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United States Army Corps of Engineers
New England District

Post – Record of Decision Supplemental Remedial Investigation Work Plan

Area of Contamination 57

Former Fort Devens Army Installation

Devens, Massachusetts

Contract No. W912WJ-19-D-0014

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June 2023

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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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Acronyms and Abbreviations

%	percent
µg/L	microgram per liter
1,4-DCB	1,4-dichlorobenzene
AOC	Area of Contamination
Army	U.S. Army
bgs	below ground surface
BERA	baseline ecological risk assessment
BRAC	Base Realignment and Closure
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
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
ESD	Explanation of Significant Differences
FFA	Federal Facility Agreement
FFS	focused feasibility study
FOST	Finding of Suitability Transfer
ft/day	feet per day
FYR	Five Year Review
gpm	gallons per minute
GW-1	MCP groundwater standards for potable water
HAZWOPER	Hazardous Waste Operations and Emergency Response
HHRA	human health risk assessment
HLA	Harding Lawson Associates
ID	Identification
IDW	investigation-derived waste
JV	joint venture
KGS	KOMAN Government Solutions, LLC
LLC	Limited Liability Company
LOD	limit of detection
LTM	long-term monitoring
LTMMP	long-term monitoring & maintenance plan
LUC	land use control
MassDEP	Massachusetts Department of Environmental Protection
MassDevelopment	Massachusetts Development and Finance Agency
MCP	Massachusetts Contingency Plan
MEC	munitions and explosives of concern

MCL	Maximum Contaminant Levels
MMCL	Massachusetts Maximum Contaminant Levels
MNA	monitored natural attenuation
msl	mean sea level
NA	not applicable/not available
NAPL	non-aqueous phase liquid
NAVD	North American Vertical Datum
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NFA	No Further Action
NPL	National Priorities List
ng/L	nanograms per liter
ORP	oxidation-reduction potential
OU	operable unit
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
PID	photoionization detector
POL	petroleum, oil, and lubricants
PRG	preliminary remedial goal
QA	quality assurance
QAPP	quality assurance project plan
QC	quality control
RAO	remedial action objective
RI	remedial investigation
ROD	record of decision
ROE	Right-of-Entry
S-1	MCP Method 1 S-1 Soil Category
SA	Study Area
SARA	Superfund Amendments and Reauthorization Act
SI	site investigation
SOP	standard operating procedure
SRI	supplemental remedial investigation
TGI	technical guidance instruction
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 hydrocarbons
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 and the current and future protectiveness of the remedy at Building 3713 Fuel Oil Spill Site (Area of Contamination [AOC] 57) located at Devens related to contaminants of concern (COCs) identified in the AOC 57 ROD (Harding ESE 2001) and subsequent Explanation of Significant Differences (ESD; Base Realignment and Closure [BRAC] Environmental Office 2004). The presence and potential impacts of per- and polyfluoroalkyl substances (PFAS) in soil and groundwater at AOC 57 is being evaluated separately.

Historical impacts at AOC 57 are attributed to a fuel oil spill near Building 3713 in 1977 and stormwater runoff/waste management practices associated with vehicle maintenance activities conducted at the storage yards related to Building 3713 and former Buildings 3757 and 3758. Three separate areas have been defined within AOC 57: Area 1, Area 2, and Area 3:

- In Area 1 (fuel oil spill near Building 3713), a response action for the 1977 spill recovered approximately 3,000 gallons of mixed oil and water using contaminant dikes and absorbent booms. A remedial action at the spill location in 1997 removed the remaining petroleum contaminated soil.
- Additional investigations were conducted in two other areas of AOC 57 impacted by waste management practices related to vehicle maintenance activities (Area 2 and Area 3), with subsequent remedial actions conducted between 1994 and 2003.

The ROD issued for AOC 57 (Harding ESE 2001) indicated that:

- Area 1 was closed with no further action (NFA).
- For Areas 2 and 3 the ROD selected remedies that included excavation and disposal of impacted soil, long-term monitoring (LTM) of groundwater for site contaminants, land use controls (LUCs), which prevent exposures to potential receptors, and five-year reviews.

An LTM plan was implemented in 2004 (USACE 2004) to monitor for concentrations of ROD-listed site contaminants (arsenic and tetrachloroethene [PCE] in Area 2; arsenic, cadmium, and 1,4-dichlorobenzene [1,4-DCB] in Area 3). In March 2004, an ESD was prepared for AOC 57 based on data collected during soil excavation activities at Area 2 in 2003 (BRAC Environmental Office 2004). Subsequently, extractable petroleum hydrocarbons (EPH) C11-C22 aromatic hydrocarbons and the polychlorinated biphenyl (PCB) Aroclor-1260 were added as AOC 57 groundwater COCs (KGS 2020).

In September 2020, during discussions between the Army and the United States Environmental Protection Agency (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

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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).

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 (OUs) evaluated in the Final Fifth 2020 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 57 was not protective in the long-term. The USEPA stated, "*A protectiveness determination of the remedy at AOC 57 cannot be made at this time until further information is obtained. Further information will be obtained by taking the following action: amend/revise the current LTMMP to ensure collection of site-specific data necessary to accurately define the extent of groundwater contamination, to resolve ongoing, consistently disputed issues/deficiencies in annual LTM reports, evaluate possible off-site migration of contaminated groundwater and identify current impacts, if any, on downgradient public and/or private drinking water supply and irrigation wells; and provide details regarding the investigation/removal of the buried wastes discovered in March 2019 to support the identification and/or subsequent investigation of the buried waste/disposal area as a new AOC 57 source area."*

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. In November and December 2021, debris was removed from AOC 57 in accordance with the Debris Removal Workplan (S-A JV 2021a). Additional information is presented in the Draft Debris Removal Activities Summary Report submitted to the USEPA in January 2022 (S-A JV 2022).

This SRI WP details the proposed supplemental investigation of AOC 57 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 site-specific data to accurately define/confirm the lateral and vertical extent of groundwater contamination
- Evaluate possible off-site migration of contaminated groundwater and identify current impacts, if any, on downgradient public and/or private drinking water supply and irrigation wells
- Monitor attainment of ROD/ESD-specified RAOs and cleanup goals
- Assess short- and long-term protectiveness of the selected remedy.

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

The Army is preparing under separate cover a stand-alone land use control implementation plan (LUCIP) specific for AOC 57, which describes the LUCs that have been implemented as part of the remedy. This plan will replace the LUCIPs for AOC 57 being implemented under the 2015 *Long-Term Monitoring and Maintenance Plan for Former Fort Devens Army Installation and Sudbury Annex* (Main Post LTMMP; Sovereign/HydroGeologic [HGL]).

1.2. Regulatory Requirements

Activities completed under this AOC 57 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) 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 or oil.

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 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 the 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 57 (Building 3713 Fuel Oil Spill Site)

1.3.2.1. AOC 57 Site Background

AOC 57 is located between Barnum Road and Cold Spring Brook on the northeast side of what was formerly the Main Post of Fort Devens, in the town of Harvard, Massachusetts (**Figure 1-1**). AOC 57 is located within a Zone II aquifer protection area for the Town of Ayer Grove Pond public water supply wells. It is in an area of Devens that was used primarily for the storage and maintenance of military vehicles.

AOC 57 comprises three sub-areas, as defined in the ROD: Area 1, Area 2 (floodplains), and Area 3 (upland). These areas are located south and southeast of former building 3713 and former buildings 3756, 3757, and 3758. (**Figure 1-2**). These sub-areas received stormwater runoff and wastes from vehicle maintenance activities conducted at the storage yards related to Building 3713 and former Buildings 3757 and 3758. The yards were abandoned in 1998, and the area was later redeveloped.

- Area 1 consists of a former stormwater outfall and drainage area for runoff from paved areas proximal to former Building 3713. An estimated 50- to 100-gallon spill of No. 4 fuel oil was discharged through the Area 1 outfall in 1977. Approximately 3,000 gallons of mixed oil and water were recovered through the use of containment dikes and absorbent booms in 1977.
- Area 2 (floodplains) is located approximately 700 feet northeast of Area 1 and adjacent to a former vehicle storage yard associated with the motor repair shops located in former Buildings 3757 and 3758. The nearby former Building 3756 served as a mess hall and was later converted to a general storehouse. Area 2 was originally thought to have been contaminated by the Area 1 No. 4 fuel oil spill; however, area grading was such that overland flow to Area 2 would not have been possible. When initially investigated, Area 2 consisted of an eroded drainage ditch created by periodic rainfall runoff from vehicle storage yards associated with Buildings 3757 and 3758.
- Area 3 (upland) is located approximately 600 feet to the northeast of Area 2, south of former vehicle maintenance motor pools. The site is characterized by a historic garage and vehicle waste disposal area. Area 3 was identified through historical photograph analysis that indicated an area of soil staining.

A manufacturing facility was constructed between Areas 2 and 3 of AOC 57 and Barnum Road between 2008 and 2009. Occupancy and use of the building have varied since construction, but the building footprint and infrastructure have not been modified.

1.3.2.2. AOC 57 Regulatory Background

As part of the BRAC closure process, AOC 57, then Study Area (SA) 57, was investigated under the CERCLA process as part of the Site Investigation (SI) of Groups 2 and 7 Historic Gas Stations (ABB Environmental Services, Inc. 1995). Based on the results of the SI, the Army recommended further investigation of Area 1 as part of an installation-wide storm sewer study (Arthur D. Little, Inc. 1994). Although a preliminary risk evaluation indicted that there were no unacceptable risks, in 1997 the Army performed a soil removal action of approximately

25 cubic yards (cy) at the Area 1 outfall area in response to newly promulgated Massachusetts Contingency Plan (MCP) standards to address soil contamination resulting from releases of petroleum, oil, and lubricants (POL) (Weston 1998). A formal assessment of risks was performed as part of the 1995 AOC 57 RI (Harding Lawson Associates [HLA] 2000) to demonstrate that any remaining contamination at Area 1 did not pose unacceptable risks for future unrestricted land use. The RI report recommended no further action at AOC 57 Area I (Harding ESE 2001).

At Area 2, data gathered during the RI suggested that Area 2 contamination was most likely the result of the historical disposal of vehicle maintenance related wastes to ground. Contaminant distributions indicated that the disposal occurred along the break in slope above the floodplain (Harding ESE 2001). Following a soil removal action in 1994, Area 2 was re-graded and a permanent drainage swale was installed. Results of sampling conducted during and at the completion of the removal action in 1994 indicated the presence of total petroleum hydrocarbons, PCBs, lead, and volatile organic compounds (VOCs) in soil and/or groundwater at the site. Reducing conditions caused by the contamination also released naturally occurring arsenic in soil to groundwater and caused elevated levels of arsenic in groundwater. Subsequent activities included subsurface investigations with soil sampling and monitoring well installation, removal of additional contaminated soil, construction of an interceptor trench, and operation of a petroleum product recovery system. The 2000 RI report identified EPH C11-C22 aromatic carbon range, PCBs, arsenic, chromium, and lead as COCs for Area 2 soil and arsenic and PCE as COCs for Area 2 groundwater. The RI concluded that there were no risks to ecological receptors and recommended that the Army perform a feasibility study for Area 2 to evaluate alternatives to address risks to human health (Harding ESE 2001).

In 1995, four test-pits were excavated northeast of Area 2 where historical photos indicated soil staining. Sample analysis showed the presence of total petroleum hydrocarbons and chlorinated VOCs. The area was subsequently designated AOC 57 Area 3. After further investigation, the Army conducted a soil removal action in 1999 that targeted soils with total petroleum hydrocarbons and PCB concentrations exceeding soil standards published under the MCP (HLA 1999). A total of 1,860 cy of materials was removed for off-site disposal. Residual petroleum, PCB, and pesticides contamination remained in soils near the southern end of the excavation (Harding ESE 2000). Subsequently, EPH C11-C22 aromatic carbon range was identified as a soil COC for Area 3 and arsenic, cadmium, and 1,4-DCB were identified as groundwater COCs for Area 3.

Remedial alternatives to control risk at Area 2 and Area 3 were evaluated in the AOC 57 Focused Feasibility Study (FFS; Harding ESE 2000). The November 2000 AOC 57 FFS (Harding ESE) evaluated multiple remedial action alternatives for cleanup of soil and groundwater in Areas 2 and 3. The Army's preferred remedies were detailed in the AOC 57 Proposed Plan (Harding ESE 2000a) which was issued in February 2000. The preferred alternative for Area 1 was No Further Action (NFA). The Proposed Plan identified Alternative II-3: Excavation (for Possible Future Use) and Institutional Controls as the Preferred Alternative for Area 2, and Alternative III-2: Limited Action as the Preferred Alternative for Area 3. During the public comment period, the Army received numerous comments requesting that a more aggressive approach than limited action be implemented at Area 3 to speed up groundwater cleanup. In response to the comments, the Army developed and decided to implement, Alternative III-2a: Excavation (to Accelerate Groundwater Cleanup) and Institutional Controls at Area 3.

1.4. AOC 57 CERCLA Remedial Actions

The AOC 57 ROD (Harding ESE 2001) was signed in November 2000 and formalized the recommendation for NFA at Area 1 and documented the selection of remedial actions to control site risks at Areas 2 and 3 of AOC 57.

To address potential risk to human health at AOC 57 the FFS identified remedial action objectives (RAOs) for media at AOC 57 based on the results of the risk assessment, The following finalized RAOs were presented in the ROD:

Area 2 Floodplain

- Protect possible future construction workers that might work within Area 2 floodplain (recreational) areas from ingesting soils containing Aroclor-1260 and lead at concentrations in excess of preliminary remedial goals (PRGs) considered protective of human health.
- Prevent unrestricted use residential receptors from coming in dermal contact with and ingesting Area 2 floodplain soils containing Aroclor-1260, arsenic, chromium, lead, and the EPH C11-C22 aromatic carbon range at concentrations in excess of PRGs considered protective of human health.
- Prevent unrestricted potable use of Area 2 floodplain groundwater containing arsenic and PCE at concentrations that exceed USEPA Maximum Contaminant Levels (MCLs) and Massachusetts Maximum Contaminant Levels (MMCLs) for drinking water.

Area 3 Upland

- Protect possible future commercial/industrial workers from ingesting Area 3 upland groundwater that contains arsenic, cadmium, and 1,4-DCB at concentrations that exceed MCLs and MMCLs for drinking water.
- Prevent unrestricted residential potable use of Area 3 upland groundwater containing arsenic, cadmium, and 1,4-DCB at concentrations that exceed MCLs and MMCLs for drinking water.

Area 3 Floodplain

- Prevent unrestricted use residential receptors from coming in dermal contact with and ingesting surface soils containing the EPH C11-C22 aromatic carbon range at concentrations in excess of PRGs considered protective of human health.
- Prevent unrestricted residential potable use of Area 3 floodplain groundwater containing arsenic and PCE at concentrations that exceed MCLs and MMCLs drinking water.

The remedial action alternatives selected in the ROD to control site risks for Areas 2 and 3 at AOC 57 included the following key components:

- Excavation and disposal of impacted soil in Area 2 to protect possible future use construction workers from the threat of exposure to contaminated floodplain soil by removal of soil exceeding cleanup criteria.
- Excavation and disposal of impacted soil in Area 3 to accelerate groundwater cleanup by removing soil containing contaminants that cause reducing conditions which result in release of naturally occurring arsenic from soil to groundwater.
- Institutional Controls, including deed and/or land use restrictions (i.e., LUCs) to prohibit residential use of floodplain property and potable use of groundwater in the floodplain "…*to protect potential future area residents from the threat of direct contact exposure to floodplain soil and exposure to contaminated groundwater* ...". Institutional Controls established for AOC 57 are discussed below in **Section 1.4.1.**
- Environmental Monitoring of groundwater and surface water "…to assess for decreases in arsenic; maintenance of PCE, cadmium, and 1,4-DCB concentrations (upland and floodplain COCs) at or below cleanup levels; and for the need for continued groundwater institutional controls to protect human receptors " (Harding ESE 2001). Results of surface water sampling were to be used to "…assess off-site migration of human-health COCs in excess of PRGs via the groundwater to surface water pathway." The ROD noted that the AOC 57 FFS estimated that 1 to 2 years beyond the completion of the 2003 excavation may be required for groundwater beneath wetland/floodplain areas at Area 2 to attain cleanup levels and that 1 to 8 years beyond the completion of the 2003 excavation may be required for

groundwater beneath wetland/floodplain areas at Area 3 to attain cleanup levels. However, the cost summaries in the FFS for the Area 2 and Area 3 remedial alternatives each used a 30-year lifespan for cost estimates. The 2004 ESD added EPH C11-C22 aromatic hydrocarbons and PCB Aroclor-1260 as AOC 57 groundwater COCs (KGS 2020). As discussed in **Section 1.4.2**, the current Devens LTMMP (Sovereign/HGL 2015) removed 1,4-DCB, PCE, PCBs, and EPH from the AOC 57 monitoring program and the only remaining ROD/ESD-listed COC is arsenic.

- Five Year Reviews - Because contaminant would remain on-site above concentrations that allow for UU/UE, statutory reviews must be performed, "…to assess whether the remedy remains or will remain protective of human health and the environment." (Harding ESE 2001). Five-year reviews must be performed, "…as long as hazardous substances, pollutants, or contaminants remain on-site above concentrations that allow for UU/UE."

1.4.1. Institutional Controls

AOC 57 is owned by the Army but is leased to the Massachusetts Development and Finance Agency (MassDevelopment) per a Lease in Furtherance of Conveyance agreement. Under the Lease in Furtherance of Conveyance agreement, MassDevelopment must comply with the LUCs of the 2001 ROD to limit the potential exposure to the residual contaminated soil and groundwater under both existing and future site conditions. The LUCs identified in the Selected Remedies for Area 2 in the ROD and included in the Lease in Furtherance of Conveyance calls for "*Existing zoning that prohibits residential use of Area 2 property and proposed deed restrictions that prohibit potable use of Area 2 groundwater and residential use of flood plain property*." The LUCs identified in the Selected Remedy for Area 3 mirrored those called for in Area 2.

The LUCs ensure that exposure to potential remaining contaminated soils beneath the site is controlled and prohibit the groundwater extraction for potable water supply use. An active irrigation well is located adjacent to the building at 78 Barnum Road, which is not within the boundaries of AOC 57. The well is 505 feet deep and is believed to be an open borehole bedrock well. The property manager has indicated that the well is used for lawn care for the property from spring to fall and there is no flow meter to record the daily flow rate or volume of water used (KGS 2021).

The LUCIP for AOC 57 is included in Section 4.0 of the 2015 Main Post LTMMP (Sovereign/HGL). LUC inspections are conducted annually during sampling events to monitor for broken ground or excavations or installation of potable water wells. MassDevelopment and the tenant at 112 Barnum Road as of December 2020, Jabil, Inc., a healthcare products producer, are abiding by the LUCs imposed on the property, and annual groundwater sampling continues in accordance with the LTMMP.

1.4.2. Long Term Monitoring

The first long-term surface water and groundwater sampling round at AOC 57 was performed in December 2003 for contaminants identified in the 2001 ROD with Preliminary Remediation Goals (arsenic, cadmium, 1,4-DCB, and PCE). The 2004 ESD added cleanup levels for total PCBs and EPH C11-C22 Aromatics to the LTM program and confirmed the cleanup levels for arsenic, cadmium, 1,4-DCB, and PCE. The analytes and monitoring locations for the AOC 57 LTM program have been revised numerous times since the program was initiated. Groundwater and surface water in Area 3 have been sampled in the spring on an annual basis since 2008.

The current LTM program for AOC 57 as presented in the LTMMP (Sovereign/HGL 2015), includes monitoring only for arsenic based on historical data collected between 2003 and 2014 indicating that concentrations of the other ROD-listed COCs were below cleanup levels. The sampling program was also modified to suspend sampling at Area 2; however, water level measurements at Area 2 wells continues. The 2015 Main Post LTMMP was finalized in accordance with provisions of the 1991 Devens FFA Section 7.8 and released without USEPA concurrence or approval. **Exhibit 1-1** below summarizes the COCs historically and currently included in the AOC 57 LTM program.

Exhibit 1-1: AOC 57 Area 2 and Area 3 COC Screening Limits in Groundwater and Surface Water

Analyte [c]	Original Screening Standard (µg/L) [a]	Current Screening Standard (µg/L) [b]	Selection Basis
SVOCs			
1,4-DCB	5	NA	MMCL (ROD/ESD)
PCE	5	NA	MCL (ROD/ESD)
PCBs			
Total of all Aroclors	0.5	NA	MCL (ESD)
EPH (Area 2 only)			
C11-C22 Aromatics	200	NA	MCP Method 1 risk assessment standards for GW-1 (ESD)
Metals (total and dissolved)			
Arsenic	50	10	MCL (ROD/ESD)
Cadmium	5	NA	MCL (ROD/ESD)

NOTE:
µg/L = micrograms per liter.
NA = no applicable screening standard.
SVOCs = semi-volatile organic compounds.

a. Original Screening Levels noted as Preliminary Remediation Goals in 2001 ROD (Harding ESE) and as Cleanup Levels in 2004 ESD. Current Screening Levels as noted in 2020 FYR (KGS).
b. MCP 2021 https://www.mass.gov/regulations/310-CMR-4000-massachusetts-contingency-plan
c. SVOCs, PCB, EPH, and cadmium were removed from the AOC 57 LTM analyte list after 2014. Only arsenic (highlighted green) is currently monitored in groundwater and surface water.

Although the LTMMP (Sovereign/HGL 2015) established monitoring at AOC 57 as every 5 years, sampling has continued to be conducted annually since the LTMMP was issued in 2015. Current annual monitoring at AOC 57 consists of collection of samples from two monitoring wells in Area 3 (analyzed for total arsenic, iron, and manganese in 2020), water level measurements at Area 2 and Area 3 wells, and collection of one surface water sample in Area 3 (analyzed for dissolved arsenic, iron, and manganese in 2020).

Iron and manganese are not identified as COCs in the AOC 57 ROD. As such, AOC 57 does not have a site-specific cleanup goal for manganese and iron. AOC 57 manganese and iron concentrations in groundwater are currently compared to previously established background levels of 291 and 9,100 µg/L, respectively. Iron and manganese are monitored at AOC 57 to support the natural attenuation evaluation.

1.4.3. Five-Year Reviews

FYRs were completed for AOC 57 beginning in 2005 to confirm the remedial alternative for AOC 57 selected in the ROD continued to be protective of human health and the environment. The 2020 FYR concluded that groundwater sampling results for Areas 2 and 3 indicate that arsenic concentrations are generally stable (based on a review of time-concentration trends and Mann-Kendall trend analysis), with some fluctuations over time, and are consistent with the conceptual site model (CSM), which indicates that the extent of the dissolved phase contamination is associated with reducing conditions, limited in extent, and is controlled (bounded) by the discharge of shallow site groundwater into Cold Spring Brook (KGS 2020). Arsenic was not detected in the surface water sample collected during the spring 2020 sampling event.

The 2020 FYR Protectiveness Statement concluded:

> *"The remedy at AOC 57 is protective of human health and the environment.*
>
> *Exposure pathways that could result in unacceptable risks are being controlled. Land use controls are in place that prevent exposure to groundwater that could pose an unacceptable human health risk, the LUCs are enforced, and no exposures are currently occurring or imminent.*

> *The RAOs have been achieved through 1) excavation and disposal of contaminated soil, 2) reduction of groundwater contamination through natural attenuation, and 3) implementations of LUCs. Groundwater monitoring at AOC 57 has confirmed many of the contaminants of concern concentrations have decreased below cleanup levels.*
>
> *The FYR site inspection and interviews, and annual land use control inspections and interviews, confirmed that site use remains Rail Industrial Land Trade-Related and Open Space property."*

After review of the 2020 FYR, the USEPA issued an independent Protectiveness Statement (USEPA 2020):

> *"A protectiveness determination of the remedy at AOC 57 cannot be made at this time until further information is obtained. Further information will be obtained by taking the following action:*
>
> - *amend/revise the current LTMMP to ensure collection of site-specific data necessary to accurately define the extent of groundwater contamination, to resolve ongoing, consistently disputed issues/deficiencies in annual LTM reports, evaluate possible off-site migration of contaminated groundwater and identify current impacts, if any, on downgradient public and/or private drinking water supply and irrigation wells; and,*
> - *provide details regarding the investigation/removal of the buried wastes discovered in March 2019 to support the identification and/or subsequent investigation of the buried waste/disposal area as a new AOC 57 source area."*

1.5. Work Plan Organization

This SRI WP includes:

- Project objectives.
- 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 2020a) and the LTMMP QAPP Addendum for Supplemental Remedial Investigation at AOC 57 (QAPP Addendum; **Appendix A**). The AOC 57 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 57 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 57; describes and presents the nature and extent of COC in AOC 57, 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 57 SRI WP schedule.
- **Section 7** – References: Provides a list of references used in preparing the AOC 57 SRI WP.

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

- **Appendix A**: AOC 57 QAPP Addendum - Describes the site-specific chemical data quality objectives (DQOs), field data-gathering methods and analytical methods and measurements not included in the LTMMP QAPP.

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 remedial remedy for petroleum spills at AOC 57 was completed under 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 57, a response action was conducted for a petroleum spill in 1977, over 42 years ago, with additional excavation of impacted soil completed between 1994 and 2003. Ongoing LTM of groundwater in Areas 2 and 3 of AOC 57 has been conducted since 2003. No specific timeframe for LTM was identified in the ROD. Based on LTM site data collected between 2003 and 2020, the following observations can be made:

- Historical groundwater quality data for ROD/ESD-listed COCs indicate decreasing trends:
- SVOCs, PCBs, EPH, and cadmium are no longer monitored. These ROD/ESD-listed COCs were removed from the AOC 57 LTM analyte list after 2014, as concentrations were observed to be less than criteria from 2009 through 2013.
- Geochemical data indicate active biodegradative processes.
- Arsenic concentrations have been detected above cleanup goals at monitoring well 57M-95-03X located within the former source area and downgradient monitoring well 57M-96-11X; concentrations at monitoring well 57M-95-03X have remained fairly stable since 2005.

This SRI WP incorporates elements of the following guidance documents to assess the AOC 57 LTM data for ROD-listed COCs in groundwater to confirm the protectiveness of the remedy at AOC 57 and to identify data needed for site closeout:

- 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. 2015.
- 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

This SRI WP details the proposed supplemental investigation of AOC 57 to confirm the Army Protectiveness Statement in the 2020 Five-Year Review Report (KGS 2020)

The objectives of the AOC 57 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 site-specific data to accurately define/confirm the lateral and vertical extent of groundwater contamination
- Evaluate possible off-site migration of contaminated groundwater and identify current impacts, if any, on downgradient public and/or private drinking water supply and irrigation wells
- Monitor attainment of ROD/ESD-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 57 ROD or AOC 57 LTM program are necessary. The evaluation will also include a comparison of current site conditions to remedial endpoints for similar petroleum 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

As presented in the 2020 FYR, significant progress has been completed towards achieving the RAOs (KGS 2020):

- ROD and ESD specific COCs have attenuated or are generally stable: In Area 2, all COCs identified in the AOC 57 ROD/ESD for monitoring in groundwater (1,4-DCB, PCE, PCB, EPH C11-C22 Aromatics, cadmium, and arsenic) have attenuated and have been removed from the LTMMP. The 2015 Main Post LTMMP was finalized in accordance with provisions of the 1991 Devens FFA Section 7.8 and released without USEPA comment.
- In Area 3, petroleum-related COCs identified in the AOC 57 ROD/ESD for monitoring in groundwater (1,4-DCB, PCE, PCB, EPH C11-C22 Aromatics, and cadmium) have attenuated and have been removed from the LTMMP.
- In Area 3, consistent with the CSM which indicates that concentrations of naturally occurring metals in groundwater will remain elevated due to geochemical changes caused by the biodegradation of residual petroleum hydrocarbons, arsenic concentrations in groundwater are generally stable, with some fluctuations over time but arsenic is not migrating to surface water at concentrations above monitoring criteria.
- 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 Lease in Furtherance of Conveyance between Army and MassDevelopment. The LUCs for AOC 57 are discussed in **Section 1.4.1**

Based on 18 years of LTM data, the 2020 FYR concluded that groundwater sampling results for Area 3 indicate that arsenic concentrations, while above cleanup goals, are associated with reducing conditions, limited in extent, and controlled (bounded) by the discharge of shallow site groundwater into Cold Spring Brook (KGS 2020). In addition, there are no impacts to Cold Spring Brook based on the surface water sampling data.

The Army is conducting this SRI to confirm that the selected remedy for AOC 57 remains protective and that site conditions indicate natural attenuation of ROD-listed COC arsenic in groundwater is occurring/has occurred. Historical and new data collected will also be used evaluate the ROD-stipulated remedy for possible modification or site close-out. The study questions for this SRI are:

1. What is the current lateral and vertical extent of the ROD specified COC arsenic in groundwater?
2. How is arsenic distributed in groundwater (vertically and horizontally)?
3. Is there a stable or decreasing trend of arsenic concentrations in groundwater?
4. Are current reducing aquifer conditions associated with the petroleum releases 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 57 SRI field activities are to:

- Confirm the current lateral and vertical extent of arsenic in groundwater.
- Confirm the current nature and extent of reducing aquifer conditions.

Confirm the CSM, including aquifer reducing conditions, associated impacts on arsenic concentration trends, and the potential impacts to receptors (if any).

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 18 years of LTM groundwater data to evaluate historical trends for arsenic. Historical groundwater data is summarized in **Table 3-1**. Historical surface water data is summarized in **Table 3-2**. Information on existing monitoring wells is provided in **Table 3-3.**
- Analytical data for arsenic from existing monitoring wells and from two new proposed vertical aquifer profile (VAP) locations; one downgradient of the former petroleum release area in Area 2 and one upgradient from the former petroleum release area in Area 3 to determine vertical and lateral extent of arsenic. See Section 4 for additional details.
- Analytical data from two new proposed VAP locations and monitoring well locations located to the east of Cold Spring Book. These locations are proposed as part of the Phase II Remedial Investigation for PFAS Area 1, the Work Plan for which is currently under review by the Agencies. The installation and sampling of these locations will be completed pending the approval of the PFAS Work Plan, and sampling will be conducted in accordance with proposed PFAS investigation schedule. In addition, the sampling of these locations will be dependent on the ability to execute and retain a Right-of-Entry (ROE) permit with private property owners for access.
- 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 VAP locations 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
    - pH
- Laboratory Analyses for geochemical evaluation:
    - Aluminum (total and dissolved) – Used as a non-redox-sensitive proxy for evaluating potential for fine suspended particulates to influence other dissolved metals analyses (including iron and arsenic).
    - Iron (total and dissolved) – Used to evaluate redox status and capacity for arsenic natural attenuation via iron coprecipitation.
    - 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.

Site conditions at AOC 57 are well documented with historical LTM data collected between 2003 and 2021. However, during the 18 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 under CERCLA or the MCP, the Army will collect supplemental data at AOC 57 from two new temporary wells (i.e., vertical profile locations), a subset of existing monitoring wells, and from surface water sampling locations.

2.2.4. Boundaries of Study

The general areal boundaries for the SRI are the former POL release areas (i.e., Area 2 and Area 3 of AOC 57) and associated downgradient extents of the ROD-listed COC arsenic (**Figure 1-2**).

Historical impacts at AOC 57 are attributed to a fuel oil spill near Building 3713 in 1977 and vehicle maintenance activities conducted at the storage yards related to Building 3713 and former Buildings 3757 and 3758. A response action for the 1977 spill recovered approximately 3,000 gallons of mixed oil and water using contaminant dikes and absorbent booms. A remedial action at the spill location (Area 1) in 1997 removed the remaining petroleum contaminated soil. Additional investigations were conducted in two other areas of AOC 57 (Area 2 and Area 3), with subsequent remedial actions conducted between 1994 and 2003.

2.2.5. Decision Rules

To meet the goals of the SRI, groundwater samples will be collected from existing monitoring wells and from two new VAP locations to accurately define/confirm the lateral and vertical extent of contamination, 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 the ROD/ESD-listed COC arsenic 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 current data to confirm the current lateral and vertical extent of arsenic and other ROD-specified COCs in groundwater (i.e., are locations with samples exceeding screening criteria bounded by samples from locations and depths 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, and LTM remedy is protective and may be suitable for reduced monitoring.
    - If no, the Army will propose activities to USEPA and Mass DEP to collect additional data as needed.
- Is there sufficient current and historical data to establish a stable or decreasing trend of arsenic and other ROD-specified COCs in groundwater?
    - If yes, the Army will propose to USEPA and MassDEP that no additional sampling is required and LTM remedy is protective and may be suitable for reduced monitoring.
    - If no, the Army will propose to USEPA and Mass DEP that LTM will continue.

3. Conceptual Site Model

This section presents a discussion of the CSM for Devens and, specifically, for AOC 57.

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 2000). 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 2000). 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. AOC 57 is located to the east of and immediately adjacent to Cold Spring Brook near its confluence with Bowers Brook.

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 57 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 2000). 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 57) ranges from less than 1-foot below ground surface (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 57

The physical characteristics and hydrogeology for AOC 57 are summarized in the following sections.

3.2.1. Physical Characteristics / Use

AOC 57 is located south of former Building 3713, between Barnum Road and Cold Spring Road on the northeastern side of the former Main Post of Fort Devens in the Town of Harvard, Massachusetts. Public access to Areas 2 and 3 is not restricted, but the presence of floodplains/wetlands and existing zoning currently prevents exposure to the subsurface.

The vehicle storage yards associated with Buildings 3756, 3757, and 3758 were abandoned in 1998, and the pavement and fencing were removed. Upland portions of AOC 57 are located within an area zoned for Rail, Industrial, and Trade Related uses. A manufacturing facility was constructed in 2009 between Areas 2 and 3 and Barnum Road (112 Barnum Road; **Figure 1-2**).

Floodplain portions of AOC 57 are zoned for Open Space and Recreation (Vanasse Hangen Brustlin 1994). Future residential use of land at AOC 57 is prohibited by LUCs; the Devens Reuse Plan does not include residential development of land in the vicinity of AOC 57, and the use of the flood plain area is limited by poor soil and seasonal flooding.

3.2.2. Topography / Geology

Surface topography across AOC 57 is generally flat across the paved and developed areas in the upland region near Barnum Road and slopes down to the east/southeast towards Cold Spring Brook in the wooded/undeveloped areas.

The overburden is relatively thick throughout AOC 57 with an average thickness of approximately 100 feet, increasing to approximately 150 feet near well 5702MW-20-03A, and decreasing to approximately 80 feet or less beneath Cold Spring Brook. Overburden in the AOC 57 area is generally comprised of an unconsolidated sediment sequence of approximately 50 feet of sand with gravel overlying approximately 30 to 80 feet of silt to sandy silt, followed by a 4- to 8-foot-thick band of basal till that conforms to the underlying bedrock topography.

On the opposite side of Cold Spring Brook (east/southeast), the land surface elevation rises steeply, and it is assumed that the overburden thickness decreases accordingly as the bedrock or till and land surface increase in elevation further to the southeast.

The bedrock underlying AOC 57 consists of the Oakdale Formation under Areas 2 and 3, and the Devens Gneiss Complex under Area 1. The contact between these formations is estimated to fall between Areas 1 and 2 running along a north/northeast direction. East and southeast of Cold Spring Brook, the bedrock transitions to the Ayer Granite.

3.2.3. Hydrogeology

AOC 57 is part of the Bowers-Nonacoicus Brook Sub-basin, Nashua River Watershed. AOC 57 is located to the west of and immediately adjacent to Cold Spring Brook near its confluence with Bowers Brook. Depth to groundwater ranges from about 20 feet bgs in the upland areas of AOC 57 (near Barnum Road) to less than 1-foot bgs in the lowlands/wetlands adjacent to Cold Spring Brook. It should be noted that the 2001 ROD (Harding

ESE) defines upland as areas with elevations greater than 228 feet mean sea level (msl) and areas below 228 feet msl as 100-year floodplain. The water table occurs entirely within the overburden across AOC 57, and groundwater flows from the local topographic highs near Barnum Road to the east/southeast (topographic lows) where it discharges to Cold Spring Brook and the surrounding wetlands. A groundwater contour elevation map from the May 2022 synoptic gauging event is included as **Figure 3-1.** Data from previous investigations (including recent supplemental investigation work completed by KGS in 2020) have shown downward vertical hydraulic gradients within overburden in the upland areas (near Barnum Road) that transition to upward vertical hydraulic gradients approaching and adjacent to Cold Spring Brook, confirming that Cold Spring Brook (and the surrounding wetlands) is a discharge boundary for the overburden groundwater (KGS 2020).

AOC 57 falls within a MassDEP groundwater protection Zone II for the Town of Ayer Grove Pond public water supply wells (**Figure 1-1**). Groundwater elevation data indicate that the groundwater flow direction at AOC 57 is to the southeast toward Cold Spring Brook.

3.2.4. Contaminant Source

As presented in the ROD, the primary site-related contaminants at AOC 57 were solvent and fuel-related contaminants in soil and groundwater associated with disposal of vehicle maintenance wastes in surface and near surface soil.

Area 2 is located approximately 700 feet northeast of Area 1, and adjacent to a former vehicle storage yard associated with the motor repair shops located in former Buildings 3757 and 3758). Area 2 was originally thought to have been contaminated by the Area 1 No. 4 fuel oil spill; however, area grading was such that overland flow to Area 2 would not have been possible. When initially investigated, Area 2 consisted of an eroded drainage ditch created by periodic rainfall runoff from vehicle storage yards associated with Buildings 3757 and 3758. Based on data from various investigations, Area 2 contamination is the result of the historical disposal of vehicle maintenance related wastes (i.e., POL). Fingerprint analysis of soil collected from Area 2 in 1992 as part of the SI (ABB 1995) confirmed that contaminants in the soil were most likely derived from lubricating oil, possibly vehicle crankcase oil, and not the 1977 release of No. 4 fuel oil. Contaminant distributions indicated that the disposal occurred along the break in slope above the floodplain. Following a soil removal action in 1994, Area 2 was re-graded and a permanent drainage swale was installed. Subsequent activities included subsurface investigations with soil sampling and monitoring well installation, additional removal of contaminated soil between 2002 and 2003, construction of an interceptor trench, and operation of a petroleum product recovery system (KGS 2020).

Area 3 was identified in a location near Area 2 where historical photos indicated soil staining. Area 3 is located approximately 600 feet to the northeast of Area 2, south of former vehicle maintenance motor pools with a vehicle waste disposal area. Samples collected in test pits showed the presence of TPH and chlorinated VOCs. In 1999, the Army conducted a soil removal action that targeted soils with TPH and PCB concentrations exceeding soil standards published under the MCP (KGS 2020).

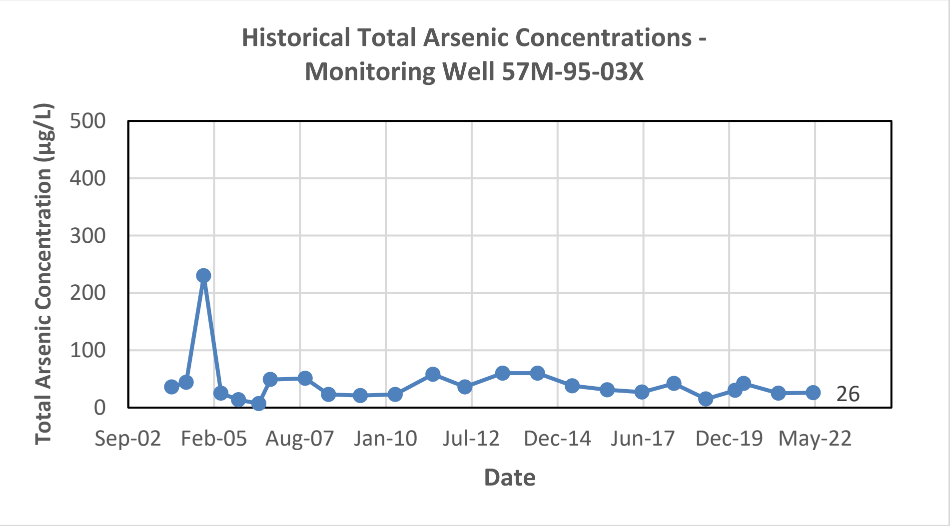
3.2.5. Nature and Extent of Arsenic

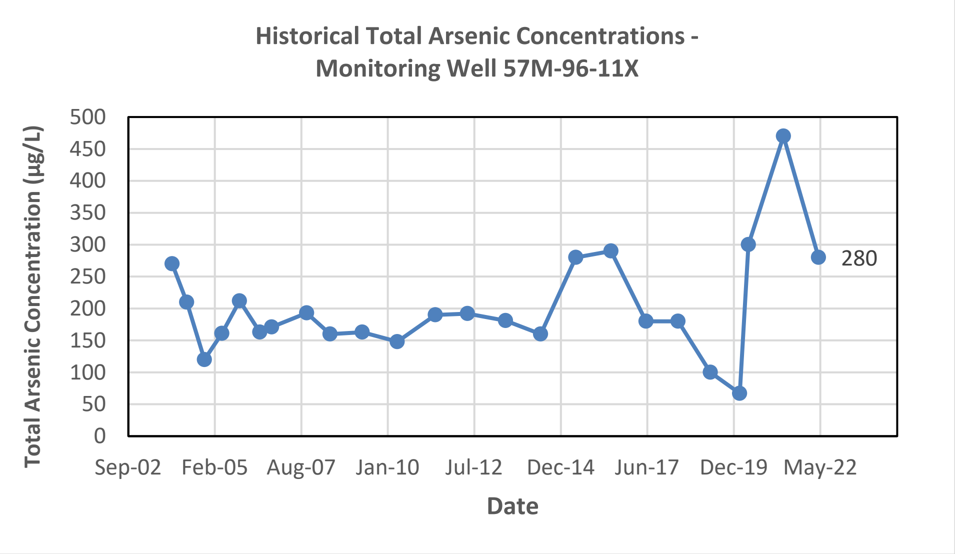
Petroleum discharges to ground occurred in Areas 2 and 3 at AOC 57 during historical vehicle maintenance activities. While removal actions between 1994 and 2003 excavated most of the petroleum-contaminated soil in Areas 2 and 3, residual petroleum remained in the soil on-site. The reducing conditions created by the natural degradation of the residual petroleum compounds in the soil have led to elevated concentrations of naturally occurring arsenic in groundwater. Groundwater and surface water has been sampled and analyzed as part of LTM since completion of the excavations. Historical groundwater data is summarized in **Table 3-1** and surface water data is summarized in **Table 3-2.** Information on existing monitoring wells is provided in **Table 3-3.**

As shown in **Table 3-1**, in the 18 years since completion of the excavations, concentrations of the petroleum related COCs in groundwater attenuated below cleanup levels. During that same time period, elevated concentrations of naturally occurring arsenic in groundwater stabilized but remain above the Cleanup Goal of 10 µg/L, as well as the background concentration of 10.5 µg/L (HLA 2000). **Figure 3-2** and **Figure 3-3** present the locations of the AOC 57 monitoring wells and surface water sample locations in Area 2 and Area 3, respectively, with the most recent total arsenic (groundwater) and dissolved arsenic (surface water) concentrations collected from each historical sampling location.

Total arsenic concentrations at well 57M-95-03X have been relatively stable, at or below 60 µg/L, since 2005 (average of 33.5 µg/L since the spring 2005 event). Total arsenic concentrations at well 57M-96-11X have varied more broadly over time, fluctuating between 100 and 470 µg/L since 2005 (average of 202 µg/L since the spring 2005 event). There is no statistically significant trend at either well. Time-concentration plots for monitoring wells 57M-95-03X and 57M-96-11X are provided below in **Exhibit 3-1:**

Exhibit 3-1: Historical Arsenic Concentrations – Monitoring wells 57M-95-03X and 57M-96-11X





As detailed in Table 3-1 and Table 3-3, the wells sampled historically during LTM sampling events (57M-03-01X to 57M-03-06X in Area 2; 57M-95-03X and 57M-96-11X in Area 3 are all screened in the shallow overburden (average total depth of 14 feet bgs), with well screen intervals designed to straddle the observed water table. Numerous additional deep overburden monitoring wells and VAP locations were installed in 2020 as part of the ongoing remedial investigation of PFAS; groundwater samples were collected and analyzed for dissolved arsenic, iron, and manganese to support the ongoing sampling efforts (KGS 2020). Sampling results are included in Table 3-1.

In Area 2, arsenic was detected in one deep overburden well (5702MW-20-01B; screened from 70-80 feet bgs) at a concentration of 17 µg/L (greater than the Cleanup Goal), which likely represents naturally-occurring arsenic levels in deeper groundwater due to (a) the observed reducing range of ORP and DO, (b) the observed upward vertical gradient, and (c) the low concentrations of arsenic (2.2 µg/L) in paired monitoring well 5702-MW-20-01A (screened from 30-40 feet bgs) (KGS 2020). Groundwater data generated during the installation of four VAP locations in Area 2 (5702VP-20-01 to 5702VP-20-04) indicate that arsenic concentrations, with one exception, were non-detect or less than the Cleanup Goal; this suggests that arsenic at levels greater than the Cleanup Goal has not been transported into or beyond Cold Spring Brook (KGS 2020).

In Area 3, arsenic was detected in one deep overburden well (5703MW-20-01B; screened from 50-60 feet bgs) at a concentration of 11 µg/L (greater than the Cleanup Goal). Similar to the Cleanup Goal exceedance in well 5702MW-20-01B, this likely represents naturally-occurring arsenic levels in deeper groundwater due to (a) the observed reducing range of ORP and DO, (b) the observed upward vertical gradient, and (c) the low concentrations of arsenic (2.2 µg/L) in paired monitoring well 5703-MW-20-01A (screened from 2-12 feet bgs) (KGS 2020). Groundwater data generated during the installation of four VAP locations in Area 3 (5703VP-20-01 to 5703VP-20-04) indicate that arsenic concentrations were non-detect or less than the Cleanup Goal; this suggests that arsenic at levels greater than the Cleanup Goal has not been transported into or beyond Cold Spring Brook (KGS 2020).

Surface water samples have been collected historically from locations 57-AREA2-SW2 and 57-AREA2-SW-3 in Area 2 and from location 57-AREA3-SW-1 in Area 3 (Figure 3-2 and Figure 3-3); the results have not exceeded surface water benchmarks (Table 3-2).

3.2.6. Fate and Transport

As presented in the 2000 RI (HLA), the primary route of contaminant migration at both Area 2 and Area 3 of AOC 57 are releases of POL to surface and subsurface soils then transport via leaching to groundwater. The release of POL resulted in the historical EPH concentrations in groundwater and may have contributed to the observed concentrations of arsenic, iron, and manganese due to reducing geochemical conditions. As described in the 2020 FYR (KGS 2020) and 2020 Annual Operations, Maintenance, and Monitoring Report (JV 2021b), groundwater flow at AOC 57 is towards Cold Spring Book; surface water samples collected in Area 2 and Area 3 have not identified arsenic concentrations at levels greater than the USEPA Water Quality Criterion (monitoring benchmark) of 150 µg/L since 2003.

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 3.2.5** of this SRI WP, historical concentrations of naturally-occurring arsenic above its Cleanup Goal have been observed in groundwater in Area 3 of AOC 57, but are relatively stable with the exception of recent increases in arsenic concentrations at monitoring well 57M-96-11X. Historical ORP and DO field measurements are included in **Table 3-1**, and an average of measurements collected over the past five to 10 LTM sampling events (some wells have been sampled less than 10 times historically) are provided below in **Exhibit 3-2**:

Exhibit 3-2: Average ORP/DO Measurements, November 2006 to February 2020 (Area 2) and June 2013 to May 2022 (Area 3)

Well ID	ORP (mV)	DO (mg/L)
Area 2		
57M-03-01X	258.3	8.3
57M-03-02X	21.2	0.6
57M-03-03X	174.2	2.3
57M-03-04X	136.9	1.8
57M-03-05X	94.3	0.8
57M-03-06X	274.6	4.7
Area 3		
57M-95-03X	-36.5	1.5
57M-96-11X	-6.6	0.7

Observations to date suggest that metals mobility in groundwater in Area 3 (and to a lesser degree in Area 2) is controlled by the geochemical changes caused by the biodegradation of the fuel hydrocarbons. Reducing conditions (negative ORP, DO less than 2 mg/L, manganese above 1 mg/L, and iron above 10 mg/L) are observed in well 57M-96-11X in Area 3, with reducing conditions (negative ORP, DO less than 1 mg/L, iron above 1 mg/L) also observed but to a lesser extent in well 57M-95-03X. Oxidizing conditions were observed in LTM wells historically sampled in Area 2, which were removed from the LTM program during sampling optimization. Additional monitoring will be conducted at these locations, as detailed in **Section 4** of this SRI WP.

3.3. Potential Receptors and Exposure Pathways

Potential human and ecological receptors and exposure pathways were presented in the 2000 RI (HLA) based on the current and future land uses at AOC 57 and used to prepare human health and ecological risk assessments. The sections below present assumptions used in those assessments.

3.3.1. Human Receptors and Exposure Pathways

The current land use for AOC 57 in the former vehicle storage yards is industrial/commercial 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 2000 RI (HLA) remain the same.

Also consistent with the 2000 HHRA (HLA), 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 2000 HHRA (HLA) evaluated post-removal conditions for soil and groundwater in Areas 2 and 3. Based on the conclusions of the risk assessment, unrestricted (residential) exposure to both upland (Area 3) and floodplain (Area 2 and Area 3) groundwater posed risks that exceeded the USEPA acceptable cancer risk range and target HI of 1, with the cancer risks primarily from arsenic (Area 2 and Area 3) and noncancer risks result primarily from hydrocarbons (Area 3) (Harding ESE 2001). However, as discussed previously, there are existing LUCs at AOC 57 that prohibit the use of groundwater for drinking water.

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 2000 RI (HLA) to evaluate the actual and potential adverse effects to ecological receptors associated with exposure to contamination from AOC 57. The BERA utilized surface soil, surface water, sediment, and groundwater data to evaluate potential risks to ecological receptors. The ecological risk assessment concluded that there were no significant adverse effects to ecological receptors (Harding ESE 2001).

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

4. Supplemental Remedial Investigation Implementation

This section presents the comprehensive project approach, methods, and operational procedures to be used for the investigations performed at AOC 57 at former Fort Devens. Detailed descriptions are presented in the SRI QAPP Addendum (**Appendix A**). Proposed investigation locations are discussed below.

4.1. Proposed Activities

The sections below detail the supplemental investigation proposed to address the study questions presented in **Section 2.2.1**, and to meet the SRI objectives.

As discussed in **Section 3** of this Work Plan, historical groundwater data (**Table 3-1**) and surface water data (**Table 3-2**) indicates that the extent of arsenic concentrations are well defined. Elevated concentrations of total arsenic have been detected historically, primarily in monitoring wells 57M-95-03X and 57M-96-11X in Area 3 and to a lesser extent in monitoring 57M-03-05X in Area 2 **(Figure 3-2** and **Figure 3-3)**.

As discussed in **Section 1.4.2** of this Work Plan, LTM groundwater data has been collected from varying monitoring wells at AOC 57 for 19 years. This SRI WP proposes sampling of a subset of wells installed at the site, including several of which were previously eliminated from the monitoring program as part of LTMMP optimization. This proposed sampling will provide 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 57, the following activities are proposed:

- **To evaluate the current lateral and vertical extent of arsenic**, one VAP boring (5702VP-23-01) will be drilled downgradient of well 57M-03-05X in Area 2; the need for a VAP at this location was identified due to define historical concentrations of arsenic above the Cleanup Goal, as well as to assess if the reducing conditions created by the wetland area are resulting in natural arsenic mobilization. Due to proximity of Cold Spring Brook to the drilling area, a surface water sample (57-AREA2-SW4) will be collected downgradient if arsenic exceeds the Cleanup Goal in proposed VAP boring 5702VP-23-01. A second VAP boring (5703VP-23-01) will be drilled upgradient of all wells in Area 3; the need for a VAP at this location was identified to confirm the lateral and vertical extent of arsenic in the groundwater, as no historical groundwater sampling locations are present upgradient from well 57M-95-03X. If arsenic exceeds the Cleanup Goal in proposed VAP boring 5703VP-23-01, contingency VAP boring 5703VP-23-02 will be installed. The proposed and contingency sample locations are shown on **Figure 4-2** and **Figure 4-3**, respectively. Two additional VAP locations (CSVP-23-02 and CSVP-23-03) are proposed to be installed to the east of Cold Spring Brook as part of the Phase II Remedial Investigation for PFAS Area 1, the Work Plan for which is currently under review by the Agencies. The installation and sampling of these locations for parameters listed in **Exhibit 4-1** will be completed pending the approval of the PFAS Work Plan, and sampling will be conducted in accordance with the proposed PFAS investigation schedule. In addition, the sampling of these locations will be dependent on the ability to execute and retain a ROE permit with private property owners for access.
- **To evaluate vertical groundwater gradients in the study area,** synoptic groundwater level gauging events will be conducted that will include all existing monitoring wells in Area 2 and Area 3 **(Table 3-3)**. These data will be used to confirm groundwater flow direction in the shallow and deep overburden, and to calculate vertical gradients to confirm discharge of the groundwater to Cold Spring Brook. Water levels also will be measured at staff gauges SG-01 to SG-03, located in Cold Spring Brook in Area 2. One

additional staff gauge (SG-04) will be installed in Cold Spring Brook adjacent to surface water location 57-AREA3-SW-1 **(Figure 3-3)**.

- **To confirm that the current lateral extent of arsenic exceeding the MCL,** a subset of monitoring wells will be sampled in Area 2 and Area 3, including several wells installed in 2020 by KGS (5702MW-20-01A, 5702MW-20-01B, 5702MW-20-02A, 5702MW-20-03A, 5702MW-20-04A, 5703MW-20-01A, 5703MW-20-01B, 5703MW-20-03A, 5703MW-20-04A) and one well that has not been sampled historically (57WP-06-03). Information on existing monitoring wells is provided in **Table 3-3** and summarized below in **Exhibit 4-1**. To evaluate trends in ROD specified COC concentrations, a statistical trend analysis (Mann Kendall + Theil-Sen slope analysis) of the new and existing data will be performed. Two additional monitoring well locations (CSMW-23-02 and CSMW-23-04) are proposed to be installed to the east of Cold Spring Brook as part of the Phase II Remedial Investigation for PFAS Area 1, the Work Plan for which is currently under review by the Agencies. The installation and sampling of these locations for parameters listed in **Exhibit 4-1** will be completed pending the approval of the PFAS Work Plan, and sampling will be conducted in accordance with the proposed PFAS investigation schedule. In addition, the sampling of these locations will be dependent on the ability to execute and retain a ROE permit with private property owners for access.
- **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 (volatile petroleum hydrocarbons [VPH], EPH, dissolved arsenic, total and dissolved manganese, total and dissolved aluminum, total and dissolved iron, TOC, sulfate, nitrate, nitrite, and ferrous iron); the analytical results will be compared against the historical EPH and total 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 from VAPs and monitoring wells 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 and arsenic).

Exhibit 4-1 presents the proposed groundwater sample locations and analytes. The proposed sample locations are shown on **Figure 4-1** and **Figure 4-2**, with the exception of the proposed PFAS investigation locations.

Exhibit 4-1: AOC 57 Proposed Sampling Locations and Laboratory Analyses

Well ID	Location Type	Rationale / Location	Analyte List								
			Total Al, As, Mn, Fe	Dissolved Al, As, Mn, Fe	VPH	EPH	Sulfate	Nitrate / Nitrite	Methane	TOC	Ferrous Iron
Area 2											
5702VP-23-01	VAP (proposed)	Assess reducing conditions created by the wetland area	X	X	X	X	X	X	X	X	X
5702MW-20-01A	MW (existing)	Deep overburden wells adjacent to 57M-03-05X. Assess vertical extent of arsenic and confirm hydraulic gradient.	X	X	X	X	X	X	X	X	X
5702MW-20-01B			X	X	X	X	X	X	X	X	X
5702MW-20-02A		Upgradient from areas with historical ROD-specified COC exceedances (arsenic)	X	X	X	X	X	X	X	X	X
5702MW-20-03A		Crossgradient from areas with historical ROD-specified COC exceedances (arsenic)	X	X	X	X	X	X	X	X	X
5702MW-20-04A		Crossgradient from areas with historical ROD-specified COC exceedances (arsenic)	X	X	X	X	X	X	X	X	X
57M-03-02X		Crossgradient from 57M-03-05X	X	X	X	X	X	X	X	X	X
57M-03-03X		Downgradient / Crossgradient from 57M-03-05X	X	X	X	X	X	X	X	X	X
57M-03-04X		Downgradient / Crossgradient from 57M-03-05X	X	X	X	X	X	X	X	X	X
57M-03-05X		Historical location with ROD-specified COC exceedances (arsenic)	X	X	X	X	X	X	X	X	X
57M-03-06X		Crossgradient from 57M-03-05X	X	X	X	X	X	X	X	X	X
57M-95-06X		Crossgradient from areas with historical ROD-specified COC exceedances (arsenic)	X	X	X	X	X	X	X	X	X
57-AREA2-SW2	SW (existing)	Historical downgradient surface water sampling locations in Cold Spring Brook	X	X	X	X	X	X	X	X	X
57-AREA2-SW3			X	X	X	X	X	X	X	X	X
57-AREA2-SW4	SW (proposed – contingent)	Sample will be collected pending sampling results from proposed VAP location 5702VP-23-01.	X	X	X	X	X	X	X	X	X
Area 3											
5703VP-23-01	VAP (proposed)	Confirm vertical extent arsenic	X	X	X	X	X	X	X	X	X
5703VP-23-02	VAP (proposed – contingent)	Location will be installed pending sampling results from proposed VAP location 5703VP-23-01	X	X	X	X	X	X	X	X	X
5703MW-20-01A	MW (existing)	Shallow overburden well downgradient from 57M-95-03X. Assess vertical extent of arsenic and confirm hydraulic gradient.	X	X	X	X	X	X	X	X	X
5703MW-20-01B		Deep overburden downgradient from 57M-95-03X. Assess vertical extent of arsenic and confirm hydraulic gradient.	X	X	X	X	X	X	X	X	X
5703MW-20-02A		Crossgradient from 57M-95-03X	X	X	X	X	X	X	X	X	X
5703MW-20-03A		Crossgradient from areas with historical ROD-specified COC exceedances (arsenic)	X	X	X	X	X	X	X	X	X
5703MW-20-04A		Downgradient from 57M-95-03X; deep overburden well	X	X	X	X	X	X	X	X	X
57M-95-03X		Historical location with ROD-specified COC exceedances (arsenic)	X	X	X	X	X	X	X	X	X
57M-96-11X		Historical location with ROD-specified COC exceedances (arsenic)	X	X	X	X	X	X	X	X	X
57M-96-12X		Crossgradient from areas with historical ROD-specified COC exceedances (arsenic)	X	X	X	X	X	X	X	X	X
57P-98-03X		Crossgradient from 57M-96-11X	X	X	X	X	X	X	X	X	X
57P-98-04X		Downgradient from 57M-96-11X	X	X	X	X	X	X	X	X	X
57WP-06-03		Adjacent to 57M-96-11X and screened in deeper overburden. Assess vertical extent of arsenic and confirm hydraulic gradient.	X	X	X	X	X	X	X	X	X
57-AREA3-SW-1	SW (existing)	Historical downgradient surface water sampling locations in Cold Spring Brook	X	X	X	X	X	X	X	X	X
PFAS Investigation Locations											
CSVP-23-02	VAP (proposed)	Proposed locations located to the east of Cold Spring Book. These locations are proposed as part of the Phase II Remedial Investigation for PFAS Area 1. The installation and sampling of these locations will be completed (a) pending the approval of the PFAS Work Plan (sampling will be conducted in accordance with proposed PFAS investigation schedule) and (b) pending the ability to execute and retain an ROE permit with private property owners for access.	X	X	X	X	X	X	X	X	X
CSVP-23-03			X	X	X	X	X	X	X	X	X
CSMW-23-02	MW (proposed)		X	X	X	X	X	X	X	X	X
CSMW-23-04			X	X	X	X	X	X	X	X	X

NOTE:

Al = aluminum MW = monitoring well SW = surface water

1. Dissolved Al/Fe/Mn samples will be field filtered.
2. 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.
3. Ferrous iron samples will be collected with a Hach field kit (or similar).

4.2. Methodology

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

- TGI – Utility Location
- TGI – Manual Water-Level Monitoring (JV; Rev #0, May 2020)
- TGI – In-Situ and Ex-Situ Water Quality Parameters (Rev #0, October 2018)
- TGI – Sample Chain of Custody (Rev #2, April 2020)
- TGI – Investigation-Derived Waste Handling and Storage (Rev #0, February 2017)
- TGI – Groundwater and Soil Sampling Equipment Decontamination (JV; Rev #1, May 2020)
- TGI – Soil Description (JV; Rev #2, February 2018)
- TGI – Vertical Aquifer Profiling (JV; Rev #1, May 2020)
- TGI – Low Stress (low flow) Purging and Sampling Procedure for the Collection of Groundwater Samples from Monitoring Wells (Rev #4, September 2017)
- TGI – Surface Water Sample Collection (JV; Rev #1, May 2020)

These TGIs are included in the AOC 57 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 Dig Safe 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. The JV will utilize a subcontractor for this task, who will utilize their own TGIs/SOPs.
- 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, MassDevelopment and the tenant at 112 Barnum Road 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 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.

Groundwater samples will be collected from VAP locations via a retractable well screen, which is advanced with 1-inch steel drilling rods (SP-22 or similar). Groundwater samples will be collected using the “top-down” approach (i.e., samples collected as the borehole is drilled to minimize the potential for cross-contamination).

Each 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. Groundwater Sampling and Water Level Measurements

Groundwater samples will be collected during the installation of VAP locations in 10-foot intervals (starting at the water table) with a peristaltic or bladder pump setup with dedicated tubing. Samples will be collected after a minimum of three casing volumes have been purged from within the drilling rods and pumping rates will be set in accordance with the low-flow sampling TGI. It is anticipated that the VAP boring will extend to a total depth of 100 feet bgs, or until refusal is encountered (whichever comes first).

Groundwater samples will also be collected from a subset of existing monitoring wells, as described in **Exhibit 4-1**. 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 existing and proposed staff gauges in order to evaluate the interaction between surface water and groundwater.

In addition to the ROD-listed analyte identified in the LTMMP (total arsenic), samples from monitoring wells will be analyzed for the following additional parameters:

- **Total and dissolved aluminum**, to assess the potential for presence of sub-0.45-micron particulates. At the observed site groundwater pH (approximately 5.5 to 6.5), aluminum exhibits very low solubility and would not be present as a dissolved ion above a concentration of approximately 0.03 mg/L (e.g., Stumm and Morgan 1996; references therein). In addition, aluminum only exhibits one stable oxidation state in water (+III), and therefore the solubility of aluminum in solution is not sensitive to redox environment, unlike iron. The presence of total aluminum would therefore indicate suspended particulates present in the groundwater sample, while the presence of filtered aluminum correlated to total aluminum would indicate the presence of very fine (sub-0.45-micron) particulates. Dissolved metals samples will be field filtered.
- **Dissolved arsenic, total/dissolved manganese, total/dissolved iron, and ferrous iron**. Total and dissolved iron/manganese will be collected to evaluate redox status and arsenic attenuation potential via iron coprecipitation upon reoxidation. Dissolved arsenic will be collected as an additional line of evidence regarding potential for suspended particulates affecting COC concentrations. Dissolved metals samples will be field filtered.

- **TOC, sulfate, nitrite, nitrate, and methane**, to assess redox status, residual reducing potential, and attenuation of petroleum hydrocarbons. TOC will contribute to ongoing reducing potential by consuming dissolved oxygen (potentially limiting iron reoxidation and extending the timeframe for arsenic 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. Methane analyses will be used to further evaluate petroleum hydrocarbon degradation and geochemical conditions.
- **VPH and EPH**, to assess the degree of naturally occurring TOC, and determine whether the TOC can be attributed to petroleum or non-petroleum compounds.

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.

4.2.4. Surface Water Sampling

Surface water samples will be collected from three historical LTMMP locations (plus one proposed contingent location) in Cold Spring Brook, as described in **Exhibit 4-1**. Samples will be collected in accordance with the TGI. Surface water samples will be analyzed for ROD-listed analytes identified in the LTMMP (dissolved arsenic), and the additional compounds listed in **Section 4.3.3** above (total and dissolved aluminum, total arsenic, total and dissolved manganese, total and dissolved iron, TOC, and sulfate). In addition, field parameters (DO, ORP, specific conductance, temperature, turbidity, and pH) will be collected from each surface water sampling location.

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 and rinsate 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 VAP locations will be surveyed for the location and elevation of the ground surface. 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. A Massachusetts-licensed surveyor will be contracted to perform surveying in accordance with the Massachusetts State Plane Coordinate System of the North American Datum (NAD) 1983 and vertically on the NAVD 1988. The surveyor will utilize their own SOPs to complete the field activities.

4.3. Risk Assessment

The 2000 HHRA (HLA) evaluated pre-removal conditions for soil and groundwater in Areas 2 and 3. Based on the conclusions of the risk assessment, unrestricted (residential) exposure to both upland (Area 3) and floodplain (Area 2 and Area 3) groundwater posed risks that exceeded the USEPA acceptable cancer risk range and target HI of 1, with the cancer risks primarily from arsenic (Area 2 and Area 3) and noncancer risks primarily from hydrocarbons (Area 3) (Harding ESE 2001).

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, 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 and surface water sample collection);
- Results of the field activities.
- Nature and extent of contamination.
- Contaminant fate and transport.
- Findings and conclusions.
- Recommendations.

As appropriate, soil and geologic logs, survey reports, 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 anticipated project schedule is presented below in **Table 6-1**.

Table 6-1 Anticipated Project Schedule

Task	Date
Army Submits Draft AOC 57 Post-ROD Supplemental RI Work Plan to USEPA/MassDEP	12/21/21
Suspension of Review by USEPA	1/20/22
Army Submits Revised Draft AOC 57 Post-ROD Supplemental RI Work Plan to USEPA/MassDEP	8/23/22
MassDEP Approval of Revised Draft AOC 57 Post-ROD Supplemental RI Work Plan	10/6/22
USEPA Review of Revised Draft AOC 57 Post-ROD Supplemental RI Work Plan	11/22/22
Army Issues Response Letter to USEPA/MassDEP Comments on Revised Draft AOC 57 Post-ROD Supplemental RI Work Plan	12/22/22
USEPA Review of Response Letter	1/9/23
Army Submits Draft Final AOC 57 Post-ROD Supplemental RI Work Plan to USEPA/MassDEP	2/8/23
USEPA Review of Draft Final AOC 57 Post-ROD Supplemental RI Work Plan	3/25/23
Army Submits Final Supplemental AOC 57 Post-ROD Supplemental RI Work Plan to USEPA/MassDEP	6/2/23
Field Work	Summer 2023 – Summer 2024
Submit Draft Post-ROD Supplemental RI Report (pending field work)	Fall/Winter 2024

7. References

ABB Environmental Services, Inc. 1995. Revised Final Site Investigation Report - Groups 2, 7, and Historic Gas Stations, Fort Devens, Massachusetts, prepared for Commander, U.S. Army Environmental Center; prepared by ABB Environmental Services, Inc., Portland, Maine; October.

Arthur D. Little, Inc. 1994. Final Storm Sewer System Evaluation (AREE 70) Report. Base Realignment and Closure Environmental Evaluation. Fort Devens, Massachusetts. prepared for the U.S. Army Environmental Center (AEC); prepared by Arthur D. Little, Inc., Cambridge, Massachusetts; June.

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Tables

Table 3-1
Historical Groundwater Monitoring Results
Post-Record of Decision Supplemental Remedial Investigation Work Plan - AOC 57
Former Fort Devens Army Installation
Devens, Massachusetts

		Analytical Method	Total Metals			Field Parameters			
		Analyte	Arsenic *	Iron**	Manganese**	pH	SPC	ORP	DO
		Unit	(µg/L)	(µg/L)	(µg/L)	(SU)	(µS/cm)	(mV)	(mg/L)
		Cleanup Goal*	10	NS	NS				
		Background**	10.5	9,100	291				
Well ID	Screen/Sample Interval (ft BGS)	Date							
AOC 57 Area 2 - Monitoring Wells									
5702MW-20-01A	30-40	Feb-20	2.2 J	50 U	38	6.8	379	98	7.3
5702MW-20-01B	70-80	Feb-20	**17**	48 J	49	8.3	303	-185	0.46
5702MW-20-02A	30-40	Feb-20	3.0 U	50 U	34	6.4	852	178	10
5702MW-20-03A	26-36	Feb-20	1.8 J	50 U	**490**	6.6	485	56	5.0
5702MW-20-04A	70-80	Feb-20	1.6 J	530	**310**	6.8	238	107	2.8
5702MW-20-05A	30-40	Feb-20	3.0 U	50 U	**600**	6.0	164	192	6.6
5702MW-20-05B	70-80	Feb-20	7.0	37 J	100	9.2	239	-99	0.10
5702MW-20-06A	70-80	Feb-20	1.9 J	86	**450**	7.0	498	160	4.9
5702MW-20-07A	30-40	Mar-20	1.8 J	50 U	64	6.7	640	-0.9	1.7
57M-03-01X	10-20	Dec-03	5.0 U	--	--	--	--	--	--
		May-04	5.0 U	--	--	--	--	--	--
		Nov-04	5.0 U	--	--	--	--	183	8.1
		Nov-05	2.5 U	--	--	--	--	459	9.0
		Jun-06	5.0 U	50 U	9.0 J	--	--	303	9.0
		Nov-06	5.0 U	50 U	10 U	--	--	268	7.7
		Oct-07	5.0 U	50 U	7.9 J	--	--	128	5.5
		Jun-08	--	--	--	--	--	237	9.2
		Jan-20	3.0 U	50 U	6.3 J	6.4	267	230	9.7
57M-03-02X	2-12	Dec-03	4.2 J	--	--	--	--	--	--
		May-04	6.4 J	--	--	--	--	--	--
		Nov-04	8.9	--	--	--	--	156	2.7
		Nov-05	8.8	--	--	--	--	-43	0.30
		Jun-06	**14**	**24,000**	**2,400**	--	--	-81	0.26
		Nov-06	**13**	**28,000**	**2,200**	--	--	20	0.42
		Oct-07	8.0	7,200	**1,070**	--	--	-4.8	0.45
		Jun-08	**13**	**11,000**	**1,130**	--	--	-29	0.83
		May-09	10	**30,000**	**2,870**	6.0	142	-25	0.21
		May-10	**18**	**37,000**	**2,450**	6.5	191	-260	0.26
		Jun-11	7.0	**10,000**	**2,840**	5.3	117	158	0.46
		May-12	8.0	**11,000**	**903**	5.9	155	27	0.51
		Jun-13	3.0 J	1,600	**422**	5.1	42	151	0.85
		Jun-14	5.0 U	3,000	**476**	5.5	110	151	0.41
		Feb-20	7.3	4,500	290	5.7	187	56	0.70
57M-03-03X	2-12	Dec-03	5.0 U	--	--	--	--	--	--
		May-04	5.0 U	--	--	--	--	--	--
		Nov-04	5.0 U	--	--	--	--	247	0.32
		Nov-05	2.5 U	--	--	--	--	297	1.1
		Jun-06	2.5 J	50 U	240	--	--	35	0.63
		Nov-06	5.0 U	50 U	90	--	--	259	0.40
		Oct-07	5.0 U	50 U	116	--	--	116	0.74
		Jun-08	5.0 U	50 U	130	--	--	120	1.1
		May-09	2.3 J	50 U	44	5.6	518	135	6.1
		May-10	5.0 U	50 U	47	5.6	450	-67	1.3
		Jun-11	5.0 U	140	129	5.1	1,060	298	2.8
		May-12	5.0 U	170	85	5.7	1,115	125	5.4
		Jun-13	2.0 J	50 U	35	5.3	467	322	2.3
		Jun-14	5.0 U	50 U	30	6.0	384	194	1.5
		Jan-20	3.0 U	50 U	96	6.3	1,013	240	1.4
57M-03-04X	2-12	Dec-03	**41**	--	--	--	--	--	--
		May-04	**30 J**	--	--	--	--	--	--
		Nov-04	**50**	--	--	--	--	104	1.6
		Nov-05	**167**	--	--	--	--	303	0.45
		Jun-06	3.7 J	80	**840**	--	--	242	1.9
		Nov-06	6.0	150	**1,400**	--	--	158	0.30
		Oct-07	5.0 U	50 U	**474**	--	--	65	0.44
		Jun-08	5.0 U	50 U	239	--	--	146	0.34
		May-09	5.0 U	50 U	**880**	6.0	309	116	1.5
		May-10	7.0	230	**3,210**	6.2	658	-164	0.28
		Jun-11	**13**	620	**2,230**	4.9	303	304	5.1
		May-12	5.0 U	30 J	**585**	5.8	1,008	119	3.4
		Jun-13	5.0 U	40 J	**525**	5.9	621	246	4.0
		Jun-14	5.0 U	20 J	165	5.4	376	189	1.8
		Jan-20	2.5 J	50 U	73	6.4	506	190	1.3
57M-03-05X	2-12	Dec-03	**22**	--	--	--	--	--	--
		May-04	**21 J**	--	--	--	--	--	--
		Nov-04	**19**	--	--	--	--	20	0.26
		Nov-05	**19**	--	--	--	--	-114	0.19
		Jun-06	**15**	3,100	**760**	--	--	-30	0.70
		Nov-06	**11**	2,100	**1,100**	--	--	52	0.19
		Oct-07	9.0	1,400	**1,380**	--	--	-91	0.18
		Jun-08	**11**	4,900	**2,380**	--	--	36	0.25
		May-09	**12**	740	**437**	5.5	252	120	0.37
		May-10	**27**	1,200	221	5.7	328	-109	0.30
		Jun-11	7.0	440	177	5.8	308	313	4.1
		May-12	**11**	640	108	5.7	539	169	1.3
		Jun-13	**18**	740	48	5.4	218	177	0.78
		Jun-14	**15**	750	43	5.5	178	209	0.34
		Feb-20	**13**	640	**590**	6.3	361	67	0.31
57M-03-06X	2-12	Dec-03	5.0 U	--	--	--	--	--	--
		May-04	5.0 U	--	--	--	--	--	--

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Post-Record of Decision Supplemental Remedial Investigation Work Plan - AOC 57
Former Fort Devens Army Installation
Devens, Massachusetts

		Analytical Method	Total Metals			Field Parameters			
		Analyte	Arsenic *	Iron**	Manganese**	pH	SPC	ORP	DO
		Unit	(µg/L)	(µg/L)	(µg/L)	(SU)	(µS/cm)	(mV)	(mg/L)
		Cleanup Goal*	10	NS	NS				
		Background**	10.5	9,100	291				
Well ID	**Screen/Sample Interval (ft BGS)**	**Date**							
57M-03-06X (cont.)	2-12	Nov-04	5.0 U	--	--	--	--	348	5.1
		Nov-05	2.5 U	--	--	--	--	355	4.8
		Jun-06	3.4 J	550	30	--	--	210	4.2
		Nov-06	5.0 U	50 U	20 U	--	--	288	4.0
		Oct-07	5.0 U	50 U	14	--	--	172	5.4
57M-95-06X	12-22	Feb-20	3.0 U	50 U	3.3 J	6.1	472	150	1.5
57WP-06-02	19-24	Feb-20	1.7 J	50 U	190	6.1	411	-20	0.07
AOC 57 Area 2 - Vertical Aquifer Profiles									
5702VP-20-01	5-9	Apr-20	2.1 J	910	**400**	7.6	623	61.5	3.5
	10-14	Apr-20	3.0 U	110	240 J	7.4	603	42.6	3.2
	15-19	Apr-20	3.4 J	2,200 J	**680**	7.4	629	41.6	4.9
	20-24	Apr-20	3.0 U	600	**300**	6.8	574	46.2	5.2
	25-29	Apr-20	3.0 U	360	180	6.7	547	47.9	4.0
	30-34	Apr-20	1.6 J	140	81	6.6	401	59.3	4.9
	35-39	Apr-20	1.9 J	830	**540**	6.6	398	61.7	4.9
	40-44	Apr-20	**13**	110	130	6.7	283	70.3	5.0
	50-54	Apr-20	5.1	320	**530**	6.7	271	61.1	3.3
5702VP-20-02	5-9	Apr-20	3.3	1,400	**320**	6.7	600	-74.3	3.8
	10-14	Apr-20	3.0 U	260	290	6.7	503	-21.6	3.2
	15-19	Apr-20	3.0 U	700	**340**	6.5	429	-17.1	2.3
	20-24	Apr-20	3.0 U	650	290	6.4	531	-0.9	2.8
	25-29	Apr-20	3.0 U	320	210	6.6	560	2.6	2.3
	30-34	Apr-20	4.4	190	170	6.7	407	38.7	6.2
	35-39	Apr-20	8.0	760	120	6.8	327	29.6	3.9
	40-44	Apr-20	2.9 J	780	190	6.9	307	14.7	5.0
	50-54	Apr-20	3.0 U	2,300	170	6.8	281	11.1	4.3
5702VP-20-03	5-9	Apr-20	3.0 U	200	49	7.2	778	81.1	6.8
	10-14	Apr-20	3.0 U	210	97	6.8	804	42.8	8.8
	15-19	Apr-20	3.0 U	550	160	6.8	937	33.5	5.0
	20-24	Apr-20	1.5 J	180	73	--	--	--	--
	25-29	Apr-20	5.0 J	1,700 J	**820 J**	7.8	268	6.3	2.6
	30-34	Apr-20	4.3	5,600	**510**	7.3	386	29.7	3.0
	35-39	Apr-20	5.9	4,100	190	7.1	399	46.1	3.3
	40-44	Apr-20	3.0 U	3,700	150	7.1	421	50.7	3.1
	45-49	Apr-20	3.0 U	3,700	150	7.1	421	50.7	3.1
	50-54	Apr-20	3.3	440	180	6.7	307	29.9	3.0
5702VP-20-04	10-12	Apr-20	3.0 U	190	170	6.6	450	102	5.8
	15-17	Apr-20	8.4 J	450 J	77	7.1	261	48	6.4
	20-22	Apr-20	5.3	1,400	50	7.0	229	37.6	5.8
	25-27	Apr-20	8.1	4,700	**710**	6.9	361	21.7	5.0
	30-32	Apr-20	2.8 J	250	**300**	6.9	421	64.7	6.0
	35-37	Apr-20	2.2 J	180	110	6.7	518	87.6	4.2
AOC 57 Area 3 - Monitoring Wells									
5703MW-20-01A	2-12	Feb-20	3.0 U	450	110	5.4	426	110	1.2
5703MW-20-01B	50-60	Feb-20	**11**	83	**1,200**	7.1	169	5.5	0.58
5703MW-20-02A	10-20	Feb-20	2.2 J	740	**920**	6.5	363	95	0.78
5703MW-20-03A	50-60	Feb-20	3.0 U	91	130	6.7	248	210	0.12
5703MW-20-04A	60-70	Feb-20	7.6	2,300	270	6.7	447	-98	0.46
57M-95-03X	7-17	Dec-03	**36**	--	--	--	--	--	--
		May-04	**44**	--	--	--	--	--	--
		Nov-04	**230**	--	--	--	--	-250	0.45
		May-05	**25**	--	--	--	--	--	--
		Nov-05	**14**	--	--	--	--	-41	1.3
		Jun-06	7.0	370	50	--	--	-41	0.98
		Oct-06	**49**	3,400	170	--	--	10	3.4
		Oct-07	**51**	1,400	278	--	--	-188	1.2
		Jun-08	**23**	1,900	77	--	--	-189	0.67
		May-09	**21**	2,400	134	6.5	214	-63	0.17
		May-10	**23**	2,400	155	6.7	209	-282	0.42
		Jun-11	**58**	6,100	153	6.2	389	-72	0.53
		May-12	**36**	5,400	273	6.4	487	-43	0.21
		Jun-13	**60**	5,400	106	6.5	310	-65	0.68
		Jun-14	**60**	5,400	106	6.7	293	-57	0.69
		Jun-15	**38**	6,350	190	5.7	280	6.8	0.37
		Jun-16	**31**	4,700	130	6.6	410	-34	2.7
		Jun-17	**27**	5,300	110	6.8	130	27	1.2
		May-18	**42**	8,400	110	5.3	150	59	1.9
		Apr-19	**15**	5,600	160	6.2	270	6.0	0.60
		Feb-20	**30**	3,900	120	6.7	712	-76	1.3
		May-20	**42**	2,200	59	6.9	170	-120	5.5
		May-21	**25**	1,700	67	6.7	67	-87	1.3
		May-22	**26**	3,100	140	6.2	29	-61	0.58
57M-96-11X	2-12	Dec-03	**270**	--	--	--	--	--	--
		May-04	**210**	--	--	--	--	--	--
		Nov-04	**120**	--	--	--	--	-93	0.10
		May-05	**161**	--	--	--	--	--	--
		Nov-05	**212**	--	--	--	--	-93	0.44
		Jun-06	**163**	**51,000**	**2,600**	--	--	-96	0.14
		Oct-06	**171**	**41,000**	**2,200**	--	--	-100	0.34
		Oct-07	**193**	**39,000**	**1,960**	--	--	-175	0.48
		Jun-08	**160**	**37,000**	**2,400**	--	--	-61	0.62

Table 3-1
Historical Groundwater Monitoring Results
Post-Record of Decision Supplemental Remedial Investigation Work Plan - AOC 57
Former Fort Devens Army Installation
Devens, Massachusetts

		Analytical Method	Total Metals			Field Parameters			
		Analyte	**Arsenic ***	**Iron****	**Manganese****	**pH**	**SPC**	**ORP**	**DO**
		Unit	**(µg/L)**	**(µg/L)**	**(µg/L)**	**(SU)**	**(µS/cm)**	**(mV)**	**(mg/L)**
		Cleanup Goal*	**10**	**NS**	**NS**				
		Background**	**10.5**	**9,100**	**291**				
Well ID	**Screen/Sample Interval (ft BGS)**	**Date**							
57M-96-11X (cont.)	2-12	May-09	**163**	**43,000**	**3,190**	5.8	240	-52	0.20
		May-10	**148**	**28,000**	**2,100**	6.9	167	-268	0.28
		Jun-11	**190**	**31,000**	**2,190**	5.9	150	-3.5	0.32
		May-12	**192**	**32,000**	**2,310**	6.4	165	-80	0.22
		Jun-13	**181**	**31,000**	**2,430**	6.5	310	-90	0.68
		Jun-14	**160**	**30,000**	**2,790**	6.5	212	-32	0.95
		Jun-15	**280**	**35,400**	**3,200**	6.2	290	2.7	0.19
		Jun-16	**290**	**32,000**	**2,800**	6.5	370	-15	0.81
		Jun-17	**180**	**31,000**	**2,900**	7.0	350	-39	1.1
		May-18	**180**	**37,000**	**2,700**	5.2	570	40	0.59
		Apr-19	**100**	**36,000**	**3,000**	6.1	1,000	8.0	0.85
		Feb-20	**67**	**31,000**	**3,300**	6.1	1,062	0.2	1.1
		May-20	**300**	**42,000**	**3,300**	6.1	820	64	0.28
		May-21	**470**	**37,000**	**2,900**	6.3	150	-21	0.65
		May-22	**280**	**43,000**	**3,100**	5.9	124	9.5	0.32
57M-96-12X	2-12	Feb-20	3.0 U	41 J	85	5.1	590	210	0.21
57P-98-03X	3-6	Feb-20	3.3	1,400	**11,000**	5.5	766	140	8.7
57P-98-04X	2-5	Feb-20	3.0 U	270	**370**	5.4	928	187	2.6
AOC 57 Area 3 - Vertical Aquifer Profiles									
5703VP-20-01	5-7	Apr-20	3.0 U	1,700	**3,100**	6.2	734	113	6.7
	10-12	Apr-20	3.0 U	790	**3,500**	--	--	--	--
	15-17	Apr-20	3.0 U	260	34	--	--	--	--
	20-22	Apr-20	3.0 U	130	63	--	--	--	--
	25-27	Apr-20	1.8 J	75	3.0 U	--	--	--	--
	30-32	Apr-20	1.9 J	190	19	--	--	--	--
5703VP-20-02	5-7	Apr-20	3.0 U	1,000	28	--	--	--	--
	10-12	Apr-20	3.0 U	460	41	8.0	447	58.9	3.2
	15-17	Apr-20	3.0 U	130	41	6.0	211	78.7	3.1
	20-22	Apr-20	3.0 U	480	25	6.4	210	69.2	3.7
	25-27	Apr-20	3.0 U	150	37	6.4	193	55.1	2.7
	30-32	Apr-20	3.5	37 J	19	6.4	185	48.9	2.5
5703VP-20-03	5-7	Apr-20	2.4 J	1,100	41	--	--	--	--
	10-12	Apr-20	3.0 U	160	15	6.6	268	62	5.1
	15-17	Apr-20	3.0 U	50 U	31	6.7	318	69.7	4.0
	20-22	Apr-20	3.0 U	200	52	6.1	163	117	4.0
	25-27	Apr-20	3.0 U	61	33	6.5	172	66.7	2.7
	30-32	Apr-20	3.9	250	50	6.4	168	89.7	2.3
5703VP-20-04	5-7	Apr-20	3.0 U	160	8.8 J	6.7	73	92.3	8.5
	10-12	Apr-20	3.0 U	89	9.7 J	6.9	107	68.7	8.0
	15-17	Apr-20	3.0 U	370	26	7.0	156	107	6.2
	20-22	Apr-20	3.0 U	52	19	6.7	131	70.9	5.2

Notes:

260 = Above cleanup goal and/or monitoring criteria

-- = Not analyzed

* = Cleanup Goal for arsenic is the MCL standard.

** = Background from the RI. (Final Remediation Investigation Report, Area of Contamination (AOC) 57, Devens, Massachusetts, HLA, 2000b)

Acronyms and Abbreviations:

µg/L = microgram per liter
µS/cm = microSiemen per centimeter
DO = dissolved oxygen
ft BGS = feet below ground surface
J = estimated result
mg/L = milligram per liter
mV = millivolt
NS = no standard
ORP = oxidation-reduction potential
SPC = specific conductivity
SU = standard unit
U = Non-detect

Table 3-2
Historical Surface Water Monitoring Results
Post-Record of Decision Supplemental Remedial Investigation Work Plan - AOC 57
Former Fort Devens Army Installation
Devens, Massachusetts

Analyte		Dissolved Metals			Field Parameters			
		Arsenic	Iron	Manganese	pH	SPC	ORP	DO
Unit		(µg/L)	(µg/L)	(µg/L)	(SU)	(µS/cm)	(mV)	(mg/L)
Surface Water Benchmark*		150	1,000	NS				
Well ID	Date							
AOC 57 Area 2								
57-AREA2-SW2	Jun-06	3.2 J	970	770	--	--	71	7.2
	May-09	5.0 U	770	632	5.9	334	61	7.9
	May-10	2.4 J	**1,400**	79	6.3	369	-133	3.3
	Jun-11	3.0 J	360	109	5.7	843	178	5.5
	May-12	2.0 J	200	157	7.4	277	25	8.2
	Jun-13	2.0 J	270	96	7.0	303	257	9.3
	Jun-14	17 J	**3,300**	91	6.7	920	68	0.1
57-AREA2-SW3	Jun-06	4.3 J	310	290	--	--	2.2	6.2
	May-09	2.6 J	760	498	5.5	290	46	7.6
	May-10	4.8 J	150	119	6.5	169	-115	8.9
	Jun-11	5.0	150	115	6.4	377	128	7.1
	May-12	2.0 J	170	140	6.5	435	-80	8.2
	Jun-13	4.0 J	380	231	6.7	286	191	6.5
	Jun-14	6.0	120	83	6.7	501	104	7.5
AOC 57 Area 3								
57-AREA3-SW1	Jun-06	5.0 U	440	500	--	--	71	3.7
	May-09	5.0 U	250	478	6.1	111	28	4.7
	May-10	5.0 U	240	446	6.7	131	-154	2.6
	Jun-11	18	**20,000**	2,430	6.5	228	-34	2.7
	May-12	8.0	**8,300**	684	6.3	172	-78	1.4
	Jun-13	8.0	**10,000**	4,840	6.7	286	-57	3.0
	Jun-14	15	**10,000**	2,380	7.0	278	-0.5	1.1
	Jun-15	3.7 J	**1,290**	790	6.4	510	140	2.7
	Jun-16	8.1	**6,500**	1,300	--	--	--	--
	Jun-17	17	**15,000**	1,300	--	--	--	--
	May-18	5.2	**4,000**	800	--	--	--	--
	Apr-19	3.0 U	760	110	--	--	--	--
	May-20	5.3	490	150	5.9	431	20	2.6
	May-21	9.2	**12,000**	3,100	6.4	151	-34	0.80
	May-22	1.3	**1,900**	640	5.0	138	162	0.49

Notes:

1,400 = Above cleanup goal and/or monitoring criteria

-- = Not analyzed

* = USEPA Aquatic Life Water Quality Criterion for Surface Water benchmarks for iron and arsenic (USEPA 2018).

Acronyms and Abbreviations:

µg/L = microgram per liter
µS/cm = microSiemen per centimeter
DO = dissolved oxygen
J = Estimated result
mg/L = milligram per liter
mV = millivolt
ORP = oxidation-reduction potential
SPC = specific conductivity
SU = standard units
U = Non-detect

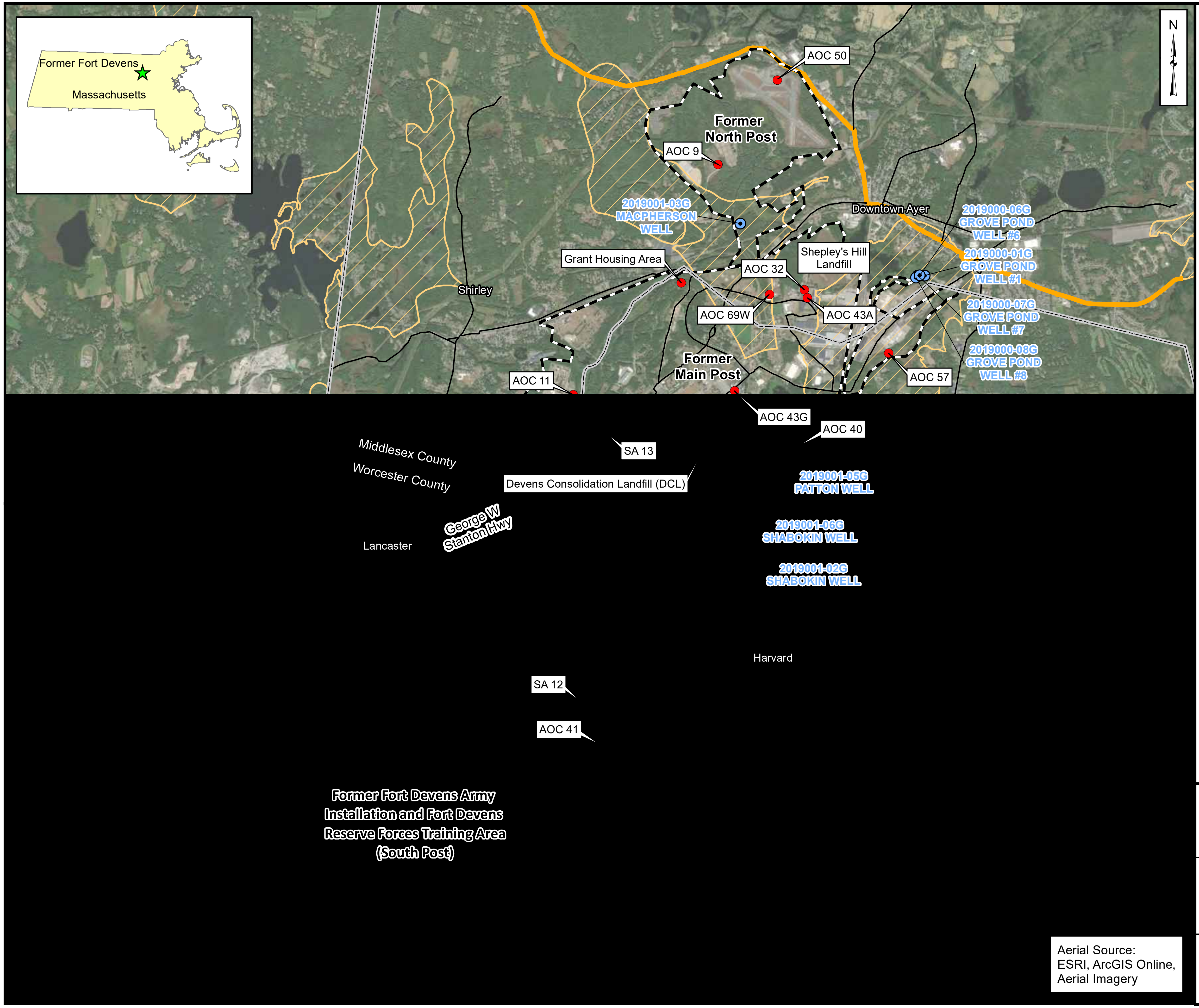
Table 3-3
Existing Monitoring Wells and Staff Gauges
Post-Record of Decision Supplemental Remedial Investigation Work Plan - AOC 57
Former Fort Devens Army Installation
Devens, Massachusetts

Location ID	Top of Casing Elevation (ft NAVD88)	Ground Surface Elevation (ft NAVD88)	Depth to Top of Screen (ft BGS)	Depth to Bottom of Screen (ft BGS)	Screen Elevation (Top) (ft NAVD88)	Screen Elevation (Bottom) (ft NAVD88)	DTW May 2022 (ft BTOR)	GWE May 2022 (ft NAVD88)
AOC 57 Area 2 - Monitoring Wells								
57M-03-01X	235.73	234.45	10	20	224.45	214.45	14.04	221.69
57M-03-02X	224.84	224.50	2	12	222.50	212.50	4.90	219.94
57M-03-03X	220.00	218.99	2	12	216.99	206.99	0.34	219.66
57M-03-04X	221.39	219.46	2	12	217.46	207.46	2.31	219.08
57M-03-05X	221.88	219.58	2	12	217.58	207.58	2.98	218.90
57M-03-06X	221.87	220.26	2	12	218.26	208.26	2.53	219.34
57M-95-05X	235.15	232.99	10	20	222.99	212.99	14.31	220.84
57M-95-06X	234.39	232.64	12	22	220.77	210.77	12.39	222.00
57M-95-07X	222.36	221.50	3	13	218.50	208.50	2.60	219.76
57WP-06-02	220.29	219.17	19	24	200.25	195.25	1.13	219.16
5702MW-20-01A	222.23	219.59	30	40	189.59	179.59	--	--
5702MW-20-01B	222.27	219.70	70	80	149.70	139.70	--	--
5702MW-20-02A	244.32	241.65	30	40	211.65	201.65	--	--
5702MW-20-03A	237.70	234.78	26	36	208.78	198.78	--	--
5702MW-20-04A	235.62	232.69	70	80	162.69	152.69	--	--
5702MW-20-05A	226.09	223.25	30	40	193.25	183.25	--	--
5702MW-20-05B	226.07	223.29	70	80	153.29	143.29	--	--
5702MW-20-06A	236.52	234.10	70	80	164.10	154.10	--	--
5702MW-20-07A	221.71	219.42	30	40	189.42	179.42	--	--
AOC 57 Area 2 - Staff Gauges								
SG-01	220.72	--	--	--	--	--	--	--
SG-02	220.65	--	--	--	--	--	--	--
SG-03	220.65	--	--	--	--	--	--	--
AOC 57 Area 3 - Monitoring Wells								
57M-95-03X	232.79	230.80	7	17	223.80	213.80	10.35	222.44
57M-96-10X	228.75	226.29	3	13	219.56	209.56	6.53	222.22
57M-96-11X	222.20	220.05	2	12	218.05	208.05	2.71	219.49
57M-96-12X	225.80	222.78	2	12	220.78	210.78	4.58	221.22
57M-96-13X	225.58	223.23	2	12	221.23	211.23	4.37	221.21
57P-98-03X	220.39	218.62	3	6	216.12	213.12	2.22	218.17
57P-98-04X	221.75	218.24	2	5	216.24	213.24	3.63	218.12
57WP-06-03	220.51	219.31	14	19	205.46	200.46	0.63	219.88
5703MW-20-01A	228.18	225.25	2	12	223.25	213.25	--	--
5703MW-20-01B	228.10	225.10	50	60	175.10	165.10	--	--
5703MW-20-02A	235.75	233.46	10	20	223.46	213.46	--	--
5703MW-20-03A	225.80	222.95	50	60	172.95	162.95	--	--
5703MW-20-04A	231.74	229.21	60	70	169.21	159.21	--	--

Acronyms and Abbreviations:

AOC = Area of Contamination
COC = chemical of concern
DTW = depth to water
ft = feet
ft BGS = feet below ground surface
ft BTOR = feet below top of riser
LTM = long-term monitoring
NAVD88 = North American Vertical Datum of 1988

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 57 Supplemental Remedial Investigation Work Plan
Former Fort Devens Army Installation
Devens, Massachusetts

Site Location
Former Fort Devens
Army Installation

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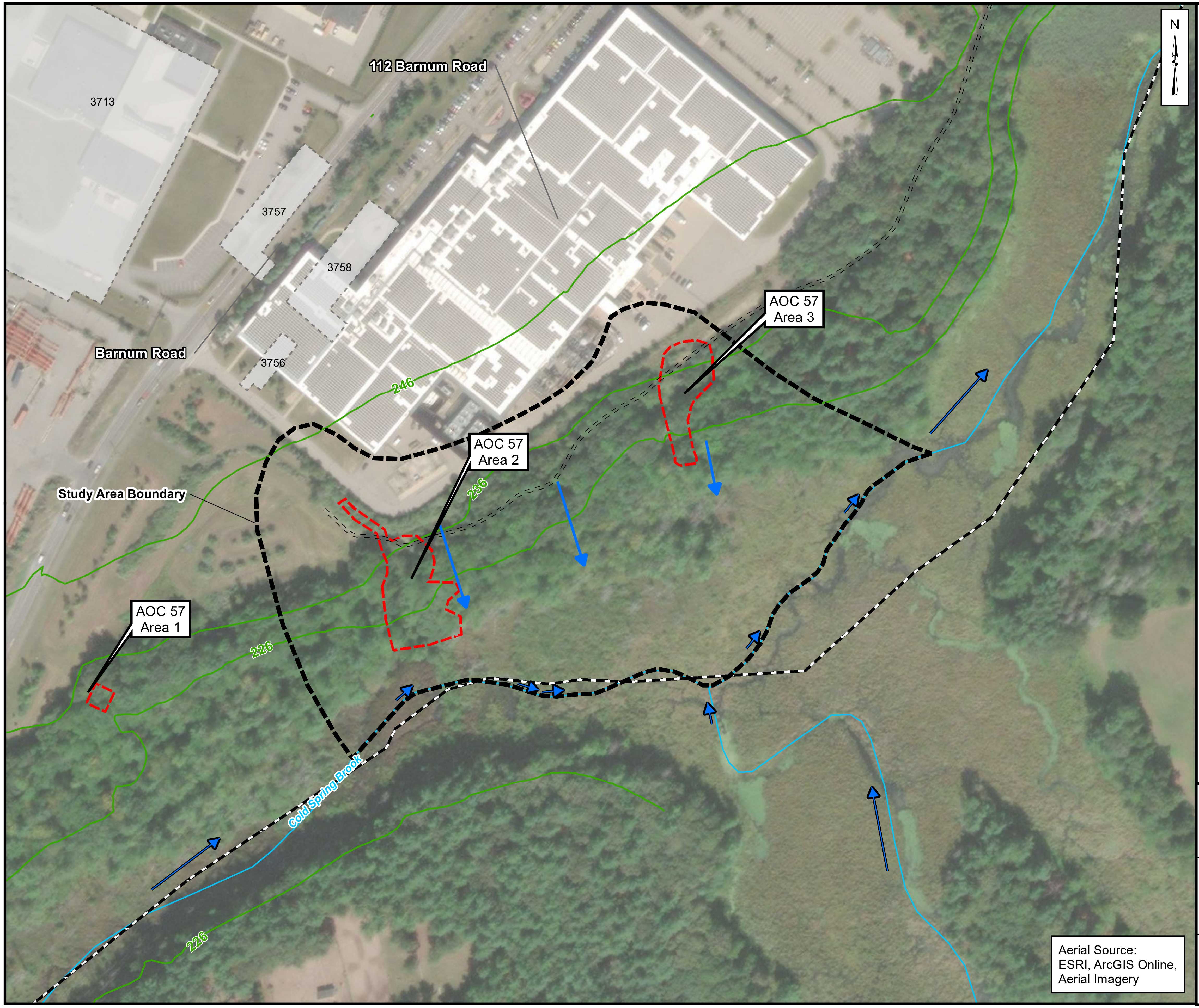
Figure
1-1



Aerial Source:
ESRI, ArcGIS Online,
Aerial Imagery

Legend

- Former Fort Devens Boundary
- Area of Contamination (AOC)
- Former Building
- ● Irrigation Well (approximate location)
- Stream
- → Groundwater Flow Direction
- → Surface Water Flow Direction
- Walking Trail
- Topographic Contour (ft AMSL)
- Study Area Boundary

Notes:
1. Boundaries and site features shown on the figure are approximate.
2. The entirety of AOC 57 lies within a MassDEP Zone II Wellhead Protection Area.

Abbreviations:
ft AMSL = feet above mean sea level
MassDEP = Massachusetts Department of Environmental Protection

0 200 400
Feet

AOC 57 Supplemental Remedial Investigation Work Plan
Former Fort Devens Army Installation
Devens, Massachusetts

Site Layout
AOC 57
Areas 1, 2, & 3

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Figure
1-2

Document Path: T:_ENV\Devens_RFTA\Seed_Task_Order\MXDs\AOC57\Figure 1-2 - AOC57 Site Layout.mxd Date Saved: 12/21/2022 3:13:58 PM User Name: ski01076

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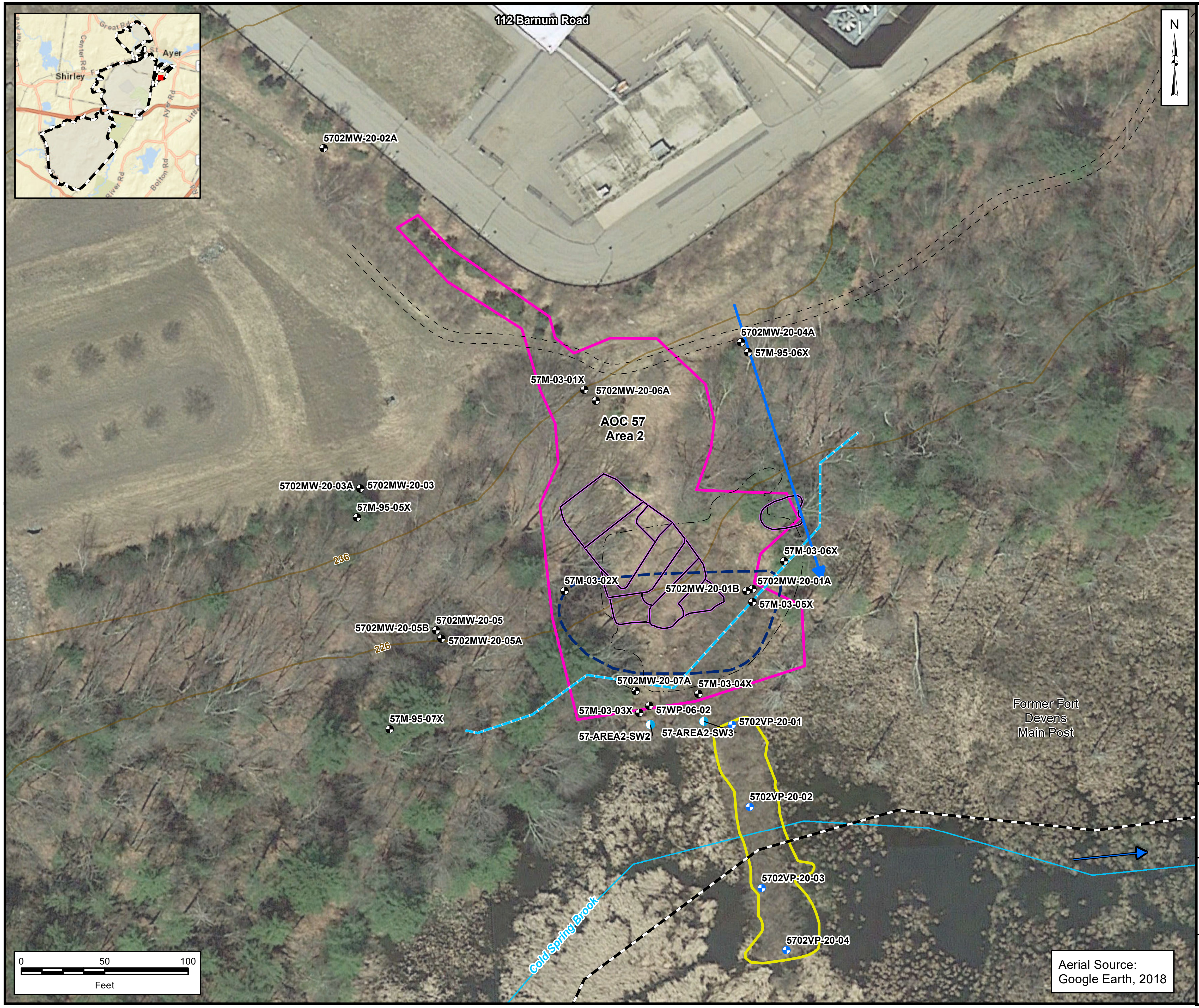

Aerial Source:
Google Earth, 2018

Legend

- Former Fort Devens Boundary
- Area of Contamination (AOC)
- Final Excavation Limit (2003)
- Conti Excavation Limit (2002)
- Flagged Wetland Limits
- Approximate Historical Extent of Groundwater Contamination in Exceedance of Cleanup Goals (based on fall 2003 to spring 2008 analytical data) (2008 Annual Report, HGL, 2009)
- Containment Dam
- Stream
- Walking Trail
- Topographic Contour (ft AMSL)
- Groundwater Flow Direction
- Surface Water Flow Direction
- ● Monitoring Well
- ● Vertical Profile
- ◑ Surface Water Sample Location

Notes and Abbreviations:
1. ft AMSL = feet above mean sea level
2. MassDEP = Massachusetts Department of Environmental Protection

AOC 57 Supplemental Remedial Investigation Work Plan
Former Fort Devens Army Installation
Devens, Massachusetts

Site Layout
AOC 57
Area 2

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Figure
1-3

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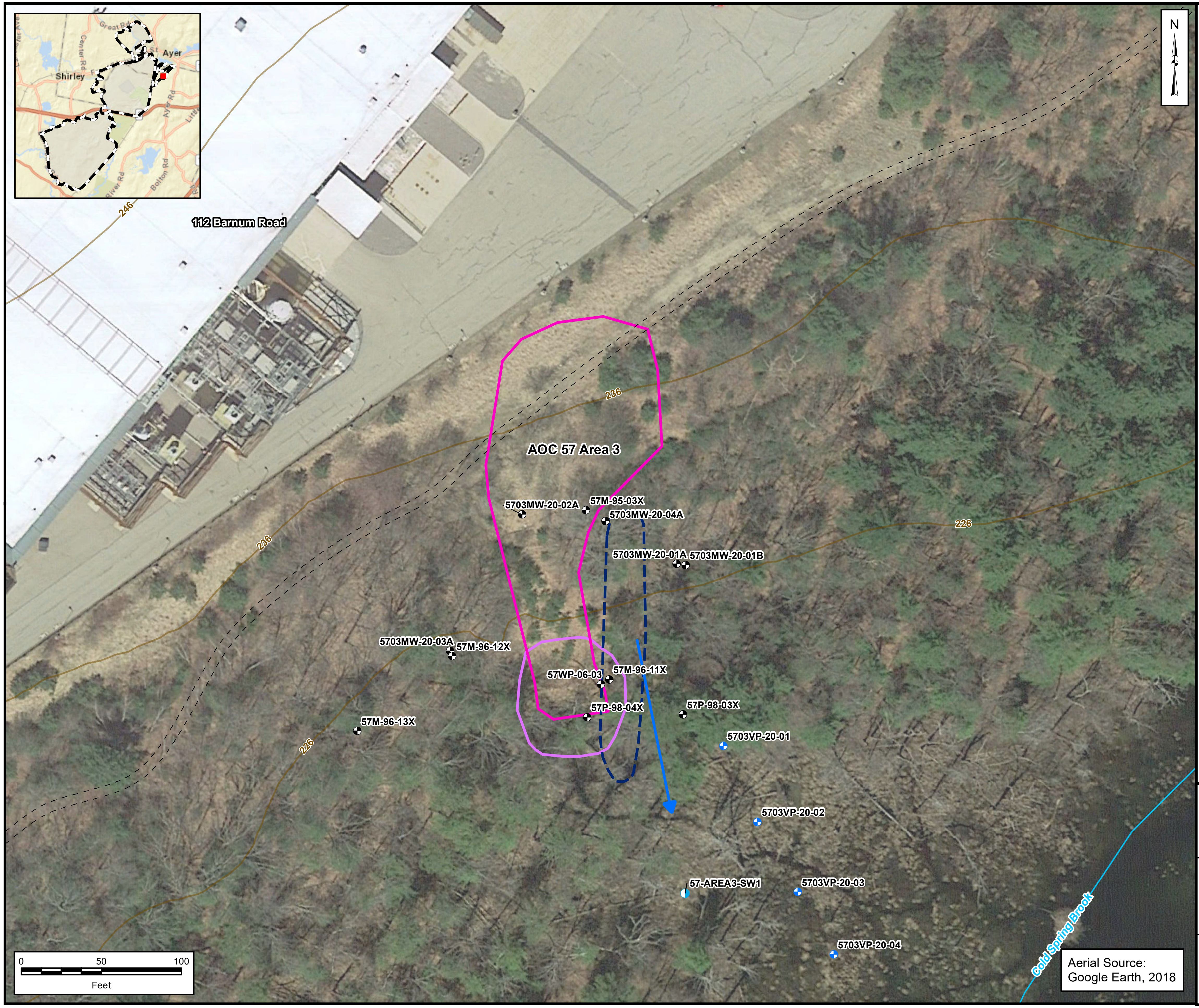

Aerial Source:
Google Earth, 2018

Legend

- ▭ Former Fort Devens Boundary
- ▭ Area of Contamination (AOC)
- ▭ Approximate Historical Extent of Groundwater Contamination in Exceedance of Cleanup Goals (based on Fall 2003 to Spring 2008 analytical data) (2008 Annual Report, HGL, 2009)
- ▭ Alternate III-2a Estimated Soil Excavation Area
- ～ Stream
- - - - Walking Trail
- ⌃ Topographic Contour (ft AMSL)
- → Groundwater Flow Direction
- → Surface Water Flow Direction
- ● Monitoring Well
- ● Vertical Profile
- ◑ Surface Water Sample Location

Notes and Abbreviations:
1. ft AMSL = feet above mean sea level
2. MassDEP = Massachusetts Department of Environmental Protection

AOC 57 Supplemental Remedial Investigation Work Plan
Former Fort Devens Army Installation
Devens, Massachusetts

Site Layout
AOC 57
Area 3

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Figure
1-4

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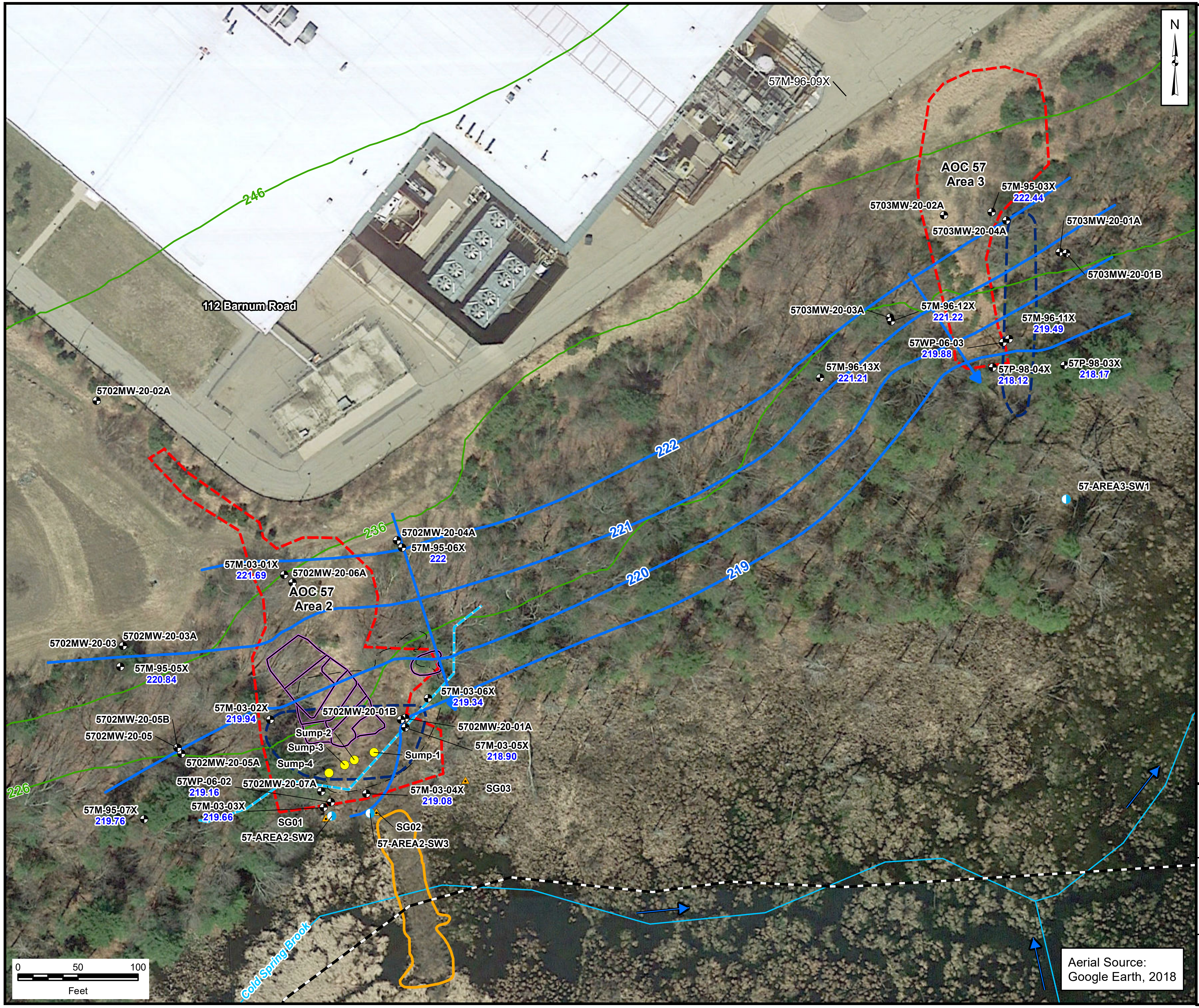

Aerial Source:
Google Earth, 2018

Legend

- Former Fort Devens Boundary
- Area of Contamination (AOC)
- Monitoring Well
- Staff Gauge
- Surface Water Sample Location
- Sump
- 222 Groundwater Contour Value (ft NAVD88)
- Groundwater Elevation Contour (ft NAVD88) (Contour Interval = 1 ft)
- Groundwater Elevation Contour (ft NAVD88) (Contour Interval = 1 ft) (Inferred)
- Final Excavation Limit (2003)
- Conti Excavation Limit (2002)
- Flagged Wetland Limits
- Approximate Historical Extent of Groundwater Contamination in Exceedance of Cleanup Goals (based on fall 2003 to spring 2008 analytical data) (2008 Annual Report, HGL, 2009)
- Containment Dam
- Stream
- Groundwater Flow Direction
- Surface Water Flow Direction
- Topographic Contour (ft AMSL)

Notes:
1. The entirety of AOC 57 lies within a MassDEP Zone II Wellhead Protection Area.

ft AMSL = feet above mean sea level
LTM = long-term monitoring
MassDEP = Massachusetts Department of Environmental Protection
NAVD88 = North American Vertical Datum of 1988

AOC 57 Supplemental Remedial Investigation Work Plan
Former Fort Devens Army Installation
Devens, Massachusetts

Groundwater Elevation Contour Map
AOC 57 - Areas 2 & 3
Spring 2022

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Figure
3-1

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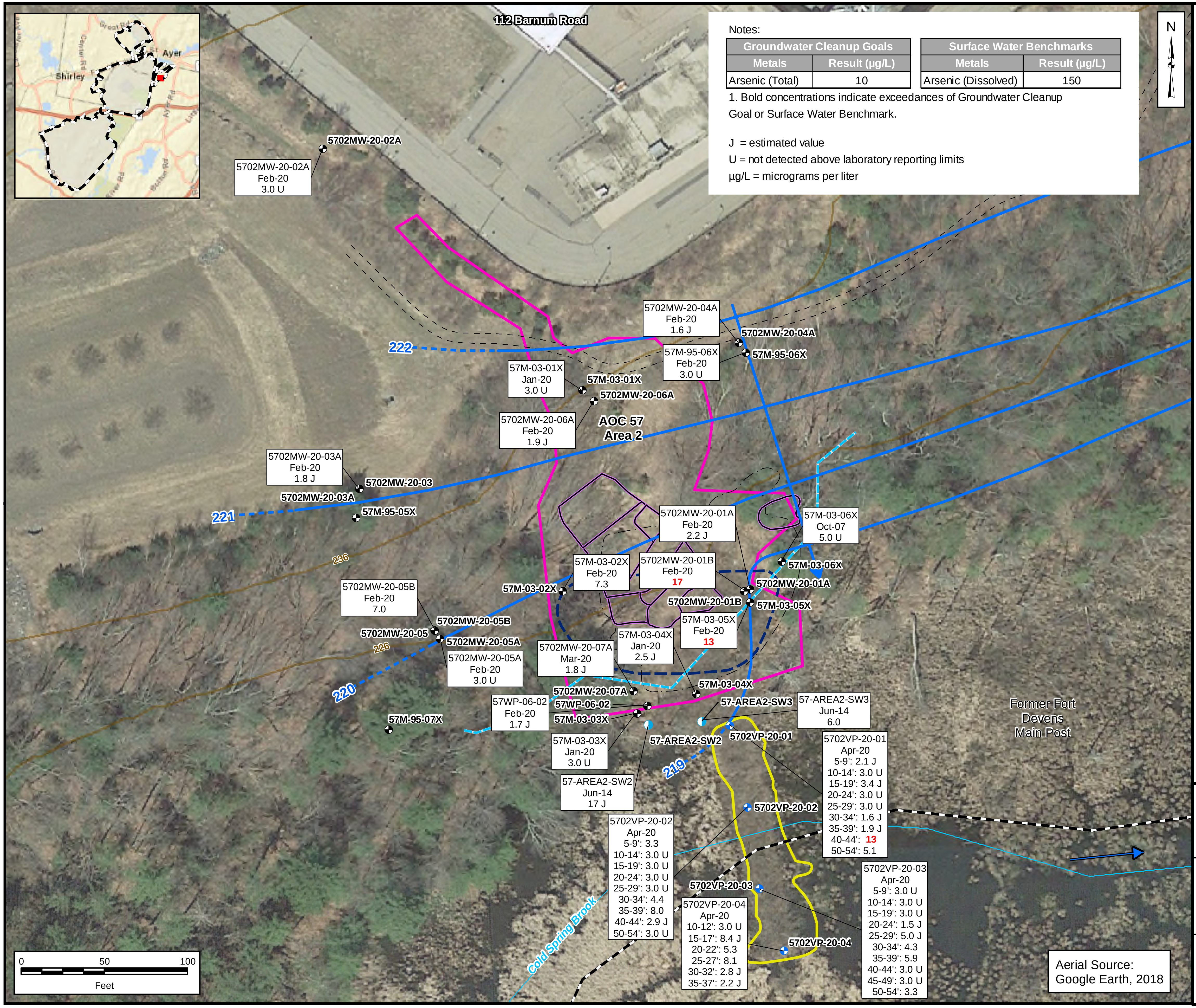

Notes:

Groundwater Cleanup Goals	
Metals	Result (µg/L)
Arsenic (Total)	10

Surface Water Benchmarks	
Metals	Result (µg/L)
Arsenic (Dissolved)	150

1. Bold concentrations indicate exceedances of Groundwater Cleanup Goal or Surface Water Benchmark.

J = estimated value
U = not detected above laboratory reporting limits
µg/L = micrograms per liter

Aerial Source:
Google Earth, 2018

Legend

▭	Former Fort Devens Boundary
▭	Area of Contamination (AOC)
—	Final Excavation Limit (2003)
-·-	Conti Excavation Limit (2002)
- - -	Flagged Wetland Limits
▭	Approximate Historical Extent of Groundwater Contamination in Exceedance of Cleanup Goals (based on fall 2003 to spring 2008 analytical data) (2008 Annual Report, HGL, 2009)
▭	Containment Dam
~	Stream
- - -	Walking Trail
∧	Topographic Contour (ft
~	Groundwater Elevation Contour (ft NAVD88) (Contour Interval = 1 ft)
~	Groundwater Elevation Contour (ft NAVD88) (Contour Interval = 1 ft) (Inferred)
→	Groundwater Flow Direction
→	Surface Water Flow Direction
●	Monitoring Well
●	Vertical Profile
◑	Surface Water Sample Location

Notes and Abbreviations:
1. ft AMSL = feet above mean sea level
2. MassDEP = Massachusetts Department of Environmental Protection

AOC 57 Supplemental Remedial Investigation Work Plan
Former Fort Devens Army Installation
Devens, Massachusetts

Arsenic Concentrations in Groundwater and Surface Water
AOC 57
Area 2

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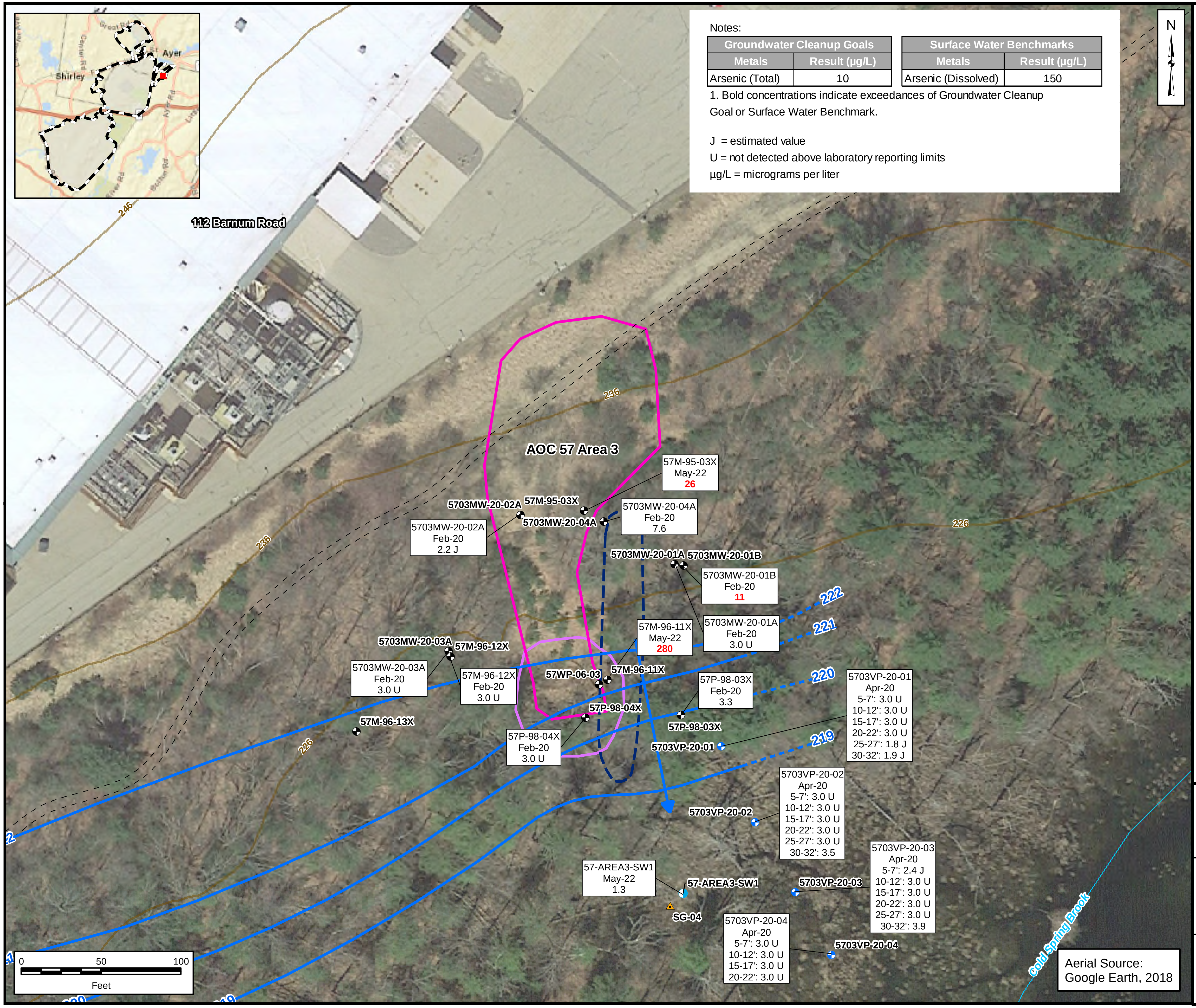
Figure
3-2

Document Path: T:_ENV\Devens_RFTA\Seed_Task_Order\MXDs\AOC57\2023-02-08\Figure 3-2- AOC57-2 Site Layout.mxd Date Saved: 2/8/2023 5:26:41 PM User Name: vmn1306



57M-95-03X
May-22
26

5703MW-20-04A
Feb-20
7.6

5703MW-20-02A
Feb-20
2.2 J

5703MW-20-01B
Feb-20
11

57M-96-11X
May-22
280

5703MW-20-01A
Feb-20
3.0 U

5703MW-20-03A
Feb-20
3.0 U

57M-96-12X
Feb-20
3.0 U

57P-98-03X
Feb-20
3.3

57P-98-04X
Feb-20
3.0 U

5703VP-20-01
Apr-20
5-7': 3.0 U
10-12': 3.0 U
15-17': 3.0 U
20-22': 3.0 U
25-27': 1.8 J
30-32': 1.9 J

5703VP-20-02
Apr-20
5-7': 3.0 U
10-12': 3.0 U
15-17': 3.0 U
20-22': 3.0 U
25-27': 3.0 U
30-32': 3.5

5703VP-20-03
Apr-20
5-7': 2.4 J
10-12': 3.0 U
15-17': 3.0 U
20-22': 3.0 U
25-27': 3.0 U
30-32': 3.9

57-AREA3-SW1
May-22
1.3

5703VP-20-04
Apr-20
5-7': 3.0 U
10-12': 3.0 U
15-17': 3.0 U
20-22': 3.0 U

Notes:

Groundwater Cleanup Goals	
Metals	Result (µg/L)
Arsenic (Total)	10

Surface Water Benchmarks	
Metals	Result (µg/L)
Arsenic (Dissolved)	150

1. Bold concentrations indicate exceedances of Groundwater Cleanup Goal or Surface Water Benchmark.

J = estimated value
U = not detected above laboratory reporting limits
µg/L = micrograms per liter

Aerial Source:
Google Earth, 2018

Legend

- Former Fort Devens Boundary
- Area of Contamination (AOC)
- Approximate Historical Extent of Groundwater Contamination in Exceedance of Cleanup Goals (based on Fall 2003 to Spring 2008 analytical data) (2008 Annual Report, HGL, 2009)
- Alternate III-2a Estimated Soil Excavation Area
- Stream
- Walking Trail
- Topographic Contour (ft AMSL)
- Groundwater Elevation Contour (ft NAVD88) (Contour Interval = 1 ft)
- Groundwater Elevation Contour (ft NAVD88) (Contour Interval = 1 ft) (Inferred)
- Groundwater Flow Direction
- Surface Water Flow Direction
- Monitoring Well
- Vertical Profile
- Surface Water Sample Location
- Staff Gauge ((Proposed)

Notes and Abbreviations:
1. ft AMSL = feet above mean sea level
2. MassDEP = Massachusetts Department of Environmental Protection

AOC 57 Supplemental Remedial Investigation Work Plan
Former Fort Devens Army Installation
Devens, Massachusetts

Arsenic Concentrations in Groundwater and Surface Water AOC 57 Area 3

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Figure
3-3

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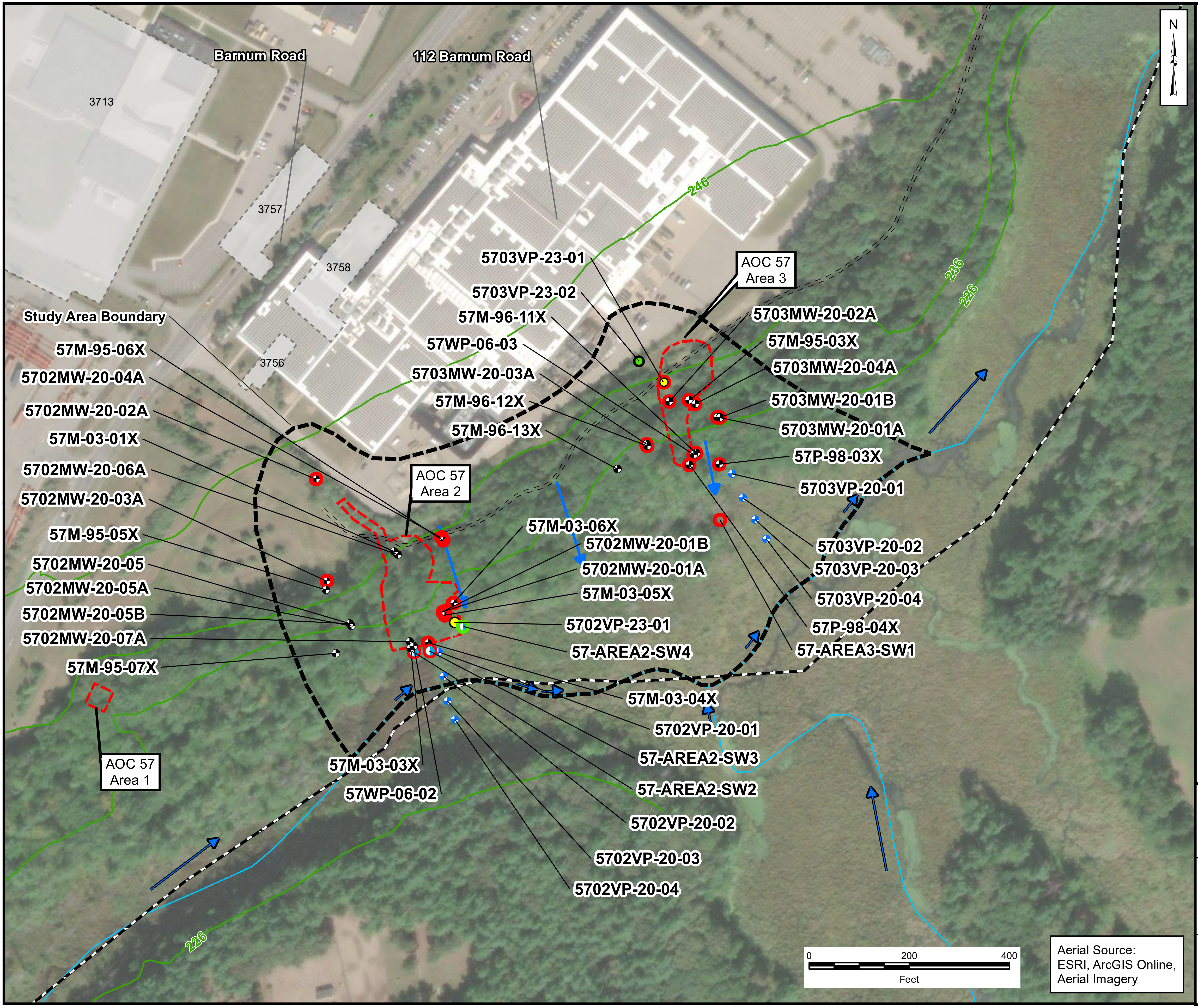

Aerial Source:
ESRI, ArcGIS Online,
Aerial Imagery

Legend

▭	Former Fort Devens Boundary
▭	Area of Contamination (AOC)
▨	Former Building
~	Stream
- - -	Walking Trail
∧	Topographic Contour (ft AMSL)
▭	Study Area Boundary
→	Groundwater Flow Direction
→	Surface Water Flow Direction
●	Monitoring Well
●	Vertical Profile
◑	Surface Water

Proposed AOC 57 Investigation Locations

○	Proposed Sampling Location (Existing)
○	Proposed Vertical Aquifer Profiling Location
○	Proposed Surface Watrer Location (Contingent)
●	Proposed Vertical Aquifer Profiling Location (Contingent)

Notes:
1. Boundaries and site features shown on the figure are approximate.
2. The entirety of AOC 57 lies within a MassDEP Zone II Wellhead Protection Area.

Abbreviations:
ft AMSL = feet above mean sea level
MassDEP = Massachusetts Department of Environmental Protection

AOC 57 Supplemental Remedial Investigation Work Plan
Former Fort Devens Army Installation
Devens, Massachusetts

Proposed Investigation Locations
AOC 57

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Figure
4-1

Path : T:_ENV\Devens_RFTA\Seed_Task_Order\MXDs\AOC57\Figure 4-1 - Proposed Investigation Locations.mxd

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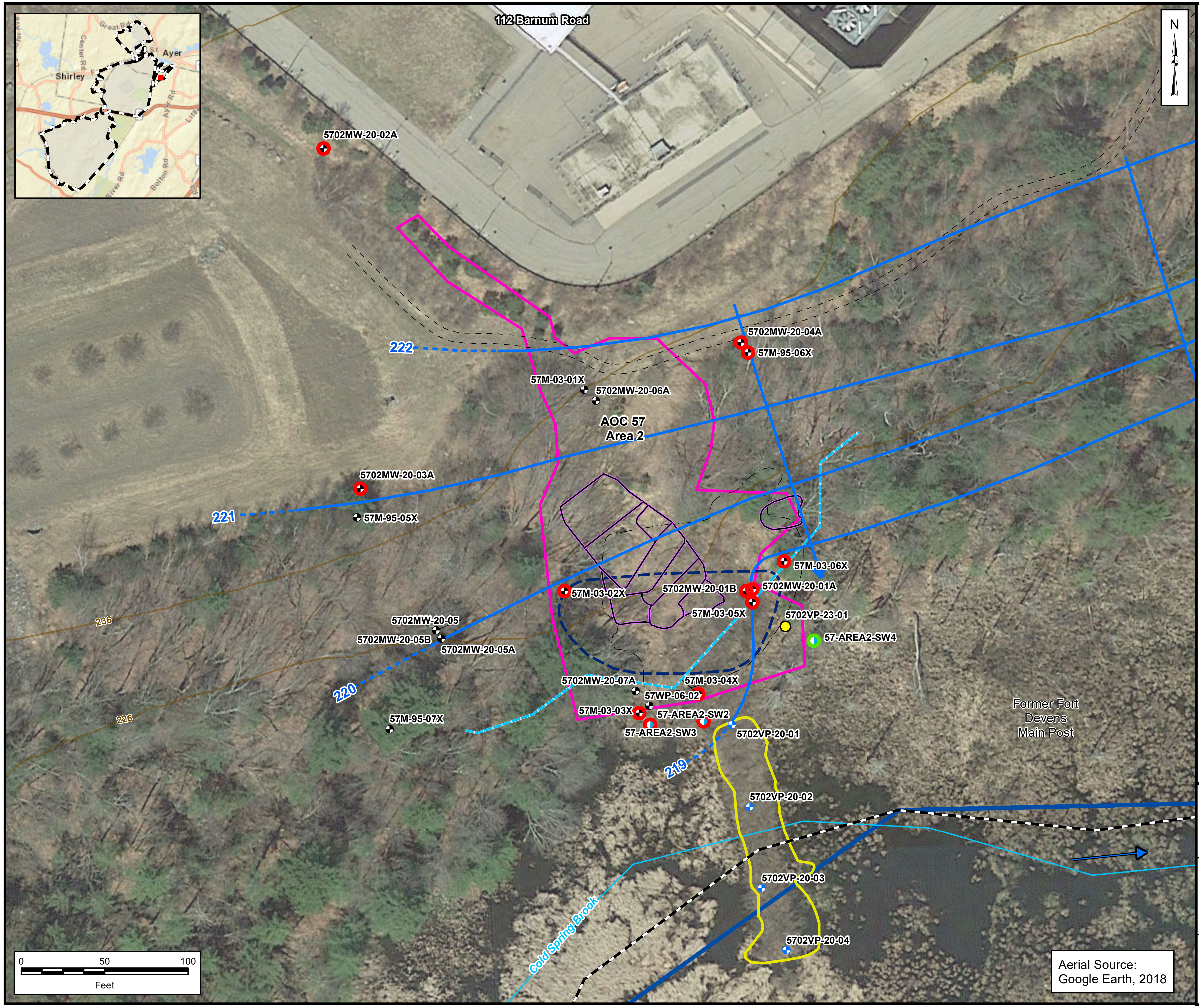

Aerial Source:
Google Earth, 2018

Legend

⬚	Former Fort Devens Boundary
▭	Area of Contamination (AOC)
—	Final Excavation Limit (2003)
-·-·	Conti Excavation Limit (2002)
- - -	Flagged Wetland Limits
⬚	Approximate Historical Extent of Groundwater Contamination in Exceedance of Cleanup Goals (based on fall 2003 to spring 2008 analytical data) (2008 Annual Report, HGL, 2009)
▭	Containment Dam
∿	Stream
- - -	Walking Trail
⋀	Topographic Contour (ft AMSL)
∿	Groundwater Elevation Contour (ft NAVD88) (Contour Interval = 1 ft)
∿	Groundwater Elevation Contour (ft NAVD88) (Contour Interval = 1 ft) (Inferred)
→	Groundwater Flow Direction
→	Surface Water Flow Direction
●	Monitoring Well
●	Vertical Profile
◑	Surface Water Location
○	Proposed Sampling Location (Existing)
○	Proposed Vertical Aquifer Profiling Location
○	Proposed Surface Watrer Location

Notes and Abbreviations:
1. ft AMSL = feet above mean sea level
2. MassDEP = Massachusetts Department of Environmental Protection

AOC 57 Supplemental Remedial Investigation Work Plan
Former Fort Devens Army Installation
Devens, Massachusetts

Proposed Investigation Locations
AOC 57
Area 2

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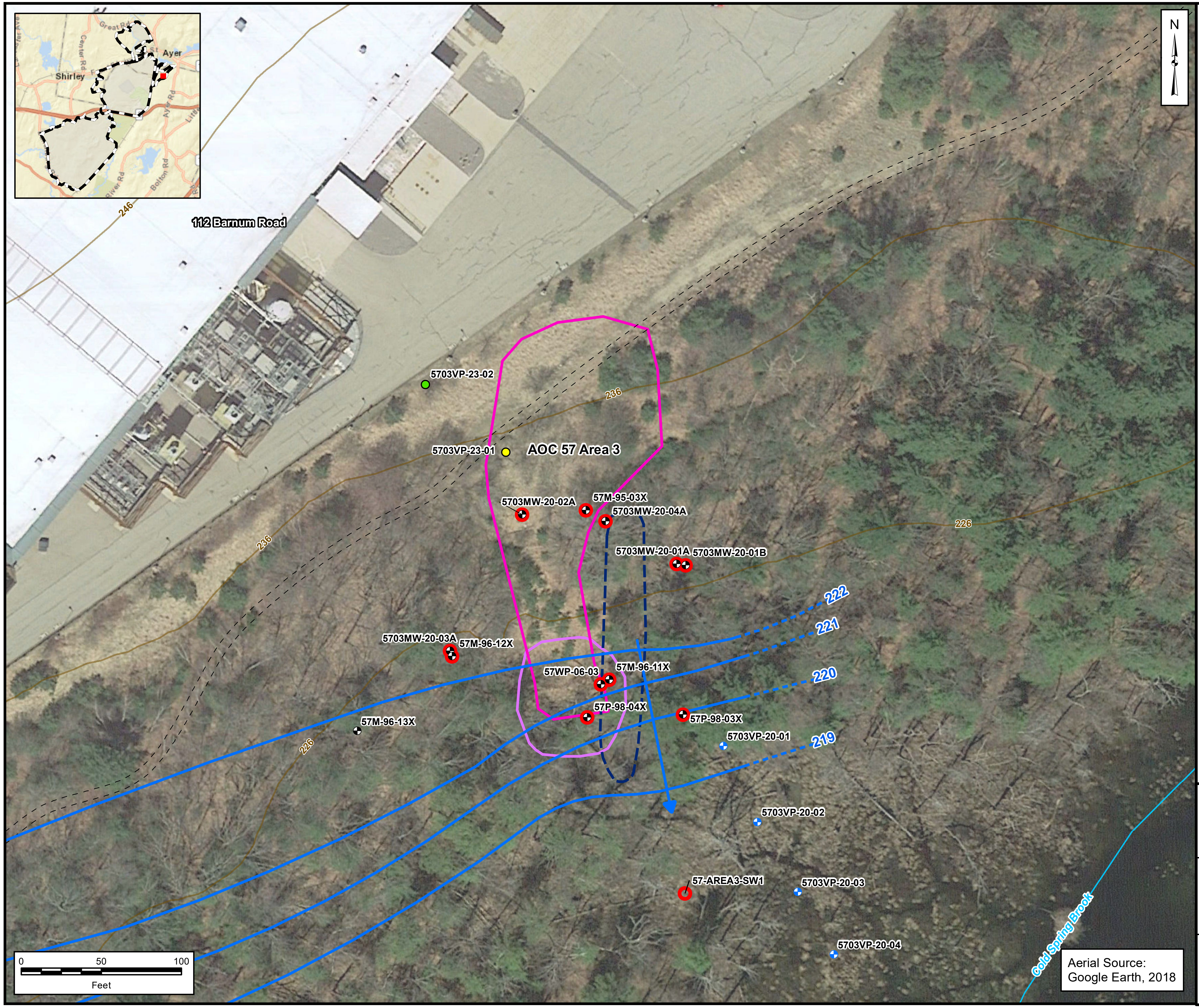
Figure
4-2

Document Path: T:_ENV\Devens_RFTA\Seed_Task_Order\MXDs\AOC57\2023-02-08\Figure 4-2 - Proposed Investigation Locations AOC57 - Area2.mxd Date Saved: 2/8/2023 2:41:21 PM User Name: vmn1306



Aerial Source:
Google Earth, 2018

Legend

- ▭ Former Fort Devens Boundary
- ▭ Area of Contamination (AOC)
- ▭ Approximate Historical Extent of Groundwater Contamination in Exceedance of Cleanup Goals (based on Fall 2003 to Spring 2008 analytical data) (2008 Annual Report, HGL, 2009)
- ▭ Alternate III-2a Estimated Soil Excavation Area
- ~ Stream
- - - - Walking Trail
- ∧ Topographic Contour (ft
- ∼ Groundwater Elevation Contour (ft NAVD88) (Contour Interval = 1 ft)
- ∼ Groundwater Elevation Contour (ft NAVD88) (Contour Interval = 1 ft) (Inferred)
- → Groundwater Flow Direction
- → Surface Water Flow Direction
- ◕ Monitoring Well
- ◕ Vertical Profile
- ◑ Surface Water
- ○ Proposed Sampling Location (Existing)
- ● Proposed Vertical Aquifer Profiling Location
- ● Proposed Vertical Aquifer Profiling Location (Contingent)

Notes and Abbreviations:
1. ft AMSL = feet above mean sea level
2. MassDEP = Massachusetts Department of Environmental Protection

AOC 57 Supplemental Remedial Investigation Work Plan
Former Fort Devens Army Installation
Devens, Massachusetts

Proposed Investigation Locations
AOC 57
Area 3

SERES Engineering & Services, LLC
ARCADIS
a joint venture

Figure
4-3

Document Path: T:_ENV\Devens_RFTA\Seed_Task_Order\MXDs\AOC57\Figure 4-3 - Proposed Investigation Locations AOC57 - Area3.mxd Date Saved: 12/12/2022 4:08:19 PM User Name: ski01076

File: Figure 4-3 - Proposed Investigation Locations AOC57 - Area3.mxd

Appendix A

AOC 57 QAPP Addendum

VERSION 2

FINAL

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

POST – RECORD OF DECISION SUPPLEMENTAL REMEDIAL INVESTIGATION – AOC 57

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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Prepared By:

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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 supplemental remedial investigation (SRI) at area of contamination (AOC) 57, a long-term-monitoring (LTM) site 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 57 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:

- Confirm the current lateral and vertical extent of arsenic in groundwater.
- Confirm the conceptual site model (CSM), including aquifer reducing conditions, associated impacts on arsenic concentration trends, and the potential impacts to receptors (if any).

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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).

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	Field Method Standard Operating Procedure (Ferrous Iron)

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LIST OF FIGURES

APPENDICES

Attachment A	Field Sampling SOPs
Attachment B	Field Method SOP (Ferrous Iron)

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
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
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
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
ROE	right-of-entry
SOP	standard operating procedures
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
VAP	vertical aquifer profile
VPH	volatile petroleum hydrocarbon
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)/HydroGeoLogic, Inc. (HGL)
2015	2015 Five-Year Review Report for Former Fort Devens Army Installation, BRAC Legacy Sites, Devens, Massachusetts.	KGS
1996	Record of Decision, Area of Contamination 57, Devens Reserve Forces Training Area, Devens, Massachusetts.	Harding ESE

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**	**Crosswalk 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		
9	Project Scoping Session Participants Sheet	NA
10	Problem Definition	Page 6
11	Project Quality Objectives/Systematic Planning Process Statements	Page 11
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	NA
16	Project Schedule/Timeline Table	Page 13
B. Measurement/Data Acquisition		
Sampling Tasks		
17	Sampling Design and Rationale	Page 14
18	Sampling Locations and Methods/SOP Requirements Table Sample Location Map(s)	Page 18
19	Analytical Methods/SOP Requirements Table	NA
20	Field QC Sample Summary Table	Page 19
21	Project Sampling SOP References Table	Page 20
22	Field Equipment Calibration, Maintenance, Testing, and Inspection Table	NA

Worksheet #	Required Information	Crosswalk to Related Information
Analytical Tasks		
23	Analytical SOPs Analytical SOP References Table	NA
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	NA
Data Management Tasks		
29	Project Documents and Records Table	NA
30	Analytical Services Table	NA
C. Assessment Oversight		
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 for Devens

QAPP Recipients	Title	Organization	Telephone Number	E-mail Address
Alex Lo	Program Manager	JV	(843) 388-7804	ahlo@seres-es.com
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QAPP WORKSHEET #10 CONCEPTUAL SITE MODEL

10.1 AOC 57 - BUILDING 3713 FUEL OIL SPILL

10.1.1. Site Description and History

AOC 57 comprises three sub-areas; Area 1, Area 2 (floodplains), and Area 3 (upland), located south and southeast of former building 3713 and former buildings 3756, 3757, and 3758. (Figure 1-1). These sub-areas received stormwater runoff and wastes from vehicle maintenance activities conducted at the storage yards related to Building 3713 and former Buildings 3757 and 3758. The yards were abandoned in 1998, and the area was later redeveloped.

Area 1 consists of a former stormwater outfall and drainage area for runoff from paved areas proximal to former Building 3713. An estimated 50- to 100-gallon spill of No. 4 fuel oil was discharged through the Area 1 outfall in 1977. Approximately 3,000 gallons of mixed oil and water were recovered through the use of contaminant dikes and absorbent booms in 1977, and approximately 25 cubic yards (cy) of petroleum contaminated soil were removed in 1997. Area 1 was recommended for No Further Action (NFA) following the removal of this contaminated soil.

Area 2 (floodplains) is located approximately 700 feet north of Area 1 and adjacent to a former vehicle storage yard associated with the motor repair shops located in former Buildings 3757 and 3758. At AOC 57 Area 2, following a soil removal action in 1994, Area 2 was re-graded and a permanent drainage swale was installed. Subsequent activities included subsurface investigations with soil sampling and monitoring well installation, removal of contaminated soil, construction of an interceptor trench, and operation of a petroleum product recovery system.

Area 3 (upland) is located approximately 600 feet to the northeast of Area 2, south of former vehicle maintenance motor pools. Area 3 was identified through historical photograph analysis indicated an area of soil staining. The Army conducted a soil removal action in 1999 that targeted soils with total petroleum hydrocarbons and polychlorinated biphenyl (PCB) concentrations exceeding soil standards published under the MCP. A total of 1,860 cy of materials was removed for off-site disposal.

A manufacturing facility was constructed between Areas 2 and 3 of AOC 57 and Barnum Road between 2008 and 2009. Occupancy and use of the building have varied since construction but the building footprint and infrastructure have not been modified.

10. 2. Site Constituents of Concern

Petroleum discharges to ground are assumed to be the source of contaminants at AOC 57 Areas 2 and 3. While removal actions between 1994 and 2001 excavated the majority of the petroleum-contaminated soil, residual petroleum remained in the soil on-site. The ROD for AOC 57 (Harding ESE 2001) indicated that Area 1 was closed with NFA and specified LTM as part of the selected remedy for Areas 2 and 3. The ROD identified arsenic and tetrachloroethene as COCs in groundwater at Area 2 and arsenic, cadmium, and 1,4-dichlorobenzene (1,4-DCB) in groundwater at Area 3. In March 2004, an Explanation of Significant Differences (ESD) was prepared for AOC 57 based on data collected during soil excavation activities at Area 2. Subsequently, EPH C11-C22 aromatic hydrocarbons and PCB Aroclor-1260 were added as AOC57 groundwater COCs.

Table 10-1: AOC 57 Groundwater COCs Monitoring Levels

Analyte	Original Screening Standard (µg/L) [a]	Current Screening Standard (µg/L) [b]	Selection Basis
SVOCs [c]			
1,4-DCB	5	NA	MMCL (ROD/ESD)
Tetrachloroethylene	5	NA	MCL (ROD/ESD)
PCB			
Total of all Aroclors	0.5	NA	MCL (ESD)
EPH			
C11-C22 Aromatics	200	NA	MCP Method 1 risk assessment standards for GW-1 (ESD)
Metals (dissolved)			
Arsenic	50	10	MCL (ROD/ESD)
Cadmium	5	NA	MCL (ROD/ESD)

NOTE:

ESD- Explanation of Significant Differences
ROD = Record of Decision

a. Screening levels as noted in 2001 ROD (Harding ESE) and 2020 FYR (KGS). µg/L = micrograms per liter.
b. MCP 2021 https://www.mass.gov/regulations/310-CMR-4000-massachusetts-contingency-plan
c. SVOCs, PCB, EPH, and cadmium were removed from the AOC 57 LTM analyte list after 2014. Only arsenic is currently monitored in groundwater.

The current LTM program for AOC 57 (Sovereign/HGL 2015) eliminated analysis of all ROD/ESD-listed COCs except arsenic. The sampling program was also modified to suspend sampling at Area 2; however, gauging of Area 2 wells continues. Although the LTMMP calls for monitoring at AOC 57 every five years, sampling has been conducted annually since the LTMMP was issued. Annual monitoring at AOC 57 consists of collection of samples from two monitoring wells in Area 3 (wells 57M-95-03X and 57M-96-11X; analyzed for total arsenic, iron, and manganese in 2022), gauging of Area 2 and Area 3 wells, and collection of one surface water sample in Area 3 (location 57-AREA3-SW1; analyzed for dissolved arsenic, iron, and manganese in 2022).

Iron and manganese are not identified as COCs in the AOC 57 ROD. USEPA Region I requested that these metals be included in the LTM program as a measure of the potential for natural attenuation. As such, AOC 57 does not have a site-specific cleanup goal for manganese and iron. AOC 57 manganese and iron concentrations in groundwater are compared to their background levels of 291 and 9,100 µg/L, respectively.

10.3 Key Physical Aspects of the Site

AOC 57 is located south of former Building 3713, between Barnum Road and Cold Spring Road on the northeastern side of the former Main Post of Fort Devens in the Town of Harvard, Massachusetts. Public access to Areas 2 and 3 is not restricted, but the presence of floodplains/wetlands and existing zoning currently prevents residential use/exposure. Areas 1, 2, and 3 include upland areas (defined in the ROD as above 228 feet msl) that slope downward to a floodplain for lower Cold Spring Brook. Area 2 grades down towards the floodplain and formerly consisted of an eroded drainage ditch created by rainfall runoff from vehicle storage yards. The upland area is forested with trees and scrub brush. The floodplain area is densely vegetated with brush and contains small areas of standing water.

10.3.1 Site Groundwater Hydrology

AOC 57 is part of the Bowers-Nonacoicus Brook Sub-basin, Nashua River Watershed. AOC 57 is located to the west of and immediately adjacent to Cold Spring Brook near its confluence with Bowers Brook. Depth to groundwater ranges from about 20 feet bgs in the upland areas of AOC 57 (near Barnum Road) to less than 1-foot bgs in the lowlands/wetlands adjacent to Cold Spring Brook. The water table occurs entirely within the overburden across AOC 57, and groundwater flows from the local topographic highs near Barnum Road to the east/southeast (topographic lows) where it discharges to Cold Spring Brook and the surrounding wetlands. Data from previous investigations (including recent supplemental investigation work completed by KGS in 2020) have shown downward vertical hydraulic gradients within overburden in the upland areas (near Barnum Road) that transition to upward vertical hydraulic gradients approaching and adjacent to Cold Spring Brook, indicating that Cold Spring Brook (and the surrounding wetlands) is a discharge boundary for the overburden groundwater (KGS 2020). AOC 57 is located approximately 2,500 feet southwest of the Devens Grove Pond well field and 3,000 feet southwest of the Town of Ayer water supply wells on the south shore of Grove Pond and falls within a MassDEP groundwater protection Zone II for the Town of Ayer Grove Pond public water supply wells. Groundwater elevation data indicate that the groundwater flow direction at AOC 57 is to the southeast and away from Grove Pond and the water supply wells.

10.3.2 Site Geology

Surface topography across AOC 57 is generally flat across the paved and developed areas in the upland region near Barnum Road and slopes down to the east/southeast towards Cold Spring Brook in the wooded/undeveloped areas.

The overburden is relatively thick throughout AOC 57 with an average thickness of approximately 100 feet, increasing to approximately 150 feet near well 5702MW-20-03A, and decreasing to approximately 80 feet or less beneath Cold Spring. Overburden in the AOC 57 area is generally comprised of an unconsolidated sediment sequence of approximately 50 feet of sand with gravel overlying approximately 30 to 80 feet of silt to sandy silt, followed by a 4- to 8-foot-thick band of basal till that conforms to the underlying bedrock topography.

On the opposite side of Cold Spring Brook (east/southeast), the land surface elevation rises steeply, and it is assumed that the overburden thickness decreases accordingly as the bedrock or till and land surface increase in elevation further to the southeast.

The bedrock underlying AOC 57 consists of the Oakdale Formation under Areas 2 and 3, and the Devens Gneiss Complex under Area 1. The contact between these formations is estimated to fall between Areas 1 and 2 running along a north/northeast direction. East and southeast of Cold Spring Brook, the bedrock transitions to the Ayer Granite.

10. 4 Primary Release Mechanism/Fate and Transport Consideration

As presented in the ROD, the primary site-related contaminants at AOC 57 are solvent and fuel-related contaminants in soil and groundwater due to disposal of vehicle maintenance wastes in surface and near surface soil. The primary migration pathway/transport mechanism at both Area 2 and Area 3 is infiltration into groundwater from source area contaminants above the water table (Harding ESE 1996).

10.4.5 Data Gaps

To address the study questions for AOC 57, the following investigations are proposed:

- **To evaluate the current lateral and vertical extent of arsenic**, one VAP boring (5702VP-23-01) will be drilled downgradient of well 57M-03-05X in Area 2; the need for a VAP at this location was identified due to define historical concentrations of arsenic above the Cleanup Goal, as well as to assess if the reducing conditions created by the wetland area are resulting in natural arsenic mobilization. Due to proximity of Cold Spring Brook to the drilling area, a surface water sample (57-AREA2-SW4) will be collected downgradient if arsenic exceeds the Cleanup Goal in proposed VAP boring 5702VP-23-01. A second VAP boring (5703VP-23-01) will be drilled upgradient of all wells in Area 3; the need for a VAP at this location was identified to confirm the lateral and vertical extent of arsenic in the groundwater, as no historical groundwater sampling locations are present upgradient from well 57M-95-03X. If arsenic exceeds the Cleanup Goal in proposed VAP boring 5703VP-23-01, contingency VAP boring 5703VP-23-02 will be installed. Two additional VAP locations (CSVP-23-02 and CSVP-23-03) are proposed to be installed to the east of Cold Spring Brook as part of the Phase II Remedial Investigation for PFAS Area 1, the Work Plan for which is currently under review by the Agencies. The installation and sampling of these locations will be completed pending the approval of the PFAS Work Plan, and sampling will be conducted in accordance with proposed PFAS investigation schedule. In addition, the sampling of these locations will be dependent on the ability to execute and retain a Right-of-Entry (ROE) permit with private property owners for access.

- **To evaluate vertical groundwater gradients in the study area,** synoptic groundwater level gauging events will be conducted that will include all existing monitoring wells in Area 2 and Area 3. These data will be used to confirm groundwater flow direction in the shallow and deep overburden, and to calculate vertical gradients to confirm discharge of the groundwater to Cold Spring Brook. Water levels also will be measured at staff gauges SG-01 to SG-03, located in Cold Spring Brook in Area 2. One additional staff gauge (SG-04) will be installed in Cold Spring Brook adjacent to surface water location 57-AREA3-SW-1.

- **To confirm that the current lateral extent of arsenic exceeding the MCL** , a subset of monitoring wells will be sampled in Area 2 and Area 3, including several wells installed in 2020 by KGS (5702MW-20-01A, 5702MW-20-01B, 5702MW-20-02A, 5702MW-20-03A, 5702MW-20-04A, 5703MW-20-01A, 5703MW-20-01B, 5703MW-20-03A, 5703MW-20-04A) and one well that has not been sampled historically (57WP-06-03). To evaluate trends in ROD specified COC concentrations, a statistical trend analysis (Mann Kendall + Theil-Sen slope analysis) of the new and existing data will be performed. Two additional monitoring well locations (CSMW-23-02 and CSMW-23-04) are proposed to be installed to the east of Cold Spring Brook as part of the Phase II Remedial Investigation for PFAS Area 1, the Work Plan for which is currently under review by the Agencies. The installation and sampling of these locations will be completed pending the approval of the PFAS Work Plan, and sampling will be conducted in accordance with proposed PFAS investigation schedule. In addition, the sampling of these locations will be dependent on the ability to execute and retain a ROE permit with private property owners for access.

- **To evaluate trends in ROD specified COC concentrations,** a statistical analysis of the new and existing data will be performed.

- **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 (volatile petroleum hydrocarbons [VPH], EPH, dissolved arsenic, total and dissolved manganese, total and dissolved aluminum, total and dissolved iron, TOC, sulfate, nitrate, nitrite, and ferrous iron); the analytical results will be compared against the historical EPH and arsenic data, as well as the spatial location of the particular sampling location. In addition, the field water quality parameters (DO, ORP, specific conductance, temperature, turbidity, and pH) and laboratory geochemical data from VAPs and monitoring wells 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 and arsenic).

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 57 Former Vehicle Storage and Motor Repair Shops 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 57 ROD still protective of human health?	1. What is the current lateral and vertical extent of the ROD specified COC arsenic in groundwater? 2. How is ROD specified COC arsenic distributed in groundwater (i.e., where is the plume)? 3. Is there a stable or decreasing trend of the ROD specified COC arsenic in groundwater? 4. Are current reducing aquifer conditions associated with a petroleum release or are they naturally occurring?	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 boundaries for the Post-ROD SRI is AOC 57.	• 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 COCs 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 57 post-ROD SRI Work Plan.

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 post-ROD 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 **Appendix 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

(UFP-QAPP Manual Section 2.8.2)

(USEPA 2106-G-05 Section 2.2.4)

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 **Appendix 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 #17

Sampling Design and Rationale
Supplemental Remedial Investigations

As stated in the Introduction, the primary goal of the SRI field activities is to confirm the Army Protectiveness Statements for AOC 57in 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 – *Utility Location* (Rev #4, 1 May 2020)
- **RI-SOP-06:** SERES-Arcadis TGI – *Manual Water-Level Monitoring* (JV; Rev #0, May 2020)
- **RI-SOP-07:** TGI - *In-Situ and Ex-Situ Water Quality Parameters* (Rev #0, 16 October 2018)
- **RI-SOP-08:** SERES-Arcadis TGI - *Sample Chain of Custody* (Rev #2, 29 April 2020)
- **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#1, 8 May 2020)
- **RI-SOP-11:** SERES-Arcadis TGI - *Monitoring Well Development* (Rev #0, 24 April 2017)

- **RI-SOP-13:** SERES-Arcadis TGI - *Soil Description* (Rev #2, 16 February 2018)
- **RI-SOP-15:** SERES-Arcadis TGI – *Vertical Aquifer Profiling (VAP),* (Rev #1, 11 May 2020)
- **RI-SOP-18:** SERES-Arcadis TGI – *Surface Water Sample Collection,* (Rev #1, 8 May 2020)

17.1.1 Installation of Monitoring Wells and/or Vertical Aquifer Profile Points

The existing monitoring well network at AOC 57 was evaluated and additional vertical aquifer profiling (VAP) locations are proposed.

New VAP borings will be installed as needed, with the objective of investigating horizontal and/or vertical data gaps. It is anticipated that shallow VAP locations will be installed using DPT. Deeper VAP locations may need to be installed using sonic drilling methods. Multiple discrete groundwater samples will be collected from each VAP boring. In deeper locations, packer isolation sampling methods will be used to collect groundwater samples. This method involves deploying a stainless-steel screen and packer assembly setup inside the outer override sonic casing; 4-inch-diameter screens will be used to allow for higher purge rates and greater sample depths.

If required, overburden wells will be drilled and installed using sonic or drive-and-wash drilling methods (including continuous sampling at select locations) to targeted intervals or the top of bedrock (depending on the location).

Overburden soil will be logged by a SERES-Arcadis JV field geologist. Drill cuttings generated during investigation activities will be spread on the ground surface adjacent to the site of generation.

Each well will be screened from the bottom of the boring using 10 feet of 2-inch-inner-diameter, machine-slotted polyvinyl chloride (PVC) 0.010-inch screen and constructed in accordance with the procedures presented in the QAPP.

Each VAP location will be abandoned using tremie-grout techniques. 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 Groundwater Well Development and Water-Level Monitoring

Wells will be developed before sampling using the methodology outlined in RI-SOP-11. 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 purge water, the IDW will be containerized and transported to a central staging area for subsequent characterization and off-site disposal.

Monitoring well measuring point elevations will be recorded by a MA-licensed professional surveyor to the nearest 0.010-inch North American Vertical Datum of 1988 (NAVD 88). Water levels in all wells will be measured from the established measurement point before each groundwater sampling event using a combination electronic water level and oil-water interface probe. Water levels will then be converted to water table elevations referenced to the measuring point elevations surveyed by a MA-licensed surveyor.

17.1.3 Groundwater Sampling

Prior to the collection of groundwater samples, synoptic water levels will be collected to confirm groundwater flow direction and vertical hydraulic gradients.

Groundwater samples will be collected from VAP locations via a retractable well screen, which is advanced with 1-inch steel drilling rods (SP-22 or similar). Groundwater samples will be collected during the installation of VAP borings using the "top-down" approach (i.e., samples collected as the borehole is drilled to minimize the potential for cross-contamination). Groundwater samples will be collected in 10-foot intervals (starting at the water table) with a peristaltic or bladder pump setup with dedicated tubing. Samples will be collected after a minimum of three casing volumes have been purged from within the drilling rods.

Groundwater from wells will be purged and sampled in accordance with the USEPA Region 1, *Low Stress (Low-Flow) Purging and Sampling Procedure for the Collection of Groundwater Samples from Monitoring Wells* (USEPA, Region 1, 2017). Groundwater sampling will be completed on a quarterly basis for one year (four sampling events). Field parameters (temperature, pH, conductivity, dissolved oxygen [DO], turbidity, and oxidation-reduction potential [ORP]) will be collected in accordance with established procedures during groundwater sampling to ensure that a stable sample is collected. Turbidity samples will be collected from a T-valve placed on the sample tubing prior to the flow-through cell and measured with a stand-alone meter. Purging will be considered complete after water quality parameters specified under the low-flow protocols can be demonstrated to be stabilized; stabilization is not a requirement for VAP sampling. Sampling conditions will be noted in the sampling logs. Groundwater samples will be collected using the same flow rate at which the well was purged.

Samples to be submitted for dissolved metals analysis will be field filtered using a 0.45-micron filter. Static depth to groundwater measurements will be measured in accordance with established procedures. In addition, the pump intake depth will be recorded on field logs to provide information on pumping depth relative to the observed water table. The sampling pump intake depth will be set at the mid-point of the saturated screened interval for all wells with screen lengths of ten feet or less. Groundwater samples will be analyzed for the parameters listed in **Workshet#18.**

17.1.4 Surface Water Sampling

Surface water samples will be collected using the procedures appropriate given analytes and site conditions and may include direct collection in the sample jar and/or use of a peristaltic pump. Surface water samples are anticipated to be collected from locations accessible by foot, and a boat/vessel will not be required. Samples will be shipped on ice and handled with chain-of-custody documentation. Surface water samples will be analyzed for the parameters listed in **Workshet#18.** Water quality parameters will be collected from each sampling location including DO, ORP, specific conductance, temperature, turbidity, and pH.

17.2 AOC 57 Sampling Design and Rationale

Groundwater sampling is proposed at AOC 57 from 20 existing monitoring wells and up to three new VAP points. It is anticipated that the VAP borings will extend to a total depth of 100 feet bgs, or until refusal is encountered (whichever comes first). In addition, surface water samples will be collected from up to four locations in Cold Spring Brook.

In addition to the ROD-listed analyte identified in the LTMMP (total arsenic), samples from monitoring wells and surface water will be analyzed for the following additional parameters:

- **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. Dissolved metals samples will be field-filtered.

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

- **TOC, sulfate, nitrate, nitrite, and methane,** to assess redox status, residual reducing potential, and attenuation of petroleum hydrocarbons. TOC will contribute to ongoing reducing potential by consuming dissolved oxygen (potentially limiting iron reoxidation and extending the timeframe for arsenic 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. Methane analyses will be used to further evaluate petroleum hydrocarbon degradation and geochemical conditions.

- **VPH and EPH,** to assess the degree of naturally occurring TOC, and determine whether the TOC can be attributed to petroleum or non-petroleum compounds.

QAPP WORKSHEET #18

Sampling Locations and Methods

Worksheet#17 describes the planned sampling events for the SRI at AOC 57. Sampling locations and analyses for the evaluation are summarized below.

Sampling Location	Matrix	Sample Depth /Screening Interval (feet below ground surface)	Sample ID [a]	Total Metals [a]	Dissolved Metals [b, c]	VPH/EPH	TOC	Methane	Sulfate	Nitrate/Nitrite	Ferrous Iron	Sample Type	Sampling SOP Reference	Rationale for Sampling Location
Monitoring Wells (Existing)	Groundwater	Groundwater samples will be collected in accordance with the methodologies outlined in the LTMMP QAPP	5702MW-20-01A (DDMMYY)	X	X	X	X	X	X	X	X	Discrete	RI-SOP-03, RI-SOP-06, RI-SOP-07, RI-SOP-08, RI-SOP-09, RI-SOP-10	Deep overburden wells adjacent to 57M-03-05X. Assess vertical extent of arsenic and confirm hydraulic gradient.
			5702MW-20-01B (DDMMYY)											
			5702MW-20-02A (DDMMYY)											Upgradient from areas with historical ROD-specified COC exceedances (arsenic)
			5702MW-20-03A (DDMMYY)											Crossgradient from areas with historical ROD-specified COC exceedances (arsenic)
			5702MW-20-04A (DDMMYY)											Crossgradient from areas with historical ROD-specified COC exceedances (arsenic)
			5703MW-20-01A (DDMMYY)											Shallow overburden well adjacent to 57M-03-05X. Assess vertical extent of arsenic and confirm hydraulic gradient.
			5703MW-20-01B (DDMMYY)											Overburden overburden well adjacent to 57M-03-05X. Assess vertical extent of arsenic and confirm hydraulic gradient.
			5703MW-20-02A (DDMMYY)											Crossgradient from 57M-95-03X
			5703MW-20-03A (DDMMYY)											Crossgradient from areas with historical ROD-specified COC exceedances (arsenic)
			5703MW-20-04A (DDMMYY)											Downgradient from 57M-95-03X; deep overburden well
			57M-03-02X (DDMMYY)											Crossgradient from 57M-03-05X
			57M-03-03X (DDMMYY)											Downgradient / Crossgradient from 57M-03-05X
			57M-03-04X (DDMMYY)											Downgradient / Crossgradient from 57M-03-05X
			57M-03-05X (DDMMYY)											Historical location with ROD-specified COC exceedances (arsenic)
			57M-03-06X (DDMMYY)											Crossgradient from 57M-03-05X
			57M-95-03X (DDMMYY)											Historical location with ROD-specified COC exceedances (arsenic)
			57M-95-06X (DDMMYY)											Historical ROD-specified COC exceedances (arsenic)
			57M-96-11X (DDMMYY)											Historical location with ROD-specified COC exceedances (arsenic)
			57M-96-12X (DDMMYY)											Crossgradient from areas with historical ROD-specified COC exceedances (arsenic)
			57WP-06-03 (DDMMYY)											Adjacent to 57M-96-11X and screened in deeper overburden. Assess vertical extent of arsenic and confirm hydraulic gradient.
			57P-98-03X (DDMMYY)											Crossgradient from 57M-96-11X
			57P-98-04X (DDMMYY)											Downgradient from 57M-96-11X
Monitoring Wells (Proposed)	Groundwater	Groundwater samples will be collected in accordance with the methodologies outlined in the LTMMP QAPP	CSMW-23-02 (DDMMYY)	X	X	X	X	X	X	X	X	Discrete	RI-SOP-03, RI-SOP-06, RI-SOP-07, RI-SOP-08, RI-SOP-09, RI-SOP-10	Proposed locations located to the east of Cold Spring Book. These locations are proposed as part of the Phase II Remedial Investigation for PFAS Area 1. The installation and sampling of these locations will be completed (a) pending the approval of the PFAS Work Plan (sampling will be conducted in accordance with proposed PFAS investigation schedule) and (b) pending the ability to execute and retain an ROE
			CSMW-23-04 (DDMMYY)											

Sampling Location	Matrix	Sample Depth /Screening Interval (feet below ground surface)	Sample ID [a]	Total Metals [a]	Dissolved Metals [b, c]	VPH/EPH	TOC	Methane	Sulfate	Nitrate/Nitrite	Ferrous Iron	Sample Type	Sampling SOP Reference	Rationale for Sampling Location
														permit with private property owners for access.
VAP (proposed) [d]	Groundwater	Groundwater samples will be collected in accordance with the methodologies outlined in the PFAS QAPP	5702VP-23-01 (DDMMYY)[c]	**X**	**X**	**X**	**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	Downgradient from 57M-03-05X
			5703VP-23-01 (DDMMYY) [c]											Upgradient of 57M-95-03X and 57M-96-11X.
			5703VP-23-02 (DDMMYY) [c]											Upgradient of 5703VP-23-01; contingent location based on the groundwater results from this location.
			CSVP-23-02 (DDMMYY) [c]											Proposed locations located to the east of Cold Spring Book. These locations are proposed as part of the Phase II Remedial Investigation for PFAS Area 1. The installation and sampling of these locations will be completed (a) pending the approval of the PFAS Work Plan (sampling will be conducted in accordance with proposed PFAS investigation schedule) and (b) pending the ability to execute and retain an ROE permit with private property owners for access.
			CSVP-23-03 (DDMMYY) [c]											
Cold Spring Brook	Surface Water	Groundwater samples will be collected in accordance with the methodologies outlined in the LTMMP QAPP	57-AREA2-SW1 (DDMMYY)	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	Discrete	RI-SOP-07, RI-SOP-08, RI-SOP-09, & RI-SOP-18	Historical downgradient surface water sampling locations in Cold Spring Brook.
			57-AREA2-SW2 (DDMMYY)											
			57-AREA3-SW3 (DDMMYY)											
			57-AREA2-SW4 (DDMMYY)											Sample will be collected pending sampling results from proposed VAP location 5702VP-23-01.

NOTE:

NA=not analyzed

a. Total Metals= aluminum, iron, arsenic, and manganese.
b. Dissolved Metals= aluminum, iron, arsenic, and manganese.
c. All dissolved metals samples will be field-filtered.
d. Multiple groundwater samples will be collected from discrete sampling depths at each VAP location.
e. Ferrous iron samples will be collected with a Hach field kit (or similar)
f. 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.

QAPP WORKSHEET #20

Field QC Sample Quantities and Control Frequencies

(UFP-QAPP Section 3.1.1 and 3.1.2) / (USEPA 2106-G-05 Section 2.3.5)

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	
AOC 57 – Groundwater / Surface Water												
Metals - Total	**160**	1/10	16	NA	0	NA	0	1/20	8	1/20	8	**192**
Metals- Dissolved	**160**	1/10	16	NA	0	NA	0	1/20	8	1/20	8	**192**
VPH	**160**	1/10	16	1/day	14	1/day	3	1/20	8	1/20	8	**209**
EPH	**160**	1/10	16	NA	0	NA	0	1/20	8	1/20	8	**192**
Sulfate	**160**	NA	0	NA	0	NA	0	NA	0	NA	0	**160**
Nitrate	**160**	NA	0	NA	0	NA	0	NA	0	NA	0	**160**
Nitrite	**160**	NA	0	NA	0	NA	0	NA	0	NA	0	**160**
Methane	**160**	NA	0	NA	0	NA	0	NA	0	NA	0	**160**
TOC	**160**	NA	0	NA	0	NA	0	NA	0	NA	0	**160**

Notes:

a. Sample quantities are approximate.
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 collected during the installation of VAP borings, expected duration of 8 days. Samples will be analyzed for dissolved metals only.
Ferrous iron samples will be collected with a Hach field kit (or similar).

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 **Appendix 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 #5, 3 January 2022)	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 (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 #1, 8 May 2020)	SERES-Arcadis JV	NA	No
RI-SOP-11	Monitoring Well Development (Rev #1, 12 April 2012).	SERES-Arcadis JV	NA	No
RI-SOP-13	Soil Description (Rev #3, 15 April 2022)	SERES-Arcadis JV	NA	No
RI-SOP-15	Vertical Aquifer Profile (VAP) Sampling (JV; Rev #2, 15 June 2022)	SERES-Arcadis JV	NA	No
RI-SOP-18	Surface Water Sample Collection, (Rev #2, 13 June 2022)	SERES-Arcadis JV	NA	No

QAPP WORKSHEET #23: ANALYTICAL STANDARD OPERATING PROCEDURE REFERENCES

(UFP-QAPP Manual Section 3.2.1)
(USEPA 2106-G-05 Section 2.3.4)

All method SOPs pertinent to environmental investigations are included for reference in **Attachment B.**

SOP #	Title, Revision Date, and/or Number	Definitive or Screening Data	Matrix/ Analytical Group	Instrument	Organization Performing Analysis	Modified for Project Work? (Yes/No)
DOC316.5 3.01049	Iron, Ferrous 1,10-Phenanthroline (Method 8146, Powder Pillows, 0.02 to 3.00 mg/L Fe2+)	Screening	Aqueous/ Metals	Field Test Kit	S-A JV	No

Notes:

LC/MS/MS = liquid chromatography with tandem mass spectrometry
N/A = not applicable

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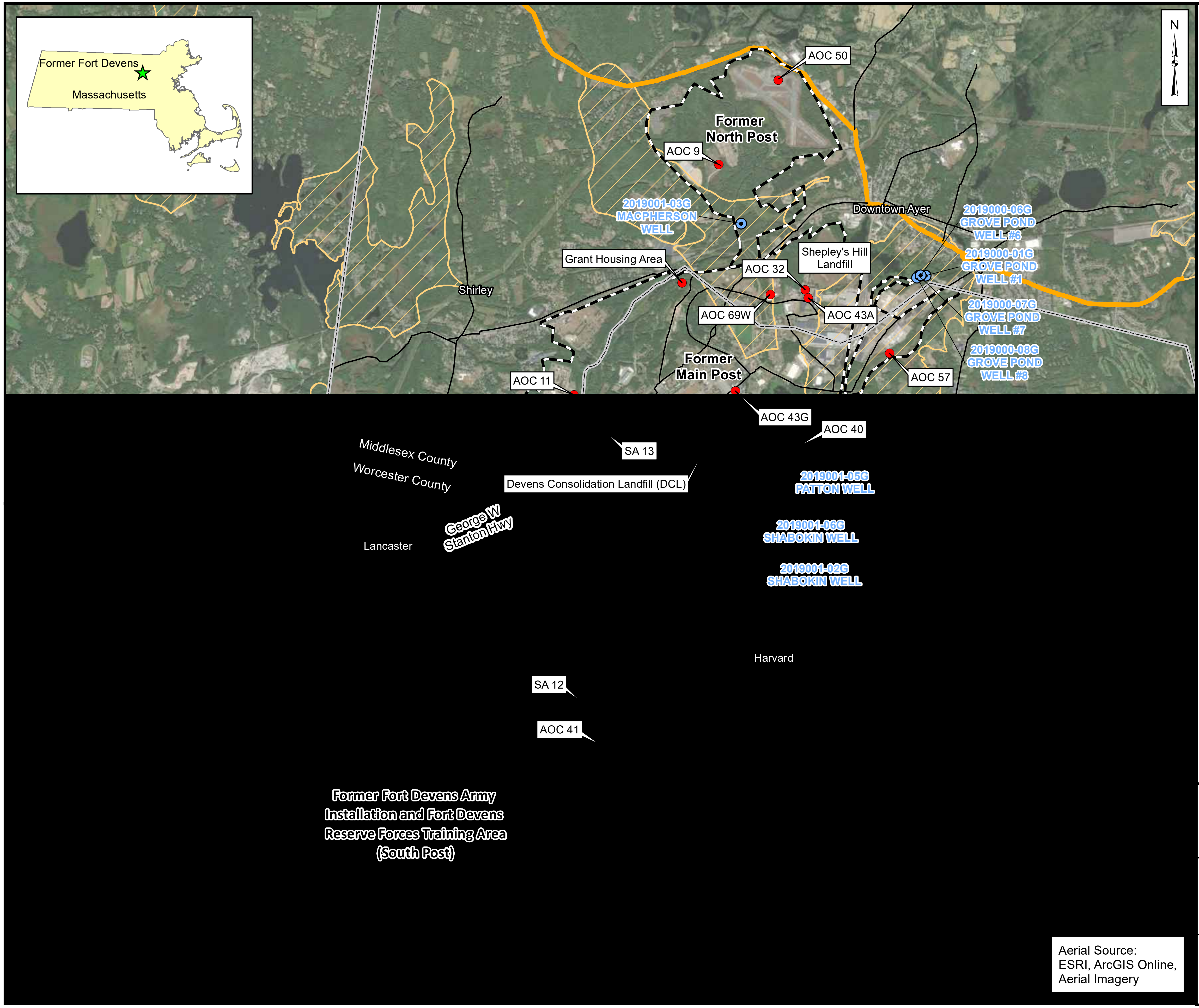
FIGURES



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 57 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

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
11 Technology Drive
North Chelmsford, MA 01863

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Prepared by:___________________________________ ____________
(Robert Reinhart, Quality Assurance Unit) Date

Approved by:___________________________________ ____________
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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

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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. <u>All changes and modifications must be approved and included in a revised SAP/QAPP before implementation in field.</u>

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. <u>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:</u>

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

Cohen, R.M. and J.W. Mercer, 1993, *DNAPL Site Evaluation*; C.K. Smoley (CRC Press), Boca Raton, Florida.

Robert W. Puls and Michael J. Barcelona, *Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures*, April 1996 (EPA/540/S-95/504).

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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.

U.S Environmental Protection Agency, EPA SW-846.

U.S Environmental Protection Agency, 40 CFR 136.

U.S Environmental Protection Agency, 40 CFR 141.

Vroblesky, Don A., Clifton C. Casey, and Mark A. Lowery, Summer 2007, Influence of Dissolved Oxygen Convection on Well Sampling, *Ground Water Monitoring & Remediation* 27, no. 3: 49-58.

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.

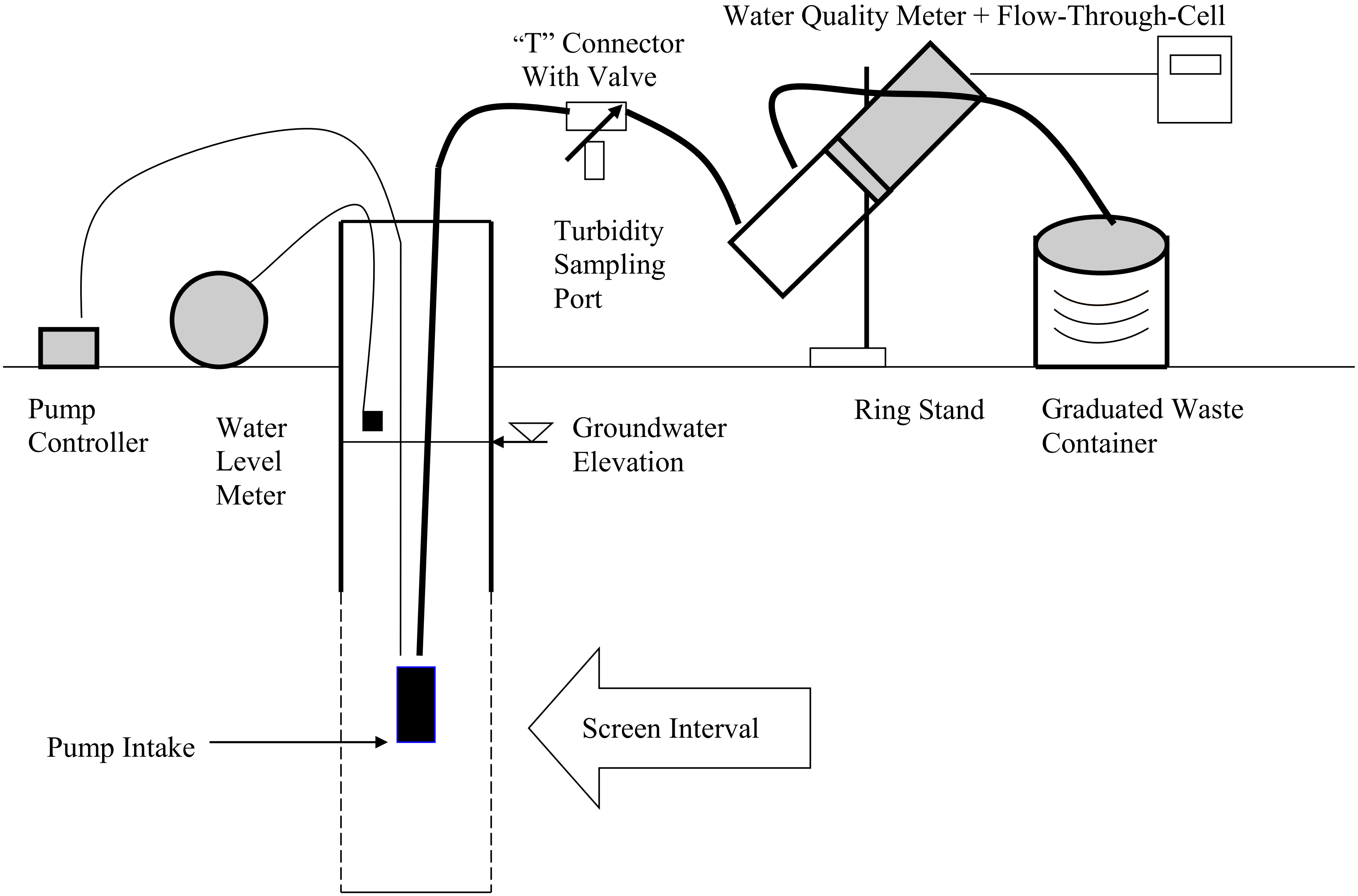
If the pump's tubing is not completely filled with water and the samples are being collected for VOCs and/or dissolved gases analyses using a centrifugal or peristaltic pump, do the following:

> 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)

TECHNICAL GUIDANCE INSTRUCTION

Ground Penetrating Radar

MAY 2020

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Initial Draft	001	March 2017	N/A	N/A	Grant Sprick
Review	002	March 22, 2017	N/A	See tracked changes	Brent Barker
Final Draft/Signatures	003	October 12, 2018	All	Modification to TGI format	Greg Byer, Brent Barker
Revision/ Signatures	004	May 11, 2020	All	Update of Technical Guidance	Brent Barker, Greg Byer

CONTENTS

I. 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 high frequency (generally between 100 and 1000 Megahertz [MHz]) electromagnetic waves into the ground and detects and records the energy reflected back to the surface with a frequency-matched receiver. The GPR unit is generally pulled or pushed across the ground surface and data collection should be done in a methodical manner either in a series of parallel lines or a grid of lines crossing at right angles to allow subsequent computer processing and analysis. Energy is reflected from boundaries that possess contrasting dielectric constants or electrical conductivities. Reflections typically occur at lithologic contacts where there may be changes in water content and/or mineral composition. 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 extremely high amplitude reflections 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 requirements of GPR investigations are the depth of penetration and required horizontal and vertical resolution. Both depth of penetration and vertical resolution are inversely related to the transmitter center frequency. Higher frequency will potentially yield better resolution, but a loss of total depth of penetration may result. Conversely, a lower frequency will yield less vertical resolution while offering deeper penetration. A key variable in signal loss is the degree of attenuation of the transmitted signal. As a rule, environments that are electrically conductive such as soils or rocks with high clay content or 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 or soil moisture, frozen ground, or massive non-conductive rock offer the greatest success to GPR surveys.

Choice of transmitter frequency can generally be matched with project objectives and limitations posed by geologic conditions and/or infrastructure. The following are examples of applications by frequency range:

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

II. 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 Geophysics Practice Area.

III. 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 forms, Site plans, field notebook, spray paint and camera.
- Specific GPR systems matched to project objectives and site conditions. 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. The most common acceptable GPR system manufactures include:
    - 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, preferably, a secondary antennae of appropriate signal frequency1 to match anticipated dimension and depth of objective(s).
- Non-conductive measuring tape or measuring wheel; and
- Optionally a GPS unit which can be mounted to the GPR system for integration of GPS position into GPR data files.
- Optionally data processing software. Arcadis has licenses to 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).

IV. CAUTIONS

The effectiveness of GPR is site-specific and subject to the skill level of the operator. Reliability and efficiency are enhanced when used in conjunction with other geophysical methods. Soils with higher electrical conductivity rapidly attenuate the radar energy, reducing the penetration depth and resolution. Clayey soils and saturated soils, particularly when high in soluble salts, limit the usefulness of GPR. Other potential interference sources include subsurface debris, rebar reinforced concrete, above ground reflective objects (cars, surface water, transmission lines), and electromagnetic generating apparatus (electrical generators, radio transmitters).

Both metallic and non-metallic utilities may be imaged by GPR. However, it should be noted that due to differences in the properties of materials, locating a non-metallic utility (plastic, vitrified clay tile, etc.) may be more difficult than a metallic pipe because of a lesser contrast in dielectric constant between non-metallics and soil. A 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) of depth to a depth of 12 feet (3.7 m). For instance, one may expect to resolve a utility 10 inches (25 cm) in diameter at a depth of 10 feet (3 m). 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.

Also, the presence of reinforcing bar (rebar) in concrete can limit the resolution of pipes present below the concrete. The resolution of smaller diameter pipes found within or just below the concrete may be completed masked by the high response caused 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 the subsurface. As a result, a metallic ceiling located 12 feet above the floor will appear in the GPR data at a “depth” of about 3 to 4 feet.

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.

V. 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.

VI. 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) for GPR. In general, soils with greater than 35% clay content are considered restrictive, and soils with less than 10% clay content are considered favourable for deep penetration with GPR.
3. Evaluate meteorological information regarding recent or forecasted precipitation that could impact soil moisture content and GPR effectiveness. Schedule GPR surveys appropriately.
4. Perform site reconnaissance in advance to identify potential sources of surface interference such as reinforced concrete, large metal objects, or electrical generators).
5. Consider complimentary technologies to supplement GPR and provide multiple lines of evidence. Technologies may include radio frequency, magnetic, electromagnetic surveys, or electrical resistivity surveys.
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.

7. Consider the depth and size of subsurface features that GPR will be used for identification. Attempt to match the signal frequency to the expected depth and size of the subsurface feature. Change antennae as necessary for variable depths and sizes of target objects. Consider the selection of a primary and secondary choice of antennae and use multiple antennae as necessary. Evaluate GPR for known utility locations and/or relative to EM results, as an indication of potential effectiveness. A guideline for effective locating depths for utilities is 1-inch (2.5 cm) diameter of utility can be discerned for each foot (0.3 m) of depth to a depth of 12 feet (3.7 m). Expect a much coarser resolution below 12 feet.
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.
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.
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.
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 and storage approach is generally one of two types. One approach 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 surveyed with GPR or taped to known locations via triangulation. This first approach is most appropriate for marking out USTs relatively simple utility patterns. The second approach is applicable to mapping large areas, complex utility layouts, fill mapping, or other geologic objectives. In such circumstances the best practice is to layout a control grid and 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 grid of lines at orthogonal orientations. In this second approach 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.
14. For projects where a complete grid of data is stored, 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.

VII. 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.

VIII. DATA RECORDING AND MANAGEMENT

Conduct data processing and analysis in accordance with the manufacturer's recommendations and industry practice. Processed data is available in electronic form. A copy of the PDF files for each individual GPR traverse should be included in the project directory along with scans of the field notes. Electronic data (raw and processed) should be maintained in accordance with data management procedures as outlined in the project sampling analysis plan (SAP), quality assurance project plan (QAPP), data quality objectives plan, or other applicable plan or guidance document.

IX. 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.

X. REFERENCES

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

TGI – MANUAL WATER-LEVEL AND NAPL MONITORING

Rev: #1

Rev Date: May 8, 2020

VERSION CONTROL

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0	October 11, 2018	All	Updated and re-written as TGI	Marc Killingstad Everett H. Fortner III
1	May 8, 2020	All	Updated and added NAPL gauging	Marc Killingstad Everett H. Fortner III Andy Pennington

APPROVAL SIGNATURES

Prepared by:		05/08/2020
	Everett H. Fortner III, PG	Date:
Technical Expert Reviewed by:		05/08/2020
	Marc Killingstad (Technical Expert)	Date:

1 INTRODUCTION

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

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

This document is not considered to be all inclusive nor does it apply to 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.

2 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 describes the equipment, field procedures, materials, and documentation procedures to measure and record water-levels using the aforementioned equipment. 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).

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*.

3 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.

4 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

5 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.

6 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.

7 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 be requested 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 *Decontamination 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 Decontamination after *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.

8 WASTE MANAGEMENT

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

9 DATA RECORDING AND MANAGEMENT

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 data for accuracy and provide feedback.

10 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 interface probe 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.

11 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 Well Depth Measurement.* January 29.

ATTACHMENT A

Water-Level Measurement Form

ARCADIS

Water-Level Measurement Form

Project No.: ____________________

Site Location: ____________________

Instrument Model ____________________

Field Personnel: ____________________

Date: ____________________

Instrument Serial No.: ____________________

		W.L. Measurements			Comments		
Well Number	Time	TD (feet)	DTW (feet)	DTL (feet)	Well Locked	Lock Condition	Other Comments

W.L.	Water Level
TD	Total Depth
DTW	Depth To Water
DTL	Depth To NAPL

ARCADIS

Water-Level Measurement Form

Project No.: ____________________

Site Location: ____________________

Instrument Model ____________________

Field Personnel: ____________________

Date: ____________________

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		W.L. Measurements			Comments		
Well Number	Time	TD (feet)	DTW (feet)	DTL (feet)	Well Locked	Lock Condition	Other Comments

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TGI - IN-SITU AND EX-SITU WATER QUALITY PARAMETERS

Rev: 0

Rev Date: October 16, 2018

VERSION CONTROL

Revision No	Revision Date	Page No(s)	Description	Reviewed by
0	October 16, 2018	All	Updated and re-written as TGI (in-situ and ex-situ adaptation)	Marc Killingstad

APPROVAL SIGNATURES

Prepared by: Chris Shepherd 10/16/2018

Chris Shepherd Date:

Technical Expert Reviewed by: 10/16/2018

Marc Killingstad (Technical Expert) Date:

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2 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 surface water will be measured in-situ or ex-situ with a multiparameter 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 millisiemens per centimeter or mS/cm) by 0.65, which assumes that sodium chloride 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 natural as 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 in water 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).

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 negative results 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 will result 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 certain reactions 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.

The measurement of turbidity is useful in that it expresses the relative amount of suspended particles in the water column. Turbidity cannot be measured in-situ.

Refer to the following documents for procedures of groundwater sample collection:

TGI – Standard Groundwater Sampling for Monitoring Wells (describes the methods to be used to collect groundwater samples using traditional purging and sampling techniques)

TGI - Low-Flow Groundwater Purging and Sampling Procedures for Monitoring Wells (describes low-flow purging and sampling techniques)

TGI – Passive Diffusion Bag Sampling, TGI – Groundwater Sampling with HydraSleeves™, and *TGI - Bailer-Grab Groundwater Sampling* (describes no-purge/passive sampling techniques)

3 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)/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 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.

4 EQUIPMENT LIST

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

- Site-specific HASP and health and safety documents identified in the HASP (e.g., job safety assessments [JSAs])
- Field Implementation Plan (FIP) that includes site map with sampling locations, well construction records (table or logs), sampling plan, and prior groundwater sampling records (if available)
- Field notebook, pen(s) (indelible ink) and/or smart device (smart phone or tablet)
- Field laptop / data manager
- Water Quality Measurement Log (**Attachment 1**)
- Water Quality Meter Calibration Log (**Attachment 2**)
- Appropriate personal protective equipment (PPE) (e.g., latex or nitrile gloves, safety glasses, etc.) as specified in the HASP
- Traffic cones, delineators, and caution tape as appropriate for securing the work area as specified in the Traffic Safety Plan (TSP)
- Well key(s)
- Photoionization detector (PID), flame ionization detector (FID) or other air monitoring equipment, as needed, in accordance with the HASP
- Dedicated plastic sheeting (e.g., Weatherall Visqueen) or other clean surface to prevent sampling equipment from coming in contact with the ground
- Electronic water-level indicator (e.g., Solinist Model 101) or oil/water interface probe with 0.01-foot accuracy (oil/water as appropriate, note that sampling will not be performed when sheen or light non-aqueous phase liquid [LNAPL] is present)
- Multiparameter (temperature/pH/specific conductivity/ORP/turbidity/DO) water quality meter or sonde with 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
- Operation manual(s) for multiparameter meter
- Water quality meter extension cable (as needed for in-situ readings of deepest well)
- Standard solutions for calibration
- Multimeter maintenance kit and extra DO membranes if using amperometric DO probe
- Extra batteries for the various instruments
- Tape measure and/or masking tape for in-situ readings
- Decontamination equipment (buckets, distilled or deionized water, cleansers appropriate for removing expected chemicals of concern, paper towels)

5 CAUTIONS

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

Verify the meter is intended for in-situ measurements and that all necessary parts are available prior to field mobilization.

Check and record the expiration dates of calibration fluids. Verify that calibration readings are reasonable and correspond to previous calibration readings when available. Expired 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.

Turbidity meters will be stored and used in dry locations.

When taking measurements in the field, verify that readings make sense and compare to historical readings when possible.

6 HEALTH AND SAFETY CONSIDERATIONS

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

Appropriate personal protective equipment (PPE) will be worn at all times in line with the task and the site-specific HASP. 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 may expose field personnel to hazardous materials such as contaminated groundwater or non-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 well head), 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 at a site with hazardous levels of volatile organic compounds, headspace and/or breathing zone readings will be measured prior to working at/in the well, in accordance with the HASP.

7 PROCEDURE

The procedure is organized into the following sections:

A. Standard Procedures – calibration, operation, and maintenance procedures that apply to all methods and meters
B. Calibration – general calibration procedures for:
    a. Multimeter
    b. Turbidity meter
C. Operation – general measurement operations for:
    a. Ex-situ measurements
        i. Multimeter
        ii. Turbidity meter
    b. In-situ measurements (downhole multimeter only)
D. Maintenance
    a. Multimeter
    b. Turbidity meter

7.1 Standard Procedures

Calibration

- The meter will be calibrated following the manufacturer’s instructions as calibration steps vary by manufacturer.
- Calibration information will be recorded in the calibration log (Attachment 2) and the field notebook.
- Check batteries/power levels during calibration.
- More frequent calibration may be necessary in harsh conditions or per project plans.

Operation

- The meter will be operated following the manufacturer’s instructions.

- Mutimeters can be operated in-situ (down-hole, in water, etc.) or ex-situ (water is transferred to container for measurement).
- Two readings will be made after stabilization (minimum 2 minutes) and the average will be recorded in the field notebook or both measurements will be recorded in the water quality measurement log and/or logger.
- Additional details for pH, conductivity, temperature, dissolved oxygen, and turbidity operation are presented in section **7.3 Operation** below.

Maintenance

- 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.
- A replacement meter and probes will be available onsite or ready for overnight shipment, as necessary.
- Additional details for pH, conductivity, temperature, dissolved oxygen, and turbidity maintenance are presented in section **7.4 Maintenance** below.
- More frequent maintenance (probe replacement, sensor reconditioning, etc.) may be necessary in harsh conditions or per project plans.

7.2 Calibration

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
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 require longer 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
8) **pH Calibration** – when in use, the pH meter will be calibrated daily, at a minimum.
    i. Connect electrode (if applicable) or remove protective cap from electrode
    ii. Rinse end of electrode in distilled/deionized water and shake off excess water

- iii. Measure and record temperature of buffer solutions
- iv. Immerse pH electrode in pH buffer 7.00, set the temperature to that of the buffer 7.00, and allow sufficient time for the electrode to stabilize
- v. Adjust the calibration for the correct readout and temperature
- vi. Confirm/press the calibration button
- vii. Remove electrode from buffer and rinse with distilled/deionized water
- viii. 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
- ix. Adjust the calibration for the correct readout and temperature
- x. Confirm/press the calibration button
- xi. Rinse electrode with distilled/deionized water
- xii. A pH 10 calibration will also be performed if high pH is anticipated, following manufacturers procedures
- xiii. The pH meter is calibrated

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

  - i. Conductivity is generally measured in specific conductivity (temperature compensated), verify with the FIP/work plan
  - ii. Soak the probe in distilled/deionized water for at least 30 minutes
  - iii. Remove the probe from the water and fling out drops clinging inside
  - iv. Immerse the probe to or beyond the vent holes in a beaker containing 1.413 mS/cm standard solution and gently agitate vertically to remove entrapped air
  - v. Repeat Steps 3 and 4 at least once more
  - vi. 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 using the air calibration method or less frequently if using an optical sensor (see below).

  - i. Preparation
    1. Polarographic sensor – periodically recondition sensor, replace fluids, and Teflon® membrane, per manufacturer, and air bubbles should not be present
    2. Galvanic sensor – Periodically recondition sensor, replace fluids, and membrane, per manufacturer, and air bubbles should not be present

3. Optical sensor – Per manufacturer, most will only require field checks and maintenance, however, weekly checks are recommended to verify the accuracy, at a minimum

ii. Obtain a barometric pressure reading from a daily weather report or from the instrument, as required by instrument

iii. Keep instrument upright and vent cap/cover while retaining a small amount of clean water (do not cover probes) for non-optical sensors only

iv. 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 barometric pressure)

v. Press calibration button, if reading is more than 2% off of the standard

12) **Oxidation reduction potential (ORP) calibration** – when in use, the ORP meter will be calibrated daily, if required.

    i. Rinse the probe in distilled/deionized water

    ii. Remove the probe from the water and fling out drops clinging inside

    iii. Immerse the probe in the ORP solution. Gently agitate vertically to remove entrapped air

    iv. Repeat Steps 3 and 4 at least once more

    v. Press calibration button, if reading is more than 2% off of the standard

13) Adjust the instrument to READ or LOGGING mode, per instruction manual and project plans; the instrument is now ready for use

Turbidity Calibration (if required)

Turbidity meters are generally calibrated weekly, unless required otherwise. However, daily checks are recommended to verify the accuracy. 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 finger prints

4) Dry the outside of the sample turbidity tubes with a clean, lint-free cloth or disposable wipe and allow 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 inaccurate results

5) Wipe the 1 Nephelometric turbidity unit (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.

7.3 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 sample from a well or water body for ex-situ measurement.

Ex-situ Operation

Multimeter

1) Fill two 100-mL plastic disposable beakers or clean beakers with water from the sample
2) Insert the probe into the first beaker immersing all sensors and allow to stabilize (2 minutes at minimum)
3) Record readings
    i. Temperature – in degrees Celsius or Fahrenheit
    ii. pH – in standard units between 0 and 14, in 0.01 increments
    iii. Specific conductivity – in mS/cm or microsiemens per centimeter (uS/cm)
    iv. DO – in mg/L and percent (will typically read between 0 and 15 mg/L)
    v. ORP – in millivolts (mV; will typically read between -1,400 mV and + 1,400 mV), if required
4) Rinse probe off with distilled/deionized water
5) Repeat Steps 2 thru 4 for the other beaker
6) Log results on the water quality measurement log and/or in field notebook - the average will be the actual result
7) Rinse probe off 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 Flow Groundwater Purging and Sampling.*

Turbidity Meter

1) Fill the two cleaned, manufacturer provided sample tubes with water from the sample
2) Wipe off and dry the outside of the sample turbidity tubes with a clean, lint-free cloth or disposable 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)

    i. If readings are over the instrument limit, a single 2X dilution can be run by mixing the sample with equal parts distilled or de-ionized water and gently mixing
    ii. 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 be qualified 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 will be 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 Flow Groundwater Purging and Sampling. The turbidity sample is recommended to be collected prior to passing through the flow through cell.*

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 a mild 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
7) Slowly lower the probe into the well or water body to the desired measurement interval using caution to prevent rubbing of cable on the well and minimize water and sediment disturbance
8) Allow readings to stabilize (typically 1 to 3 minutes)
    i. For many instruments, the instrument may need to be slowly oscillated up and down a few inches to circulate water around the probes
9) Record readings
    i. Temperature – in degrees Celsius or Fahrenheit
    ii. pH – in standard units between 0 and 14, in 0.01 increments
    iii. Specific conductivity – in mS/cm or uS/cm
    iv. DO – in mg/L <u>and</u> percent (will typically read between 0 and 15 mg/L)
    v. ORP – in mV (will typically read between -1,400 mV and +1,400 mV), if required
10) Repeat steps 4 through 9 to complete targeted in-situ measurements

11) Log results on the water quality measurement log and/or in field notebook
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 a mild soap and warm water

7.4 Maintenance

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 robe 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

Turbidity Meter

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 etched and 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

8 WASTE MANAGEMENT

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

PPE (such as gloves, disposable clothing, and other disposable equipment) resulting from personnel cleaning procedures activities will be placed in plastic bags. These bags will be disposed of as general waste unless specified otherwise.

9 DATA RECORDING AND MANAGEMENT

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.

In general, documentation of the following information is required:

- Calibration – calibration information will be recorded on a calibration form, field log, or electronic device 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 project plans
  - Instrument model
  - Measurement date/time
  - Field personnel
  - Weather
  - Measurement location and depth, if applicable
  - Value of readings and average reading, if applicable
  - Units of readings
  - In-situ vs ex-situ measurement method
  - Key observations

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

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 the frequency of calibrations.

10 REFERENCES

Not applicable.

11 ATTACHMENTS

Attachment 1 - Water Quality Measurement Log

Attachment 2 - Water Quality Meter Calibration Log

ATTACHMENT 1

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) ____________________

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 2

Water Quality Meter Calibration Log

ARCADIS Design & Consultancy for natural and built assets

WATER QUALITY METER CALIBRATION LOG

PROJECT NAME	
PROJECT NO.	
MODEL	
SERIAL #	
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	

AUTOCALIBRATION

AUTOCAL SOLUTION		CAL. READING	CAL. RANGE	TIME	CALIBRATION RANGES (1)	
(LOT #)						
(EXP. DATE)						
CALIBRATED PARAMETERS		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

SOP - SAMPLE CHAIN OF CUSTODY

Rev: #2

Rev Date: April 29, 2020

VERSION CONTROL

Revision No	Revision Date	Page No(s)	Description	Reviewed by
0	April 19, 2017	All	Re-write to COC only	Richard Murphy
1	May 23, 2017	4 9 7	Add: Guidance on use of previous version of SOP. 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 Remove obsolete link	Lyndi Mott

APPROVAL SIGNATURES

Prepared by: 05/23/2017

Peter C. Frederick Date:

Technical Expert Reviewed by: 05/29/2020

Lyndi Mott (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 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.

2 SCOPE AND APPLICATION

This Standard Operating Procedure (SOP) 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 SOP:

Although not recommended, Arcadis program-, project-, and client-teams may be able to use the previous version of this SOP 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 SOP or to continue using the previous version.

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

When adopting this new SOP, 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. QAPPs, Work Plans, SAPs, etc.) or in a more detailed SOP or TGI specific to that sampling activity, whether related to media, constituent/analyte, client, state, etc.

In addition, adopting this new SOP will require users to refer to the Arcadis 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.

3 PERSONNEL QUALIFICATIONS

Arcadis personnel performing work under the purview of this SOP 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.

4 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.

5 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 (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.

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.

6 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

7 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. <u>Unique Sample Identifier</u> – 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,” 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. When appropriate for the analytical procedure used, 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.

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.

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.

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

    1) Date: either mm/dd/yy e.g., 01/01/17 <u>OR</u> 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 or it is signed upon laboratory receipt from the overnight courier service.

4. 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.
5. Pages of the COC must retain a page count of the total number of pages; e.g., Page <u>1</u> of <u>3</u>, Page <u>2</u> of <u>3</u>, Page <u>3</u> of <u>3</u>.
6. 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.
7. 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.
8. 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.

8 WASTE MANAGEMENT

Not Applicable.

9 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.

10 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 Sampling and Analysis Plan (SAP), Quality Assurance Project Plan (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.

11 REFERENCES

Arcadis Client Document Retention Guide

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

EPA Region III – *Sample Submission Procedures for the Office of Analytical Services and Quality Assurance (OASQA) Laboratory Branch* revision 13.0 January 29, 2014

EPA Region I Office Environmental Measurement and Evaluation – *Standard Operating Procedures for Chain of Custody of Samples* revision 1 March 25, 2002

EPA Region IV Science and Ecosystem Support Division *Operating Procedure for Sample and Evidence Management* January 29, 2013

APPENDIX A
Chain of Custody Form

ARCADIS

ID#

CHAIN OF CUSTODY & LABORATORY ANALYSIS REQUEST FORM

Page ____ of ____

Lab Work Order #

Send Results to:

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

Preservative								
Filtered (✓)								
# of Containers								
Container Information								

PARAMETER ANALYSIS & METHOD

Keys

Preservation Key:	**Containment Information Key**
A. H_2SO_4	1. 40 ml Vial
B. HCL	2. 1 L Amber
C. HNO_3	3. 250 ml Plastic
D. NaOH	4. 500 ml Plastic
E. None	5. Encore
F. Other: ______	6. 2 oz. Glass
G. Other: ______	7. 4 oz. Glass
H. Other: ______	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 (✓) ☐ Intact ☐ Not Intact	Printed Name:	Printed Name:	Printed Name:	Printed Name
☐ Cooler packed with ice (✓)		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

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: 1

Rev Date: May 8, 2020

VERSION CONTROL

Revision No	Revision Date	Page No(s)	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

APPROVAL SIGNATURES

Prepared by: Derrick Maurer Date: 02/23/2017

Derrick Maurer

Technical Expert Reviewed by: Date: May 8, 2020

Marc Killingstad (Technical Expert)

1 INTRODUCTION

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2 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 includes: soil sampling tools; groundwater, sediment, and surface-water sampling devices; water testing instruments; down-hole instruments; and other activity-specific sampling equipment. Non-disposable equipment will be cleaned before collecting each sample, between 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.

3 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 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 equipment required for equipment decontamination is presented below:

- Health and safety equipment, including appropriate PPE, as required in the site Health and Safety Plan (HASP)
- Deionized water that meets that 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 VOCs, 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
- 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

5 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 rinsate 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.

6 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.

7 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 should be handled by workers wearing clean gloves, properly changed to prevent cross-contamination.

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 should not be used at sites where that may be a constituent of concern (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 should 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 should be placed on or in clean polyethylene sheeting to avoid contact with the ground surface.

8 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).

9 DATA RECORDING AND MANAGEMENT

Equipment cleaning and decontamination will be noted in the field notebook for 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.

10 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 of the tools needed to collect a specific sample.

11 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.

Design & Consultancy
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TECHNICAL GUIDANCE INSTRUCTION - MONITORING WELL DEVELOPMENT

Rev: #0

Rev Date: April 24, 2017

VERSION CONTROL

Revision No	Revision Date	Page No(s)	Description	Reviewed by
0	4/24/2017	All	Re-written as TGI	Marc Killingstad

APPROVAL SIGNATURES

Prepared by:	Jay Erickson	Date: 4/24/2017
Technical Expert Reviewed by:	Marc Killingstad	Date: 4/24/2017

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2 SCOPE AND APPLICATION

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 that this TGI only applies to monitoring well development and not remediation (injection/extraction) well development.

The purposes 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 in only in one direction, toward the well screen.
2. Pumping/overpumping – use of a pump to remove water and sediment from the well casing, overpumping 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 in only in one direction, toward the well screen. Small diameter monitoring wells have the additional constraint on pump size and flow rates.
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.
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 small and large diameter 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.
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 inch 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, jetting requires subsequent surging to remove fines dislodged in the filter pack and formation.

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

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 90-99% 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 monitoring well development. A site-specific field implementation plan for well installation and development detailing the specific methods and tools should be developed to provide site-specific instruction and guidance.

3 PERSONNEL QUALIFICATIONS

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

4 EQUIPMENT LIST

Required equipment depends on the selected method and should be detailed in the site-specific field implementation plan. However, the following are typically required.

- Health and safety equipment, as required by the site Health and Safety Plan (HASP):
- Cleaning equipment
- Field notebook and/or personal digital assistant (PDA)
- Monitoring well keys
- Water level indicator
- Field parameter meter (YSI)
- Well Development Logs
- Well construction logs/diagrams
- Weighted tape (measure depth)
- Turbidity meter
- Camera
- Watch/timing device.

5 CAUTIONS

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

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

In some cases, it may be necessary to add potable water to a well to allow surging and development, especially for new monitoring wells installed in low permeability formations. Before adding potable water to a well, the 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.

6 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.

7 PROCEDURE

As indicated above, for most monitoring wells, gentle surging coupled with bailing or pumping to remove dislodged sediment is recommended.

1 Ensure sufficient time has passed to allow for proper curing of the well seal.

2 Don appropriate PPE (as required by the site-specific HASP).

3 Place plastic sheeting around the well.

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

5 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.

6 Obtain an initial measurement of the depth to water and the total well depth from the reference point at the top of the well casing. Record these measurements in the field log book. It is recommended to use a weighted tape for the total well depth measurement.

7 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.

8 Lower a double surge block into the screened portion of the well. Starting from the bottom of the screen using 2 foot throws, gently raise and lower the surge block to force water in and out of the screen slots and sand pack. Continue surging for 15 to 30 minutes.

9 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.

10 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.

11 Remove formation water by pumping/bailing. Where pumping is used, measure and record the pre-pumping water level. Operate the pump at a relatively constant rate. Measure the pumping rate using a calibrated container and stop watch, and record the pumping rate in the field log book. Measure and record the water level in the well at least once every 5 minutes during pumping. Note any relevant observations in terms of water color, visual level of turbidity, sheen, odors, etc. Pump or bail until termination criteria specified in the Site-Specific Field Implementation plan are reached. Note: the project-specific field implementation plan may also specify a maximum turbidity requirement for completion of development. Unless otherwise specified the maximum turbidity should be 50 NTUs or less. Record the total volume of water purged from the well.

12 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.

13 While developing, calculate the rate at which water is being removed from the well. Record the volume on the Well Development Log.

14 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.

15 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 acceptable volume of water has been removed.

16 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.

17 Contain all development water in appropriate containers.

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

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

8 WASTE MANAGEMENT

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

9 DATA RECORDING AND MANAGEMENT

All well development activities should 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.

10 QUALITY ASSURANCE

All reused, non-disposable, downhole well development equipment should be cleaned in accordance with the procedures outlined in the project documents.

11 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.

TGI - SOIL DESCRIPTION

Rev: #2

Rev Date: February 16, 2018

VERSION CONTROL

Revision No	Revision Date	Page No(s)	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

APPROVAL SIGNATURES

Prepared by:		June 30, 2017
	Patrick Curry, PG	Date:
Technical Expert Reviewed by:	Niklaus R.H. Welty	June 30, 2017
	Nicklaus Welty, PG	Date:

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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.

2 SCOPE AND APPLICATION

This Arcadis Technical Guidance Instruction (TGI) describes proper soil description procedures. 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 has been developed to emphasize field observation and documentation of details required to:

- make hydrostratigraphic interpretations guided by depositional environment/geologic settings;
- provide information needed to understand the distribution of constituents of concern; properly design wells, piezometers, and/or additional field investigations; and develop appropriate remedial strategies.

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

This 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.

3 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.

4 EQUIPMENT LIST

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

- field book, field forms or PDA to record soil descriptions;
- field book for supplemental notes;
- this 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;
- jar with lid;
- personal protective equipment (PPE), as required by the HASP; and
- digital camera

5 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.

6 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.

7 PROCEDURE

1. Select the appropriate sampling method to obtain representative samples in accordance with the selected sub-surface exploration method, e.g. split-spoon or Shelby sample for hollow-stem drilling, acetate sleeves for direct push, bagged core for sonic drilling, etc.
2. Proceed with field activities in required sequence. Although completion of soil descriptions is often not the first activity after opening sampler, identification of stratigraphic changes is often necessary to select appropriate intervals for field screening and/or selection of laboratory samples.
3. Set up boring log field sheet.
    - Drillers in both the US and Canada generally work in feet due to equipment specifications. Use the Arcadis standard boring log form (**Attachment A**).
    - The preferred boring log includes a graphic log of the principal soil component 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. See an example completed boring log (**Attachment B**).
4. Examine each soil core (this is different than examining each sample selected for laboratory analysis), and record the following for each stratum:
    - depth interval;
    - principal component with descriptors, as appropriate;
    - amount and identification of minor component(s) with descriptors as appropriate;
    - moisture;
    - consistency/density;
    - color; and
    - additional description or comments (recorded as notes).
5. At the end of the boring, record the amount of drilling fluid used (if applicable) and the total depth logged.

The above is described more fully below.

DEPTH

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

1. Measured depth to the top and bottom of sampled interval. Use starting depth of sample based upon measured tool length information and the length of sample interval.
2. Length of sample recovered, not including slough (material that has fallen into hole from previous interval), expressed as fraction with length of recovered sample as numerator over length of sampled interval as denominator (e.g. 14/24 for 14 inches recovered from 24-inch sampling interval that had 2 inches of slough discarded).
3. Thickness of each stratum measured sequentially from the top of recovery to the bottom of recovery.
4. Any observations of sample condition or drilling activity that would help identify whether there was loss from the top of the sampling interval, loss from the bottom of the sampling interval, or compression of the sampling interval. Examples: 14/24, gravel in nose of spoon; or 10/18 bottom 6 inches of spoon empty.

DETERMINATION OF COMPONENTS

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

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

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

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

Udden-Wenworth Scale
Modified Arcadis, 2008

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

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

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

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

PRINCIPAL COMPONENT

The principal component is the size fraction or range of size fractions containing the majority of the volume. Examples: the principal component in a sample that contained 55% pebbles would be "Pebbles"; or the principal component in a sample that was 20% fine sand, 30% medium sand and 25% coarse sand would be "Sand, fine to coarse" or for a sample that was 40% silt and 45% clay the principal component would be "Clay and Silt". Shade the boxes on the graphic log (**Attachment A**) up to and including the box with the principal component. The purpose of the graphical log is to provide a relative estimate of permeability. 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.

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

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

Description	Criteria
Angular	Particles have sharp edges and relatively plane sides with unpolished surfaces.
Sub-angular	Particles are similar to 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-2488-06).

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

Description	Criteria
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-2488-06).

- From the specimen select enough material to mold into a ball about ½ inch (12 mm) in diameter. Mold the material adding water if necessary, until it has a soft, but not sticky, consistency.
- Smooth the ball in the palm of one hand with a small spatula.
- Shake horizontally, striking the side of the hand vigorously with the other hand several times.
- Note the reaction of water appearing on the surface of the soil.
- Squeeze the sample by closing the hand or pinching the soil between the fingers, and not the reaction as none, slow, or rapid in accordance with the table below. The reaction is the speed with which water appears while shaking and disappears while squeezing.

Description	Criteria
None	No visible change in the specimen.
Slow	Water appears slowly on the surface of the specimen during shaking and does not disappear or disappears slowly upon squeezing.
Rapid	Water appears quickly on the surface of the specimen during shaking and disappears quickly upon squeezing.

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.

MINOR COMPONENT(S)

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

Include a standard modifier to indicate percentage of minor components (see Table on Page 6) and the same descriptors that would be used for a principal component. 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. For the example above, the minor constituents with modifiers could be: some silt and clay, low plasticity; little medium to large pebbles, sub-round.

SORTING

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

Well sorted – the range of particle sizes is limited (e.g. the sample is comprised of predominantly one or two grain sizes).

Poorly sorted – a wide range of particle sizes are present.

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

MOISTURE

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

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

CONSISTENCY or DENSITY

This can be determined by standard penetration test (SPT) blow counts (ASTM D-1586) or field tests in accordance with the tables below. 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. Example: for 24-inch spoon, recorded blows per 6-inch interval are: 4/6/9/22. Since the second interval is 6” to12”, the third interval is 12” to 18”, the N value is 6+9, or 15. Fifty blow counts for less than 6 inches is considered refusal. 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
Very soft	N-value < 2 or easily penetrated several inches by thumb.
Soft	N-value 2-4 or easily penetrated one inch by thumb.
Medium stiff	N-value 9-15 or indented about ¼ inch by thumb with great effort.
Very stiff	N-value 16-30 or readily indented by thumb nail.
Hard	N-value > than 30 or indented by thumbnail with difficulty

Coarse-grained soil – Density

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

COLOR

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

ADDITIONAL COMMENTS (NOTES)

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

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

EXAMPLE DESCRIPTIONS

51.4 to 54.0’ CLAY, some silt, medium to high plasticity; trace small to large pebbles, sub-round to sub-angular up to 2” diameter; moist, stiff, dark grayish brown (10 YR 4/2) NOTE: Lacustrine; laminated 0.1 to 0.2” thick, laminations brownish yellow (10 YR 4/3).

32.5 to 38.0’ SAND, medium to very coarse, sub-round to sub-angular; little granule and pebble, trace silt; poorly sorted, wet, grayish brown (10 YR 5/2).

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.

The standard generic description order is presented below.

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

8 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.

9 DATA RECORDING AND MANAGEMENT

Upon collection of soil samples, the soil sample should be logged on a standard boring log and/or in the field log book depending on Data Quality Objectives (DQOs) for the task/project. The preferred standard boring log is presented below and is included as **Attachment A**.

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

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

10 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.

11 REFERENCES

Arcadis Soil Description Field Guide, 2008.

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

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

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

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

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

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

NIOSH Pocket Guide to Chemical Hazards.

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

ATTACHMENT A

Arcadis Standard Soil Boring Log Form

ARCADIS Design & Consultancy for natural and built assets

SOIL BORING LOG

Boring/Well ____________ Project ______________________________ Page ____ of ____

Site Location ______________________________ Drilling Started ____________

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

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

Drilling Method ____________ Drilling Fluid Used ____________

Drilling Contractor ______________________ Driller ____________

Prepared By ______________________ Helper ____________

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

SOIL BORING LOG (CONT'D)

Boring/Well ______________________________ Prepared By ____ Page ____ of ____

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

ATTACHMENT B

Example of Completed Arcadis Soil Boring Log

ARCADIS Design & Consultancy for natural and built assets

SOIL BORING LOG

Boring/Well SB-01
Project Example
Page 1 of 1
Site Location Anytown, North America
Drilling Started 6/26/17
Total Depth Drilled 20 Feet
Hole Diameter 4.5 inches
Drilling Completed 6/26/17
Type of Sample or Coring Device Continuous
Length and Diameter of Coring Device 5', 2.25" macrocore
Sampling Interval 5 feet
Drilling Method Geoprobe
Drilling Fluid Used NA
Drilling Contractor Fibertec
Driller Ryan Brown
Prepared By A. DeGrandis
Helper Grant Berger

Core Recovery (feet)	PID Reading (ppm)	Sample Depth (ft bgs)	MUD		SAND					GRAVEL				Udden-Wentworth Description: principal components, (angularity, plasticity, dilatency); minor components, (angularity, plasticity, dilatency); sorting, moisture content, consistency/density, color, additional comments
			clay	silt	very fine	fine	medium	coarse	very coarse	granular	pebble	cobble	boulder	
	0.3	1	X	X	X	X	X							(0.0-4.0) SAND, fine to medium, sub-rounded;
	0.1	2	X	X	X	X	X							little granules to small pebbles, sub-rounded
60"	0.0	3	X	X	X	X	X							to sub-angular; trace silt; poorly sorted, dry
(HA)	0.0	4	X	X	X	X	X							to moist, dark grayish brown (10YR 4/2).
	1.4	5	X	X										NOTE: Ablation till.
	1.7	6	X	X										
	0.9	7	X	X										(4.0-10.0) SILT, non-plastic, rapid dilatancy;
52"	1.2	8	X	X										dry to moist, soft to medium stiff,
	0.6	9	X	X										gray (10YR 5/1).
	0.2	10	X	X										
	0.0	11	X	X	X	X								(10.0-15.5) SAND, fine, sub-rounded; trace
	0.0	12	X	X	X	X								silt; well sorted, moist to wet, pale
60"	0.1	13	X	X	X	X								brown (10YR 6/3).
	0.0	14	X	X	X	X								
	0.0	15	X	X	X	X								NOTE: Wet at 12.0'
	0.2	16	X	X	X	X								
	0.0	17	X											(15.5-20.0) CLAY, high plasticity, no dilatancy;
58"	0.0	18	X											little silt; moist, soft to medium stiff,
	0.0	19	X											light gray (10YR 7/1) to dark gray (10YR 4/1).
	0.0	20	X											NOTE: Lacustrine, minor 0.1-0.25" lamination.
														End of boring - 20.0'

ATTACHMENT C

Arcadis Soil Description Field Guide

ON THE ORIGINAL DRAWING.
USE TO VERIFY FIGURE
REPRODUCTION SCALE

SOIL DESCRIPTION FIELD GUIDE (JUNE 30, 2017; REV. 2.0)

FINE-GRAINED SOILS

Description	Criteria
	Descriptor - Plasticity
Nonplastic	A 1/8-inch (3mm) thread cannot be rolled at any moisture content.
Low	Thread can barely be rolled, and lump cannot be formed when drier than plastic limit.
Medium	Takes considerable time and rolling to reach plastic limit. Thread cannot be rolled after reaching plastic limit. Lump crumbles when drier than plastic limit.
High	Thread is easy to roll and quickly reaches plastic limit. Thread can be rerolled several times after reaching plastic limit. Lump can be formed without crumbling when drier than 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, medium to high plasticity; trace silt; trace small to very large pebbles, subround to subangular up to 2" diameter; moist, stiff, 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
Principal Components with Descriptors
Minor Components with Descriptors
Sorting
Field Moisture Condition
Density/Consistency
Color using Munsell
Geologic Origin (if known)
Other descriptions as NOTES:
- Odor
- Stratigraphy
- Structure
- Sphericity
- Cementation
- Reaction to acid

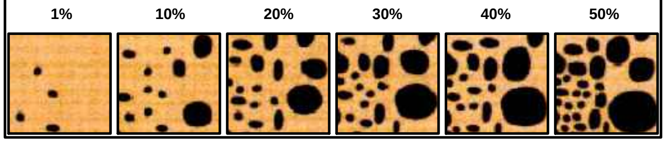
MINOR COMPONENTS % MODIFIERS

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

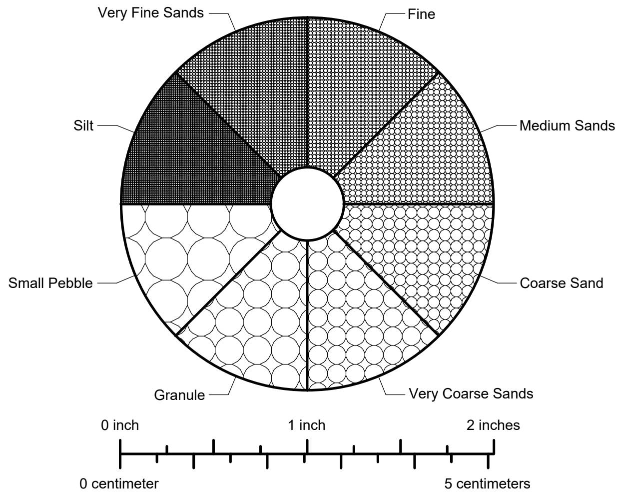
UDDEN-WENTWORTH SCALE

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.

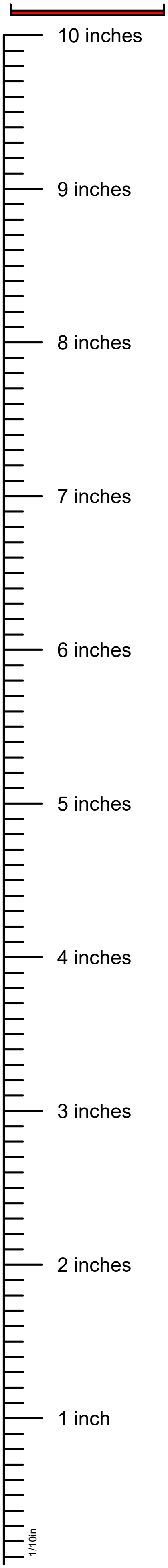
EXAMPLE OF SOIL DESCRIPTION AND PHOTO

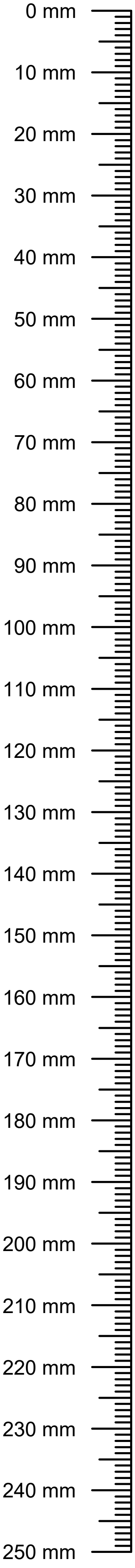
10 -15 feet SAND, medium to very coarse; little granules to medium pebbles, subround to subangular; trace silt; poorly sorted, wet, grayish brown (10YR5/2).

SOIL DESCRIPTION FIELD GUIDE (JUNE 30, 2017; REV. 2.0)

ARCADIS Design & Consultancy for natural and built assets

ON THE ORIGINAL DRAWING.
USE TO VERIFY FIGURE
REPRODUCTION SCALE





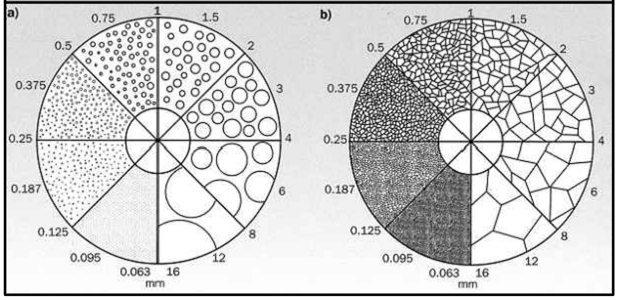
VARIATIONS IN SOIL STRATIGRAPHY

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.

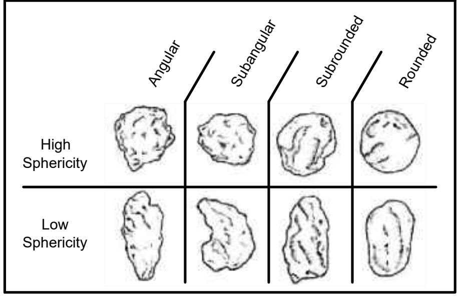
SOIL STRUCTURE DESCRIPTIONS

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.

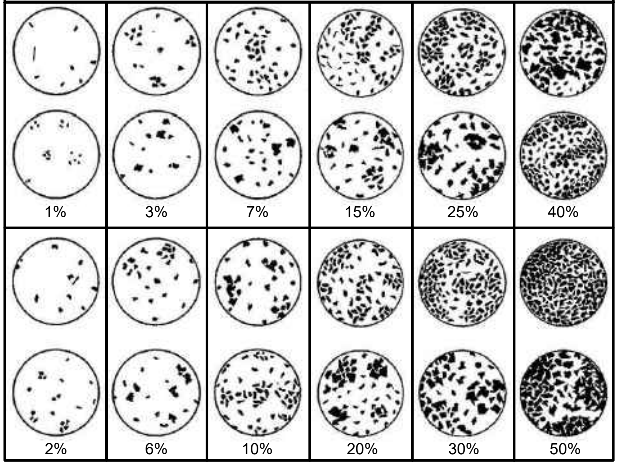
GRAPH FOR DETERMINING SIZE OF PARTICLES



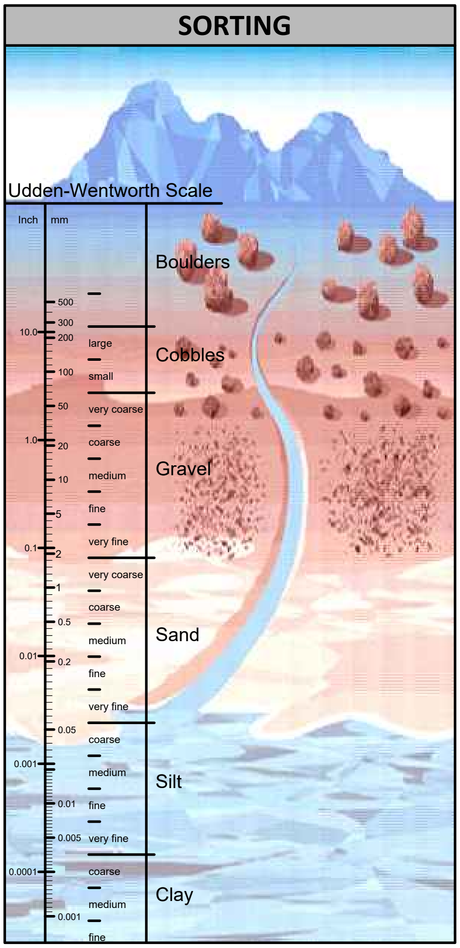
ANGULARITY CHART



PARTICLE PERCENT COMPOSITION ESTIMATION



SORTING



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	

TECHNICAL GUIDANCE INSTRUCTIONS - VERTICAL AQUIFER PROFILING (VAP)

Rev: 1

Date: 05/11/2020

VERSION CONTROL

Revision No	Revision Date	Page No(s)	Description	Reviewed by
0	June 22, 2018	All		Joe Quinnan
1	May 11, 2020	Multiple	Added content to Personnel Qualifications, references to GeoProbe® SP-16 and SP-22, Attachment 2, and updated references/formatting	Marc Killingstad

APPROVAL SIGNATURES

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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 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.

2 SCOPE AND APPLICATION

Vertical aquifer profile (VAP) borings are advanced via direct push or rotosonic drilling techniques to collect single or multiple depth-discrete groundwater samples using low-flow or grab sampling methodologies. They 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. VAP groundwater sampling intervals should be co-located with or biased 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 estimation of relative flux and mass discharge to evaluate potential risk to downgradient receptors. In the absence of permeability measurements, field soil lithological logging observations may be used to interpret hydrostratigraphy and select sampling intervals.

The intent of this Technical Guidance Instruction (TGI) is to provide VAP instructions. It also covers specific considerations for per- and polyfluoroalkyl substances (PFASs) due to their unique chemical and physical properties, low detection limits, and regulatory standards.

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], 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 should be determined relative to the scale of variability demonstrated in site hydrostratigraphy. Thin aquifers with transport zones only tens of feet thick can be sampled at intervals as close as 3 to 5 feet. In aquifers with transport zones of substantial thickness (e.g., more than 50 feet), sample spacing of 5 to 20 feet is usually adequate. It is important to note that field data should be evaluated to verify that sampling intervals provide sufficient resolution to meet data quality objectives (DQOs) (See **Section 7**).

3 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. 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.

4 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)
- Appropriate health and safety equipment, as specified in the site HASP
- Drilling Equipment
    - Drill rig (to be provided by drilling subcontractor). Type (e.g., rotosonic, 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 provided by 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 5.3** 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., Geprobe® SP-22) or rotosonic 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 to prevent 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 (Arcadis 2017b)
    - 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
  - Appropriate field forms
  - Clipboards, field binders, field notebook, and field note pages that are not waterproof

5 CAUTIONS

5.1 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 2017d) for reference.

5.2 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 should 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).

Tables 1 and 2 in **Attachment 1** 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 sample collection. For materials that are suspected of containing PFASs and/or retaining PFASs, 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 PFASs, 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 Poly- and Perfluorinated Alkyl Substances (PFAS) Field Sampling Guidance (Arcadis 2017a).The most important consideration during PFAS related VAP sampling is to prevent contact between sample media and suspect PFAS sources.

5.3 PFAS-Specific Soil Sampling

Because of the potential presence of PFASs in equipment typically used to collect samples, consideration for other sampling materials that contact the soil cuttings through the sampling process is necessary. For example, a cutting shoe is used on the head of a direct push drill string and a bucket auger is used to collect samples from a test pit using a backhoe. Each piece of equipment that comes into direct contact with the soil cuttings needs to be evaluated to determine if there are either PFAS-containing materials present, which could be a source of cross-contamination and cause false positives, or if PFASs adhere to the material, which has the potential to cause low bias sample results. If there is concern that equipment may introduce contamination, a conservative number of equipment blanks should be collected to confirm that materials in the sample equipment do not cause false positives by introducing PFASs. Equipment blanks are particularly important for any device/component where PFASs may be present or cannot be verified as being a non-PFAS containing material. Other quality assurance methods may be implemented to avoid materials that could result in potential losses associated with PFASs adhering to surfaces. For example, collecting samples from an “undisturbed” portion of a large diameter soil core and transferring it to the laboratory supplied container may provide assurance that representative soil samples are collected for PFAS sample analysis.

The following additional notes are provided regarding soil sampling materials:

- Where drilling or decontamination water is needed, it is required to submit water samples of the source water for PFAS analysis prior to investigation activities to ensure that background PFASs will not be introduced. Some water systems may be constructed with PFAS-containing thread and gasket sealants; therefore, an inspection of the source water distribution system may provide an additional level of assurance for identifying a source of PFAS-free water for site investigation.

- It is often standard practice to cover the ends of sample sleeves and protect the sample from potential cross-contamination from the plastic end caps with Teflon™ or other PTFE tape (Geotechnical Services, Inc. 2018); this practice is prohibited for PFAS sample collection (DER 2016).
- Lexan™ liner sleeves are made of polycarbonate and they are not expected to contain PFASs based on review of the Safety Data Sheet (Sabic 2016).
- Acetate (i.e., cellulose acetate butyrate) liners are commonly used as sleeves and are not expected to contain PFASs.
- Studies evaluating the use of stainless steel indicate that PFASs do not strongly sorb to stainless-steel (Obal et al. 2012). Therefore, stainless-steel sleeves and equipment should be acceptable for collection of soil samples for PFAS analysis.

5.4 PFAS-Specific Groundwater Sampling

As described for soil sampling, the potential presence of PFASs in equipment that may come in 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 should 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) should not be made of Teflon™ either, and bladder and O-rings should be changed between samples (DER 2016).

Note that if high concentrations of PFASs 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 PFASs may be present and the sample should be proactively diluted at the laboratory prior to analysis. The foaming should be noted on the sample chain of custody form. It is recommended to collect sampling equipment blanks following foam observation to confirm the effectiveness of decontamination procedures.

6 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.

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

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

7 PROCEDURE

The specific procedure for advancing VAP borings should be developed after careful review and consideration of project DQOs. Typically, VAP borings are conducted in boreholes adjacent to prior HPT borings completed to develop stratigraphic and relative permeability profiles of the aquifer to determine sampling depth intervals targeting transport zones. The primary advantage of completing stratigraphic/permeability profiles in advance of sampling is to gain understanding of hydrofacies trends to ensure that the most appropriate intervals and sampling methods are used. In the absence of HPT data from a co-located boring, sampling depth intervals can be determined based upon lithologic logging of soil cores, either from a separate adjacent borehole or from the same borehole. Soil lithologic logging should be performed in accordance with *TGI – Soil Descriptions* (Arcadis 2018). Waterloo APS^{TM} can be utilized as an alternative to HPT to provide permeability profiles, but it is more time intensive than HPT; therefore, it is not considered the preferred tool for permeability profiling.

7.1 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. 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 2**) 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, VAP sampling can be performed based on soil lithological observations alone, either from a separate borehole or in the same borehole. 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 (Waterloo APS or HPT-GWS) for PFASs sites is not recommended because low detection and regulatory thresholds for PFASs require more extensive purging to decontaminate the sampling equipment. Insufficient data are available to confirm the volume of purging required to eliminate cross-contamination with PFASs.

Direct push drilling for VAP sampling should 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 with low-flow sampling as part of sample collection process. 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. With top-down sampling, more time is required per borehole to lower the tooling and retract it and decontaminate it between subsequent sampling intervals; however, it 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.

7.1.1 Bottom-Up VAP Sampling

Bottom-up VAP sampling involves advancing dual-tube direct push casing to target depth with either a solid drive tip (without collecting soil cores) or plastic liners (or acetate liners for PFASs as specified in Table 1 of **Attachment 1**) 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 back up. Under 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. The advantages of this approach are: (a) when combined with soil cores collection, groundwater sampling depth intervals can be selected based on lithological log observations to target the transport zones, especially in the absence of any co-located permeability measurements and (b) the entire process is much more time-efficient per borehole.

The disadvantage is this doesn’t allow grouting of the borehole from bottom-up, since when the groundwater sampling device is pulled up to the next VAP sampling interval, the sidewalls of the open borehole below it collapse, thus closing off the borehole. Any potential for cross-contamination from adjacent sampling intervals due to the open borehole below is minimized by borehole collapse and can be further mitigated by adjustment of low-flow sampling rates. *Bottom-up VAP sampling should also generally be avoided when potential for dense non-aqueous phase liquid exists, or the borehole goes through multiple confining units, or the contamination is typically concentrated in the bottom portions of the aquifer. Bottom-up is not recommended for PFASs sampling due to potential cross contamination concerns associated with lack of decontamination between sample intervals.*

7.1.2 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 sampling screen is pulled back up, and decontaminated. The solid drive tip or plastic liner is lowered back in 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 (if necessary), resetting 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 has to be retracted and re-advanced every time. *Top-down is the preferred method for PFAS VAP sampling.*

7.2 Sonic Drilling Vertical Aquifer Profile Sampling

For sites with deep unconsolidated aquifers or challenging drilling conditions (e.g., presence of dense tills, caliche, cobbles), direct push drilling may not be feasible or cost effective due to limited production rates. In these cases, alternate drilling methods (e.g., rotosonic) are required. Like direct push, groundwater profilers can be used 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 manufacture 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 requires the introduction of drilling water that can potentially affect the integrity of the groundwater sample. If drilling water is used, it should be spiked with non-toxic fluorescence dyes per *SOP – Use of Visible Tracer in Drilling Fluid to Obtain Representative Groundwater Samples During Drilling* (Arcadis, 2010).

Sonic VAP sampling is typically performed in a top-down manner using dual-tube casing. Two types of VAP sampling can be conducted – (a) Push-Ahead and (b) Packer Isolation groundwater profilers.

7.2.1 Push-Ahead Groundwater Profiler

The Push-Ahead groundwater profiler is available by Cascade and is threaded to the base of the sonic drill rod and driven through and 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 drill steel 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 DQOs. The biggest disadvantage of this device is that groundwater samples are obtained from undisturbed native formation with unknown soil lithology, so a pre-existing lithological log from an adjacent borehole is needed to determine sampling depth intervals.

7.2.2 Packer Isolation Groundwater Profiler

Packer Isolation groundwater profilers (e.g., Packer Isolation groundwater profiler from Cascade, Geoprobe ® SP-60 Sonic Groundwater Profiler) work by retrieving the soil core and the sonic core barrel and inserting 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 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.

7.3 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.

8 WASTE MANAGEMENT

Investigation derived waste (IDW) 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 2017c). 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.

9 DATA RECORDING AND MANAGEMENT

The supervising field lead will be responsible for documenting drilling events to record all relevant information in a clear and concise format. The record of drilling events should include:

- 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-special tools
- Core barrel size
- Names of contractor’s drillers, inspectors, or other people onsite
- Weather conditions

Field staff should ensure COC Forms are properly completed, and verify which PFAS analytes (e.g., just PFOS and PFOA, some or all of the 537 list) are required for analysis and note on the COC.

9.1 Field Notes

Waterproof field books must not be used for field notes. Instead, field notes should 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.

10 QUALITY ASSURANCE

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.

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 should 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**
- **Store PFAS samples in a separate cooler from other types of samples**

10.1 Equipment Blanks (if relevant)

QA/QC sampling typically includes daily collection of equipment blanks using the laboratory-supplied “PFAS-free” water. For peristaltic pump tubing, laboratory supplied “PFAS-free” water should 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 should 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 PFAS analysis before work commences for PFAS-related VAP as discussed in **Section 5.3** above.

10.2 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 should be given a blind reference on the COC and sample name such as “duplicate”.

10.3 Field Blanks

QA/QC sampling for PFAS typically includes the submission of one laboratory supplied reagent 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 field blank should be placed in the same cooler as the other PFAS samples.

10.4 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.

10.5 Laboratory Analytical QA/QC

- Internal laboratory QA/QC should 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 should 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 should be analyzed in their entirety or thoroughly homogenized before extraction and analysis.
- As part of the internal QA/QC, relative percent difference should be calculated between samples and corresponding field or laboratory duplicates. The laboratory quality assurance portion of the laboratory certificates should 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 PFASs 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 PFASs. 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^{TM}	Low density polyethylene (LDPE) HydraSleeves^{TM} 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

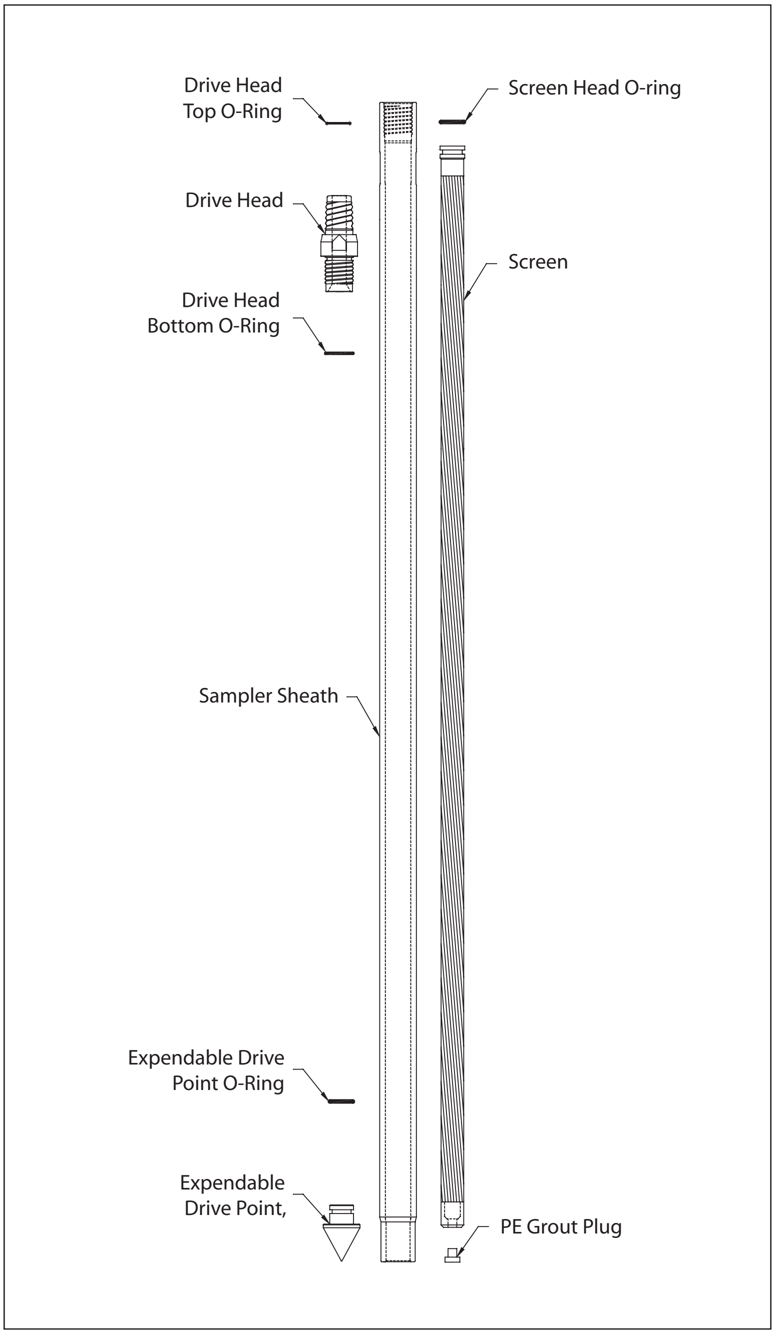
SOPs Geoprobe® Screen Point 16 and Screen Point 22 Groundwater Samplers

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.*

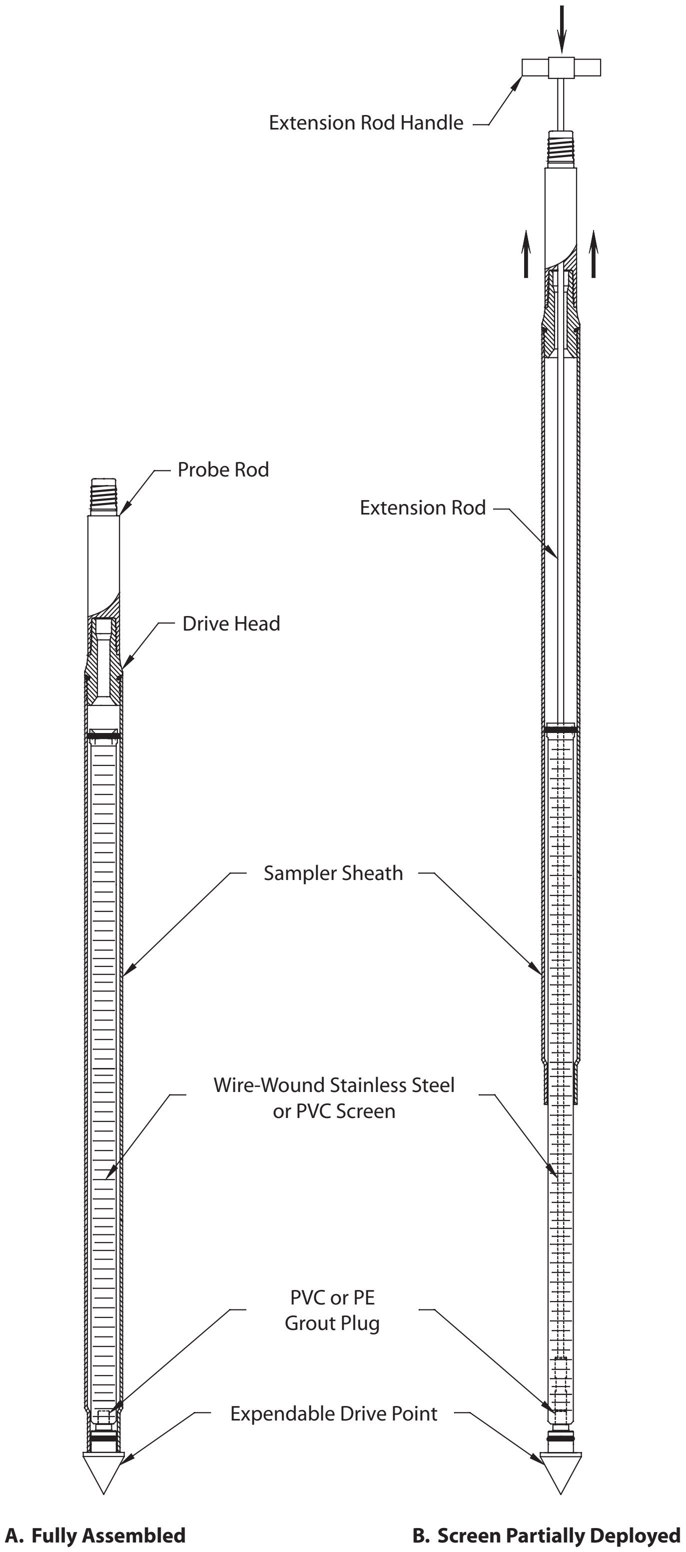


FIGURE 2.1

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

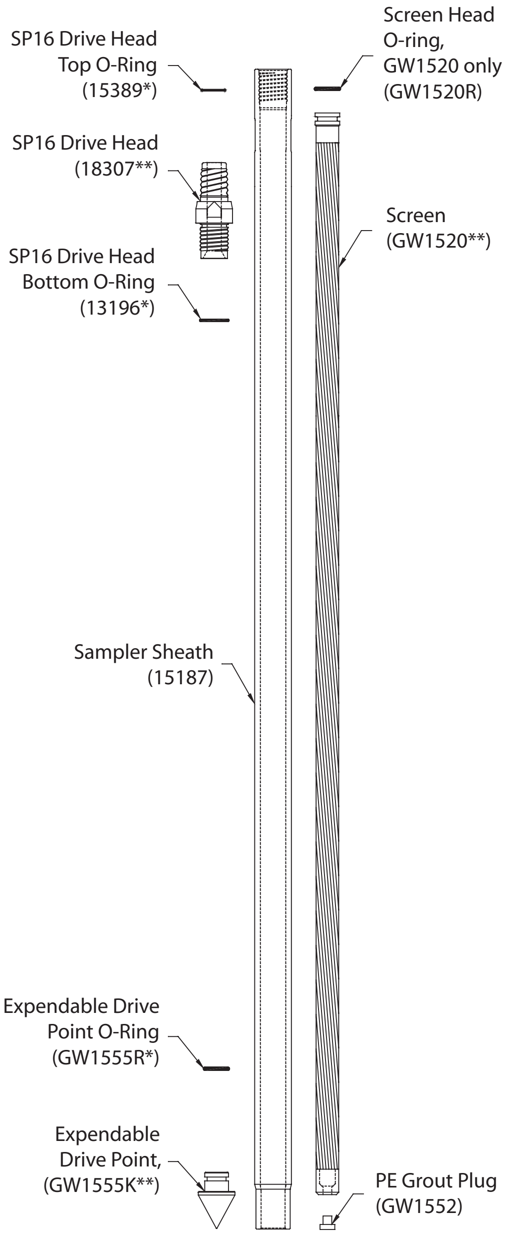
Grout Accessories	**Part Number**
Grout Nozzle, for 0.375-inch OD tubing	GW1545
High-Pressure Nylon Tubing, 0.375-inch OD / 0.25-inch ID, 100-ft. (30 m)	11633
Grout Machine, self-contained*	GS1000
Grout System Accessories Package, 1.5-inch rods	GS1015

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

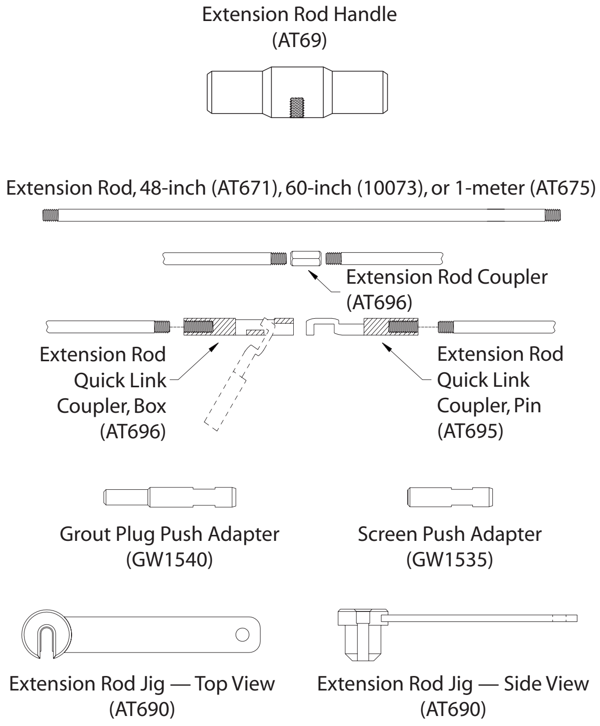


FIGURE 3.2
Geoprobe® Extension Rods and Accessories

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).

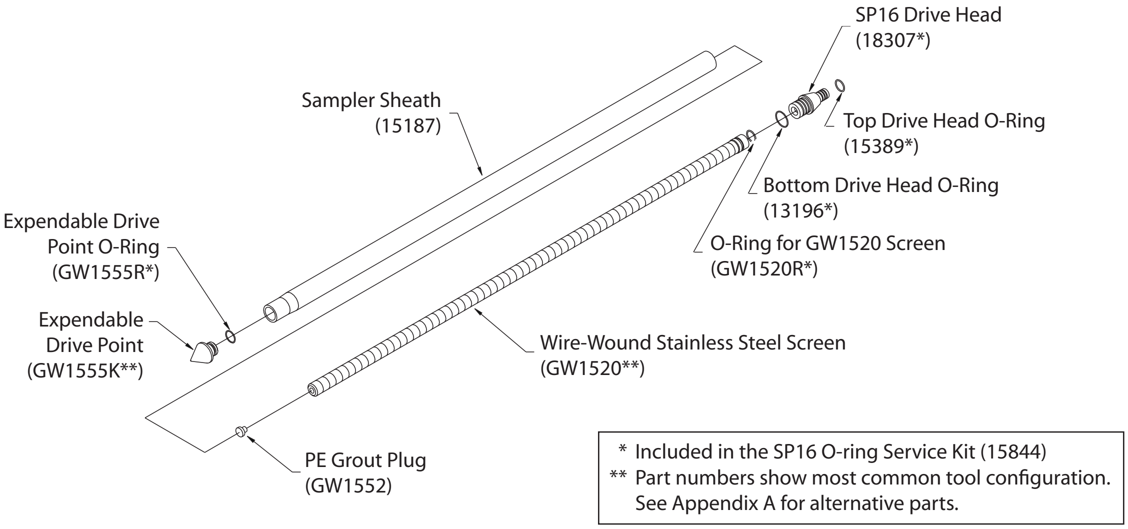
2. Install a PE Grout Plug (GW1552) in the bottom end of a Wire-wound Stainless Steel Screen (GW1520). Place a GW1520R O-ring in the groove on the top end of the screen.

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.



* Included in the SP16 O-ring Service Kit (15844)
** Part numbers show most common tool configuration. See Appendix A for alternative parts.

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.

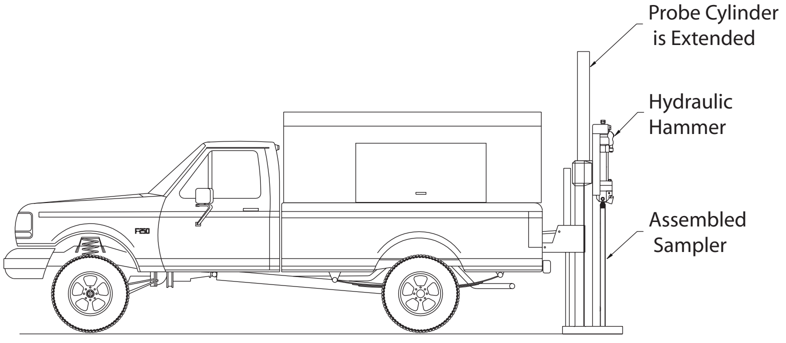


FIGURE 4.2
Screen Point 16 Groundwater Sampler in Driving Position

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.

4.6 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.

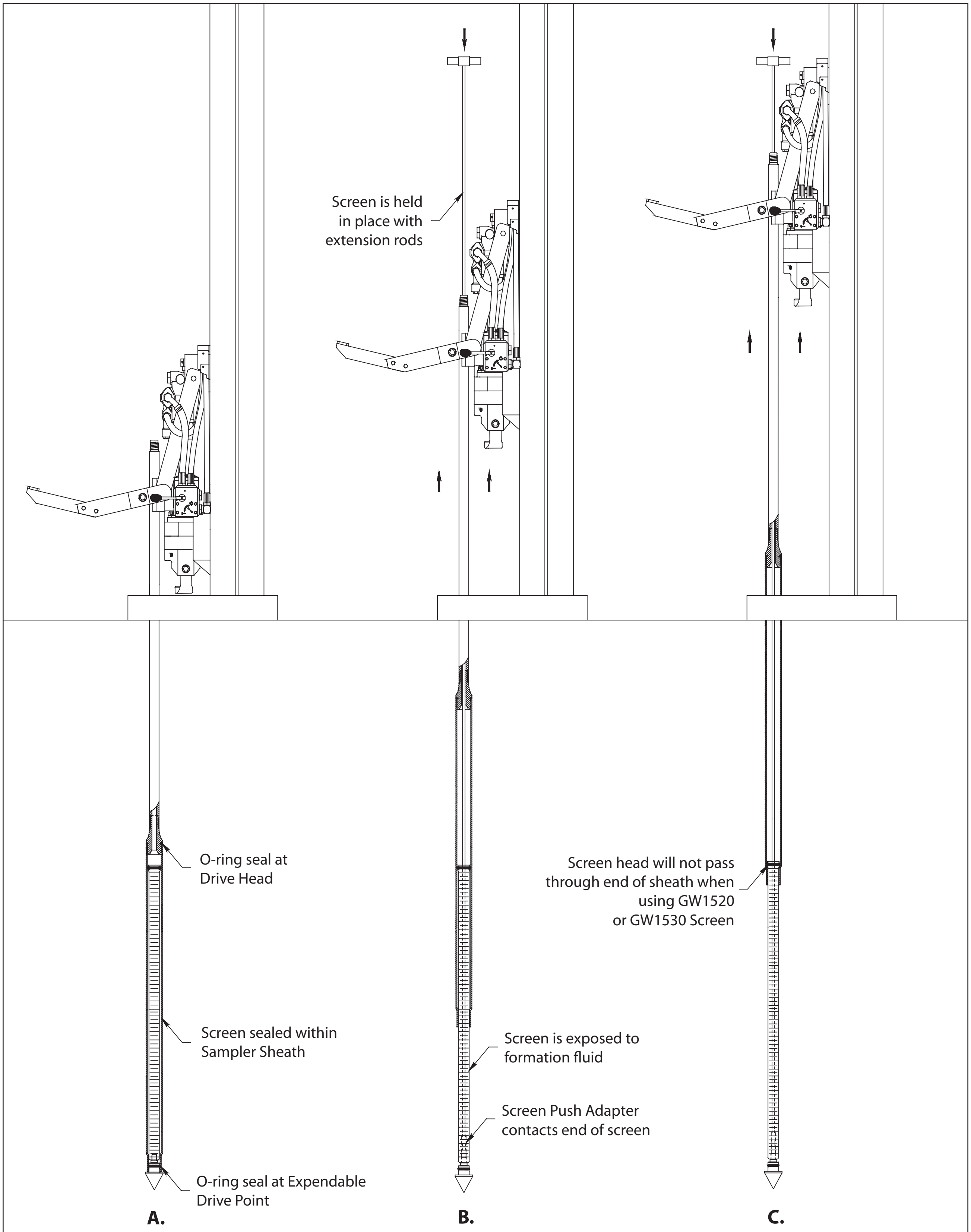


FIGURE 4.3

Screen Deployment for SP16 Sampler

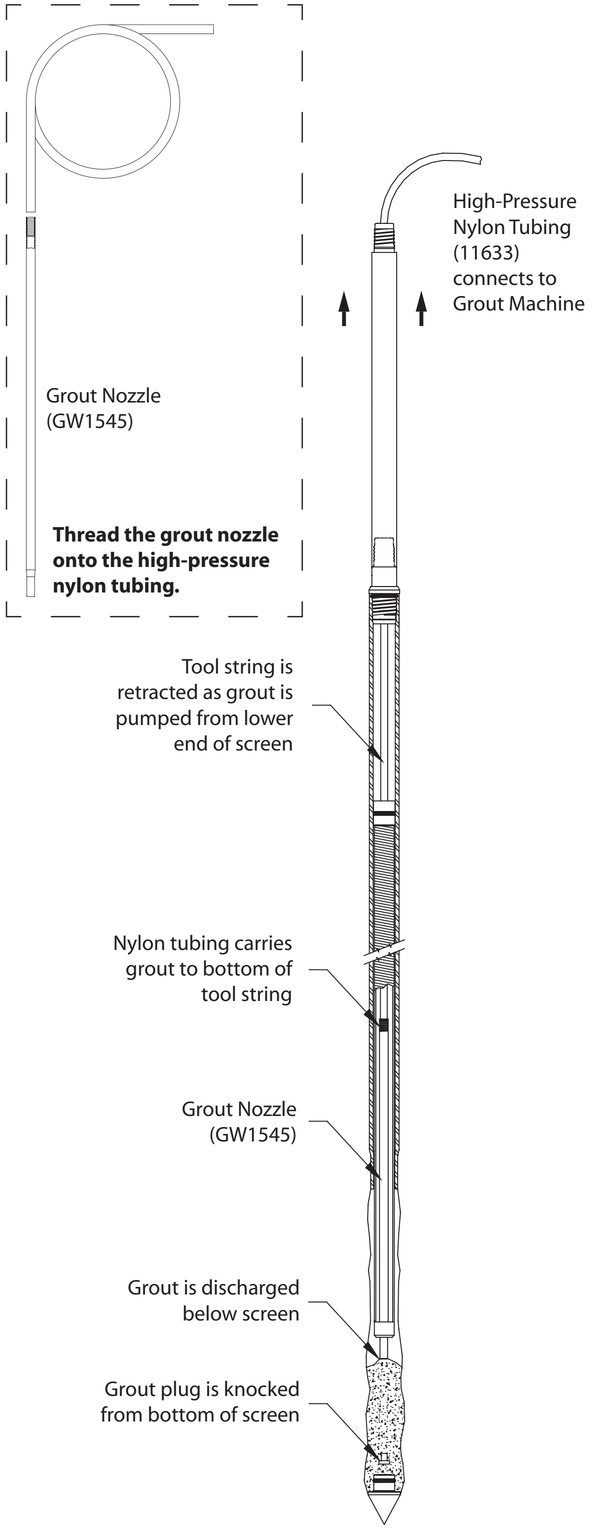


FIGURE 4.4
Grouting the SP16 Sampler With a GW1520 or GW1530 Screen

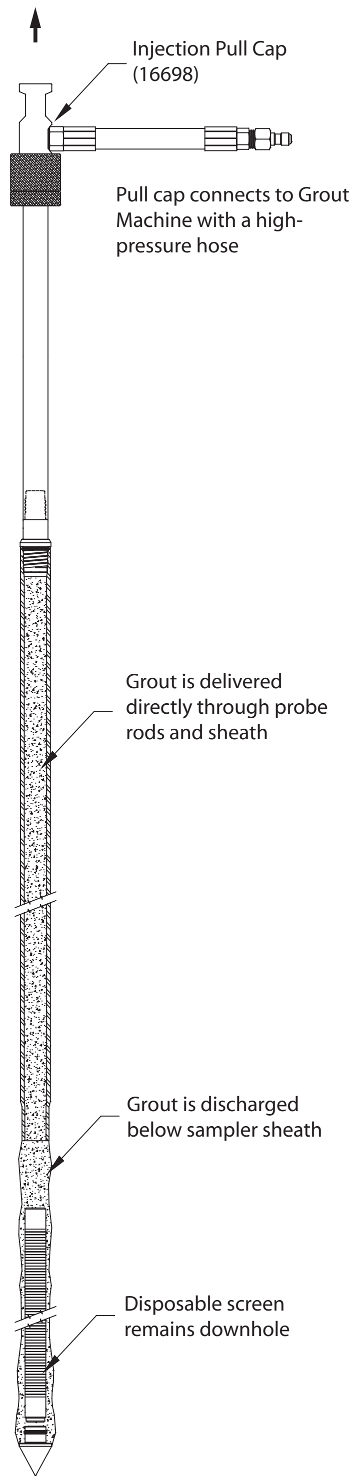


FIGURE 4.5
Grouting the SP16 Sampler With a 16089 Disposable Screen

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

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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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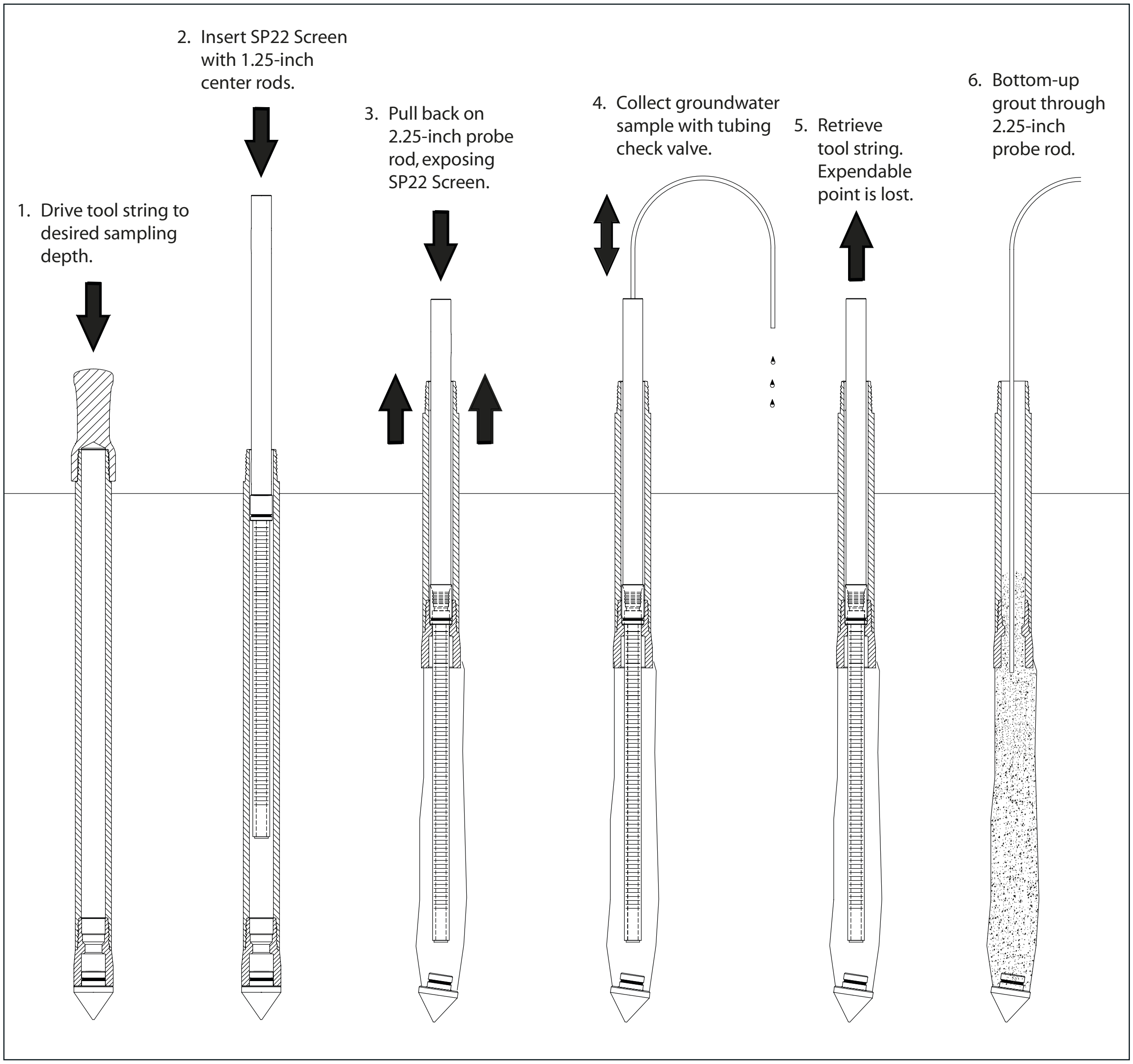
GEOPROBE® SCREEN POINT 22 GROUNDWATER SAMPLER

STANDARD OPERATING PROCEDURE

Technical Bulletin No. MK3173

PREPARED: April 2010



1. Drive tool string to desired sampling depth.
2. Insert SP22 Screen with 1.25-inch center rods.
3. Pull back on 2.25-inch probe rod, exposing SP22 Screen.
4. Collect groundwater sample with tubing check valve.
5. Retrieve tool string. Expendable point is lost.
6. Bottom-up grout through 2.25-inch probe rod.

OPERATION OF THE GEOPROBE® SCREEN POINT 22 GROUNDWATER SAMPLER

Geoprobe® and Geoprobe Systems®, Macro-Core® and Direct Image® are Registered Trademarks of Kejr, Inc., Salina, Kansas

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.*

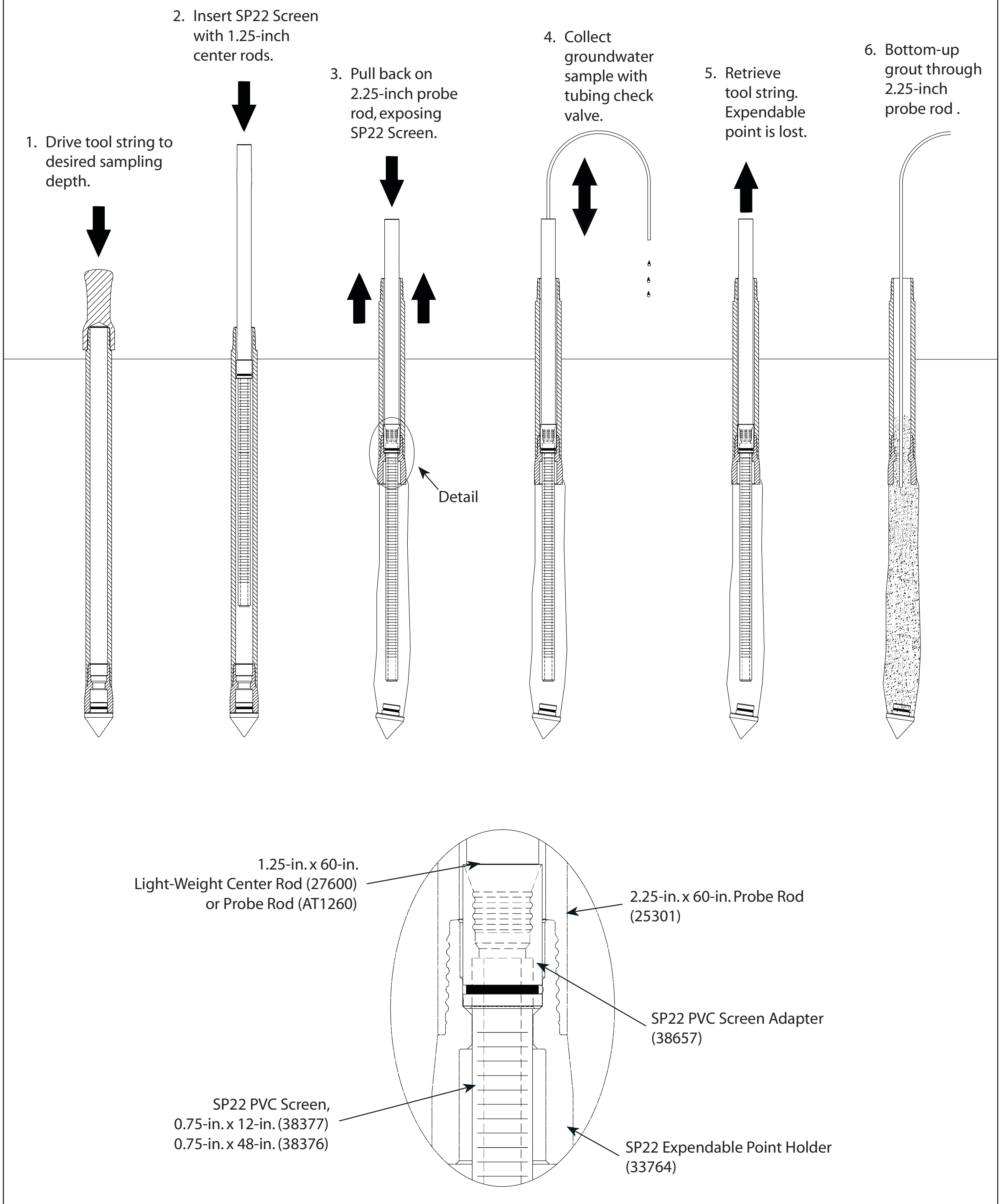


FIGURE 2.1
Screen Point 22 Groundwater Sampler - 0.75-inch PVC Screen Option

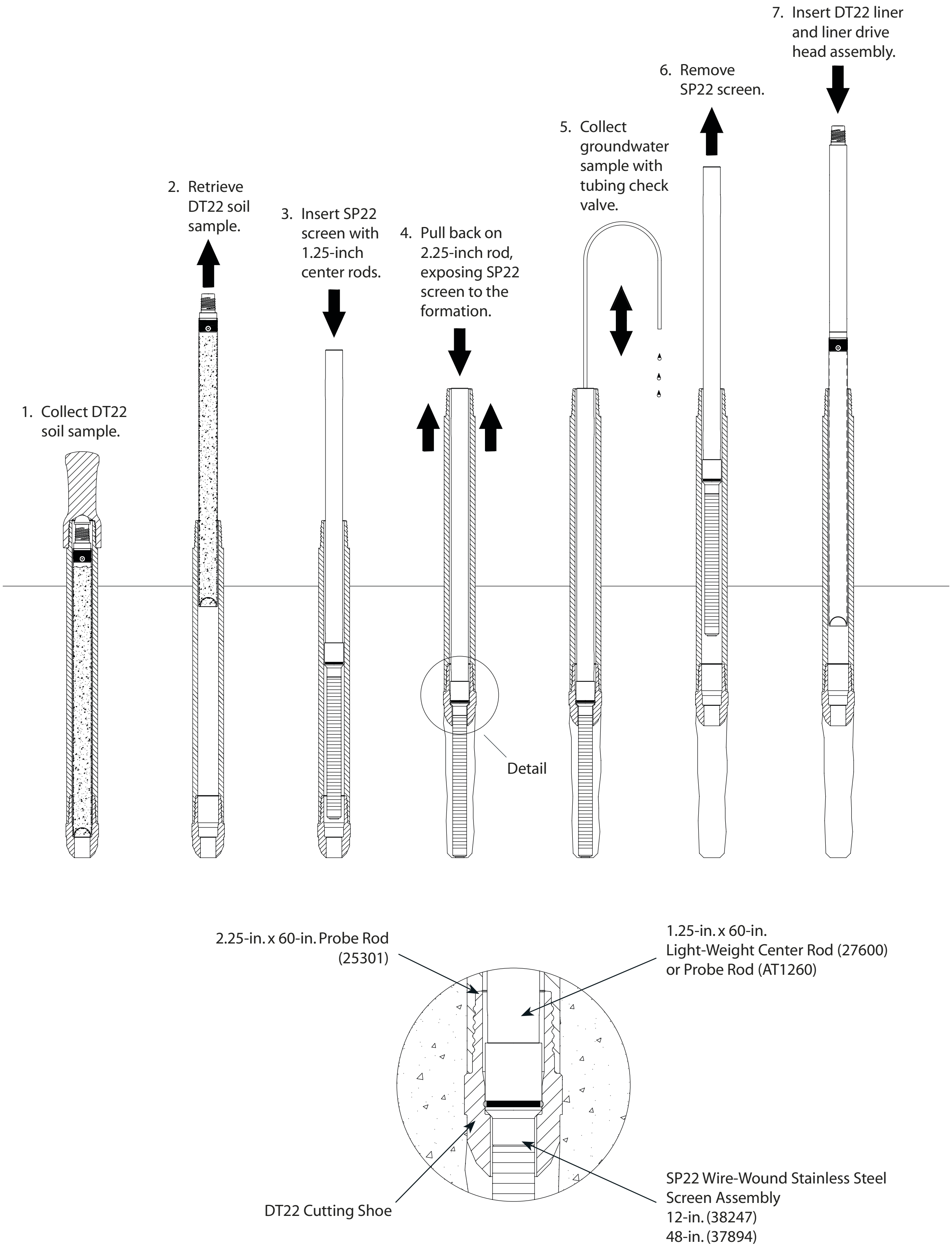


FIGURE 2.2

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

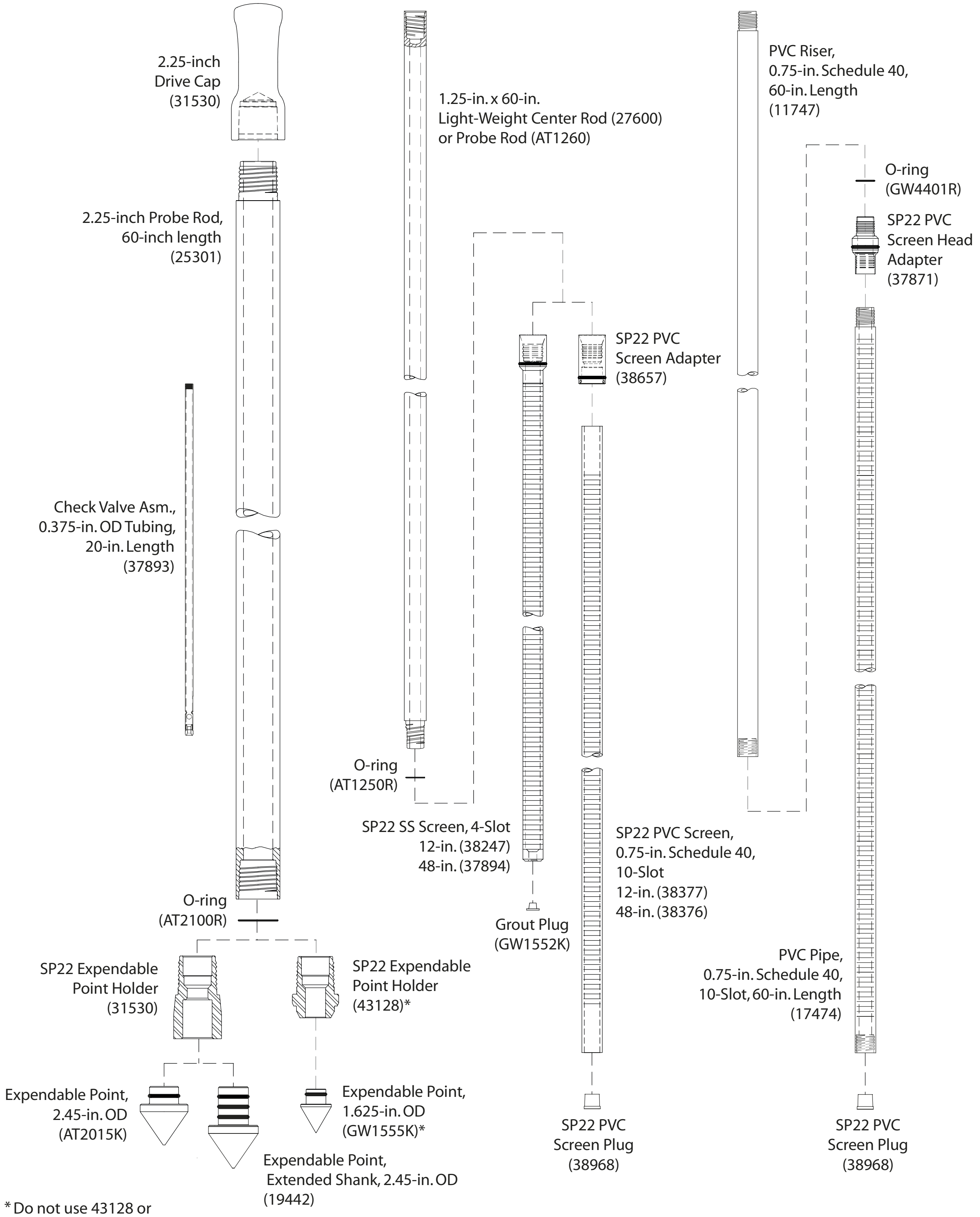
Outer Casing (2.125-inch Probe Rods) and Inner Rod String	**Part Number**
Probe Rod, 2.25-in. x 60-in.	25301
Expendable Drive Points, Steel, 2.45-in. OD (Pkg. of 25)	AT2015K
Expendable Drive Points, Steel, 2.45-in. OD, extended shank	19442
Expendable Points, steel, 1.625-in. OD (Pkg. of 25)*	GW1555K
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.



* Do not use 43128 or GW1555K with GH80 series hammers

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.

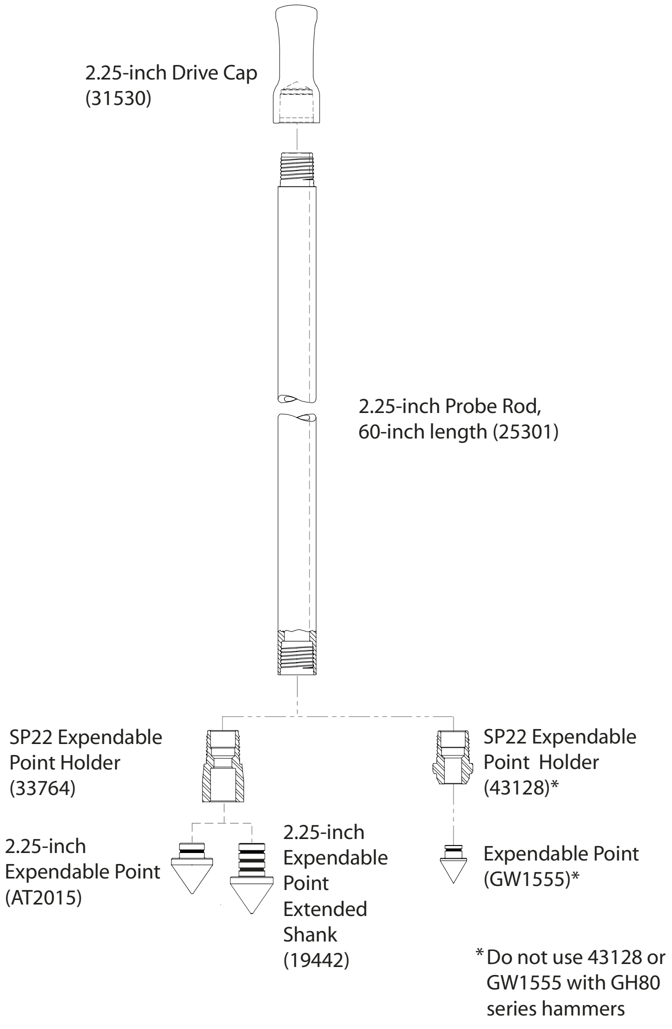


FIGURE 4.1
Lead Rod Assembly for the SP22 Groundwater Sampler

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.

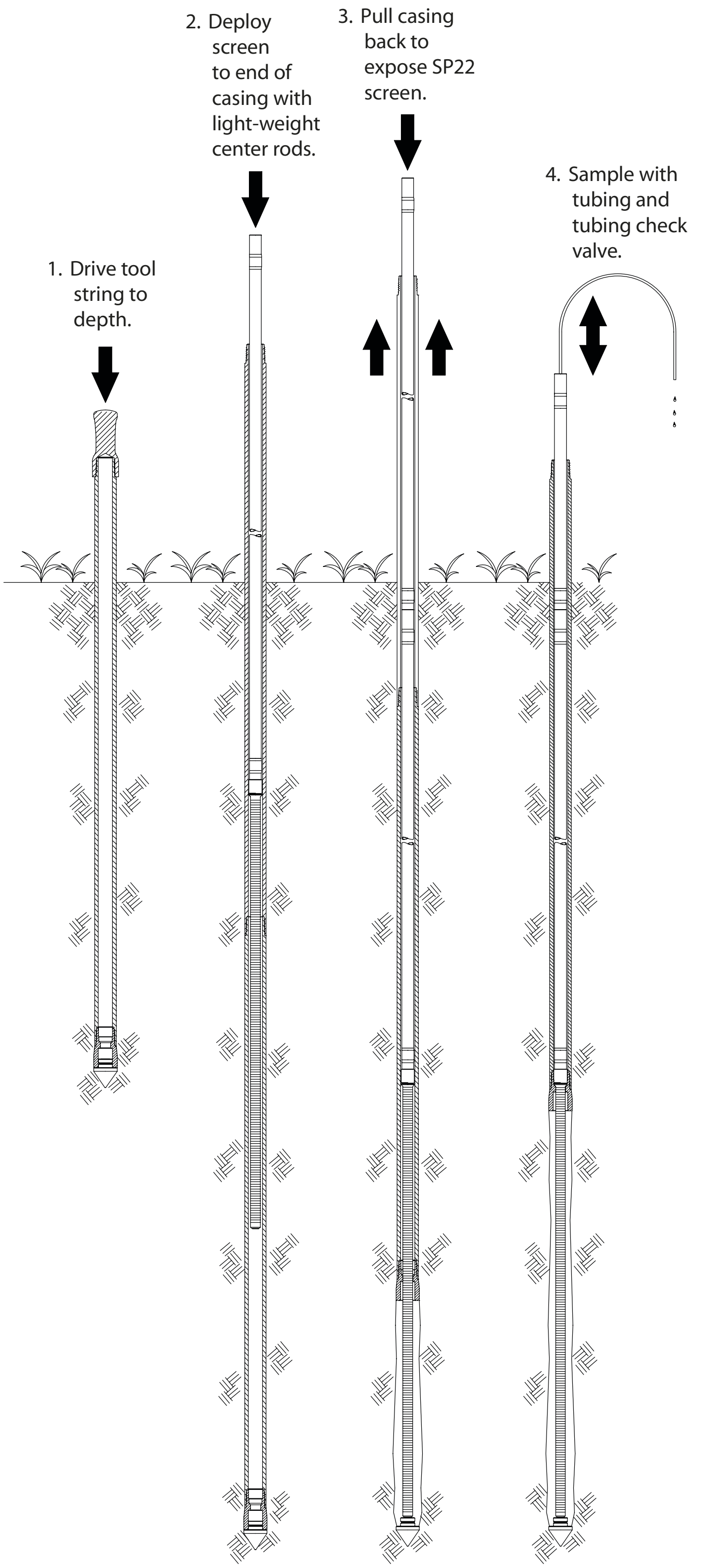


FIGURE 4.2
Screen Deployment for SP22 Sampler

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.

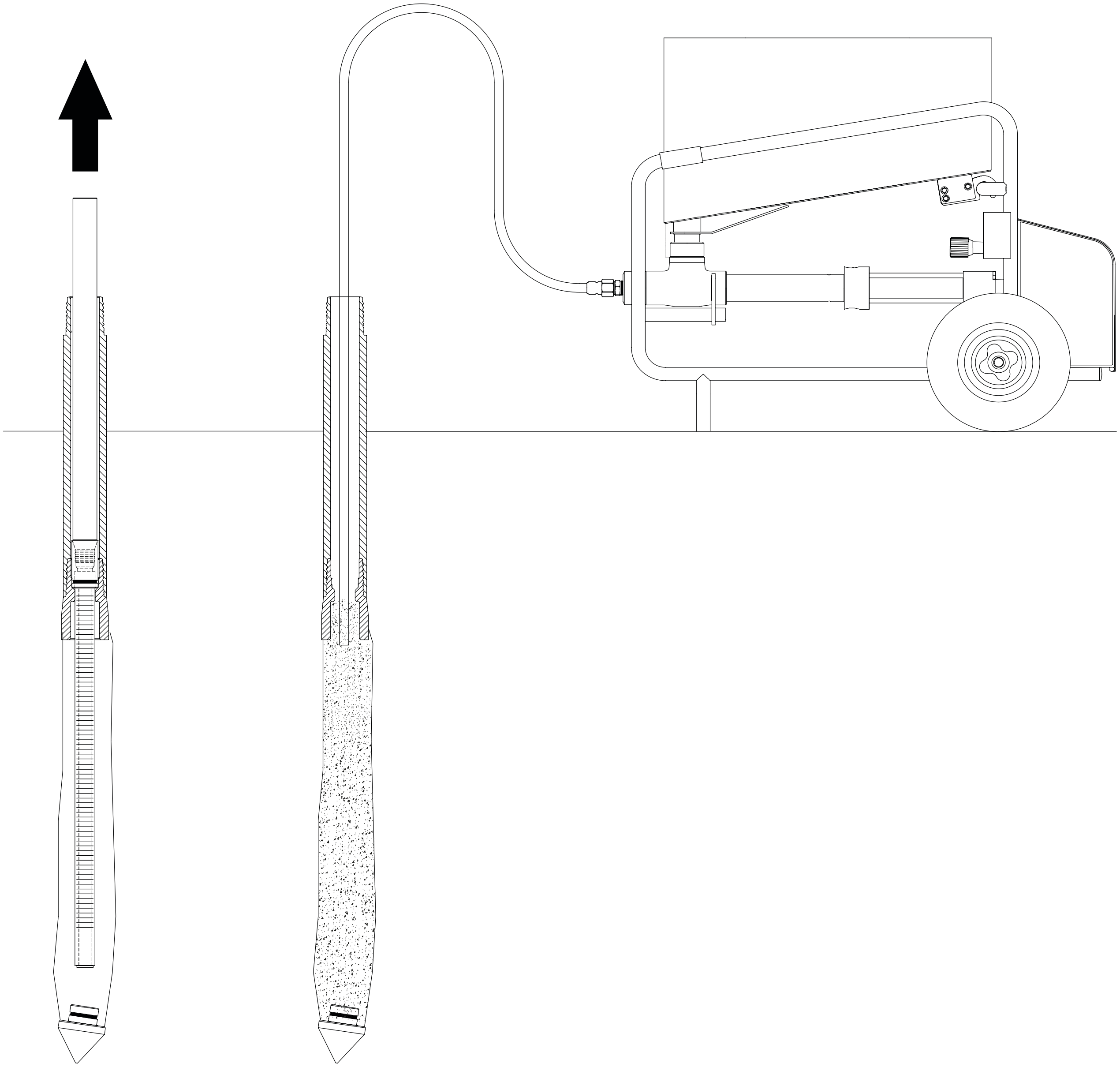


FIGURE 4.3
Abandonment Grouting for the SP22 Sampler

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.

U.S. Environmental Protection Agency (EPA), 2003. Environmental Technology Verification Report: Geoprobe Inc., Mechanical Bladder Pump Model MB470. Office of Research and Development, Washington, D.C. EPA/600R-03/086. August.

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TGI - SURFACE WATER SAMPLE COLLECTION

Rev: 1

Rev Date: May 8, 2020

VERSION CONTROL

Revision No	Revision Date	Page No(s)	Description	Reviewed by
0	April 9, 2019	All	Original approved document	Jessica Geurts / Shannon Dunn
1	May 8, 2020	None	Periodic review – no changes	Shannon Dunn

APPROVAL SIGNATURES

Prepared by: 04/05/2019

Jessica Geurts Date:

Technical Expert Reviewed by: Shannon Dunn 05/08/2020

Shannon Dunn Date:

1 INTRODUCTION

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

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

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

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

2 SCOPE AND APPLICATION

This Technical Guideline Instruction (TGI) describes the collection of surface water samples using a grab method, discrete depth sampler or peristaltic pump. This TGI should be followed whenever collecting surface water samples.

This TGI may change depending upon field conditions, equipment limitations, or limitations imposed by the procedure. Substantive modification to this TGI will be approved in advance by the Project Manager.

3 PERSONNEL QUALIFICATIONS

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

4 EQUIPMENT LIST

The following equipment list contains materials that may be needed in carrying out the procedures contained in this TGI. Not all equipment listed below may be necessary for a specific activity. Additional equipment may be required, pending field conditions.

- personal protective equipment (PPE) and other safety equipment, as required in the project Health and Safety Plan (HASP)
- project Quality Assurance Project Plan (QAPP)
- Sampling and Analysis Plan (SAP)
- indelible ink pens
- appropriate sample containers, labels, and forms
- decontamination supplies including bucket, distilled or deionized water, cleansers appropriate for removing expected chemicals of concern.
- sample packing and shipping materials
- water-quality (temperature/pH/specific conductivity/ORP/turbidity/dissolved oxygen) meter and flow-through measurement cell. Several brands may be used, including:
  - YSI 6-Series Multi-Parameter Instrument
  - Hydrolab Series 3 or Series 4a Multiprobe and Display
  - Horiba U-10 or U-22 Water Quality Monitoring System
- for grab sampling method: pole with polyethylene and/or stainless steel dipper, if applicable
- for discrete depth sampling method: discrete depth samplers (e.g., Kemmerer or Van Dorn samplers)
- for peristaltic pump sampling method: peristaltic pump with appropriate power source, Teflon® tubing or Teflon®-lined polyethylene tubing of an appropriate size for the pump being used. For peristaltic pumps, dedicated Tygon® tubing (or other type as specified by the manufacturer) will also be used through the pump apparatus.

5 CAUTIONS

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

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

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

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

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

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

The ability to safely access the surface water sampling locations should be verified prior to sampling.

6 HEALTH AND SAFETY CONSIDERATIONS

Field activities will be performed in accordance with a project-specific HASP, a copy of which will be present onsite during such activities.

Safety hazards associated with sampling surface water include fast-moving water, deep water, and steep slopes close to sampling sites. Extreme caution should be used when approaching sampling sites. Work will be performed in accordance with the project-specific HASP.

7 PROCEDURE

Sampling Method

Surface water samples will be collected from sampling locations sequentially from downstream to upstream to prevent cross-contamination associated with sediment disturbance. Surface water samples will be collected prior to sediment sample collection.

Grab Sample Collection

Personnel conducting surface water sampling using grab sample collection techniques should perform the following:

1. Collect appropriate equipment, cleaned and decontaminated.

2. Obtain appropriate sampling containers.

3. Mobilize to surface water sampling location in accordance with the work plan or SAP.

4. Collect sample by directly lowering the laboratory-supplied sample container into the water and allowing the bottle to partially fill with water. The sampler will hold the bottle immediately below the water surface and allows the bottle to fill with sample. Field personnel will handle only the portions of the sample containers that do not come in contact with the sample, to avoid contamination. Additionally, care will be taken to avoid exposing samples and sample containers to atmospheric inputs such as dirt or dust.

5. Measure water quality parameters.

6. Transfer surface water samples into laboratory-supplied sample containers to complete the scope described in the SAP. Avoid overfilling sample containers to prevent preservatives, if present, in sample container from being lost.

Sample Collection Using a Discrete Depth Sampler (e.g., Kemmerer or Van Dorn)

Personnel conducting surface water sampling using grab sample collection techniques should perform the following:

1. Collect appropriate equipment, cleaned and decontaminated.
2. Obtain appropriate sampling containers.
3. Mobilize to surface water sampling location in accordance with the work plan or SAP.
4. Carefully set the sampling device so that water is allowed to pass through the tube.
5. Lower the pre-set sampling device to the predetermined depth using marked rope or line attached to the device.
6. When at desired depth; send down the messenger, closing the device. Avoid disturbing the bottom.
7. Retrieve sampler and discharge the first 10-20 mL to clear any potential cross-contamination.
8. Measure water quality parameters
9. Transfer surface water samples into laboratory-supplied sample containers to complete the scope described in the SAP. Avoid overfilling sample containers to prevent preservatives, if present, in sample container from being lost.
10. Pack and store samples appropriately for transport to laboratory.

Sample Collection Using Peristaltic Pump

Personnel conducting surface water sampling using peristaltic pump collection techniques should perform the following:

1. Surface water will be collected using a peristaltic pump if flow is slow and conventional sampling procedures are impossible without collecting excess suspended sediment in the sample. Note any observations such as color or odors and determine the depth of water. Record the information in the field log book or field log forms.
2. Personnel should be aware that contact with peristaltic pump apparatus (e.g., control knobs) can serve as a source of metals contamination in dissolved metals analyses. Operation of pump controls should be conducted with gloves that do not come into contact with the sample or with materials that contact the sample.
3. Attach tubing to pump and configure tubing such that intake in positioned at the desired sample depth within the water column and discharge is into desired sample container.

4. Turn the pump on and adjust the flow rate as necessary to avoid splashing or overfilling.

5. Measure water quality parameters on a volume of sample that will not be shipped to the laboratory to avoid cross-contamination in the sample to be analyzed.

6. Collect surface water samples by diverting flow out of the unfiltered discharge tubing into the appropriate labeled sample container.

   - If a flow-through analytical cell is being used to measure field parameters, the flow-through cell should be disconnected after stabilization of the field indicator parameters and prior to surface water sample collection. Under no circumstances should analytical samples be collected from the discharge of the flow-through cell.
   - When the sample container is full, tightly screw on the cap.
   - Samples should be collected in the following order: VOCs, TOC, SVOCs, metals and cyanide, and others (or other order as defined in the Sampling and Analysis Plan (SAP)).

7. Pack and store samples appropriately for transport to laboratory.

8 WASTE MANAGEMENT

Liquid investigation-derived wastes (IDWs), such decontamination liquids or excess surface water, will be collected into 55-gallon drums and may be transferred into large-volume polyethylene tanks with secondary containment pending treatment and/or disposal.

Non-aqueous liquid wastes, if generated (e.g., hexane, non-aqueous phase liquid [NAPL]), will be segregated and stored in appropriately sized buckets with secondary containment pending disposal.

PPE, soiled disposable items, and other trash will be stored in 55-gallon drums and stored on site pending disposal.

IDWs will be collected and stored on site in United States Department of Transportation (DOT)-compliant 55-gallon drums and/or large-volume tanks with secondary containment. Fifty-five-gallon drums and tanks will be labeled with DOT-compliant labels with the following information: drum contents, generator contact information, and date container was filled. IDWs known to be hazardous will be segregated and stored separately from non-hazardous IDWs. Solid IDWs will be segregated and stored separately from liquid IDWs.

IDWs will be sampled as needed for disposal characterization and stored on site pending treatment and/or disposal. IDWs may be managed in conjunction with remedial activities.

All IDWs will be stored in a secure onsite location pending treatment and disposal and/or discharge.

9 DATA RECORDING AND MANAGEMENT

Record field data in field notebook and/or on field log sheets.

10 QUALITY ASSURANCE

Sample quality will be achieved by complying with the procedures outlined in this TGI. Cross-contamination will be prevented by following standard decontamination protocols. Field activities will be supervised by appropriate experienced field supervisors. Additional quality assurance information is presented in the project-specific Quality Assurance Project Plan.

ATTACHMENT B

FIELD METHOD STANDARD OPERATING PROCEDURE (FERROUS IRON)

Iron, Ferrous

DOC316.53.01049

1,10-Phenanthroline Method[1]

Method 8146

0.02 to 3.00 mg/L Fe^{2+}

Powder Pillows

Scope and application: For water, wastewater, seawater, brine solutions, produced waters and hydraulic fracturing waters.

[1] Adapted from Standard Methods for the Examination of Water and Wastewater, 15th ed. 201 (1980).

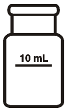
Test preparation

Instrument-specific information

Table 1 shows all of the instruments that have the program for this test. The table also shows sample cell and orientation requirements for reagent addition tests, such as powder pillow or bulk reagent tests.

To use the table, select an instrument, then read across to find the applicable information for this test.

Table 1 Instrument-specific information

Instrument	Sample cell orientation	Sample cell
DR6000 DR3800 DR2800 DR2700 DR1900	The fill line is to the right.	2495402 
DR5000 DR3900	The fill line is toward the user.	
DR900	The orientation mark is toward the user.	2401906 

Before starting

Samples must be analyzed immediately after collection and cannot be preserved for later analysis.
Install the instrument cap on the DR900 cell holder before ZERO or READ is pushed.
For the best results, measure the reagent blank value for each new lot of reagent. Replace the sample with deionized water in the test procedure to determine the reagent blank value. Subtract the reagent blank value from the sample results automatically with the reagent blank adjust option.
Review the Safety Data Sheets (MSDS/SDS) for the chemicals that are used. Use the recommended personal protective equipment.
Dispose of reacted solutions according to local, state and federal regulations. Refer to the Safety Data Sheets for disposal information for unused reagents. Refer to the environmental, health and safety staff for your facility and/or local regulatory agencies for further disposal information.

Items to collect

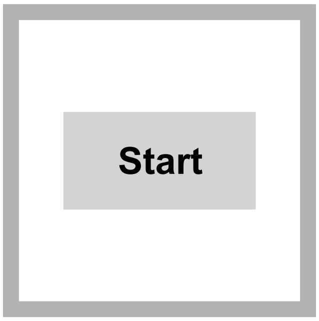
Description	Quantity
Ferrous Iron Reagent Powder Pillows, 25 mL	1
Sample cells. (For information about sample cells, adapters or light shields, refer to Instrument-specific information on page 1.)	2

Refer to Consumables and replacement items on page 4 for order information.

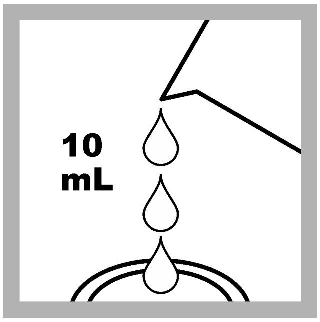
Sample collection

- Analyze the samples immediately. The samples cannot be preserved for later analysis.
- Collect samples in clean glass or plastic bottles with tight-fitting caps. Completely fill the bottle and immediately tighten the cap.
- Prevent agitation of the sample and exposure to air.

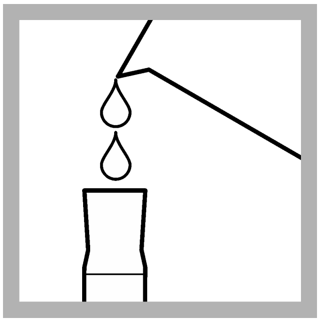
Test procedure



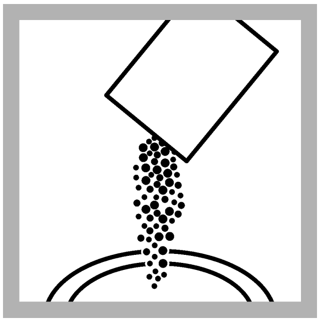
1. Start program **255 Iron, Ferrous**. For information about sample cells, adapters or light shields, refer to Instrument-specific information on page 1.



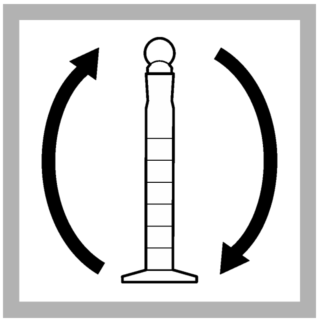
2. Prepare the blank: Fill the sample cell with 10 mL of sample.



3. Prepare the sample: Fill a mixing cylinder to the 25-mL line with sample.

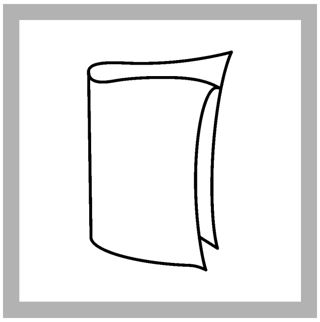


4. Add the contents of one Ferrous Iron Reagent Powder Pillow to the mixing cylinder.
An orange color shows if ferrous iron is present in the sample.

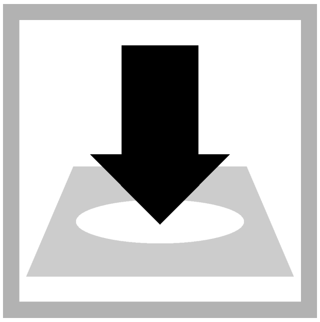


5. Put the stopper on the mixing cylinder. Invert the mixing cylinder several times to mix.
Undissolved powder does not affect accuracy.

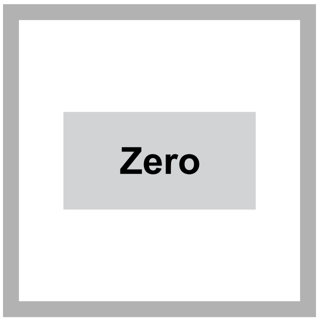
6. Start the instrument timer. A 3-minute reaction time starts.



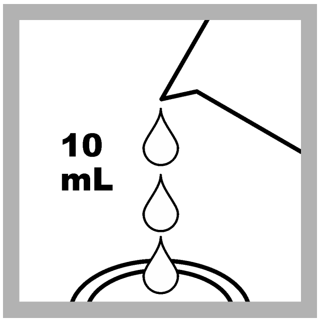
7. When the timer expires, clean the blank sample cell.



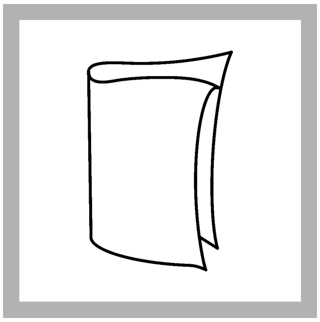
8. Insert the blank into the cell holder.



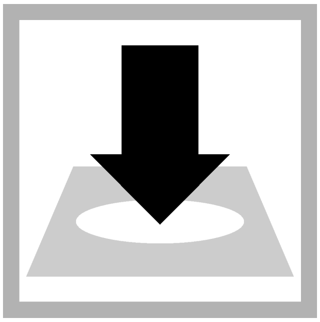
9. Push **ZERO**. The display shows 0.00 mg/L Fe^{2+}.



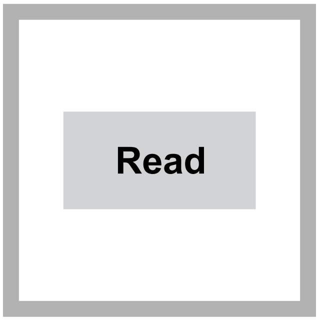
10. Fill a second sample cell with 10 mL of the reacted prepared sample.



11. Clean the prepared sample cell.



12. Insert the prepared sample into the cell holder.



13. Push **READ**. Results show in mg/L Fe^{2+}.

Accuracy check

Standard solution method

Use the standard solution method to validate the test procedure, the reagents and the instrument.

Items to collect:

- Ferrous Ammonium Sulfate, hexahydrate
- 1-L volumetric flask, Class A
- 100-mL volumetric flask, Class A
- 2-mL volumetric pipet, Class A and pipet filler
- Deionized water

1. Prepare a 100-mg/L Fe^{2+} ferrous iron stock solution as follows:
    - **a.** Add 0.7022 g of ferrous ammonium sulfate, hexahydrate into a 1-L volumetric flask.
    - **b.** Dilute to the mark with deionized water. Mix well.
2. Prepare a 2-mg/L ferrous iron standard solution as follows:
    - **a.** Use a pipet to add 2.00 mL of the 100-mg/L Fe^{2+} ferrous iron stock solution into a 100-mL volumetric flask.
    - **b.** Dilute to the mark with deionized water. Mix well. Prepare the standard solution immediately before use.
3. Use the test procedure to measure the concentration of the prepared standard solution.
4. Compare the expected result to the actual result.

    Note: *The factory calibration can be adjusted slightly with the standard calibration adjust option so that the instrument shows the expected value of the standard solution. The adjusted calibration is then used for all test results. This adjustment can increase the test accuracy when there are small variations in the reagents or instruments.*

Method performance

The method performance data that follows was derived from laboratory tests that were measured on a spectrophotometer during ideal test conditions. Users can get different results under different test conditions.

Program	Standard	Precision (95% confidence interval)	Sensitivity Concentration change per 0.010 Abs change
255	2.00 mg/L Fe^{2+}	1.99–2.01 mg/L Fe^{2+}	0.021 mg/L Fe^{2+}

Summary of method

The 1,10-phenanthroline indicator in the Ferrous Iron Reagent reacts with ferrous iron (Fe^{2+}) in the sample to form an orange color in proportion to the iron concentration. Ferric iron (Fe^{3+}) does not react. The ferric iron concentration can be determined by subtracting the ferrous iron concentration from the results of a total iron test. The measurement wavelength is 510 nm for spectrophotometers or 520 nm for colorimeters.

Consumables and replacement items

Required reagents

Description	Quantity/test	Unit	Item no.
Ferrous Iron Reagent Powder Pillow, 25 mL	1	100/pkg	103769

Recommended standards and apparatus

Description	Unit	Item no.
Balance, analytical, 80 g x 0.1 mg 100–240 VAC	each	2936701
Ferrous Ammonium Sulfate, hexahydrate, ACS	113 g	1125614
Flask, volumetric, Class A, 1000 mL glass	each	1457453
Pipet filler, safety bulb	each	1465100
Pipet, volumetric, Class A, 1.00 mL	each	1451535
Water, deionized	4 L	27256
Wipes, disposable	280/pkg	2097000

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Appendix B

Responses to Comments

US Army Corps
of Engineers®

New England District
696 Virginia Road
Concord, Massachusetts
01742-2751

Project Name: Former Fort Devens Army Installation	Date:	January 2023
Location: Devens, Massachusetts	Reviewer:	USEPA
Document Name: Draft Final Post-Record of Decision Supplemental Remedial Investigation Work Plan - Area of Contamination 57		
Document Prepared By: Seres Arcadis 8(a) JV		

No.	Ref. Page / Para.	COMMENT (November 2022)	RESPONSE (December 2022)	COMMENT (January 2023)	RESPONSE (January 2023)
		GENERAL COMMENTS			
1.		As acknowledged in the Remedial Investigation Work Plan (RIWP), the site is located within the Zone II protection area for the Town of Ayer's drinking water wells. EPA believes that this indicates the importance of refining the Conceptual Site Model (CSM) and determining the nature and extent of groundwater contamination associated with AOC 57.	Noted.		
2.		The PFAS investigations in the AOC 57 area have increased the three-dimensional understanding of subsurface and groundwater conditions at AOC 57. EPA strongly suggests incorporating data and CSM understandings gained by the PFAS investigations into the CERCLA RI proposed in the present document.	Additional text has been added to Section 3.2.5 Nature and Extent of Arsenic from the Area 1 PSCS and 2020 FYR (new paragraphs 4, 5, and 6 after Exhibit 3-1) discussing CSM understandings from these reports. Groundwater results from the VAP borings installed in 2020 have been added to Table 3-1 and are also discussed in Section 3.2.5. Revised text is presented below: *"As detailed in Table 3-1 and Table 3-3, the wells sampled historically during LTM sampling events (57M-03-01X to 57M-03-06X in Area 2; 57M-95-03X and 57M-96-11X in Area 3 are all screened in the shallow overburden (average total depth of 14 feet bgs), with well screen intervals designed to straddle the observed water table. Numerous additional deep overburden monitoring wells and VAP locations were installed in 2020 as part of the ongoing remedial investigation of PFAS; groundwater samples were collected and analyzed for dissolved arsenic, iron, and manganese to support the ongoing sampling efforts (KGS 2020). Sampling results are included in Table 3-1.* *In Area 2, arsenic was detected in one deep overburden well (5702MW-20-01B; screened from 70-80 feet bgs) at a concentration of 17 µg/L (greater than the Cleanup Goal), which likely represents naturally-occurring arsenic levels in deeper groundwater due to (a) the observed reducing range of ORP and DO, (b) the observed upward vertical gradient, and (c) the low concentrations of arsenic (2.2 µg/L) in paired monitoring well 5702-MW-20-01A (screened from 30-40 feet bgs) (KGS 2020). Groundwater data generated during the installation of four VAP*		

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			locations in Area 2 (5702VP-20-01 to 5702VP-20-04) indicate that arsenic concentrations, with one exception, were non-detect or less than the Cleanup Goal; this suggests that arsenic at levels greater than the Cleanup Goal has not been transported into or beyond Cold Spring Brook (KGS 2020). *In Area 3, arsenic was detected in one deep overburden well (5703MW-20-01B; screened from 50-60 feet bgs) at a concentration of 11 µg/L (greater than the Cleanup Goal). Similar to the Cleanup Goal exceedance in well 5702MW-20-01B, this likely represents naturally-occurring arsenic levels in deeper groundwater due to (a) the observed reducing range of ORP and DO, (b) the observed upward vertical gradient, and (c) the low concentrations of arsenic (2.2 µg/L) in paired monitoring well 5703-MW-20-01A (screened from 2-12 feet bgs) (KGS 2020). Groundwater data generated during the installation of four VAP locations in Area 3 (5703VP-20-01 to 5703VP-20-04) indicate that arsenic concentrations were non-detect or less than the Cleanup Goal; this suggests that arsenic at levels greater than the Cleanup Goal has not been transported into or beyond Cold Spring Brook (KGS 2020).”*		
3.		Monitoring should continue for manganese given exceedances of background conditions (monitoring for iron is included to support natural attenuation evaluation). See, for example, Section 1.4.2, last paragraph.	To support natural attenuation evaluation, manganese analyses will be added to the Work Plan scope.		
4.		EPA remains concerned that the area with elevated arsenic concentrations may not be bounded by Cold Spring Brook (CSB). It is possible that fine-grained sediment at the bottom of this water body are acting as an aquitard, allowing groundwater to migrate beneath CSB. Additional well control is required on the other side of CSB to evaluate groundwater flow directions and determine to what extent (and under what conditions) groundwater with elevated arsenic is captured by the Brook. See, for example, Section 2.2.1, page 13, 2nd paragraph. As pointed out in EPA comments on previous reports, Army has promised to install and sample wells on the far side of Cold Spring Brook but has not yet done so.	The Army is proposing to collect current data to evaluate the nature and extent of arsenic from existing wells and two new VAPs. The Army will review the data to determine if the extent of arsenic is defined west of CSB and if additional sampling for arsenic is warranted. Potential for flow under CSB is being evaluated as part of the Area 1 PFAS investigation (see Draft Final PFAS Phase II RI Work Plan for Area 1). If the PFAS investigation shows flow under the CSB, the Army will sample the new PFAS wells for arsenic during a subsequent AOC 57 LTM monitoring event.	Please note that the extent of contamination associated with AOC 57 cannot be confirmed (i.e., adequately defined) without site/location-specific field/sample data. As stated in numerous EPA comment letters on draft Main Post Annual Reports and recent FYRs, statements such as “likely represents” and “this suggests,” must be supported by actual site/location specific field/sample data. Although Army did agreed to investigate flow under CSB in the Phase 2 PFAS RI (and “sample new PFAS wells for arsenic during a subsequent AOC 57 LTM monitoring event”), if warranted, the issue will remain a data gap upon conclusion of the supplemental RI until the necessary data from beneath and downgradient of CSB are collected to confirm long-held hypotheses regarding the fate and transport and current boundaries of contamination associated with AOC 57.	The Army agrees to collect data from the new PFAS wells proposed to be installed to the east of CSB, regardless of the results of the proposed onsite investigation locations in AOC 57. PFAS well locations will be sampled for the same suite of parameters described in the AOC 57 workplan.
5.		For figures that include CSB, please add flow arrows.	Groundwater contours, groundwater flow arrows, and surface water flow arrows have been added to the figure set.		
		PAGE-SPECIFIC COMMENTS			

No.	Ref. Page / Para.	COMMENT (November 2022)	RESPONSE (December 2022)	COMMENT (January 2023)	RESPONSE (January 2023)
1.	Page 2, Section 1.1, 5th paragraph	The text indicates that buried wastes discovered in March 2019 are addressed separately. Please describe the investigation program and/or include references to relevant report(s) addressing this potential source area.	A paragraph referencing the debris area investigation program has been added to the paragraph: *"In November and December 2021, debris was removed from AOC 57 in accordance with the Debris Removal Workplan (S-A JV 2021a); additional information is presented in the Draft Debris Removal Activities Summary Report submitted to the USEPA in January 2022 (S-A JV 2022)."*		
2.	Page 6, Section 1.4, last bullet	The second sentence quotes a ROD requirement to "assess off-site migration of human health COCs ... via the groundwater to surface water pathway." Strictly speaking, the lack of observed COC exceedances in CSB appears to indicate that this migration pathway has been assessed. However, there is more than one potential explanation for the lack of surface water exceedances. First, groundwater from beneath the site could discharge to CSB, but COCs have already attenuated by then. Second, impacted groundwater could discharge to CSB, but CSB has sufficient flow to dilute the COCs. Third, impacted groundwater does not discharge to CSB, but flows beneath it. Fourth, some impacted groundwater discharges to CSB and some flows beneath it and this may vary with seasonal and hydrologic conditions.	Please see response to General Comment No. 4.	Please see follow-up on General Comment No. 4.	Please see response to General Comment #4.
3.	Page 7, Section 1.4.1, 2nd paragraph of section	Among other things, LUCs are intended to prohibit the groundwater extraction for potable water supply use. However, A neighbor has recently installed a bedrock well for irrigation use. Given that the Zone of Contribution to this well is unknown, it is possible that the well pumps impacted groundwater from AOC 57. Are there safeguards in place that would warn a future owner or occupant of the property with the irrigation well against using that water for potable purposes?	The Army assumes that the referenced "neighbor" is 78 Barnum Road and the referenced well is the irrigation wells installed at that location by others after transfer of the property. The Army notes that this well is upgradient of AOC 57 and is installed in bedrock to a depth of 505 feet bgs; therefore, the well and any associated administrative controls are not relevant to this investigation.	Please provide references consulted to confirm the location, depth, pumping rate, and zone of influence for this irrigation well.	The available information on the irrigation well (sample ID "74IG-01") was presented in the PFAS Area 1 PSCS (KGS 2020): *"The irrigation well off the southeast corner of former Bldg. 3773 is 505 feet deep and sampled in October 2018. The screen information of the irrigation well is unknown. It is assumed to be cased into bedrock and that it is an open bedrock hole. A sample was collected from the output of the existing pump within the well. The sample was non-detect for all PFAS compounds."*
4.	Page 7, Section 1.4.2, 2nd paragraph of section	This paragraph describes reductions in monitoring based on the 2015 LTMMP. This LTMMP was never approved by EPA, so the reductions should have occurred without EPA occurrence.	The 2015 LTMMP was finalized in accordance with provisions of the FFA Section 7.8.	Please amend the discussion to state, "Although the 2015 LTMMP was finalized in accordance with provisions of the FFA Section 7.8, it was released without EPA concurrence."	The text in Section 1.4.2 has been revised to state, *"The 2015 Main Post LTMMP was finalized in accordance with provisions of the 1991 Devens FFA Section 7.8 and released without USEPA comment."*
5.	Page 8, Section 1.4.3, 1st paragraph of section	EPA does not agree that all the conclusions cited here, from the 2020 5-year report, have been demonstrated. Particularly, Army states that "the extent of dissolved phase contamination ... is controlled (bounded) by the discharge of shallow site groundwater into Cold Spring Brook." Army has presented data that shows that shallow site groundwater <u>flows toward</u> CSB but has not presented data that shows that shallow site groundwater <u>discharges into</u> CSB. While this may indeed be the case, some or all of the shallow groundwater may pass	Please see response to General Comment No. 4.	Please see follow-up on General Comment No. 4.	Please see response to General Comment #4.

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		beneath CSB some or all of the time. This possibility may be even more likely for intermediate or deep groundwater, if groundwater at these depths is impacted. Although other investigations could answer these questions (and have been suggested in the past), the most straightforward approach may be to install and sample monitoring wells on the far side of CSB. Army has agreed to this in the past but has neither done so nor claimed access infeasibility.			
6.	Page 9, Section 2.1, 1st bullet	Please note that EPA did not approve removal of analytes from the analyte list after 2014?	The 2015 LTMMP was finalized in accordance with provisions of the FFA Section 7.8.	Please amend the discussion to state, "Although the 2015 LTMMP was finalized in accordance with provisions of the FFA Section 7.8, it was released without EPA concurrence."	The text in Section 1.4.2 and Section 2.2.1 has been revised to state, *"The 2015 Main Post LTMMP was finalized in accordance with provisions of the 1991 Devens FFA Section 7.8 and released without USEPA comment."*
7.	Page 12, Section 2.2, 2nd paragraph	EPA agrees with the four bullet-point goals. EPA notes, relative the first sentence in the paragraph, that the SRI results may either confirm or disconfirm some or all of the elements of Army's protectiveness statement in the 2020 5-year report.	Noted.		
8.	Page 12, Section 2.2, 3rd paragraph	For the evaluation as to whether changes to the LTM program are indicated by the SRI results, the starting point should be the last LTMMP that was agreed upon by Army, DEP, and EPA.	Noted. Please see response to Page-Specific Comment No. 4.	Please see follow-up on General Comment No. 4.	Please see response to General Comment #4.
9.	Page 13, Section 2.2.1, 1st bullet	Please note that EPA did not approve removal of the listed analytes from Area 2 monitoring.	The 2015 LTMMP was finalized in accordance with provisions of the FFA Section 7.8.	Please amend the discussion to state, "Although the 2015 LTMMP was finalized in accordance with provisions of the FFA Section 7.8, it was released without EPA concurrence."	The text in Section 2.2.1 has been revised to state, *"The 2015 Main Post LTMMP was finalized in accordance with provisions of the 1991 Devens FFA Section 7.8 and released without USEPA comment."*
10.	Page 13, Section 2.2.1, 3rd bullet	Army concludes, for Area 3, that "arsenic is not migrating to surface water at concentrations above monitoring criteria." EPA agrees that this statement is consistent with results but more elaboration is needed. Does impacted groundwater migrate to surface water but with sufficient dilution or other attenuation of arsenic, or does groundwater with elevated arsenic flow beneath CSB rather than discharge to it?	Please see response to General Comment No. 4.	Please see follow-up on General Comment No. 4.	Please see response to General Comment #4.
11.	Page 13, Section 2.2.1, 1st paragraph after bullets	Army states that the 2020 FYR concluded that for Area 3, "arsenic concentrations ... controlled (bounded) by the discharge of shallow groundwater into Cold Spring Brook." As discussed in other comments, Army has demonstrated that groundwater flows toward CSB but has only hypothesized that groundwater actually discharges into CSB. Unless Army has new evidence to present, the conclusion is not backed by on-site investigations. Installation and sampling of new wells on the other side of CSB, as well as other investigations, col serve to confirm or dis-confirm Army's hypothesis.	Please see response to General Comment No. 4.	Please see follow-up on General Comment No. 4.	Please see response to General Comment #4.
12.	Page 14, Section 2.2.2	There is only one bulleted goal for the field investigation portion of the SRI. This corresponds to the first of the numbered study questions listed at the end of Section 2.2.1 and can also be reasonably expected to address study question 2. Study question 3 can be addressed by analyzing existing and new field data. How does Army propose to address study question 4? Will field investigations be needed to answer this question? The 7th bullet in Section 2.2.3 appears to answer	An additional bullet item has been added to Section 2.2.2: *"Confirm the current nature and extent of reducing aquifer conditions."*		

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		this question but should be included as a bullet item in Section 2.2.2.			
13.	Page 14, Section 2.2.3, 2nd bullet	The text indicates that new vertical aquifer profile (VAP) locations will be added upgradient of the former petroleum release area in Area 2 and downgradient of the former release area in Area 3. This is the opposite of what is shown in Figure 4-1 and 4-2; please confirm text. Also, it would be helpful to add figure references to this bullet.	Text has been corrected, and a reference to Section 4 of the report has been added: *"Current analytical data for arsenic from existing monitoring wells and from two proposed vertical aquifer profile (VAP) locations; one downgradient of the former petroleum release area in Area 2 and one upgradient from the former petroleum release area in Area 3 to determine vertical and lateral extent of arsenic. See Section 4 for additional details.'"*		
14.	Page 15, Section 2.2.4, 1st paragraph	General study area is discussed, with reference to Figure 1-2, but the figure does not show study area boundaries. Please add the proposed study area boundaries (dashed and with question marks if uncertain), for review and comment. More critically, the text of this paragraph defines the study area to include "associated downgradient extents of the ROD-related COC arsenic." However, determining the extent of the arsenic impacts is one of the express goals of the SRI. Because the extent is yet to be determined, the study area should be defined in some other way and should include monitoring points on the far side of CSB.	Study area boundaries have been added to Figure 1-2 and Figure 4-1, which are attached for reference.	Please see follow-up on General Comment No. 4.	Please see response to General Comment #4.
15.	Page 15, Section 2.2.5	Two new locations for sampling may not be sufficient. If arsenic impacts are detected at either location, the extent of the impacts may not yet be bounded. Additional "step-out" sampling may be needed and should be added to the plan as a contingency. Also, new VAP, monitoring well, or other sampling points must be installed on the far side of CSB, or an alternate way of determining whether impacted groundwater occurs on the far side of CSB must be proposed.	In Area 2, proposed VAP location 5702VP-23-01 will be located adjacent to CSB. Since a step-out location here would fall within the CSB, the Army is proposing a contingent surface water sample location downgradient. See revised Figure 4-2. In Area 3, proposed VAP location 5703VP-23-01 has been moved closer to the 57M-95-03X area, and the previous VAP location will be used as a contingent location (5703VP-23-02). See revised Figure 4-3. Please see response to General Comment No. 4.	Please see follow-up on General Comment No. 4.	Please see response to General Comment #4.
16.	Page 16, Section 2.2.5, 1st bullet	EPA agrees that data are needed to determine the "current lateral and vertical extent of arsenic in groundwater." The parenthetical portion should "samples from locations and depths not exceeding screening criteria."	Text in parentheses has been updated.: *"Is there sufficient current data to confirm the current lateral and vertical extent of arsenic in groundwater (i.e., are locations with samples exceeding screening criteria bounded by samples from locations and depths not exceeding screening criteria)?"*		
17.	Page 18, Section 3.2.3, 1st sentence	AOC 57 is located west of CSB, not east of it.	Correct. Text has been revised.		

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18.	Page 19, Section 3.2.3, last sentence of 1st paragraph at top of page	Upward gradients near CSB are a necessary, but not sufficient, condition for groundwater to discharge to CSB. If the brook is perched on a low-permeability or impermeable deposit, some or all of the groundwater that flows toward the brook may pass beneath the brook rather than discharge to it, especially at intermediate or deeper levels. In such cases, a vertical upward gradient may still be maintained, even with little or no upward discharge.	Please see response to General Comment No. 4.	Please see follow-up on General Comment No. 4.	Please see response to General Comment #4.
19.	Page 20, Section 3.2.5, last paragraph	Please state what the benchmarks for surface water are or refer the reader to another section of text or a table that provides the information.	There is already a reference in this section to Table 3-2 which includes the surface water benchmarks.		
20.	Page 23, Section 4.1, 1st bullet	The stated purpose for the activities proposed for the first bullet is "To evaluate the current lateral and vertical extent of arsenic." However, the two proposed VAP borings are expressly intended to address different questions. The stated purpose of 5702-VP-22-01 is to see if naturally reducing conditions associated with wetlands are mobilizing arsenic. EPA agrees that this is a worthwhile goal, but this VAP boring does not help with the stated purpose. The expressed rationale for 5703-VP-22-01 is even further from the stated purpose in this first bullet. Please explain how a VAP boring in an upgradient location might confirm the vertical extent of arsenic in the groundwater. Does Army believe this location will represent the thickness of a contaminant plume? A background location? How will it be used to define vertical extent if it is upgradient of contaminant sources? EPA recommends that a discussion and depiction (maps and cross-sections or block diagram) of current data gaps should precede a discussion of where new VAP borings, monitoring wells, or other investigations should be undertaken in order to answer the stated question.	Please refer to updated text in Section 4.1, 1st bullet (in addition to the project goal added to Section 2.2.2): *"To evaluate the current lateral and vertical extent of arsenic, one VAP boring (5702VP-232-01) will be drilled downgradient of well 57M-03-05X in Area 2; the need for a VAP at this location was identified due to define historical concentrations of arsenic above the Cleanup Goal, as well as to assess if the reducing conditions created by the wetland area are resulting in natural arsenic mobilization. If arsenic exceeds the Cleanup Goal in proposed VAP boring 5702VP-23-01, a surface water sample (57-AREA2-SW4) will be collected downgradient from this location. A second VAP boring (5703VP-232-01) will be drilled upgradient of all wells in Area 3; the need for a VAP at this location was identified to confirm vertical the lateral and vertical extent of arsenic in the groundwater, as no historical groundwater sampling locations are present upgradient from well 57M-95-03X. If arsenic exceeds the Cleanup Goal in proposed VAP boring 5703VP-23-01, contingency VAP boring 5703VP-23-02 will be installed. The two proposed and contingency sample locations are shown on Figure 4-2 and Figure 4-3, respectively."*	Please see follow-up on General Comment No. 4.	Please see response to General Comment #4.
21.	Page 23, Section 4.1, 2nd bullet	Presence of an upward vertical gradient in a pair of piezometers installed at the streambank and in the stream bed does not necessarily confirm that groundwater is discharging to CSB. The brook could be underlain by a low-permeability layer of silt, clay, peat, etc. that restricts discharge of shallow groundwater to CSB. Also, a low-permeability layer might restrict upward groundwater flow from intermediate or deep aquifer layers to the shallow aquifer and CSB. All of these scenarios could occur and still maintain an upward gradient. EPA encourages installation of piezometer pairs and vertical gradient calculations at the stream bank or in the stream bed; these will be much more informative than similar calculations made in the wetland at some distance from CSB or at the slope break between uplands and the wetland or stream valley. To confirm discharge of groundwater from the shallow, intermediate, or deep aquifer to CSB, other	Please see response to General Comment No. 4.	Please see follow-up on General Comment No. 4.	Please see response to General Comment #4.

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		investigations are also needed. For example, a combination of vertical gradient calculations with boring logs that show permeable deposits between the stream bed and the aquifer would be very helpful. A thorough investigation might either confirm or disconfirm Army's belief that groundwater discharges to CSB and that the brook serves as a boundary or limit to any site-related arsenic (or other) impacts. As discussed on multiple occasions, a complementary or alternate approach is to conduct sufficient well or VAP installation and sampling on the far side of CSB to make a convincing case, one way or the other.			
		END OF COMMENTS			

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

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 57, 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 12, 2023, concerning the *Draft Final Post-Record of Decision (ROD) Supplemental Remedial Investigation Work Plan, Area of Contamination 57*, *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. Although requested in EPA's comments on the draft SRI work plan, revised draft SRI work plan, and responses to Army comments on the revised draft SRI work plan, the text in subsection 1.4.2 was not amended to indicate that while the 2015 LTMMP Update was "finalized in accordance with provisions of the 1991 Devens FFA Section 7.8," it was released <u>*without EPA concurrence and/or approval*</u>; Army's decision to unilateral decision to unilaterally modify Main Post [AQOC 57] LTMMP in 2015 (i.e., discontinue sampling in Area 2, reduce sampling frequency, and eliminate ROD-specified COCs (i.e., analytes) from the LTMP), may limit the available dataset from which to verify attainment of ROD-specified RAOs, cleanup goals and achieve site closeout under CERCLA.

    - <u>Army Response</u>: The Army notes that the 2015 LTMMP Update was finalized after the EPA failed to provide comments on the Draft Final document. The Army waited until well after the FFA Section 7.8 requirement of 45 days to finalize the document. However, in the interest of cooperation and moving the project forward, the Army has added the requested text to the document. This change is shown in the attached Red-Line-Strikeout (RLSO) PDF of the text.

2. As stated in EPA comments on post-2015 Main Post Annual LTMMP Reports, recent [2015 and 2020] FYR Reports, and draft/draft final revised AOC 57 SRI WPs, the extent of contamination associated with AOC 57 cannot be confirmed (i.e., adequately defined) without site/location-specific sample data) to delineate the vertical extent of all ROD-specified contaminants (i.e., analytes) and verify deeper ground flow direction near and beyond CSB.

   - Army Response: As discussed in Section 4 of the February 2023 Draft Final SRI Work Plan, the Army added four sampling locations (two vertical aquifer profiles and two monitoring wells) to the east of CSB (Cold Spring Brook), as well as contingent investigation locations and surface water samples, to address this concern.

3. As stated in EPA comments on post-2015 Main Post Annual LTMMP Reports, recent [2015 and 2020] FYR Reports, and draft/draft final revised AOC 57 SRI WPs, statements such as “likely represents” and “this suggests” must be supported by site/location-specific sample data; for example, Army’s long-held hypotheses regarding the fate and transport and current boundaries of downgradient contamination associated with AOC 57 will continue to be data gaps unless the SRI includes investigation of groundwater flow beneath and downgradient of CSB.

   - Army Response: As discussed in Section 4 of the February 2023 Draft Final SRI Work Plan, the Army added four sampling locations to the east of CSB (Cold Spring Brook) to address this concern.

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 in Area 2 and 3 groundwater, surface water and sediment (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 those COCs that are demonstrated to be associated with AOC 57.

6. Army’s December 11, 2020, SOW specified that “Army will prepare a supplemental RI work plan for AOC 57 to achieve the following objectives: (1) delineate the vertical extent of groundwater contamination and verify deeper ground flow direction based on site-specific groundwater data; (2) confirm the hydraulic connection between CSB and AOC 57 groundwater and contaminant transport paths via installation of additional wells and piezometers on the east side of CSB; (3) define the downgradient extent of COC

concentrations in groundwater and confirm the boundary of reducing (low ORP and DO) conditions via sampling of existing downgradient monitoring wells and installation of new downgradient monitoring wells; (4) determine if off-site migration of contaminated groundwater is occurring and identify current impacts, if any, on downgradient public and/or private drinking water supply and irrigation wells; and (5) collect necessary data to support a focused FS, specifically to evaluate remedial alternatives and to estimate remedy timeframes, with particular focus on the source area and any continuing sources that are contributing to groundwater contamination." However, the focus of the SRI seems to be solely on arsenic (i.e., pg. 14, Sec. 2.2.2 Project Goals - (1) confirm the current lateral and vertical extent of arsenic in groundwater, (2) confirm the current nature and extent of reducing aquifer conditions); unless Army is confident that sufficient historic data exists to verify the existing lateral and vertical boundaries of all ROD-specified COCs, then additional data should be collection for evaluation, concurrent with historic data, in the draft SRI Report; such information will be necessary, and is critical, to support an FFS.

- Army Response: As discussed in Section 4 of the February 2023 Draft Final SRI Work Plan, the Army added the analyses of all groundwater samples for Volatile Petroleum Hydrocarbons (VPH) and Extractable Petroleum Hydrocarbons (EPH), as well as the intrinsic petroleum bioremediation parameters nitrate, nitrite, and ferrous iron, to the investigation scope to address this concern. In addition, the Army will now also add analysis of dissolved methane to the list of analytes to further the evaluation. This change is shown in the attached RLSO PDF of the text.

7. 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)