing							X	Change as needed

D = daily; W = Weekly; M = monthly; Q = Quarterly; SA = semi-annually; A = annually; AN = as needed

Troubleshooting

Troubleshooting should be documented as outlined above. If possible, troubleshooting is best performed in a step-wise manner to systematically isolate instrument components. Refer to the instrument manufacturer's guides for specific information and strategies. Enlist assistance from technical and/or department management as needed.

Contingency Plan

Maintenance contracts are carried for most instrumentation and close contact is maintained with service personnel to ensure optimal instrument functioning. An extensive spare parts inventory is maintained for routine repairs, consisting of detectors, pump tubing, cones, lenses, torches, and other common instrumentation components. Since instrumentation is standardized throughout the laboratory network, spare parts and components can be readily exchanged among the network.

In general, the laboratory has at least one backup unit for each critical unit. In the event of instrument failure, portions of the sample load may be diverted to duplicate instrumentation, the analytical technique switched to an alternate approved technique (such as manual colorimetric determination as opposed to automated colorimetric determination), or samples shipped to another properly certified or approved Eurofins location.

Attachment 5:
Recommended Analysis Masses, Internal Standards, and Tune Steps

The following are the recommended analysis masses, internal standards, and tune steps:

Element	IS	Tune Step
Be 9	Li 6	1
B 11	Li 6	1
Na 23	Sc 45	3
Mg 24	Sc 45	3
K 39	Ge 74	3
Ca 40	Sc 45	2
Ti 47	Sc 45	3
V 51	Ge 74	3
Cr 52	Ge 74	3
Mn 55	Ge 74	3
Fe 56	Sc 45	2
Co 59	Ge 74	3
Ni 60	Ge 74	3
Cu 63	Ge 74	-3
Ca 44	Sc 45	3

Element	IS	Tune Step
Zn 66	Ge 74	3
As 75	Ge 74	-3
Se 78	Ge 74	2
Sr 88	Y 89	3
Mo 95	In 115	3
Ag 107	In 115	3
Cd 111	In 115	3
Sn 118	In 115	3
Sb 121	In 115	3
Ba 137	In 115	3
Hg 202	Bi 209	3
Tl 205	Tb 159	3
Pb 208*	Tb 159	3
U 238	Bi 209	1

* Pb 208 = Pb 208 + Pb 207 + Pb 206

Note: Different masses and internal standards may be utilized, as matrix issues deem necessary.

Note: Agilent ICP-MS 7700 currently does not run H_2 reaction mode; only He collision mode and normal mode (no gas).

Tune Steps:

1. Normal mode: No gas
2. H_2 reaction mode: typical flows of 2.0 to 5.8 mL/min of Hydrogen gas
3. He collision mode: typical flows of 2.0 to 5.8 mL/min of Helium gas

Tune Check Criteria:

Instrument tunes must be performed before each calibration. A solution at ~1ppb of Be, Mg, Co, In, and Pb is analyzed, and the precision, mass calibration, and resolution are checked.

The following limits are used to evaluate the tune:

Mass calibration:	+/- 0.1amu
Resolution check:	<0.9amu at 10% peak height (baseline resolution)
Stability (5 reps):	<5%

Attachment 6:
Recommended Element-specific Masses and Concentrations

Element	Mass/ Mode #	Calibration Conc. (ug/L)	ICV/CCV Conc. (ug/L)	RL Std. Conc. (ug/L)	Linear Range Std. Conc. (ug/L)*	Matrix Spike / Post Spike Conc.	
						Water (ug/L)	Soil (mg/kg)
Aluminum (Al)	27 / #1	10000, 5000, 2500, 1000,10	400/500	10	100000	5000	500
Antimony (Sb)	121 / #3	100,50,25,10,1.0	40/50	1.0	100	50	5
Arsenic (As)	75 / #2	100,50,25,10,0.5	40/50	0.50	2000	100	10
Barium (Ba)	137 / #3	100,50,25,10,1.0	40/50	1.0	2000	100	10
Beryllium (Be)	9 / #3	100,50,25,10,0.1	40/50	0.10	100	50	5.0
Boron (B)	11 / #3	200,100,50,20	80/100	20	2000	200	20
Cadmium (Cd)	111 / #3	100,50,25,10,0.5	40/50	0.50	100	50	5.0
Calcium (Ca)	40 / #1	10000,5000,100,50	4000/ 5000	50	100000	5000	500
Chromium (Cr)	52 / #2	100,50,25,10,1.0	40/50	1.0	2000	100	10
Cobalt (Co)	59 / #3	100,50,25,10,0.1	40/50	0.10	2000	50	5
Copper (Cu)	65 / #2	100,50,25,10,1.0	40/50	1.0	100	100	10
Iron (Fe)	56 / #1	10000,5000,100,50,20	4000/ 5000	20	100000	5000	500
Lead (Pb)	208 / #3	100,50,25,10,0.3	40/50	0.30	2000	50	5.0
Lithium (Li)	7	100, 50, 25, 10, 2	40/50	2	100	500	50
Magnesium (Mg)	24 / #1	10000,5000,100,50	4000/ 5000	50	100000	5000	500
Manganese (Mn)	55 / #3	100, 50, 25, 10, 1.0	400/500	1.0	2000	500	50
Mercury (Hg)	202 / #3	5,2.5,1.25,0.5,0.16	2.0/2.5	0.16	100	5.0	0.50
Molybdenum (Mo)	95 / #3	100,50,25,10,1.0	40/50	1.0	2000	100	10
Nickel (Ni)	60 / #2	100,50,25,10,0.2	40/50	0.20	2000	100	10
Potassium (K)	39 / #2	10000,5000,100,50	4000/ 5000	50	100000	5000	500
Selenium (Se)	78 / #1	100,50,25,10,0.5	40/50	0.50	100	100	10
Silver (Ag)	107 / #3	100,50,25,10,0.2	40/50	0.20	100	50	5.0
Sodium (Na)	23 / #1	10000,5000,100,5	4000/	50	100000	5000	500

Element	Mass/ Mode #	Calibration Conc. (ug/L)	ICV/CCV Conc. (ug/L)	RL Std. Conc. (ug/L)	Linear Range Std. Conc. (ug/L)*	Matrix Spike / Post Spike Conc.	
						Water (ug/L)	Soil (mg/kg)
		0	5000				
Strontium (Sr)	88 / #3	100,50,25,10,0.2	40/50	0.20	2000	100	10
Thallium (Tl)	205 / #3	100, 50, 25,10,0.2	8/10	0.20	20	40	4.0
Thorium (Th)	232 / #3	100,50,25,10,0.5	40/50	0.5	100	100	10
Tin (Sn)	118 / #3	100,50,25,10,1.0	40/50	1.0	2000	100	10
Titanium (Ti)	47 / #3	100,50,25,10,1.0	40/50	1.0	2000	100	10
Uranium (U)	238 / #3	100,50,25,10,0.5	40/50	0.5	100	100	10
Vanadium (V)	51 / #2	100,50,25,10,1.0	40/50	1.0	2000	100	10
Zinc (Zn)	66 / #3	100,50,25,10,4.0	40/50	4.0	2000	100	10

*For guidance only - instrument sensitivity will vary.

Attachment 7:
Standard Preparation

Note: All standards must be stored at room temperature. Standards containing mercury have a 28 day expiration date from the date prepared. All other standards have an expiration date of 6 months from date prepared.

All calibration standards and working standards are prepared using a rinse/blank solution containing 0.5% Hydrochloric Acid and 2% Nitric Acid by volume. The solution is prepared as follows:

Standard Final Volume (mL)	Hydrochloric acid (mL)	Nitric Acid (mL)
20000	100	400

Note: Adjustments to the final volume are acceptable provided that the acid by volume concentrations are adhered to.

CALIBRATION STANDARDS

Calibration Standard Stock Solution

Element	Parent Concentration (mg/L)	Volume Added (mL)	Final Volume (mL)	Final Volume (mg/L)
Aluminum (Al)	10000	1.0	100	100
Antimony (Sb)	1000	1.0		10
Arsenic (As)	1000	1.0		10
Barium (Ba)	1000	1.0		10
Beryllium (Be)	1000	1.0		10
Boron (B)	1000	2.0		20
Cadmium (Cd)	1000	1.0		10
Calcium (Ca)	10000	10		1000
Chromium (Cr)	1000	1.0		10
Cobalt (Co)	1000	1.0		10
Copper (Cu)	1000	1.0		10
Iron (Fe)	10000	10		1000
Lead (Pb)	1000	1.0		10
Lithium (Li)	1000	1.0		10
Magnesium (Mg)	10000	10		1000
Manganese (Mn)	1000	10		100
Mercury (Hg)	1000	0.050		0.50
Molybdenum (Mo)	1000	1.0		10
Nickel (Ni)	1000	1.0		10
Potassium (K)	10000	10		1000
Selenium (Se)	1000	1.0		10
Silver (Ag)	1000	1.0		10
Sodium (Na)	10000	10		1000
Strontium (Sr)	1000	1.0		10
Thallium (Tl)	1000	0.2		2.0
Thorium (Th)	1000	1.0		10
Tin (Sn)	1000	1.0		10
Titanium (Ti)	1000	1.0		10
Uranium (U)	1000	1.0		10
Vanadium (V)	1000	1.0		10
Zinc (Zn)	1000	1.0		10

The above standards may be grouped together into more than one stock standard to maximize the stability of the standards. For example, silver may need to be kept as a separate stock due to the stability of the silver in solution. Alternatively, a custom made vendor supplied Calibration Stock Standard may be purchased instead of making it in the laboratory.

WORKING CALIBRATION STANDARDS

Calibration Blank (ICB, CCB) – All standards are made up to the same acid concentrations as the calibration blank
Add 500mL to 600mL of reagent water to a clean 1L volumetric flask. Add 20mL of concentrated nitric acid (HNO_3) and 5.0mL of hydrochloric acid (HCl) to the volumetric flask. Dilute to a final volume of 1000mL with reagent water. Store the standard at room temperature. Other volumes may be prepared at the discretion of the lab. The nitric acid concentration must be 2% by volume, and the hydrochloric acid concentration must be 0.5% by volume.

Calibration Standards concentration (ug/L) – example for a final volume of 1000mL

Element	Standard 5 (10mL stock)	Standard 4 (5mL stock)	Standard 3 (2.5mL stock)	Standard 2 (1mL stock)
Aluminum (Al)	1000	500	250	100
Antimony (Sb)	100	50	25	10
Arsenic (As)	100	50	25	10
Boron (B)	200	100	50	20
Barium (Ba)	100	50	25	10
Beryllium (Be)	100	50	25	10
Cadmium (Cd)	100	50	25	10
Calcium (Ca)	10000	5000	2500	1000
Cobalt (Co)	100	50	25	10
Chromium (Cr)	100	50	25	10
Copper (Cu)	100	50	25	10
Iron (Fe)	10000	5000	2500	1000
Lead (Pb)	100	50	25	10
Lithium (Li)	100	50	25	10
Magnesium (Mg)	10000	5000	2500	1000
Manganese (Mn)	1000	500	250	100
Mercury (Hg)	5.0	2.5	1.25	0.5
Molybdenum (Mo)	100	50	25	10
Nickel (Ni)	100	50	25	10
Potassium (K)	10000	5000	2500	1000
Selenium (Se)	100	50	25	10
Silver (Ag)	100	50	25	10
Sodium (Na)	10000	5000	2500	1000
Strontium (Sr)	100	50	25	10
Thallium (Tl)	20	10	5.0	2.0
Thorium (Th)	100	50	25	10
Tin (Sn)	100	50	25	10
Titanium (Ti)	100	50	25	10
Uranium (U)	100	50	25	10
Vanadium (V)	100	50	25	10
Zinc (Zn)	100	50	25	10

Note: The Standard 5 listed above is utilized when calibrating with a single standard and a blank.

Standard 1 is equivalent to the RL/PQL Working Standard described below.

CONTINUING CALIBRATION VERIFICATION (CCV) STANDARD

The calibration standard Level 4 is used as the continuing calibration verification standard.

INITIAL CALIBRATION VERIFICATION (ICV) SOLUTION

All ICV standards must be from a different source than those used for the calibration standards.

Note: ICV must be made fresh daily.

Preparation of the ICP-MS initial calibration verification solution

Element	Parent Concentration (mg/L)	Volume Added (mL)	Final Volume (mL)	Final Concentration (mg/L)
Aluminum (Al)	10000	0.40	100	40
Antimony (Sb)	1000	0.40		4.0
Arsenic (As)	1000	0.40		4.0
Boron (B)	1000	0.80		8.0
Barium (Ba)	1000	0.40		4.0
Beryllium (Be)	1000	0.40		4.0
Cadmium (Cd)	1000	0.40		4.0
Calcium (Ca)	10000	4.0		400.0
Cobalt (Co)	1000	0.40		4.0
Chromium (Cr)	1000	0.40		4.0
Copper (Cu)	1000	0.40		4.0
Iron (Fe)	10000	4.0		400.0
Lead (Pb)	1000	0.40		4.0
Lithium (Li)	1000	0.40		4.0
Magnesium (Mg)	10000	4.0		400.0
Manganese (Mn)	1000	1.0		40.0
Mercury (Hg)	100	0. 40		4.0
Molybdenum Mo)	1000	0.40		4.0
Nickel (Ni)	1000	0.40		4.0
Potassium (K)	10000	4.0		400.0
Selenium (Se)	1000	0.40		4.0
Silver (Ag)	1000	0.40		4.0
Sodium (Na)	10000	4.0		400.0
Strontium (Sr)	1000	0.40		4.0
Thallium (Tl)	1000	0.20		0.8
Tin (Sn)	1000	0.40		4.0
Thorium (Th)	1000	0.40		4.0
Titanium (Ti)	1000	0.40		4.0
Vanadium (V)	1000	0.40		4.0
Uranium (U)	1000	0.40		4.0
Zinc (Zn)	1000	0.40		4.0

Preparation of Initial Calibration Verification Working Standard

Dilute 1.0mL of the ICP-MS initial calibration verification solution to a final volume of 100mL using the same matrix solution as the calibration blank.

The final concentrations of the various elements are the same as listed in Table 1.

REPORTING LIMIT (RL) CHECK STANDARD

RL/PQL Stock A

Element	Parent Concentration (mg/L)	Volume Added (mL)	Final Volume (mL)	Final Concentration (mg/L)
Aluminum (Al)	10000	1.0	100	100
Antimony (Sb)	1000	1.0		10
Arsenic (As)	1000	0.5		5.0
Boron (B)	1000	20		200
Barium (Ba)	1000	1.0		10
Beryllium (Be)	1000	0.10		1.0
Cadmium (Cd)	1000	0.10		1.0
Calcium (Ca)	10000	5.0		500
Cobalt (Co)	1000	0.1		1.0
Chromium (Cr)	1000	1.0		10
Copper (Cu)	1000	1.0		10
Iron (Fe)	10000	2.0		200
Lead (Pb)	1000	0.30		3.0
Lithium (Li)	1000	2.0		20
Magnesium (Mg)	10000	5.0		500
Manganese (Mn)	1000	1.0		10
Molybdenum Mo)	1000	1.0		10
Nickel (Ni)	1000	1.0		10
Potassium (K)	10000	5.0		500
Selenium (Se)	1000	0.50		5.0
Sodium (Na)	10000	5.0		500
Strontium (Sr)	1000	0.20		2.0
Thallium (Tl)	1000	0.20		2.0
Thorium (Th)	1000	0.5		5.0
Tin (Sn)	1000	1.0		10
Titanium (Ti)	1000	1.0		10
Uranium (U)	1000	0.5		5.0
Vanadium (V)	1000	1.0		10
Zinc (Zn)	1000	4.0		40

* Other standard concentrations may be used to verify higher or lower reporting limits.

RL/PQL Stock B

Element	Parent Standard (mg/L)	Volume Added (mL)	Final Volume (mL)	Final Concentration (mg/L)
Mercury (Hg)	1000	0.050	100	0.50

RL/PQL Stock C

Element	Parent Standard (mg/L)	Volume Added (mL)	Final Volume (mL)	Final Concentration (mg/L)
Silver (Ag)	1000	0.020	100	0.20

Preparation of RL/PQL Working Standard

Dilute 10uL of the RL/PQL Stock A, 32uL of the RL/PQL Stock B, and 100uL of the RL/PQL Stock C to a final volume of 100mL using the same matrix solution as the calibration blank.

ICP INTERFERENCE CHECK SOLUTIONS (for EPA 6020A and EPA 6020B)

Preparation of ICP Interference Check Solution A

Element	Parent Standard (mg/L)	Volume Stock A (mL)	Final Volume (mL)	Final Concentration (mg/L)
Aluminum (Al)	1000	50	500	100
Calcium (Ca)	1000			100
Iron (Fe)	1000			100
Magnesium (Mg)	1000			100
Sodium (Na)	1000			100
Phosphorus (P)	1000			100
Potassium (K)	1000			100
Sulfur (S)	1000			100
Carbon (C)	2000			200
Chloride (Cl)	10000			1000
Molybdenum (Mo)	20			2.0
Titanium (Ti)	20			2.0

Preparation of ICP Interference Check Solution AB

Element	Parent Concentration (mg/L)	Volume Stock A (mL)	Volume Stock B (mL)	Final Volume (mL)	Final Concentration (mg/L)
Aluminum (Al)	1000	50	1.0	500	100
Calcium (Ca)	1000				100
Iron (Fe)	1000				100
Magnesium (Mg)	1000				100
Sodium (Na)	1000				100
Phosphorus (P)	1000				100
Potassium (K)	1000				100
Sulfur (S)	1000				100
Carbon (C)	2000				200
Chloride (Cl)	10000				1000
Molybdenum (Mo)	20				2.0
Titanium (Ti)	20				2.0
Arsenic (As)	10				0.020
Cadmium (Cd)	10				0.020
Chromium (Cr)	10				0.020
Cobalt (Co)	10				0.020
Copper (Cu)	10				0.020
Manganese (Mn)	10				0.020
Nickel (Ni)	10				0.020
Silver (Ag)	10				0.020
Zinc (Zn)	10				0.020

ICP-MS LCS/MATRIX SPIKE SOLUTION

Preparation of the ICP-MS Matrix Spiking / Post Digestion Spiking Solution

Element	Parent Concentration (mg/L)	Volume Added (mL)	Final Volume (mL)	Final Concentration (mg/L)
Aluminum (Al)	10000	5.0	100	500
Antimony (Sb)	1000	0.5		5
Arsenic (As)	1000	1.0		10
Boron (B)	1000	2.0		20
Barium (Ba)	1000	1.0		10
Beryllium (Be)	1000	0.5		5.0
Cadmium (Cd)	1000	0.5		5.0
Calcium (Ca)	10000	5.0		500
Cobalt (Co)	1000	1.0		5.0
Chromium (Cr)	1000	1.0		10
Copper (Cu)	1000	1.0		10
Iron (Fe)	10000	5.0		500
Lead (Pb)	1000	0.50		5.0
Lithium (Li)	1000	5.0		50
Magnesium (Mg)	10000	5.0		500
Manganese (Mn)	1000	5.0		50
Mercury (Hg)	1000	0.050		0.50
Molybdenum Mo)	1000	1.0		10
Nickel (Ni)	1000	1.0		10
Potassium (K)	10000	5.0		500
Selenium (Se)	1000	1.0		10
Silver (Ag)	1000	0.50		5.0
Sodium (Na)	10000	5.0		500
Strontium (Sr)	1000	1.0		10
Thallium (Tl)	1000	0.4		4.0
Thorium (Th)	1000	1.0		10
Tin (Sn)	1000	1.0		10
Titanium (Ti)	1000	1.0		10
Uranium (U)	1000	1.0		10
Vanadium (V)	1000	1.0		10
Zinc (Zn)	1000	1.0		10

Separate mixtures can be utilized for stability considerations.

MDL SOLUTION

The MDL solution is used to determine the Method Detection Limit (MDL) of each target analyte (SOP SA-QA-007).

Preparation of Recommended MDL Intermediate Stock Solution

Element	Parent Concentration (mg/L)	Volume Added (mL)	Final Volume (mL)	Final Concentration (mg/L)
Antimony (Sb)	1000	1.25	100	12.5
Arsenic (As)	1000	1.0		10
Barium (Ba)	1000	1.0		10
Beryllium (Be)	1000	0.25		2.5
Cadmium (Cd)	1000	0.10		1.0
Cobalt (Co)	1000	0.20		2.0
Chromium (Cr)	1000	2.5		25.0
Copper (Cu)	1000	1.0		10
Lead (Pb)	1000	0.30		3.0
Lithium (LI)	1000	?		?
Magnesium (Mg)	10000	1.0		100
Manganese (Mn)	1000	1.0		10
Molybdenum Mo)	1000	10		10
Nickel (Ni)	1000	1.0		10
Selenium (Se)	1000	1.0		10
Silver (Ag)	1000	0.20		2.0
Strontium (Sr)	1000	0.50		5.0
Thallium (Tl)	1000	0.5		5.0
Tin (Sn)	1000	1.0		10
Titanium (Ti)	1000	1.25		12.5
Vanadium (V)	1000	5.0		50
Aluminum (Al)	10000	2.5		250
Boron (B)	1000	25.0		250.0
Calcium	10000	12.5		1250.0
Iron (Fe)	10000	2.5		250
Potassium (K)	10000	10.0		1000
Sodium (Na)	10000	10.0		1000
Zinc	1000	5.0		50.0

Preparation of MDL Working Solutions:

Preparation of the MDL Working solution is as follows dilute 2.0mL of the MDL Intermediate stock solution and 2.0mL of the Mercury Intermediate Calibration standard and bring to a final volume of 100mL. The standard is now ready for digestion.

Linearity Check Solutions:

The linearity check solutions are prepared individually according to the following equation:

$$Vs = \frac{Vlc \otimes Clc}{Cs}$$

Where: Vs = volume of stock standard (mL)
Cs = concentration of stock standard (mg/L)
Vlc = volume of linearity check standard to prepare (mL)
Clc = concentration of linearity check standard to prepare (mg/L)

The linearity check solutions are prepared at the concentrations specified in Attachment 6. Prepare sufficient volume to perform the linearity check, maintaining the hydrochloric acid concentration at 0.5% by volume and the nitric acid concentration at 1% by volume.

Internal Standards:

A solution at 1mg/L is prepared for all elements. That solution is added in-stream by the use of a T-fitting. The sample is pumped into the T-fitting with a white/white peristaltic pump tube and the internal standard is pumped in using a blue/orange pump tube.

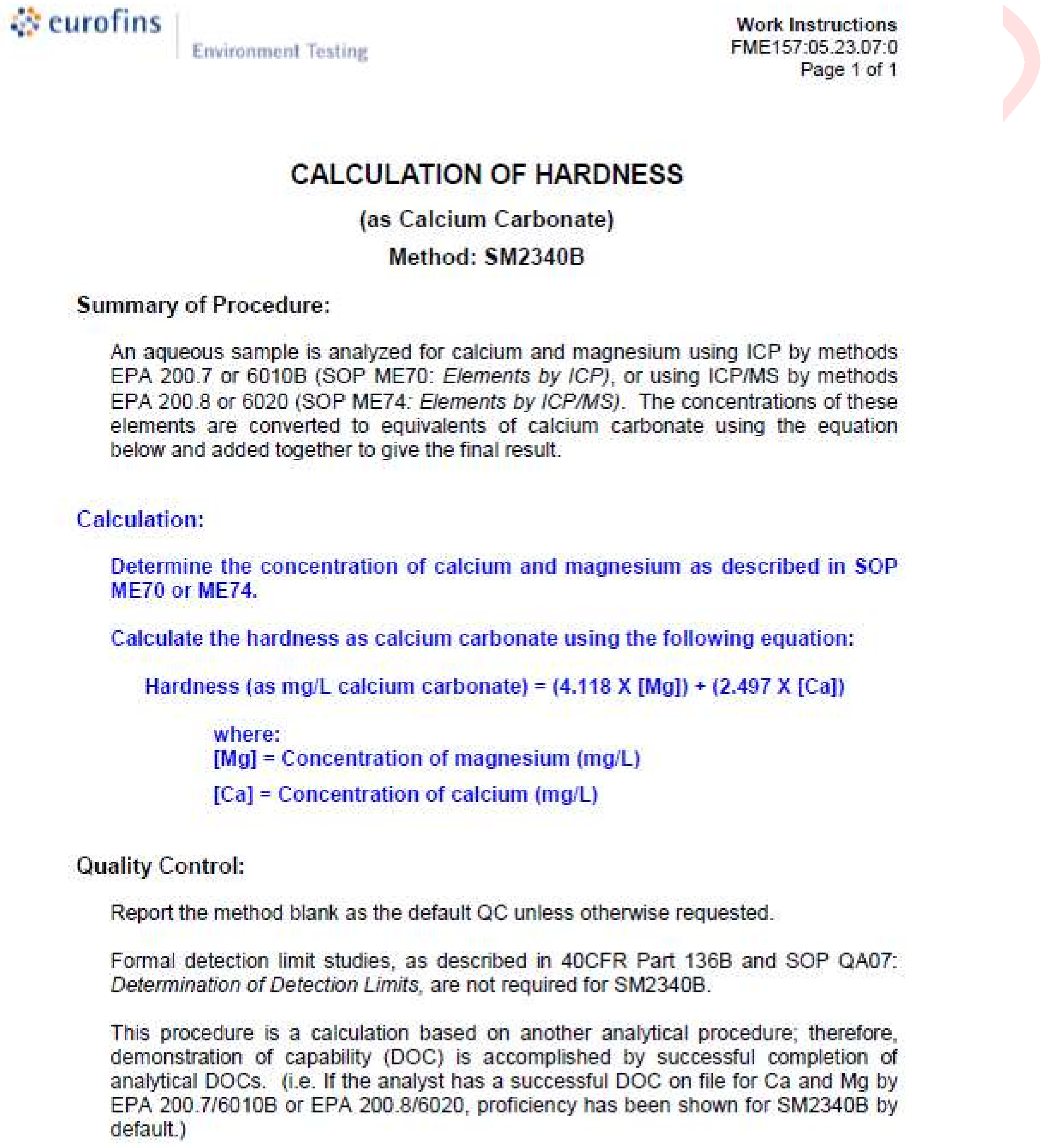
Attachment 8:
Drinking Water MCLGs and MCLs

Element	Regulation	MCLG (mg/L)	MCL (mg/L)	Secondary Standard (mg/L)
Antimony	National Primary Drinking Water Regulations	0.006	0.0060	
Arsenic		0	0.010	
Barium		2.0	2.0	
Beryllium		0.0040	0.0040	
Cadmium		0.0050	0.0050	
Chromium		0.10	0.10	
Copper (1)		1.3	Action Level = 1.3	
Lead (1)		0	Action Level = 0.015	
Mercury		0.0020	0.0020	
Selenium		0.050	0.050	
Thallium		0.00050	0.0020	
Uranium		0	0.030	
Aluminum	National Secondary Drinking Water Regulations			0.05 – 0.2
Copper				1.0
Iron				0.30
Manganese				0.050
Silver				0.10
Zinc				5.0

---

[1] Lead and copper are regulated by a Treatment Technique that requires systems to control the corrosiveness of their water. If more than 10% of tap water samples exceed the action level, water systems must take additional steps. For copper, the action level is 1.3 mg/L, and for lead is 0.015 mg/L.

Attachment 9:
Hardness Calculation Work Instruction



Work Instructions
FME157:05.23.07:0
Page 1 of 1

CALCULATION OF HARDNESS

(as Calcium Carbonate)

Method: SM2340B

Summary of Procedure:

An aqueous sample is analyzed for calcium and magnesium using ICP by methods EPA 200.7 or 6010B (SOP ME70: *Elements by ICP)*, or using ICP/MS by methods EPA 200.8 or 6020 (SOP ME74: *Elements by ICP/MS)*. The concentrations of these elements are converted to equivalents of calcium carbonate using the equation below and added together to give the final result.

Calculation:

Determine the concentration of calcium and magnesium as described in SOP ME70 or ME74.

Calculate the hardness as calcium carbonate using the following equation:

Hardness (as mg/L calcium carbonate) = (4.118 X [Mg]) + (2.497 X [Ca])

where:
[Mg] = Concentration of magnesium (mg/L)
[Ca] = Concentration of calcium (mg/L)

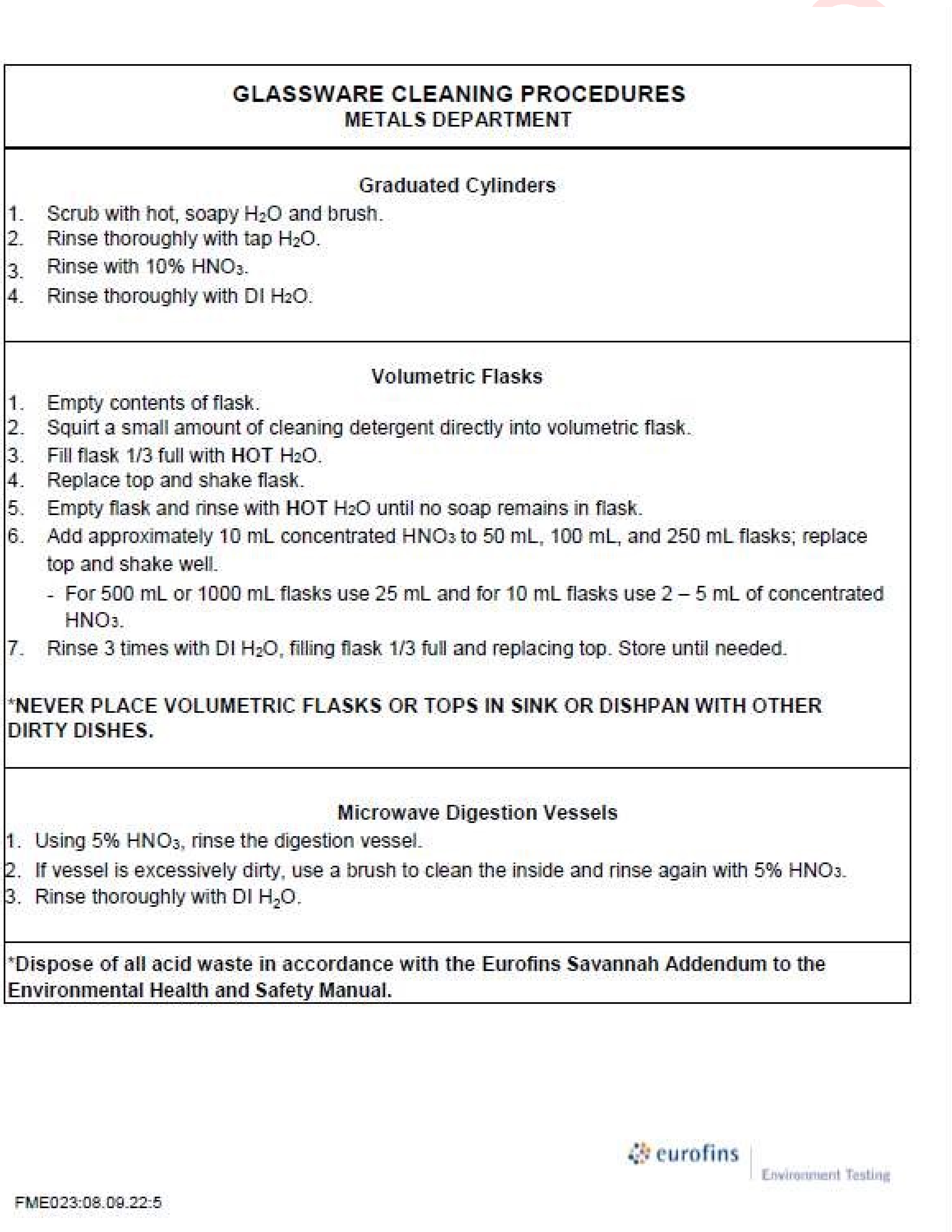
Quality Control:

Report the method blank as the default QC unless otherwise requested.

Formal detection limit studies, as described in 40CFR Part 136B and SOP QA07: *Determination of Detection Limits,* are not required for SM2340B.

This procedure is a calculation based on another analytical procedure; therefore, demonstration of capability (DOC) is accomplished by successful completion of analytical DOCs. (i.e. If the analyst has a successful DOC on file for Ca and Mg by EPA 200.7/6010B or EPA 200.8/6020, proficiency has been shown for SM2340B by default.)

Attachment 10:
Glassware Cleaning Procedures



GLASSWARE CLEANING PROCEDURES
METALS DEPARTMENT

Graduated Cylinders

1. Scrub with hot, soapy H_2O and brush.
2. Rinse thoroughly with tap H_2O.
3. Rinse with 10% HNO_3.
4. Rinse thoroughly with DI H_2O.

Volumetric Flasks

1. Empty contents of flask.
2. Squirt a small amount of cleaning detergent directly into volumetric flask.
3. Fill flask 1/3 full with **HOT** H_2O.
4. Replace top and shake flask.
5. Empty flask and rinse with **HOT** H_2O until no soap remains in flask.
6. Add approximately 10 mL concentrated HNO_3 to 50 mL, 100 mL, and 250 mL flasks; replace top and shake well.
   - For 500 mL or 1000 mL flasks use 25 mL and for 10 mL flasks use 2 – 5 mL of concentrated HNO_3.
7. Rinse 3 times with DI H_2O, filling flask 1/3 full and replacing top. Store until needed.

***NEVER PLACE VOLUMETRIC FLASKS OR TOPS IN SINK OR DISHPAN WITH OTHER DIRTY DISHES.**

Microwave Digestion Vessels

1. Using 5% HNO_3, rinse the digestion vessel.
2. If vessel is excessively dirty, use a brush to clean the inside and rinse again with 5% HNO_3.
3. Rinse thoroughly with DI H_2O.

***Dispose of all acid waste in accordance with the Eurofins Savannah Addendum to the Environmental Health and Safety Manual.**

FME023:08.09.22:5

18.0 Revision History

Summary of Changes for Revision 16:

- Updated section 9.2.1 that a minimum of five (5) points is required for a multip-point calibration. The laboratory is performing a multip-point calibration using five points. Audit 1/2023

Summary of Changes for Revision 15:

- Added Lithium to calibration analytes for ICP-MS analysis due to the addition of Li by 6020/200.8 to our certification scope.
- Added Emma Ogletree as Department Manager.

Summary of Changes Revision 14:

- Removed reference to TestAmerica from document.
- Added readback criteria to section 9.2.2 for calibrations. Updated EPA 6020A and EPA 6020B to be consistent with reference methods.
- Added DODQSM V5 criteria to applicable sections.

Summary of Changes Revision 13B:

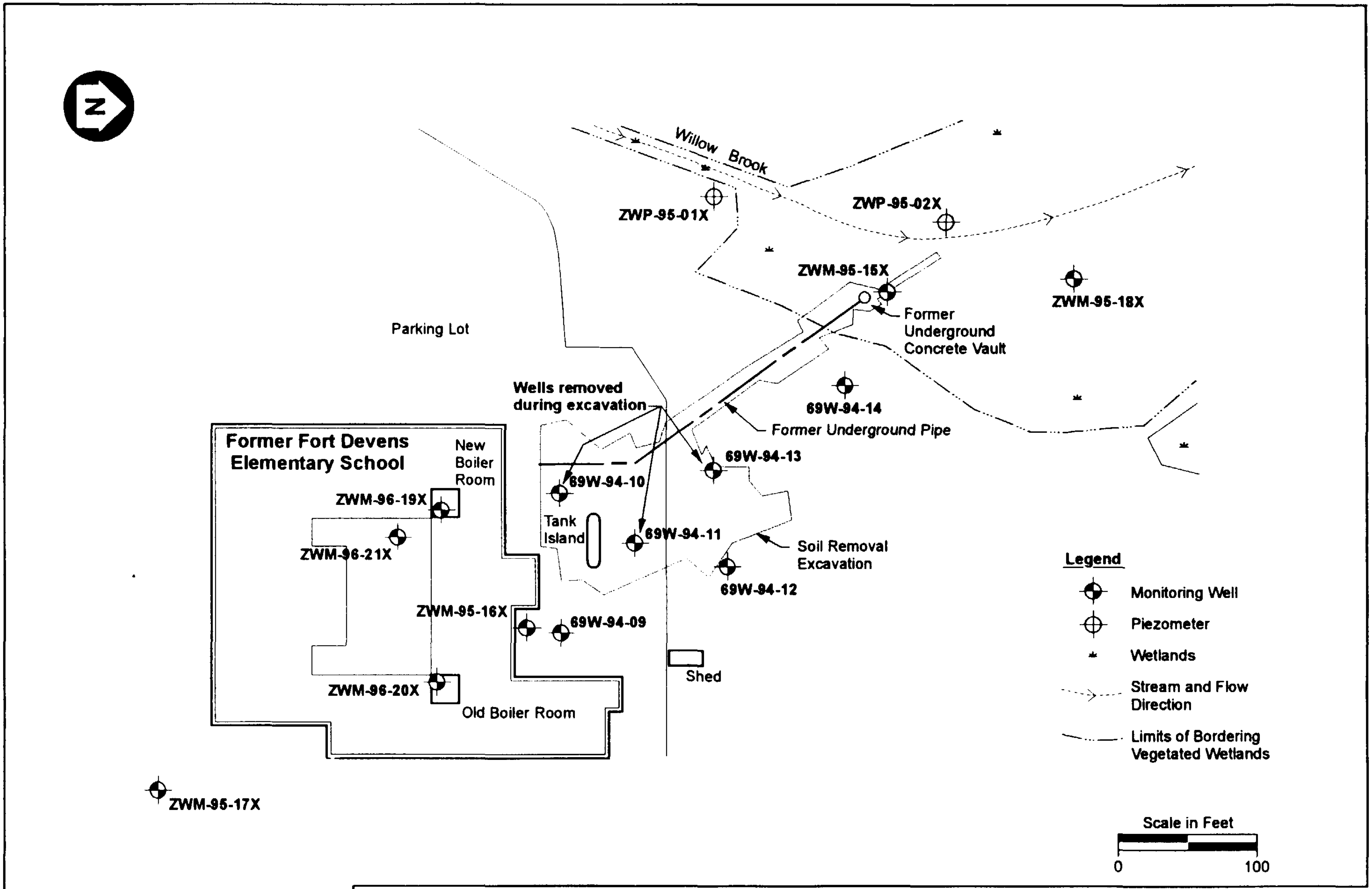
Added reference to the Master Equipment Listing maintained by QA to Section 6.1. ANAB Audit 2020.

Summary of Changes from Previous Revision 13:

- Minor editorial, grammatical, and/or formatting changes made.
- Updated SOP signatories to reflect current responsibilities and titles.
- Updated company name and logo where applicable.
- Updated Attachment 7, Attachment 5 and Attachment 6 with current information.
- Updated Attachment 9 with current logo.
- Updated section 10.3.1 with current instrument instructions.

Appendix B

Historical Site Plan



Harding Lawson Associates
Engineering and
Environmental Services

Site Plan
AOC 69W Record of Decision
Devens, Massachusetts

FIGURE
2

DRAWN	JOB NUMBER	FILE NUMBER	APPROVED	DATE	REVISED DATE
jph	45001	W9906003(b)		6/99	

Appendix C

Response to Comments

New England District
696 Virginia Road
Concord, Massachusetts
01742-2751

US Army Corps
of Engineers ®

Project Name: Former Fort Devens Army Installation	Location: Devens, Massachusetts
Document Name: Post- Record of Decision Supplemental Remedial Investigation Work - AOC 69W (February 2023)	
Prepared By: Seres Arcadis 8(a) JV	

No.	Ref. Page / Para.	COMMENT (August 2022)	RESPONSE	COMMENT (February 2023)	RESPONSE
		GENERAL COMMENTS			
1.		In its responses to several of EPA's 1/7/22 comments (e.g., EPA 1/7 Comment #G1, G2, G3, and G5 in Army's RTC), Army agreed to omit references to Massachusetts Contingency Plan (MCP) standards (i.e., 310 CMR 40) and site cleanup criteria (i.e., GW-1) in the revised draft supplemental Remedial Investigation (RI) Work Plan (WP) for AOC 69W. However, these same references are cited throughout the revised draft WP. EPA understood that the revised draft RI WP would include the sampling activities identified by Army as necessary to support its proposed, subsequent close out of the AOC 69W site under CERCLA and transfer the site to MassDEP for cleanup under the MCP. However, Army agreed that text related to the CERCLA petroleum exclusion and its relevance to the AOC 69W remedy, MCP petroleum spill requirements and standards, and other issues not specifically addressed in the 1995 AOC 69W CERCLA Record of Decision (ROD) would be removed from the revised draft supplemental RI WP.	At USEPA's request, references to the comparison of groundwater data collected during the SRI to MCP / GW-1 screening criteria were removed from the work plan. Remaining references to the MCP are related to previous investigations or to the screening criteria in the current (2015) LTMMP, and thus, remain. While the Army agreed to remove the discussion of MCP petroleum spill requirements, the Army did not agree to remove text related to the CERCLA petroleum exclusion. Response to 1/7/22 Page Specific Comment #6 states: *The Army acknowledges that "Oil" is referenced in the FFA.* *Please see https://www.epa.gov/epcra/specific-substances-excluded-under-cercla-petroleum-exclusion regarding the use of the EPA's interpretation of CERCLA section 101(14), which is not limited to specific sites.*	Still bothers me but not sure I'm willing to go to battle on this one. Thoughts?	Noted.
2.		In its previous 1/7/22 and 4/15/22 comments (1/7 Comment #4 and 4/15 Comment #2 in Army's RTC), EPA requested changes related to the characterization of different contaminants, including arsenic and other analytes. Having reviewed Army's responses and the ROD requirements itself, EPA wishes to expand upon and provide a clarification to its prior comments. EPA recently discovered an inconsistency in references to site-specific contaminants in the revised draft supplemental RI WP and 1999 ROD. Specifically, the ROD does not identify, list, or refer to Contaminants of Concern (COCs) at all. Instead, the ROD refers to "Contaminants of Potential Concern" (CPCs). Army's draft supplement RI WP (and EPA's prior comment on this issue) therefore incorrectly refers to "Contaminants of Concern" (COCs). For consistency with the 1999 CERCLA decision document, EPA requests that all references to "COCs" in the draft supplemental RI WP be revised to "CPCs" and that the field sampling program	The Army disagrees that references to COCs should be changed to CPCs. The USEPA is correct that the 1999 ROD does not specifically reference COCs. However, the CPCs are referenced in an explanation of analytes to be included in the risk evaluation prepared for the 1998 RI, not as de facto COCs. USEPA's Risk Assessment Guidance for Superfund (RAGS): Part A establishes criteria to evaluate COPCs to determine which should be retained or eliminated as COCs for the Baseline Risk Assessment. The USEPA Region 4 HHRA Supplemental Guidance (March 2018) succinctly states: *2.6 COPC Selection Process* *All concentrations of each chemical detected in a site sample/media should be compared to the appropriate*	NA	NA

No.	Ref. Page / Para.	COMMENT (August 2022)	RESPONSE	COMMENT (February 2023)	RESPONSE
		include the collection of site-specific data sufficient to (1) define/confirm the lateral and vertical extent of ROD-specified contaminants (where sufficient sample data is not available (see 1999 ROD, Appendix B, Table 1)), (2) effectively evaluate/identify current and potential human health risks, (3) evaluate attainment of ROD-specified RAOs and cleanup goals, and (4) ensure short- and long-term protectiveness of the selected remedy (see Page-Specific Comment (PSC) 1).	*screening level. … The chemicals selected by this process are retained for further risk evaluation in the BRA.* *6.2 Chemicals of Concern* *COCs are the COPCs that significantly contribute to an exposure pathway for a receptor (e.g. hypothetical future child resident, current youth trespasser, current adult construction worker, etc.) that either (a) exceeds a 1x10-4 cumulative site cancer risk; or (b) exceeds a non-carcinogenic HI of 1. … Chemicals are not considered as significant contributors to risk and therefore are not included as COCs if their individual carcinogenic risk contribution is less than 1x10-6 and their non-carcinogenic HQ is less than 0.1* The USEPA-approved 2000 LTMP for AOC 69W is more specific and identifies the CPCs that contributed greater than or equal to a hazard quotient (HQ) of 1.0 in the child resident (and adult resident) reasonable maximum exposure scenario and were, therefore, considered COCs. These included arsenic (HQ=40), iron (HQ=5.5), manganese (HQ=7.2), bis(2-ethylhexyl)phthalate (HQ=1.6), and VPH C9-C10 aromatics (HQ=1.3). Arsenic was the only COC that also contributed a carcinogenic risk greater than 1 x 10^{-4}. "Action Levels" were established for the COCs in the 2000 LTMP. In accordance with the ROD requirement to restore the AOC 69W aquifer to drinking water standards, arsenic concentrations were compared to the federal MCL. Dissolved iron and manganese were compared to background levels established in the 1998 AOC 69W RI (ABB 1998). Because the monitoring wells for AOC 69W fall within groundwater protection Zone II for the MacPherson supply well, VPH/EPH concentrations in samples collected from the AOC 69W wells were compared to GW-1 screening criteria (310 CMR 40 Subpart P). References to COCs will not be revised for the reasons stated, but arsenic, iron, manganese, bis(2-ethylhexyl)phthalate, and VPH will be added to the SRI WP discussion of COCs originally identified for AOC 69W groundwater. The field sampling, human health risk evaluation, and evaluation of RAOs portions of the text were revised to		

No.	Ref. Page / Para.	COMMENT (August 2022)	RESPONSE	COMMENT (February 2023)	RESPONSE
			include all COCs not previously removed from the LTM program.		
		PAGE-SPECIFIC COMMENTS			
1.	Page 2, § 1.1 -	EPA notes that Army's March 14, 2022 Response to EPA's 1/7/22 Comment #5 requested that EPA provide language regarding its characterization of the events leading up to this Additional Work. EPA has determined that the only necessary addition to this section is simply recitation of the Additional Work Requirements themselves. While the requirements specified in EPA's September 29, 2020 Additional Work letter are discussed in Section 1.4.3, EPA recommends that they be moved to the discussion on page 2 where the additional work determined by the USEPA to be necessary to "assess" and "document" protectiveness is discussed.	The Additional Work Requirements will be added to this section.	NA	NA
2.	Page 2, § 1.1, Full ¶ 3	The Additional Work identified by EPA as necessary to resolve issues at AOC 69W focused specifically on the effective implementation and communication of ROD-required LUCs and expansion of the existing LTMMP. The performance of a supplemental RI was not an Additional Work task but was proposed by Army in its November 17, 2020, response (to EPA's September 29, 2020 Additional Work letter). Specifically, the "preliminary analysis, understanding and proposed path forward" for AOC 69W stated that Army would prepare a [supplemental RI] work plan and "based on these additional investigations, historical site data and updated CSM, prepare a focused FS to evaluate changes to the remedy and any applicable ROD amendments."	Noted.	Please ensure that text in the draft final document has been amended to accurately describe/differentiate between the Additional Work required by EPA and that proposed by Army.	The following text was added to the end of Section 1.1: *"To address the USEPA's requirement for a revised LTMMP, the Army offered to prepare this SRI WP and an SRI report. Based on the results of the SRI, historical site data, and an updated conceptual site model (CSM), the Army will prepare a focused feasibility study (FFS) to evaluate changes to the remedy, including updates to the LTMMP, if necessary, and prepare any applicable ROD amendments."*
3.	Page 2, § 1.1, Full ¶ 4, last sentence	For reasons discussed in General Comment (GC) 1, the text should be amended to clarify that the "use of historical and new data to evaluate the ROD-stipulated remedy for possible modification or site close-out" is separate from and unrelated to the activities identified in EPA's 9/29/20 Additional Work Letter and description of work to be performed in Army's 11/17/20 response.	Text will be added to state that goals of the SRI are to address items in the Additional Work letter and that "**In addition**, the SRI will use historical and new data to evaluate the ROD-stipulated remedy for possible modification or site close-out."	NA	NA
4.	Page 4, § 1.3.2.2, last sentence (and top of Page 5, 2nd to last sent)	Please amend the current text to read, "… these risks were primarily due to the presence of arsenic in groundwater in monitoring wells 69W—94-10 and 69W—94-13. 69W-94-10 was removed during the 1998 removal action."	Text will be revised to state, "…these risks were primarily due to the presence of arsenic in the groundwater **(specifically monitoring wells 69W-94-10 and 69W-94-13)**, which was not interpreted to be directly related to the release of fuel oil at AOC 69W (KGS 2020). Monitoring well 69W-94-10 was	Please provide supporting documentation/data to support this statement, which is inconsistent with the AOC 69 W, pg 10 which states, "Contaminant concentrations were highest between the new boiler room and monitoring well 69W—94-13, which was also the area of highest observed soil concentrations. The soil around monitoring	Noted – text has been revised to *"these risks were primarily due to the presence of arsenic in the groundwater (specifically monitoring wells 69W-94-10 and 69W-94-13. Monitoring well 69W-94-10 was subsequently removed during excavation of contaminated soils in 1997/1998. Current well ZWM-*

No.	Ref. Page / Para.	COMMENT (August 2022)	RESPONSE	COMMENT (February 2023)	RESPONSE
			subsequently removed during excavation of contaminated soils in 1997/1998.	wells 69W—94-10 and 69W—94-13 exhibited the highest contaminant and inorganic concentrations and were removed during the soil Removal Action."	*99-22X was installed as a replacement well, adjacent to former well 69W-94-10 (**Figure 1-2**)"*
5.	Page 6, § 1.4.2, ¶ 1, 3rd sentence	In line with EPA's 1/7/22 Comment #12, amend the sentence to read, "Because the ROD requires restoration of the AOC 69W aquifer to drinking water standards (within a reasonable time), samples collected from the AOC 69W wells are compared to MCLs."	To be consistent with the USEPA-approved 2000 LTMP, the following will be added to Section 1.4.2: "In accordance with the ROD requirement to restore the AOC 69W aquifer to drinking water standards, arsenic concentrations are compared to the federal MCL. Dissolved iron and manganese are compared to background levels established in the 1998 AOC 69W RI (ABB 1998)."	NA	NA
6.	Page 6, § 1.4.2, ¶ 3	The text states that Bis(2-ethylhexyl)phthalate was dropped from the LTM program in 2002 because it was found to be a common laboratory contaminant and that Iron was eliminated as a non-ROD-listed CPC, but both are actually identified as groundwater CPCs in the 1999 ROD (Appendix B, Table 1). See GC 2 above.	Text will be revised to note arsenic and EPH/VPH were specifically called out in the ROD for monitoring but iron, manganese, and bis(2-ethylhexyl)phthalate also contributed to unacceptable risk and were originally identified as COCs in the 2000 LTMP for monitoring.	NA	NA
7.	Page 6, § 1.4.2, ¶ 4, new 2nd sentence	As a follow-up to Army's response to EPA's 1/7/22 Comment #12, please insert "EPA's disapproval of the changes proposed therein and associated deficiencies in post-2015, annual LTM reports gave rise to concerns surrounding the continued efficacy of the ROD-required long-term groundwater monitoring program and ongoing protectiveness of the selected remedy."	The 2015 LTMMP was finalized in accordance with provisions of the FFA Section 7.8. Text will be revised to indicate that USEPA does not concur with the 2015 LTMMP.	NA	NA
8.	Page 6, Exhibit 1-1	This table is an inaccurate summary of ROD-specified CPCs and cleanup goals and should be revised (based on the comments herein) or deleted. See GC 2 above.	The table (Exhibit 1-1) will be revised to include all COCs (those CPCs that contributed to unacceptable risk) as identified in the 2000 LTMP.	NA	NA
9.	Page 9, § 2.0	Please amend this section to identify and discuss the activities necessary to respond to/resolve the Additional Work requirements specific to the AOC 69W LTMMP.	The following text will be added to the draft final report to resolve the comment: The objectives of the AOC 69W SRI are to confirm the Army Protectiveness Statement in the 2020 Five-Year Review Report (KGS 2020) and address items specified in the USEPA Additional Work Requirements Table. Specifically, the goals of the SRI are to: • Collect sufficient and accurate site-specific data needed to accurately define/confirm the lateral and vertical extent of contamination • Evaluate/identify current and potential human health risks • Monitor attainment of ROD-specified RAOs and cleanup goals	NA	NA

No.	Ref. Page / Para.	COMMENT (August 2022)	RESPONSE	COMMENT (February 2023)	RESPONSE
			• Assess short- and long-term protectiveness of the selected remedy.		
10.	Page 10, § 2.2, last sent.	For consistency with EPA's Additional Work letter, please replace "AOC 69W ROD" with "AOC 69W LTMMP."	The text will be clarified by stating "AOC 69W ROD **or AOC 69W LTMMP"**	NA	NA
11.	Page 11, § 2.1.1	For reasons discussed in EPA's 4/15/22 PSC #1, soil samples must be collected from monitoring well locations/areas to support Army's generalized correlation between elevated dissolved arsenic concentrations and areas of observed reducing conditions (low DO and ORP). Site-specific data must be collected from areas where elevated metals remain although reducing or oxidizing conditions aren't present to support such conclusions or they should be omitted from future AOC 69W deliverables (i.e., supplemental RI report, annual LTM reports, LTMMP Updates, etc.)	Text will be added to the work plan to state that two soil samples will be collected from the saturated/proposed screen interval zones (i.e., within the top 10 feet of saturated soil) from each of the three proposed monitoring well locations, and from the corresponding interval at the proposed VAP location. Each soil sample will be submitted for an SPLP leach test via USEPA Method 1312 with analysis of arsenic, aluminum, iron, manganese, and pH on the leachate. The same samples will also be submitted for acid digestion via USEPA Method 3050B (coupled with EPA Method 6020A) for analysis of arsenic, aluminum, iron, and manganese. The SPLP-leachable arsenic will be compared with the groundwater arsenic in the same location to evaluate whether adsorbed arsenic is present and in equilibrium with groundwater, thereby providing evidence for arsenic adsorption potential.	NA	NA
12.	Page 11, § 2.2.1, ¶ 2, 2nd bullet, 1st sentence	While "The ROD anticipated that arsenic and EPH will be the monitored analytes" (emphasis added), the 1999 ROD (Appendix B, Table 1) identified "10 soil analytes, 14 groundwater analytes, three sediment analytes, and four air analytes" as CPCs and required ICs to restrict or prevent potential human exposure to site soil and ground water contaminants left in place. While the existing LTMMP is focused on the collection and evaluation of arsenic, manganese, iron, and EPH groundwater data, Army must ensure that there is sufficient historical groundwater data available to support elimination of the other ROD-specified, groundwater CPCs from the groundwater monitoring program in the supplemental RI report (and LTMMP Update). See GC 2 above.	See response to General Comment #2.	NA	NA
13.	Page 13, § 2.2.5	As discussed in the next comment, PSC 14, "To meet the goals of the SRI" and "confirm protectiveness of the remedy," the decision rules should be amended to address each of the Additional Work requirements identified in EPA's 9/29/20 letter (i.e., ensure collection of site-specific data necessary to accurately define/confirm the lateral and vertical extent of contamination, effectively evaluate/identify current and potential human health risks, monitor attainment	Introductory language will be revised to include USEPA Additional Work requirements in SRI goals.	NA	NA

No.	Ref. Page / Para.	COMMENT (August 2022)	RESPONSE	COMMENT (February 2023)	RESPONSE
		of ROD-specified RAOs and cleanup goals; and ensure short- and long-term protectiveness of the selected remedy).			
14.	Page 13 & 14, § 2.2.5	For reasons discussed in EPA's 4/15/22 PSC #5, EPA disagrees with the proposed use of "Decision Rules" to determine if sufficient data exists to confirm the current lateral and vertical extent of the ROD-listed CPCs in groundwater (and/or establish a stable or decreasing trend of the ROD-listed CPCs in groundwater which isn't even identified as a task in EPA's 9/29/20 Additional Work letter) and requests that this language be deleted. To adequately satisfy the AOC 69W Additional Work requirements, sample data from the supplemental RI should be compiled and presented, with relevant, existing data, in a draft supplemental RI report for regulatory review and comment. If EPA determines, upon review of the information provided, that no additional sampling is necessary, Army shall prepare and submit an amended LTMMP to ensure future, ROD-required groundwater monitoring is sufficient to effectively monitor attainment of ROD-specified RAOs and cleanup goals and ensure short- and long-term protectiveness of the 1999 remedy.	The establishment of Decision Rules is a key component of the DQO process, as specified in Chapter 5 of the USEPA's *Data Quality Objectives Process for Hazardous Waste Site Investigations.* The Decision Rules proposed in the SRI WP present simple "if…then ..." statements to determine if adequate data has been collected during the SRI to meet the goals of the SRI and allow the planning team (including the USEPA) to make decisions. The Decision Rules are not an attempt to pre-empt the review and decision-making process. The Decision Rules include the collection of data needed to address each of the USEPA's Additional Work requirements and outline specific data required for decision making.	EPA remains opposed to the use of the "Decision Rules" to evaluate whether Army has satisfied the requirements specified in its 9/29/20 Additional Work letter.	The Army's position on the use of decision rules, as specified in, and in accordance with, EPA's own published guidance, remains unchanged.
15.	Page 16, §§ 3.2.1 & 3.2.2	As EPA previously stated in its 4/15/22 PSC #6, EPA is interested in how extensive the peat deposits are in the site vicinity. Specifically, how much of the course of Willow Brook near the site is underlain by peat? Based on the overburden deposits described in Section 3.2.1, peat appears to be the only one capable of providing hydraulic isolation of Willow Brook from the aquifer below. This element of the CSM needs to be better characterized to help determine whether groundwater from the site (and contaminants) might be expected to migrate to the brook. Section 3.2.2 states that groundwater either discharges to Willow Brook or is recharged by Willow Brook, depending on groundwater levels at any given time. This suggests that the brook is hydraulically connected to the aquifer and not perched on peat or other low-permeability material. Section 3.2.2 acknowledges that deep wells are not present and vertical gradients are not measured. Is the statement regarding Willow Brook and groundwater speculative or evidence-based? Better characterization of the hydraulic relationship between the brook and groundwater may be necessary in order to state with confidence that the area of elevated CPCs is bounded to the southwest, west, and northwest.	The Army is planning to use the existing wells, proposed monitoring wells, and proposed staff gauges to further characterize the gradient and degree of hydraulic connection between groundwater and Willow Brook. The historical RI report from 1998 could not be located to confirm the number of drilling locations with peat deposits, but as described in Section 3.2.1, peat has been observed in the area north of the Charter School. It is the Army's opinion that these layers may be contributing to the localized reducing or moderately reducing conditions at well points 69WP-08-01 and 69WP-13-01, but that the layers are still permeable enough to allow for recharge and discharge to and from Willow Brook.	NA	NA

No.	Ref. Page / Para.	COMMENT (August 2022)	RESPONSE	COMMENT (February 2023)	RESPONSE
16.	Page 19, § 3.3.1, 3	While risk assessment results estimated cancer and non-cancer risks associated with the possible current and future exposures to surface soil, subsurface soil, sediment, groundwater discharge to surface water and indoor air were all within acceptable levels, the ROD did include a RAO to address potential health risks to individuals based on current and future use scenarios (i.e., maintenance worker, and elementary school children scenario) at the site. To ensure attainment of the RAO, ICs (in addition to those prohibiting extraction of groundwater for industrial and/or potable uses) were required to reduce/eliminate the direct contact threat of human exposure to remaining contaminated soils beneath and adjacent to the building/school.	The following text will be added to address the comment. In addition, LUCs were implemented to reduce/eliminate the direct contact threat of human exposure to remaining contaminated soils beneath and adjacent to the building/school.	NA	NA
17.	Page 20, § 4.1, ¶ 3	EPA appreciates Army's inclusion of all wells installed at the site, including those unilaterally eliminated from the current monitoring program "as part of Main Post LTMMP optimization." However, EPA recommends that an additional monitoring well be installed north of 69W-22-02, near ZWP-95-02X to confirm/deny the presence of contamination, downgradient of the southernmost boundary of the "Soil Excavation Limit" on the far side of Willow Brook.	Proposed monitoring well 69W-22-01 is already located north of 69W-22-02 (on the far side of Willow Brook). The Army believes that samples collected from these two wells, in addition to adjacent wells on the east side of Willow Brook (69WP-13-01, 69WP-08-01, ZWM-95-18X) will provide sufficient chemical and hydraulic data to answer the USEPA's questions.	NA	NA
18.	Page 20, § 4.1, ¶ 4, bullets 1 and 2	Army's response to EPA's 4/15/22 PSC #2 is incorrect. Iron and manganese are both ROD-specified CPCs (see Appendix B, Table 1). Please amend the current discussion to include manganese and iron. See GC 2 above.	See response to General Comment #2. Vertical and lateral extent, and trends in concentrations of iron and manganese will be added to this section.	NA	NA
19.	Page 23, § 4.2.2 -	In addition to the continuous logging and PID screening of overburden soils, EPA requests that soil samples be collected from a subset of monitoring well locations to support statements regarding the correlation between dissolved arsenic concentrations and reducing conditions (low DO and ORP) (see PSC 7).	See response to Page-Specific Comment #11.	NA	NA
20.	Page 24, § 4.2.5	Please be sure to submit an Off-Site Rule Compliance package to Carol Keating and Conor O'Brien, EPA Region 1 OSR Coordinator at Obrien.Conor@epa.gov prior to shipping the IDW waste off site to ensure that the receiving facility is operating in compliance and is acceptable to receive CERCLA waste at the time of shipment.	Noted.	NA	NA
21.	Page 25, § 5.0	See PSC 12 above.	See response to General Comment #2.	NA	NA

No.	Ref. Page / Para.	COMMENT (August 2022)	RESPONSE	COMMENT (February 2023)	RESPONSE
22.	Table 3-1	Please explain the cited 200 ug/L "cleanup goal" for EPH C11-C12 aromatics. Consistent with the 1999 ROD, Appendix B, Table 1 (and to EPA's knowledge), there is no applicable drinking water standard (i.e.. MCL) or risk-based cleanup goal for EPH/VPH in groundwater. Accordingly, please delete "200 ug/L" next to "cleanup goal" and insert "NS." See also GC 2 above.	Consistent with the USEPA-approved 2000 LTMP, references to "Cleanup Goal" will be changed to "Action Level." See response to General Comment #2.	NA	NA
		END OF COMMENTS			

DEPARTMENT OF THE ARMY
OFFICE OF THE DEPUTY CHIEF OF STAFF, G-9
600 ARMY PENTAGON
WASHINGTON, DC 20310-0600

June 2, 2023

SUBJECT: Final Post-Record of Decision (ROD) Supplemental Remedial Investigation Work Plan, Area of Contamination 69W, Former Fort Devens Army Installation, Devens, Massachusetts

Michael Daly
U.S. EPA Region 1
5 Post Office Square
Suite 100 - OSRR7-03
Boston, MA 02109

Dear Mr. Daly:

Thank you for providing your letter dated May 18, 2023, concerning the *Draft Final Post-Record of Decision (ROD) Supplemental Remedial Investigation Work Plan, Area of Contamination 69W*, *Former Fort Devens Army Installation, Devens, Massachusetts* (SRI Work Plan). As noted in your letter, the United States Environmental Protection Agency (USEPA) has approved the SRI Work Plan in the interest of commencing field work and the collection of data necessary to define the nature and extent of known and suspected contaminants of concern, evaluate groundwater conditions/contaminant concentrations, confirm/deny possible off-site contaminant migration, and verify protectiveness of the selected remedy. However, this approval is subject to concurrence by the Army that several unresolved issues will be addressed during the course of the project. These issues, and the Army's subsequent responses, are presented below.

1. Any discussion of the AOC 69W response action should be consistent with the description of the remedy and RAOs in the June 1999, AOC 69W ROD; specifically, "the Limited Action remedy will consist of long-term groundwater monitoring (to verify that elevated arsenic concentration will continue to decrease over time and not migrate downgradient) and institutional controls (to limit the potential exposure to the contaminated soil and groundwater under both existing and future site conditions). Institutional controls will ensure that exposure to contaminated soils remaining beneath and adjacent to the building are controlled and the extraction of groundwater from the site for industrial and/or potable uses will not be permitted. These institutional controls will be incorporated either in full or by reference into all deeds, easements, mortgages, leases, or any other instruments of transfer prior to the transfer of the property to MassDevelopment. Overall protectiveness will be assessed during five-year site reviews. Alternatively, if the Army can demonstrate based on currently available or newly acquired data, that site access restriction can be relaxed or removed while protection of human health is maintained, the Army may petition USEPA for such a relaxation or removal of restrictions."

- Army Response: The corresponding text from the second paragraph of ROD Section IV. SCOPE AND ROLE OF THE RESPONSE ACTION has been added to Section 1.4 of the Work Plan verbatim. This change is shown in the attached RLSO PDF of the text, which has been provided to aid USEPA review.

2. EPA's September 29, 2020, Additional Work letter specified that Army shall revise/amend the existing LTMMP to include collection of data necessary to adequately evaluate the full extent (lateral and vertical) of contamination, effectively evaluate/identify current and potential human health risks, monitor attainment of ROD-specified RAOs and cleanup goals; and ensure short- and long-term protectiveness of the selected remedy; Army's December 11, 2020, SOW indicated that it would "prepare a supplemental RI work plan for AOC 69W to confirm the lateral and vertical extent of contamination, assess contaminant distribution, and assess aquifer conditions (including reducing conditions and associated impacts on metals concentrations). The work plan will focus on data needed to evaluate remedial alternatives and to estimate remedy timeframes in a focused FS, with particular focus on the source area and any continuing sources that are contributing to groundwater contamination…. After approval of the supplemental RI report, Army will prepare a focused FS using the results of the RI, historical site data, and updated CSM. The focused FS will develop and assess a range of remedial alternatives to address contamination that remains at the site. The focused FS will include evaluation of alternatives for any continuing sources that are contributing to groundwater contamination." however, the goals and objectives of the DF SRI WP appear to focus solely on the collection of data necessary to (1) support Army's 2020 FYR Protectiveness Statement, (2) confirm that natural attenuation of petroleum in groundwater is occurring, and (3) evaluate the June 1999 remedy for possible modification or site close-out under CERCLA; unless Army is confident that sufficient historic data exists to address all of the tasks identified in EPA's September 28, 2020 Additional Work letter and objectives set forth in its December 11, 2020 SOW, then the scope of the SRI should be expanded to collect the additional data necessary to achieve these goals and objectives, specifically the evaluation of the current and/or a proposed, amended remedy to ensure short- and long-term protectiveness of human health and the environment, for all ROD-specified COCs/LTM monitored analytes in addition to arsenic, iron, manganese and EPH.

   - Army Response: The reference to the Army Protective Statement in Section 4 of the SRI Work Plan has been removed. In addition, the Army has added the analyses of all groundwater samples for Volatile Petroleum Hydrocarbons (VPH) (in addition to the analysis for Extractable Petroleum Hydrocarbons (EPH) already included), as well as the intrinsic petroleum bioremediation parameters nitrate, nitrite, sulfide, ferrous iron, and dissolved methane to the investigation scope to address the stated concerns. These changes supplement the additional soil and groundwater testing already included in the March 2023 submission to aid in the evaluation of the nature and extent of contamination.

3. As noted in EPA's comments on the draft, revised draft SRI WPs and draft FYR Reports, Commonwealth of Massachusetts regulations in 310 CMR 4000 and/or 310 CMR 40 are not ARARs associated with the June 1999 AOC 69W ROD (see Table 5); as such, text and tables that discuss ROD-specified COCs and applicable cleanup goals should

accurately distinguish between those analytes for which there are promulgated, enforceable risk-based cleanup standards or consensus-based, Devens-specific background concentrations (i.e., aluminum, iron, arsenic, manganese, 2, Methylnaphthalene, Bis(2,ethyihexyl)phthalate, naphthalene, chloroform, and trichloroethylene) and those for which there are none (i.e., EPH and VPH); while "monitoring criteria" were established in the LTTMP for EPH/VPH, neither are ROD-specified "action levels" identified in the June 1999 AOC 69W ROD, Appendix B, Table 6, Chemical-, Location-, and Action-Specific ARARs, Criteria, Advisories, and Guidance.

- Army Response: The requested text has been added to Section 1.4.2 and Exhibit 1-1 of the Final Work Plan where the comparison of EPH and VPH to 310 CMR criteria is discussed/presented.

4. Sample locations with detections above drinking water standards must have corresponding reducing aquifer (ORP) and dissolved oxygen (DO) data.

   - Army Response: The Army will collect ORP and DO data concurrent with all groundwater samples.

5. Boundaries of the site will be determined by the nature and extent (lateral and vertical) of all ROD-specified COC concentrations (using the ROD-specified cleanup goals (i.e., risk-based concentrations, MCLs and/or MMCLs)).

   - Army Response: The Army understands and acknowledges that the boundaries of the site will be subject to the listed criteria, with the addition that these criteria will be applicable for COCs that are demonstrated to be associated with AOC 69W.

6. Rather than rely on the decision rules in Section 2.2.5 to support post-SRI decisions regarding subsequent data needs, contaminant trends, and necessary changes to the existing remedy and/or LTMMP, EPA will rely upon data in the draft SRI report to determine whether additional data collection is necessary, whether an FFS can be prepared, and whether changes to the remedy and/or updates to the LTMMP, are necessary.

   - Army Response: The Army understands and acknowledges that recommendations and/or activities proposed by the Army based on the data from the SRI will be subject to review and approval by USEPA (and the Massachusetts Department of Environmental Protection ((MassDEP)). However, the Army also believes that the use of Decision Rules established in accordance with USEPA guidance is appropriate and useful to guide the process. Accordingly, the Army has revised the Decision Rules text in Section 2.2.5 to reflect that decisions will be subject to USEPA and MassDEP review. These changes are shown in the attached RLSO PDF of the text.

The Army appreciates the cooperation of the USEPA in moving this investigation forward to facilitate the evaluation of remedy protectiveness. Accordingly, also attached please find an electronic copy of the Final SRI Work Plan.

My point of contact for this action is Jeffrey Dvorak at the US Army Corps of Engineers – New England District (USACE), who can be reached at (978) 318-8464/ Jeffrey.a.dvorak@usace.army.mil; or I can be reached at (703) 545-2487/ Thomas.A.Lineer.civ@army.mil.

Sincerely,

Thomas Lineer
BRAC Program Manager
Army Environmental Division
Installation Services Directorate

Enclosures:

1. RLSO Text (e-copy)
2. Final SRI Work Plan (e-copy)

cc: Shawn Lowry, EPA (e-copy)
Joanne Dearden, MassDEP (e-copy)
Meg Delorier, MassDevelopment (e-copy)
Penny Reddy, USACE (e-copy)
Jeffrey Dvorak, USACE (e-copy)
Andrew Vitolins, SERES-Arcadis JV (e-copy)