FINAL
Remedial Investigation Mobilization 1 Quality Assurance Project Plan Grand Ledge Army Aviation Support Facility and Armory, Michigan

Remedial Investigations (RI) / Feasibility Studies (FS), Decision Documents,
Time Critical Removal Actions (TCRA) for Per- and Polyfluoroalkyl Substances (PFAS)
Impacted Sites, Army National Guard Installations, Nationwide

September 2022

Prepared for:

Army National Guard Bureau
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Acronyms and Abbreviations

%	percent
°C	degrees Celsius
°F	degrees Fahrenheit
µg/kg	micrograms per kilogram
AASF	Army Aviation Support Facility
AECOM	AECOM Technical Services, Inc.
AFFF	aqueous film forming foam
AHA	Activity Hazard Analysis
AM	Action Memorandum
amsl	above mean sea level
AOI	Area of Interest
APP	Accident Prevention Plan
ARAR	Applicable or Relevant and Appropriate Requirement
ARNG	Army National Guard
ASTM	American Society for Testing and Materials
BERA	Baseline Ecological Risk Assessment
bgs	below ground surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CoC	chain of custody
COC	chemical of concern
COPC	chemical of potential concern
COPEC	chemical of potential ecological concern
CPR	cardiopulmonary resuscitation
CSM	conceptual site model
DA	Department of the Army (US)
DERP	Defense Environmental Restoration Program
DHHS	Department of Health and Human Services
DL	detection limit
DLZM	DLZ Michigan, Inc.
DO	dissolved oxygen
DoD	Department of Defense
DPT	direct-push technology
DQI	data quality indicator
DQL	data quality limit
DQO	data quality objective
DUA	data usability assessment
ECF	electrochemical fluorination
EDD	electronic data deliverable
EDR™	Environmental Data Resources, Inc.™
EGLE	Michigan Department of Environment, Great Lakes, and Energy
ELAP	Environmental Laboratory Accreditation Program

ELCR	excess lifetime cancer risk
EM	Engineering Manual
EPC	exposure point concentration
ERA	Ecological Risk Assessment
ESTCP	Environmental Security Technology Certification Program
EtFOSA	N-ethyl perfluorooctane sulfonamide
EtFOSE	N-ethyl perfluorooctane sulfonamido ethanol
FD	field duplicate
FRB	field reagent blank
FS	Feasibility Study
FTA	fire training area
FTOH	fluorotelomer alcohol
FTS	fluorotelomer sulfonic acid
GCC	Generic Cleanup Criteria
GIS	geographic information system
GPS	global positioning system
HA	Health Advisory
HAZWOPER	Hazardous Waste Operations and Emergency Response
HDPE	high-density polyethylene
HFPO-DA	hexafluoropropylene oxide dimer acid
HHRA	Human Health Risk Assessment
HI	Hazard Index
IDQTF	Intergovernmental Data Quality Task Force
IDW	investigation-derived waste
ISC	instrument sensitivity check
ITRC	Interstate Technology Regulatory Council
K_{oc}	organic carbon-normalized distribution coefficients
LC/MS/MS	liquid chromatography tandem mass spectrometry
LOD	limit of detection
LOQ	limit of quantitation
MCL	Maximum Contaminant Level
MDEQ	Michigan Department of Environmental Quality
MDMVA	Michigan Department of Military and Veterans Affairs
MDNR	Michigan Department of Natural Resources
MeFOSA	N-methyl perfluorooctane sulfonamide
MeFOSE	N-methyl perfluorooctane sulfonamido ethanol
mg/kg	milligrams per kilogram
MIARNG	Michigan Army National Guard
MPART	Michigan PFAS Action Response Team
MPC	measurement performance criteria
mph	miles per hour
MS	matrix spike
MSD	matrix spike duplicate

MSU	Michigan State University
mV	millivolts
NELAP	National Environmental Laboratory Accreditation Program
N-EtFOSAA	2-(N-Ethylperfluorooctanesulfonamido) acetic acid
ng/L	nanograms per liter
N-MeFOSAA	2-(N-Methylperfluorooctanesulfonamido) acetic acid
NTU	nephelometric turbidity unit
ORP	oxidation-reduction potential
OSD	Office of the Secretary of Defense
OSHA	Occupational Safety and Health Administration
PA	Preliminary Assessment
PARCCS	precision, accuracy, representativeness, comparability, completeness, and sensitivity
PFAA	perfluoroalkyl acid
PFAS	per- and polyfluoroalkyl substances
PFBA	perfluorobutanoic acid
PFBS	perfluorobutanesulfonic acid
PFC	perfluorinated compound
PFCA	perfluoroalkyl carboxylic acid
PFDA	perfluorodecanoic acid
PFDoA	perfluorododecanoic acid
PFDS	perfluorodecanesulfonic acid
PFHpA	perfluoroheptanoic acid
PFHpS	perfluoroheptanesulfonic acid
PFHxA	perfluorohexanoic acid
PFHxS	perfluorohexanesulfonic acid
PFNA	perfluorononanoic acid
PFNS	perfluoro-1-nonanesulfonate
PFOA	perfluorooctanoic acid
PFOS	perfluorooctanesulfonic acid
PFOSA	perfluorooctanesulfonamide
PFPA	perfluoropentanoic acid
PFPeA	perfluoropentanoic acid
PFPeS	perfluoro-1-pentanesulfonate
PFSA	perfluoroalkyl sulfonic acid
PFTeA	perfluorotetradecanoic acid
PFTrDA	perfluorotridecanoic acid
PFUdA	perfluoroundecanoic acid
PID	photoionization detector
PPE	personal protective equipment
PRB	permeable reactive barrier
PRG	Preliminary Remediation Goal
PWS	Performance Work Statement

QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
QL	quantitation limit
QSM	Quality Systems Manual
RAGS	Risk Assessment Guidance for Superfund
RI	Remedial Investigation
ROE	right of entry
RSL	Regional Screening Level
SC	specific conductivity
SDG	sample delivery group
SERDP	Strategic Environmental Research and Development Program
SI	Site Inspection
SL	Screening Level
SLERA	Screening-Level Ecological Risk Assessment
SOP	standard operating procedure
SP	screen point
SS	Site Supervisor
SSHO	Site Safety and Health Officer
SSHP	Site Safety and Health Plan
SU	sampling unit
T&E	threatened and endangered
TAT	turn-around time
TAL	target analyte list
TBD	to be determined
TCRA	time critical removal action
TIR	Thermal Infrared
TO	task order
TOC	total organic carbon
TPP	technical project planning
TSA	Technical System Audit
UCL	upper confidence limit
UFP	Uniform Federal Policy
US	United States
USACE	United States Army Corps of Engineers
USCS	Unified Soil Classification System
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UU/UE	unlimited use/unrestricted exposure
VOC	volatile organic compound
VSI	visual site inspection
VSP	Visual Sampling Plan

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1.0 Introduction

1.1 Project Authorization

This Remedial Investigation (RI) Uniform Federal Policy-Quality Assurance Project Plan (UFP-QAPP) addresses RI activities to be completed at the Grand Ledge Army Aviation Support Facility (AASF) and Armory (also referred to as "Grand Ledge AASF" and the "facility"), in Grand Ledge, Michigan. RI activities for the facility will be conducted over multiple mobilizations. This UFP-QAPP addresses investigation activities to be completed as part of the Mobilization 1.

The Army National Guard (ARNG) G9 is the lead agency in performing *Remedial Investigations (RI)/ Feasibility Studies (FS), Decision Documents, Time Critical Removal Actions (TCRA) for Per- and Polyfluoroalkyl Substances (PFAS) Impacted Sites, ARNG Installations, Nationwide*. This work is supported by the United States (US) Army Corps of Engineers (USACE) Baltimore District and their contractor AECOM Technical Services, Inc. (AECOM) under Contract Number W912DR-15-D-0017, TO W912DR18F0741, issued 30 September 2018. Programmatically, the ARNG is assessing the potential environmental impacts primarily from aqueous film forming foam (AFFF) and similar chemical releases suspected at their properties related to processes that used PFAS (e.g., fire training, firefighting, and metal plating).

A Preliminary Assessment (PA) and Site Inspection (SI) were performed under a separate contract vehicle on behalf of the ARNG. The PA determined whether or not there was a potential release to the environment related to processes that use PFAS. During the PA, two Areas of Interest (AOIs) were identified that had three potential PFAS release areas; therefore, AOI 1 AASF Hangar and Armory (Former AASF) and AOI 2 Annex Building moved forward to the SI phase. The SI concluded there was a release to the environment from AOI 1 AASF Hangar and Armory (Former AASF), identified in the PA and determined the presence of perfluorooctanoic acid (PFOA), perfluorooctanesulfonic acid (PFOS), and perfluorobutanesulfonic acid (PFBS) at or above screening levels (SLs) established in a memorandum from the Office of the Secretary of Defense (OSD) dated 15 September 2021 (Assistant Secretary of Defense, 2021). The SI concluded at AOI 2, that there was a detection for PFOS slightly below to the SLs indicating a possible release and potential data gap relative to the SI data, therefore; AOI 2 will be further investigated during the RI. The former AASF Hangar property was occupied by MIARGE prior to the 1980s. This property is currently owned by Transfast Trucking, Inc. and will be included in this investigation as AOI3 – Former AASF Hangar.

RI activities for the facility will be conducted in multiple mobilizations. RI Mobilization 1 at Grand Ledge AASF will aim to refine the onsite occurrence of PFOA, PFOS, and PFBS in groundwater and soil at the potential PFAS source and release areas as well as the exceedance of the screening levels (SLs) in the perched groundwater aquifer. The analytical data from the RI Mobilization 1 data will be used to develop the approach for RI Mobilization 2.

The RI project elements will be performed by AECOM in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA; US Environmental Protection Agency [USEPA], 1980), as amended, the National Oil and Hazardous Substances Pollution Contingency Plan (40 Code of Federal Regulations [CFR] Part 300; USEPA, 1994), and in compliance with US Department of the Army (DA) requirements and guidance for field investigations, including specific requirements for sampling for PFOA, PFOS, and PFBS, and the group of related compounds technically referred to as PFAS. The term PFAS will be used throughout this plan to encompass all PFAS chemicals being evaluated. This includes PFOA, PFOS, and PFBS, which are the key components of the suspected releases being evaluated, and the other PFAS described in this QAPP.

1.2 RI Purpose

The objective of the RI is to determine the extent of PFOA, PFOS, and PFBS at or above SLs at the AOI identified in the PA where the presence of these PFAS was confirmed during the SI.

Additionally, the RI will gather sufficient data to define release areas, potential migration pathways, potential receptors, and associated exposure routes. The data will support informed risk management decisions, including:

- Determining whether, or to what extent, a threat to human health or the environment exists.
- Developing and evaluating remedial alternatives (including the no-action alternative).
- Supporting future enforcement or cost-recovery activities.

1.3 QAPP Document Organization

This QAPP meets the requirements and elements set forth in the UFP for QAPPs (Intergovernmental Data Quality Task Force [IDQTF], 2005a-c) and *EPA Requirements for Quality Assurance Project Plans* (USEPA, 2001). The QAPP is comprehensive to the extent practicable and does not refer to or rely on separate work plans, consistent with the USEPA's intent that the QAPP be the premier planning document for an entire project (IDQTF, 2012). Minimizing the existence of separate work plans maintains consistency across project elements and optimizes the administrative effort required to review and revise project documents. The components that are covered under this QAPP are described in **Table 1-1** below.

Table 1-1 Components of the RI QAPP

Site-Specific QAPP Worksheets
Worksheets #1 & #2 - Title and Approval Page and QAPP Identifying Information
Worksheets #3 & #5 - Project Organization and QAPP Distribution
Worksheets #4, #7, & #8 - Personnel Qualifications and Sign-off Sheet
Worksheet #6 - Communication Pathways
Worksheet #9 - Technical Project Planning Session Summary
Worksheet #10 - Conceptual Site Model
Worksheet #11 - Project/Data Quality Objectives
Worksheet #12 - Measurement Performance Criteria
Worksheet #13 - Secondary Data Uses and Limitations
Worksheets #14 and #16 - Project Tasks and Schedule
Worksheet #15 - Project Data Quality Limits and Laboratory-Specific Detection/Quantitation Limits
Worksheets #17 & #18 - Sampling Design and Rationale
Worksheets #19 & #30 - Sample Containers, Preservation, and Hold Times
Worksheet #20 - Field Quality Control Summary
Worksheet #21 - Field Standard Operating Procedures
Worksheet #22 - Field Equipment Calibration, Maintenance, Testing, and Inspection
Worksheet #23 - Analytical Standard Operating Procedures
Worksheet #24 - Analytical Instrument Calibration

Site-Specific QAPP Worksheets
Worksheet #25 - Analytical Instrument and Equipment Maintenance, Testing, and Inspection
Worksheets #26 & #27 - Sample Handling, Custody, and Disposal
Worksheet #28 - Analytical Quality Control and Corrective Actions
Worksheet #29 - Project Documents and Records
Worksheets #31, #32, & #33 - Assessments and Corrective Action
Worksheet #34 - Data Verification and Validation Inputs
Worksheet #35 - Data Verification Procedures
Worksheet #36 - Data Validation Procedures
Worksheet #37 - Data Usability Assessment

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QAPP Worksheets #1 & #2: Title and Approval Page and QAPP Identifying Information

Site Name/Project Name: Remedial Investigations (RI)/ Feasibility Studies (FS), Decision Documents, Time Critical Removal Actions (TCRA) for Per- and Polyfluoroalkyl Substances (PFAS) Impacted Sites, ARNG Installations, Nationwide

Installation: Grand Ledge AASF and Armory, Michigan

Contract Work Assignment Number: USACE Contract No. W912DR-15-D-0017
Delivery Order No. W912DR18F0741

Relevant Plans and Reports from Previous Investigations: Relevant plans and reports from previous investigations are identified in the references cited in the introductory text that precedes these worksheets and in subsequent worksheets, as appropriate.

	Harrington, Jacquelyn Digitally signed by Harrington, Jacquelyn DN: cn=Harrington, Jacquelyn, ou=USOMA1, email=jacquelyn.harrington@aecom.com Date: 2022.09.13 08:03:23 -05'00' 09/13/2022
Investigative Organization Project Manager Printed Name / Organization	Signature / Date Jacquelyn Harrington / AECOM Project Manager
	Gettier, Sarah Digitally signed by Gettier, Sarah Date: 2022.09.13 12:34:34 -04'00'
Investigative Organization Quality Manager Printed Name / Organization	Signature / Date Sarah Gettier / AECOM Project QC Officer
	CONNOLLY.DAVID.M.1292853633 Digitally signed by CONNOLLY.DAVID.M.1292853633 Date: 2022.09.14 08:28:08 -04'00'
Army National Guard Printed Name / Organization	Signature / Date David Connolly / ARNG Program Manager
	EDGERLY.JONATHAN.W.1280242108 Digitally signed by EDGERLY.JONATHAN.W.1280242108 Date: 2022.09.14 12:54:14 -04'00'
Michigan Army National Guard Printed Name / Organization	Signature / Date Jonathan Edgerly / Environmental Manager
	PECK.TIMOTHY.JOSEPH.1252325553 Digitally signed by PECK.TIMOTHY.JOSEPH.1252325553 Date: 2022.09.13 15:28:46 -04'00'
Contract Organization Project Manager Printed Name / Organization	Signature / Date Timothy Peck / USACE, Baltimore District

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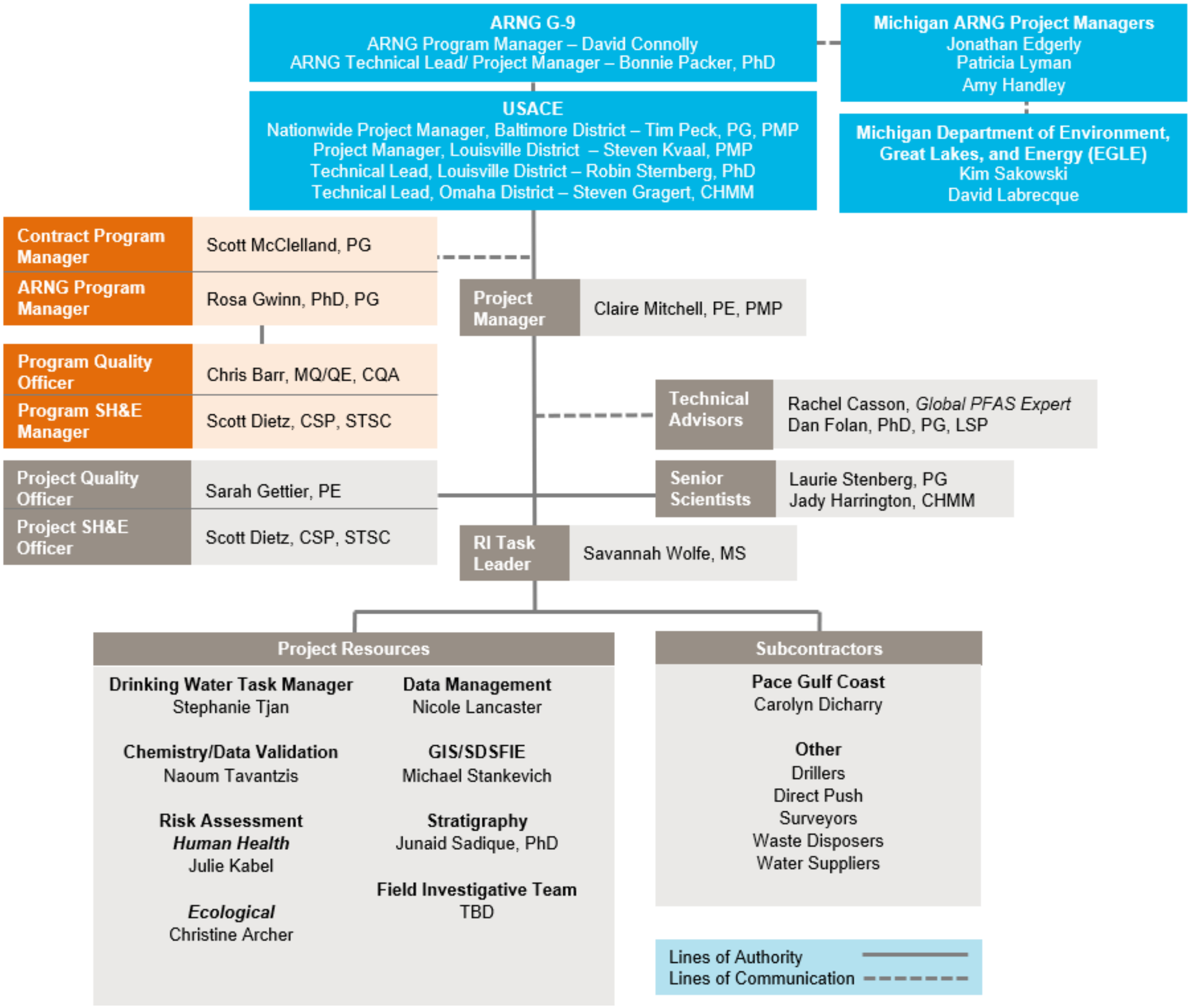
QAPP Worksheets #3 & #5: Project Organization and QAPP Distribution

The organization chart in **Figure 3-1** identifies key project personnel, as well as lines of authority and communication among the ARNG, USACE, prime contractor (AECOM) and other stakeholders. The QAPP will be distributed to all parties noted in the figure below.

Figure 3-1 Project Organizational Chart



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QAPP Worksheets #4, #7 & #8: Personnel Qualifications and Sign-off Sheet

This worksheet contains a list of the key project personnel who are identified as performing the tasks that are defined in this QAPP and includes the personnel's organization, project role, education/experience, and specialized training/certifications. The personnel have signed and dated the worksheet to signify that they agree with the information in this QAPP and agree to implement it.

Name	Organization	Project Role	Education/Experience	Specialized Training / Certifications	Signature/Date
Scott McClelland, PG	Prime Contractor (AECOM)	Contract Program Manager	Education: BA, Geology; MS, Geology Experience. 30+ years; executing and managing environmental investigation and remediation projects including program management of USACE Baltimore contracts.	Professional Geologist, KY AECOM Certified Project Manager	Signature available upon request.
Rosa Gwinn, PG, PhD	AECOM	ARNG Program Project Manager	Education: BA, Geology; MS, Geology; PhD, Geology Experience: 33+ years; managed 4 ORA Phase II TOs of similar scope, complexity, and duration for USACE and ARNG; experience with PFAS investigations.	Professional Geologist, WA, UT AECOM Certified Project Manager OSHA 40hr HAZWOPER OSHA 8hr Refresher AECOM PFAS Sampling Training	Signature available upon request.
Claire Mitchell, PE, PMP	AECOM	Project Manager, RI Senior Lead	Education: BS, Civil Engineering Experience: 10+ years; environmental engineering experience, including task management for PFAS investigations for DoD clients; PFAS Technical Practice Lead Verifier.	Professional Engineer, MO PMP Certification AECOM Certified Project Manager OSHA 40hr HAZWOPER OSHA 8hr Refresher AECOM PFAS Sampling Training	Signature available upon request.

Name	Organization	Project Role	Education/Experience	Specialized Training / Certifications	Signature/Date
Savannah Wolfe, MS	AECOM	RI Task Manager	Education: MS, Chemistry; BS, Chemistry Experience: 3+ years working on remediation projects in federal DoD contracts with experience in Army National Guard and Army preliminary assessments, site inspections, and remedial investigations; experience with PFAS investigations.	AECOM Certified Project Manager OSHA 40hr HAZWOPER OSHA 8hr Refresher First Aid/CPR AECOM PFAS Sampling Training	Signature available upon request.
Dan Folan, PhD, PG, LSP	AECOM	Senior Hydrologist/ Geochemist/ Technical Advisor, PFAS	Education: BS, Chemistry/Geology (double major); PhD, Geochemistry Experience: 28+ years of experience specializing in hydrogeological investigations and contaminant geochemistry for DoD clients including RI/FS projects on USACE New England contracts.	Professional Geologist, AL, IN, NH, ME Licensed Site Professional (MA) OSHA 40hr HAZWOPER OSHA 8hr Refresher AECOM PFAS Sampling Training	Signature available upon request.
Laurie Stenberg, PG	AECOM	Senior Scientist	Education: BA, Geology Experience: 27+ years; served as senior scientist for ORA Phase II TOs; experience with PFAS investigations; PFAS Technical Practice Lead Verifier.	Professional Geologist, PA AECOM Certified Project Manager OSHA 40hr HAZWOPER OSHA 8hr Refresher AECOM PFAS Sampling Training	Signature available upon request.
Rachel Casson	AECOM	Technical Advisor, PFAS	Education: BS, Physical Geography and Marine Science Experience: 20+ years; global expertise in fate and transport, risks, management and treatment/ remedial options for PFAS; experience collaborating on a global level with other PFAS-related discipline experts.	NA	Signature available upon request.

Name	Organization	Project Role	Education/Experience	Specialized Training / Certifications	Signature/Date
Chris Barr, CMQ/OE, CQA	AECOM	Program QA Officer	Education: BA, Chemistry Experience: 35+ years; managing project quality and laboratory services for DoD and USEPA projects.	ASQ CMQ/OE ASQ CQA ISO9001 Lead Auditor, 2003 ISO14000 Lead Auditor, 2003 NQA-1 Qualified Auditor	Signature available upon request.
Sarah Gettier, PE	AECOM	Project QA Officer	Education: BS, Civil Engineering MS, Environmental/ Environmental Health Engineering Experience: 15+ years direct experience developing QAPPs and other environmental planning documents	Professional Engineer, MD AECOM Certified Project Manager OSHA 40hr HAZWOPER OSHA 8hr Refresher	Signature available upon request.
Scott Dietz, CSP, STSC	AECOM	Federal Program Safety, Health, and Environment Manager	Education: BS, Safety Sciences Experience: 23+ years; managing safety, health, and environment on construction, environmental, and remediation projects including government projects requiring compliance with the USACE Engineering Manual 385-1-1.	CSP, STSC OSHA 40hr HAZWOPER OSHA 500 Trainer for Occupational Safety and Health Standards for Construction Industry OSHA 510 Occupational Safety and Health Standards for the Construction Industry OSHA 30hr Construction OSHA 10hr Construction OSHA 8hr Refresher	Signature available upon request.
Jacquelyn Harrington, CHMM	AECOM	Senior Scientist	Education: BA, Biology Experience: 28+ years; served as a PM for ARNG PFAS PA/SI, NDNODS MMRP RI/FS; MMRP Comprehensive Site Evaluations; Phase I/II (PA/SI) at multiple ANG/AFBs; and served as senior scientist for ORA Phase II TOs; Technical Advisor, PFAS	CHMM AECOM Certified Project Manager OSHA 40hr HAZWOPER OSHA 8hr Refresher OSHA 8hr Supervisor First Aid/CPR AECOM PFAS Sampling Training	Signature available upon request.

Name	Organization	Project Role	Education/Experience	Specialized Training / Certifications	Signature/Date
Robert Kennedy	AECOM	Senior Chemist	Education: BA, Chemistry Experience: 27+ years; served as senior scientist for ORA Phase II TOs; experience with PFAS investigations.	Auditing/Data Review training AECOM PFAS Sampling Training	Signature available upon request.
Naoum Tavantzis	AECOM	Project Chemist	Education: BA, Environmental Science; MBA Experience: 10+ years; project chemist for ORA Phase II TOs; PFAS Investigations, data validation, laboratory coordination; project chemist for ANG expanded SIs; PFAS Technical Practice Lead Verifier.	OSHA 40hr HAZWOPER OSHA 8hr Refresher OSHA 8hr Site Supervisor	Signature available upon request.
Michael Stankevich	AECOM	GIS Specialist	Education: BA, Geography – Environmental Track Experience: 9+ years; completed SDSFIE submittals for multiple ARNG installations	NA	Signature available upon request.
Julie Kabel	AECOM	Human Health Risk Assessor	Education: BS, Chemistry; Master of Public Health, Concentration Environmental Health Experience: 20+ years; performing HHRAs, vapor intrusion assessment, exposure modelling, and data management; multi-pathway, multi-media HHRAs involving PFAS; AECOM HHRA and vapor intrusion practice leader.	PFAS Workshops Certificate in Environmental Studies AECOM PFAS Sampling Training	Signature available upon request.
Christine Archer	AECOM	Ecological Risk Assessor	Education: BS, Zoology Experience: 20+ years; experience with ERAs, environmental toxicity testing, and sediment/water quality evaluations for DoD sites; experience with PFAS evaluations.	OSHA 40hr HAZWOPER OSHA 8hr Refresher First Aid/CPR	Signature available upon request.

Name	Organization	Project Role	Education/Experience	Specialized Training / Certifications	Signature/Date
Junaid Sadique, PhD	AECOM	Senior Stratigrapher	Education: BS, Geology and Mining MS, Petroleum Geology PhD, Sequence Stratigraphy Experience: 19+ years; executing subsurface geological investigations both in the petroleum and environmental industry. Recognized Subject Matter Expert in sedimentology. Playing a pivotal role in applying sequence stratigraphic concepts for predicting contamination flow paths, and developing CSMs. Experienced in integrating stratigraphic, hydrogeological and chemical data for predictive stratigraphic modeling.	GIS Training for Geologists Applied Clastic Stratigraphy Application of Well-log Correlation GoCAD, Petrel, and Geographix for stratigraphic interpretation	Signature available upon request.
Ben Campanaro	AECOM	Geologist/ Stratigrapher	Education: BA, Geosciences Experience: 2+ years; experience performing sequence stratigraphic analysis (PRISM^{TM}) and building visual conceptual site mpodels at Sites across North America.	OSHA 40hr HAZWOPER OSHA 8hr Refresher	Signature available upon request.
Nicole Lancaster	AECOM	Data Management	Education: BS, Marine Biology, MS Chemistry Experience: 10+ years, experience with data validation, data management, laboratory coordination, and field sampling.	OSHA 40hr HAZWOPER OSHA 8hr Refresher First Aid/CPR AECOM PFAS Sampling Training	Signature available upon request.
Carolyn Dicharry	Pace Gulf Coast	Laboratory Project Manager	Education: BS, Geology, post-Baccalaureate in Education Experience: 30 years in the environmental lab industry – 15 years experience in Quality Assurance; 7 years experience as a Project Manager/client services; 2 years in Data Validation; 2 years as Safety Manager and Waste Coordinator; 8 years in Asbestos laboratory	NA	Signature available upon request.

Name	Organization	Project Role	Education/Experience	Specialized Training / Certifications	Signature/Date
William Perry	Pace Gulf Coast	Laboratory QA Specialist	Education: BS, Chemistry, American Chemistry Society Program Experience: 30 years; QAPP development, data validation, laboratory auditing and procurement, laboratory and sampling management, organic analysis and sample preparation management.	Statistics and 17025/The National Environmental Laboratory Accreditation Conference Institute QSM standards	Signature available upon request.

Notes:
AL = Alabama
ASQ = American Society for Quality
BA = Bachelor of Arts
BS = Bachelor of Science
CHMM = Certified Hazardous Materials Manager
CMQ/OE = Certified Manager of Quality/Organizational Excellence
CPR = cardiopulmonary resuscitation
CQA = Certified Quality Auditor
DoD = Department of Defense
ERA = Ecological Risk Assessment
ESA = Ecological Society of America
GIS = Geographic Information System
HAZWOPER = Hazardous Waste Operations and Emergency Response
HHRA = human health risk assessment
hr = hour
IN = Indiana
KY = Kentucky
LSP = Licensed Site Professional
MA = Massachusetts
MBA = Master of Business Administration
ME = Maine
MMRP = Military Munitions Response Program
MO = Missouri
MS = Master of Science
NA = not applicable
NDNODS = Non-Operational Non-Department of Defense Site
NH = New Hampshire
ORA= Operational Range Assessments
OSHA = Occupational Safety and Health Administration
PE = Professional Engineer
PG = Professional Geologist
PhD = Doctor of Philosophy
PMP = Project Management Professional
PRISM™ = PRedictive Integrated Stratigraphic Modelling
QA = quality assurance
QSM = Quality Systems Manual
SDSFIE = Spatial Data Standards for Facilities, Infrastructure, and Environment
STSC = Safety Trained Supervisor Construction
TO = task order
UT = Utah
WA = Washington

QAPP Worksheet #6: Communication Pathways

Worksheet #6 documents the communication drivers that trigger the need to communicate with other project personnel or stakeholders. The purpose of **Worksheet #6** is to ensure there are procedures in place for providing the appropriate notifications and generating the appropriate documentation when handling important communications, including those involving regulatory interfaces, unexpected events, emergencies, non-conformances, and stop-work orders.

Communication Driver	Organization	Name	Contact Information	Procedure (Timing, Pathway, Documentation)
Program Manager decisions and modification	USACE Baltimore District Nationwide Project Manager USACE Louisville District Project Manager	Tim Peck, PG, PMP Steven Kvaal, PMP	410-962-3416 timothy.j.peck@usace.army.mil 502-315-6316 steven.kvaal@usace.army.mil	Award work and options. Track project progress through monthly reporting and daily field reporting. Stop work for quality or performance concerns.
Program technical review	USACE Louisville District Technical Lead USACE Omaha District Technical Lead	Robin Sternberg, PhD Steven Gragert, CHMM	502-315-3829 robin.m.sternberg@usace.army.mil 402-995-2743 steven.gragert@usace.army.mil	The AECOM PM will obtain USACE technical review and concurrence of the QAPP and project documents and any field modifications/QAPP changes, as necessary. Approved modifications will be included in QAPP revisions (prior to field work). USACE technical review and comments will be incorporated into the QAPP and project documents and a record of USACE comments saved in project files for documentation.
Project Manager and program technical review	ARNG Project Manager	Bonnie Packer, PhD	703-607-7977 bonnie.m.packer.ctr@mail.mil	The AECOM PM will obtain ARNG technical review and concurrence of the QAPP and project documents and any field modifications/QAPP changes, as necessary. Approved modifications will be included in QAPP revisions (prior to field work). ARNG technical review and comments will be incorporated into the QAPP and project documents and a record of ARNG comments saved in project files for documentation.
Installation interface	MIARNG	Jonathan Edgerly Patricia Lyman	517-481-7630 jonathan.w.edgerly.nfg@army.mil 517-481-7631 lymanp@michigan.gov	Communicate project scope/schedule and coordinate logistics between project team and installation personnel on an as-needed basis, documented via phone records and emails.

Communication Driver	Organization	Name	Contact Information	Procedure (Timing, Pathway, Documentation)
Regulatory agency interface		Amy Handley	517-219-2209 handleya@michigan.gov	Communicate technical approaches and decisions directly to regulatory agencies' representative(s) on an as-needed basis, documented via phone records and emails.
Community/ media interface				Communicate information directly to communities or media on an as-needed basis.
Manage all project phases Field progress reports Field modifications/QAPP changes	AECOM Project Manager	Claire Mitchell, PE, PMP	703-682-9098 claire.mitchell@aecom.com	All materials and information about the project will be forwarded from the AECOM PM to ARNG/ USACE. The AECOM PM will obtain ARNG/ USACE approval/ concurrence for field modifications/QAPP changes as necessary. All approved modifications will be included in QAPP revisions (prior to field work) or non-conformance report(s) (during field work), and resolution / corrective action identified.
	AECOM RI Task Manager	Savannah Wolfe, MS	310-465-6190 Savannah.wolfe@aecom.com	Support AECOM PM in implementing RI tasks/procedures.
	AECOM Project QA Officer	Sara Gettier, PE	301-820-3166 sarah.gettier@aecom.com	Oversees/conducts quality audits to assure field program performed in accordance with approved protocols. Supports AECOM PM, Technical Task Manager, and Team Leaders to assure quality reviews are completed on project deliverables, including consistency and conformance with applicable regulatory and DoD guidance and with industry practices. Works with Project Chemist to resolve performance problems with contracted analytical laboratory.
Analytical laboratory modifications and performance problems	AECOM Project Chemist/ Data Validator	Naoum Tavantzis	301-267-8761 naoum.tavantzis@aecom.com	Notify AECOM PM and QA Officer in a timely manner of performance problems encountered by the contracted analytical laboratory. PM will secure approval for modifications to the QAPP as necessary from ARNG/ USACE. All approved modifications will be included in non-conformance Reports.

Communication Driver	Organization	Name	Contact Information	Procedure (Timing, Pathway, Documentation)
Data verification issues (e.g., incomplete records) and data validation issues (e.g., non-compliance with procedures)				Verify/validate all analytical chemistry sample results from analytical laboratories with criteria developed in this QAPP and deliver to the PM and the Project QA Managers.
Data review corrective actions				Notify Laboratory PMs to identify resolution/corrective actions.
Sample receipt variances	Pace Gulf Coast	Carolyn Dicharry	225-769-4900 carolyn.dicharry@pacelabs.com	Report all project non-conformances and problems to the AECOM Project Chemist. AECOM and laboratory chemists will resolve all non-conformances with appropriate error codes in verification processes.
Laboratory QC variances				Report all project non-conformances and problems to the AECOM Project Chemist. AECOM and laboratory chemists will resolve all non-conformances with appropriate error codes in verification processes.
Analytical corrective actions				Report all project non-conformances and problems to the AECOM Project Chemist. AECOM and laboratory chemists will resolve all non-conformances with appropriate error codes in verification processes.
Laboratory modifications and performance problems				Report all project non-conformances and problems to the laboratory PMs. Laboratory PMs will report to AECOM Project Chemist. AECOM and laboratory chemists will resolve all non-conformances with appropriate error codes in verification processes.

Notes:
DoD = Department of Defense
MS = Master of Science
PE = Professional Engineer
PMP = Project Management Professional
QA = quality assurance
QC = Quality Control

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QAPP Worksheet #9: Technical Project Planning Session Summary

This worksheet will serve as a record of future Technical Project Planning (TPP) sessions. The intent is to provide a concise record of participants, key decisions or agreements reached, and action items. Minutes will be approved by participants prior to being incorporated into the QAPP (**Appendix A**).

AECOM will implement the TPP process as listed in Engineering Manual (EM) 200-1-2 (USACE, 2016), including facility-specific meetings in a professional and organized manner to obtain consensus on specific Data Quality Objectives (DQOs) for the RI work. Per the Performance Work Statement (PWS), eight TPP meetings will be held (four in person [travel permitting] and four via teleconference), as described below:

- Meeting 1 (RI) - Introduce project team members and stakeholders to ARNG's PFAS RI program, discuss the overall planned RI approaches, discuss the project schedule, and gain input on stakeholder preferences (date to be determined [TBD]).
- Meeting 2 (RI) - Present the facility-specific QAPP for RI Mobilization 1, including planned approaches implementation. Ensure all stakeholders are in agreement with planned investigative strategies, work schedules, and notification procedures to ensure smooth execution of field work (date TBD).
- Meeting 3 (RI) - Present the results for RI Mobilization 1, the evaluation of the plume and source area(s) extent to date, and a preview of the anticipated scope for the RI Mobilization 2 (date TBD).
- Meeting 4 (RI) - Resolve comments or concerns about the facility-specific QAPP for RI Mobilization 2 or implementation not already addressed during response to comments (date TBD).
- Meeting 5 (RI) - Present findings of the RI (Mobilization 1 and 2). Gain concurrence on presentation of findings in the RI Report (date TBD).
- Meeting 6 (FS) - Discuss potential remedial action objectives and remedial alternatives to support development of the FS (date TBD).
- Meeting 7 (FS) - Present FS remedial action alternatives, discuss the evaluation of those alternatives, and gain consensus on preferred remedy to be presented in the Proposed Plan and Decision Document (date TBD).
- Meeting 8 (as needed) - Additional meeting to address any unforeseen issue that requires further discussion.

TPP meeting minutes will be prepared after each TPP meeting and added as an attachment to the corresponding document. TPP Meeting Minutes are included in **Appendix A**.

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QAPP Worksheet #10: Conceptual Site Model

10.1 Facility Location and Description

Grand Ledge AASF is located in Grand Ledge, in Clinton County, Michigan, approximately 1 mile north of the Grand River. The facility falls within Watertown Township, where Clinton County borders Eaton County along West Eaton Highway. The facility is bordered to the north by Abrams Municipal Airport, to the east and west by residences and agricultural land, and to the south by residences and commercial/industrial operations. The AASF and Armory comprise approximately 35 acres (DLZ Michigan, Inc. [DLZM], 2015). The facility has a main area that consists of the AASF and Armory as well as an Annex located southwest of the main area. The facility location is shown on **Figure 10-1.** Additionally, to the northwest of the facility, a parcel of land currently owned by Transfast Trucking, Inc. was formerly owned by MIARNG until the 1980s.

Grand Ledge AASF provides training and maintenance for the various aviation units that support the Michigan ARNG (MIARNG). The AASF consists of a maintenance shop, office areas, a maintenance hangar, a grated manhole (also referred to as ‘wash bay’), and an unheated “cold” storage building. The Armory includes a shop area, fenced motor pool, aircraft parking area, and various small storage buildings. An Annex Building that is used for storage and training purposes including flight simulations is on the southwestern portion of the property, on the corner of Wright Road and Eaton Highway; historical aerial imagery indicates the Annex Building was built between 1986 and 1993. Prior to 2007, the AASF was located in the current Armory. Historical aerial photography indicates that the current Armory building was constructed between 1974 and 1981 (Environmental Data Resources, Inc. [EDR™], 2018). According to interviews with facility personnel and historical aerial photography, construction of the current AASF hangar began in 2005 and was completed in January/February of 2007. The construction of this AASF also involved the removal/replacement of old pavement and soil excavation/grading. Prior to construction of the AASF, a drainage ditch was situated at the western edge of the old tarmac and flowed north before it connected with an off-facility drainage ditch at Abrams Municipal Airport. As a result of these construction activities, the soil from the drainage ditch, all the way to the north edge of the property and east to the parking area, was regraded and disturbed. The drainage ditch was filled in and paved over, and an approximately 10,500-square foot stormwater retention basin was constructed to the northwest of the current tarmac. The stormwater retention basin is L-shaped and approximately 600 feet long, 300 feet wide, and 16 feet deep. The Grand Ledge AASF property was acquired by the State of Michigan, Department of Military Affairs through two separate land deeds dated 29 May 1975 and 31 August 2000.

10.2 Facility Environmental Setting

The Grand Ledge AASF is in the lower peninsula of Michigan, in the Central Lowlands Physiographic Province of the US. The province is part of the Interior Plains division of the US and is characterized by flat lands with glacial geomorphic remnants. The majority of the Central Lowlands province is bounded by higher relief and comprises elevations of 2,000 feet or less (National Park Service, 2017). Elevation at the Grand Ledge AASF ranges from 829 to 860 feet above mean sea level (amsl), with an average of 850 feet amsl (EDR™, 2018). The topography at the facility is relatively flat, with a gentle slope towards the northwest, in the direction of a stormwater retention basin. Local topographic changes exist, with ground surface elevation from the southern side of the Abrams Municipal Airport sloping in the direction of Grand Ledge AASF. The facility topography of Grand Ledge AASF is shown on **Figure 10-2**. The facility geology is provided on **Figures 10-3** through **10-6** (with the exception of AOI 1-1 through AOI 1-5; and AOI 2-1, through AOI 2-3); groundwater features are presented on **Figure 10-7**; and surface water features are presented on **Figure 10-8**. The locations of of AOI 1-1 through AOI 1-5, and AOI 2-1, through AOI 2-3 can be found in **Figure 10-12**.

10.2.1 Geology

The bedrock formations of the Grand Ledge area in south-central Michigan are sedimentary deposits of Pennsylvanian age. These rocks were formed in a deltaic depositional setting typical of an ancient near-shore marine beach environment. A study of the exposed strata visible in exposed bedrock outcrops (the Ledges) along the Grand River reveals evidence of cyclic sedimentation. Marine soils in the section alternate with those deposited under terrestrial conditions. The early geologic history of the Ledges is essentially that of any marine beach with an open-water lagoon and swamps behind it (Kelly, 1933). These different yet interrelated environments each produced a distinct set of soil types. The beach environment, dominated by high-energy waves, produced quartz sand with few fossils and resulted in clean sandstones. The lagoon environment, in which low-energy currents moved, accumulated black muds, provided a home for various shellfish, and produced fossiliferous shales. The shores of the lagoon were tidal flats where mud and fine sand settled with the rise and fall of the tides and produced greywackes. Each of these three rock types are interlayered and represented in this area. These rocks have been formally subdivided into the Saginaw Formation (Early Pennsylvanian) and Grand River Formation (Late Pennsylvanian). The Saginaw Formation constitutes the bulk of the Pennsylvanian rock sequence in the Grand Ledge area and consists of inter-bedded sandstone, siltstone, shale, coal, and limestone. According to Kelly (1936), the typical Saginaw sequence is as follows: a basal sandstone overlain successively by sandy shale, gray fissile shale, underclay, coal, black limey shale and limestone. Sandstones of the Saginaw Formation are lenticular, discontinuous, and irregularly bedded. Texturally, they are fine-grained with a conglomeratic zone at the base.

Structural deformation in the region was limited primarily to the actions of the last glacial advance and retreat, resulting only in minor jointing of the bedrock; therefore, bedrock aquifer conductivity is chiefly dependent on the primary porosity of the unit. The Saginaw Formation acts as the main aquifer for much of central Michigan, including Michigan's capital, Lansing, which is located about 10 miles east of Grand Ledge AASF. In the Grand Ledge area, unconsolidated glacial soils , which range from 0 to over 100 feet, overlie the bedrock. These soils were deposited during glacial advance and retreat cycles that took place from approximately 35,000 to 10,000 years before the present. Residential well logs supplied by the Barry-Eaton District Health Department list bedrock at depths ranging from 35 to 82 feet below ground surface (bgs) for 12 locations immediately south of the facility. Clays and gravels were variously indicated to overlie the bedrock, consistent with the well-sorted fluvial deposits, lacustrine-type clay deposits, and other glacial deposits present in much of the surficial geology of central Michigan.

During the SI Mobilization 1, six shallow borings were completed in AOI 1 (locations AOI 1-1 through AOI 1-5, shown on **Figure 10-12;** location AOI 1-6, shown on **Figure 10-4**), most of which revealed deposits of predominantly lean or fat clay to a maximum explored depth of 22 feet bgs, with sand components present ranging from 0 percent (%) to 20% within 5-10 feet bgs in many of the borings. Three shallow borings completed at AOI 2 (locations AOI 2-1, AOI 2-2, and AOI 2-3, shown on **Figure 10-12**) all exhibited layers of clay with 10% to 25% sand to a maximum explored depth of 10 feet bgs. Due to the presence of these apparent thick clay layers underlying the facility, vertical migration of contamination is considered limited. However, the heterogeneity of clay layers across the facility suggests there may not be a continuous, confining clay layer present. Distinct occasions of relatively coarse-grained interbeds were observed within the clay deposits in borings AOI 1-4 and AOI 1-6 (AECOM, 2021a). To support the information provided above, the SI Mobilization 1 boring logs can be found in **Appendix E**.

In AOI 1-6, located along the northern facility boundary, the clay layer was encountered at ground surface and extended to 18 feet bgs, with well-graded sand observed below to a maximum explored depth of 20 feet bgs (AECOM, 2021a). This overlying clay layer may act as a confining unit to this interbed of sand and likely explains the artesian flow encountered in this boring.

During SI Mobilization 2, seven additional deep borings were drilled to improve understanding of the subsurface geology and groundwater conditions for nearby private drinking water wells screened at a similar depth. Six of these borings were completed at AOI 1 (AOI 1-10 through AOI 1-15). At AOI 1 borings AOI 1-12, AOI 1-13, AOI 1-14 and AOI 1-15, the geology is generally characterized by lean clays to a depth of approximately 35 to 50 feet bgs. Less than 15 feet of coarse-grained components of sand, gravel, and cobbles are within this 35- to 50-foot range. The boring for well AOI 1-10 is unique because displayed approximately 15 feet of lean clay followed by no recovery from 15 to 50 feet bgs. The absence of recovery over this 35-foot interval is interpreted to be due to loose gravel and cobbles that were not retained in the drill casing. From 50 to 75 feet, sand and gravel were observed along with thin lenses of poorly cemented sandstone. Overall, AOI1-10 appears to display the greatest thickness (60 feet) of highly permeable coarse sand, gravel, and cobbles. The boring for well AOI 1-11 is also unique because sandy facies predominate the upper 17 feet. Below this relatively thick, uppermost sand layer, lean clay is present from 17 to 28 feet bgs, and sand from 28 to 31 feet bgs, followed by sandstone to a maximum explored depth of 50 feet bgs (AECOM, 2021a). Perched water table conditions may be present at the surface of the clay layer at 17 feet bgs at this location. The SI Mobilization 2 boring logs can be found in **Appendix E**.

Historical aerial imagery shows that AOI1-11 was previously the location of a building that has since been removed. The location was heavily impacted by the construction of the stormwater retention basin, and the upper soils potentially contain reworked facility soil or backfill from off-facility. Based on these deep borings, the overburden thickness at AOI-1 varies from 33 to 90 feet bgs (see **Figure 10-3**). As shown on **Figure 10-4**, the depth to top of the clay unit across AOI-1 ranges from 0 to 17 feet bgs, and the thickness of this clay layer ranged from 11 to 49.7 feet. The depths and thickness of permeable units containing predominantly sand, gravel, and/or cobbles are presented in **Figure 10-5**. These figures show that the thickness of the different overburden units varies widely across the facility.

It appears that an upper clay unit may be contiguous across the facility. At least 9 feet of clay have been observed in 10 out of 11 soil borings conducted within AOI 1 during the SI. Clay was not encountered in shallow boring AOI 1-5; however, it was only drilled to 10 feet bgs, and the clay unit most likely exists slightly deeper. At least 5.5 feet of clay were encountered in all four borings advanced in AOI 2. The Grand Ledge area is well known for the mining of surficial clay. A map showing a large extent of morainic or boulder clay deposits within and surrounding the Grand Ledge area is provided in the geological report, *Michigan's Clay Deposits and Industry* (Sorenson, 1970).

Bedrock was encountered in five out of six deep borings within AOI 1, except at AOI 1-14, with depths to bedrock ranging from 35 to 90 feet bgs (see **Figure 10-6**). Sands with occasional silts, gravels, and cobbles encountered above the sandstone bedrock likely represent weathered sandstone bedrock. The depth to bedrock in AOI 1-10 was encountered deeper than elsewhere at the facility. Based on this depth to bedrock and the higher groundwater elevation in this well compared to the other deep wells, AOI 1-10 potentially represents a different hydrogeologic composition that is distinct from the other locations.

One additional deep boring was completed at AOI 2 (location AOI 2-4) and had a total depth of 50 feet bgs. The first 3 feet of soil at AOI 2-4 were characterized by well-graded gravel with silt and sand, followed by approximately 22 feet of fine-grained material (i.e., silts and clays), with the content of sand and gravel each ranging from 0 to 25%. Additionally, a small layer of interbedded elastic silt with 30-45% gravel was observed at 20.0 to 21.4 feet bgs. As shown on **Figure 10-4**, The thickness of the clay unit at AOI 1-2 measured 22 feet. Additionally, sandstone bedrock was encountered at 30.5 feet bgs and was overlain by 5 feet of well-graded gravel with silt, sand, and cobbles.

Based on these borings, the facility is predominantly characterized by a shallow clay layer underlain by occasional silt units and a highly variable thickness of coarse-grained materials. The thickness of clay observed in the borings drilled during the SI appear to support the concept of limited vertical migration of contaminants at the facility. The coarser-grained materials (sand, gravel and cobbles) below the upper clay unit are interpreted to be highly variable weathered bedrock. Permeable soils were most shallow in AOI 1-11, AOI 1-12, and AOI 2-4, with a range of encountered depths of 25.5 to 36.5 feet bgs, and were encountered in all other sample locations at depths ranging from 42 to 50 feet bgs (**Figure 10-5**). Depth to bedrock across the facility range from 30.5 to 90 feet bgs and is similar to bedrock depths recorded in the residential wells as indicated by logs provided by the Barry-Eaton District Health Department.

10.2.2 Hydrogeology

According to data received from the EDR™ report for the facility (EDR^{TM}, 2018) and the Michigan Department of Environment, Great Lakes, and Energy (EGLE) Wellogic database (EGLE, 2018a), several federal and state-documented groundwater wells are located within 1 mile of the facility (**Figure 10-7**). The majority of these wells are private domestic wells, and there are additional undocumented private wells located in the immediate vicinity that were discovered through a Freedom of Information Act request submitted during the off-site potable well sampling conducted by ARNG G9 in 2020 (see **Section 10.4.1**). There are also two public water supply wells within 1 mile of the facility; one is located within facility boundaries and provides drinking water for the Annex Building, and another public water supply well is located approximately 1,000 feet to the southwest of the facility boundary. Grand Ledge AASF receives its potable water from the City of Grand Ledge's municipal water utility, with the exception of the Annex Building, which receives water from an on-facility public supply groundwater well. Drinking water from the Annex Building's well was previously sampled by the ARNG in May 2017 and found to be non-detect for PFAS. Additionally, PFOA, PFOS, and PFBS were not detected in drinking water samples collected by EGLE in August 2020 at the Abrams Municipal Airport adjacent to and upgradient of the facility.

All local domestic and public water supply wells identified from the EGLE database are situated in the Saginaw aquifer at depths of approximately 100 to 180 feet bgs, with the exception of a single well installed in 1942 that was installed at a depth of 404 feet bgs (EDR™, 2018). During May 2019 SI (Mobilization 1) sampling activities, groundwater in shallow temporary wells at AOI 1 was encountered at depths ranging from 2 to 14 feet bgs, except for sample location AOI 1-6. An artesian well was formed at sample location AOI 1-6 upon installation of the temporary well. A synoptic gauging event performed on 8 January 2020 measured groundwater depths ranging from 10 to 36 feet bgs from permanent monitoring wells. Observed groundwater elevations from the 8 January 2020 synoptic gauging event and corresponding contours are displayed on **Figure 10-9**. The groundwater elevation for AOI 1-10 was excluded from **Figure 10-9** because this well appears to be set in a separate and distinct hydrologic unit (see **Section 10.2.1**). Groundwater at the facility was measured to flow in the south-southeast direction. Additional information of the bedrock hydrogeology of the Saginaw aquifer can be found in Westjohn and Weaver (1996).

Due to the shallow depth of the clay unit at the facility, some perched water table conditions that contain elevated PFAS may be present. For example, during the SI, a groundwater sample collected from temporary shallow well AOI 1-5 (screened from 5 to 10 feet bgs) contained PFAS above SLs (53 nanograms per liter [ng/L] of PFOA and 60 ng/L of PFOS). The nearby permanent deep well AOI 1-13 that is screened in the lower sand and gravel unit (screened from 42 to 52 feet bgs) below the 39.5-foot-thick upper clay unit indicated a depth to water of 19.58 feet bgs.

Low levels of PFAS were detected in AOI 1-13 below the SLs. These results suggest that confined aquifer conditions may be present and will be further evaluated during the RI. The depth to water in the seven permanent deep wells (AOI 1-10 through AOI 1-15 and AOI 2-4) ranged from 9.55 to 35.78 feet bgs across the facility. Permeable materials (silty sand, sandy silt or sand with gravel) are present above the uppermost clay layer in several wells, and perched water table conditions may be present at the surface of the upper clay layer in the vicinity of AOI 1-2, AOI 1-5, AOI 1-11, and AOI 1-13. The RI will evaluate these potential perched water table conditions by attempting collection of groundwater grab samples directly above these upper clay layers or include wells that are screened on top of the uppermost clay layer in locations where overlying permeable materials are observed.

10.2.3 Hydrology

Although the Grand River is located approximately 1 mile south of the facility, the AASF and Armory fall within the Husted and Landenburg Drain-Looking Glass River Watershed (**Figure 10-8**), which drains to the north. There are no perennial surface water bodies within the property boundaries of the Grand Ledge AASF (US Fish and Wildlife Service [USFWS], 2018). The majority of the current facility is paved with grassy areas surrounding the perimeter. Prior to 2007, when the new hangar and cold storage facility were built, the area west of the Armory was largely unpaved. Drainage ditches surround the property and direct stormwater from paved areas to the stormwater retention basin located at the northwest corner of the facility. Behind the hangar, there is a paved area with a catch basin that functions as the wash rack, which discharges to the oil water separator, and ultimately discharges to the sanitary sewer. The stormwater retention basin is typically saturated, with standing water typically present up to 1 foot deep. Overflow from the retention pond drains to Reed Drain, a small drainage creek located 0.25 miles north of the retention pond that ultimately drains to the Looking Glass River via Husted and Landenburg Drain. Given the shallow clay layer encountered at the northern boundary of the facility at location AOI 1-6, the depth of the stormwater retention basin could extend into the saturated groundwater zone and allow groundwater to discharge to surface water.

The stormwater retention basin located nearby in the northern area of the facility extends from the ground surface to approximately 16 feet bgs at its deepest point. The closest monitoring well, AOI 1-11, is immediately south of the stormwater retention basin ridge, and groundwater was gauged within the well at approximately 12 feet bgs. Based on this information, in addition to surface water from the nearby area (i.e., the AASF and Abrams Municipal Airport), the stormwater retention basin may receive groundwater. The presence of the groundwater table at an elevation above the stormwater retention basin is indicative of groundwater to surface water migration.

10.2.4 Climate

The climate of the Grand Ledge AASF area is temperate, with an average temperature of 48.7 degrees Fahrenheit (°F). Seasonally, temperatures vary from summer highs of 84 °F to winter lows of 15 °F. Precipitation falls primarily as snowfall in the winter months well into April, with an average of 7.8 inches of snowfall per month. The remainder of precipitation falls as rain, which is distributed evenly throughout the summer months at an average of 3.2 inches per month. The prevailing wind is typically from the west at 8.5 miles per hour (National Oceanic and Atmospheric Administration, 2021).

10.2.5 Current and Future Land Use

Current Grand Ledge AASF operations include training and maintenance for the various aviation units that support the MIARNG. In addition to aircraft maintenance and aircraft support for MIARNG, periodic training exercises and course work for the National Guard/Army Reserve units are conducted at the facility's flight simulators located in the Annex Building. The facility is staffed by both full- and part-time employees and shares tarmac space with the neighboring Abrams Municipal Airport to the north.

Portions of the eastern and western borders of Grand Ledge AASF are abutted primarily by rural residences and agricultural land use. Two residential homes are located between the AASF Hangar and Armory buildings and the Annex Building. Abrams Municipal airport bounds the northern boundary of the facility. South of Eaton Highway, a rural two-lane highway that demarcates the facility's southern border is a small industrial park and lightly wooded areas. Several residences are also located south of Eaton Highway in the immediate vicinity of the facility. The closest urban center is the City of Grand Ledge, which is approximately 1.5 miles to the southwest.

Reasonably anticipated future land use is not expected to change from the current land use described above.

10.2.6 Critical Habitat and Threatened/ Endangered Species

The following species are listed as federally endangered, threatened, proposed, and/or candidate species in Clinton and Eaton County, Michigan (USFWS, 2022):

- **Clams**: Snuffbox mussel, *Epioblasma triquetra* (endangered).
- **Plants**: Eastern prairie fringed orchid, *Platanthera leucophaea* (threatened).
- **Mammals**: Indiana bat, *Myotis sodalist* (endangered); Northern long-eared bat, *Myotis septentrionalis* (threatened).
- **Reptiles**: Eastern massasauga rattlesnake, *Sistrurus catenatus* (threatened).
- **Insects**: Monarch butterfly, *Danaus plexippus* (candidate).

None of these sensitive species have been recorded within the Grand Ledge AASF. No critical habitats have been identified within the Grand Ledge AASF.

The snuffbox mussel, the Indiana bat, and the northern long-eared bat are not expected to be present at the facility due to a lack of appropriate habitats (i.e., swiftly flowing small to medium sized rivers for the mussel and caves and mature trees for the bats) (Michigan State University [MSU], 2022a,b,c). While the remaining three species have not been identified at the facility, it is possible that relevant habitats are present at the facility. The eastern prairie fringed orchid prefers wet prairies and bogs but can be found in degraded prairie remnants including ditches, fallow agricultural fields, and similar disturbed habitats (MSU, 2022d) and the eastern massasauga rattlesnake is primarily associated with wetlands but may also occur in upland forests, fields, and prairies (MSU, 2022e). Monarch butterflies feed on nectar from a wide variety of flowers but require the presence of milkweed for reproduction (USFWS, 2022). A habitat assessment will be conducted as part of RI to determine if relevant habitats and/ or listed species are present at the facility.

10.3 History of AFFF Use

The AASF hangar is currently equipped with an AFFF fire suppression system that contains a 700-gallon tank of 3% Ansulite. The current Armory building was the previous location of the AASF, prior to the new hangar's construction in 2007. The Armory historically housed a certified firefighting unit in the 1980s that was disbanded in the early 1990s. During the PA, former Grand Ledge AASF personnel commented during their interview that a firetruck used to be stationed within a garage located in the Armory building during approximately the 1980s to early 1990s. The Annex Building stores empty Tri-Max™ 30 fire extinguishers and bulk and expired AFFF in both 55-gallon drums and 5-gallon buckets. Based on the above information, three potential PFAS release areas (AASF Hangar, Armory, and Annex Building) were identified during the PA at the Grand Ledge AASF (AECOM, 2019a). The potential PFAS release areas where AFFF may have been used or released historically were grouped into two AOIs based on proximity to one another and presumed groundwater flow. A description of each AOI is presented in **Section 10.5.1**.

During the PA, one potential adjacent source was identified, Abrams Municipal Airport. After the PA was completed, discussions with both the airport authority and the municipal government occurred, where it was verbally verified that Abrams Airport did not store or use AFFF. No sampling has occurred within the Abrams Airport to verify presence or absence of PFAS.

After SI Mobilization 1 field activities, additional information was obtained regarding PFAS use at the Armory. Based on interviews with retired AASF personnel in December 2019, Tri-Max™ 30 extinguishers and a firetruck may have been used for fire training with AFFF on the tarmac north of the Armory, the adjacent motor pool to the east, and the adjacent wash bay to the west. An additional potential PFAS release area at the current location of Transfast Trucking, Inc., a privately owned trucking company, was also identified. According to interviews with retired AASF personnel, this location was a former AASF hangar under control of the MIARNG until about the 1980s. One of the interviewees stated there was an incident in the hangar in which fuel was spilled from an aircraft, and AFFF may have been used to wash off the fuel. There was also a firetruck located at the former AASF Hangar, but it is unknown if the firetruck had foam capabilities. This firetruck was an older model than the firetruck previously located at the Armory. The Transfast Trucking, Inc. (Former Hangar) was not investigated during the SI due to it being an off-facility property (no longer under the control of the MIARNG) (AECOM, 2021a). However, the former AASF Hangar is being investigated during this RI and is referred to as AOI 3.

10.4 Historical PFAS Investigations

In 2018, the ARNG conducted a PA at Grand Ledge AASF that identified three potential PFAS release areas (AECOM, 2019a). These potential PFAS release areas were divided into two AOIs in the PA based on proximity of the potential release areas to one another and the assumed groundwater flow direction (**Figure 10-11**). Descriptions of the potential release areas and AOIs are presented as part of the conceptual site model (CSM) in **Section 10.5.** An SI was subsequently conducted at the facility to determine the presence or absence of PFOA and PFOS at the AOIs at concentrations at or above the USEPA Health Advisories (HAs) and/or OSD SLs, the applicable standard at the time of the investigation, completed in two “mobilizations”:

- Mobilization 1 of the SI focused on sampling subsurface soil, grab groundwater from temporary monitoring wells, sediment, and surface water. Mobilization 1 was conducted from 7 to 10 May 2019 (AECOM, 2021a).
- Mobilization 2 of the SI focused on permanent groundwater monitoring well installation, development, and sampling, as well as surface water and sediment sampling. Mobilization 2 was conducted from 4 November to 20 December 2019 (AECOM, 2021a).

Based on the results of the SI, PFOA and PFOS were detected in soil and groundwater at the release areas at AOI 1 and AOI 2. The findings of the SI at each AOI are included in the summary of the nature and extent of contamination presented in **Section 10.5**.

10.4.1 Drinking Water Sampling

Grand Ledge AASF receives its potable water from the City of Grand Ledge's municipal water utility, except for the Annex Building, which receives water from an on-facility public supply groundwater well. Drinking water from the Annex Building's well was previously sampled by the ARNG in May 2017, and by MIARNG in January 2020 and August 2021. For each year, all results were reported as non-detect for PFAS.

On 22 - 23 January 2020 and 28 - 29 July 2020, ARNG collected off-facility drinking water samples from private residential wells, due to the exceedance of SLs observed in groundwater from temporary well location AOI 1-5 during the May 2019 SI Mobilization 1 (results presented in **Section 10.5.2**). Due to their proximity to Grand Ledge AASF and the potential for drinking water impacts, 25 properties along West Eaton Highway, Wright Road, Hartel Road, and Bauer Road were selected to be sampled (see **Figure 10-10**); PFAS were non-detect at 23 properties. One property had an estimated PFOS detection of 3.38 J ng/L, and another property had an estimated perfluorohexanoic acid (PFHxA) detection of 2.37 J ng/L (see **Appendix B**). The results of the drinking water sampling were provided in letters to the residents and are also provided in the SI Report (AECOM, 2021a).

10.5 Preliminary Conceptual Site Model

A summary of the preliminary CSM for the Grand Ledge AASF is presented below. A description of the primary PFAS release mechanism(s) at each AOI is presented in **Section 10.5.1**. The current interpretation of the nature and extent of PFAS contamination at each AOI is presented in **Section 10.5.2**. The fate and transport of PFAS in environmental media are discussed in **Section 10.5.3**. Lastly, the potential receptors and exposure pathways are discussed in **Section 10.5.4**. Sampling locations completed during SI Mobilization 1 and Mobilization 2 are presented on **Figures 10-12** and **10-13**, respectively.

The preliminary CSM presents the current understanding of the site conditions with respect to known and suspected sources, potential transport mechanisms and migration pathways, and potentially exposed receptors. An exposure pathway is considered potentially complete when each of the following conditions are present:

1. Contaminant source;
2. Environmental fate and transport;
3. Exposure point;
4. Exposure route; and
5. Potentially exposed populations.

In their anionic forms, PFAS are water-soluble and can migrate readily from soil to groundwater or surface water via leaching and run-off. Given the length of time since the AFFF releases, the average precipitation at the facility, and degree of soil permeability, potential PFAS contamination at the AOIs may have leached from the soil to groundwater and migrated to nearby surface water bodies. For example, the on-facility retention pond that ultimately drains to the Looking Glass River is suspected to have groundwater interaction with surface water; therefore, as described in **Section 10.5.4**, human and ecological receptors may be exposed to PFAS in the on-facility AOIs and in downgradient off-facility surface water bodies.

As described in **Section 10.4.1**, PFOS was detected below the HA in one residential well downgradient from AOI 2; therefore, the ingestion exposure pathway for groundwater is potentially complete for off-facility residents.

10.5.1 Summary of Potential Release Areas

Based on the findings of the PA, the potential PFAS release areas were grouped into two AOIs, based on proximity and direction of groundwater flow. The AOIs are shown on **Figure 10-11** and described in the subsections below:

- AOI 1: AASF Hangar and Armory (Former AASF)
- AOI 2: Annex Building

Two additional potential PFAS release areas, Abrams Municipal Airport and Transfast Trucking, Inc. (Former AASF Hangar), are also shown on **Figure 10-11** for informational purposes. Abrams Municipal Airport and Transfast Trucking, Inc. (Former AASF Hangar) are adjacent to the facility (not under the control of ARNG) and were therefore not previously evaluated as part of the SI. Since the former AASF Hangar (currently owned by Transfast Trucking, Inc.) was occupied by the MIARNG prior to the 1980s, the following AOI will be included in this investigation and is described below:

- AOI 3: Former AASF Hangar

10.5.1.1 AOI 1

The current configuration of the AASF comprises the AASF administrative building and AASF hangar. Construction on the current hangar building was completed in January/February 2007, moving previous operations over from what is now the Armory. This hangar is equipped with an AFFF fire suppression system that contains a 700-gallon tank of 3% Ansulite. No leaks or releases, emergency or otherwise, have occurred from this system, and no evidence of leaking was observed during the visual site inspection (VSI). The system is tested and inspected annually by an outside contractor; system contents are not discharged during testing. In May 2014, the tank's liner required a replacement; a contractor drained the system into a holding tank, relined the system tank, and pumped the original AFFF concentrate back into the system, reportedly without incident or release. Additionally, trench drains are located in the hangar bay and maintenance/fueling areas and are connected to an oil/water separator that subsequently drains to the Grand Ledge municipal sanitary sewer.

The hangar bay is used for routine maintenance on aircrafts and similar activities. When required, the MIARNG would use a commercial floor scrubber machine to clean the floors. The machine would capture the discharge water used during cleaning, which contained the lubricants or other materials that dripped onto the floor during maintenance. The captured discharge water would then be emptied into the wash bay catch basin immediately to the north outside the hangar bay. Additionally, the MIARNG would use a power washer to clean aircrafts at the wash bay, where the discharge water was emptied into the catch basin. The wash bay catch basin discharges to the stormwater retention pond when the line to the oil/water separator and municipal system is blocked; the discharge to the stormwater retention pond has reportedly occurred in the past at an unknown frequency. These cleaning activities took place from the time the building was constructed, until June 2021. In April 2021, MIARNG took a sample of the discharge water from the commercial floor scrubber machine, and the sample was found to have detections of PFAS.

As noted above, the current Armory building was the previous location of the AASF, prior to the new hangar's construction in 2007. The Armory has never been equipped with a foam fire suppression system, and AFFF is not currently stored within the Armory. The use of dry chemical fire suppressant was noted at a storage area within the current Armory Building.

The Armory historically housed a certified firefighting unit in the 1980s that was disbanded in the early 1990s. During the PA, former Grand Ledge AASF personnel commented during their interview that a firetruck used to be stationed within a garage located in the Armory building during approximately the 1980s to early 1990s. Currently, this garage is used as general office/storage space. Personnel interviewed during the PA did not believe AFFF was stored on or in the firetruck; however, following SI Mobilization 1 field activities, additional information was obtained regarding the Armory and AFFF storage.

Based on interviews with retired AASF personnel in December 2019, Tri-Max™ 30 extinguishers were used for fire training with AFFF on the tarmac north of the Armory, the adjacent motor pool to the east, and the adjacent wash bay to the west. There were variable accounts regarding the frequency of training and whether the firetruck parked at the Armory contained AFFF and was used for fire training as well. The residual AFFF from training activities would reportedly run-off into a drainage ditch formerly located along the western edge of the then-present extent of the tarmac. Based on historical aerial imagery (EDR™, 2018), this former drainage ditch existed in 1998, prior to construction activities in 2005 and flowed north before connecting with an off-facility drainage ditch at Abrams Municipal Airport. As a result of the construction activities, the drainage ditch was filled in, and the stormwater retention basin was established at the northwestern corner of AOI 1. In addition, the construction involved the removal and replacement of old pavement and the excavation and re-grading of underlying soil in the former tarmac area. As reported by interviewees, the original soil likely remains at the facility and was moved around during excavation and grading activities, which primarily impacted the soil at the former tarmac area to a depth of approximately 5 feet bgs.

10.5.1.2 AOI 2

The Annex Building, located on the corner of Wright Road and Eaton Highway, is used for general storage as well as housing flight simulators used for training. Bulk and expired AFFF is stored within the Annex Building in both 55-gallon drums and 5-gallon buckets. Manufacturer and percent concentrate varies among the AFFF stored in the Annex Building. The inventory recalled by interviewees includes the following:

- 3% Concentrate: Twenty 55-gallon drums and six 5-gallon buckets (1,130 gallons);
- 3% / 6% Concentrate: Thirty-two 5-gallon buckets (160 gallons); and
- 6% Concentrate: Forty-six 5-gallon buckets (230 gallons)

In addition, approximately 16 empty compressed air foam portable fire suppression systems (Tri-Max™ 30 extinguishers) are stored in the Annex Building. All extinguishers are empty and tagged; however, it is not known if they were ever used or tested at the facility. Interviewees reported that no leaks or releases have occurred. Evidence of leaking was not observed during the VSI.

10.5.1.3 AOI 3

Based on interviews with retired AASF personnel in December 2019, Tri-Max™ 30 extinguishers and a firetruck may have been used for fire training with AFFF on the tarmac north of the Armory, the adjacent motor pool to the east, and the adjacent wash bay to the west. An additional potential PFAS release area at the current location of Transfast Trucking, Inc., a privately owned trucking company, was also identified. According to interviews with retired AASF personnel, this location was a former AASF Hangar under control of the MIARNG until about the 1980s. One of the interviewees stated there was an incident in the hangar in which fuel was spilled from an aircraft, and AFFF may have been used to wash off the fuel. There was also a firetruck located at the former hangar, but it is unknown if the firetruck had foam capabilities. This firetruck was an older model than the firetruck previously located at the Armory. The Transfast Trucking, Inc. (former AASF Hangar) was not investigated during the SI due to it being an off-facility property (no longer under the control of the MIARNG) (AECOM, 2021a).

10.5.2 Current Understanding of Nature and Extent of Contamination

The current understanding of the nature and extent of PFAS contamination at each AOI is presented in the subsections below. The summaries are based on review and evaluation of available analytical results from historical PFAS investigations, as summarized in **Section 10.4**. Sampling included multi-interval soil samples, grab groundwater samples, groundwater sampling of monitoring wells, and co-located sediment and surface water samples. Additionally, drinking water samples were subsequently collected from private properties down-gradient and cross-gradient of the facility.

The DoD has adopted a policy within the CERCLA process to compare results against risk-based SLs for soil and groundwater, as first described in a memorandum from the OSD dated 15 October 2019 (Assistant Secretary of Defense, 2019) and revised in a subsequent memorandum from the OSD dated 15 September 2021 (Assistant Secretary of Defense, 2021). The ARNG program under which this RI is being performed follows this DoD policy. The SLs established in the OSD memorandum apply to three compounds: PFOA, PFOS, and PFBS. The SLs were calculated using the USEPA Office of Superfund Sites On-Line Calculator (USEPA, 2021a; USEPA, 2021b).

Additionally, the USEPA issued drinking water lifetime Health Advisories (HAs) for PFOA and PFOS in May 2016 (USEPA 2016a; USEPA, 2016b). The USEPA HAs will also be used as SLs for groundwater samples because off-facility drinking water wells are present downgradient. The SLs are shown in **Table 10-1**, with SI Mobilization 1 and Mobilization 2 sampling results discussed below.

Table 10-1 Screening Levels (Soil and Groundwater)

Analyte	Residential (Soil) (µg/kg)[a,b,c] 0-2 feet bgs	Industrial/ Commercial Composite Worker (Soil) (µg/kg)[a,b,c] 2-15 feet bgs	Tap Water (Groundwater) (ng/L)[a,c]	USEPA HA (Groundwater representative of Drinking Water) (ng/L)[d,e]
PFOA	130	1,600	40	70
PFOS	130	1,600	40	70
PFBS	1,900	25,000	600	-

Notes:

a.) Assistant Secretary of Defense, 2021. Risk Based Screening Levels Calculated for PFOS, PFOA, PFBS in Groundwater and Soil using USEPA's Regional Screening Level Calculator. HQ=0.1. 15 September 2021.

b.) The SLs for soil are based on incidental ingestion of soil applied to the soil intervals reasonably anticipated to be encountered; surface soil (0 to 2 feet bgs for the residential scenario) and subsurface soil (>2 to 15 feet bgs for the industrial/commercial worker scenario).

c.) USEPA, 2021c. Regional Screening Levels (RSLs) for PFBS in Tap Water and Soil. HQ = 0.1. November 2021.

d.) USEPA Drinking Water HA for Perfluorooctanoic Acid (PFOA) and Drinking Water HA for Perfluorooctane Sulfonate (PFOS) (USEPA, 2016a; USEPA, 2016b).

e.) USEPA HAs apply to the PFOS and PFOA concentrations individually or combined.

µg/kg = micrograms per kilogram
bgs = below ground surface
HA = Health Advisory
ng/L = nanograms per liter
OSD = Office of the Secretary of Defense
SL = screening level

USEPA = United States Environmental Protection Agency

Figure 10-14 and **Figure 10-15** present detections in soil for PFOA and PFOS, respectively, within the shallow, intermediate, and deep samples collected from within a given soil boring from Mobilization 1. **Figure 10-16** and **Figure 10-17** present the surface soil sample results for PFOS and PFOA, respectively, during SI Mobilization 2. **Figure 10-18** and **Figure 10-19** present detections for PFOA and PFOS for grab groundwater samples from SI Mobilization 1, were collected from depths near the top of the groundwater table, and for monitoring well samples from SI Mobilization 2. **Figure 10-20** through **Figure 10-24** present PFOA and PFOS detections in co-located sediment and surface water samples, respectively, for sampling during RI Mobilization 1 and RI Mobilization 2. Tables of results from the mobilizations of the SI, including soil sampling at the surface (0 to 2 feet bgs), shallow subsurface (>2 to 15 feet bgs), and deep subsurface (>15 feet bgs) sampling intervals, groundwater samples from temporary wells and monitoring wells, and co-located sediment and surface water sampling, are provided in **Appendix B**. The combined results from both mobilizations of the SI are further summarized in the subsections below.

10.5.2.1 AOI 1

Based on the SI findings, PFOA, PFOS, and PFBS were detected in AOI 1. The following statements present the SI findings for AOI 1.

- In soil, PFOA, PFOS, and PFBS were detected but did not exceed the OSD SLs.
    - During Mobilization 1, soil was sampled at three depth intervals from two borings (AOI 1-4 and AOI 1-6) and two depth intervals from four borings (AOI 1-1, AOI 1-2, AOI 1-3, and AOI 1-5). PFOA, PFOS, and PFBS were detected in the surface interval (0 to 2 feet bgs) at concentrations more than an order of magnitude lower than the residential soil SLs and in the shallow interval (2 to 4 feet bgs) at concentrations more than three orders of magnitude lower than the industrial/commercial soil SLs. PFOA was detected at concentrations ranging from 0.00784 J micrograms per kilogram (µg/kg) to 0.171 J µg/kg. PFOS was detected at concentrations ranging from 0.018 J µg/kg to 2.22 J+ µg/kg. PFBS was detected at concentrations ranging from 0.00424 J µg/kg to 0.00917 J µg/kg. The occurrence and concentration of individual PFAS varied across depth intervals and between sampling locations. All soil samples obtained were from the unsaturated zone.
    - During Mobilization 2, surface soil (0 to 2 feet bgs) was sampled from locations AOI 1-16 through AOI 1-20. The soil sample locations were placed around the existing wash bay, northwest of the AASF Hangar. PFOA and PFOS were detected in the surface soil at concentrations more than an order of magnitude lower than the residential soil SLs. PFBS was not detected in any of the surface soil locations. PFOA was detected at concentrations ranging from 0.181 J µg/kg to 0.331 J µg/kg. PFOS was detected at concentrations ranging from 0.802 J µg/kg to 11.0 µg/kg. The highest concentrations and most compounds detected were observed at AOI 1-19, located in the northeast corner of the pavement outside the AASF Hangar. All soil samples obtained were from the unsaturated zone.
- In groundwater, PFOA and PFOS exceeded the SLs at AOI 1. PFBS was detected but did not exceed the SL.
    - During Mobilization 1, groundwater was sampled from temporary monitoring well locations AOI 1-1 through AOI 1-6. At location AOI 1-5, PFOA and PFOS were detected at concentrations of 53.0 ng/L and 60.0 ng/L, respectively, exceeding their respective SLs of 40 ng/L. AOI 1-5 is located northeast of the Armory (Former AASF)

source area. PFBS was detected at concentrations ranging from 1.58 J ng/L to 46.1 ng/L, below the SL of 600 ng/L.

  - During Mobilization 2, groundwater was sampled from permanent monitoring well locations AOI 1-10 through AOI 1-15. PFOA was detected at a concentration of 28.2 ng/L in AOI 1-12; PFOS was detected at a concentration of 1.97 J ng/L in AOI 1-11; and PFBS was detected at a concentration of 70.7 ng/L in AOI 1-12. All detections of PFOA, PFOS, and PFBS were below their SLs. The highest concentrations and most compounds detected were generally observed at AOI 1-12, located slightly north (upgradient) of temporary well AOI 1-5, which exhibited the previous Mobilization 1 SL exceedances for PFOA and PFOS.

Based on the results of the SI completed to date, PFOA, PFOS, and PFBS were detected in soil at AOI 1; however, the detected concentrations were several orders of magnitude lower than the soil SLs. At location AOI 1-5, PFOS and PFOA were detected in groundwater at concentrations exceeding the individual SLs of 40 ng/L. PFBS was detected in groundwater at concentrations below the SL. PFOA, PFOS, and PFBS were also detected in sediment and surface water at AOI 1. However, data quality limits (DQLs) for these media are presented in **Worksheet #15** and will be considered during the evaluation of RI Mobilization 1 sampling results. Based on the currently available data and the exceedances of the SLs for PFOA and PFOS in groundwater, the extent of these impacts is not currently vertically or laterally delineated.

10.5.2.2 AOI 2

Based on the SI findings, PFOA, PFOS, and PFBS were detected in AOI 2. The following statements present the SI findings for AOI 2.

- In soil, PFOA, PFOS, and PFBS were detected but did not exceed the OSD SLs.
  - Soil was sampled at boring locations AOI 2-1, AOI 2-2, and AOI 2-3. Samples were collected at the surface interval (0 to 2 feet bgs) for all three locations and at a shallow interval (2 to 4 feet bgs) for AOI 2-2. PFOA, PFOS, and PFBS were detected in the surface interval at concentrations more than two orders of magnitude lower than the residential soil SLs and in the shallow interval at concentrations more than three orders of magnitude lower than the industrial/commercial soil SLs. All soil samples obtained were from the unsaturated zone.
  - PFOA was detected in the surface/shallow interval at concentrations ranging from 0.016 J to 0.117 J µg/kg. PFOS was detected in the surface/shallow interval at concentrations ranging from 0.123 J µg/kg to 0.486 J µg/kg. PFBS was detected in the surface interval at concentrations 0.011 J µg/kg and 0.014 J µg/kg. The greatest number of compounds were observed in the surface intervals of AOI 2-1 and AOI 2-3. All soil samples obtained were from the unsaturated zone.
- In groundwater, PFOA, PFOS, and PFBS were detected but did not exceed the September 2021 OSD SLs.
  - During Mobilization 1, groundwater was sampled at temporary monitoring well locations AOI 2-1, AOI 2-2, and AOI 2-3. PFOA and PFBS were only detected at AOI 2-2, which is located in the most downgradient position from the Annex Building source area. The PFOA detection of 4.10 J ng/L was below the SL of 40 ng/L, and the PFBS detection of 4.21 J ng/L was below the SL of 600 ng/L. The maximum concentration of PFOS (31.7 ng/L) was also detected at AOI 2-2 below the SL of 40 ng/L.

- During Mobilization 2, groundwater was sampled from permanent monitoring well location AOI 2-4. The permanent monitoring well had no detections of PFOA, PFOS, or PFBS.

Based on the results of the SI, PFOA, PFOS, and PFBS were detected in soil at AOI 2; however, the detected concentrations were at least two orders of magnitude lower than the soil SLs. PFOA, PFOS, and PFBS were also detected in groundwater, but detected concentrations did not exceed the groundwater SLs. Based on the PFOS detection of 31.7 ng/L during the SI, there is a potential data gap indicating a possible release area. This data gap will be further evaluated with supplemental work as part of this investigation.

10.5.3 Fate and Transport of PFAS

Contaminant fate and transport is an evaluation of the changes that occur in constituents and concentrations as they move through different environmental media. Understanding the fate and transport of chemicals is important in evaluating their potential impacts to receptors. Fate is a summary of all the physical and chemical processes that act on the constituents during transport. Transport is the simple movement of the constituents, for example, with the flow of groundwater or surface water.

The primary source of PFAS at Grand Ledge AASF is likely from AFFF training activities attributable to ARNG. Multiple AFFF formulations have been produced over the years, and the exact composition of any given AFFF used or manufactured in any given year is highly variable (Backe et.al, 2013). AFFF contains highly diverse mixtures of PFAS which may vary based on the production process used: electrochemical fluorination (ECF) or fluorotelomerization. The ECF process results in a PFAS mixture dominated by perfluoroalkyl acids (PFAAs), both perfluoroalkyl sulfonic acid (PFSA) and perfluoroalkyl carboxylic acid (PFCA) homologues, while the fluorotelomerization process produces AFFF formulations dominated by polyfluorinated compounds with lesser amounts of PFAAs (Houtz et al., 2013). In general, ECF-based AFFF is the dominant source of PFAS at AFFF-impacted sites (Interstate Technology Regulatory Council [ITRC], 2018a).

Both the PFSA and PFCA homologues produced as part of AFFF manufacture (including PFOA and PFOS) are long-chain PFAS chemicals that are persistent in the environment, bioaccumulative in wildlife and humans, and are toxic to laboratory animals and wildlife, producing reproductive, developmental, and systemic effects in laboratory tests. Shorter-chain PFSAs, such as PFBS and PFHxS, are generally less toxic and less bioaccumulative in wildlife and humans, and alternative products containing these shorter-chain chemicals have been introduced as replacements for long-chain PFAS. Increasing levels of PFBS and PFHxS in surface water have been observed indicating that short-chain alternatives to PFOA and PFOS are also persistent in the environment (Buck et al., 2011).

Precursors typically are raw materials or intermediary compounds in the PFAS manufacturing process. Generally, they consist of polyfluorinated alkyl compounds that can be biotically and abiotically transformed into PFAA terminal “end-member” compounds (i.e., PFAS) in the environment. Transformation of these precursors to PFAAs has been shown to occur in a variety of environmental media and can result in unexpected temporal and spatial trends in PFAS occurrence. The susceptibility of individual precursors to transformation processes can also influence how each will bioconcentrate and bioaccumulate within various biotic species. The analysis of precursor compounds in surface soils can be used to help identify source release areas because precursor compounds tend to be larger, transform slowly and adsorb more strongly to soil. Fluorotelomer alcohols (FTOHs) and fluorinated sulfonamides, such as N-ethyl perfluorooctane sulfonamido ethanol (EtFOSE), are examples of such precursor compounds (Houtz et al., 2013).

PFAS most commonly detected in the environment typically have a carbon-fluorine “tail” and a nonfluorinated “head” consisting of a polar functional group. The tail is hydrophobic and lipophobic, while the head groups are polar and hydrophilic. These competing tendencies of the head and the tail can lead to a wide distribution in the environment. Important PFAS partitioning mechanisms include hydrophobic and lipophobic effects, electrostatic interactions, and interfacial behaviors. The hydrophobic and lipophobic effects drive the association with organic carbon in soils and sediments (ITRC, 2018a). Because the head and the tail compete, partitioning to interfaces of environmental media such as soil/water, air/water and water/non-aqueous phase liquid co-contaminants can occur (Guelfo and Higgins, 2013; McKenzie et al., 2016; Brusseau, 2018). Preferential accumulation of PFAS above the water table within the vadose zone is a common example of partitioning at the air/water interface.

PFCAs and PFSAs are present as organic anions at most pH levels found in the environment and are therefore relatively mobile in groundwater (Xiao et al., 2015) but tend to associate with the organic carbon fraction that may be present in soil or sediment (Higgins and Luthy, 2006; Guelfo and Higgins, 2013). When sufficient organic carbon is present, organic carbon-normalized distribution coefficients (K_{oc} values) can help in evaluating transport potential, though other geochemical factors (for example, pH and presence of polyvalent cations) may also affect PFAS sorption to solid phases (ITRC, 2018a).

Sorption and retardation of PFAS compounds show correlations with carbon chain length and structure. Sorption generally increases with increasing perfluoroalkyl tail length (Higgins and Luthy, 2006; Guelfo and Higgins, 2013; Sepulvado et al., 2011), indicating that the short-chain PFSAs, like PFBS and PFHxS, are retarded less than longer chain chemicals like PFOA and PFOS. Also, branched versus linear isomers of the same compound display different sorptive behavior, with linear isomers tending to sorb more strongly than their branched counterparts.

Sorption of PFCAs and PFSAs is also affected by soil solution chemistry, with decreased pH and increased levels of polyvalent cations (for example, calcium $[Ca]^{2+}$) leading to increased sorption and retardation (Higgins and Luthy, 2006; McKenzie et al., 2015). Vapor pressures of these compounds are generally low, and water solubilities are high, limiting partitioning from water to air (USEPA, 2000).

Once organic chemicals are released to soils, a variety of processes may occur that cause them to become immobilized or to be mobilized to another environmental medium. Chemicals may be taken up and held on soil particles by adsorption (sticking to a particle surface) or absorption (diffusion into the particle). Chemicals may sorb directly to the soil grains or to organic or metal oxyhydroxide coatings on the grains. The degree of sorption of a particular chemical in the environment is controlled by both soil properties (i.e., organic carbon content, metal oxyhydroxide content, clay content, or specific surface area) and by chemical properties (i.e., partition coefficients, solubility, polarity). PFOS adsorbs to soil and sediment and does not readily desorb once adsorbed to these matrices. The fate properties of PFOA are similar to those of PFOS, while PFBS and PFHxS are slightly less likely to sorb to soil (ITRC, 2018a).

Chemicals may be transported downward through the soil strata by liquids that infiltrate through the soils or by water from precipitation. Chemicals released to, or transported into, soils beneath the groundwater surface may be leached from the soils by groundwater and transported downgradient in groundwater. Leaching potential is a function of both media properties (for example, pH, redox conditions, and increased partitioning with organic-rich soil) and PFAS structural properties (for example, ionic charge, and chain length) (Gellrich, Stahl, and Knepper 2012). PFAS may be transported to the sediment and surface water through direct discharges from drainage outfalls, overland runoff/erosion, and groundwater discharge.

10.5.4 Potential Receptors and Exposure Pathways

As described above, soil and groundwater may have been impacted by PFAS releases associated with historical ARNG activities at two AOIs within the Grand Ledge AASF. In addition, PFAS in these media may have migrated to surface water, sediment, and porewater via groundwater migration or stormwater flow into the stormwater retention basin. Therefore, human and ecological receptors present within these AOIs may be exposed to PFAS. The currently understood human health and ecological receptors and potentially complete exposure pathways under current and reasonably anticipated future land use scenarios are summarized below and are presented on **Figure 10-25**. These receptors and exposure pathways will be updated, if necessary, following evaluation of the data collected as part of this and subsequent mobilizations, as applicable.

Human Health

Current human receptors at the facility include on-facility workers and approved visitors (e.g., National Guard/Army Reserve trainees) of Grand Ledge AASF. Outdoor workers may contact surface soil on the facility while performing maintenance or other similar activities. Visitors and trainees may also contact soil on the facility but are anticipated to have a lower exposure potential as compared to outdoor workers who would presumably be present more frequently and perform more soil-intense activities, such as landscaping.

The facility is currently surrounded by a 6-foot chain link fence with barbed wire extension; therefore, entry by trespassers is considered unlikely. However, it is conservatively assumed that trespassers may access surface soil at the facility in the future if there is no longer controlled access. Construction/ utility workers may also be present and access facility soil and shallow groundwater in the future if redevelopment or utility activities were to occur.

There is a stormwater retention basin located to the northwest corner of the facility. It is conservatively assumed that on-facility outdoor workers may contact sediment and surface water in the stormwater retention basin while performing maintenance activities such as clearing the drainage areas of debris. The stormwater retention basin is not likely to be attractive to a trespasser; although, a trespasser might walk through it under a future scenario in which access to the facility is not controlled. Potential exposure to sediment and surface water in the stormwater retention basin by a future trespasser is likely to be infrequent (minimal) and is, therefore, considered to be an insignificant exposure pathway that will not be quantitatively evaluated. As discussed in **Section 10.2.3**, overflow from the stormwater retention basin drains to a small drainage creek located 0.25 miles north of the facility and ultimately drains to the Looking Glass River. It is conservatively assumed that off-facility recreational users may have the potential for exposure to sediment and surface water in these areas. Therefore, on-facility sediment and surface water will be evaluated for a recreational user (adult and child) exposure scenario as a conservative surrogate of concentrations that have the potential to migrate from the facility to downstream off-facility water bodies.

Grand Ledge AASF receives its potable water from the City of Grand Ledge’s municipal water utility, except for the Annex Building, which receives water from an on-facility public supply groundwater well. It is understood that the source of water used in the wash bays on the facility is also the municipal water. Drinking water from the Annex Building’s well, which is installed in the bedrock aquifer, was previously sampled by the National Guard Bureau in May 2017, and by MIARNG in January 2020 and August 2021. For each year, all results were reported as non-detect for PFAS. A hypothetical future scenario in which on-facility perched groundwater is used as a source of potable water (i.e., drinking water) will be evaluated. This potable use scenario is also protective of incidental exposure to groundwater via non-potable uses, such as in the wash bays.

Non-military land uses in off-facility areas adjoining the facility include commercial, residential, and agricultural use, where access is open to the public. As discussed in **Section 10.4.1**, ARNG collected off-facility drinking water samples from private residential wells and 25 off-facility private properties along West Eaton Highway, Wright Road, Hartel Road, and Bauer Road in proximity to Grand Ledge AASF between January and July 2020. The results of the drinking water sampling indicated non-detect results at 23 properties, and no exceedances of the USEPA HA of 70 ng/L for both PFOA and/or PFOS, and PFOA+PFOA. Based on these results obtained from the properties closest to the facility, the ingestion exposure pathway to PFAS in groundwater is not considered to pose a potential unacceptable risk or hazard, as defined in the NCP [40 CFR § 300.430] (USEPA, 1991; USEPA, 1994), to off-facility residents.

Reasonably anticipated future land use is not expected to change from the current land use described above. However, the Human Health Risk Assessment (HHRA) (to be performed as part of the RI following Mobilization 2) will conservatively evaluate an unlimited use/unrestricted exposure (UU/UE) scenario to inform future risk-management decisions in the FS, if applicable. This scenario includes the evaluation of a hypothetical future on-facility residential scenario and the evaluation of on-facility groundwater as a source of drinking water. A remedial response will not necessarily be taken based on the results of the future UU/UE scenario, given it is not a reasonably anticipated future use for the facility, per the DoD Defense Environmental Restoration Program (DERP) Management Manual, which states "The DoD Component shall consider current and reasonably anticipated future land uses in risk assessments. The DoD Component does not have to assume that the reasonably anticipated future land use is residential." (DoD, 2012).

The receptors and potentially complete exposure pathways that will be considered for a current and/or future use scenario are as follows. For future land-use scenarios that may involve some level of construction to convert the area to the desired use (i.e., worker and residential scenarios), it is assumed that current subsurface soils may be brought to the surface and mixed with surface soil for exposure by future receptors.

- Current On-facility Outdoor Worker
    - Exposure to on-facility surface soil (0 to 2 feet bgs) through incidental ingestion and dermal contact; and exposure to sediment and surface water in the stormwater retention basin via incidental ingestion and dermal contact. (The water-dermal contact pathway will not be quantitatively evaluated for PFOA and PFOS, as further discussed below).
- Future On-facility Outdoor Worker
    - Exposure to combined surface and subsurface soil (0 to 15 feet bgs [or the top of the water table if it is shallower]) through incidental ingestion and dermal contact; exposure to groundwater via ingestion as drinking water; and exposure to sediment and surface water in the stormwater retention basin via incidental ingestion and dermal contact. (The water-dermal contact pathway will not be quantitatively evaluated for PFOA and PFOS, as further discussed below).
- Future Construction/Utility Worker
    - Exposure to on-facility combined surface and subsurface soil (0 to 15 feet bgs [or the top of the water table if it is shallower]) through incidental ingestion and dermal contact; and exposure to shallow groundwater (to a maximum depth of 15 feet bgs) via incidental ingestion and dermal contact in an excavation trench. (The water-dermal contact pathway will not be quantitatively evaluated for PFOA and PFOS, as further discussed below).

- Future Adolescent Trespasser (7 to <16 years old)*
    - Exposure to on-facility surface soil through incidental ingestion and dermal contact.

      *The adolescent trespasser exposure scenario is also protective of an adult trespasser; a young child is not reasonably anticipated to trespass onto the site.
- Hypothetical Future On-facility Resident (Adult and Child)
    - Exposure to on-facility combined surface and subsurface soil through incidental ingestion and dermal contact; and exposure to on-facility groundwater via ingestion of drinking water.
- Current/Future Off-facility Recreational User
    - Exposure to sediment and surface water in the stormwater retention basin (as a conservative surrogate for concentrations that have the potential to migrate from the facility) via incidental ingestion and dermal contact. (The water-dermal contact pathway will not be quantitatively evaluated for PFOA and PFOS, as further discussed below).

Based on currently available scientific data (Franko et al., 2012) and consistent with USEPA's approach (USEPA, 2021c), the dermal contact pathway associated with PFOS and PFOA in water (i.e., groundwater and surface water) will not be quantitatively evaluated due to limited dermal absorption of PFOS and PFOA in water. The dermal contact with water pathway for PFOS and PFOA will be qualitatively discussed in the uncertainty assessment. The USEPA Regional SL (RSL) calculator includes the dermal contact with water pathway for PFBS. Therefore, the data will be evaluated to determine whether dermal contact with water will be quantitatively evaluated for PFBS. Potential exposure to airborne particles in outdoor air (from soil) will not be quantitatively evaluated because toxicity values for the inhalation exposure route are not available for PFOS, PFOA, or PFBS; therefore, quantitative assessment of the inhalation exposure pathway cannot be performed. The associated uncertainties with the dermal water and inhalation pathways will be discussed in the HHRA.

Ecological

The majority of the current facility is paved with grassy areas surrounding the perimeter. The terrestrial habitats associated with the AOIs are limited due to the continuing military land uses, and actively mowed, disturbed, and maintained areas where PFAS releases occurred. Fencing surrounding the facility is expected to limit access to the AOIs for large mammals such as deer. Given the proximity of the facility to the Abrams Municipal Airport and the potential for air strikes due to wildlife, upland habitats that would support significant plant or animal communities are not currently present and not likely to be encouraged. However, it is conservatively assumed that terrestrial plants and soil invertebrates may serve as food sources for birds and mammals that may be present in areas with viable habitat.

The primary exposure pathways for upland areas with viable habitat include:

- Soil invertebrates, terrestrial plants, reptiles, and amphibians directly exposed to PFAS in surface soil (0 to 2 feet bgs).
- Terrestrial birds and mammals exposed to PFAS through incidental ingestion of soil and by ingestion of contaminated plant and prey items impacted by surface soil.

Wetland habitat exists on the facility within the stormwater retention basin. No other aquatic habitats are located within the facility. The retention pond drains to Reed Drain and eventually into the Looking Glass River, and these downstream areas may provide additional off-facility aquatic habitat. Ecological receptors are typically not directly exposed to groundwater; however, exposure to constituents present in groundwater may occur when groundwater discharges into a water body, such as the retention pond. The aquatic habitat within the Grand Ledge AASF stormwater retention basin (i.e., habitat with overlying water) will be the focus of the RI Mobilization 1 on-facility ecological evaluation, as this is likely to represent an area where PFAS-impacted groundwater may be discharging. The conditions in the retention pond are expected to represent a conservative surrogate for concentrations that have the potential to migrate from the facility into downgradient waterbodies. The evaluation of downgradient off-facility aquatic habitats may be considered following the Mobilization 1 evaluation.

Based on existing data, the primary exposure pathways for aquatic habitats associated with the retention basin include:

- Aquatic plants, amphibians, reptiles, aquatic invertebrates, small fish, and benthic invertebrates directly exposed to PFAS in surface sediment, porewater, and/or surface water in the retention basin.
- Aquatic-dependent birds and mammals exposed to PFAS through incidental ingestion of sediment or surface water, and by ingestion of contaminated plant and prey items impacted by sediment, porewater, or surface water in the wetland habitat associated with the stormwater retention basin.

Exposure pathways within downgradient off-facility aquatic habitats are expected to be similar to those in the retention basin. The Mobilization 1 evaluation will conservatively evaluate exposure to sediment, porewater, and surface water in the stormwater retention basin as a conservative surrogate for concentrations that have the potential to migrate from the facility into off-facility aquatic habitats. In cases where receptor-specific PFAS toxicity information is not available, potential impacts on receptors (e.g., reptiles) will be considered qualitatively in the Screening-Level Ecological Risk Assessment (SLERA).

These human health and ecological exposure pathways will be refined based on data from Mobilization 1 of the RI. Further evaluations of the exposure pathways will be considered during future mobilization(s).

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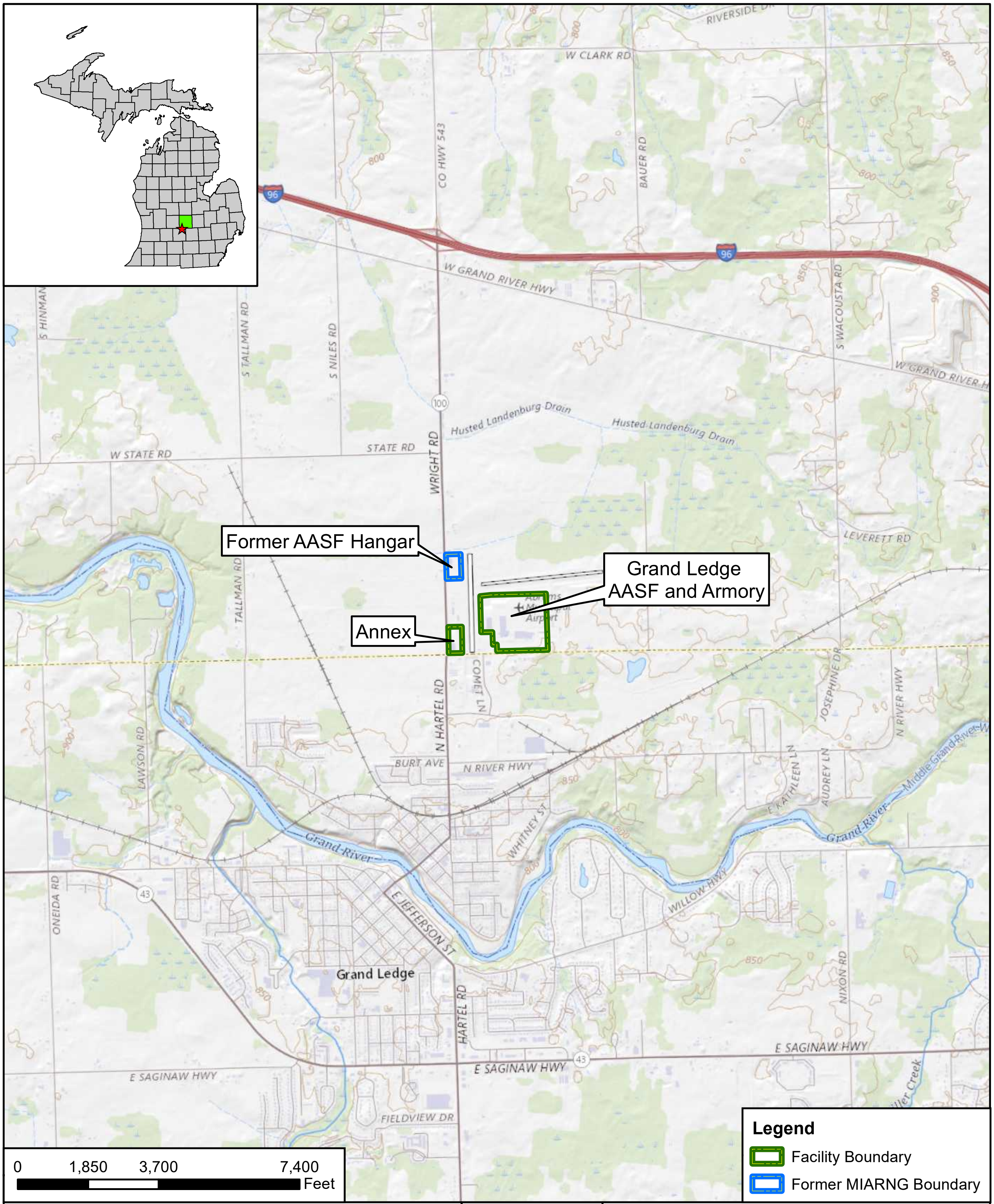

CLIENT	ARNG			
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REVISED	6/3/2022	GIS BY	MS	6/3/2022
SCALE	1:44,400	CHK BY	SI	6/3/2022
Base Map: USGS The National Map: National Boundaries Dataset, 3DEP Elevation Program,		PM	CM	6/3/2022

N

Facility Location

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Figure 10-1

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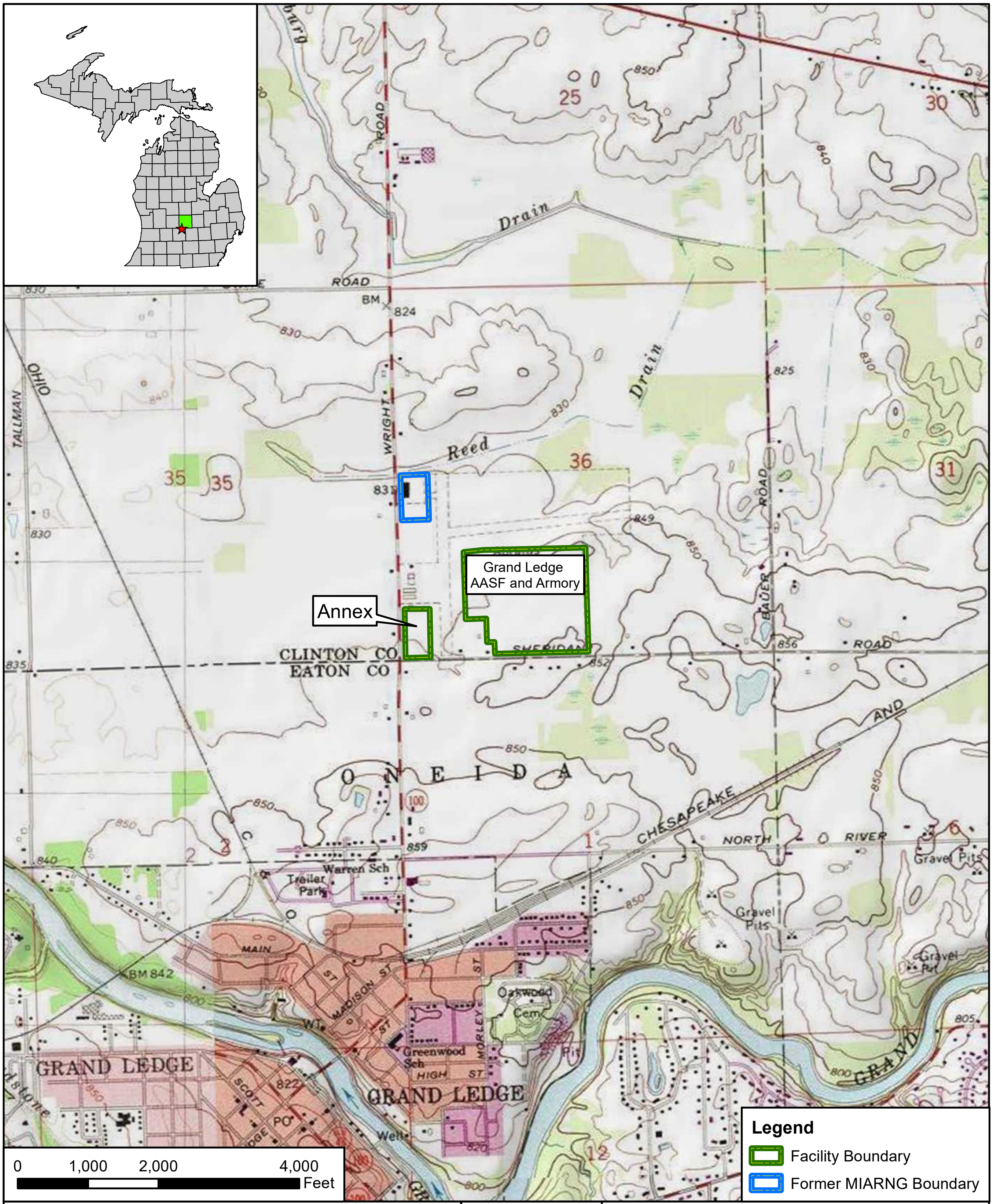

CLIENT	ARNG			
Remedial Investigation for PFOA, PFOS and PFBS at Grand Ledge AASF and Armory, MI				
REVISED	6/17/2022	GIS BY	MS	6/17/2022
SCALE	1:24,000	CHK BY	ST	6/17/2022
Base Map: Copyright:© 2013 National Geographic Society, i-cubed		PM	CM	6/17/2022

N

Facility Topography

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Figure 10-2

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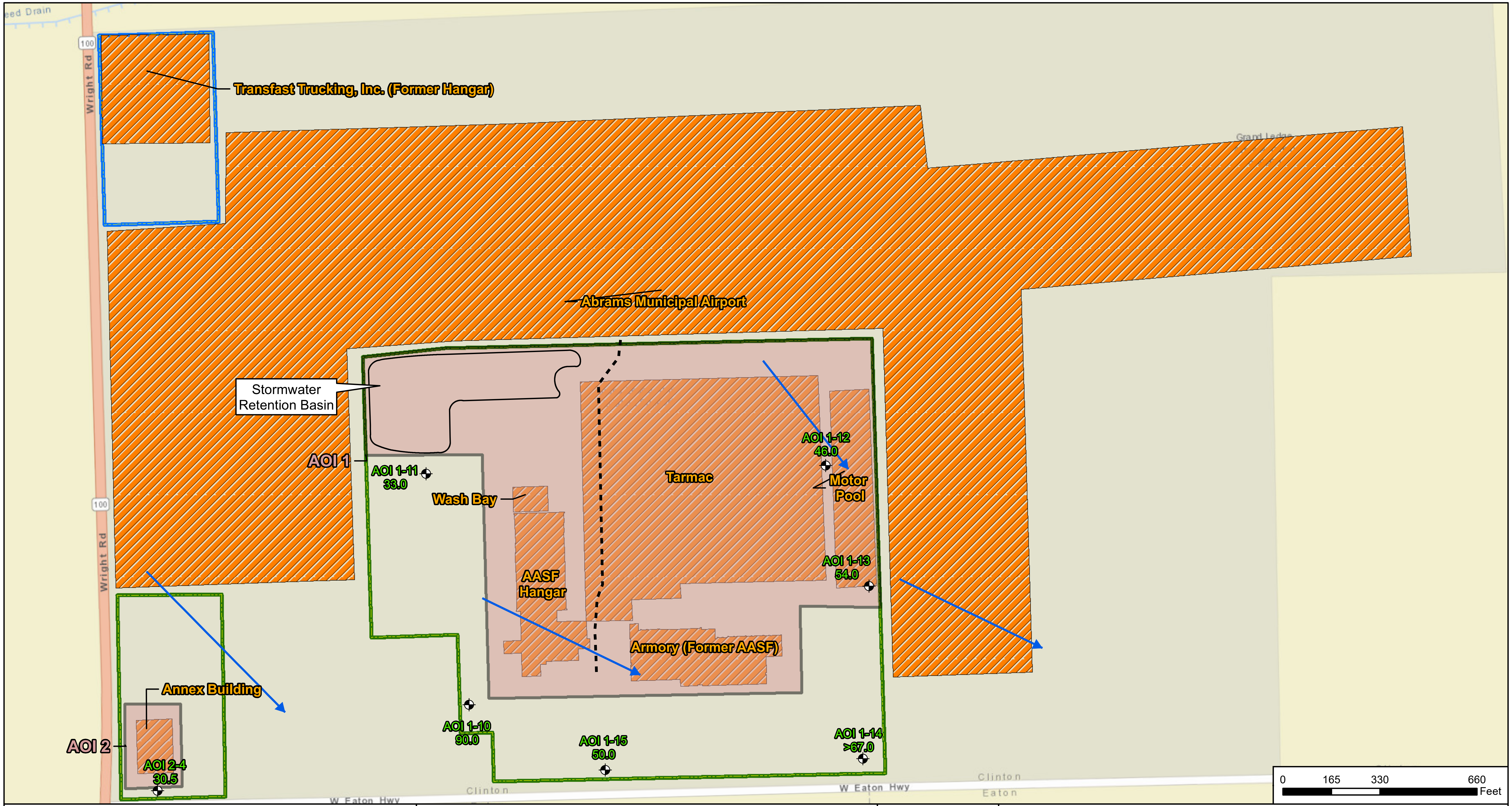

CLIENT	ARNG			
PROJECT	Remedial Investigation for PFOA, PFOS and PFBS at Grand Ledge AASF and Armory, MI			
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SCALE	1:3,960	CHK BY	JW	6/17/2022
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap		PM	CM	6/17/2022

⊕ Permanent Monitoring Well
→ Groundwater Flow Direction
▨ Area of Interest
▨ Potential PFAS Release
🟩 Facility Boundary
🟦 Former MIARNG Boundary
- - Former Ditch

AOI 1-10 = Sample Location ID
90.0 = Overburden Thickness (Feet)

N

Facility Overburden Thickness

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Figure 10-3

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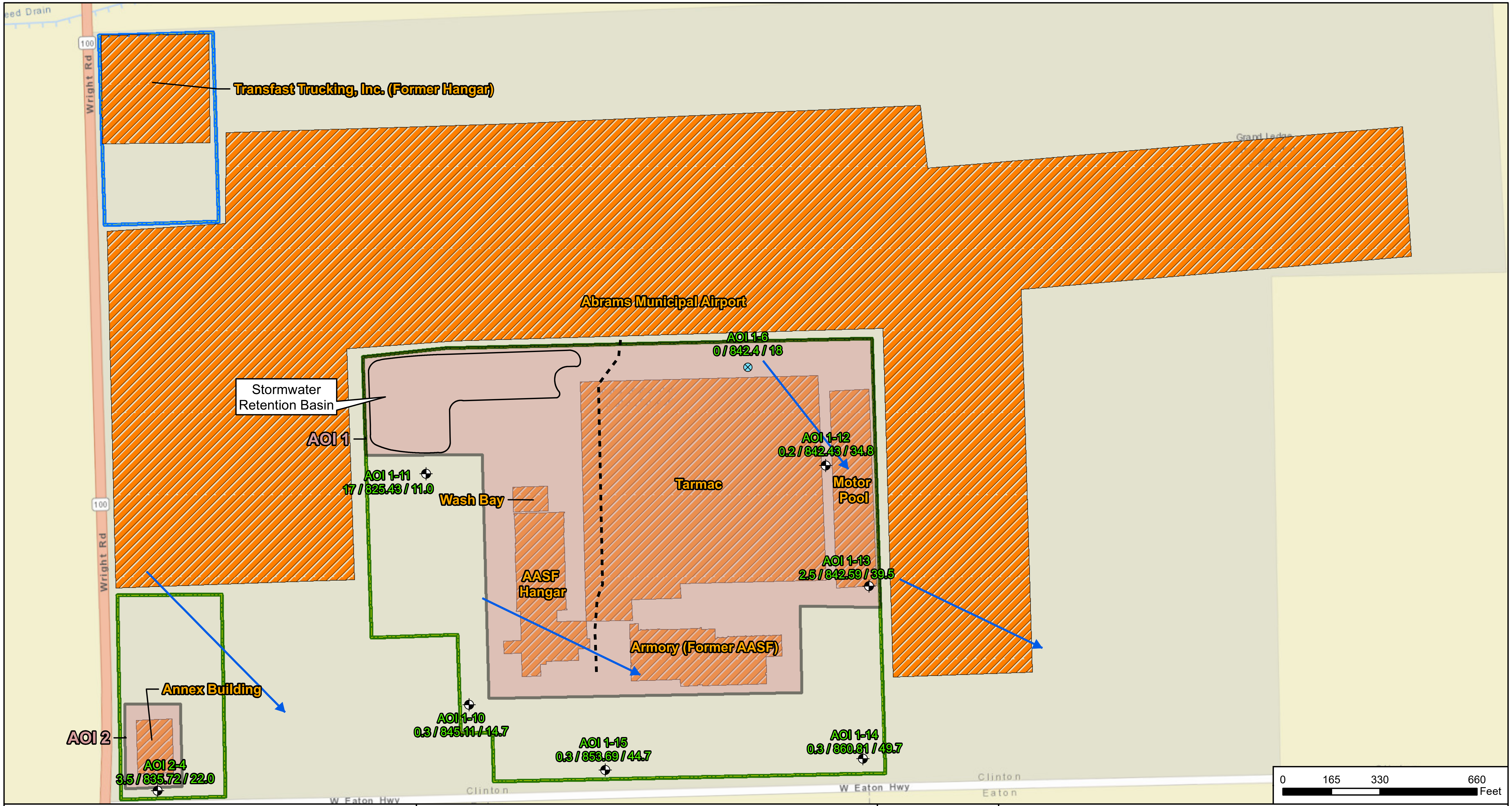

CLIENT	ARNG			
PROJECT	Remedial Investigation for PFOA, PFOS and PFBS at Grand Ledge AASF and Armory, MI			
REVISED	6/17/2022	GIS BY	MS	6/17/2022
SCALE	1:3,960	CHK BY	JW	6/17/2022
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap		PM	CM	6/17/2022

⊗ DPT Boring/Temporary Well
⌖ Permanent Monitoring Well
▭ Area of Interest
▨ Potential PFAS Release
▭ Facility Boundary
▭ Former MIARNG Boundary
- - Former Ditch
→ Groundwater Flow Direction
AOI 1-10 = Sample Location ID
0.3/845.11/14.7 = Depth to Top of Clay (Feet) / Top of Clay Elevation (Feet NAVD88) / Clay Unit Thickness (Feet)

N

Facility Clay Unit Thickness

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Figure 10-4

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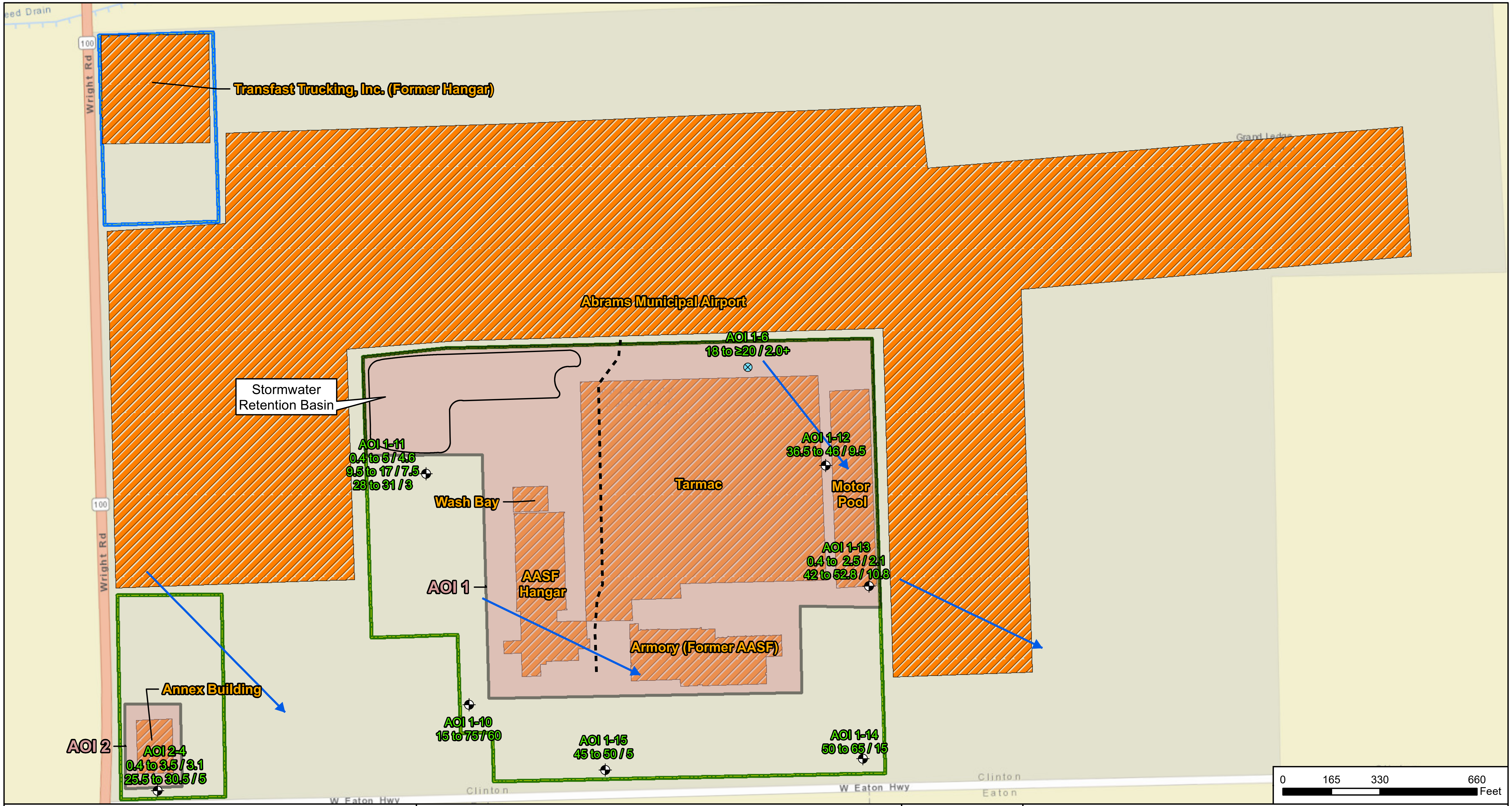

CLIENT ARNG				
PROJECT Remedial Investigation for PFOA, PFOS and PFBS at Grand Ledge AASF and Armory, MI				
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SCALE	1:3,960	CHK BY	JW	6/17/2022
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap		PM	CM	6/17/2022

⊗ DPT Boring/Temporary Well
⊕ Permanent Monitoring Well
▭ Area of Interest
▨ Potential PFAS Release
▭ Facility Boundary
▭ Former MIARNG Boundary
- - Former Ditch
→ Groundwater Flow Direction

Permeable Unit = Sand, Sand and Gravel, Cobbles.

AOI 1-10 = Sample Location ID
15 to 75 / 60 = Depth to top of permeable unit (Feet) to Depth to bottom of permeable unit (feet) / Thickness of permeable unit (Feet)

N

Facility Depth/Thickness of Permeable Units

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Figure 10-5

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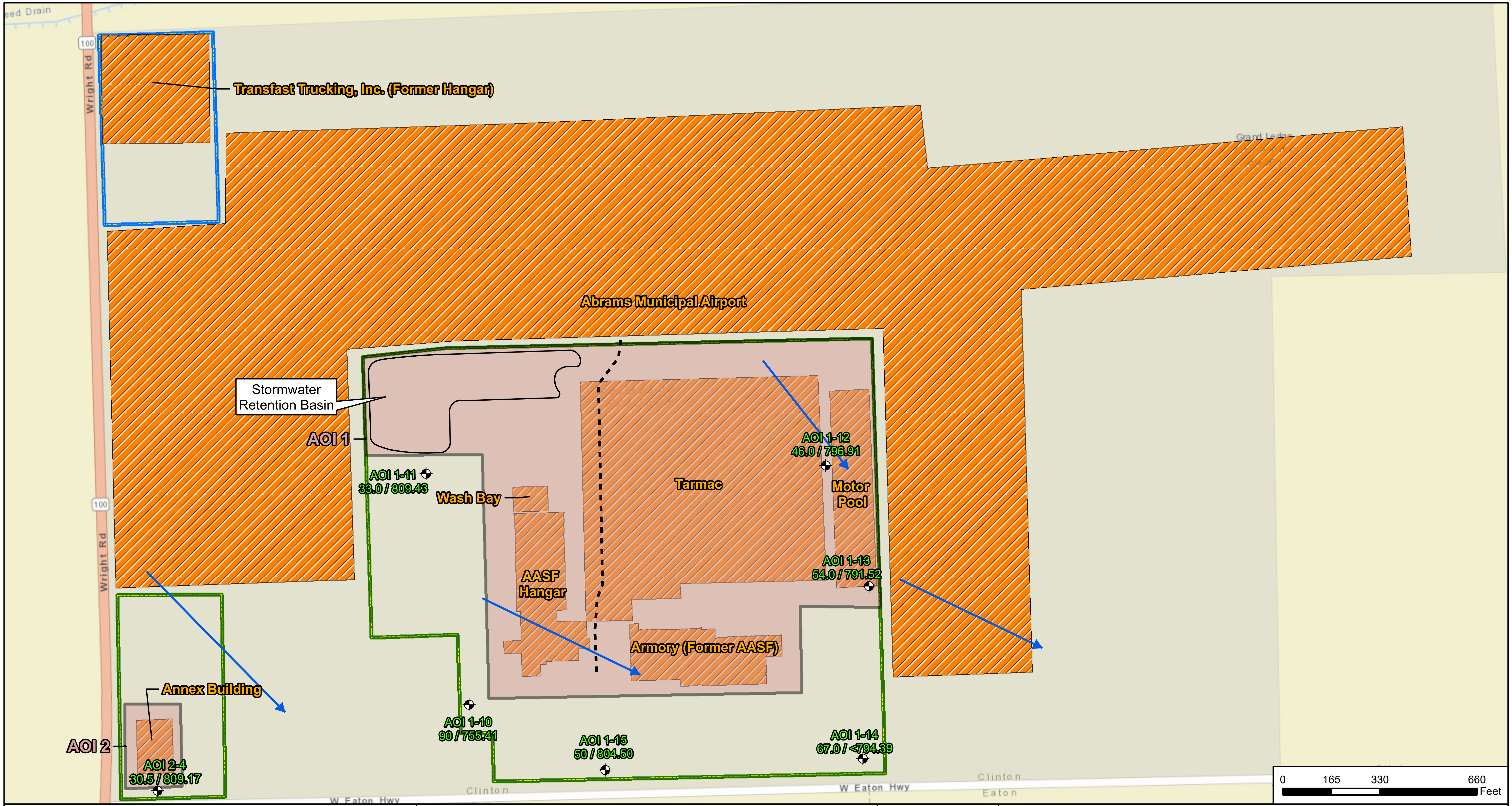

CLIENT	ARNG			
REVISED	Remedial Investigation for PFOA, PFOS and PFBS at Grand Ledge AASF and Armory, MI			
REVISED	6/17/2022	GIS BY	MS	6/17/2022
SCALE	1:3,960	CHK BY	JW	6/17/2022
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap		PM	CM	6/17/2022

⌖ Permanent Monitoring Well
🟩 Facility Boundary
▭ Area of Interest
🟦 Former MIARNG Boundary
▨ Potential PFAS Release
- - Former Ditch
→ Groundwater Flow Direction

AOI 1-10 = Sample Location ID
90/755.41 = Depth to Bedrock (Feet) / Bedrock Surface Elevation (Feet NAVD88)

N

Facility Bedrock Surface Elevations

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Figure 10-6

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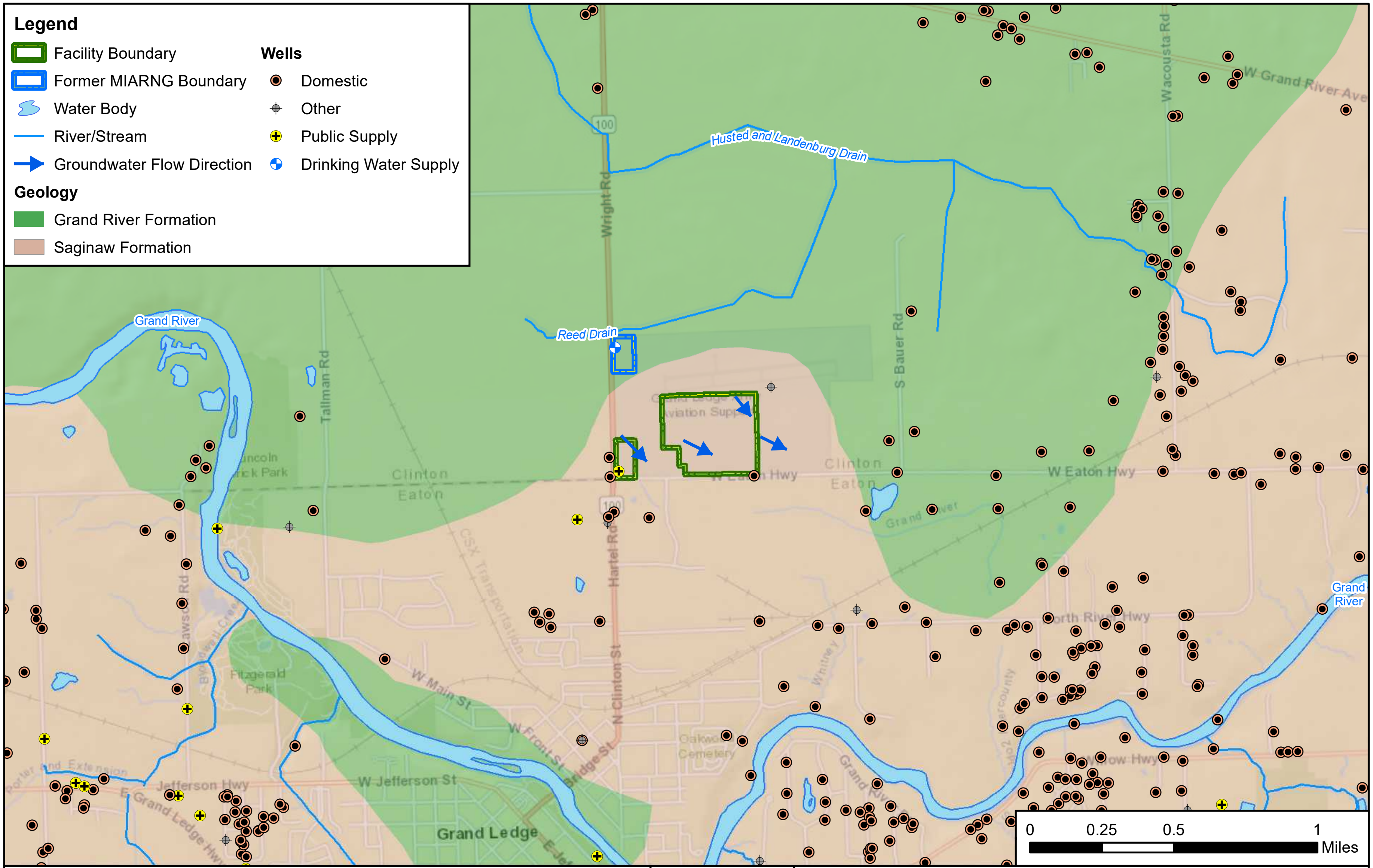

CLIENT	ARNG			
PROJECT	Remedial Investigation for PFOA, PFOS, and PFBS at Grand Ledge AASF and Armory, MI			
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SCALE	1:31,680	CHK BY	JW	6/17/2022
Base Map: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c)		PM	CM	6/17/2022

Groundwater Features

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Figure 10-7

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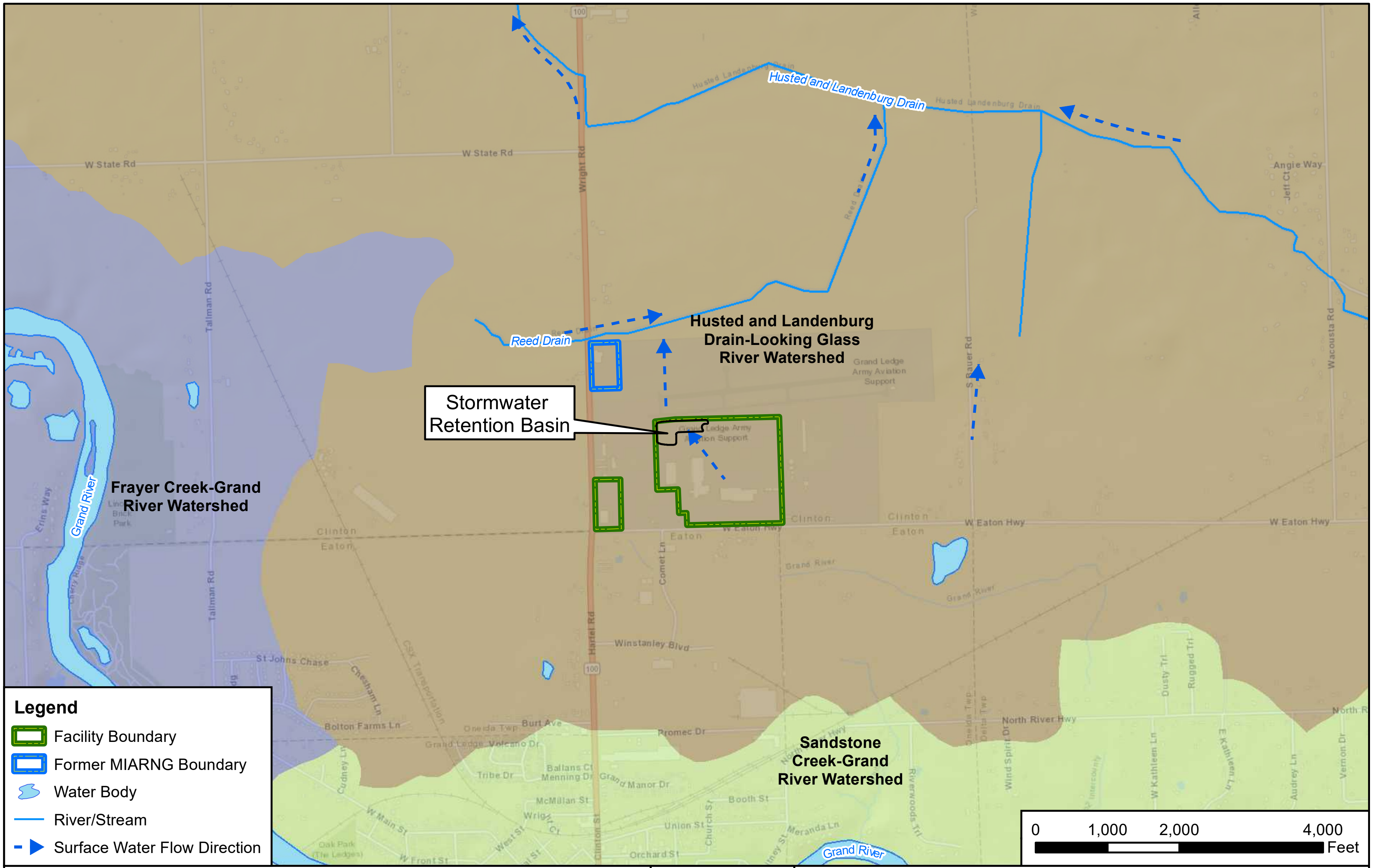

CLIENT	ARNG			
PROJECT	Remedial Investigation for PFOA, PFOS, and PFBS at Grand Ledge AASF and Armory, MI			
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SCALE	1:24,000	CHK BY	JW	6/17/2022
Base Map: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c)		PM	CM	6/17/2022

Surface Water Features

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Figure 10-8

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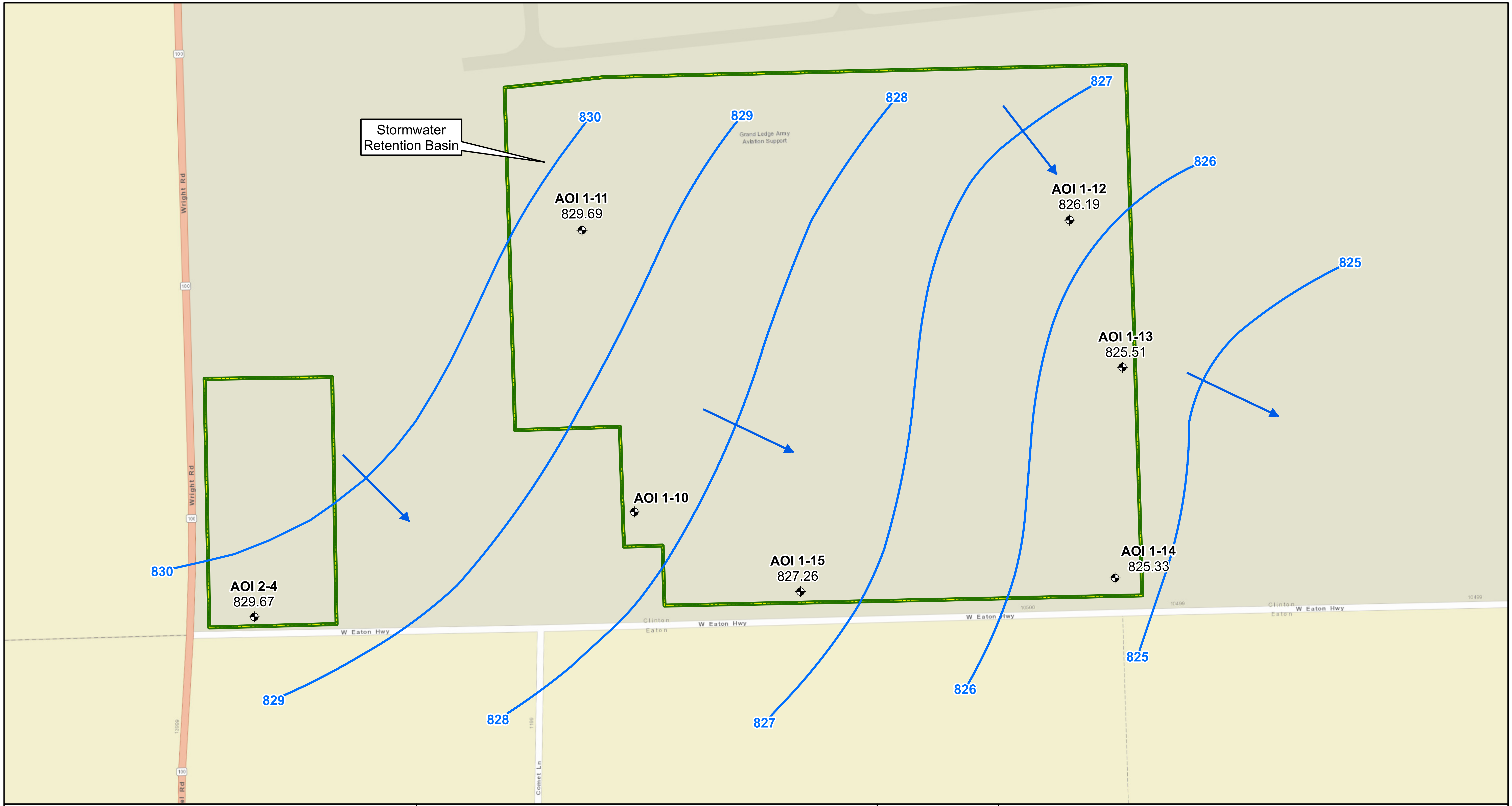

CLIENT	ARNG			
PROJECT	Remedial Investigation for PFOA, PFOS, and PFBS at Grand Ledge AASF and Armory, MI			
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SCALE	1:3,245	CHK BY	JW	6/17/2022
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap		PM	CM	6/17/2022

🟩 Facility Boundary
⌖ Monitoring Well
— Groundwater Contour
→ Groundwater Flow Direction

0 135 270 540 Feet

Groundwater elevations are presented in feet above mean sea level using North American Vertical Datum 1988.

N

Groundwater Elevations, January 2020

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Figure 10-9

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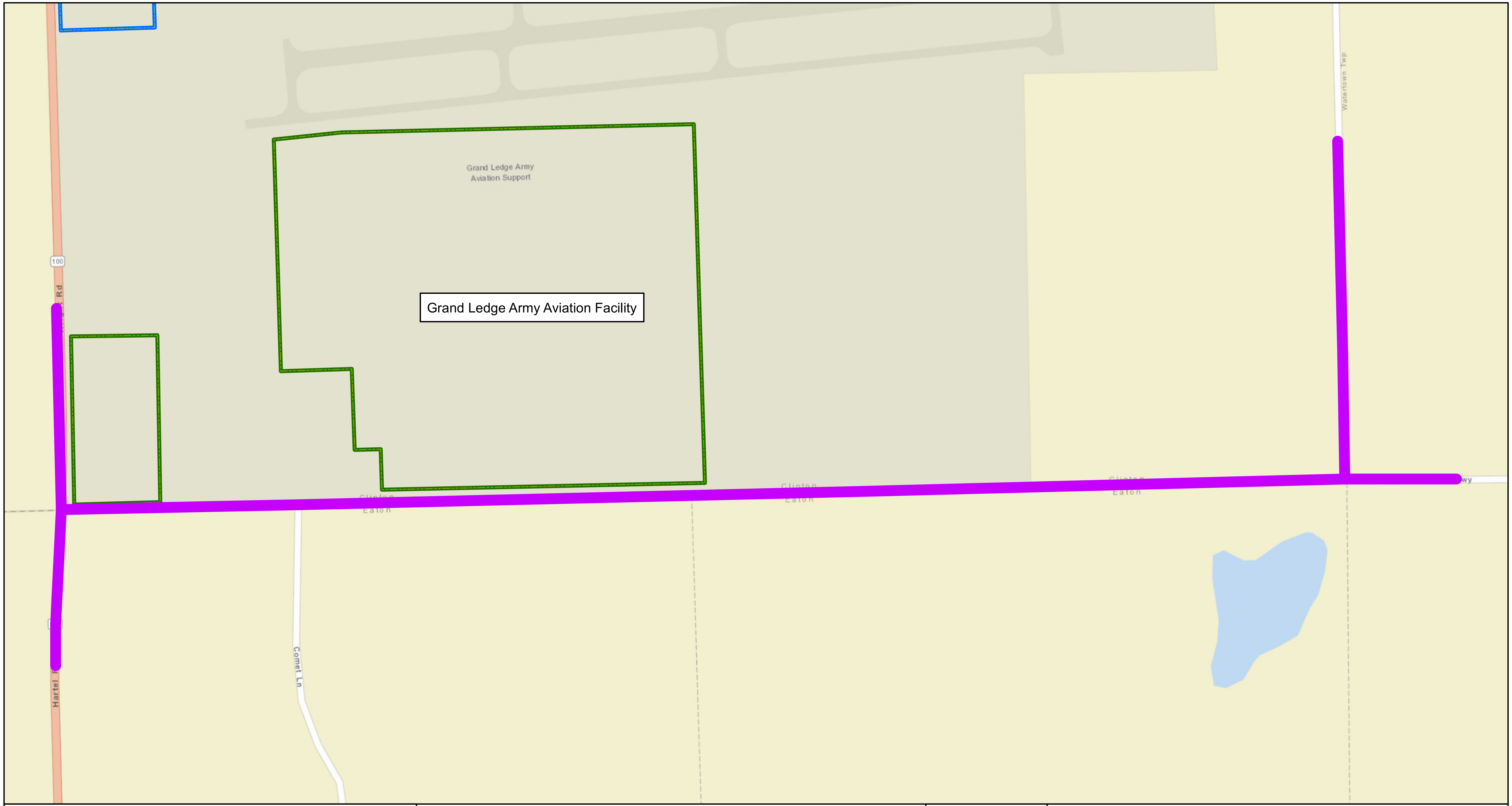

CLIENT ARNG				
PROJECT Remedial Investigation for PFOA, PFOS, and PFBS at Grand Ledge AASF and Armory, MI				
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SCALE	1:4,800	CHK BY	JW	6/17/2022
Base Map: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c)		PM	CM	6/17/2022

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▬	Private Drinking Water Well Sampling Target Zones
▭	Facility Boundary
▭	Former MIARNG Boundary

0 200 400 800 Feet

N

Residential Sampling Areas

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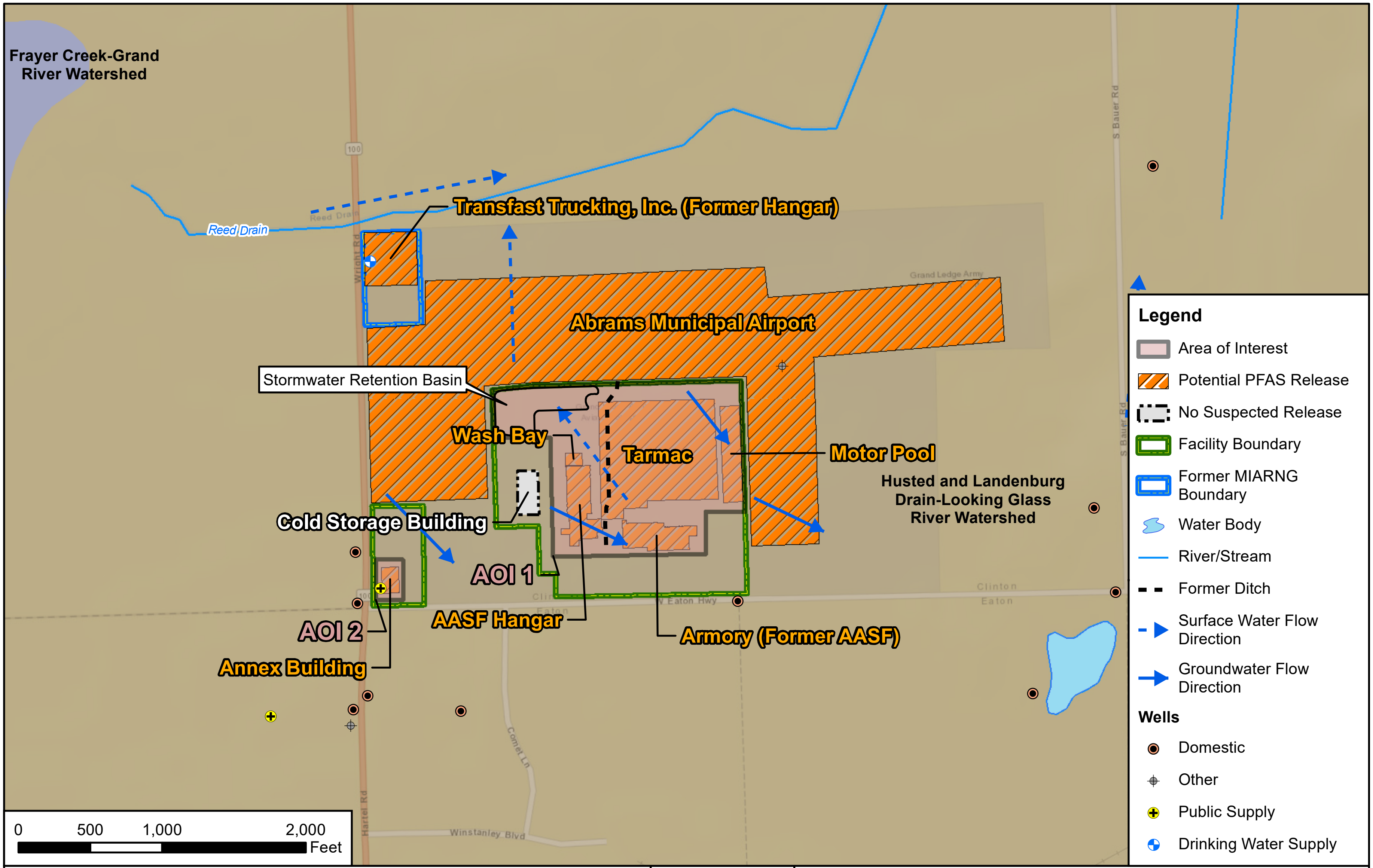
Figure 10-10



CLIENT	ARNG			
PROJECT	Remedial Investigation for PFOA, PFOS, and PFBS at Grand Ledge AASF and Armory, MI			
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SCALE	1:12,000	CHK BY	JW	6/17/2022
Base Map: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c)		PM	CM	6/17/2022

Areas of Interest

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Figure 10-11

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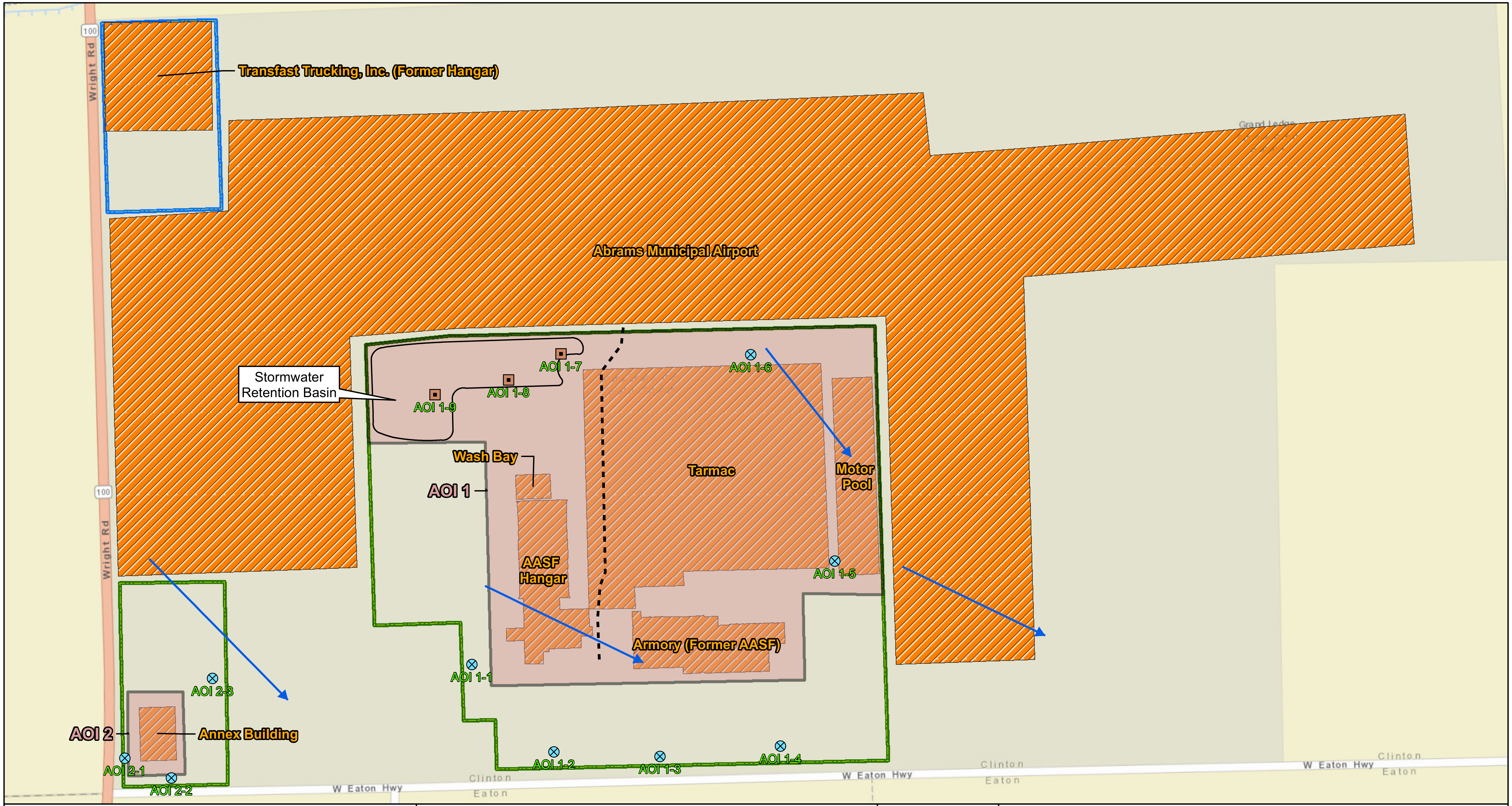

CLIENT	ARNG			
PROJECT	Remedial Investigation for PFOA, PFOS, and PFBS at Grand Ledge AASF and Armory, MI			
REVISED	6/17/2022	GIS BY	MS	6/17/2022
SCALE	1:3,960	CHK BY	JW	6/17/2022
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap		PM	CM	6/17/2022

- ⊗ DPT Boring/Temporary Well
- ▣ Surface Water/Sediment Sample
- ▭ Area of Interest
- ▨ Potential PFAS Release
- 🟩 Facility Boundary
- 🟦 Former MIARNG Boundary
- - - Former Ditch
- → Groundwater Flow Direction

0 165 330 660 Feet

N

Site Inspection Sample Locations (Mobilization 1)

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Figure 10-12

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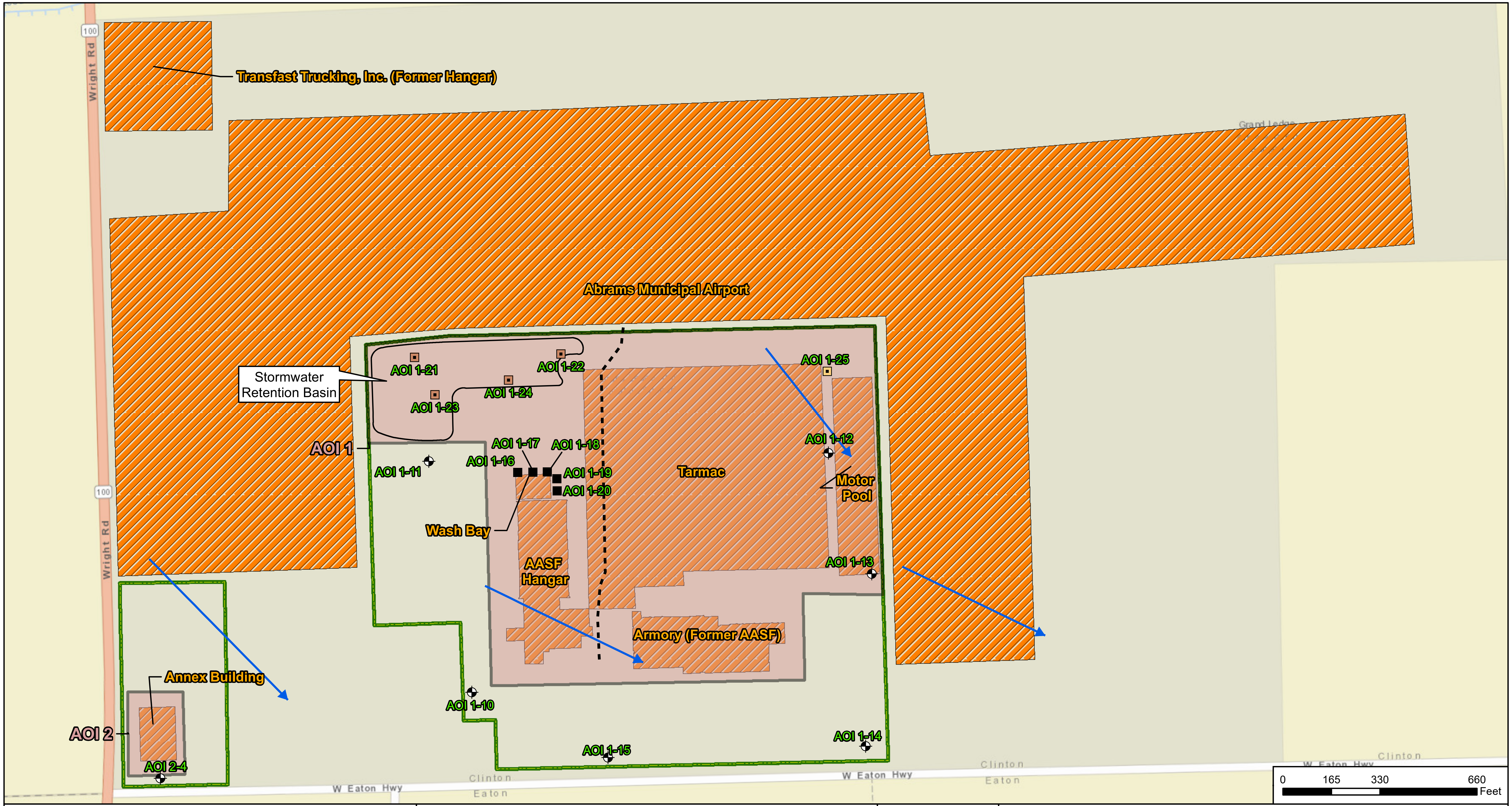

CLIENT	ARNG			
PROJECT	Remedial Investigation for PFOA, PFOS, and PFBS at Grand Ledge AASF and Armory, MI			
REVISED	6/17/2022	GIS BY	MS	6/17/2022
SCALE	1:3,960	CHK BY	JW	6/17/2022
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap		PM	CM	6/17/2022

- ⌖ Permanent Monitoring Well
- ▣ Surface Water/Sediment Sample
- ▣ Sediment Sample
- ■ Surface Soil Sample
- ▭ Area of Interest
- ▨ Potential PFAS Release
- ▭ Facility Boundary
- - - Former Ditch
- → Groundwater Flow Direction

N

Site Inspection Sample Locations (Mobilization 2)

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Figure 10-13

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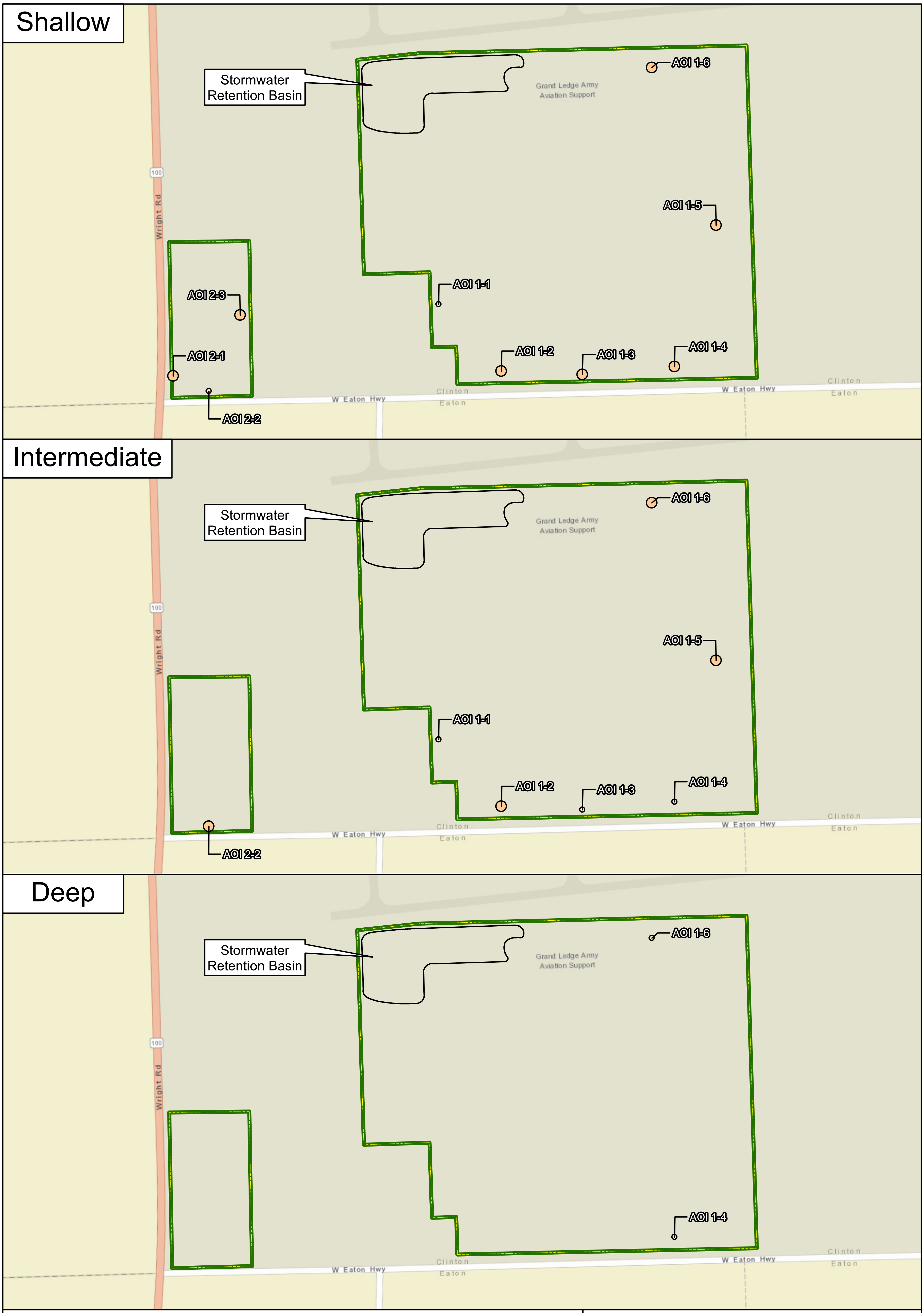

🟩 Facility Boundary

PFOS Results (µg/Kg)

- ○ ND
- ● >ND - 10
- ● >10 -130
- ● >130 - 1,600
- ● >1,600

N

0 215 430 860 Feet

Depth intervals shown represent respective sampling position within a given soil boring location.

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PFOS Detections in Soil (SI Mobilization 1)

CLIENT ARNG

PROJECT Remedial Investigation for PFAS at Grand Ledge AASF and Armory, MI

REVISED	5/9/2022	GIS BY	MS	5/9/2022
SCALE	1:5,160	CHK BY	JW	5/9/2022
Base Map: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong		PM	CM	5/9/2022

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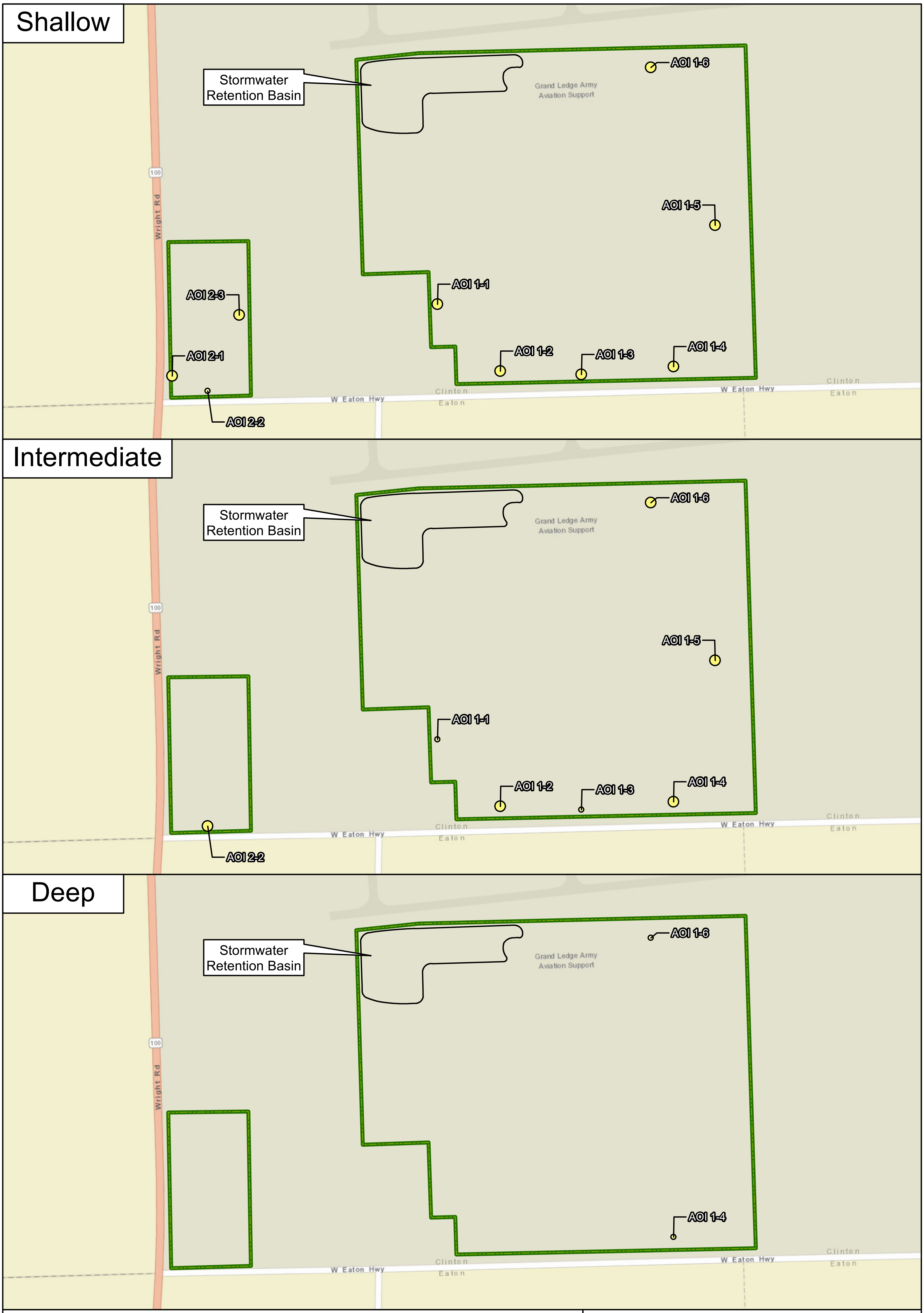
Figure 10-14



🟩 Facility Boundary **PFOA Results (µg/Kg)**

- ○ ND
- ● >ND - 10
- ● >10 - 130
- ● >130 - 1,600
- ● >1,600

N

0 215 430 860 Feet

Depth intervals shown represent respective sampling position within a given soil boring location.

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PFOA Detections in Soil (SI Mobilization 1)

CLIENT ARNG

PROJECT Remedial Investigation for PFAS at Grand Ledge AASF and Armory, MI

REVISED	5/9/2022	GIS BY	MS	5/9/2022
SCALE	1:5,160	CHK BY	JW	5/9/2022
Base Map: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong		PM	CM	5/9/2022

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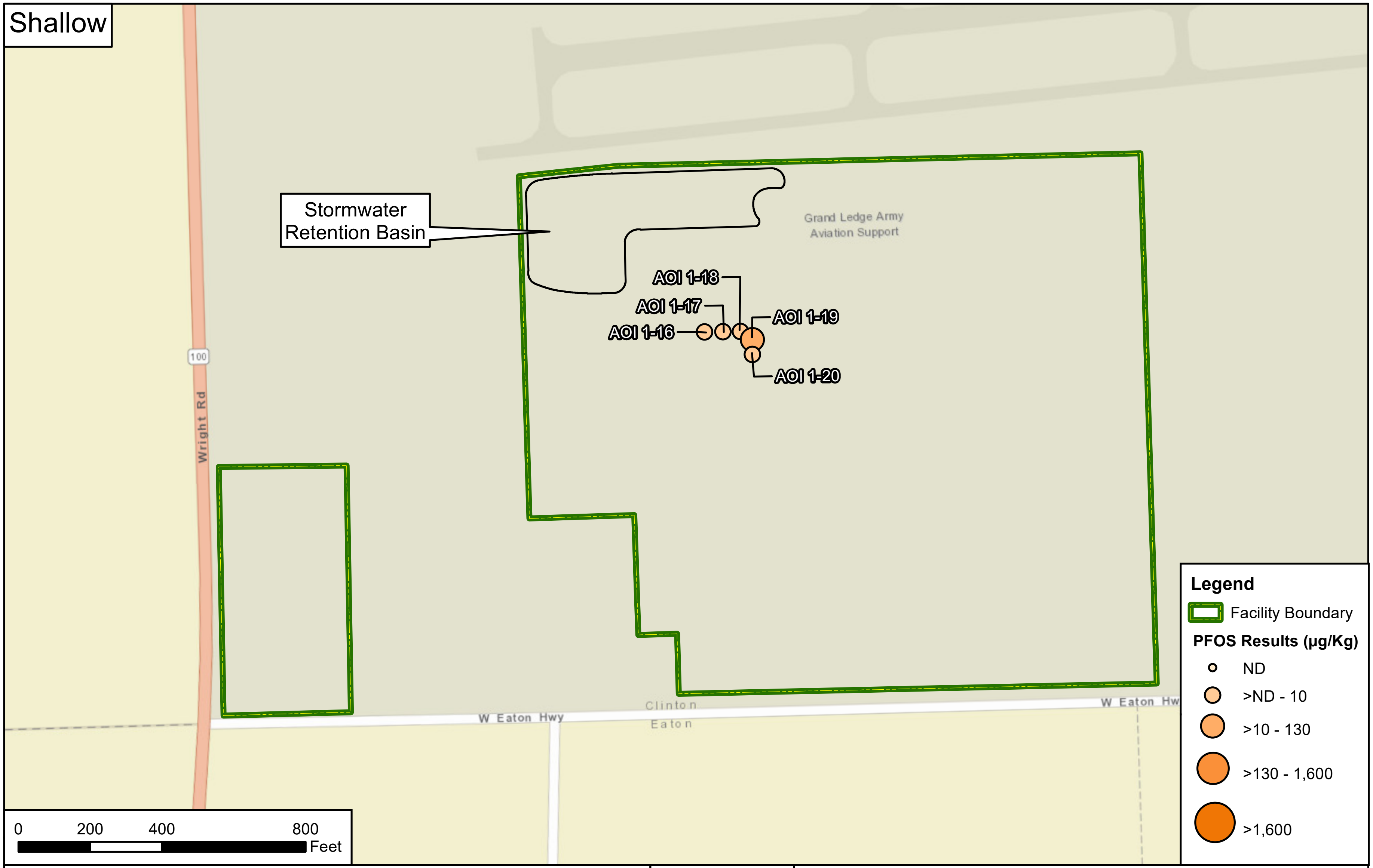
Figure 10-15



CLIENT	ARNG			
PROJECT	Remedial Investigation for PFAS at Grand Ledge AASF and Armory, MI			
REVISED	5/9/2022	GIS BY	MS	5/9/2022
SCALE	1:4,800	CHK BY	JW	5/9/2022
Base Map: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c)		PM	CM	5/9/2022

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PFOS Detections in Soil (SI Mobilization 2)

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Germantown, MD 20876

Figure 10-16

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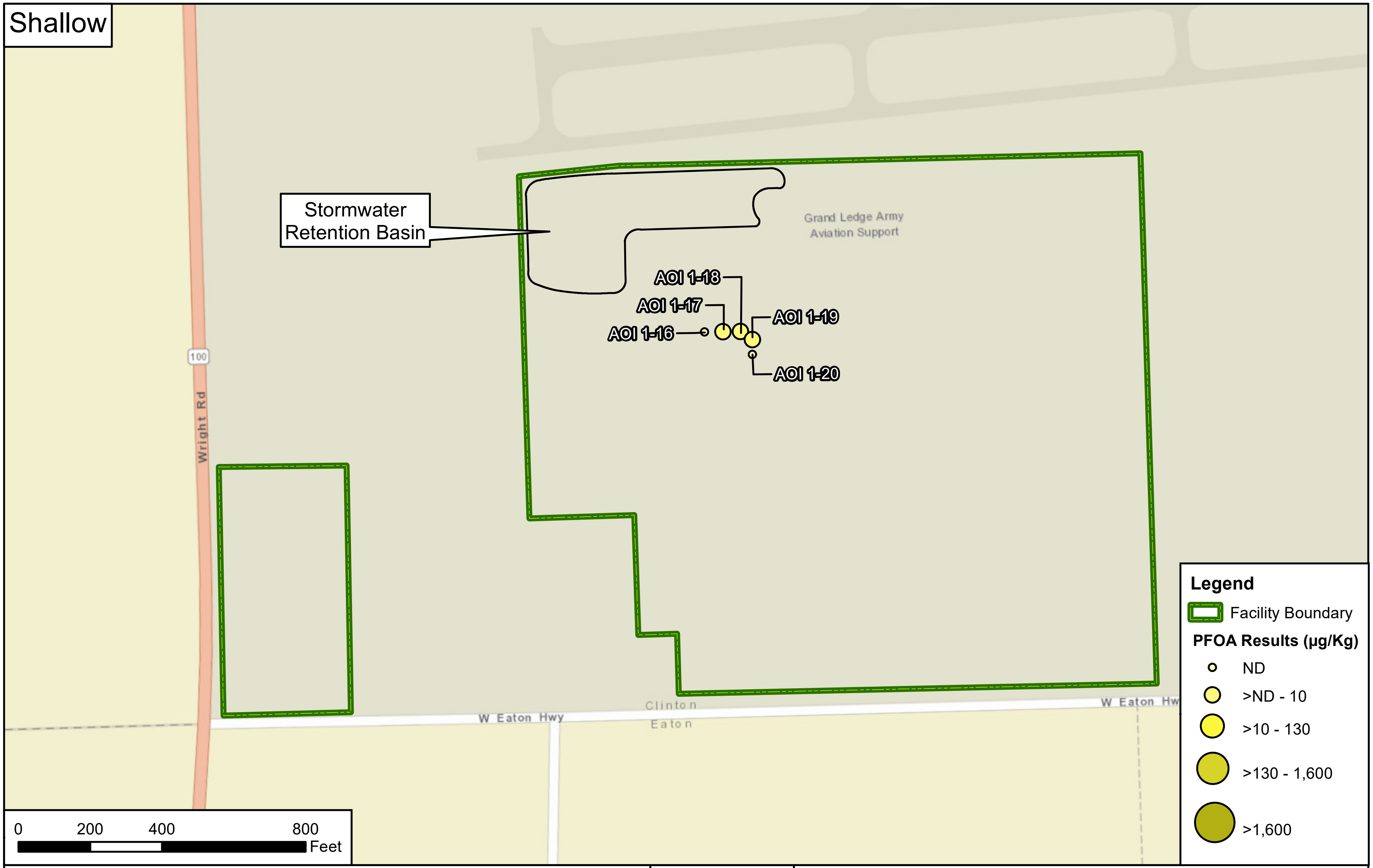

CLIENT	ARNG			
PROJECT	Remedial Investigation for PFAS at Grand Ledge AASF and Armory, MI			
REVISED	5/9/2022	GIS BY	MS	5/9/2022
SCALE	1:4,800	CHK BY	JW	5/9/2022
Base Map: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c)		PM	CM	5/9/2022

PFOA Detections in Soil (SI Mobilization 2)

AECOM

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Figure 10-17

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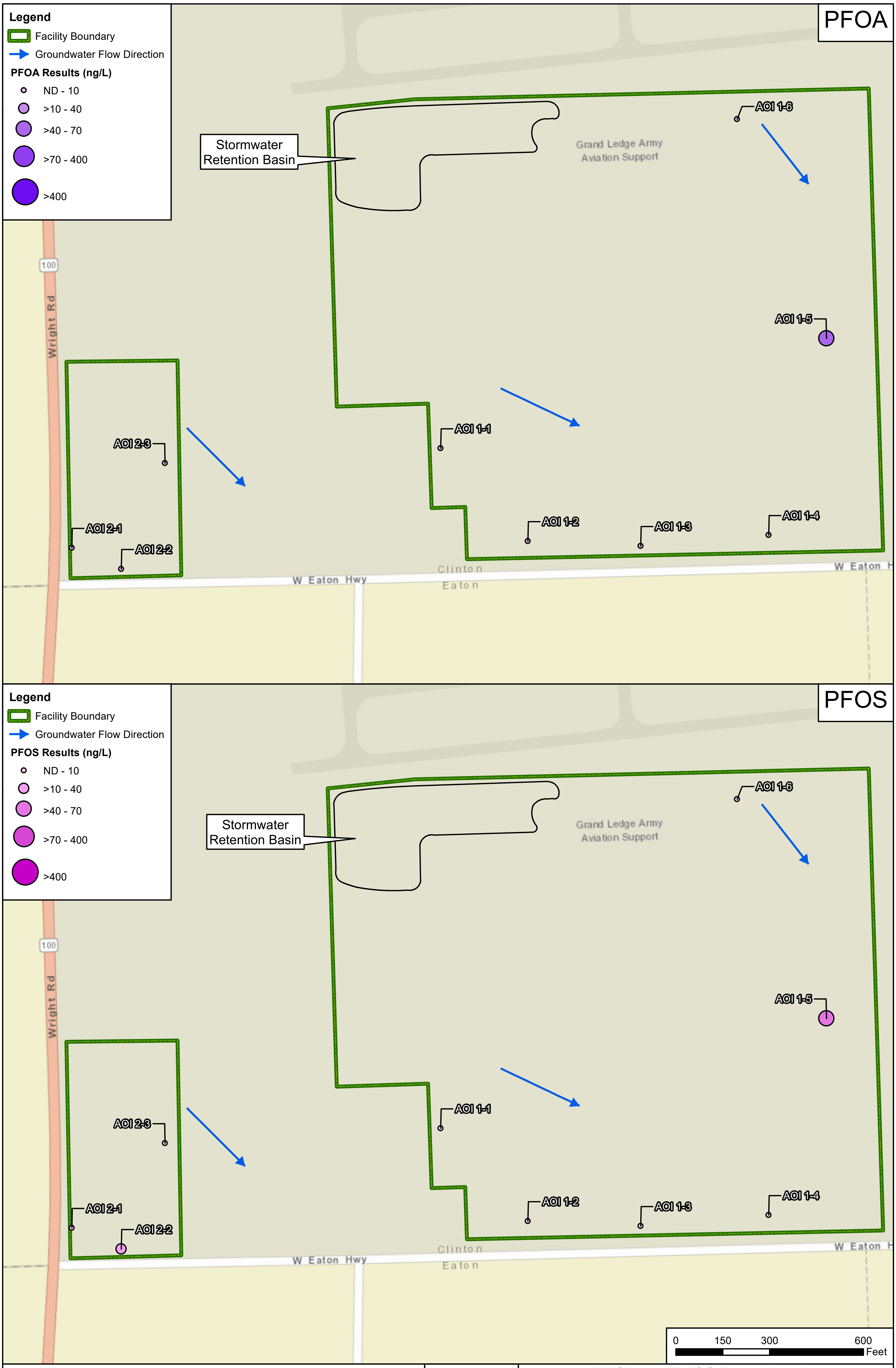

CLIENT	ARNG			
PROJECT	Remedial Investigation for PFAS at Grand Ledge AASF and Armory, MI			
REVISED	5/9/2022	GIS BY	MS	5/9/2022
SCALE	1:3,600	CHK BY	JW	5/9/2022
Base Map: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c)		PM	CM	5/9/2022

N

PFOA and PFOS Detections in Groundwater (SI Mobilization 1)

AECOM

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Germantown, MD 20876

Figure 10-18

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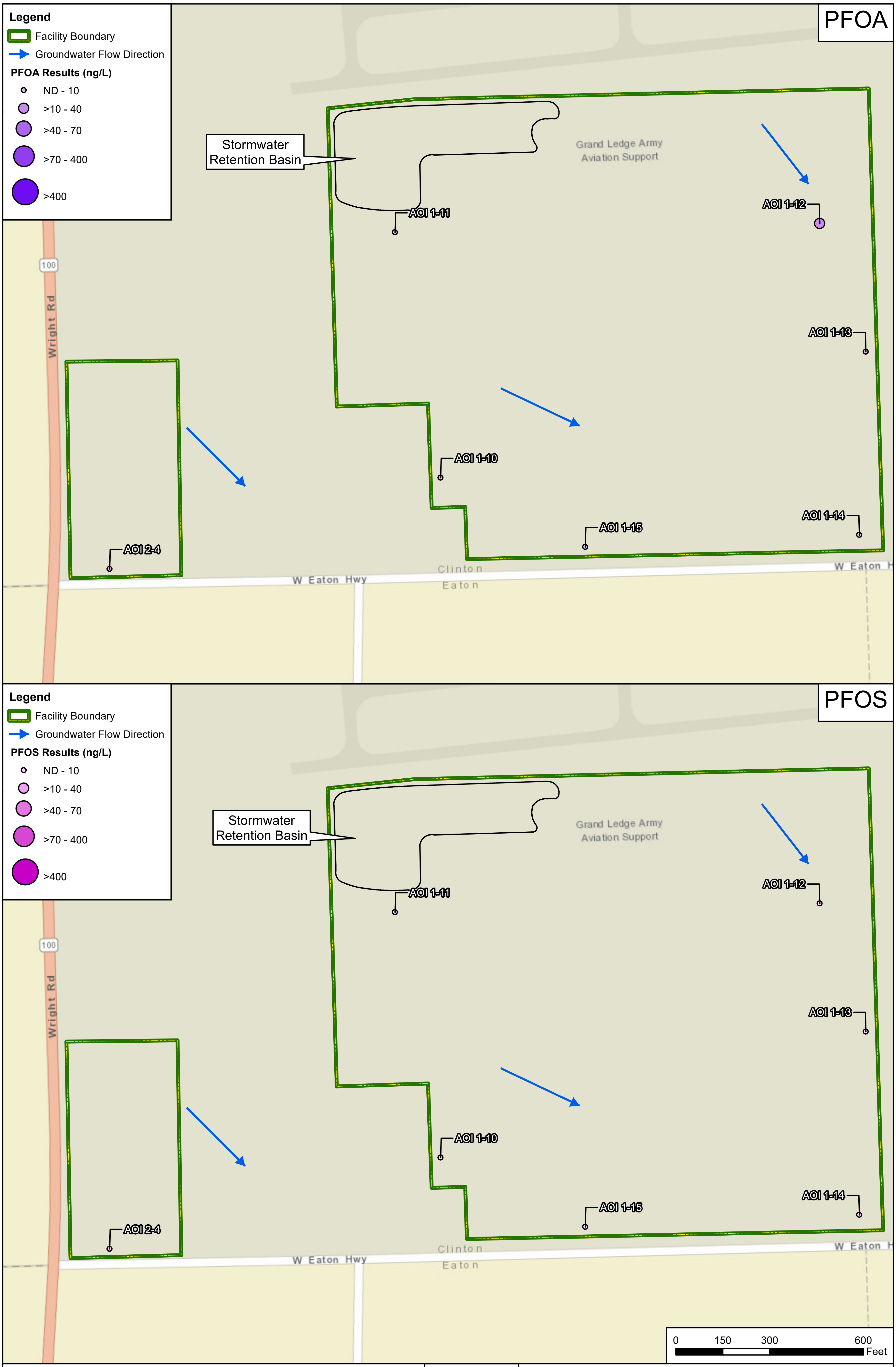

CLIENT	ARNG			
PROJECT	Remedial Investigation for PFAS at Grand Ledge AASF and Armory, MI			
REVISED	5/9/2022	GIS BY	MS	5/9/2022
SCALE	1:3,600	CHK BY	JW	5/9/2022
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap		PM	CM	5/9/2022

N

PFOA and PFOS Detections in Groundwater (SI Mobilization 2)

AECOM

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Germantown, MD 20876

Figure 10-19

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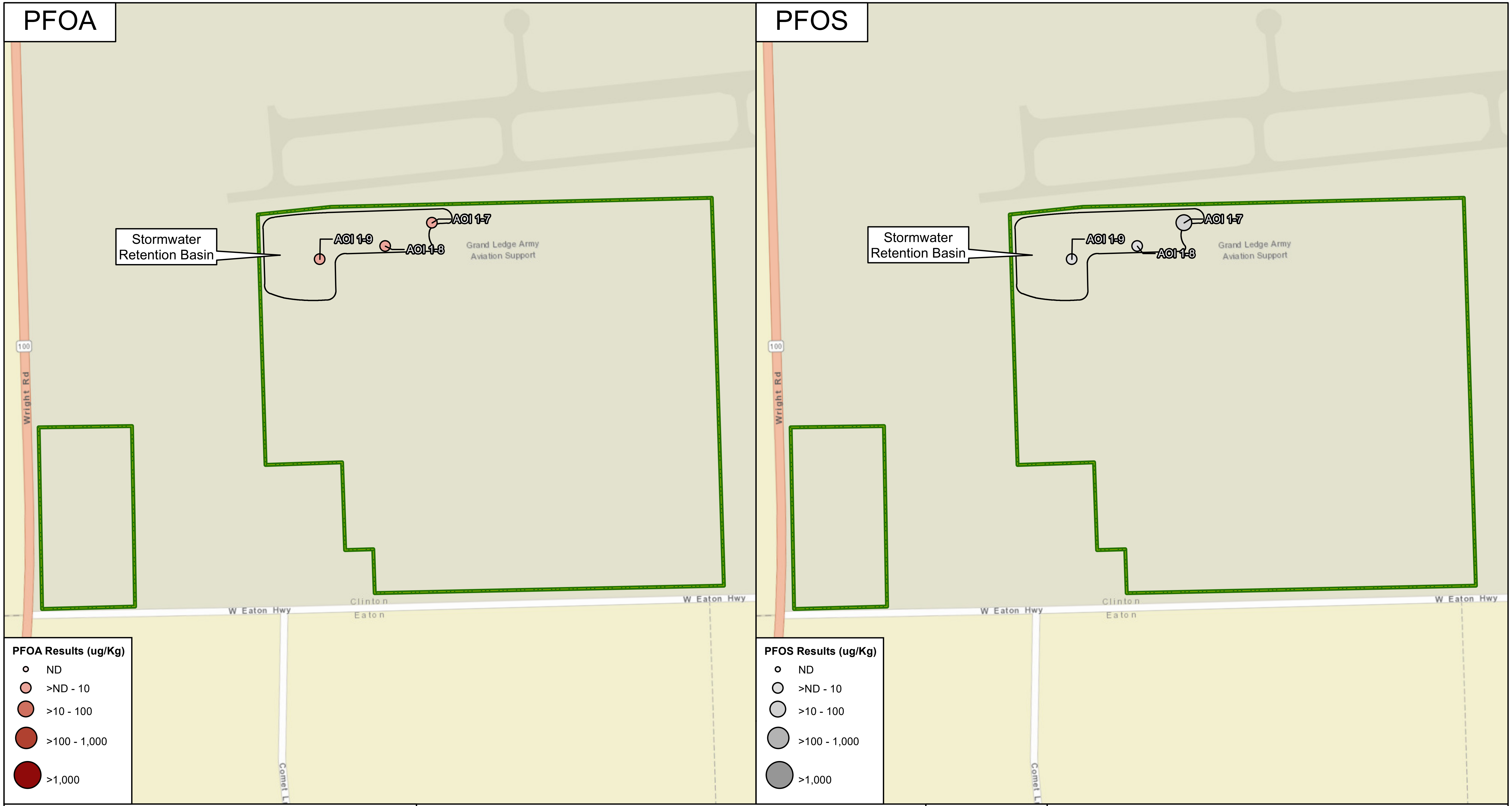

CLIENT	ARNG			
Remedial Investigation for PFAS at Grand Ledge AASF and Armory, MI				
REVISED	5/9/2022	GIS BY	MS	5/9/2022
SCALE	1:4,440	CHK BY	JW	5/9/2022
Base Map: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c)		PM	CM	5/9/2022

🟩 Facility Boundary

0 185 370 740
Feet

N

PFOA and PFOS Detections in Sediment (SI Mobilization 1)

AECOM
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Germantown, MD 20876

Figure 10-20

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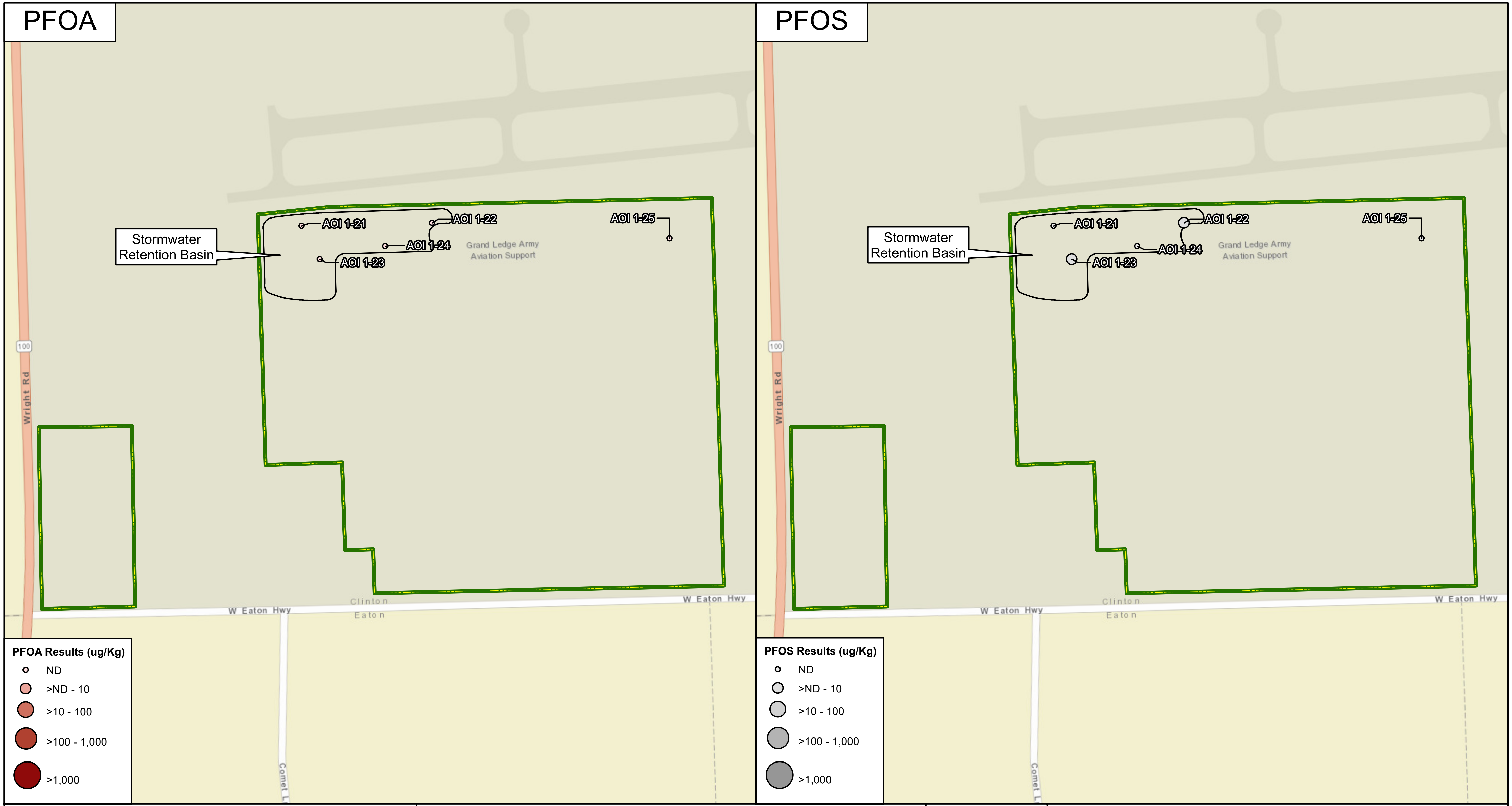

CLIENT	ARNG			
Remedial Investigation for PFAS at Grand Ledge AASF and Armory, MI				
REVISED	5/9/2022	GIS BY	MS	5/9/2022
SCALE	1:4,440	CHK BY	JW	5/9/2022
Base Map: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c)		PM	CM	5/9/2022

🟩 Facility Boundary

0 185 370 740
Feet

N

PFOA and PFOS Detections in Sediment (SI Mobilization 2)

AECOM
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Germantown, MD 20876

Figure 10-21

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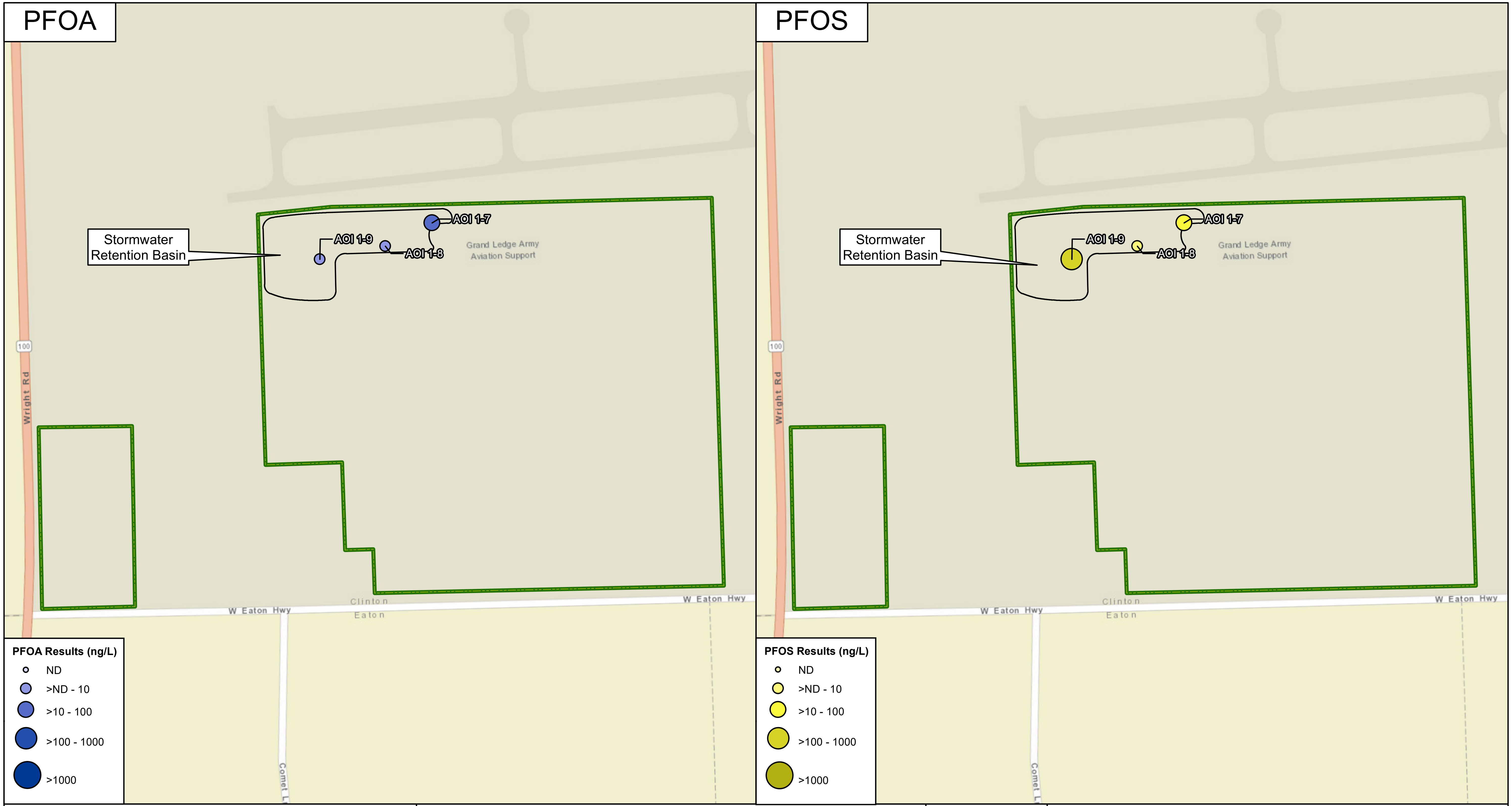

CLIENT	ARNG			
Remedial Investigation for PFAS at Grand Ledge AASF and Armory, MI				
REVISED	5/9/2022	GIS BY	MS	5/9/2022
SCALE	1:4,440	CHK BY	JW	5/9/2022
Base Map: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c)		PM	CM	5/9/2022

🟩 Facility Boundary

0 185 370 740 Feet

N

PFOA and PFOS Detections in Surface Water (SI Mobilization 1)

AECOM
12420 Milestone Center Drive
Germantown, MD 20876

Figure 10-22

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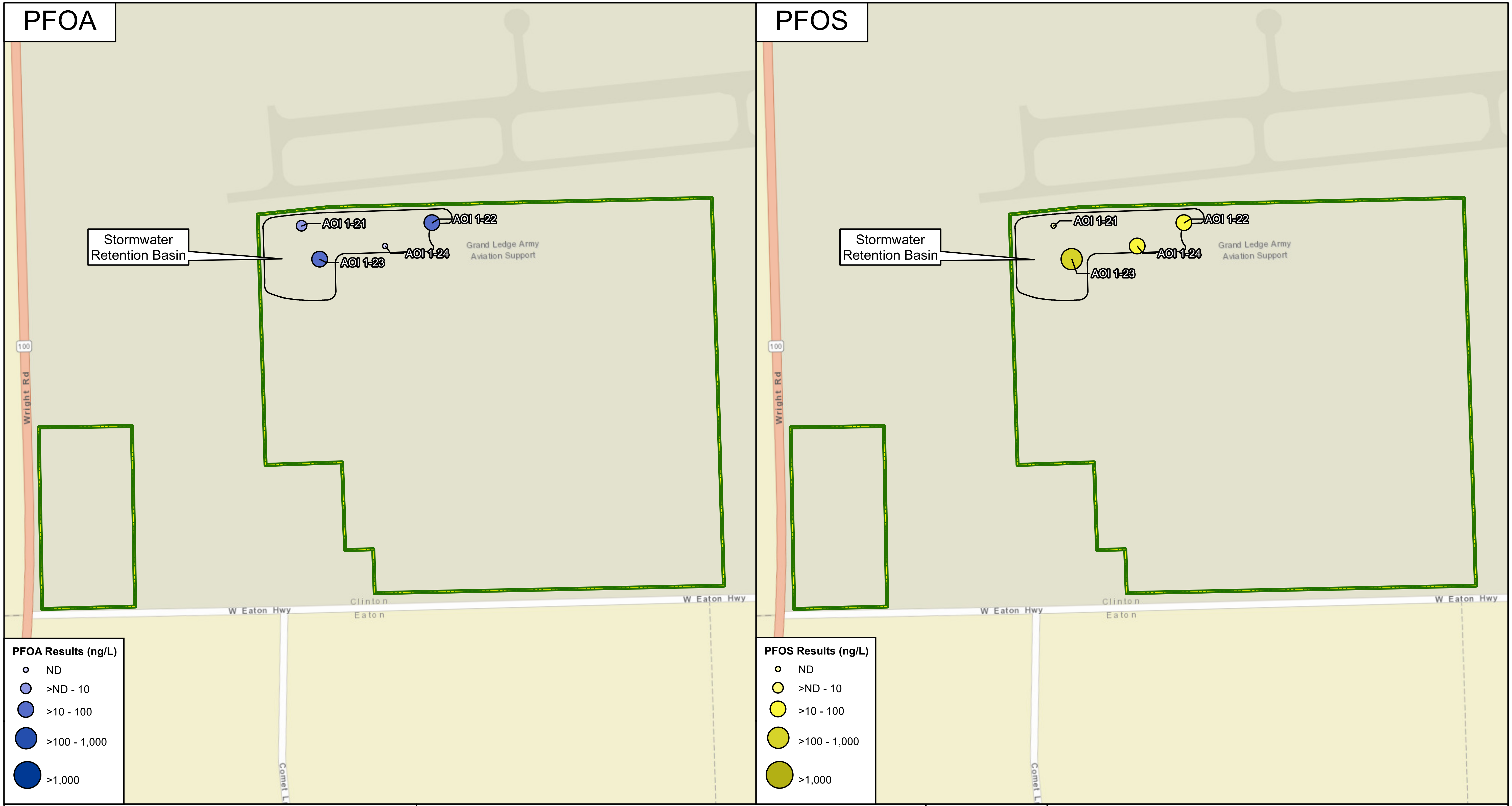

CLIENT	ARNG			
Remedial Investigation for PFAS at Grand Ledge AASF and Armory, MI				
REVISED	5/9/2022	GIS BY	MS	5/9/2022
SCALE	1:4,440	CHK BY	JW	5/9/2022
Base Map: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c)		PM	CM	5/9/2022

🟩 Facility Boundary

0 185 370 740 Feet

N

PFOA and PFOS Detections in Surface Water (SI Mobilization 2 / 5 November 2019)

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Figure 10-23

Note: Samples were collected during a dry weather sampling event.

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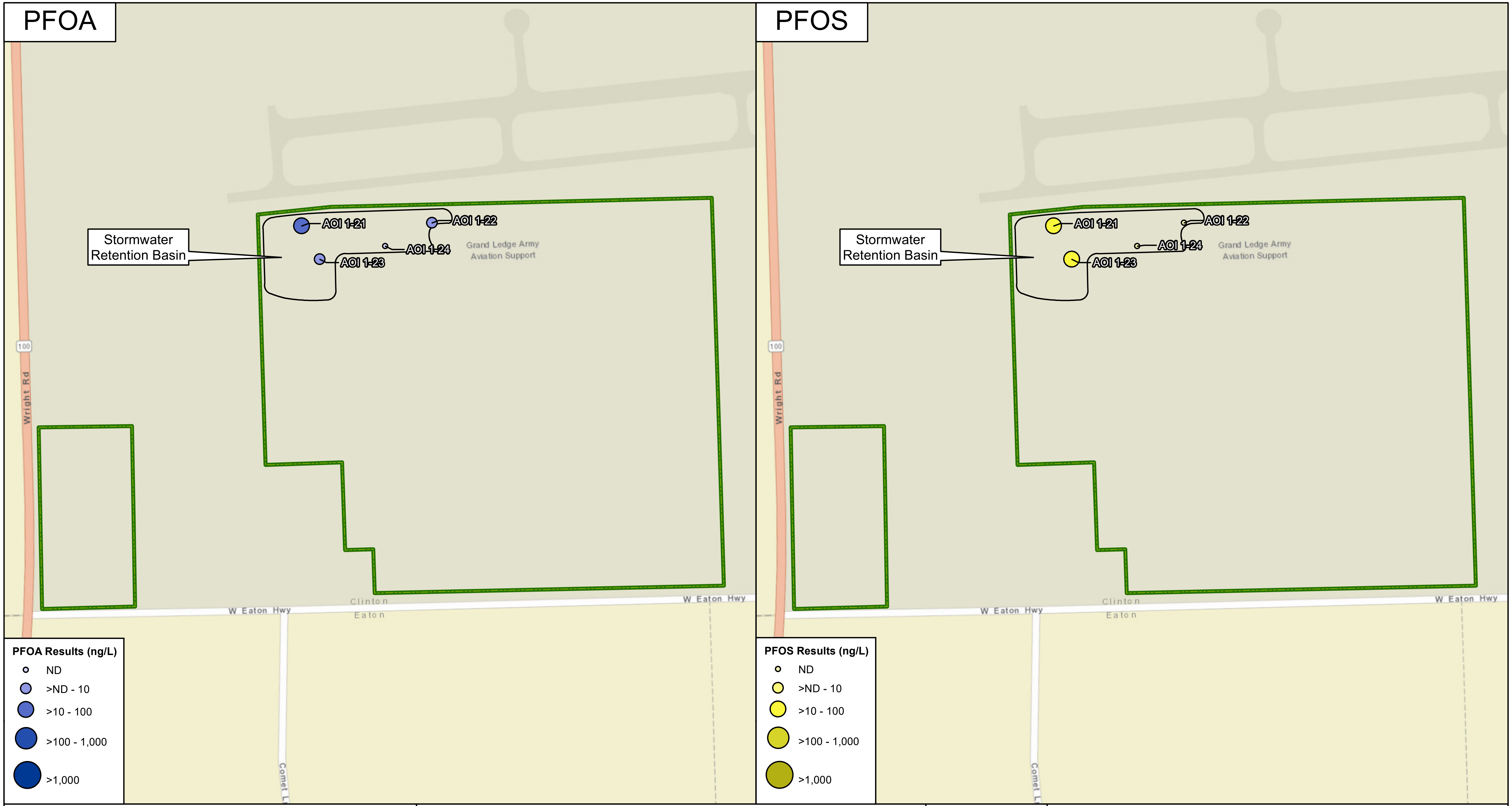

PFOA and PFOS Detections in Surface Water (SI Mobilization 2 / 21 November 2019)

CLIENT ARNG

Remedial Investigation for PFAS at Grand Ledge AASF and Armory, MI

REVISED	5/9/2022	GIS BY	MS	5/9/2022
SCALE	1:4,440	CHK BY	JW	5/9/2022
Base Map: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c)		PM	CM	5/9/2022

🟩 Facility Boundary

0 185 370 740 Feet

N

Note: Samples were collected during a qualifying storm event.

AECOM

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Figure 10-24

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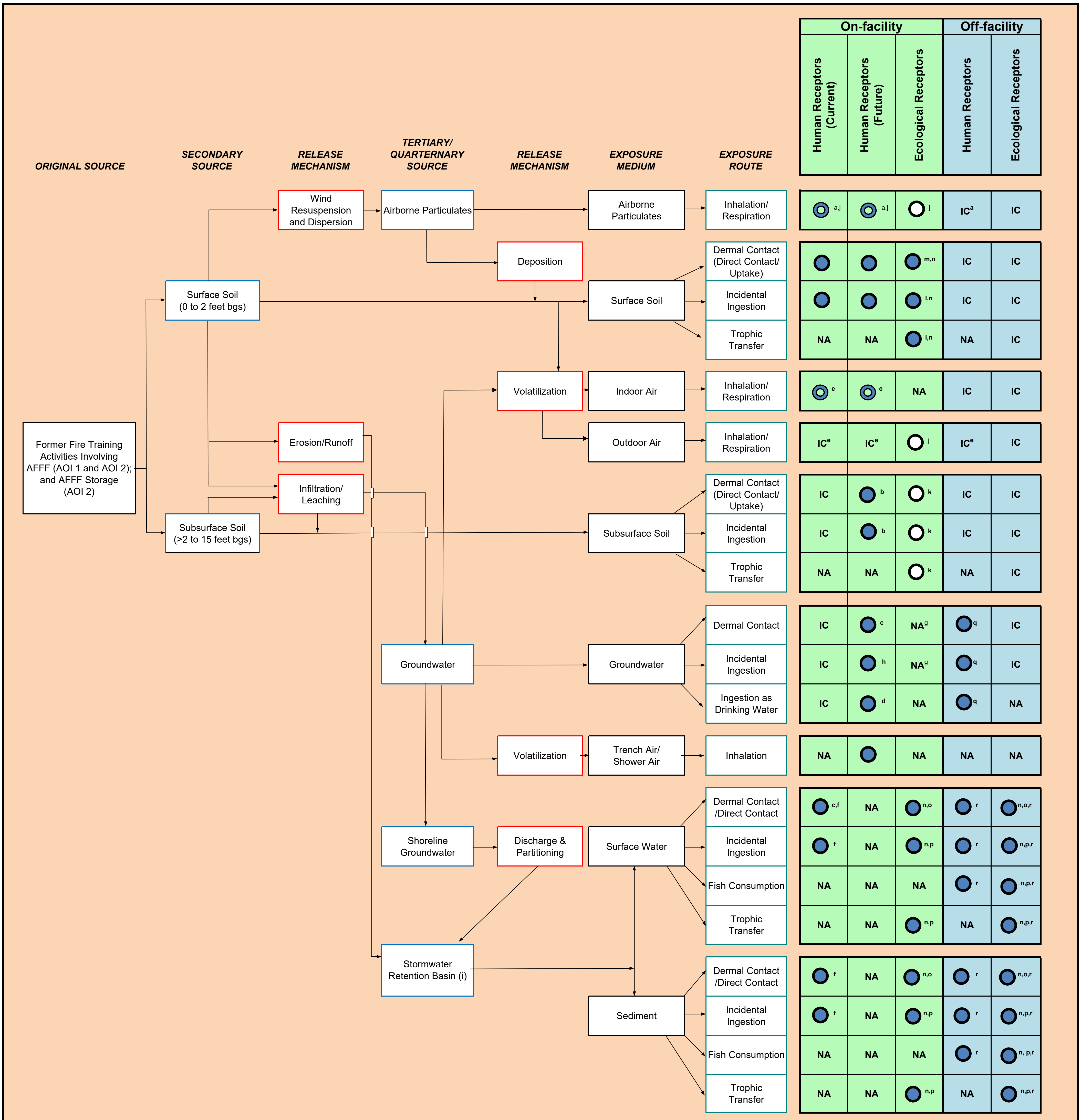

Exposure Medium	Exposure Route	On-facility: Human Receptors (Current)	On-facility: Human Receptors (Future)	On-facility: Ecological Receptors	Off-facility: Human Receptors	Off-facility: Ecological Receptors
Airborne Particulates	Inhalation/ Respiration	◉[a,j]	◉[a,j]	○[j]	IC[a]	IC
Surface Soil	Dermal Contact (Direct Contact/ Uptake)	●	●	●[m,n]	IC	IC
	Incidental Ingestion	●	●	●[l,n]	IC	IC
	Trophic Transfer	NA	NA	●[l,n]	NA	IC
Indoor Air	Inhalation/ Respiration	◉[e]	◉[e]	NA	IC	IC
Outdoor Air	Inhalation/ Respiration	IC[e]	IC[e]	○[j]	IC[e]	IC
Subsurface Soil	Dermal Contact (Direct Contact/ Uptake)	IC	●[b]	○[k]	IC	IC
	Incidental Ingestion	IC	●[b]	○[k]	IC	IC
	Trophic Transfer	NA	NA	○[k]	NA	IC
Groundwater	Dermal Contact	IC	●[c]	NA[g]	●[q]	IC
	Incidental Ingestion	IC	●[h]	NA[g]	●[q]	IC
	Ingestion as Drinking Water	IC	●[d]	NA	●[q]	NA
Trench Air/ Shower Air	Inhalation	NA	●	NA	NA	NA
Surface Water	Dermal Contact /Direct Contact	●[c,f]	NA	●[n,o]	●[r]	●[n,o,r]
	Incidental Ingestion	●[f]	NA	●[n,p]	●[r]	●[n,p,r]
	Fish Consumption	NA	NA	NA	●[r]	●[n,p,r]
	Trophic Transfer	NA	NA	●[n,p]	NA	●[n,p,r]
Sediment	Dermal Contact /Direct Contact	●[f]	NA	●[n,o]	●[r]	●[n,o,r]
	Incidental Ingestion	●[f]	NA	●[n,p]	●[r]	●[n,p,r]
	Fish Consumption	NA	NA	NA	●[r]	●[n, p,r]
	Trophic Transfer	NA	NA	●[n,p]	NA	●[n,p,r]

Legend

● **Potentially complete pathway**

◉ **Potentially complete pathway; but not quantitatively evaluated, as discussed in the report text.**

○ **Minor or insignificant pathway**

IC Incomplete

NA Not Applicable

🟦 **Source Medium**

🟥 **Release Mechanism**

🟩 **Exposure Route**

Abbreviations

> - greater than.
AFFF - Aqueous film forming foams.
bgs - below ground surface.
PFAS - Per- and polyfluoroalkyl substances.

Notes

(a) Potential exposure with airborne particulates will not be quantitatively evaluated because toxicity values for the inhalation exposure route are not available for PFAS.
(b) It is conservatively assumed that there could be future redevelopment of the facility, and current subsurface soils may be brought to the surface and mixed with surface soil for exposure under a future use scenario.
(c) The dermal contact pathway in water will not be quantitatively evaluated for PFOA and PFOS due to limited dermal absorption of PFAS, as discussed in Worksheet #10.
(d) The evaluation of on-facility groundwater as a future source of drinking water will be performed for informational purposes to represent an unrestricted groundwater use scenario.
(e) PFAS have low volatility and therefore are not considered to volatilize into air.
(f) Exposure to sediment and surface water in the stormwater retention basin by on-facility outdoor workers may occur while performing maintenance activities such as clearing the drainage areas of debris.
(g) There are no direct complete ecological pathways to groundwater; however, given the possible groundwater connection with surface water bodies, ecological exposure pathways to surface water, sediment and porewater may be complete.
(h) Incidental ingestion of shallow groundwater may occur during soil disturbing actives by future construction/utility workers.
(i) Potential exposures will be evaluated for sediment and surface water (for human health and ecological receptors), and porewater (for ecological receptors only).
(j) Inhalation/respiration of airborne particulates (dust) is expected to be minor or insignificant compared to surface soil exposure pathways.
(k) Exposure pathways for subsurface soil (> 2 ft bgs) are minor or insignificant compared to surface soil exposure pathways.
(l) Incidental ingestion/trophic transfer pathways for surface soil are potentially complete for birds and mammals.
(m) Direct contact/uptake exposure pathways for surface soil are potentially complete for terrestrial plants, soil invertebrates, reptiles and amphibians.
(n) Amphibians and reptiles may be exposed to PFAS in surface water, sediment, or soil; however, PFAS screening values may not be available to evaluate these pathways.
(o) Direct contact/uptake exposure pathways for surface water, sediment, and/or porewater are potentially complete for aquatic organisms, reptiles and amphibians and direct contact/uptake exposure pathways for sediment and sediment porewater are also potentially complete for benthic invertebrates.
(p) Incidental ingestion/trophic transfer pathways for surface water, sediment, and/or porewater are potentially complete for aquatic dependent wildlife.
(q) The results of off-facility drinking water sampling conducted to date indicated that there are no down- or side-gradient impacts to drinking water attributable to ARNG activities.
(r) It is conservatively assumed at this phase of the investigation that sediment and surface water in the stormwater retention system has the potential to migrate from the facility to downstream off-facility water bodies and be available for exposure by off-facility recreational users (if present), aquatic life, and wildlife.

Project No.
60591182

Grand Ledge Army Aviation Support Facility and Armory, MI

Preliminary Human Health and Ecological Receptors and Exposure Pathways

Figure 10-25

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QAPP Worksheet #11: Project/Data Quality Objectives

DQOs specify the level of data required to support the decision-making process for a project. Specific DQOs have been established for the RI at this facility and are described in this worksheet. The DQOs follow the USEPA's seven-step iterative process for DQO development. DQOs are influenced by the ongoing project planning discussions with stakeholders and will be updated if new consensus decisions materialize.

RI activities for the Site will be conducted in multiple mobilizations. This UFP-QAPP addresses DQOs for Mobilization 1, which have been updated based on the OSD memorandum dated 6 July 2022 (Assistant Secretary of Defense, 2022)

1. State the Problem

PFAS are classified as emerging environmental contaminants that have garnered regulatory interest due to their potential risks to human health and the environment. The regulatory framework for managing PFAS at both the federal and state level continues to evolve. The DoD has adopted a policy to retain facilities in the CERCLA process based on risk-based SLs for soil and groundwater, as described in a memorandum from the OSD dated 15 October 2019 (Assistant Secretary of Defense, 2019) and revised in a subsequent memorandum dated 6 July 2022 (Assistant Secretary of Defense, 2022). The ARNG program under which the SI was performed follows this DoD policy. The policy indicates that if the maximum concentration for sampled media exceeds the SLs established in the OSD memorandum during the SI phase, the AOI will proceed to the RI phase under CERCLA. The SLs established in the OSD memorandum apply to three compounds: PFOA, PFOS, PFBS, PFHxS, HFPO-DA, and/ or PFNA.

The presence of PFOA and PFOS in excess of the OSD SLs has been confirmed at AOI 1 at Grand Ledge AASF. However, whether, or to what extent, potential risk is posed to human health or the environment from PFAS in environmental media at the Site and downgradient of the Site is currently unknown. If the results of the risk assessment performed as part of the comprehensive RI report that will be prepared following this and subsequent mobilizations, as indicated in **Section 14.6**, identify potential unacceptable risk as defined under the NCP (40 CFR Part 300.430; USEPA, 1994), then a Feasibility Study (FS) will be recommended to evaluate remedial action alternatives.

Additionally, the state of Michigan has formally adopted Maximum Contaminant Levels (MCLs) for seven PFAS: PFOA, PFOS, PFBS, perfluorononanoic acid (PFNA), PFHxS, perfluorohexanoic acid (PFHxA), and hexafluoropropylene oxide dimer acid (HFPO-DA), also known as GenX (EGLE, 2020b). Although the EGLE MCLs are not considered SLs during the RI phase because Applicable or Relevant and Appropriate Requirements (ARARs) will be considered during the FS stage in accordance with the CERCLA process, the extent of these compounds in groundwater is currently unknown on-facility at Grand Ledge AASF and downgradient within the City of Grand Ledge.

2. Identify the Goals of the Study

The unique nature of PFAS was considered when establishing goals for the investigation. Because of the very low action levels and highly mobile nature of PFAS, the traditional characterization of nature and extent and definition of boundaries will be modified, focusing on data necessary to evaluate response actions. Additionally, the ubiquitous nature of PFAS was considered when establishing the goals. Many studies have been published showing widespread distribution of certain PFAS, such as PFAAs, in various matrices including sediment, surface water, groundwater, wildlife, and human blood (whole, plasma, and serum) (Kannan et al., 2004; Yamashita et al., 2005; Higgins et al., 2005; Rankin et al., 2016). Some

PFAS (such as PFAAs) are found in many places throughout the globe, even in areas well beyond where they were initially used or manufactured (Houde et al., 2011).

The goals of the RI Mobilization 1 are:

1. Conduct an on-facility geological investigation to aid in geologic and hydrogeologic characterization in support of the on-facility RI drilling and sampling program. Based on data collected during the SI, the lithology and geology is highly variable across the facility. This investigation will examine the subsurface extent and thickness of clay layers, particularly any potential aquitards, sand, and gravel beds that may act as preferential flow pathways, and the depth to bedrock beneath the Site. The on-facility historical drainage ditch used during AFFF training activities that was backfilled during previous Site construction activities will also be investigated using direct push methods to specifically locate and, if possible, sample environmental media (e.g., soil).
2. Identify potential PFAS release areas and refine the extent of PFOA, PFOS, PFBS, PFNA, PFHxS, PFHxA, and HFPO-DA/ GenX, attributable to ARNG activities in the surficial groundwater aquifers at concentrations above the USEPA HAs, OSD SLs, Michigan EGLE MCLs, and Generic Cleanup Criteria (GCC) on-facility at the Grand Ledge AASF (USEPA, 2016a; USEPA, 2016b; Assistant Secretary of Defense, 2022; EGLE, 2020b).
3. Collect groundwater samples from permanent monitoring wells for analysis of PFAS to refine the extent of PFOA, PFOS, PFBS, PFNA, PFHxS, PFHxA, and HFPO-DA, also known as GenX, attributable to ARNG activities in groundwater at concentrations above the USEPA HAs, OSD SLs, EGLE MCLs, and EGLE GCC at the Grand Ledge AASF and formerly MIARNG owned land. Determine whether the concentrations of these compounds in groundwater are more than likely the result of ARNG activities (originate on the facility or at formerly MIARNG owned land). If PFOA, PFOS, PFBS, PFHxS, HFPO-DA, and/ or PFNA are detected, conduct preliminary screening and evaluate the results in the HHRA as part of the comprehensive RI report that will be prepared following completion of Mobilization 1 and Mobilization 2, as indicated in **Section 14.6**, as described in Goals 10 and 11 below.
4. Within an established AOI, locate the release areas in soil where PFOA, PFOS, PFBS, PFHxS, HFPO-DA, and/ or PFNA in soil are linked to groundwater containing these compounds that is attributable to ARNG activities. Refine occurrence of PFOA, PFOS, PFBS, PFHxS, HFPO-DA, and/ or PFNA in soil to the OSD SLs (Assistant Secretary of Defense, 2022). If due to significant site construction and soil movement no release area is apparent, collect sufficient soil data to support a quantitative risk assessment. If PFOA, PFOS, PFBS, PFHxS, HFPO-DA, and/ or PFNA are detected, further evaluate these results in the risk assessment as part of the comprehensive RI report that will be prepared following completion of Mobilization 1 and Mobilization 2, as described in Goals 8 and 9 below.
5. Collect surface water samples from the stormwater retention basin to determine the presence or absence of PFOA, PFOS, PFBS, PFHxS, HFPO-DA, and/ or PFNA within surrounding surface water bodies attributable to ARNG activities at concentrations above the Rule 57 Water Quality Values for surface water (EGLE, 2020c). If PFOA, PFOS, PFBS, PFHxS, HFPO-DA, and/ or PFNA are detected in Mobilization 1, further evaluate these results via screening and additional data collection during Mobilization 2 to inform the risk assessment as part of the comprehensive RI report that will be prepared following completion of Mobilization 1 and Mobilization 2, as described in Goals 8 and 9 below.
6. Collect sediment and porewater samples from the stormwater retention basin to evaluate PFOA, PFOS, PFBS, PFHxS, HFPO-DA, and/ or PFNA in sediment and porewater within surrounding surface water bodies where groundwater with PFAS impacts attributable to

ARNG activities may be discharging to surface water. If PFOA, PFOS, PFBS, PFHxS, HFPO-DA, and/ or PFNA are detected during Mobilization 1, further evaluate these results via screening and additional data collection during Mobilization 2 to inform the risk assessment as part of the comprehensive RI report that will be prepared following completion of Mobilization 1 and Mobilization 2, as indicated in **Section 14.6**, as described in Goals 8 and 9 below.

7. Collect data to evaluate Site characteristics that influence PFOA, PFOS, PFBS, PFNA, PFHxS, PFHxA, and HFPO-DA fate and transport, support refinement of the CSM, and inform the potential remedial alternatives evaluation.
8. Conduct a Site-specific HHRA in accordance with USEPA Risk Assessment Guidance for Superfund (RAGS) and DA risk assessment guidance and policies (DA, 1999; Assistant Secretary of Defense, 2022) as part of the comprehensive RI report that will be prepared following this and subsequent mobilizations, as indicated in **Section 14.6**. If no potential unacceptable risk or hazard to human receptors, as defined in the NCP [40 CFR § 300.430] (USEPA, 1991; USEPA, 1994), is identified, then no further action for human receptors will be recommended. If potential unacceptable risk or hazard to human health, as defined in the NCP [40 CFR § 300.430] (USEPA, 1991; USEPA, 1994), is presented by Site-related concentrations of PFOA, PFOS, PFBS, PFHxS, HFPO-DA, and/ or PFNA in soil, groundwater, sediment, and/or surface water, then an FS will be recommended to evaluate remedial action alternatives.
9. If PFOA, PFOS, PFBS, PFHxS, HFPO-DA, and/ or PFNA are detected in on-facility media, a SLERA will be conducted following completion of RI Mobilization 2 data collection. The SLERA will be conducted in accordance with USEPA Ecological RAGS (USEPA, 1997) and DA risk assessment guidance (DA, 2010) for PFOA, PFOS, PFBS, PFHxS, HFPO-DA, and/ or PFNA, as well as other PFAS with relevant ecological screening values (e.g., perfluorododecanoic acid [PFDoA], perfluoroundecanoic acid [PFUdA], perfluorodecanoic acid [PFDA], PFNA, perfluoroheptanoic acid [PFHpA], PFHxA, PFHxS, perfluoropentanoic acid [PFPeA], and perfluorobutanoic acid [PFBA]). An exceedance of an ecological screening value does not necessarily correlate to an effect and a weight of evidence assessment will be used to determine the need for further evaluation. Lower trophic level receptors (e.g., invertebrates, plants) will be evaluated qualitatively on a community level basis. If the SLERA and subsequent SLERA refinement (Step 3a in the USEPA ecological risk assessment [ERA] process) identify the potential for adverse effects on ecological receptors due to exposure to PFAS in soil, sediment, porewater, or surface water, then a risk management decision will be made by the team regarding the need for further ecological evaluations.

3. Identify Information Inputs

Primary information inputs include:

- Findings from the CERCLA PA completed for the Grand Ledge AASF (AECOM, 2019a). This information was used to identify potential PFAS release areas and release mechanisms.
- Findings from the CERCLA SI completed for the facility, including PFAS analytical data from groundwater, soil, surface water, and sediment from both AOIs, as well as off-facility potable water samples (AECOM, 2021a). The soil and groundwater data were used to determine the current understanding of nature and extent of contamination in these media, as described in **Worksheet #10**. Additionally, the data were used refine the sampling approach for these media during the RI Mobilization 1, as described in **Worksheets #17 & #18**.

- The CSM will be refined in accordance with the field and analytical data collected during the RI Mobilization 1.
- Field data collected during the SI and RI Mobilization 1, including water quality parameters in groundwater, surface water, and porewater, and lithological data observed in soil borings. This information will be used to evaluate fate and transport, support refinement of the CSM, and inform the potential remedial alternatives evaluation.
- Groundwater elevation data from the SI and RI Mobilization 1 will be used to understand groundwater flow direction and gradient, and staff gauge data from the RI Mobilization 1 and will aid in the interpretation of groundwater to surface water interaction. This information will also be used to refine the preliminary CSM.

4. Define the Boundaries of the Study

The scope of the RI Mobilization 1 is horizontally bounded by the Grand Ledge AASF facility boundary. PFAS were detected in soil, surficial groundwater, sediment and surface water samples during the SI. As such, to meet DQOs, additional sampling will be bound vertically by the bedrock aquifer, which ranges from 35 – 100 feet below ground surface (AECOM, 2021a).

Sampling beyond the facility boundaries, in the city of Grand Ledge and the areas adjacent, upgradient, and downgradient to the facility, may be considered during subsequent mobilization(s). Where off-facility sampling is required, the proper stakeholders will be notified, and necessary proper right of entry (ROE) obtained by USACE and ARNG with property owner(s).

5. Develop the Analytic Approach

Environmental samples will be analyzed by a DoD Environmental Laboratory Accreditation Program (ELAP) and National Environmental Laboratory Accreditation Program (NELAP)-certified laboratory. Copies of the laboratory accreditation certificates are included in **Appendix C**. Analytical services are summarized on **Worksheets #19 & #30**. Analyses will be conducted in accordance with DoD Quality Systems Manual (QSM) Version 5.3 and the laboratory standard operating procedures (SOPs) cited.

Chemical analyses will be performed in accordance with the analytical methods identified in **Worksheet #23**. Analytical sensitivity for the methods selected is compared to project DQLs on **Worksheet #15**. Requirements for laboratory instrument calibration and equipment maintenance and testing are presented on **Worksheet #24** and **Worksheet #25**. Measurement performance criteria for field and laboratory quality control (QC) samples are presented on **Worksheet #12** and **Worksheet #28**, respectively. The general analytic approach to achieve the goals outlined in Step 2 of this **Worksheet #10** is described below.

The environmental sampling program during RI Mobilization 1 will include:

- Collection of multi-interval soil samples via direct-push technology (DPT) for further characterization and refinement of the potential source areas and extent of potential impacts;
- Collection of multi-interval grab groundwater samples for analysis of PFAS (target list of 32 PFAS analytes) from new temporary monitoring wells to be installed on-facility;
- Collection of groundwater samples from existing monitoring wells for analysis of PFAS (target list of 32 PFAS analytes);
- Collection of synoptic water levels in existing monitoring wells and newly-installed temporary monitoring wells;

  - Collection of surface water, sediment, and porewater samples for analysis of PFAS (target list of 32 PFAS analytes) from the stormwater retention basin; and
  - Installation and measurement of staff gauges with piezometers placed in the stormwater retention basin.

The specific details and rationale for the environmental sampling design, in addition to the sampling locations and methods, are presented in **Worksheets #17 & #18.**

6. Specify Performance/Acceptance Criteria

The performance and acceptance criteria are established in **Worksheet #12** and **Worksheet #28**. Laboratory data are considered usable if data validation criteria are met, as described in **Worksheet #34**, **Worksheet #35**, and **Worksheet #36**. Analytical data quality will be compared to DoD QSM (DoD, 2019a) specification for precision, accuracy, representativeness, comparability, completeness, and sensitivity (PARCCS). The analytical methods will provide the lowest available detection limits (DLs) using standard methods that will allow the data to be screened against the DQLs in **Worksheet #15**.

7. Develop the Detailed Plan for Obtaining Data

The detailed plan for obtaining data is established in **Worksheets #17 & #18** of this QAPP.

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QAPP Worksheet #12: Measurement Performance Criteria

Matrix	Groundwater/ Surface Water/ Porewater/ Potable Wells
Analytical Group	PFAS
Concentration	Low

Data Quality Indicators	Measurement Performance Criteria	QC Sample and/or Activity Used to Assess Measurement Performance	QC Sample Assesses Error for Sampling, Analytical, or Both
Accuracy/Bias	LCS/LCSD and MS/MSD shall be spiked with all analytes. Analyte recovery limits per Worksheet #15	LCS/LCSD, MS/MSD	A
Precision	Laboratory duplicates analysis should have an RPD < 30%	LCS/LCSD, MS/MSD	A
Precision	Values > 5X LOQ: RPD must be ≤ 30%	Field Duplicates	S
Accuracy/ Contamination	Values ≤ 5X LOQ: Absolute difference ≤ 2x the LOQ	Method Blank, Field Reagent Blanks, Equipment Rinsate Blanks	A
Sensitivity	No analytes detected > 1/2 LOQ or > 1/10 the amount measured in any sample or 1/10 the regulatory limit, whichever is greater	Detection Limits, Instrument Sensitivity Check	A
Completeness	Detection limits ≤ to acceptance criteria	Reported Sample Data	S & A
Comparability	Instrument Sensitivity Check concentrations must be within ±30% of their true values	Use of standardized SOPs in field and laboratory	S & A
Comparability	Completeness criteria will be considered met if 100% of all planned sample data (as requested on CoC in lab reports and EDD; including requested reanalyses) are collected	Field shake test	S & A
Representativeness	Based on accuracy and media comparison	Laboratory Receipt Checklist, Cooler Temperature Blank	S

Notes:
< = less than
> = greater than
≤ = less than or equal to
A = analytical
CoC = chain of custody
EDD = electronic data deliverable
LCS/LCSD = laboratory control spike/ laboratory control spike duplicate
LOQ = limit of quantitation
MS/MSD = matrix spike/ matrix spike duplicate
RPD = relative percent difference
S = sampling

Matrix	Soil/ Sediment
Analytical Group	PFAS
Concentration	Low

Data Quality Indicators	Measurement Performance Criteria	QC Sample and/or Activity Used to Assess Measurement Performance	QC Sample Assesses Error for Sampling, Analytical, or Both
Accuracy/ Bias	LCS/LCSD and MS/MSD shall be spiked with all analytes. Analyte recovery limits per Worksheet #15	LCS/LCSD, MS/MSD	A
Precision	Laboratory duplicates analysis should have a RPD < 30%	LCS/LCSD, MS/MSD	A
Precision	Values > 5X LOQ: RPD must be ≤ 30% Values ≤ 5X LOQ: Absolute difference ≤ 2x the LOQ	Field Duplicates	S
Accuracy/ Contamination	No analytes detected > 1/2 LOQ or > 1/10 the amount measured in any sample or 1/10 the regulatory limit, whichever is greater	Method Blank, Field Reagent Blanks, Equipment Rinsate Blanks	A
Sensitivity	Detection limits ≤ to acceptance criteria Instrument Sensitivity Check concentrations must be within ±30% of their true values	Detection Limits, Instrument Sensitivity Check	A
Completeness	Completeness criteria will be considered met if 100% of all planned sample data (as requested on CoC in lab reports and EDD; including requested re-analyses) are collected	Reported Sample Data	S & A
Comparability	Based on accuracy and media comparison	Use of standardized SOPs in field and laboratory	S & A
Representativeness	Samples met conditions per Worksheet #19/30	Laboratory Receipt Checklist, Cooler Temperature Blank	S

Notes:
< = less than
> = greater than
≤ = less than or equal to
A = analytical
CoC = chain of custody
EDD = electronic data deliverable
LCS/LCSD = laboratory control spike/ laboratory control spike duplicate
LOQ = limit of quantitation
MS/MSD = matrix spike/ matrix spike duplicate
RPD = relative percent difference
S = sampling

Matrix Solid
Analytical Group Total Organic Carbon (TOC)

Data Quality Indicators	Measurement Performance Criteria	QC Sample and/or Activity Used to Assess Measurement Performance	QC Sample Assesses Error for Sampling, Analytical, or Both
Accuracy/ Bias	LCS/LCSD: 72-122% for soil; 87-112% for water MS/MSD: 72-122% for soil; 87-112% for water	LCS/LCSD and MS/MSD	A
Precision	Laboratory duplicates analysis should have RPD ≤ 20% for soil; RPD ≤ 10% for water	Matrix Duplicate	A
Accuracy/ Contamination	Target compound < RL	Method Blank	A
Completeness	Completeness criteria will be considered met if 100% of all planned sample data (as requested on CoC in lab reports and EDD; including requested re-analyses) are collected	Reported Sample Data	S & A
Comparability	Based on accuracy and media comparison	Use of standardized SOPs in field and laboratory	S & A

Notes:
A = analytical
CoC = chain of custody
EDD = electronic data deliverable
LCS/LCSD = laboratory control spike/ laboratory control spike duplicate
MS/MSD = matrix spike/ matrix spike duplicate
RL = reporting limit
RPD = relative percent difference
S = sampling

Matrix Solid
Analytical Group pH

Data Quality Indicators	Measurement Performance Criteria	QC Sample and/or Activity Used to Assess Measurement Performance	QC Sample Assesses Error for Sampling, Analytical, or Both
Accuracy/ Bias	85-115% for soil	LCS/LCSD	A
Precision	RPD ≤ 20% for soil	Matrix Duplicate	A
Completeness	Completeness criteria will be considered met if 100% of all planned sample data (as requested on CoC in lab reports and EDD; including requested reanalyses) are collected	Reported Sample Data	S & A
Comparability	Based on accuracy and media comparison	Use of standardized SOPs in field and laboratory	S & A

Notes:
A = analytical
CoC = chain of custody
EDD = electronic data deliverable
LCS/LCSD = laboratory control spike/ laboratory control spike duplicate
LOQ = limit of quantitation
RPD = relative percent difference
S = sampling

Matrix Solid
Analytical Group Grain Size

Data Quality Indicators	Measurement Performance Criteria	QC Sample and/or Activity Used to Assess Measurement Performance	QC Sample Assesses Error for Sampling (S), Analytical (A) or Both (S&A)
Precision	RPD ≤ 20%	Sample Duplicate	A
Completeness	Completeness criteria will be considered met if 100% of all planned sample data (as requested on CoC in lab reports and EDD; including requested re-analyses) are collected	Reported Sample Data	S & A
Comparability	Based on accuracy and media comparison	Use of standardized SOPs in field and laboratory	S & A

Notes:
A = analytical
CoC = chain of custody
EDD = electronic data deliverable
QC = quality control
RPD = relative percent difference
S = sampling

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QAPP Worksheet #13: Secondary Data Uses and Limitations

Secondary data sources, uses, and limitations are tabulated below. Original source documents were reviewed for uncertainty discussions that may identify additional or more suitable data limitations.

Data Type	Source	Data Uses Relative to Current Project	Factors Affecting Reliability of Data and Limitations on Data Use
Meteorological	National Weather Service	Estimates of seasonal fluctuations in precipitation.	Meteorological data are generally for a regional area. Actual site conditions may vary.
Topographic	USGS	Inferred groundwater flow pathways based on local topography at each Site. Groundwater flow maps will ultimately rely upon groundwater measurements from monitoring wells.	Topography of some sites may have been altered by building or grading activities.
Soil and groundwater chemistry, groundwater monitoring data, and data gaps identification	Historical site reports	Applicable to the evaluation of historical site conditions in soil and groundwater to supplement data being collected under this delivery order.	The data may not represent current conditions because of the age of some of the data. Reliability of second- or third-party data quality.
Historical site records (i.e., material inventories)	Purchase records, site inventories, on-facility records, safety data sheets	Applicable to the evaluation of potential constituents of concern and release areas.	Records may be incomplete or inaccurate.
Periodicals (i.e., news articles)	Local newspapers, magazines, or other periodicals	Applicable to the evaluation of the use of potential constituents of concern at off-facility locations or mutual use/ aid agreements with local fire department or other entities.	Records may be incomplete or inaccurate.

Notes:
USGS = United States Geological Survey

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QAPP Worksheet #14 & #16: Project Tasks and Schedule

Worksheet #14 & 16 provides the project schedule and details the general project tasks that are expected to be completed as part of the RI. The RI program will include tasks as detailed in the following sections:

- **Section 14.1** – Mobilization
- **Section 14.2** – Field Investigation Activities
- **Section 14.3** – Laboratory Analysis
- **Section 14.4** – Data Management, Review, and Validation
- **Section 14.5** – Human Health and Ecological Risk Assessment
- **Section 14.6** – Report Preparation

The RI field activities for the Grand Ledge AASF will consist of multiple mobilizations. This RI QAPP Addendum specifically addresses the activities to be performed during the RI Mobilization 1, as developed in conjunction with the data from the SI (AECOM, 2021a). During this RI Mobilization 1, discrete soil, grab groundwater, groundwater samples from monitoring wells, surface water, sediment, and porewater samples will be collected to further refine the nature and extent of impacts previously identified, as summarized in **Worksheet #10**. As part of the RI Mobilization 1, the objectives, approach, and rationale for these RI sample locations are to further delineate the presence/absence of PFAS, similar to those outlined in the SI. Any results in exceedance of the screening levels will be considered for ongoing refinement of the RI Mobilization 2 sampling locations, as possible. The specific details and rationale for the environmental sampling design, in addition to sampling locations and methods, are presented in **Worksheets #17 & #18.** Field activities will be completed per the SOPs in **Appendix D**.

Table 14-1 below presents the schedule for the RI as anticipated based on ongoing project planning discussions with stakeholders, to be updated if new consensus decisions materialize.

Table 14-1 RI Schedule

Task	Start Date	End Date
RI QAPP (Mobilization 1)	November 2021	August 2022
Pre-mobilization (Mobilization 1)	July 2022	August 2022
Mobilization (Mobilization 1)	September 2022	September 2022
Field Work (Mobilization 1)	September 2022	September 2022
Demobilization (Mobilization 1)	September 2022	September 2022
Data Analysis/Data Validation (Mobilization 1)	September 2022	November 2022
RI QAPP (Mobilization 2)	November 2022	March 2023
Pre-mobilization (Mobilization 2)	March 2023	April 2023
Field Work (Mobilization 2)	April 2023	April 2023
Demobilization (Mobilization 2)	April 2023	April 2023
Data Analysis/Data Validation (Mobilization 2)	April 2023	June 2023
Reporting	June 2023	April 2024

14.1 Mobilization

The following subsections present field tasks that may be completed as part of the mobilization activities.

Right of Entry Documentation Support

ROEs will not be necessary to complete Mobilization 1 of the RI. However, sampling locations to be considered thereafter may necessitate ROEs.

Health and Safety Requirements

Health and safety requirements for field activities will be specified in the Accident Prevention Plan (APP) and Site Safety and Health Plan (SSHP). Personnel mobilized to the site will be required to meet training requirements identified in Federal Regulation 29 CFR 1910.120 and applicable Occupational Safety and Health Administration (OSHA) training, including Hazardous Waste Operations and Emergency Response (HAZWOPER) and medical surveillance requirements. At least two personnel trained in first aid and cardiopulmonary resuscitation (CPR) will be on-facility during field activities. Training certificates for personnel (HAZWOPER 40-hour training; current HAZWOPER 8-hour refresher training; and first aid/CPR) will be maintained on-facility.

The Site Safety and Health Officer (SSHO) will have completed the 30-hour OSHA General Industry or Construction Industry Safety Class or equivalent, as specified in *EM 385-1-1* (USACE, 2014). The SSHO will be responsible for managing, implementing, and enforcing the health and safety program in accordance with the accepted APP/SSHP. The SSHO will be a competent person that can identify existing and predictable hazards in the working environment or working conditions that are dangerous to personnel, and who has authorization to take prompt corrective measures to eliminate them.

The Site Supervisor (SS) will have completed the 8-hour OSHA Supervisor training, as specified in EM-385. The SS will lead field operations, coordinate field activities, and act as the liaison between site and laboratory personnel, among other responsibilities.

In general, field personnel will wear PFAS-free Level D personal protective equipment (PPE). If elevated levels of PPE are warranted based on site conditions, it will be established in the site-specific SSHP. Detailed Activity Hazard Analysis (AHA) forms identifying the physical, chemical, and biological hazards that may be encountered at the Site and the associated mitigation methods are presented in the APP/SSHP.

Personnel and visitors who enter the Site will be required to review the APP/SSHP and sign the acknowledgement form. Site workers will be required to sign the daily tailgate safety meeting form and fill out daily AHA forms. Safety issues that arise during implementation of field activities will be addressed during tailgate safety meetings held daily before the workday and will be documented in the daily tailgate safety meeting form.

Additional Personnel Qualifications

In addition to the health and safety requirements specified above, personnel mobilized to the Site will complete the DoD’s *Operations Security Awareness for Military Members, DoD Employees, and Contractors* and *Level 1 Antiterrorism Awareness Training*. AECOM employees that will be performing sample collection will also take an internal PFAS sampling guidance training.

The field work at the facility will be performed on airfield property. Field personnel may be required to participate in Airfield Safety Training or similar facility-specific training as necessary.

Permits and Notifications

Utility clearance is required for intrusive work, regardless of planned intrusive depth. Prior to intrusive activities, a site walk will be scheduled with the appropriate ARNG personnel to mark out locations of the subsurface utilities. AECOM or its drilling subcontractor will contact MISS DIG (811), the local one-call utility location system. Precautionary measures (e.g., geophysical survey, air knifing methods, hand-digging to 5 feet, etc.) are required if utility clearance is not confirmed. Lack of confirmation can include urban locations, areas adjacent to roadways, areas not previously assessed, areas with insufficient utility information, or areas with multiple utility lines. The location of utilities will be noted and recorded during the Site visits and referenced when selecting investigation locations. Utility Clearance will be conducted in accordance with *SOP 3-01: Utility Clearance* (**Appendix D**).

AECOM will also contact the Grand Ledge AASF Environmental Manager at least 20 business days prior to the scheduled start of the field activities. Field work will be coordinated with the Environmental Manager and/or his/her designee to ensure investigation activities do not impact Site operations. Additionally, a pre-fieldwork briefing will be performed at the Operations Building prior to field work activities. Anticipated work hours are 0700 to 1900.

Site Preparation

Preparation activities for the RI field investigation operations include mobilization of field team personnel and equipment. No vegetation clearance is planned during field investigation activities, as the investigation sampling locations are generally free of vegetation or debris that would inhibit ingress and egress. If vegetation is encountered, vegetation clearance will be coordinated with the facility staff.

Additionally, traffic control measures may be required to complete investigations at sampling locations at or near a roadway. Procedures will be outlined in the SSHP.

14.2 Field Investigation Activities

The following subsections present field tasks that may be completed as part of the RI field efforts. Field tasks will be completed following the SOPs listed in **Worksheet #21** and provided in **Appendix D**. In instances where deviations from the field protocols established in the Worksheet are made due to unforeseen conditions, a Field Change Request Form will be generated to document the change and request feedback from the AECOM Task and Project Managers, USACE, and ARNG.

Habitat Assessment

An initial habitat assessment will be performed as part of RI Mobilization 1 to identify representative habitats and species present in the vicinity of the sampling locations and downgradient waterbodies. The habitat assessment findings may be used to confirm the receptors and exposure pathways identified in the preliminary CSM (**Worksheet #10**) and may be considered in the characterization of potential adverse impacts, if identified based on comparisons to screening values. Habitats will initially be identified through the review of existing maps, available geographic information system (GIS) data, and aerial images.

It is anticipated that the primary habitats of interest will be the on-facility AOI and the stormwater retention basin. A site visit will be conducted to identify potential habitat on and off the facility. A brief qualitative survey of up to six locations will be conducted. The locations will be identified in the field by the biologist to ensure the habitats are representative of the species in the vicinity of the sampling locations.

Although these assessments are not intended to be threatened and endangered (T&E) species surveys, the biologists will be familiar with the habitat requirements and appearance of the federally listed species and any observations of relevant habitats or listed species will be noted. Additionally, other general habitat and species observations will be recorded.

If needed based on the results of the initial habitat assessment and the evaluation of the data collected during RI Mobilization 1 and RI Mobilization 2, additional assessment may be needed during subsequent mobilization(s) of the RI. Risk management decisions related to performing additional receptor or habitat surveys will be made by the project team and additional efforts may include wetland delineation, vegetation surveys, T&E species surveys, or other methods, as needed. If no potential for adverse impacts on ecological receptors are identified, additional, more intensive habitat or receptor survey efforts will not be warranted.

Field Instrument Calibration and Quality Control

Equipment will be checked to ensure its completeness and operational readiness. Any equipment found damaged or defective will be returned to the point of origin, and a replacement will be secured. Instruments and equipment that require routine maintenance and/or calibration will be checked initially upon arrival and then prior to use each day, if needed, to support that day’s operations. Equipment calibration and daily checks will be documented in accordance with appropriate SOPs.

This system of checks ensures that the equipment is functioning properly. If an equipment check indicates that any piece of equipment is not operating properly, and field repair cannot be made, the equipment will be tagged and removed from service, and a request for replacement equipment will be placed immediately. Replacement equipment will meet the same specifications for accuracy and precision as the equipment removed from service.

PFAS Site Water Supply Sampling and Sampling Equipment Acceptability

A sample from the potable water source (i.e., decontamination water) will be collected prior to mobilization to confirm that it is acceptable for use for during field activities. The water source is acceptable for use if the detected concentration is less than 1/5 the SL. If the decontamination water has concentrations greater than 1/5 the SL, the project team will determine whether the water is acceptable for its intended use based on site-specific factors (i.e., drilling methodology, relevant sample media). If the water is deemed unacceptable, water will be brought on-facility from another source confirmed to be PFAS-free.

Materials being purchased or rented for field work will be confirmed as acceptable for use in the PFAS sampling environment. A summary of acceptability of materials for use in the PFAS sampling environment is provided in *SOP 3-41: Perfluoroalkyl Substance Field Sampling Protocol* (**Appendix D**). As an additional layer of control, prior to the start of field work each day, a PFAS Sampling Checklist will be completed. The checklist will serve as a reminder to each field team member regarding the allowable materials within the sampling environment. An example of the checklist is included in the SOP.

Additionally, all field staff is required to complete AECOM's internal *PFAS Sampling Training*. This training accounts for correct equipment, prohibited field items, clothing, personal care products, sunscreen, insect repellants, and additional confirmed or suspected sources of environmental sample contamination. The ITRC guidance on *Site Characterization, Considerations, Sampling Precautions, and Laboratory Analytical Methods for PFAS* was referenced in the development of this guidance (ITRC, 2018b).

Synoptic Groundwater Measurement

Prior to sampling activities, a round of groundwater elevation measurements will be collected from the existing monitoring wells. Measurements of the complete collection of wells will be taken within a relatively short period and will follow a period of little to no precipitation, in order to ensure an accurate "snapshot" of the potentiometric surface and calculation of the groundwater gradient. All depth to water measurements will be collected from the northern side of the well casing to the nearest 0.01 foot.

Soil Sample Collection

Soil borings will be advanced until a competent clay unit is encountered or drilling refusal is encountered, whichever comes first, to a maximum depth of approximately 60 feet bgs. If a clay layer is observed in a boring with a thickness in excess of 3 feet, boring activities will be terminated in order to avoid completely penetrating a competent clay layer. Soil borings will be advanced via DPT using a GeoProbe® DT45 or DT60 dual-tube sampling system (or equivalent) or via a DPT macro-core sampling system; however, hand augers will be used to clear the top 5 feet of the boring in accordance with AECOM utility clearance protocols. If refusal is encountered before reaching the target depth, a second attempt will be made at an offset location within 10 feet of the original boring.

Soil will be recovered at each location and all soil cores will be continuously logged, due to the potential presence of a competent clay layer in the area and to further identify areas of relative high or low permeability (e.g., gravel lenses or silt/clay lenses, respectively). Soil cores will be logged continuously by a field geologist. In accordance with the APP/SSHP, the soil core will be screened for volatile organic compounds with a photoionization detector (PID) immediately upon recovery (AECOM, 2019b; AECOM, 2021b). Details regarding the air monitoring procedures and specific action levels are provided in the APP. Observations and measurements will be recorded on a soil boring log. At a minimum, depth interval, recovery thickness, PID concentrations, moisture, relative density, color (using a Munsell soil color chart), and texture will be recorded using the USCS. Additional observations to be recorded may include PFAS foaming, glistening, detectable odors, groundwater or perched water depth, organic material, cultural debris, and/or color changes indicating staining. Refer to *SOP 3-16: Soil and Rock Classification* and *SOP 3-17: Direct Push Sampling Techniques* (**Appendix D**) for additional details.

A total of three soil samples will be collected from selected borings (see **Table 17-2**): one surface soil sample (0 to 2 foot bgs), one subsurface soil sample from 2 to 4 feet bgs, and one subsurface soil sample at the mid-point between the surface and the groundwater table, if the depth to water is up to 30 feet bgs or shallower, or from 13 to 15 feet bgs if the depth to water is greater than 30 feet deep. Specific sampling locations and target boring depths are specified in **Worksheets #17 & #18**.

The sampling locations within the soil grid in AOI 1 were generated using Visual Sample Plan (VSP) version 7 software, developed by the Pacific Northwest National Laboratory, was used to generate a statistical sampling plan for the soil grid at AOI 1 within the established sampling area (VSP Development Team, 2020). From 12 locations, a total of 24 samples (two depths per location) will be collected. These 12 locations are placed on a systematic triangular grid with a random start location to minimize bias and maximize spatial coverage and representativeness. The VSP software projected a sample size of 12 per depth provides at least 95% confidence level and 90% to 95% power of detection to detect an average of one standard deviation difference for a data set that follows a normal distribution (i.e., parametric). If a non-parametric distribution is assumed, the aforementioned statistical error rates are expected to be moderately reduced. Hand augers will be used to collect surface and shallow subsurface soil samples from 0 to 2 feet bgs and 2 to 4 feet bgs, respectively, at the 12 locations.

Each sample will be collected into laboratory-supplied bottleware and submitted to the laboratory for analysis of selected parameters. Surface and subsurface samples will be analyzed under standard turn-around time (TAT) for the target list of 32 PFAS (liquid chromatography tandem mass spectrometry [LC/MS/MS] compliant with QSM 5.3 Table B-15). Additionally, TOC (USEPA Method 9060A), pH (USEPA Method 9045D), and grain size (American Society for Testing and Materials [ASTM] D-422) will be analyzed in a subset (25%) of soil samples to support evaluation of PFAS fate and transport, in addition to the remedial alternatives analysis. The laboratory method DLs for these analytes are presented in **Worksheet #15**. The required sample containers, preservatives, and holding times are specified in **Worksheets #19 & #30**. Refer to *SOP 3-21: Surface and Subsurface Soil Sampling* (**Appendix D**) for additional details. The sampling design and rationale, as well as the sampling locations and methods, are presented in **Worksheet #17 & #18**. However, based on the soil and/or groundwater analytical results and the field findings, modifications to these sampling locations and/or the sampling approach may be considered. In this event, a Field Change Request Form will be generated to document the change and request feedback from the AECOM Task and Project Managers, USACE, and ARNG.

The majority of borings will be advanced in areas without surface cover; however, one boring along the former drainage ditch is now covered in asphalt by the tarmac. The boring advanced in asphalt will be abandoned by backfilling with bentonite chips to approximately 6 inches bgs, and the remainder of the borehole will be patched with an asphalt cold patch or concrete to provide as flush a surface as possible. The surface at each location will be restored to match the surrounding area.

Drilling materials will be PFAS-free. Sample locations will be marked with a pin flag with sample identification number, photo-documented, and recorded with a hand-held global positioning (GPS) system. See *SOP 3-21: Surface and Subsurface Soil Sampling* (**Appendix D**) for more details.

Grab Groundwater Sample Collection using Direct-Push Technology

Upon completion of each soil sampling location, corresponding grab groundwater samples be collected (**Figure 17-1** and **Figure 17-2**). Grab groundwater samples will be collected from multiple depth intervals at each sampling location, using the same drilling methodology as its corresponding soil sample location:

- If utilizing DPT dual-tube sampling system, the drill stem would be advanced until the target depth has been reached or refusal encountered, the DPT tooling will be retracted, the dual-tube sampling equipment will be removed, and the screen point (SP) sampler will be attached. Groundwater samples will be collected via the SP sampler from the shallowest interval first. The tooling will then be retracted and decontaminated before offsetting (no more than 5 feet from the original location) and advancing to the next interval depth.
- If utilizing DPT macro-core sampling system, the drill stem will be advanced until the shallowest target depth has been reached or drilling refusal is encountered, and the SP will be attached, and groundwater would be sampled. The SP will then be retracted, and a new expendable point attached and the boring advanced to the next desired depth; and the process repeated for each subsequent interval depth.

Two to three grab groundwater samples will be collected per location, depending on the total encountered thickness of the water column, as further discussed in **Worksheet #17**. However, the target intervals may be adjusted based upon the soils encountered and any presumed relatively high or low permeability zone(s) at each corresponding soil boring location:

- one slightly below the water table;
- one at the total boring depth (anticipated to be approximately 30-45 feet); and

A grab groundwater sample will be collected from each interval using a peristaltic pump with tubing that has been determined to be PFAS-free (i.e., high-density polyethylene [HDPE] or other PFAS-free material). If the peristaltic pump cannot generate enough hydraulic lift to bring the groundwater to the surface, groundwater samples will be collected using a PFAS-free 0.85-inch Geotech Bladder pump or other sampling device. Non-disposable sampling equipment will be decontaminated between each temporary well.

Prior to sampling, the temporary well will be purged to remove sediment, to the extent reasonable, in an effort to minimize the turbidity of the sample. Refer to *SOP 3-37: Grab Groundwater Sampling Techniques* (**Appendix D**) for additional details. The degree of purging will be dependent on groundwater recharge within the well. If sufficient groundwater recharge is observed, the well will be purged until the turbidity is ≤ 25 nephelometric turbidity units (NTU), stabilizes at a level above 25 NTU, or for a maximum duration of one hour, whichever occurs first. In wells with limited groundwater recharge, the sample will be collected using the available groundwater.

In addition to turbidity, other water quality parameters (e.g., temperature, specific conductivity [SC], pH, dissolved oxygen [DO], and oxidation-reduction potential [ORP]) will be measured and recorded on the field sampling form every 5 minutes until the above turbidity criteria are met. Water quality parameters will be measured using a water quality meter and flow-through cell. Refer to *SOP 3-14: Monitoring Well Sampling* and *SOP 3-24: Water Quality Parameter Testing* for additional details. The multi-parameter water quality meter will be calibrated initially and continually throughout its usage each day, as needed. A calibration check will be performed at the end of each day.

Once the water quality parameters reach stabilization, each groundwater sample will be collected into laboratory-supplied bottleware and submitted to the laboratory for analysis of selected parameters. Sample containers will be PFAS-free, and the samples will not be filtered. In addition, a subsample of each groundwater sample will be collected in a separate container and undergo a shaker test to identify if there is any foaming. If foaming is observed, the observation will be noted on the CoC to notify the laboratory prior to analysis.

Groundwater samples from permanent monitoring wells will be analyzed under standard TAT for the target list of 32 PFAS (LC/MS/MS compliant with QSM 5.3 Table B-15). The laboratory method DLs for these analytes are presented in **Worksheet #15**. The required sample containers, preservatives, and holding times are specified in **Worksheets #19 & #30**. Non-disposable sampling equipment will be decontaminated between each well.

In addition, a subsample of each groundwater sample will be collected in a separate container and undergo a shaker test to identify if there is any foaming. If foaming is observed, the observation will be noted on the chain of custody (CoC) to notify the laboratory of potentially high PFAS concentrations in the sample prior to analysis. Any non-dedicated sampling materials will be decontaminated between boring locations.

Drilling materials will be PFAS-free. Sample locations will be marked with a pin flag with sample identification number, photo-documented, and recorded with a hand-held global positioning system (GPS).

Groundwater Sample Collection from Permanent Monitoring Wells

The specific monitoring wells selected for groundwater sample collection are specified in **Worksheets #17 & #18**. The monitoring wells will be purged using low-flow sampling techniques using a PFAS-free 1.75-inch Geotech Bladder pump or other sampling device with HDPE tubing and, will be sampled in accordance with *SOP 3-14: Groundwater Sampling* (**Appendix D**).

Water clarity will be visually monitored and water quality parameters, including DO, SC, ORP, pH, temperature, and turbidity will be measured using a flow-through cell per the *SOP 3-24: Water Quality Parameter Testing for Groundwater Sampling*. Readings will be collected every 5 minutes until the well produces clear (silt-free) water with a minimum of three stable water quality readings, as outlined below:

- pH – within ± 0.2 units
- DO – within ± 10%
- SC – within ± 3%
- ORP – within ± 10 mV
- Temperature – within ±1°C
- Turbidity – at or below 10 NTU, or within ± 10% if above 10 NTU

The multi-parameter water quality meter will be calibrated initially and continually throughout its usage each day, as needed. A calibration check will be performed at the end of each day.

Once the water quality parameters reach stabilization, each groundwater sample will be collected into laboratory-supplied bottleware and submitted to the laboratory for analysis of selected parameters. Sample containers will be PFAS-free, and the samples will not be filtered. In addition, a subsample of each groundwater sample will be collected in a separate container and undergo a shaker test to identify if there is any foaming. If foaming is observed, the observation will be noted on the CoC to notify the laboratory prior to analysis.

Groundwater samples from permanent monitoring wells will be analyzed under standard TAT for the target list of 32 PFAS (LC/MS/MS compliant with QSM 5.3 Table B-15). The laboratory method DLs for these analytes are presented in **Worksheet #15**. The required sample containers, preservatives, and holding times are specified in **Worksheets #19 & #30**. Non-disposable sampling equipment will be decontaminated between each well. The laboratory method DLs for VOCs are presented in **Worksheet #15**. The required sample containers, preservatives, and holding times are specified in **Worksheets #19 & #30**. The exact list of permanent monitoring wells within each AOI that would be sampled specified in **Worksheets #17 & #18**. Refer to *SOP 3-14: Monitoring Well Sampling and SOP 3-24: Water Quality Parameter Testing* (**Appendix D**) for additional details.

Surface Water, Sediment, and Porewater Sample Collection

Surface water, sediment, and porewater samples will be collected from the stormwater retention basin located at the northwestern corner of the facility. Specific sampling locations and additional information on porewater sampling procedures are specified in **Worksheets #17 & #18**. Surface water, sediment, and porewater samples will be collected in areas that are considered “wading” depths along the shoreline. The porewater locations will be identified using a Thermal Infrared (TIR) camera to locate groundwater seepage; therefore, the surface water and sediment samples may not be co-located. Sample locations will be biased to locations of suspected groundwater discharge to surface water and adjacent to the stormwater culverts that discharge from the wash bay to the retention pond. Sample locations will be photo-documented and recorded with a hand-held GPS.

Surface water, sediment, and porewater samples will not be collected directly following a rain event to avoid capturing surface water or overland flow influencing the porewater sample. Every effort will be made to collect the samples after several days without precipitation so that samples will represent base flow conditions. Sampling will occur from downstream to upstream in locations where surface flow direction can be clearly identified; agitation of the sediment and water at shallow locations will be minimized.

Surface water samples will be collected first at each location, prior to porewater or sediment sampling. The surface water samples will be collected from a single point in the waterbody by dipping the sample container in the water, approximately from the depth midpoint of the water. Sampling will be performed deliberately and methodically to minimize disturbance of bottom sediments, and as quickly as possible to ensure a representative sample is collected. After the surface water sample is collected, water quality parameters, including ORP, pH, SC, salinity, temperature, DO, and turbidity, will be measured with a water quality meter and recorded in the field logbook or sampling form. Physical characteristics of the sampling locations (e.g., water depth and stream width) will be documented. Additionally, at each location, the depth of water and width of channel will be recorded. Refer to *SOP 3-10: Surface Water and Liquid Sampling* (**Appendix D**) for additional details.

After surface water sampling is complete, porewater samples will be collected from 1.5 to 5 feet bgs using stainless steel push point samplers at the specific location identified via the TIR camera. More information regarding the process using the TIR camera can be found in **Worksheet #17 & #18.** Each sampler will be fitted with 4-inch long well screen. The samplers are equipped with a “T” handle and will be manually pushed to refusal or to a maximum depth of 60 inches below the basin bottom. If refusal is encountered at depths less than 1.5 feet, then the sample location will be adjusted slightly to hopefully achieve a depth of 1.5 feet or greater below the basin bottom. Porewater samples will be drawn from the push point sampler via a small diameter tubing with a peristaltic pump. After the porewater sample is collected, water quality parameters, including ORP, pH, specific conductivity (SC), salinity, temperature, DO, and turbidity, will be measured with a water quality meter and recorded in the field logbook or sampling form. Water quality parameters will be measured in both the porewater and adjacent surface water to ensure that the push point sampler is drawing porewater and is isolated from surface water. After sampling, the potentiometric surface of the porewater relative to the pond level will be measured by raising the water filled tubing vertically and allowing the porewater level to stabilize. The difference between the porewater level and surface water level will be measured using a ruler or measuring tape. Refer to *SOP 3-43: Porewater Sampling* (**Appendix D**) for additional details.

After porewater sampling is complete, sediment samples will be collected from 0 to 1 feet bgs using a hand-driven coring barrel. The sediment will be transferred to a stainless-steel bowl or other PFAS-free container (i.e., 1-gallon Ziploc® bags) from which material such as twigs, leaves, and stones will be removed prior to homogenization and documented in the field log or field forms. Sediment samples will target fine-grained material from depositional areas. Refer to *SOP 3-22: Sediment Sampling* (**Appendix D**) for additional details. The surface water dipper, sediment coring device, and water quality probe will be stainless steel or another PFAS-free material.

Each sample will be collected into laboratory-supplied bottleware and submitted to the laboratory for analysis of selected parameters. Sample containers will be PFAS-free, and the aqueous samples will not be filtered. Surface water, sediment, and porewater samples will be analyzed under standard TAT for the target list of 32 PFAS (LC/MS/MS compliant with QSM 5.3 Table B-15). Additionally, 25% of sediment samples will be analyzed for total organic carbon (TOC) (USEPA Method 9060A), pH (USEPA Method 9045D), and grain size (ASTM D-422). The laboratory method DLs for these analytes are presented in **Worksheet #15**. The required sample containers, preservatives, and holding times are specified in **Worksheets #19 & #30**.

In addition, a subsample of each surface water sample will be collected in a separate container and undergo a shaker test to identify if there is any foaming. If foaming is observed, the observation will be noted on the CoC to notify the laboratory prior to analysis.

Staff Gauge Installation

Staff gauges will be installed within the Grand Ledge AASF stormwater retention basin, to aid in the evaluation of surface water/groundwater interaction. The staff gauges will be located in known or suspected areas of groundwater to surface water discharge. The staff gauges will consist of 1.5-inch galvanized pipe and will be driven into the stormwater retention basin bottom using a slide hammer at targeted locations along the edge of the stormwater retention basin that is at wading depths. The depth of the gauge will be approximately 3 feet below the stormwater retention basin's sediment bottom. The top of the gauge height will allow for measurement of water levels within and outside of the pipe using a hand-held water level meter. Following installation, the horizontal location and elevation of the gauges will be surveyed by a state-registered surveyor.

Synoptic Groundwater and Surface Water Level Measurements

Synoptic groundwater level measurements will be collected from existing and newly installed temporary groundwater monitoring wells. Synoptic groundwater level measurements from newly installed wells will be collected a minimum of 24 hours after completion of well development. In addition, surface water level measurements will be collected from the newly installed staff gauges installed in the stormwater retention basin. The specific locations of groundwater and surface water level measurements are specific in **Worksheet #17 & #18**.

The synoptic groundwater and surface water level gauging round will be conducted within as short a time period as reasonably feasible and will follow a period of little to no precipitation. The water level gauging event will be conducted on a day when little to no precipitation is forecasted. Because surface water levels may fluctuate more strongly than groundwater levels, the surface water levels will be measured at the designated staff gauge locations at the very end of the gauging event.

Field Quality Control Samples

Field QC samples will include field duplicates (FDs), matrix spike (MS)/MS duplicates (MSDs), field reagent blanks (FRBs), and temperature blanks. FD samples will be collected at a rate of 10% and analyzed for the same parameters as the accompanying samples. MS/MSD samples will be collected at the rate of 5% and analyzed for the same parameters as the accompanying samples. FRBs will be collected at a rate of one per sampling event for groundwater, soil, surface water, and sediment media, or one per day or one per 10 samples (whichever is more) for drinking water media, as needed based on collection. A temperature blank shall be placed in each cooler to ensure that samples are preserved at or below 6 degrees Celsius (°C) during shipment.

If non-dedicated sampling equipment is used, an equipment blank will be collected at a rate of 5% and analyzed for the same parameters as the accompanying samples.

Sampling Handling, Storage, and Transport

Samples will be stored on ice, packaged, and submitted to the analytical laboratory for analysis as specified in **Worksheet #15**. **Worksheet #17 & #18** provides the sampling design and rationale. **Worksheet #17 & #18**, **Worksheets #19 & #30**, and **Worksheet #20** provide sample identifications, necessary sample volume and preservative requirements, and hold time limitations. Samples will be QC checked by the SS (label correctness and completeness) and recorded on CoC forms. Samples will be packaged on ice and transported overnight by commercial carrier or a laboratory courier under standard custody procedures to the laboratory. See *SOP 3-04: Sample Handling, Storage, and Shipping* (**Appendix D**) for additional information.

Field Documentation

Field documentation will be performed in accordance with *SOP 3-02: Logbooks*. Sample collection information will be recorded in bound field notebooks, tablet computers, or specific field forms. A summary of field activities will be properly recorded in a bound logbook with consecutively numbered pages that cannot be removed. Logbooks will be assigned to field personnel and stored in a secured area when not in use. Entries will be written in indelible ink, and no erasures will be made. If an incorrect entry is made, striking a single line through the incorrect information will correct the text, and the person making the correction will initial and date the change. Sampling forms and other field forms will also be used to document field activities. *See SOP 3-02: Logbooks* (**Appendix D**) for additional information.

Borehole Abandonment & Site Restoration

DPT borings will be abandoned using wetted bentonite chips at completion of sampling activities unless they are converted into monitoring wells. The majority of borings will be advanced in areas without surface cover; however, one boring along the former drainage ditch is now covered in asphalt by the tarmac. The boring advanced in asphalt will be abandoned by backfilling with bentonite chips to approximately 6 inches bgs, and the remainder of the borehole will be patched with an asphalt cold patch or concrete to provide as flush a surface as possible. The surface at each location will be restored to match the surrounding area. See *SOP 3-15: Monitoring Well Abandonment* (**Appendix D**) for more details.

Equipment Decontamination

The team will utilize dedicated and disposable sampling equipment to the extent possible to avoid cross contamination due to inadequate decontamination processes. The dedicated/disposable sampling equipment will include disposable polyethylene tubing, disposable gloves, and laboratory-supplied sample bottles.

Non-disposable or non-dedicated sampling equipment (e.g., water level meters, water quality meters, etc.) will be decontaminated prior to sampling and between sample locations. Decontamination will generally consist of a water rinse station to remove gross contamination, followed by a non-phosphate detergent (e.g., Liquinox®) water rinse, and a double rinse with PFAS-free, de-ionized water, in accordance with EGLE's recommended equipment decontamination procedures (Michigan Department of Environmental Quality [MDEQ], 2018). Paper towels containing recycled paper content are prohibited. Decontamination activities will be performed in accordance with *SOP 3-06: Decontamination* (**Appendix D**).

Land Surveying and Geographic Position Measurement

Sample locations will be documented using a hand-held GPS.

Investigation-Derived Waste (IDW) Management

Currently, the disposal of PFAS investigation-derived waste (IDW) is not regulated. PFAS IDW is considered a non-hazardous waste and will be managed in accordance with USEPA Management of IDW (USEPA, 2014a) and applicable state regulations. If waste requires containerization, it will be managed in accordance with the Army Guidance for Addressing Releases of PFAS, Q18 (DA, 2018).

Non-hazardous solid IDW (i.e., soil cuttings) generated on-facility during RI activities will be left in place at the point of the source. The soil cuttings will be distributed on the downgradient side of the borehole. This IDW will not be sampled and will assume the PFAS characteristics of the associated soil samples collected from that source location. See *SOP 3-05: Investigation-Derived Waste Management* (**Appendix D**) for more details.

Liquid IDW (e.g., purge water and decontamination fluids) generated on-facility during RI activities will be discharged directly to the ground surface slightly downgradient of the source of generation in accordance with USEPA Management of IDW (USEPA, 2014a). This IDW will not be sampled and will assume the PFAS characteristics of the associated groundwater samples collected from that source location. However, if the shaker test of aqueous samples indicates foaming or if direct ground discharge is not permitted, liquid IDW will be containerized in properly labeled 55-gallon drums.

If IDW requires containerization, it will be further managed in accordance with the Army Guidance for Addressing Releases of PFAS, Q18 (DA, 2018). The IDW will be stored at a location designated by the Grand Ledge AASF Environmental Manager and MIARNG. The containerized IDW will be segregated based on location, to the extent possible, and the material will assume the characteristics of the associated sample. If analytical samples are not planned for the location (i.e., soil PFAS samples at well boring locations), IDW samples will be collected for analysis of PFAS. Solid IDW will be properly transported and disposed of at a permitted Subtitle C landfill. If liquid IDW exceeds the SLs, it will be run through granulated active carbon filters, and if the liquid IDW does not exceed the SLs, it will be discharged to the sanitary sewer.

At locations where soil and liquid IDW are left on the ground surface at the source of generation, AECOM will collect GPS points around (i.e., polygon) the location of the where the IDW was placed. The polygon will be included in the reporting phase for future use, if required.

Other solids such as spent personal protective equipment, plastic sheeting, tubing, rope, unused monitor well construction materials, and other environmental media generated during the field activities will be disposed of at a licensed solid waste landfill.

14.3 Laboratory Analysis

Chemical analyses will be performed by Pace Gulf Coast, a DoD ELAP and NELAP certified laboratory. Copies of the laboratory accreditation certificates are included in **Appendix C**. Analytical services are summarized on **Worksheets #19 & #30**. PFAS analyses will be conducted in accordance with DoD QSM Version 5.3 (DoD, 2019a) and the laboratory SOPs cited.

Chemical analyses will be performed in accordance with the analytical methods identified in **Worksheet #23**. Analytical sensitivity for the methods selected is compared to project screening criteria on **Worksheet #15**. Requirements for laboratory instrument calibration, and equipment maintenance and testing are presented on **Worksheet #24** and **Worksheet #25**. Measurement performance criteria for field and laboratory QC samples are presented on **Worksheet #12** and **Worksheet #28**, respectively.

The laboratory will provide Contract Laboratory Program-like Level IV data packages, which will include summary forms containing QC information and raw data (Stage IV data packages as described in the DoD QSM v5.3).

14.4 Data Management, Review, and Validation

The principal data generated for this project will be from laboratory analytical data. Copies of the field forms, CoCs, air bills, and logbooks will be placed in the project files after completion of the field program. The field logbooks for this project will be used only for this facility and will also be categorized and maintained in the project files after the completion of the field program. Project records will be maintained in a secure location.

Data Tracking

The AECOM RI Task Manager is responsible for the overall tracking and control of data generated for the project. Data are tracked from generation to archiving in the project-specific files. The Project Chemist, or designee, is responsible for tracking the samples collected and shipped to the contracted laboratory. The laboratory will report data using AECOM format Electronic Data Deliverables (EDDs) along with a hard copy of the laboratories final data report, which will include supporting documentation such as chromatographs and instrument calibrations. Upon receipt of the data packages from the analytical laboratory, the Project Chemist will oversee the data validation effort, which includes verifying that the data packages are complete, and that results for samples have been delivered by the analytical laboratory.

Data Review and Validation

Upon receipt of data packages from the analytical laboratory, the AECOM Project Chemist will oversee the data validation effort, which includes verifying data completeness as specified on **Worksheet #34**. To evaluate whether the analytical results meet the project quality objectives, the laboratory data will undergo verification and validation as cited in **Worksheet #34**, **Worksheet #35**, and **Worksheet #36.** The usability assessment processes are described in **Worksheet #37**.

Prior to data validation, the electronic data will be verified for accuracy against the hardcopy of the laboratory report and the QAPP. Accuracy will be established using project-specific criteria defined in **Worksheet #12**, **Worksheets #19 & #30**, and **Worksheet #28**. The laboratory will be requested to resubmit electronic data found to be inaccurate. Laboratory calibration will be assessed against the criteria presented in **Worksheet #24**.

Data Storage, Archiving, and Retrieval

After the data are validated, the data packages are entered into the AECOM file system and archived in secure files. The field records including field logbooks, sample logs, CoC records, and field calibration logs will be submitted by the AECOM field team lead to be entered into the file system before archiving in secure project files. Project files will be kept in a secured, limited access area. AECOM will add electronic data to the existing project database.

Data Security

Laboratory data, provided in electronic format, will be verified for accuracy prior to use and during the data review process. After data are reviewed, the electronic data results will be uploaded into the AECOM database for use in data evaluation and subsequent report preparation. The project database will be on a password protected secure network, and access to changing data files will be restricted to qualified personnel. The AECOM RI Task Manager, or designee, is responsible for the overall tracking and control of data generated for the project. File and data backup procedures are routinely performed.

14.5 Human Health and Ecological Risk Assessment

A HHRA and SLERA will be conducted in accordance with CERCLA and USACE risk assessment guidance following completion of RI Mobilization 1 and RI Mobilization 2 as part of the comprehensive RI report that will be prepared following this and subsequent mobilizations, as indicated in **Section 14.6**. The results of the SLERA, in conjunction with the SLERA refinement (Step 3a) and the habitat assessment, will determine whether an optional Baseline Ecological Risk Assessment (BERA) is needed.

Human Health Risk Assessment

The primary objective of the HHRA is to evaluate whether chemicals attributable to facility activities have the potential to cause unacceptable adverse health effects to human receptors within the area under investigation. The HHRA will perform quantitative estimation of potential excess lifetime cancer risk (ELCR) and noncancer hazard (as a Hazard Index [HI]) to current and potential future human receptors that may come into contact with facility-related concentrations of PFOA, PFOS, PFBS, PFHxS, HFPO-DA, and/ or PFNA in soil, groundwater, surface water, and sediment. For each associated exposure scenario (i.e., receptor/medium) with a potential ELCR or HI above USEPA targets, Chemicals of Concern (COCs) will be selected from those chemicals of potential concern (COPCs) significantly contributing to the cumulative ELCR or target organ HI.

The HHRA conclusions will inform risk management decisions. If remedial action is determined to be necessary based upon the results of the HHRA, the HHRA will be used to inform the development of risk-based target levels to be considered in conjunction with federal and state-specific ARARs in the selection of Preliminary Remediation Goals (PRGs) in the FS.

Ecological Risk Assessment

The primary objective of the ecological risk assessment is to evaluate the potential for adverse effects on ecological receptors due to exposures to PFAS detected in relevant media, including soil, sediment, surface water, and porewater and to provide input to remedial decision-making that will protect the health of local populations and communities of biota.

The USEPA (1997) and DA (2010) ERA process follows a tiered approach that incorporates different levels of assessment complexity and provides an opportunity to off-ramp from the ERA process prior to proceeding to the next tier based on the available findings. The tiered approach may be implemented in its entirety depending upon the level and magnitude of risk that is determined in prior tiers. This approach consists of the following two tiers as summarized below:

- Tier 1 – SLERA
- Tier 2 – BERA

The primary objective for a SLERA is to determine which, if any, exposure pathways and chemicals of potential ecological concern (COPECs) warrant immediate action or require further evaluation in a more refined ERA. The SLERA includes Steps 1 and 2 of the eight step USEPA ERA (USEPA, 1997) process:

- Identification and summarization of relevant datasets.
- Development of a preliminary CSM.
- Comparison of maximum detected concentrations to ecological screening levels to identify COPECs.

Based on the outcome of the SLERA, certain media, COPECs, and pathways may be eliminated from further evaluation due to the level of conservatism built into the SLERA process. In cases where sites are fully paved, there is no upland habitat present, soil contamination is below the reach of ecological receptors, or contaminated groundwater does not discharge to surface water habitats, documentation that the potential ecological exposure pathways are incomplete will be sufficient to address ecological concerns. In the event that potentially complete and significant ecological exposure pathways are identified, and maximum concentrations of certain COPECs exceed the generic screening levels, additional evaluation may be recommended.

Prior to beginning problem formulation in the BERA (Step 3), the results of the SLERA may be refined in Step 3a, as described below. The decision to continue beyond the SLERA does not indicate that adverse effects are occurring or that risk reduction is necessary, rather it indicates that a more focused evaluation and characterization of the potential for risk and accompanying uncertainty is needed (DA, 2010).

The primary purpose of the BERA is to assess the potential for adverse effects on the focused list of ecological receptors due to exposure to the COPECs identified upon completion of the SLERA. The BERA includes Steps 3 through 7 of the eight step USEPA ERA (USEPA, 1997) process and uses site-specific information whenever possible:

- Step 3a (SLERA refinement) provides a refinement of the conservative assumptions and resulting risk estimates identified in the SLERA. This step is conducted to refine some of the conservative assumptions used in the SLERA and assess whether more realistic assumptions would reduce the risk estimates to acceptable levels prior to implementing a site-specific BERA with associated sampling and analyses. A weight of evidence evaluation that considers the Step 3a results, available habitat, wildlife management goals for the areas evaluated, and other relevant factors as appropriate will be conducted to determine whether a BERA is recommended.

- Steps 3b through 7 are completed for pathways and COPECs retained after the completion of Step 3a. These steps include identifying endpoints to be evaluated, the laboratory and field methods to be used to collect additional data, the statistical analyses to be used for evaluating data, and the methods to be used for estimating and characterizing the potential for adverse effects on ecological receptors.

A BERA (including Steps 3b through 7) will only be warranted if the results of the SLERA and SLERA refinement indicate that adverse ecological effects are likely. In the event a BERA is warranted, the evaluation will be focused on the key receptors, pathways, and PFAS of potential concern identified following a weight of evidence assessment included in the SLERA refinement. The BERA would consider more detailed aspects related to the COPECs, receptors, and exposure pathways retained at the end of Step 3a and could include food web modeling, tissue sampling, additional habitat assessments, or collection of other site-specific data.

If the outcome of the ERA process indicates the need for risk management measures, ecological PRGs may be developed for PFAS showing the potential for risk to guide remedial decision-making. PRGs may be based on available ecological screening levels, site-specific background concentrations, calculated values based on food web modeling, and/or site-specific toxicity data, if available.

Results from the HHRA and SLERA/BERA will be used to update and refine the RI CSM.

14.6 Report Preparation

Following the completion of data collection from Mobilization 1, laboratory analysis, and data validation, RI Mobilization 2 will be considered and a QAPP Addendum will be prepared to outline additional data gaps identified following RI Mobilization 1. Following this and any subsequent mobilizations, a comprehensive RI Report including data from Mobilization 1 and Mobilization 2 will be prepared per CERCLA guidance. The RI report will present the methods used for the RI, the refined CSM resulting from the investigation (including exposure pathways and receptors), the results of the site characterization and risk assessment, and a recommendation of whether further remedial action is needed.

Additionally, the RI Report will include the following elements:

- Restatement of program goals;
- Facility background, environmental setting, previous investigations, current and reasonably expected future land use both on- and off-facility, and potential off-facility PFAS sources;
- Summary of field investigation conducted (e.g., sampling dates, soil samples collected, wells sampled, parameters analyzed, and field procedures);
- Physical characteristics of the study area, including soils, geology, hydrogeology, hydrology, and ecological setting;
- Habitat Assessment discussion;
- Deviations from the initial site-specific QAPP and/or any QAPP modifications;
- Tables summarizing the samples collected and sample analytical data;
- Figures showing the layout of each sampling area, updated site features, results of geophysical surveys, soil boring locations, and summaries of pertinent analytical results;
- Discussion of data validation and PARCCS;
- Data evaluation;
- Fate and transport discussion, including potential routes of migration, contaminant persistence, and contaminant migration;
- HHRA and SLERA/BERA summaries (full HHRA and SLERA/BERA documentation to be included as attachments to the RI report); and, Conclusions and summary of the RI findings.

QAPP Worksheet #15: Project Data Quality Limits and Laboratory-Specific Detection/ Quantitation Limits

The following tables specify the list of target analytes for groundwater, surface water, porewater, soil, and sediment and the associated DQLs and laboratory-specific detection/ quantitation limits for the target analytes. The analytical laboratory reference limits include the limits of detection [LODs], limits of quantitation [LOQs], and DLs. The objective is for the laboratory to achieve LOQs low enough to measure analytes at concentrations less than the DQLs to obtain a dataset of known quality and sufficient sensitivity to meet the project DQOs established in **Worksheet #11**. The DQLs represent the lowest of the relevant criteria that may be used in the RI and later stages of the CERCLA process (e.g., FS). These criteria include the relevant Michigan-specific criteria, USEPA health advisories, and human health and ecological screening values, as further described below. Conservative assumptions were made when selecting screening values for use as DQLs for purposes of achieving an appropriate level of data quality. Site-specific refinements may be made during application of screening values for use in the evaluation of analytical data. The DQLs are not intended to be used as cleanup levels. Concentrations above the DQLs would not automatically trigger a response action but would suggest further site-specific consideration is appropriate. Details on the medium-specific DQL selection are provided in the notes below the following media-specific tables.

Target Analyte List for PFAS

A target list of 32 PFAS has been established for the project. This includes 28 PFAS on the October 2019 Michigan PFAS Action Response Team (MPART) PFAS minimum laboratory analyte list (MPART, 2019). Additionally, four other PFAS have been added to the RI Mobilization 2 target analyte list (TAL) and include N-ethyl perfluorooctane sulfonamide (EtFOSA), N-ethyl perfluorooctane sulfonamido ethanol (EtFOSE), N-methyl perfluorooctane sulfonamide (MeFOSA) and N-methyl perfluorooctane sulfonamido ethanol (MeFOSE). These compounds were added to aid in the potential identification of source areas since these compounds have a greater affinity for soil organic matter than most other more commonly observed PFAS (e.g., PFOS, PFOA, PFBS, PFHxS).

RI Screening Levels for PFAS

The DoD has adopted a policy within the CERCLA process to compare analytical results for PFAS to risk-based human health SLs for soil and groundwater (Assistant Secretary of Defense, 2022). The ARNG program under which this RI is being performed follows this DoD policy. The SLs established in the OSD memorandum apply to the following compounds: PFOA, PFOS, PFBS, PFHxS, HFPO-DA, and/ or PFNA. The SLs were calculated using the USEPA RSL On-Line Calculator (USEPA, 2021c). Risk-based human health screening levels for surface water and sediment were also calculated in accordance with the OSD memorandum.

Ecological Screening Criteria for PFAS

Ecological screening criteria for PFAS have not been developed by USEPA. Risk-based screening levels for ecological receptors to be used in the SLERA are identified in Appendix A and are included in the DQLs. Ecological risk-based screening levels for soil, surface water, and sediment were identified primarily from SERDP guidance documents (Conder, et al., 2020; Divine, et al., 2020) and recent documentation from Argonne National Laboratory (Grippo, et al., 2021).

Michigan Criteria for PFAS

The state of Michigan has formally adopted MCLs for seven PFAS: PFOA, PFOS, PFBS, PFNA, PFHxS, PFHxA, and HFPO-DA, also known as GenX (EGLE, 2020b). The EGLE MCLs are not considered SLs during the RI phase because ARARs will be considered during the FS stage in accordance with the CERCLA process. Additionally, other Michigan screening criteria, including EGLE GCC for groundwater (EGLE, 2020b), EGLE Cleanup Criteria Requirements for Response Activity (Formerly the Part 201 Generic Cleanup Criteria and Screening Levels) for soil (EGLE, 2018b), and Rule 57 Water Quality Values for surface water (EGLE, 2020c), are included in the DQLs.

Laboratory: Pace Gulf Coast

Matrix: Groundwater
Analyte Group: PFAS (32 Compound Target List)
Method: PFAS by LC/MS/MS compliant with QSM 5.3 Table B-15

Analyte	Abbreviation	CAS Number	DQL (ng/L) [1]	DQL Source	LCS Lower Control Limit (%)	LCS Upper Control Limit (%)	Achievable Laboratory Limits		
							DL (ng/L)	LOD (ng/L)	LOQ (ng/L)
Perfluorobutanoic acid	PFBA	375-22-4	NA	--	73	129	0.90	2.0	4.0
Perfluorobutanesulfonic acid	PFBS	375-73-5	420	HH; EGLE GCC	72	130	0.81	2.0	4.0
Perfluoropentanoic acid	PFPeA	2706-90-3	NA	--	72	129	0.85	2.0	4.0
Perfluorohexanoic acid	PFHxA	307-24-4	400,000	HH; EGLE GCC	72	129	0.99	2.0	4.0
Perfluorohexanesulfonic acid	PFHxS	355-46-4	51	HH; EGLE GCC	68	131	0.95	2.0	4.0
Perfluoroheptanoic acid	PFHpA	375-85-9	NA	--	72	130	0.48	2.0	4.0
Perfluoroheptanesulfonic acid	PFHpS	375-92-8	NA	--	69	134	0.84	2.0	4.0
Perfluorooctanoic acid	PFOA	335-67-1	8	HH; EGLE GCC	71	133	0.95	2.0	4.0
Perfluorooctanesulfonic acid	PFOS	1763-23-1	16	HH; EGLE GCC	65	140	0.81	2.0	4.0
Perfluorooctanesulfonamide	PFOSA	754-91-6	NA	--	67	137	0.96	2.0	4.0
Fluorotelomer sulfonic acid 6:2	FTS 6:2	27619-97-2	NA	--	64	140	0.94	2.0	4.0
Perfluorononanoic acid	PFNA	375-95-1	6	HH; EGLE GCC	69	130	0.78	2.0	4.0
Perfluorodecanoic acid	PFDA	335-76-2	NA	--	71	129	0.86	2.0	4.0
Perfluorodecanesulfonic acid	PFDS	335-77-3	NA	--	53	142	0.80	2.0	4.0
Fluorotelomer sulfonic acid 8:2	FTS 8:2	39108-34-4	NA	--	67	138	0.90	2.0	4.0
Perfluoroundecanoic acid	PFUdA	2058-94-8	NA	--	69	133	0.95	2.0	4.0
Perfluorododecanoic acid	PFDoA	307-55-1	NA	--	72	134	0.88	2.0	4.0
Perfluorotridecanoic acid	PFTrDA	72629-94-8	NA	--	65	144	0.99	2.0	4.0
Perfluorotetradecanoic acid	PFTeA	376-06-7	NA	--	71	132	0.98	2.0	4.0
2-(N-Ethylperfluorooctanesulfonamido) acetic acid	N-EtFOSAA	2991-50-6	NA	--	61	135	0.97	4.0	8.0
2-(N-Methylperfluorooctanesulfonamido) acetic acid	N-MeFOSAA	2355-31-9	NA	--	65	136	0.91	4.0	8.0
Fluorotelomer sulfonic acid 4:2	FTS 4:2	757124-72-4	NA	--	63	143	0.85	2.0	4.0
Perfluorononanesulfonic acid	PFNS	68259-12-1	NA	--	69	127	0.78	2.0	4.0
Perfluoropentanesulfonic acid	PFPeS	2706-91-4	NA	--	71	127	0.69	2.0	4.0
N-ethyl perfluorooctane sulfonamide	EtFOSA	5141-50-2	NA	--	70	130	0.96	4.0	8.0
N-ethyl perfluorooctane sulfonamido ethanol	EtFOSE	1691-99-2	NA	--	70	130	0.90	4.0	8.0
N-methyl perfluorooctane sulfonamide	MeFOSA	31506-32-8	NA	--	70	130	0.97	4.0	8.0
N-methyl perfluorooctane sulfonamido ethanol	MeFOSE	24448-09-7	NA	--	70	130	0.87	4.0	8.0
Hexafluoropropylene oxide dimer acid	HFPO-DA	2062-98-8	370	HH; EGLE GCC	70	130	1.86	10	20

Analyte	Abbreviation	CAS Number	DQL (ng/L) [1]	DQL Source	LCS Lower Control Limit (%)	LCS Upper Control Limit (%)	Achievable Laboratory Limits DL (ng/L)	LOD (ng/L)	LOQ (ng/L)
11-Chloroeicosafluoro-3-oxaundecane-1-sulfonic acid	11 CL-PF3ONS	763051-92-9	NA	--	70	130	0.80	2.0	4.0
9-Chlorohexadecafluoro-3-oxanonane-1-sulfonic acid	9CL-PF3ONS	756426-58-1	NA	--	70	130	0.84	2.0	4.0
4,8-dioxa-3H-perfluorononanoate	ADONA	919005-14-4	NA	--	70	130	1.00	2.0	4.0

Notes:

1.) DQLs for groundwater were selected based on the lower of the following:
   (a) EGLE GCCs (EGLE, 2020b). Note: EGLE GCCs are equivalent to the Michigan drinking water MCLs (EGLE, 2020a).
   (b) Risk-based tap water SLs calculated in accordance with the OSD Memorandum (Assistant Secretary of Defense, 2021). The OSD SLs were calculated using the USEPA RSL Calculator (USEPA, 2021c) for a residential tap water exposure scenario using USEPA default exposure assumptions based on a target hazard quotient of 0.1 (PFOS, PFOA, PFBS), a target risk level of 1E-06 (PFOA only), and the following toxicity values:
      - USEPA's chronic RfD for PFOA (2E-05 mg/kg-day) published in "Drinking Water Health Advisory for Perfluorooctanoic Acid (PFOA)" (USEPA, 2016a).
      - USEPA's chronic RfD for PFOS (2E-05 mg/kg-day) published in "Drinking Water Health Advisory for Perfluorooctane Sulfonate (PFOS)" (USEPA, 2016b).
      - USEPA's provisional chronic RfD for PFBS (3E-04 mg/kg-day) published in USEPA's PPRTV paper (USEPA, 2021b).

% = percent
CAS = Chemical Abstracts Service
DL = detection limit
DQL = data quality limit
EGLE = Michigan Department of Environment, Great Lakes, and Energy
GCC = Generic Cleanup Criteria
HA = Health Advisory
HH = human health based DQL
LC/MS/MS = liquid chromatography tandem mass spectrometry
LCS = laboratory control spike
LOD = limit of detection
LOQ = limit of quantitation
MCL = Maximum Contaminant Level
NA = not available
ng/l = nanograms per liter
PPRTV = Provisional Peer-Reviewed Toxicity Values
OSD = Office of the Secretary of Defense
QSM = Quality Systems Manual
RfD = reference dose
RSL = Regional Screening Level
SL = screening level
USEPA = United States Environmental Protection Agency

Laboratory: Pace Gulf Coast
Matrix: Surface Water (32 Compound Target List)
Analyte Group: PFAS
Method: PFAS by LC/MS/MS compliant with QSM 5.3 Table B-15

Analyte	Abbreviation	CAS Number	DQL (ng/L) [1]	DQL Source	LCS Lower Control Limit (%)	LCS Upper Control Limit (%)	Achievable Laboratory Limits		
							DL (ng/L)	LOD (ng/L)	LOQ (ng/L)
Perfluorobutanoic acid	PFBA	375-22-4	64,600	Eco; Freshwater Chronic ESV Aquatic Life	73	129	0.90	2.0	4.0
Perfluorobutanesulfonic acid	PFBS	375-73-5	1,000	HH; Surface Water SL Protective of Fish Consumption	72	130	0.81	2.0	4.0
Perfluoropentanoic acid	PFPeA	2706-90-3	140,000	Eco; Freshwater Chronic RWQ RBSL	72	129	0.85	2.0	4.0
Perfluorohexanoic acid	PFHxA	307-24-4	28,800	Eco; Freshwater Chronic ESV Aquatic Life	72	129	0.99	2.0	4.0
Perfluorohexanesulfonic acid	PFHxS	355-46-4	5,500	Eco; Wildlife ESV	68	131	0.95	2.0	4.0
Perfluoroheptanoic acid	PFHpA	375-85-9	870,000	Eco; Freshwater Chronic RWQ RBSL	72	130	0.48	2.0	4.0
Perfluoroheptanesulfonic acid	PFHpS	375-92-8	NA	--	69	134	0.84	2.0	4.0
Perfluorooctanoic acid	PFOA	335-67-1	68	HH; Surface Water SL Protective of Fish Consumption	71	133	0.95	2.0	4.0
Perfluorooctanesulfonic acid	PFOS	1763-23-1	4.6	HH; Surface Water SL Protective of Fish Consumption	65	140	0.81	2.0	4.0
Perfluorooctanesulfonamide	PFOSA	754-91-6	NA	--	67	137	0.96	2.0	4.0
Fluorotelomer sulfonic acid 6:2	FTS 6:2	27619-97-2	NA	--	64	140	0.94	2.0	4.0
Perfluorononanoic acid	PFNA	375-95-1	2,080	Eco; Wildlife ESV	69	130	0.78	2.0	4.0
Perfluorodecanoic acid	PFDA	335-76-2	660	Eco; Wildlife ESV	71	129	0.86	2.0	4.0
Perfluorodecanesulfonic acid	PFDS	335-77-3	NA	--	53	142	0.80	2.0	4.0
Fluorotelomer sulfonic acid 8:2	FTS 8:2	39108-34-4	NA	--	67	138	0.90	2.0	4.0
Perfluoroundecanoic acid	PFUdA	2058-94-8	49,000	Eco; Freshwater Chronic RWQ RBSL	69	133	0.95	2.0	4.0
Perfluorododecanoic acid	PFDoA	307-55-1	72,000	Eco; Freshwater Chronic RWQ RBSL	72	134	0.88	2.0	4.0
Perfluorotridecanoic acid	PFTrDA	72629-94-8	NA	--	65	144	0.99	2.0	4.0

Analyte	Abbreviation	CAS Number	DQL (ng/L) [1]	DQL Source	LCS Lower Control Limit (%)	LCS Upper Control Limit (%)	Achievable Laboratory Limits		
							DL (ng/L)	LOD (ng/L)	LOQ (ng/L)
Perfluorotetradecanoic acid	PFTeA	376-06-7	NA	--	71	132	0.98	2.0	4.0
2-(N-Ethylperfluorooctanesulfonamido) acetic acid	N-EtFOSAA	2991-50-6	NA	--	61	135	0.97	4.0	8.0
2-(N-Methylperfluorooctanesulfonamido) acetic acid	N-MeFOSAA	2355-31-9	NA	--	65	136	0.91	4.0	8.0
Fluorotelomer sulfonic acid 4:2	FTS 4:2	757124-72-4	NA	--	63	143	0.85	2.0	4.0
Perfluorononanesulfonic acid	PFNS	68259-12-1	NA	--	69	127	0.78	2.0	4.0
Perfluoropentanesulfonic acid	PFPeS	2706-91-4	NA	--	71	127	0.69	2.0	4.0
N-ethyl perfluorooctane sulfonamide	EtFOSA	5141-50-2	NA	--	70	130	0.96	4.0	8.0
N-ethyl perfluorooctane sulfonamido ethanol	EtFOSE	1691-99-2	NA	--	70	130	0.90	4.0	8.0
N-methyl perfluorooctane sulfonamide	MeFOSA	31506-32-8	NA	--	70	130	0.97	4.0	8.0
N-methyl perfluorooctane sulfonamido ethanol	MeFOSE	24448-09-7	NA	--	70	130	0.87	4.0	8.0
Hexafluoropropylene oxide dimer acid	HFPO-DA	2062-98-8	NA	--	70	130	1.86	10	20
11-Chloroeicosafluoro-3-oxaundecane-1-sulfonic acid	11 CL-PF3ONS	763051-92-9	NA	--	70	130	0.80	2.0	4.0
9-Chlorohexadecafluoro-3-oxanonane-1-sulfonic acid	9CL-PF3ONS	756426-58-1	NA	--	70	130	0.84	2.0	4.0
4,8-dioxa-3H-perfluorononanoate	ADONA	919005-14-4	NA	--	70	130	1.00	2.0	4.0

Notes:

1.) DQLs for surface water were selected based on the lower of the following:

(a) EGLE Rule 57 Surface Water Quality Values (EGLE, 2020c). Lower of the following:
- Human non-cancer value for surface water body not protected as a source of public drinking water supply.
- Ecological aquatic life final chronic value.

(b) Risk-based surface water SLs protective of incidental ingestion by recreational users. Values were calculated using the USEPA RSL Calculator (USEPA, 2021c) for a recreational exposure scenario based on an exposure frequency of 52 days/year, exposure time of 2.6 hours/day, and ingestion rate of 0.12 L/hour (child) and 0.11 L/hour (adult). Other exposure assumptions are equal to USEPA default values provided in the calculator. USEPA default exposure assumptions are based on a target hazard quotient of 0.1 (PFOS, PFOA, PFBS), a target risk level of 1E-06 (PFOA only), and the following toxicity values:
- USEPA's chronic RfD for PFOA (2E-05 mg/kg-day) published in "Drinking Water Health Advisory for Perfluorooctanoic Acid (PFOA)" (USEPA, 2016a).
- USEPA's chronic RfD for PFOS (2E-05 mg/kg-day) published in "Drinking Water Health Advisory for Perfluorooctane Sulfonate (PFOS)" (USEPA, 2016b).
- USEPA's provisional chronic RfD for PFBS (3E-04 mg/kg-day) published in USEPA's PPRTV paper (USEPA, 2021b).

(c) Risk-based surface water SLs protective of fish consumption by recreational users. SLs were calculated by application of published chemical-specific bioaccumulation factors (Divine et al., 2020) to the risk-based fish tissue SLs calculated using the USEPA RSL Calculator (USEPA, 2021c), based on a fish ingestion rate of 0.011 kilograms of fish per day, a target hazard quotient of 0.1 (PFOS, PFOA, PFBS), a target risk level of 1E-06 (PFOA only), and the following toxicity values:
- USEPA's chronic RfD for PFOA (2E-05 mg/kg-day) published in "Drinking Water Health Advisory for Perfluorooctanoic Acid (PFOA)" (USEPA, 2016a).
- USEPA's chronic RfD for PFOS (2E-05 mg/kg-day) published in "Drinking Water Health Advisory for Perfluorooctane Sulfonate (PFOS)" (USEPA, 2016b).
- USEPA's provisional chronic RfD for PFBS (3E-04 mg/kg-day) published in USEPA's PPRTV paper (USEPA, 2021b).

(d) Guidance for Assessing the Ecological Risks of PFAS to Threatened and Endangered Species at Aqueous Film Forming Foam-Impacted Sites (Conder et al., 2020). The following value was used:
- Ecological aquatic life 5% hazardous concentration.

(e) Approach for Assessing PFAS Risk to Threatened and Endangered Species (Divine et al., 2020). The following values were used:
- Lowest NOAEL RBSL for surface water for aquatic wildlife.
- Freshwater chronic screening level for aquatic life, RWQ RBSL.

(f) Derivation of PFAS Ecological Screening Values. Argonne National Laboratory (Grippo, et al., 2021). The following values were used:
- Surface water ESV for aquatic-dependent wildlife.
- Freshwater chronic ESV for aquatic life.

Notes (continued):

% = percent
CAS = Chemical Abstracts Service
DL = detection limit
DQL = data quality limit
Eco = ecological based DQL
EGLE = Michigan Department of Environment, Great Lakes, and Energy
ESV = ecological screening value
HH = human health based DQL
L = liter
L/hour = liter per hour
LC/MS/MS = liquid chromatography tandem mass spectrometry
LCS = laboratory control spike
LOD = limit of detection
LOQ = limit of quantitation
NA = not available
ng/l = nanograms per liter
NOAEL = No Observed Adverse Effect Level
PPRTV = Provisional Peer-Reviewed Toxicity Values
QSM =Quality Systems Manual
RBSL = risk-based screening level
RSL = Regional Screening Level
RWQ = Recommended Water Quality
SL = screening level
USEPA = United States Environmental Protection Agency

Laboratory: Pace Gulf Coast
Matrix: Porewater (32 Compound Target List)
Analyte Group: PFAS
Method: PFAS by LC/MS/MS compliant with QSM 5.3 Table B-15

Analyte	Abbreviation	CAS Number	DQL (ng/L) [1]	DQL Source	LCS Lower Control Limit (%)	LCS Upper Control Limit (%)	Achievable Laboratory Limits		
							DL (ng/L)	LOD (ng/L)	LOQ (ng/L)
Perfluorobutanoic acid	PFBA	375-22-4	64,600	Eco; Freshwater Chronic ESV Aquatic Life	73	129	0.90	2.0	4.0
Perfluorobutanesulfonic acid	PFBS	375-73-5	400,000	Eco; Freshwater Chronic ESV Aquatic Life	72	130	0.81	2.0	4.0
Perfluoropentanoic acid	PFPeA	2706-90-3	140,000	Eco; Freshwater Chronic RWQ RBSL	72	129	0.85	2.0	4.0
Perfluorohexanoic acid	PFHxA	307-24-4	28,800	Eco; Freshwater Chronic ESV Aquatic Life	72	129	0.99	2.0	4.0
Perfluorohexanesulfonic acid	PFHxS	355-46-4	5,500	Eco; Wildlife ESV	68	131	0.95	2.0	4.0
Perfluoroheptanoic acid	PFHpA	375-85-9	870,000	Eco; Freshwater Chronic RWQ RBSL	72	130	0.48	2.0	4.0
Perfluoroheptanesulfonic acid	PFHpS	375-92-8	NA	--	69	134	0.84	2.0	4.0
Perfluorooctanoic acid	PFOA	335-67-1	4,400	Eco; Wildlife NOAEL-based RBSL	71	133	0.95	2.0	4.0
Perfluorooctanesulfonic acid	PFOS	1763-23-1	12	HH; EGLE HNV (Non-Drinking Water Source)	65	140	0.81	2.0	4.0
Perfluorooctanesulfonamide	PFOSA	754-91-6	NA	--	67	137	0.96	2.0	4.0
Fluorotelomer sulfonic acid 6:2	FTS 6:2	27619-97-2	NA	--	64	140	0.94	2.0	4.0
Perfluorononanoic acid	PFNA	375-95-1	2,080	Eco; Wildlife ESV	69	130	0.78	2.0	4.0
Perfluorodecanoic acid	PFDA	335-76-2	660	Eco; Wildlife ESV	71	129	0.86	2.0	4.0
Perfluorodecanesulfonic acid	PFDS	335-77-3	NA	--	53	142	0.80	2.0	4.0
Fluorotelomer sulfonic acid 8:2	FTS 8:2	39108-34-4	NA	--	67	138	0.90	2.0	4.0
Perfluoroundecanoic acid	PFUdA	2058-94-8	49,000	Eco; Freshwater Chronic RWQ RBSL	69	133	0.95	2.0	4.0
Perfluorododecanoic acid	PFDoA	307-55-1	72,000	Eco; Freshwater Chronic RWQ RBSL	72	134	0.88	2.0	4.0
Perfluorotridecanoic acid	PFTrDA	72629-94-8	NA	--	65	144	0.99	2.0	4.0
Perfluorotetradecanoic acid	PFTeA	376-06-7	NA	--	71	132	0.98	2.0	4.0

Analyte	Abbreviation	CAS Number	DQL (ng/L) [1]	DQL Source	LCS Lower Control Limit (%)	LCS Upper Control Limit (%)	Achievable Laboratory Limits		
							DL (ng/L)	LOD (ng/L)	LOQ (ng/L)
2-(N-Ethylperfluorooctanesulfonamido) acetic acid	N-EtFOSAA	2991-50-6	NA	--	61	135	0.97	4.0	8.0
2-(N-Methylperfluorooctanesulfonamido) acetic acid	N-MeFOSAA	2355-31-9	NA	--	65	136	0.91	4.0	8.0
Fluorotelomer sulfonic acid 4:2	FTS 4:2	757124-72-4	NA	--	63	143	0.85	2.0	4.0
Perfluorononanesulfonic acid	PFNS	68259-12-1	NA	--	69	127	0.78	2.0	4.0
Perfluoropentanesulfonic acid	PFPeS	2706-91-4	NA	--	71	127	0.69	2.0	4.0
N-ethyl perfluorooctane sulfonamide	EtFOSA	5141-50-2	NA	--	70	130	0.96	4.0	8.0
N-ethyl perfluorooctane sulfonamido ethanol	EtFOSE	1691-99-2	NA	--	70	130	0.90	4.0	8.0
N-methyl perfluorooctane sulfonamide	MeFOSA	31506-32-8	NA	--	70	130	0.97	4.0	8.0
N-methyl perfluorooctane sulfonamido ethanol	MeFOSE	24448-09-7	NA	--	70	130	0.87	4.0	8.0
Hexafluoropropylene oxide dimer acid	HFPO-DA	2062-98-8	NA	--	70	130	1.86	10	20
11-Chloroeicosafluoro-3-oxaundecane-1-sulfonic acid	11 CL-PF3ONS	763051-92-9	NA	--	70	130	0.80	2.0	4.0
9-Chlorohexadecafluoro-3-oxanonane-1-sulfonic acid	9CL-PF3ONS	756426-58-1	NA	--	70	130	0.84	2.0	4.0
4,8-dioxa-3H-perfluorononanoate	ADONA	919005-14-4	NA	--	70	130	1.00	2.0	4.0

Notes:

1.) DQLs for porewater were selected based on the lower of the following:
- (a) EGLE Rule 57 Surface Water Quality Values (EGLE, 2020c).
  - HNV for surface water body not protected as a source of public drinking water supply.
- (b) EGLE Rule 57 Surface Water Quality Values (EGLE, 2020c).
  - Ecological aquatic life final chronic value.
- (c) Guidance for Assessing the Ecological Risks of PFAS to Threatened and Endangered Species at Aqueous Film Forming Foam-Impacted Sites (Conder et al., 2020).
  - Ecological aquatic life 5% hazardous concentration.
- (d) Approach for Assessing PFAS Risk to Threatened and Endangered Species (Divine et al., 2020). The following values were used:
  - Lowest NOAEL-based RBSL for surface water for aquatic wildlife.
  - Freshwater chronic screening levels for aquatic life, RWQ RBSL.
- (e) Derivation of PFAS Ecological Screening Values. Argonne National Laboratory (Grippo, et al., 2021). The following values were used:
  - Surface water ESV for aquatic-dependent wildlife.
  - Freshwater chronic ESV for aquatic life.

Notes (continued):

% = percent
CAS = Chemical Abstracts Service
DL = detection limit
DQL = data quality limit
Eco = ecological based DQL
EGLE = Michigan Department of Environment, Great Lakes, and Energy
ESV = ecological screening value
HH = human health based DQL
HNV = Human Non-cancer Value
LC/MS/MS = liquid chromatography tandem mass spectrometry
LCS = laboratory control spike
LOD = limit of detection
LOQ = limit of quantitation
NA = not available
ng/l = nanograms per liter
NOAEL = No Observed Adverse Effect Level
QSM = Quality Systems Manual
RBSL = risk-based screening level
RWQ = Recommended Water Quality

Laboratory: Pace Gulf Coast
Matrix: Soil
Analyte Group: PFAS (32 Compound Target List)
Method: PFAS by LC/MS/MS compliant with QSM 5.3 Table B-15

Analyte	Abbreviation	CAS Number	DQL (µg/kg) [1]	DQL Source	LCS Lower Control Limit (%)	LCS Upper Control Limit (%)	Achievable Laboratory Limits		
							DL (µg/kg)	LOD (µg/kg)	LOQ (µg/kg)
Perfluorobutanoic acid	PFBA	375-22-4	2,980	Eco; Mammalian Soil ESV	71	135	0.070	0.50	1.0
Perfluorobutanesulfonic acid	PFBS	375-73-5	817	Eco; Mammalian Soil ESV	72	128	0.050	0.50	1.0
Perfluoropentanoic acid	PFPeA	2706-90-3	NA	--	69	132	0.050	0.50	1.0
Perfluorohexanoic acid	PFHxA	307-24-4	6,200	Eco; Mammalian Soil ESV	70	132	0.040	0.50	1.0
Perfluorohexanesulfonic acid	PFHxS	355-46-4	2.8	Eco; Mammalian Soil ESV	67	130	0.11	0.50	1.0
Perfluoroheptanoic acid	PFHpA	375-85-9	1,000	Eco; Invertebrates NOEC Soil SL	71	132	0.080	0.50	1.0
Perfluoroheptanesulfonic acid	PFHpS	375-92-8	NA	--	70	132	0.040	0.50	1.0
Perfluorooctanesulfonic acid	PFOS	1763-23-1	0.24	HH; EGLE Groundwater Surface Water Interface Protection Criteria	68	136	0.19	0.50	1.0
Fluorotelomer sulfonic acid 6:2	FTS 6:2	27619-97-2	NA	--	64	140	0.070	0.50	1.0
Perfluorooctanoic acid	PFOA	335-67-1	84	Eco; Plants NOEC Soil SL	69	133	0.060	0.50	1.0
Perfluorooctanesulfonamide	PFOSA	754-91-6	NA	--	67	137	0.10	0.50	1.0
Perfluorononanoic acid	PFNA	375-95-1	24.2	Eco; Mammalian Soil ESV	72	129	0.060	0.50	1.0
Perfluoroundecanoic acid	PFUdA	2058-94-8	NA	--	64	136	0.010	0.50	1.0
Perfluorodecanoic acid	PFDA	335-76-2	67.7	Eco; Mammalian Soil ESV	69	133	0.040	0.50	1.0
Perfluorodecanesulfonic acid	PFDS	335-77-3	NA	--	59	134	0.040	0.50	1.0
Fluorotelomer sulfonic acid 8:2	FTS 8:2	39108-34-4	NA	--	65	137	0.12	0.50	1.0
Perfluorododecanoic acid	PFDoA	307-55-1	NA	--	69	135	0.10	0.50	1.0
Perfluorotridecanoic acid	PFTrDA	72629-94-8	NA	--	66	139	0.12	0.50	1.0
Perfluorotetradecanoic acid	PFTeA	376-06-7	NA	--	69	133	0.12	0.50	1.0
2-(N-Ethylperfluorooctanesulfonamido) acetic acid	N-EtFOSAA	2991-50-6	NA	--	61	139	0.10	0.50	1.0
2-(N-Methylperfluorooctanesulfonamido) acetic acid	N-MeFOSAA	2355-31-9	NA	--	63	144	0.20	0.50	1.0
Fluorotelomer sulfonic acid 4:2	FTS 4:2	757124-72-4	NA	--	62	145	0.080	0.50	1.0

Analyte	Abbreviation	CAS Number	DQL (µg/kg) [1]	DQL Source	LCS Lower Control Limit (%)	LCS Upper Control Limit (%)	Achievable Laboratory Limits		
							DL (µg/kg)	LOD (µg/kg)	LOQ (µg/kg)
Perfluorononanesulfonic acid	PFNS	68259-12-1	NA	--	69	125	0.050	0.50	1.0
Perfluoropentanesulfonic acid	PFPeS	2706-91-4	NA	--	73	123	0.050	0.50	1.0
N-ethyl perfluorooctane sulfonamide	EtFOSA	5141-50-2	NA	--	70	130	0.10	0.50	1.0
N-ethyl perfluorooctane sulfonamido ethanol	EtFOSE	1691-99-2	NA	--	70	130	0.090	0.50	1.0
N-methyl perfluorooctane sulfonamide	MeFOSA	31506-32-8	NA	--	70	130	0.090	0.50	1.0
N-methyl perfluorooctane sulfonamido ethanol	MeFOSE	24448-09-7	NA	--	70	130	0.090	0.50	1.0
Hexafluoropropylene oxide dimer acid	HFPO-DA	2062-98-8	NA	--	70	130	0.24	1.0	2.0
11-Chloroeicosafluoro-3-oxaundecane-1-sulfonic acid	11 CL-PF3ONS	763051-92-9	NA	--	70	130	0.11	0.50	1.0
9-Chlorohexadecafluoro-3-oxanonane-1-sulfonic acid	9CL-PF3ONS	756426-58-1	NA	--	70	130	0.16	0.50	1.0
4,8-dioxa-3H-perfluorononanoate	ADONA	919005-14-4	NA	--	70	130	0.050	0.50	1.0

Notes:

1.) DQLs for soil were selected based on the lower of the following:

(a) EGLE Cleanup Criteria Requirements for Response Activity (Formerly the Part 201 Generic Cleanup Criteria and Screening Levels) (EGLE, 2018b).
- Soil values for GSIPC.

(b) Risk-based soil SLs calculated in accordance with the OSD Memorandum (Assistant Secretary of Defense, 2021). The OSD SLs values were calculated using the USEPA RSL Calculator (USEPA, 2021c) for a residential exposure scenario using USEPA default exposure assumptions based on a target hazard quotient of 0.1 (PFOS, PFOA, PFBS), a target risk level of 1E-06 (PFOA only), and the following toxicity values:
- USEPA's chronic RfD for PFOA (2E-05 mg/kg-day) published in "Drinking Water Health Advisory for Perfluorooctanoic Acid (PFOA)" (USEPA, 2016a).
- USEPA's chronic RfD for PFOS (2E-05 mg/kg-day) published in "Drinking Water Health Advisory for Perfluorooctane Sulfonate (PFOS)" (USEPA, 2016b).
- USEPA's provisional chronic RfD for PFBS (3E-04 mg/kg-day) published in USEPA's PPRTV paper (USEPA, 2021b).

(c) Risk-based soil SLs calculated in accordance with the OSD Memorandum (Assistant Secretary of Defense, 2021). These values were calculated using the USEPA RSL Calculator (USEPA, 2021c) for an industrial exposure scenario using USEPA default exposure assumptions based on a target hazard quotient of 0.1 (PFOS, PFOA, PFBS), a target risk level of 1E-06 (PFOA only), and the following toxicity values:
- USEPA's chronic RfD for PFOA (2E-05 mg/kg-day) published in "Drinking Water Health Advisory for Perfluorooctanoic Acid (PFOA)" (USEPA, 2016a).
- USEPA's chronic RfD for PFOS (2E-05 mg/kg-day) published in "Drinking Water Health Advisory for Perfluorooctane Sulfonate (PFOS)" (USEPA, 2016b).
- USEPA's provisional chronic RfD for PFBS (3E-04 mg/kg-day) published in USEPA's PPRTV paper (USEPA, 2021b).

(d) Guidance for Assessing the Ecological Risks of PFAS to Threatened and Endangered Species at Aqueous Film Forming Foam-Impacted Sites (Conder et al., 2020). Recommended Toxicity Benchmarks for Terrestrial Plants and Invertebrates; based on NOECs.

(e) Approach for Assessing PFAS Risk to Threatened and Endangered Species (Divine et al., 2020). The following values were used:
- Lowest NOAEL-based RBSL for soil for terrestrial wildlife.
- NOEC-based soil screening level for plants.
- NOEC-based soil screening level for invertebrates.

(f) Derivation of PFAS Ecological Screening Values. Argonne National Laboratory (Grippo, et al., 2021). The following values were used:
- Lowest soil ESV for birds and mammals.
- Soil ESV for terrestrial plants.
- Soil ESV for terrestrial invertebrates.

Notes (continued):

μg/kg = micrograms per kilogram
CAS = Chemical Abstracts Service
DL = detection limit
DQL = data quality limit
Eco = ecological based DQL
EGLE = Michigan Department of Environment, Great Lakes, and Energy
ESV = ecological screening value
FTS = fluorotelomer sulfonic acid
GSIPC = Groundwater Surface Water Interface Protection Criteria
HH = human health based DQL
LC/MS/MS = liquid chromatography tandem mass spectrometry
LCS = laboratory control spike
LOD = limit of detection
LOQ = limit of quantitation
NA = not available
NOAEL = No Observed Adverse Effect Level
NOEC = No Observed Effect Concentration
QSM = Quality Systems Manual
RBSL = Risk-Based Screening Level
RSL = Regional Screening Level
SL = Screening Level
USEPA = United States Environmental Protection Agency

Laboratory: Pace Gulf Coast
Matrix: Sediment
Analyte Group: PFAS (32 Compound Target List)
Method: PFAS by LC/MS/MS compliant with QSM 5.3 Table B-15

Analyte	Abbreviation	CAS Number	DQL (µg/kg) [1]	DQL Source	LCS Lower Control Limit (%)	LCS Upper Control Limit (%)	Achievable Laboratory Limits		
							DL (µg/kg)	LOD (µg/kg)	LOQ (µg/kg)
Perfluorobutanoic acid	PFBA	375-22-4	1,600	Eco; NOAEL-based RBSL	71	135	0.070	0.50	1.0
Perfluorobutanesulfonic acid	PFBS	375-73-5	730	Eco; NOAEL-based RBSL	72	128	0.050	0.50	1.0
Perfluoropentanoic acid	PFPeA	2706-90-3	NA	--	69	132	0.050	0.50	1.0
Perfluorohexanoic acid	PFHxA	307-24-4	1,800	Eco; NOAEL-based RBSL	70	132	0.040	0.50	1.0
Perfluorohexanesulfonic acid	PFHxS	355-46-4	NA	--	67	130	0.11	0.50	1.0
Perfluoroheptanoic acid	PFHpA	375-85-9	NA	--	71	132	0.080	0.50	1.0
Perfluoroheptanesulfonic acid	PFHpS	375-92-8	NA	--	70	132	0.040	0.50	1.0
Perfluorooctanesulfonic acid	PFOS	1763-23-1	0.76	HH; Sediment SL Protective of Fish Consumption	68	136	0.19	0.50	1.0
Fluorotelomer sulfonic acid 6:2	FTS 6:2	27619-97-2	NA	--	64	140	0.070	0.50	1.0
Perfluorooctanoic acid	PFOA	335-67-1	3.3	HH; Sediment SL Protective of Fish Consumption	69	133	0.060	0.50	1.0
Perfluorooctanesulfonamide	PFOSA	754-91-6	NA	--	67	137	0.10	0.50	1.0
Perfluorononanoic acid	PFNA	375-95-1	10	Eco; NOAEL-based RBSL	72	129	0.060	0.50	1.0
Perfluoroundecanoic acid	PFUdA	2058-94-8	NA	--	64	136	0.010	0.50	1.0
Perfluorodecanoic acid	PFDA	335-76-2	NA	--	69	133	0.040	0.50	1.0
Perfluorodecanesulfonic acid	PFDS	335-77-3	NA	--	59	134	0.040	0.50	1.0
Fluorotelomer sulfonic acid 8:2	FTS 8:2	39108-34-4	NA	--	65	137	0.12	0.50	1.0
Perfluorododecanoic acid	PFDoA	307-55-1	NA	--	69	135	0.10	0.50	1.0
Perfluorotridecanoic acid	PFTrDA	72629-94-8	NA	--	66	139	0.12	0.50	1.0

Analyte	Abbreviation	CAS Number	DQL (µg/kg) [1]	DQL Source	LCS Lower Control Limit (%)	LCS Upper Control Limit (%)	Achievable Laboratory Limits		
							DL (µg/kg)	LOD (µg/kg)	LOQ (µg/kg)
Perfluorotetradecanoic acid	PFTeA	376-06-7	NA	--	69	133	0.12	0.50	1.0
2-(N-Ethylperfluorooctanesulfonamido) acetic acid	N-EtFOSAA	2991-50-6	NA	--	61	139	0.10	0.50	1.0
2-(N-Methylperfluorooctanesulfonamido) acetic acid	N-MeFOSAA	2355-31-9	NA	--	63	144	0.20	0.50	1.0
Fluorotelomer sulfonic acid 4:2	FTS 4:2	757124-72-4	NA	--	62	145	0.080	0.50	1.0
Perfluorononanesulfonic acid	PFNS	68259-12-1	NA	--	69	125	0.050	0.50	1.0
Perfluoropentanesulfonic acid	PFPeS	2706-91-4	NA	--	73	123	0.050	0.50	1.0
N-ethyl perfluorooctane sulfonamide	EtFOSA	5141-50-2	NA	--	70	130	0.10	0.50	1.0
N-ethyl perfluorooctane sulfonamido ethanol	EtFOSE	1691-99-2	NA	--	70	130	0.090	0.50	1.0
N-methyl perfluorooctane sulfonamide	MeFOSA	31506-32-8	NA	--	70	130	0.090	0.50	1.0
N-methyl perfluorooctane sulfonamido ethanol	MeFOSE	24448-09-7	NA	--	70	130	0.090	0.50	1.0
Hexafluoropropylene oxide dimer acid	HFPO-DA	2062-98-8	NA	--	70	130	0.24	1.0	2.0
11-Chloroeicosafluoro-3-oxaundecane-1-sulfonic acid	11 CL-PF3ONS	763051-92-9	NA	--	70	130	0.11	0.50	1.0
9-Chlorohexadecafluoro-3-oxanonane-1-sulfonic acid	9CL-PF3ONS	756426-58-1	NA	--	70	130	0.16	0.50	1.0
4,8-dioxa-3H-perfluorononanoate	ADONA	919005-14-4	NA	--	70	130	0.050	0.50	1.0

Notes:

1.) DQLs for sediment were selected based on the lower of the following:

(a) Risk-based SLs protective of incidental ingestion and dermal contact by recreational users. Values were calculated using the USEPA RSL Calculator (USEPA, 2021c) for a recreational exposure scenario based on an exposure frequency of 52 days/year and ingestion rate of 200 mg/day (child) and 100 mg/day (adult). Other exposure assumptions are equal to USEPA default values provided in the calculator. USEPA default exposure assumptions are based on a target hazard quotient of 0.1 (PFOS, PFOA, PFBS), a target risk level of 1E-06 (PFOA only), and the following toxicity values:
- USEPA's chronic RfD for PFOA (2E-05 mg/kg-day) published in “Drinking Water Health Advisory for Perfluorooctanoic Acid (PFOA)” (USEPA, 201a6a).
- USEPA's chronic RfD for PFOS (2E-05 mg/kg-day) published in “Drinking Water Health Advisory for Perfluorooctane Sulfonate (PFOS)” (USEPA, 2016b).
- USEPA's provisional chronic RfD for PFBS (3E-04 mg/kg-day) published in USEPA's PPRTV paper (USEPA, 2021b).

(b) Risk-based sediment SLs protective of fish consumption by recreational users. SLs were calculated by application of published chemical-specific biota-sediment accumulation factors (Divine et al. 2020) to the risk-based fish tissue SLs calculated using the USEPA RSL Calculator (USEPA, 2021c), based on an ingestion rate of 0.011 kg of fish per day, a target hazard quotient of 0.1 (PFOS, PFOA), a target risk level of 1E-06 (PFOA only), and the following toxicity values:
- USEPA's chronic RfD for PFOA (2E-05 mg/kg-day) published in “Drinking Water Health Advisory for Perfluorooctanoic Acid (PFOA)” (USEPA, 2016a).
- USEPA's chronic RfD for PFOS (2E-05 mg/kg-day) published in “Drinking Water Health Advisory for Perfluorooctane Sulfonate (PFOS)” (USEPA, 2016b).
- USEPA's provisional chronic RfD for PFBS (3E-04 mg/kg-day) published in USEPA's PPRTV paper (USEPA, 2021b).

(c) Approach for Assessing PFAS Risk to Threatened and Endangered Species (Divine et al., 2020). The following values were used:
- Lowest NOAEL-based RBSL for sediment for aquatic wildlife.

(d) Screening of Polyfluorinated Compounds at Four Fire Training Facilities in Norway (NPCA, 2008). The following values were used:
- NPCA No Toxic Effects range from 0.17 -220 UG/KG (Table 20).

Notes (continued):
µg/kg = micrograms per kilogram
CAS = Chemical Abstracts Service
DL = detection limit
DQL = data quality limit
Eco = ecological based DQL
HH = human health based DQL
LC/MS/MS = liquid chromatography tandem mass spectrometry
LCS = laboratory control spike
LOD = limit of detection
LOQ = limit of quantitation
mg/day = milligrams per day
NA = not available
NOAEL = No Observed Adverse Effect Level
NPCA = Norwegian Pollution Control Authority
QSM = Quality Systems Manual
RBSL = Risk-Based Screening Level
RfD = reference dose
RSL = Regional Screening Level
SL = screening level
USEPA = United States Environmental Protection Agency

Laboratory: Pace Gulf Coast
Matrix: Solid (Soil/ Sediment)
Analyte Group: TOC
Method: USEPA 9060A

Analyte	CAS Number	DQL (µg/kg)	DQL Source	Screening Standard and Source	LOQ (µg/kg)	LOD (µg/kg)	DL (µg/kg)	Accuracy Control Limit (%R)	Precision Control Limit RPD
Total Organic Carbon	C-012	NA	--	NA	250,000	200,000	153,000	69-128	≤20

Notes:
%R = percent recovery
µg/kg = micrograms per kilogram
CAS = Chemical Abstracts Service
DL = detection limit
DQL = data quality limit
LOD = limit of detection
LOQ = limit of quantitation
NA = not available
RPD = relative percent difference
TOC = total organic carbon
USEPA = United States Environmental Protection Agency

Laboratory: Pace Gulf Coast
Matrix: Solid (Soil/ Sediment)
Analyte Group: pH
Method: SM USEPA 9045D

Analyte	CAS Number	DQL (SU)	DQL Source	Screening Standard and Source	LOQ (SU)	LOD (SU)	DL (SU)	Accuracy Control Limit (%R)	Precision Control Limit RPD
pH	NA	NA	--	1	1	1	NA	±0.05	±0.1

Notes:
%R = percent recovery
CAS = Chemical Abstracts Service
DL = detection limit
LOD = limit of detection
LOQ = limit of quantitation
NA = not available
RPD = relative percent difference
SU = standard unit
USEPA = United States Environmental Protection Agency

QAPP Worksheet #17 & #18: Sampling Design and Rationale

Worksheet #17 & #18 provide the sampling design and rationale, in addition to the sampling locations and methods, for the Grand Ledge AASF RI Mobilization 1. The sampling program was designed to meet the DQOs established in **Worksheet #11**, while considering the CSM summarized in **Worksheet #10**. Based on the updated OSD SLs (Assistant Secretary of Defense, 2022) and the discussion in **Worksheet #10**, two AOIs with exceedances of the OSD SLs were identified at the facility (AECOM, 2021a):

- AOI 1: AASF Hangar and Armory
- AOI 2: Annex Building

The RI field activities for the Grand Ledge AASF will be conducted over two field mobilizations. During the RI Mobilization 1, soil and grab groundwater samples will be collected for PFAS from multiple intervals at biased sampling locations surrounding known impacts as identified during the SI. The sampling locations for RI Mobilization 1 primarily include a perimeter sampling approach for temporary well installation and surface soil collection. Additionally, surface water/sediment/porewater samples will be obtained from the retention pond and former drainage ditch. Data collected during RI Mobilization 1 will be used to determine areas where Rapid Site Characterization (RSC) is needed to refine the locations for permanent monitoring well installation. The RSC and permanent well installation will take place during RI Mobilization 2.

Grab groundwater data collected during the RI Mobilization 1 are screening-level data that will not be used in the risk assessments; however, the soil data obtained during RI Mobilization 1 may be considered in the risk assessments to occur after RI Mobilization 2. This Worksheet describes the sampling design and rationale for the RI Mobilization 1.

Analytical data from the 2021 ARNG SI (AECOM, 2021a) within the investigation area were used to refine the approach for RI Mobilization 1. The data from this source are considered screening-level and will not be used in the risk assessment.

The sampling program for the RI Mobilization 1 will include:

- Collection of grab soil samples from DPT soil borings and one soil grid;
- Collection of grab groundwater samples from multi-interval temporary monitoring wells;
- Collection of low-flow groundwater samples from existing monitoring wells;
- Collection of synoptic water levels in existing monitoring wells, newly-installed temporary monitoring wells, and staff gauges; and,
- Collection of surface water, sediment, and porewater samples from the stormwater retention basin.

The following subsections provide the specific sampling design and rationale for the selection of sampling locations for the RI Mobilization 1. The proposed locations of samples to be collected are presented on **Figure 17-1** and **Figure 17-2**. The specific design rationale for each task, in addition to the sampling locations and methods, are included in **Table 17-1** and **Table 17-2**. References to the SOP used during sampling can be found in the footnotes of **Table 17-1** and **Table 17-2**. Analytical requirements to achieve project objectives and support the quantification of potential risks are detailed in **Worksheet #15**. Field activities will be completed in accordance with the procedures outlined in **Worksheet #14** and the SOPs in **Appendix D**.

In instances where deviations from this sampling design and rationale are made due to unforeseen conditions, a Field Change Request Form will be generated to document the change and request feedback from the AECOM Task and Project Managers, USACE, and ARNG.

17.1 Soil and Groundwater Sampling Design and Rationale

The RI field activities for the Grand Ledge AASF will consist of at least two Mobilizations. During Mobilization 1, soil and grab groundwater samples will be collected for PFAS in the vicinities where sampling locations during the SI previously identified exceedance(s) of the OSD screening levels, along the facility boundaries and from transects across the Site to investigate potential PFAS source areas.

Data collected during RI Mobilization 1 will be used to refine the approach for RI Mobilization 2, currently anticipated to include further groundwater sampling and the installation of additional permanent monitoring wells, as well as any additional necessary screening-level data. The purpose of the RI Mobilization 1 is to perform additional screening-level sampling at AOI 1, AOI 2, and AOI 3:

- In AOI 1, exceedances of the PFOA, PFOS, and PFHxS OSD SLs were documented in perched groundwater sampled between the tarmac and motor pool areas.
- In AOI 2, exceedance of PFOS and PFHxS OSD SLs in groundwater. Additionally, fire training activities may have been performed. Bulk and expired AFFF units are stored within the Annex building. Based on the SI data, a potential data gap may exist relative to the location of the SI samples. Additional sampling is needed within the potential release area to fill the data gap.
- In AOI 3, firetruck storage and fire training activities may have occurred. There also may have been a fuel spill where AFFF may have been used to wash the fuel off. This area was previously owned by the MIARNG, but is not currently under the control of the MIARNG. As a result, this area was not investigated during the SI.

The exact locations of these PFAS releases to soil, their full lateral and/or vertical extent of impacts to groundwater, and/or the migration pathways between the source areas and boundaries are not fully understood and are further complicated by significant soil movement during construction activities. Therefore, to fill data gaps in both the vertical and horizontal distribution of PFAS in groundwater and soil, a total of 38 boring locations will be completed using DPT, in a strategic order, with a total of 66 surface and subsurface soil samples and a minimum of 75 grab groundwater samples (not including QC samples). Additionally, one soil grid comprised of 12 surface and 12 shallow subsurface soil in the undisturbed area of AOI 1 will be evaluated. Groundwater will also be sampled from each of the seven permanent monitoring wells previously installed at the facility during the SI.

Groundwater and soil samples will be analyzed under standard TAT for the target list of 32 PFAS by LC/MS/MS compliant with QSM 5.3 Table B-15, as specified in **Worksheet #15**. Additionally, 25% of soil samples will be analyzed for TOC (USEPA Method 9060A), pH (USEPA Method 9045D), and grain size with sieve and hydrometer (ASTM D-422). Sampling results will be used to allow for modifications and ongoing refinement of RI Mobilization 2 sampling locations, as possible, in combination with any other observations (e.g., the presence of clay confining units).

The sample locations are shown on **Figure 17-1** and **Figure 17-2**. The rationale for the sample locations is provided in **Table 17-1** and **Table 17-2**. Sampling activities will be conducted in accordance with the procedures established in **Worksheet #14** and in the SOPs (**Appendix D**).

17.2 Synoptic Groundwater and Surface Water Level Gauging Design and Rationale

As part of RI Mobilization 1, groundwater levels will be collected from existing permanent groundwater monitoring wells. The purpose is to determine the potentiometric surface and calculation of the groundwater gradient at the facility. The monitoring well locations are those as outlined below and shown as monitoring wells in **Figure 17-1**. The procedures for collection of water levels from monitoring wells are presented in **Worksheet #14**.

- AOI 1: AOI 1-10 through AOI 1-15
- AOI 2: AOI 2-4

Additionally, water levels will be collected from staff gauges installed within the stormwater retention basin. Two staff gauges will be installed with slotted piezometers to allow for porewater sampling within the stormwater retention basin. The purpose of the staff gauges is to aid in the interpretation of groundwater/ surface water interactions and overall groundwater flow through the surficial aquifer system. The procedures for the installation of staff gauges and collection of water levels from staff gauges are presented in **Worksheet #14**. The preliminary approximate locations of the staff gauges are shown on **Figure 17-1**.

The groundwater/surface water level gauging round will be conducted within as short a time period as reasonably feasible and will follow a period of little to no precipitation. The water level gauging event will be conducted on a day when little to no precipitation is forecasted, and because surface water levels may fluctuate more strongly than groundwater levels, the surface water levels will be measured at the two designated staff gauge locations at the very end of the gauging event.

17.3 Surface Water, Sediment, and Porewater Sampling Design and Rationale

Surface water, sediment, and porewater samples will be collected from the stormwater retention basin that receives surface water runoff from paved areas, and conveyance from the facility. PFAS released at the facility may also be transported via groundwater to the stormwater retention basin. Within this surface water body, a minimum of seven samples per media will be collected in order to refine the nature and extent of PFAS within the surface water, sediment, and porewater features.

As a conservative approach, sample locations will be biased to locations of suspected groundwater discharge to surface water. Approximate locations of groundwater discharge to surface water will be determined based on the results of a TIR survey. As an initial survey tool, TIR provides an efficient evaluation in shallow surface water environments. To evaluate the potential locations of groundwater seepage, the TIR survey will be conducted with a hand-held forward-looking infrared camera. TIR methods utilize the temperature contrast between groundwater and surface water to visualize groundwater seeps under ideal conditions. Groundwater temperature typically remains constant year-round and often is approximated as annual air temperature, which ranges from 39°F to 57°F in Michigan (US Climate Data, 2021). Surface water temperature generally equalizes with the surrounding air temperature and is subject to the diurnal and annual temperature fluctuations; therefore, utilizing the thermal contrast between groundwater temperature and surface water temperature provides a method of identifying groundwater seepage/discharge into a given surface water body. Thermal methods are particularly successful during the summer and winter months, when there is the largest contrast between groundwater and surface water temperatures.

Through the collection of the relative temperature difference data, using the TIR, relative groundwater seepage fluxes can be distinguished. These differences can be induced by hydraulic pressure differences or can be a result of differences in the hydraulic conductivity between the stream materials and the adjacent soils. A low seepage flux of groundwater to surface water will result in a groundwater seepage temperature that is more similar to the surface water temperature, while a higher seepage flux will result in a greater temperature contrast. Therefore, the lower the seepage flux magnitude, the more difficult it is to distinguish the groundwater seep from the background surface water. Additionally, the evaluation of the TIR images can be difficult with respect to the identification of separate locations of diffuse seepage and areas of mixing from upgradient discrete sources. It should be noted that the evaluation of the TIR images provides relative seepage flux comparisons but is not capable of predicting quantifiable seepage flux estimates (Röper et al., 2014).

The approximate locations of the surface water, sediment, and porewater samples are shown on **Figure 17-1**; however, the locations will be adjusted in the field based on field conditions**.** The exact porewater location will be selected based on TIR survey to determine the locations of groundwater seepage, which discharges to surface water. If a groundwater seep cannot be identified during the TIR survey, a porewater sample will not be obtained. As a result of the TIR survey, the porewater samples may not be co-located with the surface water and sediment samples. Sample location AOI1-51 is near the outfall that discharges off-facility. One sample per media will be collected in both dry and wet conditions at this location. Dry weather is defined as more than 72 hours after the end of the latest precipitation event.Surface water, sediment, and porewater samples will be analyzed under standard TAT for the target list of 32 PFAS by LC/MS/MS compliant with QSM 5.3 Table B-15, as specified in **Worksheet #15**. Additionally, 25% of sediment samples will be analyzed for TOC (USEPA Method 9060A), pH (USEPA Method 9045D), and grain size with sieve and hydrometer (ASTM D-422). The sediment samples analyzed for TOC, pH, and grain size will be selected to represent the range of habitat and substrate types available at the sampling locations. The sampling procedures are further detailed in *SOP 3-10: Surface Water Sampling*, *SOP 3-22: Sediment Sampling*, and *SOP 3-43: Porewater Sampling* (**Appendix D**).

Table 17-1: RI Mobilization 1 Sampling Design and Rationale - Groundwater, Surface Water/Sediment/Porewater

Area of Interest	Sample Matrix	Location Identifier	Sub-Location Identifier	Well Status	Target Screen Interval (feet bgs)	Synoptic Gauging	Sample Identifier	Number of Samples per Location	Sampling Tool	Analyte Group	Rationale
AOI 1	Groundwater	AOI 1-10	GL-MW-01-10	existing	80-100	X	GL-MW-01-10-[MMDDYY]	1	Bladder Pump[1]	PFAS, Target 32 Compound List (LC/MS/MS compliant with QSM 5.3 Table B-15)	Evaluate deeper groundwater at existing well locations surrounding the AOI 1 potential release area.
		AOI 1-11	GL-MW-01-11	existing	30-40	X	GL-MW-01-11-[MMDDYY]	1			
		AOI 1-12	GL-MW-01-12	existing	47-57	X	GL-MW-01-12-[MMDDYY]	1			
		AOI 1-13	GL-MW-01-13	existing	42-52	X	GL-MW-01-13-[MMDDYY]	1			
		AOI 1-14	GL-MW-01-14	existing	50-60	X	GL-MW-01-14-[MMDDYY]	1			
		AOI 1-15	GL-MW-01-15	existing	60-75	X	GL-MW-01-15-[MMDDYY]	1			
		AOI 1-26	GL-TMW-01-26	proposed	5-10 20-25	X	GL-TMW-01-26-[end depth]	2	Peristaltic Pump or Bladder Pump[2]		Evaluate groundwater at most upgradient location within the facility boundary and of the stormwater retention basin. AOI 1-26 is one of four groundwater well locations surrounding the stormwater retention basin. See rationale for AOI 1-47 through AOI 1-49 for further explanation.
		AOI 1-27	GL-TMW-01-27	proposed	5-10 20-25	X	GL-TMW-01-27-[end depth]	2			Evaluate groundwater along transects at facility perimeter locations and the former drainage ditch in the AOI 1.
		AOI 1-28	GL-TMW-01-28	proposed	5-10 20-25	X	GL-TMW-01-28-[end depth]	2			Evaluate groundwater at facility perimeter to determine if PFAS contamination is coming onto facility at various locations on the northern boundary. Only one grab groundwater sample was obtained during the SI Mobilizations; therefore, the additional three groundwater locations satisfy a data gap on the northern boundary.
		AOI 1-29	GL-TMW-01-29	proposed	5-10 20-25	X	GL-TMW-01-29-[end depth]	2			
		AOI 1-30	GL-TMW-01-30	proposed	5-10 20-25	X	GL-TMW-01-30-[end depth]	2			
		AOI 1-31	GL-TMW-01-31	proposed	5-10 20-25	X	GL-TMW-01-31-[end depth]	2			Evaluate groundwater downgradient from the motor pool area where there was reportedly fire training with AFFF fire extinguishers. These locations also serve as perimeter wells to determine if PFAS is migrating off facility. Additionally, during the SI Mobilization 2, PFOA was detected at AOI 1-12 with a concentration of 28.2 ng/L. The proposed locations AOI 1-31 through AOI 1-36 are downgradient of AOI 1-12. In order to evaluate vertical extent at the most downgradient location, AOI 1-32 and AOI 1-36 will include a third depth of 40-45 ft bgs.
		AOI 1-32	GL-TMW-01-32	proposed	5-10 20-25 40-45	X	GL-TMW-01-32-[end depth]	3			
		AOI 1-33	GL-TMW-01-33	proposed	5-10 20-25	X	GL-TMW-01-33-[end depth]	2			
		AOI 1-34	GL-TMW-01-34	proposed	5-10 20-25	X	GL-TMW-01-34-[end depth]	2			
		AOI 1-35	GL-TMW-01-35	proposed	5-10 20-25	X	GL-TMW-01-35-[end depth]	2			
		AOI 1-36	GL-TMW-01-36	proposed	5-10 20-25 40-45	X	GL-TMW-01-36-[end depth]	3			
		AOI 1-37	GL-TMW-01-37	proposed	5-10 20-25	X	GL-TMW-01-37-[end depth]	2			Proposed locations AOI 1-37 through AOI 1-40 are downgradient from the Armory where a fire truck potentially containing AFFF had been parked in the 1980s. Temporary monitoring wells AOI 1-37 and AOI 1-38 are located on eastern facility boundary, and AOI 1-39 is located on the southern facility boundary. During the SI Mobilization 1, PFOA and PFOS exceeded the OSD SL from a temporary well immediately to the east of proposed location AOI 1-35. In order to evaluate vertical extent at the most downgradient location, AOI 1-38 will include a third depth of 40-45 ft bgs.
		AOI 1-38	GL-TMW-01-38	proposed	5-10 20-25 40-45	X	GL-TMW-01-38-[end depth]	3			
		AOI 1-39	GL-TMW-01-39	proposed	5-10 20-25	X	GL-TMW-01-39-[end depth]	2			
		AOI 1-40	GL-TMW-01-40	proposed	5-10 20-25	X	GL-TMW-01-40-[end depth]	2			
		AOI 1-41	GL-TMW-01-41	proposed	5-10 20-25	X	GL-TMW-01-41-[end depth]	2			Proposed locations AOI 1-41 through AOI 1-44 are downgradient from the Hangar which is equipped with an AFFF fire suppression system. These locations are located on the southern facility boundary to determine if there is any PFAS migration. Historical aerial imagery shows surface debris and lack of vegetation to the south/southeast of the cold storage. Location AOI 1-41 is downgradient the area to determine if there is a potential source area.
		AOI 1-42	GL-TMW-01-42	proposed	5-10 20-25	X	GL-TMW-01-42-[end depth]	2			
		AOI 1-43	GL-TMW-01-43	proposed	5-10 20-25	X	GL-TMW-01-43-[end depth]	2			
		AOI 1-44	GL-TMW-01-44	proposed	5-10 20-25	X	GL-TMW-01-44-[end depth]	2			

Table 17-1: RI Mobilization 1 Sampling Design and Rationale - Groundwater, Surface Water/Sediment/Porewater

Area of Interest	Sample Matrix	Location Identifier	Sub-Location Identifier	Well Status	Target Screen Interval (feet bgs)	Synoptic Gauging	Sample Identifier	Number of Samples per Location	Sampling Tool	Analyte Group	Rationale
AOI 1	Groundwater	AOI 1-45	GL-TMW-01-45	proposed	5-10 20-25	X	GL-TMW-01-45-[end depth]	2	Peristaltic Pump or Bladder Pump[2]	PFAS, Target 32 Compound List (LC/MS/MS compliant with QSM 5.3 Table B-15)	Evaluate groundwater along transect at the former drainage ditch and downgradient from the wash rack. During the SI Mobilization 2, several surface soil samples were obtained from the surrounding area of the Wash Bay. In this vicinity, the maximum surface soil detections for PFOA and PFOS were 0.331 J µg/Kg and 11.0 µg/Kg, respectively. Proposed locations AOI 1-45 and AOI 1-46 will determine if there is a source area, and if groundwater is impacted near the Wash Bay. AOI 1-46 is located within the immediate area of the Wash Bay, and AOI 1-45 is located downgradient.
		AOI 1-46	GL-TMW-01-46	proposed	5-10 20-25	X	GL-TMW-01-46-[end depth]	2			
		AOI 1-47	GL-TMW-01-47	proposed	5-10 20-25	X	GL-TMW-01-47-[end depth]	2			Evaluate groundwater surrounding the stormwater retention basin to determine pathway/extent of PFAS migration. Due to perched groundwater, there is a potential the groundwater is reaching the surface and co-mingling with surface water. AOI 1-26, and AOI 1-47 through AOI 1-49 will help determine if PFAS contamination reaches the surficial groundwater in the immediate area surrounding the stormwater retention basin, or, if PFAS migration is occurring through the engineered stormwater structures.
		AOI 1-48	GL-TMW-01-48	proposed	5-10 20-25	X	GL-TMW-01-48-[end depth]	2			
		AOI 1-49	GL-TMW-01-49	proposed	5-10 20-25	X	GL-TMW-01-49-[end depth]	2			
	Surface Water	AOI 1-50	GL-SRB-01-50	proposed	middle of water column	N/A	GL-SRB-01-50-SW-[MMDDYY]	1	None[3]	PFAS, Target 32 Compound List (LC/MS/MS compliant with QSM 5.3 Table B-15)	Evaluate surface water, sediment, and porewater at the stormwater retention basin. In this area, surface water flows to the northwest from the Hangar and Wash Bay. The catch basins in the Wash Bay discharges to the retention pond when the line to the oil/water separator and municipal system is blocked. Sample locations AOI 1-54, and AOI 1-55 are adjacent to the stormwater culverts to evaulate if discharge from the Wash Bay is occurring. Sample location AOI 1-53 is adjacent to the stormwater culvert discharging from the large apron in the center/east side of the facility. During the SI Mobilization 1 and 2, the maximum surface water concentration for PFOA and PFOS was 20.5 ng/L, and 283 J+ ng/L, respectively. Additionally, the maximum sediment concentrations for PFOA and PFOS was 7.15 J µg/Kg , and 26.3 µg/Kg, respectively. Proposed locations AOI 1-50 through AOI 1-58 are situated to further characterize the perimeter of the stormwater retention basin. It is unknown if PFAS migration to the stormwater retention basin is due to overland surface water flow and engineered stormwater structures, or, via perched groundwater/surface water interactions. The surface water, sediment, porewater samples, will be compared to the surrounding groundwater samples to help determine if there is any interaction of groundwater and surface water. The exact porewater location will be selected based on TIR survey to determine the locations of groundwater discharges to surface water. If a seep cannot be identified during the TIR survey, a porewater sample will not be obtained. As a result, surface water and sediment samples may not be co-located with the porewater samples.
		AOI 1-51	GL-SRB-01-51	proposed		N/A	GL-SRB-01-51-SW-[MMDDYY]	2[d]			
		AOI 1-52	GL-SRB-01-52	proposed		N/A	GL-SRB-01-52-SW-[MMDDYY]	1			
		AOI 1-53	GL-SRB-01-53	proposed		N/A	GL-SRB-01-53-SW-[MMDDYY]	1			
		AOI 1-54	GL-SRB-01-54	proposed		N/A	GL-SRB-01-54-SW-[MMDDYY]	1			
		AOI 1-55	GL-SRB-01-55	proposed		N/A	GL-SRB-01-55-SW-[MMDDYY]	1			
		AOI 1-56	GL-SRB-01-56	proposed		N/A	GL-SRB-01-56-SW-[MMDDYY]	1			
	Sediment	AOI 1-50	GL-SRB-01-50	proposed	0-0.5	N/A	GL-SRB-01-50-SD-[MMDDYY]	1	Coring Device (e.g., Hand Auger)[4]	PFAS, Target 32 Compound List (LC/MS/MS compliant with QSM 5.3 Table B-15) Limited Sample Selection (25% of samples): TOC (USEPA Method 9060A) pH (USEPA Method 9045D) Grain Size/Clay Content (ASTM D-422)	
		AOI 1-51	GL-SRB-01-51	proposed		N/A	GL-SRB-01-51-SD-[MMDDYY]	2[d]			
		AOI 1-52	GL-SRB-01-52	proposed		N/A	GL-SRB-01-52-SD-[MMDDYY]	1			
		AOI 1-53	GL-SRB-01-53	proposed		N/A	GL-SRB-01-53-SD-[MMDDYY]	1			
		AOI 1-54	GL-SRB-01-54	proposed		N/A	GL-SRB-01-54-SD-[MMDDYY]	1			
		AOI 1-55	GL-SRB-01-55	proposed		N/A	GL-SRB-01-55-SD-[MMDDYY]	1			
		AOI 1-56	GL-SRB-01-56	proposed		N/A	GL-SRB-01-56-SD-[MMDDYY]	1			
	Porewater	AOI 1-50	GL-SRB-01-50	proposed	1.5-5	N/A	GL-SRB-01-50-PO-[MMDDYY]	1	Pushpoint Sampler; Peristaltic Pump; Piezometer[5]	PFAS, Target 32 Compound List (LC/MS/MS compliant with QSM 5.3 Table B-15)	
		AOI 1-51	GL-SRB-01-51	proposed		N/A	GL-SRB-01-51-PO-[MMDDYY]	2[d]			
		AOI 1-52	GL-SRB-01-52	proposed		N/A	GL-SRB-01-52-PO-[MMDDYY]	1			
		AOI 1-53	GL-SRB-01-53	proposed		N/A	GL-SRB-01-53-PO-[MMDDYY]	1			
		AOI 1-54	GL-SRB-01-54	proposed		N/A	GL-SRB-01-54-PO-[MMDDYY]	1			
		AOI 1-55	GL-SRB-01-55	proposed		N/A	GL-SRB-01-55-PO-[MMDDYY]	1			
		AOI 1-56	GL-SRB-01-56	proposed		N/A	GL-SRB-01-56-PO-[MMDDYY]	1			
	Staff Gages/ Piezometers/ Porewater	AOI 1-57	GL-SRB-01-57	proposed	1.5-5	N/A	GL-SRB-01-57-PO-[MMDDYY]	1			To aid in the interpretation of groundwater/ surface water interactions and overall groundwater flow through the surficial aquifer system. The exact porewater location will be selected based on TIR survey to determine the locations of groundwater discharges to surface water. If a seep cannot be identified during the TIR survey, a porewater sample will not be obtained.
		AOI 1-58	GL-SRB-01-58	proposed		N/A	GL-SRB-01-58-PO-[MMDDYY]	1			

Table 17-1: RI Mobilization 1 Sampling Design and Rationale - Groundwater, Surface Water/Sediment/Porewater

Area of Interest	Sample Matrix	Location Identifier	Sub-Location Identifier	Well Status	Target Screen Interval (feet bgs)	Synoptic Gauging	Sample Identifier	Number of Samples per Location	Sampling Tool	Analyte Group	Rationale
AOI 2	Groundwater	AOI 2-4	GL-MW-02-04	existing	25-30	X	GL-MW-02-04-[MMDDYY]	1	Peristaltic Pump or Bladder Pump[1,2]	PFAS, Target 32 Compound List (LC/MS/MS compliant with QSM 5.3 Table B-15)	Evaluate deeper groundwater at existing well locations surrounding AOI 2.
		AOI 2-5	GL-TMW-02-05	proposed	5-10 20-25	X	GL-TMW-02-05-[end depth]	2			There may have been fire training activities conducted using the bulk and expired AFFF units stored at the Annex. A PFOS concentration of 31.7 ng/L was detected during the SI, indicating a possible release and potential data gap relative to the SI data. Locations AOI 2-5 though AOI 2-8 are placed in areas where the AFFF may have been dispensed to ground surface.
		AOI 2-6	GL-TMW-02-06	proposed	5-10 20-25	X	GL-TMW-02-06-[end depth]	2			
		AOI 2-7	GL-TMW-02-07	proposed	5-10 20-25	X	GL-TMW-02-07-[end depth]	2			
		AOI 2-8	GL-TMW-02-08	proposed	5-10 20-25	X	GL-TMW-02-08-[end depth]	2			
AOI 3	Groundwater	AOI 3-1	GL-TMW-03-01	proposed	5-10 20-25	X	GL-TMW-03-01-[end depth]	2	Peristaltic Pump or Bladder Pump[2]	PFAS, Target 32 Compound List (LC/MS/MS compliant with QSM 5.3 Table B-15)	While under MIARNG ownership, One of the interviewees stated there was an incident in the hangar in which fuel was spilled from an aircraft, and AFFF may have been used to wash off the fuel. There was also a firetruck located at the former AASF Hangar, but it is unknown if the firetruck had foam capabilities. The exact location of the fuel spill and firetruck storage is unknown. Groundwater conditions in this area is are uncertain. The proposed sample locations are placed around the perimeter of the facility to further understand groundwater flow and to identify if any source areas exist. Proposed locations AOI 3-5, AOI 3-6, AOI 3-7 and AOI 3-8 are placed to evaluate any groundwater that may flow to the south-southeast towards the Abrams Municipal Airport. Proposed locations AOI 3-1, AOI 3-2, AOI 3-3, AOI 3-4 and AOI 3-9 are located to evaluate any groundwater that may flow to the north-northwest towards Reed Drain. Proposed location AOI 3-10 is where the wash rack for the facility is located. It is unknown if the firetruck was ever washed at this location.
		AOI 3-2	GL-TMW-03-02	proposed	5-10 20-25	X	GL-TMW-03-02-[end depth]	2			
		AOI 3-3	GL-TMW-03-03	proposed	10-15	X	GL-TMW-03-03-[end depth]	1			
		AOI 3-4	GL-TMW-03-04	proposed	5-10 20-25	X	GL-TMW-03-04-[end depth]	2			
		AOI 3-5	GL-TMW-03-05	proposed	10-15	X	GL-TMW-03-05-[end depth]	1			
		AOI 3-6	GL-TMW-03-06	proposed	5-10 20-25	X	GL-TMW-03-06-[end depth]	2			
		AOI 3-7	GL-TMW-03-07	proposed	5-10 20-25	X	GL-TMW-03-07-[end depth]	2			
		AOI 3-8	GL-TMW-03-08	proposed	10-15	X	GL-TMW-03-08-[end depth]	1			
		AOI 3-9	GL-TMW-03-09	proposed	10-15	X	GL-TMW-03-09-[end depth]	1			
		AOI 3-10	GL-TMW-03-10	proposed	5-10 20-25	X	GL-TMW-03-10-[end depth]	2			
							Total Samples (not including QC)	**108**			

Notes:

a) The vertical location and the screen intervals of the proposed on-facility multi-interval monitoring wells may be adjusted in the field based on lithologic observations (i.e., the presence of clay confining layers).

b) The quantity of groundwater samples included in this table includes 82 planned groundwater samples from existing and proposed multi-interval monitoring wells.

c) The quantity of porewater samples included in this table includes 9 planned porewater samples. However, if groundwater seeps are not identified during the TIR survey, the porewater sample will not be obtained. This may result in fewer porewater samples obtained.

d) Sample location AOI1-51 is near the outfall that discharges off-facility. One sample per media will be collected in both dry and wet conditions. Dry weather is identified as more than 72 hours after the end of the latest precipitation event. See Worksheet #17 for further information.

1) Sampling will be in accordance with SOP 3-14, found in Appendix D.

2) Sampling will be in accordance with SOP 3-37, found in Appendix D.

3) Sampling will be in accordance with SOP 3-10, found in Appendix D.

4) Sampling will be in accordance with SOP 3-22, found in Appendix D.

5) Sampling will be in accordance with SOP 3-43, found in Appendix D.

AOI = area of interest
bgs = below ground surface
GW = groundwater
J = estimated
LC/MS/MS = liquid chromatography tandem mass spectrometry
MMDDYY = two-digit month, day, year
MW = Monitoring Well
μg/Kg = micrograms per kilogram
N/A = not applicable
ng/L = nanograms per liter

PFAS = per- and polyfluoroalkyl substances
PO = porewater
SE = sediment
SRB = stormwater retention basin
SW = surface water
QC = quality control
QSM = Quality Systems Manual
RI = Remedial Investigation
TBD = to be determined
TIR = thermal infrared imagery
TMW = temporary monitoring well

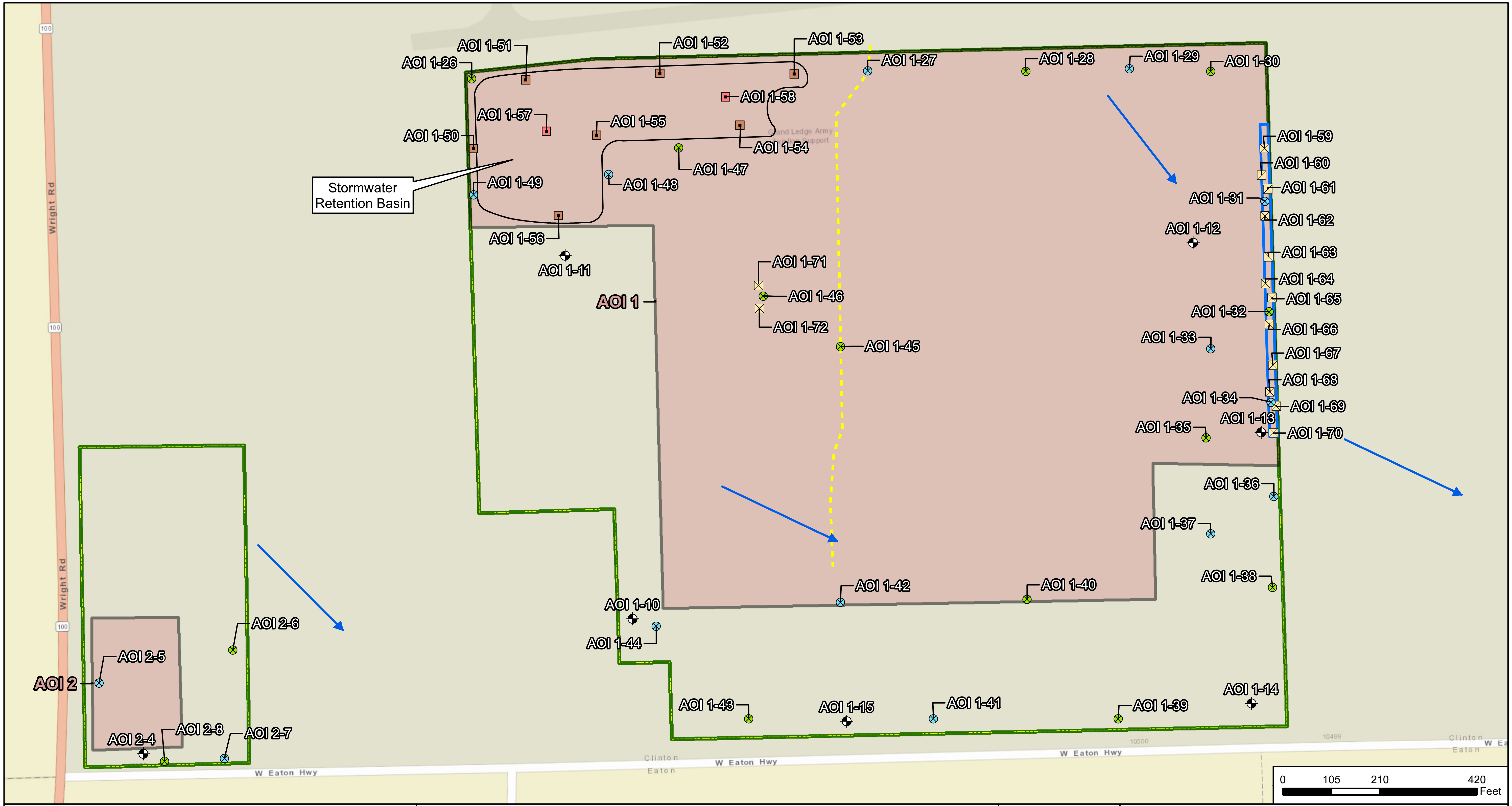
Table 17-2: RI Mobilization 1 Sampling Design and Rationale - Soil

Area of Interest	Location Identifier	Sub-Location Identifier	Sample Identifier	Number of Samples	Target Sample Depth (feet bgs)	Matrix	Sampling Tool	Analyte Group	Rationale
AOI 1	AOI 1-59	GL-SG-01-59	GL-SG-01-59-[Upper Depth]-[Bottom Depth]	2	0-2; 2-4	Surface and Shallow Subsurface Soil	Hand Auger^{1}	PFAS, Target 32 Compound List (LC/MS/MS compliant with QSM 5.3 Table B-15)	Soil samples will evaluate the undisturbed soil in this area where there were reportedly several fire training activities that occurred. This area did not undergo construction when the other areas on the facility experienced signifigant change. The results obtained from this soil grid in RI Mobilization 1 will inform if soil units are needed in the RI Mobilization 2 should the data suggest an obvious source in soil.
	AOI 1-60	GL-SG-01-60	GL-SG-01-60-[Upper Depth]-[Bottom Depth]	2					
	AOI 1-61	GL-SG-01-61	GL-SG-01-61-[Upper Depth]-[Bottom Depth]	2					
	AOI 1-62	GL-SG-01-62	GL-SG-01-62-[Upper Depth]-[Bottom Depth]	2					
	AOI 1-63	GL-SG-01-63	GL-SG-01-63-[Upper Depth]-[Bottom Depth]	2					
	AOI 1-64	GL-SG-01-64	GL-SG-01-64-[Upper Depth]-[Bottom Depth]	2					
	AOI 1-65	GL-SG-01-65	GL-SG-01-65-[Upper Depth]-[Bottom Depth]	2					
	AOI 1-66	GL-SG-01-66	GL-SG-01-66-[Upper Depth]-[Bottom Depth]	2					
	AOI 1-67	GL-SG-01-67	GL-SG-01-67-[Upper Depth]-[Bottom Depth]	2					
	AOI 1-68	GL-SG-01-68	GL-SG-01-68-[Upper Depth]-[Bottom Depth]	2					
	AOI 1-69	GL-SG-01-69	GL-SG-01-69-[Upper Depth]-[Bottom Depth]	2					
	AOI 1-70	GL-SG-01-70	GL-SG-01-70-[Upper Depth]-[Bottom Depth]	2					
	AOI 1-71	GL-SB-01-71	GL-SB-01-71-[Upper Depth]-[Bottom Depth]	2					Soil samples will evaluate the soil closest to the wash bay to determine if runoff is reaching the grassy area near the wash bay. During the SI Mobilization 2, surface soil samples were obtained on the north and northeast corner of the wash bay. The highest concentration for PFOS was 11.0 µg/Kg, suggesting a potential source. The results obtained from these soil samples will inform if soil units are needed in the RI Mobilization 2.
	AOI 1-72	GL-SB-01-72	GL-SB-01-72-[Upper Depth]-[Bottom Depth]	2					
	AOI 1-26	GL-SB-01-26	GL-SB-01-26-[Upper Depth]-[Bottom Depth]	3	0-2; 2-4; mid-point of boring or 13-15	Surface and Subsurface Soil	Hand Auger/ Geoprobe Dual-tube Sampling System^{1,2}	PFAS, Target 32 Compound List (LC/MS/MS compliant with QSM 5.3 Table B-15) Limited Sample Selection (Two samples per depth interval per SU): TOC (USEPA Method 9060A) pH (USEPA Method 9045D)	Soil samples will be collected from selected locations. The locations selected provide sufficient spatial coverage to use the results in a risk assessment, if no further soil sampling is deemed necessary. The results obtained from RI Mobilization 1 will inform if soil units are needed in the RI Mobilization 2 should the data suggest an obvious source in soil. Based on aerial imagery, significant soil movement occurred during construction activities; therefore, it is unlikely any defined source areas in soil exist.
	AOI 1-28	GL-SB-01-28	GL-SB-01-28-[Upper Depth]-[Bottom Depth]	3					
	AOI 1-30	GL-SB-01-30	GL-SB-01-30-[Upper Depth]-[Bottom Depth]	3					
	AOI 1-32	GL-SB-01-32	GL-SB-01-32-[Upper Depth]-[Bottom Depth]	3					
	AOI 1-35	GL-SB-01-35	GL-SB-01-35-[Upper Depth]-[Bottom Depth]	3					
	AOI 1-38	GL-SB-01-38	GL-SB-01-38-[Upper Depth]-[Bottom Depth]	3					
	AOI 1-39	GL-SB-01-39	GL-SB-01-39-[Upper Depth]-[Bottom Depth]	3					
	AOI 1-40	GL-SB-01-40	GL-SB-01-40-[Upper Depth]-[Bottom Depth]	3					
	AOI 1-43	GL-SB-01-43	GL-SB-01-43-[Upper Depth]-[Bottom Depth]	3					
	AOI 1-45	GL-SB-01-45	GL-SB-01-45-[Upper Depth]-[Bottom Depth]	3					
	AOI 1-46	GL-SB-01-46	GL-SB-01-46-[Upper Depth]-[Bottom Depth]	3					
	AOI 1-47	GL-SB-01-47	GL-SB-01-47-[Upper Depth]-[Bottom Depth]	3					
AOI 2	AOI 2-6	GL-SB-02-06	GL-SB-02-06-[Upper Depth]-[Bottom Depth]	3					
	AOI 2-8	GL-SB-02-08	GL-SB-02-08-[Upper Depth]-[Bottom Depth]	3					
AOI 3	AOI 3-1	GL-SB-03-01	GL-SB-03-01-[Upper Depth]-[Bottom Depth]	3					
	AOI 3-2	GL-SB-03-02	GL-SB-03-02-[Upper Depth]-[Bottom Depth]	3					
	AOI 3-3	GL-SB-03-03	GL-SB-03-03-[Upper Depth]-[Bottom Depth]	3					
	AOI 3-4	GL-SB-03-04	GL-SB-03-04-[Upper Depth]-[Bottom Depth]	3					
	AOI 3-5	GL-SB-03-05	GL-SB-03-05-[Upper Depth]-[Bottom Depth]	3					
	AOI 3-6	GL-SB-03-06	GL-SB-03-06-[Upper Depth]-[Bottom Depth]	3					
	AOI 3-7	GL-SB-03-07	GL-SB-03-07-[Upper Depth]-[Bottom Depth]	3					
	AOI 3-8	GL-SB-03-08	GL-SB-03-08-[Upper Depth]-[Bottom Depth]	3					
			Total (not including QC)	**94**					

Notes:
1) Sampling will be in accordance with SOP 3-21, found in Appendix D.
1) Sampling will be in accordance with SOP 3-17, found in Appendix D.

AOI = area of interest
bgs = below ground surface
bgs = below ground surface
LC/MS/MS = liquid chromatography tandem mass spectrometry
NA = not applicable
PFAS = per- and polyfluoroalkyl substances
QC = quality control

QSM = Quality Systems Manual
SB = soil boring
SG = soil grid
TOC = total organic carbon
USEPA = United States Environmental Protection Agency



CLIENT	ARNG			
Remedial Investigation for PFOA, PFOS, and PFBS at Grand Ledge AASF and Armory, MI				
REVISED	6/28/2022	GIS BY	MS	6/28/2022
SCALE	1:2,520	CHK BY	SI	6/28/2022
Base Map: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c)		PM	CM	6/28/2022

⊗ Proposed DPT Multi-Interval Grab Groundwater Well
⊗ Proposed DPT Multi-Interval Grab Groundwater Well & Soil Sample
■ Proposed Staff Gage/Piezometer/Porewater Sample
■ Proposed Surface Water/Sediment/Porewater Sample
☒ Proposed Surface Soil Sample
⊕ Permanent Monitoring Well
▭ Proposed Soil Grid
▭ Area of Interest
▭ Facility Boundary
--- Former Drainage Ditch
→ Groundwater Flow Direction

N

Remedial Investigation Sample Locations Mobilization 1 - AOI 1 and AOI 2

AECOM

12420 Milestone Center Drive
Germantown, MD 20876

Figure 17-1

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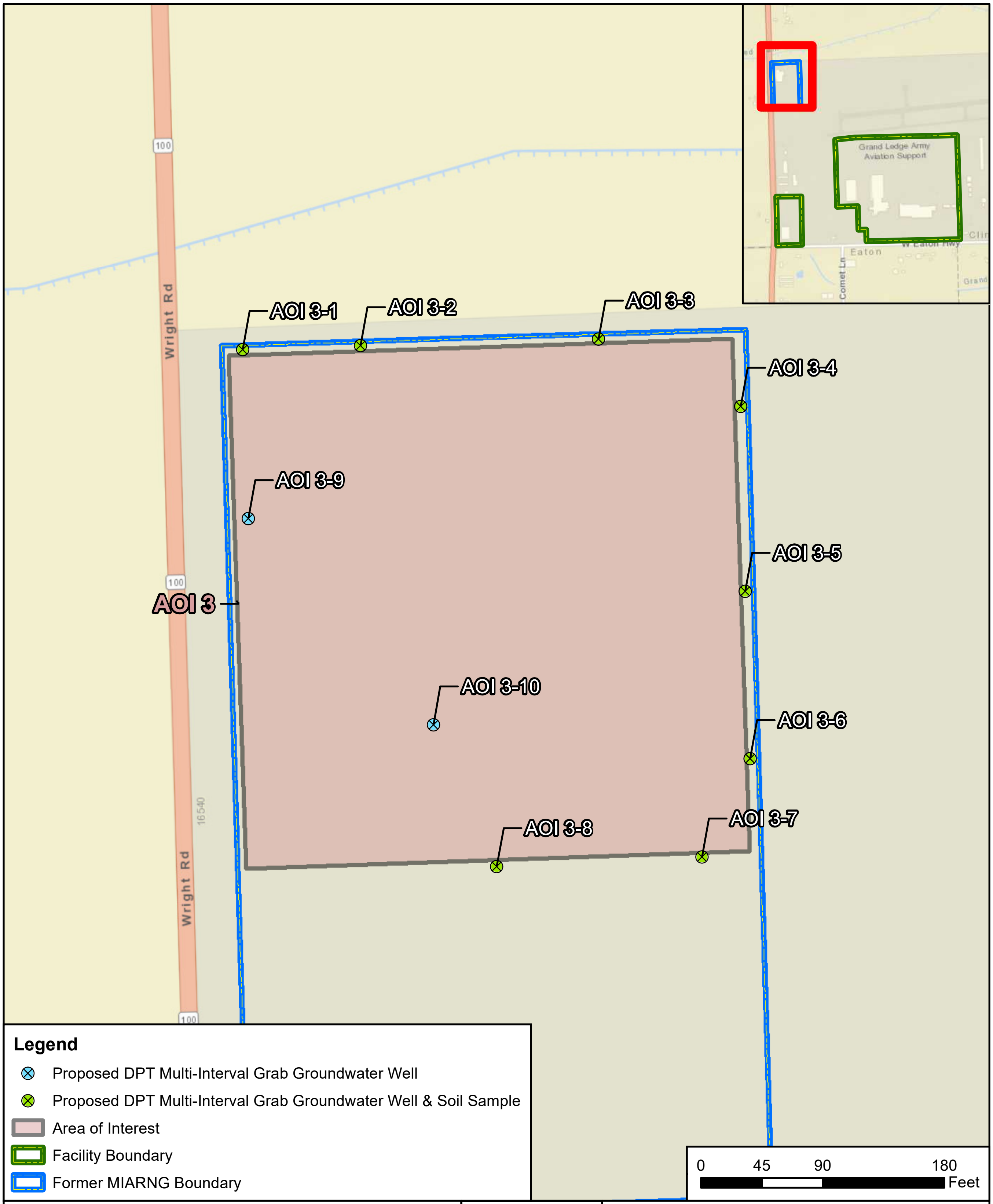

Legend

- ⊗ Proposed DPT Multi-Interval Grab Groundwater Well
- ⊗ Proposed DPT Multi-Interval Grab Groundwater Well & Soil Sample
- ▨ Area of Interest
- ▭ Facility Boundary
- ▭ Former MIARNG Boundary

CLIENT	ARNG			
Remedial Investigation for PFOA, PFOS, and PFBS at Grand Ledge AASF and Armory, MI				
REVISED	6/20/2022	GIS BY	MS	6/20/2022
SCALE	1:1,250	CHK BY	SI	6/20/2022
Base Map: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI,		PM	CM	6/20/2022

Remedial Investigation Sample Locations Mobilization 1 - AOI 3

AECOM
12420 Milestone Center Drive
Germantown, MD 20876

Figure 17-2

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QAPP Worksheet #19 & #30: Sample Containers, Preservation, and Hold Times

Laboratory: Pace Gulf Coast
7979 Innovation Park Dr.
Baton Rouge, Louisiana 70820
(225) 769-4900
List any required accreditations/certifications: DoD ELAP
Back-up Laboratory: NA
Sample Delivery Method: FedEx

Analyte/ Analyte Group	Matrix	Method/SOP	Accreditation Expiration Date	Container(s) (number, size & type per sample)	Preservation	Preparation Holding Time	Analytical Holding Time	Data Package Turnaround
PFAS	Aqueous	PFAS by LC/MS/MS compliant with QSM 5.3 Table B-15/ ENV-SOP-BRTO-0111	ELAP-01/31/2023 NELAP-6/30/2021	HDPE w/ HDPE screw cap 2 x 125 mL	Cool, 0-6°C	14 days from collection to extraction	28 days from extraction to analysis	48 hours (upon request) 28 days
PFAS	Solid	PFAS by LC/MS/MS compliant with QSM 5.3 Table B-15/ ENV-SOP-BRTO-0111	ELAP-01/31/2023 NELAP-6/30/2021	HDPE w/ HDPE screw cap 1 x 125 mL	Cool, 0-6°C	14 days from collection to extraction	28 days from extraction to analysis	48 hours (upon request) 28 days
Total Organic Carbon	Solid	USEPA 9060A, SM 5310 B-2011/ENV-SOP-BRTO-0044	ELAP-01/31/2023 NELAP-6/30/2021	Polyethylene, Glass 1 x 2 oz	Cool, 0-6ºC,	30 days to extraction	7 days from extraction to analysis	28 days
pH	Solid	USEPA 9045D/ENV-SOP-BTRO-0037	ELAP-01/31/2023 NELAP-6/30/2021	Polyethylene, Glass 1 x 2 oz	None	NA	ASAP[1]	28 days
Grain Size	Solid	ASTM D422/ CA-551	02/01/2022	Polyethylene, Glass 1 x 8oz	Cool, 0-6°C	None	None	28 days

Notes:

1.) pH determination is intended to be an in-situ parameter. Pace Gulf Coast is located in Baton Rouge, Louisiana and commits to analyzing pH samples received at its facility in an “as soon as possible” manner. Resulting data is qualified to reflect the variance to the method’s assumptions.

Notes (continued):

°C = degrees Celsius
ASAP = as soon as possible
DoD = Department of Defense
ELAP = Environmental Laboratory Accreditation Program
HDPE = high-density polyethylene
LC/MS/MS = liquid chromatography tandem mass spectrometry
mL = milliliter
NA = not applicable
oz = ounce
PFAS = per- and polyfluoroalkyl substances
QAPP = Quality Assurance Project Plan
QSM = Quality Systems Manual
SOP = standard operating procedure
USEPA = United States Environmental Protection Agency

QAPP Worksheet #20: Field Quality Control Summary

The table below provides a summary of the quantities of field QC samples to be collected. The remaining tables in **Worksheet #20** establish the Measurement Performance Criteria.

Matrix	Analytical Group	Field Samples	Field Duplicates	Matrix Spikes	Matrix Spike Duplicates	Field Reagent Blanks	Equipment Rinsate Blanks[1]	Total Samples
Groundwater	PFAS (32)	105	11	5	5	1	0	127
Soil	PFAS (32)	94	10	5	5	0	3	117
Surface Water	PFAS (32)	8	2	1	1	0	1	13
Sediment	PFAS (32)	8	2	1	1	0	1	13
Porewater[2]	PFAS (32)	9	2	1	1	0	1	14
Decontamination Water	PFAS (32)	1	0	0	0	0	0	1

Notes:

1.) ERBs apply only if use of non-dedicated sampling equipment is necessary. ERBs for solid matrices are aqueous samples.

2.) The quantity of porewater samples included in this table includes nine planned porewater samples. However, if groundwater seeps are not identified during the TIR survey, the porewater sample will not be obtained. This may result in fewer porewater samples obtained; therefore, may require fewer QC samples.

ERB = equipment rinsate blank
PFAS = per- and polyfluoroalkyl substances

Measurement Performance Criteria Table — Field Quality Control Samples				
QC Sample	**Analytical Group**	**Frequency**	**Data Quality Indicators**	**MPC**
Matrix: Aqueous (Groundwater)				
Field Duplicate	PFAS, TOC	One per 10 field samples	Precision	Values > 5X LOQ: RPD must be ≤ 30% Values ≤ 5X LOQ: Absolute difference ≤ 2x the LOQ
Matrix Spike/Matrix Spike Duplicate	PFAS, TOC	One per 20 field samples[1]	Bias/Accuracy/Precision (lab)	RPD ≤ 30%; Refer to Worksheet #28 for recovery criteria
Equipment Rinsate Blank	PFAS	One per 20 field samples per type of reusable equipment used[2]	Accuracy/ Bias	No target analytes ≥ ½ LOQ, unless target analytes in field samples are > 10x those in rinsate blank. Laboratory-certified PFAS-free water will be used to collect ERBs.

Measurement Performance Criteria Table — Field Quality Control Samples				
QC Sample	**Analytical Group**	**Frequency**	**Data Quality Indicators**	**MPC**
Field Reagent Blank	PFAS	One per sampling event[3]	Accuracy/ Bias	No target analytes ≥ ½ LOQ, unless target analytes in field samples are > 10x those in rinsate blank
Cooler Temperature Blank	PFAS	One per cooler	Representativeness	Temperature must be above freezing and ≤ 6 °C
Matrix: Solid (Soil)				
Field Duplicate	PFAS, TOC	One per 10 field samples	Precision	Values > 5X LOQ: RPD must be ≤ 30% Values ≤ 5X LOQ: Absolute difference ≤ 2x the LOQ
Matrix Spike/Matrix Spike Duplicate	PFAS, TOC	One per 20 field samples[1]	Bias/Accuracy/Precision (lab)	RPD ≤ 30%; Refer to Worksheet #28 for recovery criteria
Field Reagent Blank	PFAS	One per sampling event[3]	Accuracy/ Bias	No target analytes ≥ ½ LOQ, unless target analytes in field samples are > 10x those in rinsate blank
Equipment Rinsate Blank	PFAS	One per 20 field samples per type of reusable equipment used[2]	Accuracy/ Bias	No target analytes ≥ ½ LOQ, unless target analytes in field samples are > 10x those in rinsate blank
Cooler Temperature Blank	PFAS	One per cooler	Representativeness	Temperature must be above freezing and ≤ 6°C

Notes:

1.) Analyzed more frequently than one per twenty samples or per sample delivery group.
2.) Only for re-usable equipment, not for disposable equipment/ supplies.
3.) Regardless of matrix.
4.) Field Reagent Blank: an aliquot of reagent water that is placed in a sample container in the laboratory and treated as a sample in all respects, including shipment to the sampling site, exposure to sampling site conditions, storage, preservation, and analytical procedures. The purpose of the FRB is to determine if method analytes or other interferences are present in the field environment.

% = percent
≤ = less than or equal to
≥ = greater than or equal to
°C = degrees Celsius
ERB = equipment rinsate blank

LOQ = limit of quantitation
MPC = measurement performance criteria
PFAS = per- and polyfluoroalkyl substances
QC = quality control
RPD = relative percent difference
TOC = total organic carbon

QAPP Worksheet #21: Field Standard Operating Procedures

A summary of SOPs is provided in the table below which can be found in **Appendix D**. Field staff will be trained through AECOM's internal PFAS Sampling Training prior to performing any sampling activities. A summary of the acceptability of certain materials for use in the PFAS sampling environment and a daily PFAS sampling checklist are provided in *SOP 3-41: Per- and Polyfluoroalkyl Substance Field Sampling Protocol* (**Appendix D**).

Reference Number	Title, Revision Date, and/or Number	Originating Organization	Modified for Project Work?	Comments
3-01	*Utility Clearance*	AECOM	Y	Modified for programmatic details
3-02	*Logbooks*	AECOM	Y	Modified for PFAS sampling and programmatic details
3-03	*Recordkeeping, Sample Labeling and Chain of Custody*	AECOM	Y	Modified for PFAS sampling and programmatic details
3-04	*Sample Handling, Storage, and Shipping*	AECOM	Y	Modified for PFAS sampling and programmatic details
3-05	*Investigation-Derived Waste Management*	AECOM	Y	Modified for programmatic details
3-06	*Equipment Decontamination*	AECOM	Y	Modified for PFAS sampling and programmatic details
3-07	*Land Surveying*	AECOM	Y	Modified for programmatic details
3-09	*Geophysics*	AECOM	Y	Modified for programmatic details
3-10	*Surface Water Sampling*	AECOM	Y	Modified for PFAS sampling and programmatic details
3-12	*Monitoring Well Installation*	AECOM	Y	Modified for PFAS sampling and programmatic details
3-13	*Monitoring Well Development*	AECOM	Y	Modified for PFAS sampling and programmatic details
3-14	*Monitoring Well Sampling*	AECOM	Y	Modified for PFAS sampling and programmatic details
3-15	*Monitoring Well Abandonment*	AECOM	Y	Modified for programmatic details
3-16	*Soil and Rock Classification*	AECOM	Y	Modified for programmatic details
3-17	*Direct Push Sampling Techniques*	AECOM	Y	Modified for PFAS sampling and programmatic details
3-20	*Operation and Calibration of Photoionization Detector*	AECOM	Y	Modified for programmatic details

Reference Number	Title, Revision Date, and/or Number	Originating Organization	Modified for Project Work?	Comments
3-21	*Surface and Subsurface Soil Sampling Procedures*	AECOM	Y	Modified for PFAS sampling and programmatic details
3-22	*Sediment Sampling*	AECOM	Y	Modified for PFAS sampling and programmatic details
3-24	*Water Quality Parameter Testing for Groundwater Sampling*	AECOM	Y	Modified for PFAS sampling and programmatic details
3-33	*Subsurface Soil Sampling by Split Spoon*	AECOM	Y	Modified for PFAS sampling and programmatic details
3-37	*Grab Groundwater Sampling Techniques*	AECOM	Y	Modified for PFAS sampling and programmatic details
3-41	*Per- and Polyfluoroalkyl Substance Field Sampling Protocol*	AECOM	Y	Modified for PFAS sampling and programmatic details
3-42	*Potable Well Sampling*	AECOM	Y	Modified for PFAS sampling and programmatic details
3-43	*Porewater Sampling*	AECOM	Y	Modified for PFAS sampling and programmatic details

Notes:
AECOM = AECOM Technical Services, Inc.
PFAS = per- and polyfluoroalkyl substances
VOC = volatile organic compound
Y = yes

QAPP Worksheet #22: Field Equipment Calibration, Maintenance, Testing, and Inspection

Worksheet #22 addresses procedures for calibrating, maintaining, testing, and/or inspecting field equipment (e.g., tools, pumps, gauges, pH meters, water-level measurement devices). **Equipment that will come into contact with sample media will be evaluated for PFAS-containing components prior to use.**

Field Equipment	Calibration Activity	Maintenance Activity	SOP Reference	Testing Activity	Inspection Activity	Title or Position of Responsible Person	Frequency	Calibration Acceptance Criteria	Corrective Action
Water Quality Meter (pH, ORP, DO, conductivity, temperature, turbidity)	Calibrate with standard solutions	Per page 8 of SOP 3-24	SOP 3-24	Operational equipment check and calibration	Visually inspect for cleanliness and obvious defects (broken/missing parts)	Field Technician Lead	Prior to use	pH: ± 0.01 pH units Conductivity: ± 0.01 µS/cm Turbidity: ± 0.01 NTU DO: ± 0.01 mg/L Temperature: ± 0.01 °C	Minor: Repair Major: Replace instrument
MiniRAE 2000 (Photoionization Detector)	Calibrate with fresh air and isobutylene calibration gas	Per page 4 of SOP 3-20	SOP 3-20	Operational equipment check and calibration	Visually inspect for cleanliness and obvious defects (broken/missing parts)	Field Technician Lead	Prior to use	0-99 ppm ± 0.1 ppm 100-1,999 ppm ± 1.0 ppm 2000-10,000 ppm ± 10 ppm	Minor: Repair Major: Replace instrument
QED MP10 Controller (Bladder Pump Controller Box)	NA	NA	SOP 3-14	Operational equipment check	Visually inspect for cleanliness and obvious defects (broken/missing parts)	Field Technician Lead	Prior to use	NA	Minor: Repair Major: Replace instrument
QED SamplePro (Stainless Steel Submersible Bladder Pump)	NA	Per page 7 of SOP 3-14	SOP 3-14	Operational equipment check	Visually inspect for cleanliness and obvious defects (broken/missing parts)	Field Technician Lead	Prior to use	NA	Minor: Repair Major: Replace instrument

Field Equipment	Calibration Activity	Maintenance Activity	SOP Reference	Testing Activity	Inspection Activity	Title or Position of Responsible Person	Frequency	Calibration Acceptance Criteria	Corrective Action
Solinst 101 (Water Level Meter)	NA	Per page 5 of SOP 3-14	SOP 3-14	Operational equipment check	Visually inspect for cleanliness and obvious defects (broken/missing parts)	Field Technician Lead	Prior to use	NA	Minor: Repair Major: Replace instrument
Geotech GeoPump (Peristaltic Pump)	NA	NA	SOP 3-14	Operational equipment check	Visually inspect for cleanliness and obvious defects (broken/missing parts)	Field Technician Lead	Prior to use	NA	Minor: Repair Major: Replace instrument

Notes:
°C = degrees Celsius
DO = dissolved oxygen
mg/L = milligrams per liter
NA = not applicable
NTU = nephelometric turbidity unit
ORP = oxidation-reduction potential
PFAS = per- and polyfluoroalkyl substances
ppm = parts per million
SOP = standard operating procedure
µS/cm = micro Siemens per centimeter

QAPP Worksheet #23: Analytical Standard Operating Procedures

Lab SOP Number	Title, Revision Date, and / or Number	Definitive or Screening Data[1]	Matrix and Analytical Group	Instrument	Organization Performing Analysis	Modified for Project Work? (Y/N)
ENV-SOP-BRTO-0111	*PFAS in NPW/SCM by LC/MS/MS with Isotopic Dilution (QSM Table B-15 Compliant) and SPE/DIA Extraction, 01/08/2021, Revision 01*	Definitive	Aqueous/PFAS	LC/MS/MS	Pace Gulf Coast	N
			Solid/PFAS			
ENV-SOP-BTRO-0044 01	*TOC in Solids and Wastes by Combustion Analyzer, 09/02/2020, Revision 01*	Definitive	Solid/TOC	Shimadzu TOC Analyzer	Pace Gulf Coast	N
ENV-SOP-BTRO-0037	*pH and ORP in Waters, Solids, and Wastes, 09/01/2020, Revision 01*	Definitive	Solid/pH	Orion 720A pH Meter, Combination Electrode	Pace Gulf Coast	Y[2]
CA-551	*Grain Size Analysis, 04/19, Revision 2*	Definitive	Solid/Grain Size	Sieve	Katahdin Analytical Services, Inc.	N

Notes:

1.) Definitive or screening data are defined per the Part 2B, Quality Assurance/Quality Control Compendium: Minimum QA/QC Activities (IDQTF, 2005c):

Screening data can support an intermediate or preliminary decision but should eventually be supported by definitive data before a project is complete.

Definitive data should be suitable for final decision-making (of the appropriate level of precision and accuracy, as well as legally defensible).

2.) pH determination is intended to be an in-situ analysis. Pace Gulf Coast performs test remote to field operations.

DIA = data independent acquisition
LC/MS/MS = liquid chromatography tandem mass spectrometry
N = no
NPS = non-potable water
PFAS = per- and polyfluoroalkyl substances
SCM = solid/ chemical materials
SOP = standard operating procedure
SPE = solid phase extraction
TOC = total organic carbon
Y = yes

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QAPP Worksheet #24: Analytical Instrument Calibrations

Instrument/ Equipment	Calibration Procedure	Calibration range	Frequency of Calibration	Acceptance Criteria	Corrective Action	Person(s) Responsible	SOP Reference
LC/MS/MS	Calibration standards	NA	Prior to sample analysis	For analytes which have both linear and branched isomers and have standards available containing both linear and branched isomers, the analytes are calibrated and quantitated using a single continuous baseline to integrate identifiable isomers.	NA	Analyst, Supervisor, QA Manager	ENV-SOP-BTRO-0111
LC/MS/MS	Minimum five-point ICAL for all analytes	5.0 – 100 ppb on column	ICAL prior to sample analysis	The isotopically labeled analog of an analyte (EIS Analyte) must be used for quantitation if commercially available (Isotope Dilution Quantitation). Commercial PFAS standards available as salts are acceptable providing the measured mass is corrected to the neutral acid concentration. Results shall be reported as the neutral acid with appropriate CAS number. If a labeled analog is not commercially available, the EIS Analyte with the closest retention time or chemical similarity to the analyte must be used for quantitation. (Internal Standard Quantitation) Analytes must be within 70-130% of their true value for each calibration standard. ICAL must meet one of the two options below: Option 1: The RSD of the RFs for all analytes must be ≤ 20%. Option 2: Linear or nonlinear calibrations must have $r^2 \geq 0.99$ for each analyte.	Repeat calibration if criterion is not met	Analyst, Supervisor, QA Manager	ENV-SOP-BTRO-0111
LC/MS/MS	Second source calibration verification	50 ppb on column	Once after each initial calibration	Analytes must calculate to be within 70-130% of true value and internal extracted standard must calculate to be within 50-150% of true value.	Remake standard, recalibrate if necessary	Analyst, Supervisor, QA Manager	ENV-SOP-BTRO-0111

Instrument/ Equipment	Calibration Procedure	Calibration range	Frequency of Calibration	Acceptance Criteria	Corrective Action	Person(s) Responsible	SOP Reference
LC/MS/MS	Retention time windows	NA	Prior to sample analysis	Established with the first CCV of the day or the average of the ICAL on days when calibration is performed. See Table 3 of LCMS-011 for RT Windows.	Perform maintenance on pump or column. Recalibrate if necessary to re-establish retention times.	Analyst, Supervisor, QA Manager	ENV-SOP-BTRO-0111
LC/MS/MS	Tune check	NA	When the masses fall outside of the ±0.5 amu of the true value (as determined by the product ion formulas).	Mass assignments of tuning standard within 0.5 amu of true value.	Retune instrument and verify. If the tuning will not meet acceptance criteria, an instrument mass calibration must be performed, and the tune check repeated.	Analyst, Supervisor, QA Manager	ENV-SOP-BTRO-0111
LC/MS/MS	LOD/LOQ verification	Various, see Table 3 of LCMS-011	Quarterly	LOD meets method qualitative requirements or is at least 3x higher than noise; LOQ is recovered within LCS criteria.	Perform instrument maintenance and repeat failed LOD or LOQ study passing two consecutive tests or perform new DL study.	Analyst, Supervisor, QA Manager	ENV-SOP-BTRO-0111
LC/MS/MS	Mass spectral acquisition rate	NA	Each analyte, EIS Analyte	Calibrate the mass scale of the MS with calibration compounds and procedures described by the manufacturer. Mass calibration range must bracket the ion masses of interest. The most recent mass calibration must be used for every acquisition in an analytical run. Mass calibration must be verified to be ±0.5 amu of the true value, by acquiring a full scan continuum mass spectrum of a PFAS stock standard.	NA	Analyst, Supervisor, QA Manager	ENV-SOP-BTRO-0111

Instrument/ Equipment	Calibration Procedure	Calibration range	Frequency of Calibration	Acceptance Criteria	Corrective Action	Person(s) Responsible	SOP Reference
LC/MS/MS	Calibration, calibration verification, and spiking standards	5 ppb and 50 ppb on column	Instrument must have a valid mass calibration prior to any sample analysis. Mass calibration is verified after each mass calibration, prior to ICAL.	Standards containing both branched and linear isomers must be used when commercially available. PFAS method analytes may consist of both branched and linear isomers, but quantitative standards that contain the linear and branched isomers do not exist for all method analytes. For PFAS that do not have a quantitative branched and linear standard, identify the branched isomers by analyzing a qualitative standard that includes both linear and branched isomers and determine retention times, transitions and transition ion ratios. Quantitate samples by integrating the total response (i.e., accounting for peaks that are identified as linear and branched isomers) and relying on the initial calibration that uses the linear isomer quantitative standard.	NA	Analyst, Supervisor, QA Manager	ENV-SOP-BTRO-0111
LC/MS/MS	ISC	NA	Prior to analysis and at least once every 12 hours.	Analyte concentrations must be at LOQ; concentrations must be within ±30% of their true values.	Correct problem, rerun ISC. If problem persists, repeat ICAL.	Analyst, Supervisor, QA Manager	ENV-SOP-BTRO-0111
LC/MS/MS	Instrument blanks	NA	Immediately following the highest standard analyzed and daily prior to sample analysis.	Concentration of each analyte must be ≤ ½ the LOQ. Instrument blank must contain EIS to enable quantitation of contamination.	If acceptance criteria are not met after the highest calibration standard, calibration must be performed using a lower concentration for the highest standard until acceptance criteria is met. If sample concentrations exceed the highest allowed standard and the sample(s) following exceed this acceptance criteria (>1/2 LOQ), they must be reanalyzed.	Analyst, Supervisor, QA Manager	ENV-SOP-BTRO-0111

Instrument/ Equipment	Calibration Procedure	Calibration range	Frequency of Calibration	Acceptance Criteria	Corrective Action	Person(s) Responsible	SOP Reference
LC/MS/MS	RT Window	NA	Once per ICAL and at the beginning of the analytical sequence.	Position shall be set using the midpoint standard of the ICAL curve when ICAL is performed. On days when ICAL is not performed, the initial CCV is used.	NA	Analyst, Supervisor, QA Manager	ENV-SOP-BTRO-0111
LC/MS/MS	RT Window Width	NA	Every field sample, standard, blank, and QC sample	RT of each analyte and EIS analyte must fall within 0.4 minutes of the predicted retention times from the daily calibration verification or, on days when ICAL is performed, from the midpoint standard of the ICAL. Analytes must elute within 0.1 minutes of the associated EIS. This criterion applies only to analyte and labeled analog pairs.	Correct problem and reanalyze samples.	Analyst, Supervisor, QA Manager	ENV-SOP-BTRO-0111
LC/MS/MS	Ion Transitions (Precursor →Product)	NA	Every field sample, standard, blank, and QC sample	In order to avoid biasing results high due to known interferences for some transitions, the following transitions must be used for the quantification of the following analytes: PFOA: 413 → 369 PFOS: 499 → 80 PFHxS: 399 → 80 PFBS: 299 → 80 4:2 FTS: 327 → 307 6:2 FTS: 427 → 407 8:2 FTS: 527 → 507 N-EtFOSAA: 584 → 419 N-MeFOSAA: 570 → 419 If these transitions are not used, the reason must be technically justified and documented (e.g., alternate transition was used due to observed interferences).	NA	NA	ENV-SOP-BTRO-0111
Analytical Balances	Class “S” weight are completed by an approved ISO 17025	0.050-200.000 g	Each day prior to use	±0.1% or ±0.5 mg	Clean pan and compartment daily and/or as needed. Replace as needed.	Analyst, Supervisor, QA Manager (Pace Gulf Coast)	ENV-SOP-BTRO-0013

Instrument/ Equipment	Calibration Procedure	Calibration range	Frequency of Calibration	Acceptance Criteria	Corrective Action	Person(s) Responsible	SOP Reference
Shimadzu TOC-V CSH or TOC-V CPH	ICAL	Various	Analyzed and evaluated before any result can be quantitated.	The correlation coefficient must be 0.995 or greater	Correct problem; recalibrate instrument, new calibration verified	Analyst, Supervisor, QA Manager (Pace Gulf Coast)	ENV-SOP-BTRO-0044
Shimadzu TOC-V CSH or TOC-V CPH	ICV	10,000 µg & 20,000 µg	Immediately following the ICAL	±10% (90-110% of true value)	Instrument maintenance, reanalysis of ICV or initial calibration or re-preparation of the standards	Analyst, Supervisor, QA Manager (Pace Gulf Coast)	ENV-SOP-BTRO-0044
Shimadzu TOC-V CSH or TOC-V CPH	CCV	10,000 µg	Each day that an ICAL is not performed a CCV must be performed before sample analysis. Also, analyze every 10 samples ant at the end of analytical batch	±10 % (90-110% of true value)	Instrument maintenance, reanalysis of ICV or initial calibration or re-preparation of the standards	Analyst, Supervisor, QA Manager (Pace Gulf Coast)	ENV-SOP-BTRO-0044
Shimadzu TOC-V CSH or TOC-V CPH	CCB	<250 mg/kg	Analyzed after every 10 samples or more frequently and at the end of analytical batch	Concentration must be less than the LOQ	Correct problem; recalibrate instrument	Analyst, Supervisor, QA Manager (Pace Gulf Coast)	ENV-SOP-BTRO-0044
Orion 720 pH Meter	Calibrate meter	1.00-13.00	Daily before use	92-108%	Recalibrate meter	Analyst, Supervisor QA Manager (Pace Gulf Coast)	ENV-SOP-BTRO-0037
Orion 720 pH Meter	QC Check Buffer	8.00	Immediately after calibration and with every 20 samples	0.05 pH units of the true value	Recalibrate meter	Analyst, Supervisor, QA Manager (Pace Gulf Coast)	ENV-SOP-BTRO-0037
Grain Size	Sieve – Visual inspection	Each sieve	Every use	No clogging or tears in mesh	Remove from service	Analyst, Department Manager	CA-551

Notes:

> = greater than
≥ = greater than or equal to
< = less than
≤ = less than or equal to
± = plus or minus
% = percent
amu = atomic mass unit
CAS = Chemical Abstract Service
CCB = Continuing Calibration Blank
CCV = Continuing Calibration Verification
DL = detection limit
EIS = extracted internal standard
ESI = electrospray ionization
ICAL = initial calibration for all analytes
ICV = independent calibration verification
ISC = instrument sensitivity check
LC/MS/MS = liquid chromatography tandem mass spectrometry
LCS = laboratory control spike
LOD = limit of detection
LOQ = limit of quantitation
mg/kg = milligrams per kilogram
MS = matrix spike
NA = not applicable
ppb = parts per billion
QA = quality assurance
QC = quality control
R^2 = coefficient of determination
RSD = relative standard deviation
RT = retention time
SOP = standard operating procedure
µg = microgram

QAPP Worksheet #25: Analytical Instrument and Equipment Maintenance, Testing, and Inspection

Laboratory: Pace Gulf Coast

Instrument/ Equipment	Maintenance Activity	Testing Activity	Inspection Activity	Frequency	Acceptance Criteria	Corrective Action	Responsible Person	SOP Reference
LC/MS/MS	Clean ESI Chamber	NA	NA	Weekly or as needed	NA	NA	Analyst	ENV-SOP-BTRO-0111
LC/MS/MS	Backflush Analytical Column and Hold Column for Solvent Cleaning	NA	Peak Asymmetry	As needed	NA	NA	Analyst	ENV-SOP-BTRO-0111
Analytical Balance	Clean pan and compartment, check with Class S weights, service engineer cleaning and calibrations	Solids	Monitor instrument and tubing	Each day prior to use	±0.1% or ±0.5 mg	Clean pan and compoartment daily or as needed	Analyst, Supervisor, QA Manager	ENV-SOP-BTRO-0013
Oven	Temperature verification	Solids	Temperature checks	Each day prior to use	103ºC – 105ºC	Adjust temperature or discontinue use	Analyst, Supervisor, QA Manager	ENV-SOP-BTRO-0072
Shimadzu TOC-V CSH or TOC-V CPH	Change injection needle, change catalyst	TOC	Monitor instrument performance via Continuing Calibration Verification	As needed or replace as necessary, loss of sensitivity or failing resolutions,	No maintenance is required as long as instrument QC meets criteria	Perform instrument maintenance, clean injection needle, change catalyst	Analyst, Supervisor, QA Manager	ENV-SOP-BTRO-0044
Orion 720 pH Meter	Check electrode	pH	Flush and refill electrode; clean electrode with methanol	As needed	No maintenance is required as long as instrument QC meets criteria	Clean or replace as necessary	Analyst, Supervisor QA Manager	ENV-SOP-BTRO-0037
Seives	Cleaning	Grain Size	Visual inspection for clogs or tears	Each use	No instrument error message	Remove from service	Analyst, Department Manager	CA-551

Notes:
amu = atomic mass unit
ESI = electrospray ionization
LCMS = liquid chromatography/ mass spectrometry
LC/MS/MS = liquid chromatography tandem mass spectrometry
mg = milligrams
NA = not applicable
QA = quality assurance
QC = quality control
SOP = standard operating procedure
TOC = Total Organic Carbon

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QAPP Worksheet #26 & #27: Sample Handling, Custody, and Disposal

Sampling Organization: AECOM
Laboratory: Pace Gulf Coast
Method of sample delivery (shipper/carrier): FedEx
Number of days from reporting until sample disposal: 60 Days

Activity	Organization and title or position of person responsible for the activity	SOP reference
Sample labeling	AECOM	*SOP 3-03 Recordkeeping, Sample Labeling, and Chain of Custody*
CoC form completion	AECOM	
Packaging	AECOM	*SOP 3-04 Sample Handling, Storage, and Shipping*
Shipping coordination	AECOM	
Sample receipt, inspection, and log-in	Pace Gulf Coast	*SOP-BTRO-0118: Sample Receiving and Laboratory Information Management System Log-In*
Sample custody and storage	Pace Gulf Coast	*SOP-BTRO-0119: Sample Chain of Custody and Sample Integrity*
Sample disposal	Pace Gulf Coast	*SOP-BTRO-0117: Waste Collection, Storage, Disposal*

Notes:
AECOM = AECOM Technical Services, Inc.
CoC = chain of custody
SOP = standard operating procedure

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QAPP Worksheet #28: Analytical Quality Control and Corrective Actions

Matrix: Solid & Aqueous
Analytical Group: PFAS
Analytical Method: PFAS by LC/MS/MS compliant with QSM 5.3 Table B-15
Pace Gulf Coast SOP Reference: ENV-SOP-BRTO-0111
Certification Status: DoD ELAP/NELAP Certification

QC Sample	Frequency/Number	Method/SOP Acceptance Limits	Corrective Action	Person(s) Responsible	Measurement Performance Criteria
Aqueous Sample Preparation	Each sample and associated batch QC samples.	SPE must be used unless samples are known to contain high PFAS concentrations e.g., AFFF. Inline SPE is acceptable. Entire sample plus bottle rinsate must be extracted using SPE. Known high PFAS concentration samples require serial dilution be performed in duplicate. Documented project approval is needed for samples prepared by serial dilution as opposed to SPE.	NA	Analyst, Supervisor, QA Manager	As per Table B-15
Solid Sample Preparation	Each sample and associated batch QC samples.	Entire sample received by the laboratory must be homogenized prior to subsampling.	NA	NA	As per Table B-15
Sample Cleanup Procedure	Each sample and associated batch QC samples. Not applicable to AFFF and AFFF Mixture Samples.	ENVI-Carb™ or equivalent must be used on each sample and batch QC sample.	NA	NA	As per Table B-15
MB	One per preparatory batch, maximum of 20 samples.	No analytes detected > ½ LOQ or > 1/10th the amount measured in any sample or 1/10th the regulatory limit, whichever is greater.	Correct problem. If required, re-extract and reanalyze MB and all QC samples and field samples processed with the contaminated blank. Samples may be reextracted and analyzed outside of hold times, as necessary for	Analyst, Supervisor, QA Manager	As per Table B-15

QC Sample	Frequency/Number	Method/SOP Acceptance Limits	Corrective Action	Person(s) Responsible	Measurement Performance Criteria
			corrective action associated with QC failure. Apply B-flag to all results for the specific analyte(s) in all samples in the associated preparatory batch.		
LCS	One per preparatory batch, maximum of 20 samples.	Blank spiked with all analytes at a concentration ≥ LOQ and ≤ the mid-level calibration concentration. As Per Worksheet #15 and Table C-44 and 45 of QSM 5.3.	Correct problem, then re-extract and reanalyze the LCS and all samples in the associated preparatory batch for failed analytes if sufficient sample material is available. Samples may be reextracted and analyzed outside of hold times, as necessary for corrective action associated with QC failure.	Analyst, Supervisor, QA Manager	As per Table B-15
MS	One per preparatory batch. Not required for aqueous samples prepared by serial dilution instead of SPE.	Sample spiked with analytes at a concentration ≥ LOQ ≤ the mid-level calibration concentration. 70-130% of True Value	Evaluate the data to determine if the failed criteria are due to sample matrix or laboratory error. Re-prep if sufficient sample is available when lab error is suspected, otherwise qualify data with narrative.	Analyst, Supervisor, QA Manager	As per Table B-15
MSD or MD	For MSD: One per preparatory batch. For MD: Each aqueous sample prepared by serial dilution instead of SPE.	For MSD: Sample spiked with analytes at a concentration ≥ LOQ and ≤ the mid-level calibration concentration. For MSD: 70-130% of True Value RPD ≤ 30% (between MS and MSD or sample and MD).	The data shall be evaluated to determine the source of difference. For Sample/MD: RPD criteria only apply to analytes whose concentration in the sample is greater than or equal to the LOQ. The MD is a second aliquot of the field sample that has been prepared by serial dilution.	Analyst, Supervisor, QA Manager	As per Table B-15
EIS	Every field sample, standard, blank, and QC sample.	Added to solid sample prior to extraction. Added to aqueous samples, into the original container, prior to extraction. For aqueous samples prepared by serial dilution instead of SPE, added to final dilution of samples prior to analysis.	If recoveries are acceptable for QC samples, but not field samples, the field samples must be re-prepped and reanalyzed (greater dilution may be needed). If recoveries are unacceptable for QC samples, correct problem,	Analyst, Supervisor, QA Manager	As per Table B-15

QC Sample	Frequency/Number	Method/SOP Acceptance Limits	Corrective Action	Person(s) Responsible	Measurement Performance Criteria
		EIS Analyte recoveries must be within 50% to 150% of ICAL midpoint standard area or area measured in the initial CCV on days when an ICAL is not performed.	and reanalyze associated failed field samples.		
Injection Internal Standard Analytes	Every field sample, standard, blank, and QC sample.	Added to aliquot of sample dilutions, QC samples, and standards just prior to analysis. Peak areas must be within -50% to +50% of the area measured in the ICAL midpoint standard. On days when ICAL is not performed, the peak areas must be within -50% to +50% of the peak area measured in daily initial CCV.	If peak areas are unacceptable, analyze a second aliquot of the extract or sample if enough extract remains. If there is not enough extract, reanalyze the first aliquot. If second analysis meets acceptance criteria, report the second analysis. If it fails, either analysis may be reported with the appropriate flags.	Analyst, Supervisor, QA Manager	As per Table B-15
Post Spike Sample	Only applies to aqueous samples prepared by serial dilution instead of SPE that have reported value of “<LOQ” for analyte(s).	Spike aliquot(s) of sample at the final dilution(s) reported for sample with analytes that have reported value of “<LOQ” in the final dilution. The spike must be at the LOQ concentration to be reported with the sample (the “<LOQ” value). When analyte concentrations are calculated as “<LOQ,” the spike must recover within 70-130%of its true value.	When analyte concentrations are calculated as “<LOQ,” and the spike recovery does not meet the 70 130% acceptance criteria, the sample, sample duplicate, and post spike sample must be reanalyzed at consecutively higher dilutions until the criteria is met.	Analyst, Supervisor, QA Manager	As per Table B-15
Sample PFAS Identification	All analytes detected in a sample.	The chemical derivation of the ion transitions must be documented. A minimum of two ion transitions (Precursor → quant ion and precursor → confirmation ion) and the ion transitions ratio per analyte are required for confirmation. Exception is made for analytes where two transitions do not exist (PFBA and PFPeA). Documentation of the primary and confirmation transitions and the ion ratio is required.	NA	Analyst, Supervisor, QA Manager	As per Table B-15

QC Sample	Frequency/Number	Method/SOP Acceptance Limits	Corrective Action	Person(s) Responsible	Measurement Performance Criteria
		In-house acceptance criteria for evaluation of ion ratios must be used and must not exceed 50-150%. S/N must be ≥ 10 for all ions used for quantification and must be ≥ 3 for all ions used for confirmation. Quant ion and confirmation ion must be present and must maximize simultaneously (±2 seconds).			

Notes:
> = greater than
≥ = greater than or equal to
< = less than
≤ = less than or equal to
% = percent
AFFF = aqueous film forming foam
CCV = continuing calibration verification
EIS = extracted internal standard
ICAL = initial calibration for all analytes
LC/MS/MS = liquid chromatography tandem mass spectrometry
LCS = laboratory control spike
LOQ = limit of quantitation
MD = matrix duplicate
MS/MSD = matrix spike/matrix spike duplicate
NA = not applicable
QA = quality assurance
QC = quality control
RPD = relative percent difference
S/N = signal to noise
SOP = standard operating procedure
SPE = solid phase extraction

Matrix: Solid
Analytical Group: Grain Size
Analytical Method: ASTM D422
Pace Gulf Coast SOP Reference: Grain Size
Certification Status: DoD ELAP/ NELAP Certification

QC Sample	Frequency/Number	Method/SOP Acceptance Limits	Corrective Action	Person(s) Responsible	Measurement Performance Criteria
NA: Laboratory QC samples are not planned for grain size analysis.					

Notes:
ASTM = American Society for Testing and Materials
DoD = Department of Defense
ELAP = Environmental Laboratory Accreditation Program
NA = not applicable
NELAP = National Environmental Laboratory Accreditation Program
QC = quality control
SOP = standard operating procedure

Matrix: Solid
Analytical Group: TOC
Analytical Method: USEPA 9060A, SM 5310 B-2011/WL-057
Pace Gulf Coast SOP Reference: ENV-SOP-BRTO-0044
Certification Status: ELAP/NELAP Certification

QC Sample	Frequency/Number	Method/SOP Acceptance Limits	Corrective Action	Person(s) Responsible	DQIs	Measurement Performance Criteria
Method Blank	One per preparatory batch, maximum of 20 samples.	Concentration shall not be > 1/2 the LOQ or 1/10 the amount of sample.	The source of contamination should be investigated, and samples should be reanalyzed. If, additional sample is not available, report with narrative.	Analyst, Supervisor, QA Manager	Bias/ Contamination	Same as method
LCS	One per preparatory batch, maximum of 20 samples.	QC acceptance criteria specified in Worksheet #15.	If LCS fails to meet lab criteria, the source of inaccuracy should be investigated, and should be samples reanalyzed. If additional sample is not available, report in a narrative.	Analyst, Supervisor, QA Manager	Accuracy/Bias	Same as method
MS	One pair per batch (assuming sufficient volume exists) or as specified by client request.	For matrix evaluation, use LCS recovery and RPD acceptance criteria.	If recovery is outside control limits and a lab error suspected, repeat the MS determination. If the LCS is within control limits and the matrix interference is indicated, analyze a post digestion spike and report results with a narrative.	Analyst, Supervisor, QA Manager	Accuracy/Bias	Same as method
DUP/MSD	One pair per batch (assuming sufficient volume exists) or as specified by client request.	For matrix evaluation, use LCS recovery and RPD acceptance criteria.	Investigate the source of the precision error. A source of precision error in the DUP/MSD may be the homogenous nature of the sample. If lab error is suspected, repeat analysis. If matrix issue is indicated, report with a narrative.	Analyst, Supervisor, QA Manager	Accuracy/Bias	Same as method

Notes:

> = greater than
DQI = data quality indicator
DUP = duplicate
ELAP = Environmental Laboratory Accreditation Program
LCS = laboratory control spike
LOQ = limit of quantitation
MD = matrix duplicate
MS/MSD = matrix spike/matrix spike duplicate
NELAP = National Environmental Laboratory Accreditation Program
QA = quality assurance
QC = quality control
RPD = relative percent difference
TOC = Total Organic Carbon
SOP = standard operating procedure
USEPA = United States Environmental Protection Agency

Matrix: Solid
Analytical Group: pH
Analytical Method: USEPA 9045D
Pace Gulf Coast SOP Reference: ENV-SOP-BTRO-0037
Certification Status: ELAP/NELAP Certification

QC Sample	Frequency/Number	Method/SOP Acceptance Limits	Corrective Action	Person(s) Responsible	DQIs	Measurement Performance Criteria
LCS	One per preparatory batch, maximum of 20 samples.	85-115% for water.	Re-analyze or re-prepare and re-analyze.	Analyst or Project Chemist	Accuracy/Bias	Same as method
MD	Each aqueous sample prepared by serial dilution instead of SPE.	RPD ≤ 20% for soil.	Defer to MS and LCS.	Analyst or Project Chemist	Accuracy/Bias	Evaluate to determine if sample is homogenous

Notes:
% = percent
≤ = less than or equal to
DQI = data quality indicator
ELAP = Environmental Laboratory Accreditation Program
LCS = laboratory control spike
MD = matrix duplicate
MS = matrix spike
NELAP = National Environmental Laboratory Accreditation Program
QC = quality control
SOP = standard operating procedure
SPE = solid phase extraction
USEPA = United States Environmental Protection Agency

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QAPP Worksheet #29: Project Documents and Records

Record	Generation	Verification	Storage Location/Archival
Field Logbook or Data Collection Sheets	Field Task Leader	Facility Task Manager	Project Central File (electronic, Germantown Server/ hard copy, Germantown, MD Office)
Chain-of-Custody Forms	Field Task Leader	Facility Task Manager	Project Central File
Air Bills	Field Task Leader	Facility Task Manager	Project Central File
Contractor Daily QC Reports	Contractor Task Leader	Field Task Leader/Project Director	Project Central File
Custody Seals	Field Task Leader	Analytical Laboratory	Project Central File
Corrective Action Forms	Field Task Leader	Facility Task Manager	Project Central File
Field Sampling Forms	Field Task Leader	Facility Task Manager	Project Central File
Sample Location and Depth Data	Field Task Leader	Facility Task Manager	Project Central File
Field Equipment Calibration Logs	Field Task Leader	Facility Task Manager	Project Central File
Equipment Inspection Forms	Facility Task Leader	Facility Task Manager	Project Central File
Boring Logs	Field Task Leader	Facility Task Manager	Project Central File
Daily Tailgate SH&E Sign-In Sheet	Field Task Leader	Facility Task Manager	Project Central File
APP/ SSHP Acknowledgement	Field Task Leader	Facility Task Manager	Project Central File
Dig Permits	Drilling Contractor	Facility Task Manager	Project Central File
Sample Receipt, Custody, and Tracking Records	Analytical Laboratory	Facility Task Manager	Project Central File
Sample Prep Logs	Analytical Laboratory	Facility Task Manager	Project Central File
Equipment Calibration Logs	Field Task Leader	Facility Task Manager	Project Central File
Run Logs	Analytical Laboratory	Chemistry Lead	Project Central File
Reported Analytical Results	Analytical Laboratory	Chemistry Lead	Project Central File
Data Package Completeness Checklists	Chemistry Lead	Facility Task Manager	Project Central File
Sample Disposal Records	Analytical Laboratory	Chemistry Lead	Project Central File
Raw Data	Analytical Laboratory	Chemistry Lead	Project Central File
EQuIS™	Chemistry/Database Lead	Facility Task Manager	Project Central File
ROE Agreements	Field Task Leader	Facility Task Manager	Project Central File

Record	Generation	Verification	Storage Location/Archival
Photographic Logs	Field Task Leader	Facility Task Manager	Project Central File
Field Sampling Audit Records	Field Task Leader	Facility Task Manager	Project Central File
Laboratory Audit Records	Chemistry Lead	Facility Task Manager	Project Central File
Data Validation Reports	Chemistry Lead	Facility Task Manager	Project Central File
Data Usability Assessment Reports	Chemistry Lead	Facility Task Manager	Project Central File
Field Change Request Forms	Field Task Leader	Facility Task Manager	Project Central File

Notes:
APP/SSHP = Accident Prevention Plan/ Site Safety and Health Plan
CoC = chain of custody
EQuIS = Environmental Quality Information System
NA = not applicable
ROE = right of entry
SH&E = Safety, Health, and Environment

QAPP Worksheet #31, #32 & #33: Assessments and Corrective Action

This worksheet is used to document responsibilities for conducting project assessments, responding to assessment findings and implementing corrective action. Appropriately scheduled assessments allow management to implement corrective action in a timely manner, thereby correcting non-conformances and minimizing their impact on DQOs/Project Quality Objectives.

Assessments:

Assessment Type	Frequency	Internal or External	Organization Performing Assessment	Person(s) Responsible for Performing Assessment	Person(s) Responsible for Responding to Assessment Findings	Person(s) Responsible for Identifying and Implementing Corrective Action	Person(s) Responsible for Monitoring Effectiveness of Corrective Action
PM Review	Monthly (for field efforts that are longer than one month)	Internal	AECOM	PM/AECOM	Field Sampling Team Leader/ AECOM	Field Sampling Team Leader/ AECOM	Project Manager/ AECOM
Review of CoC forms	Daily	Internal	AECOM	Project Chemist/ AECOM	Field Sampling Team Leader/ AECOM	Field Sampling Team Leader/ AECOM	Project Chemist/ AECOM
Laboratory Data Assessment (validation)	Once	Internal	AECOM	Data Validator	Project Chemist/ AECOM	Data Validator	Project Chemist/ AECOM
Daily QC Audits	Daily	Internal	AECOM	Field Sampling Team Leader/ AECOM	Field Sampling Team Leader/ AECOM	Field Sampling Team Leader/ AECOM	QA Officer/ AECOM
Field TSAs	Daily	Internal	AECOM	Field Sampling Team Leader/ AECOM	Field Sampling Team Leader/ AECOM	Field Sampling Team Leader/ AECOM	QA Officer/ AECOM
Field Performance Audits	Weekly	Internal	AECOM	PM/ AECOM or representative	Field Sampling Team Leader/ AECOM	Field Sampling Team Leader/ AECOM	Project Manager/ AECOM

Notes:
AECOM = AECOM Technical Services, Inc.
CoC = chain of custody
PM = project manager
QA = quality assurance
QC = quality control
TSA = technical system audit

Assessment Response and Corrective Action:

Assessment Type	Nature of Deficiencies Documentation	Individual(s) Notified of Findings	Timeframe of Notification	Nature of Corrective Action Response Documentation	Individual(s) Receiving Corrective Action Response	Timeframe for Response
Field Sampling Audit	Email	Field Sampling Team Leader/AECOM PM	Immediate	Daily QC Report/ Email	Project Quality Manager/ PM	24 hours after notification
PM Review	Email	Field Sampling Team Leader/ AECOM	Immediate	Daily QC Report/ Email	AECOM PM	24 hours after notification
Review of CoC forms	Email	Field Sampling Team Leader/AECOM PM	Immediate	Daily QC Report/ Email	Project Chemist	24 hours after notification
Laboratory Data Assessment (validation)	Written Audit Report	Laboratory QA Manager; AECOM Project Chemist	Within 24 hours after audit	Email	Data Validator	Up to 1 week after notification
Daily QC Audits	Email/ Daily QC Report	Field Sampling Team Leader/AECOM PM	Immediate	Daily QC Report/ Email	AECOM PM	24 hours after notification
Field TSAs	Email/ Daily QC Report	Field Sampling Team Leader/AECOM PM	Immediate	Daily QC Report/ Email	AECOM PM	24 hours after notification
Field Performance Audits	Email	Field Sampling Team Leader	Immediate	Daily QC Report/ Email	AECOM PM	24 hours after notification

Notes:
AECOM = AECOM Technical Services, Inc.
CoC = chain of custody
PM = project manager
QA = quality assurance
QC = quality control
TSA = technical system audit

Laboratory Assessments

Assessment Type	Responsible Party & Organization	Number/ Frequency	Estimated Dates	Assessment Deliverable	Deliverable Due Date
DoD/ELAP Accreditation	Accreditation body	Every 2 Years	NA	Certification	NA
Performance testing samples	Laboratory QA Manager	Accreditation	Per Accrediting Authority	Per Accrediting Authority	Per Accrediting Authority
Data Review	Naoum Tavantzis, AECOM	Once	45 days after receipt of data	Validation Report	45 days after receipt of data
External Laboratory Audit	Accreditation Body	Bi-annually	NA	Written Audit Report	NA
Internal Laboratory Audit	Contracted Laboratory	Annually	NA	Written Audit Report	NA

Notes:
AECOM = AECOM Technical Services, Inc.
DoD = Department of Defense
ELAP = Environmental Laboratory Accreditation Program
NA = not applicable
QA = quality assurance

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QAPP Worksheet #34: Data Verification and Validation Inputs

Item	Description	Verification (Completeness)	Validation (Conformance to Specifications)
Planning Documents/Records			
1	Approved QAPP	X	
2	Contract	X	
4	Field SOPs	X	
5	Laboratory SOPs	X	
Field Records			
6	Field logbooks	X	
7	Equipment calibration records	X	
8	CoC Forms	X	X
9	Sampling diagrams/surveys	X	
10	Drilling logs	X	
11	Relevant correspondence	X	
12	Change orders/deviations	X	
13	Field audit reports	X	
14	Field change request forms	X	
Analytical Data Package			
16	Cover sheet (laboratory identifying information)	X	X
17	Case narrative	X	X
18	Internal laboratory CoC	X	X
19	Sample receipt records	X	X
20	Sample chronology (i.e., dates and times of receipt, preparation, and analysis)	X	X
21	Communication records	X	
22	LOD/LOQ establishment and verification	X	
23	Standards traceability	X	
24	Instrument calibration records	X	X
25	Definition of laboratory qualifiers	X	
26	Results reporting forms	X	X
27	QC sample results	X	X
28	Corrective action reports	X	X
29	Raw data	X	X
30	Electronic data deliverable	X	X

Notes:
CoC = chain of custody
LOD = limit of detection
LOQ = limit of quantitation
QAPP = Quality Assurance Project Plan
QC = quality control
SOP = standard operating procedure

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QAPP Worksheet #35: Data Verification Procedure

This worksheet documents procedures that will be used to verify project data. The procedures apply to both field and laboratory records. Data verification is a completeness check to confirm that all required activities were conducted, all specified records are present, and the contents of the records are complete. As illustrated in the following example, verification often is performed at more than one step by more than one person.

Records Reviewed	Requirement Documents	Process Description	Responsible Person, Organization
Chain of custody forms and shipping forms	CoC, Shipping Documents	CoC forms and shipping documentation will be reviewed internally upon their completion and verified against the packed sample coolers they represent. The shipper’s signature on the CoC should be initialled by the reviewer, a copy of the CoC retained in the site file, and the original and remaining copies taped inside the cooler for shipment.	Appropriate Field Sampling Team Leaders for the individual medias
Review of field logbooks	Field Logbooks	Review for completeness and accuracy.	Appropriate field Sampling Team Leaders
Field sampling TSAs	TSA Reports	Assessment of field sampling process prior to start of, or as close to the start of sampling as possible.	QA Manager or designee
Fixed laboratory analytical data review	Laboratory Data Package	Data controls are compared to this QAPP and DoD QSM 5.3 (PFAS by LC/MS/MS compliant with QSM 5.3 Table B-15) in a Three-Tiered process using a minimum 100% peer review.	PM or QA Manager
Fixed laboratory TSAs	Laboratory Data Package	ELAP audit and internal quality audits.	QA Manager
Fixed laboratory data verification	Data Validation Reports	100% data verification/validation for water and soil.	AECOM Project Chemist
Fixed laboratory data validation	Data Validation Reports	Calculate and assess laboratory DQIs.	QA Manager, or designee

Notes:
% = percent
AECOM = AECOM Technical Services, Inc.
CoC = chain of custody
DoD = Department of Defense
DQI = data quality indicator
ELAP = Environmental Laboratory Accreditation Program
PFAS = per- and polyfluoroalkyl substances
PM = Project Manager
QA = quality assurance
QAPP = Quality Assurance Project Plan
QSM = Quality Systems Manual
TSA = technical system audit
USEPA = United States Environmental Protection Agency

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QAPP Worksheet #36: Data Validation Procedures

Data Validator: AECOM

Analytical Group/Method	Definitive Analytical Data	RSC Analytical Data **(if applicable)**
Analytical specifications	WS#24, WS #28 & Laboratory SOPs	
Measurement performance criteria	WS #12, WS#15, and WS#28	
Percent of data packages to be validated	100%	100%
Percent of raw data reviewed	100%	0%
Percent of results to be recalculated	0%	0%
Validation procedure and qualification	National Functional Guidelines for Organic Superfund Data Review, January 2017 (USEPA, 2017); Department of Defense General Data Validation Guidelines, November 2019 (DoD, 2019b); Data Validation Guidelines Module 3: Data Validation Procedure for Per- and Polyfluoroalkyl Substances Analysis by QSM Table B-15 (DoD, 2020).	
Validation code	S2bVEM/S2bVM	S2aVM
Electronic validation program/version	AECOM EarthSoft EQuIS™ Automated Validation Assistant	

Notes:
% = percent
AECOM = AECOM Technical Services, Inc.
DoD = Department of Defense
EQuIS = Environmental Quality Information System
SOP = standard operating procedure
USEPA = United States Environmental Protection Agency
WS = worksheet

[1] Stage 2A Deliverable includes review of batch-level QC including method blanks, LCS/MS percent recoveries, duplicate precision.

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QAPP Worksheet #37: Data Usability Assessment

The Data Usability Assessment (DUA) is an evaluation at the conclusion of data collection activities that uses the results of both data verification and validation in the context of the overall project decisions or objectives. Using both quantitative and qualitative methods, the assessment will determine whether project execution and the resulting data the DQOs established in **Worksheet #11** were achieved. Both sampling and analytical activities will be considered with the ultimate goal to assess whether the final, qualified results support the decisions to be made with the data.

The following personnel are responsible for participating in the DUA:

AECOM Project Manager:	Claire Mitchell
AECOM Project Chemist:	Naoum Tavantzis
AECOM RI Task Manager:	Savannah Wolfe

The DUA will be documented as a discussion within the RI Report and refer to the Data Validation Report that will appear in an appendix of the RI Report. The Data Validation Report will follow the procedures given in **Worksheet #36**.

The following steps summarize the processes used to determine whether the collected data are of the right type, quality, and quantity to support the environmental decision-making for ARNG related to PFAS contamination at certain installations and describe how data quality issues will be addressed and how limitations on the use of the data will be handled.

Step 1	**Review the project's objectives and sampling design.** The key components established in the DQOs (**Worksheet #11**) will be reviewed to ensure that they are still applicable. Also, the sampling design and how it was implemented in the field will be reviewed for consistency with the stated objectives. For example, this step in the DUA will: • Reevaluate whether comparison criteria (i.e., SL; **Worksheet #15**) were updated since QAPP generation and if laboratory quantitation limits (QLs) were sensitive enough for those changes (e.g., QLs remain lower than new criteria). It is important to note several states are in various stages of developing or finalizing limits for PFAS chemicals for different media; therefore, it is critical that SLs are regularly evaluated over the course of the project to ensure the SLs remain current. Additionally, project data must meet the measurement performance criteria (MPC) for sensitivity and project QLs specified in **Worksheets #15 & 28**. • Discuss the limitations and impact on the use of project data if validation reports indicate that project specific sensitivity goals or QLs were not achieved for a specific sampling or laboratory group, dataset or sample delivery group (SDG), matrix, analytical group, or concentration level.
Step 2	**Review the data verification and data validation outputs.** Available Quality Assurance (QA) reports, including both field and laboratory generated forms, will be reviewed for deviations from planned activities identified in Step 1 (e.g., number and locations of samples, holding time exceedances, damaged samples, non-compliant proficiency testing sample results, and SOP deviations) and determine their impacts on the data usability. Validated data will be summarized and/or compiled to identify patterns, trends, and anomalies as they relate to the data quality indicators (DQIs) precision, accuracy/bias, representativeness, comparability, completeness, and sensitivity. Descriptions of each DQI and examples of how each may be incorporated into the usability report follow.

Step 2 (cont.)	**Precision** Precision is the degree to which a set of observations or measurements of the same property, obtained under similar conditions, conform to themselves. Precision is usually expressed as standard deviation, variance, percent difference, or range, in either absolute or relative terms. QC measures for precision include field duplicates, laboratory duplicates, MSDs, analytical replicates, and surrogates. To meet the needs of the data users, RI project data must meet the MPC for precision specified in **Worksheet #12** of this QAPP. Precision errors may be the result of one or more of the following: PFAS cross-contamination, field instrument variation, analytical measurement variation, poor sampling technique, sample transport problems, or spatial variation (heterogeneous sample matrices). To identify the cause of imprecision, the field sampling design rationale and sampling techniques will be evaluated by the reviewer, and both field and analytical duplicate/replicate sample results will be compared. For example, if poor precision is indicated in both the field and analytical duplicates/replicates, then the laboratory may be the source of error. If poor precision is limited to the field duplicate/replicate results, then the sampling technique, PFAS contamination, field instrument variation, sample transport, medium inhomogeneity, or spatial variability may be the source of error. If data validation reports indicate that analytical imprecision exists for a particular dataset or SDG, then the impact of that imprecision on usability will be discussed in the usability report.
	Accuracy/Bias Accuracy is the degree of agreement between an observed value and an accepted reference value. Accuracy includes a combination of random error (precision) and systematic error (bias) due to sampling and analytical operations. Examples of QC measures for accuracy include MSs, Laboratory Control Samples, and ERBs. A measurement is accurate when the reported value does not differ from the true value or known concentration of the spike or standard. To meet the needs of the data users, project data must meet the MPC for accuracy/bias specified in **Worksheet #12** of this QAPP. The usability report for each installation will: • Discuss and compare data on contamination and accuracy/bias (when bias is observable) for each matrix, analytical group, and concentration level. • Describe the limitations on the use of project data if extensive contamination, inaccuracy, or bias exists, or when inaccuracy is limited to a specific sampling or laboratory group, dataset or SDG, matrix, or concentration level. • Discuss the impact of any qualitative and quantitative trends in bias on the sample data.
	Representativeness Representativeness is the measure of the degree to which data accurately and precisely represent a characteristic of a population, a parameter variation at a sampling point, a process condition, or an environmental condition, and it is achieved through a well-designed sampling program and by using standardized sampling strategies, techniques, and analytical procedures. To meet the needs of the data users, project data must meet the MPC for sample representativeness specified in **Worksheet #12** of this QAPP. **Worksheet #28 & 35** discusses how the QA/QC activities (e.g., review of sampling design and SOPs, field sampling Technical System Audits (TSAs), and analysis audits) and QC sample data will be reviewed to assess sample representativeness. For example, if field duplicate precision checks indicate potential spatial variability, additional scoping meetings and subsequent resampling may be needed to collect data that are more representative of a nonhomogeneous site. The usability report for each installation will: • Discuss the impact of field duplicate imprecision onsite representativeness. For example, when data variability is high among field duplicate datasets (i.e., high relative standard deviation), calculation of the 95% UCL of the population mean is more likely to overestimate the true mean and therefore achieve better statistical coverage. • Discuss the impact of laboratory and field sampling methods on sampling results and how they reflect site conditions.

Step 2 (cont.)	• Discuss the effect of site heterogeneity on sampling results in light of sampling methods used. • Describe the limitations on the use of project data when sampling results are non-representative for all data or for a specific sampling, group, dataset or SDG, matrix, analytical group, or concentration level.
	Comparability Comparability is the degree to which different methods, datasets, and decisions agree or can be represented as similar. Comparability describes the confidence (expressed qualitatively or quantitatively) that two datasets can contribute to a common analysis and interpolation. The RI results will be used as benchmarks for determining comparability for data collected during any future sampling events at the various installations using the same or similar sampling and analytical SOPs. At this time, data will not be compared to other datasets or data using different sampling or analytical SOPs. To ensure future comparability of data generated for the installations, standard sample collection procedures and approved analytical methods will be used. Sample analyses will be performed by the laboratory using approved methods and procedures. Comparability criteria will be considered met for the project if, based on data reviewed, the sample collection and analytical procedures (such as use of alternate preparation if indicated by a positive field shake test) are determined to have been followed or defined to show that variations did not affect the values reported. Deviations to sampling scope will be documented in sampling nonconformance reports which may contain some of the discussion of comparability. The usability reports will describe the limitations on the use of project data when project-required data comparability is not achieved for the overall project or is limited to a specific sampling or laboratory group, dataset or SDG, matrix, analytical group, or concentration level.
	Completeness Completeness is a measure of the amount of valid data obtained from a measurement system compared with the amount that was expected to be obtained under correct, normal circumstances. To meet the needs of the data users, project data must meet the MPC for data completeness. Completeness criteria will be considered met if 100% of all planned sample data are collected. As applicable, the usability report may also: • Describe how the amount of valid data will be determined as a percentage of the number of valid measurements for each matrix, analytical group, and concentration level. • Describe how critical data were assessed for completeness when certain sample locations or analytes and matrices are more critical than others in making project decisions. • Evaluate the impact of missing information. Ensure that enough information was obtained for the data to be usable to meet the DQOs (**Worksheet #11**).
	Sensitivity Sensitivity is the capability of a test method or instrument to discriminate between measurement responses representing different levels (e.g., concentrations) of a variable of interest. Examples of QC measures for determining sensitivity include laboratory fortified blanks, a DL study, Limit of Detection (LOD)/Limit of Quantitation (LOQ) Verifications, and Instrument Sensitivity Checks (ISC). To meet the needs of the data users, project data must meet the MPC for sensitivity and project QLs specified in **Worksheets #15 & 28** of this QAPP. If appropriate, the usability report may also: • Discuss and compare sensitivity and DL/LOD/LOQ from the datasets collected for the project for each matrix, analytical group, and concentration level. • Discuss the impact of a lack of sensitivity or higher DL/LOD/LOQ on data usability, if validation reports indicate that sensitivity goals or DL/LOD/LOQ goals were not achieved.

Step 2 (cont.)	- Describe the limitations on the use of project data when sampling results are non-representative for all data or for a specific sampling, group, dataset or SDG, matrix, analytical group, or concentration level.
Step 3	**Verify the assumptions of the selected statistical method** The use of statistical methods for data assessment for this project will be limited to estimating a 95% UCL (or mean as appropriate for the analyte) for the assessment of risks.
Step 4	**Implement the statistical method** Where statistical methods are used, the underlying assumptions will be assessed during the DUA. The consequences of selecting the incorrect alternative will be discussed, and uncertainty tolerances will be considered.
Step 5	**Document data usability and draw conclusions** The DUA will determine and document whether the data can be used as intended given any deviations and corrective actions that may have occurred. Limitations on data use will be considered and discussed as appropriate, and the performance of the sampling design assessed. Conclusions will be drawn taking any data limitations into consideration and documented in the RI Report.

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Appendix A
TPP1&2 Meeting Minutes

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Meeting Minutes
Grand Ledge AASF & Armory, MI
Technical Project Planning (TPP) – Meeting 1 and 2
Remedial Investigations (RI), Feasibility Studies (FS), Decision Documents (DD), and Time Critical / Non-Time Critical Removal Actions (TCRA/NTCRA) for Per-and Polyfluoroalkyl Substances (PFAS) Impacted Sites

Army National Guard (ARNG) Installations, Nationwide
Contract No. W912DR-19-D-0001, DO W912DR21F0349
Monday, 1 August 2022
1530-1615 EDT

Participants			
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** Notes: ARNG-G9 - Army National Guard-G9; MIARNG – Michigan ARNG; EGLE – Michigan Department of Environment, Great Lakes, and Energy; USACE – United States Army Corps of Engineers*

Ms. Savannah Wolfe (AECOM) welcomed participants and reviewed the purpose of the meeting, outlined the agenda, and led a roundtable of introductions for everyone on the virtual Technical Project Planning (TPP) meeting. The meeting was TPP 1 and 2 with the purpose of discussing the Army National Guard (ARNG) Per- and Polyfluoroalkyl Substance (PFAS) Remedial Investigations (RI), Feasibility Studies (FS), Decision Documents (DD), and Time Critical / Non-Time Critical Removal Actions (TCRA/NTCRA), the Grand Ledge AASF and Armory PA/SI findings, and proposed RI approach for Mobilization 1.

Presentation slides were provided to participants prior to the meeting and are included in **Attachment A**. Key points that supplement the presentation are summarized below. A safety moment was provided to the participants. Ms. Wolfe discussed hand safety.

Programmatic Discussion (Slides 5-8):

- The ARNG PA/SI program is contracted through the Baltimore District of the United States Army Corps of Engineers (USACE) with support from other districts but is managed by the ARNG.
- The program follows the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) progress.
- The first two steps in the CERCLA process are the Preliminary Assessment (PA) and Site Inspection (SI), which have been finalized for this facility.

ARNG CERCLA Status Overview (Slide 8)

- The PA was completed in October 2019.
- SI field work was completed in May 2019 (Mobilization 1) and October 2019 (Mobilization 2).
- The SI report was finalized in February 2021.
- The Draft Final RI Uniform Federal Policy for Quality Assurance Project Plan (UFP-QAPP) was provided to the Michigan Department of Environment, Great Lakes, and Energy (EGLE) on 30 June 2022.

Grand Ledge AASF & Armory PA Summary of Findings (Slide 9)

- Three potential release areas were identified during the PA and SI grouped into two Areas of Interest (AOIs): Army Aviation Support Facility (AASF) Hangar and Armory (Former AASF) and Annex Building.
  - AOI 1 includes the wash bay and Armory with associated tarmac; and
  - AOI 2 includes the Annex Building.
- PFAS releases were attributed to aqueous film forming foam releases from fire training activities, fire suppression systems, and firetruck washing/storage.

- The former AASF Hangar area, currently owned by Transfast Trucking, was occupied by the MIARNG prior to the 1980s. This parcel of land was not investigated during the SI and will be included in the RI phase as AOI 3 (SI-level sampling for presence/ absence)
- An additional PFAS release area, Abrams Municipal Airport located north and upgradient of the facility, is also shown on the figure for informational purposes.

Grand Ledge AASF & Armory SI Summary of Findings (Slide 10-12)

- SI results were compared to the updated US Environmental Protection Agency (EPA) Regional Screening Levels (RSLs, May 2022)/ Office of the Secretary of Defense (OSD) Screening Levels (SLs, July 2022).
- Perfluorooctanesulfonic acid (PFOS), perfluorooctanoic acid (PFOA), perfluorobutanesulfonic acid (PFBS), perfluorohexanesulfonic acid (PFHxS), and perfluorononanoic acid (PFNA) were detected in soil, but at concentrations below the SLs.
  - The highest PFOS concentration was 11.0 micrograms per kilogram (µg/kg) in surface soil at location AOI 1-19.
- PFOA, PFOS, PFBS, and PFHxS were detected in groundwater at all AOIs. PFNA was detected in AOI 1 only. PFBS and PFNA concentrations were below the SLs for all groundwater samples.
  - At AOI 1, PFOS exceeded the SL of 4 nanograms per liter (ng/L) with concentration of 60.0 ng/L (AOI 1-5).
  - At AOI 1, PFOA exceeded the SL of 6 ng/L, with concentrations of 53.0 ng/L (AOI 1-5) and 28.2 ng/L (AOI 1-12).
  - At AOI 1, PFHxS exceeded the SL of 39 ng/L, with concentrations of 87.8 ng/L (AOI 1-5) and 227 ng/L (AOI 1-12).
  - At AOI 2, PFOS and PFHxS exceeded the SLs of 4 ng/L and 39 ng/L, with concentrations of 31.7 ng/L and 44.9 ng/L, respectively (AOI 2-2).
- There were detections of PFOA, PFOS, PFBS, PFNA, and PFHxS in sediment and surface water samples
  - For sediment, the highest concentration detected was for PFOS, which had a range of 0.744 J to 26.3 J µg/kg.
  - For surface water, the highest concentration detected was for PFOS, which had a range of 4.66 J ng/L to 283 J+ ng/L.
  - There are no established OSD SLs for sediment and surface water.
- No residential well water samples exceeded the SLs or the USEPA Health Advisory (HA) of 70 ng/L for PFOA and/or PFOS, and 23 of the 25 samples had no detections of PFAS.

Grand Ledge AASF & Armory SI Path Forward (Slide 13):

- Based on the results of the SI in relation to the 2022 OSD SLs and EPA RSLs, AOI 1 and AOI 2 will move forward to RI.
- As discussed in Slide 9, the former AASF Hangar (currently owned by Transfast Trucking, Inc.) is included as an additional AOI in the RI, AOI 3: Former AASF Hangar. SI level data will be collected at AOI 3.

CERCLA RI/FS Introduction (Slide 14-15):

- Purpose of RI:
  - Mechanism for collecting data to characterize site conditions, determine the nature of the contamination, assess risk to human health and the environment.
  - Gather information sufficient to support an informed risk management decision regarding which remedy appears to be most appropriate for a given site.
- Purpose of FS:
  - Mechanism for the development, screening, and detailed evaluation of alternative remedial actions.
  - Determination of Applicable or Relevant and Appropriate Requirements (ARARs) will occur at this stage.
- Ms. Packer noted that she would formally request ARARs from EGLE.

- Adopting a traditional approach to characterizing nature and extent is complicated by the unique challenges of PFAS, including the low or currently nonexistent action levels, varying state regulations, and high mobility and ubiquitous nature of PFAS.

CERCLA RI/FS Goals (Slide 16):

- The goals of the RI/FS were discussed, including:
  - Refining the extent of PFOA, PFOS, PFBS, PFHxS, PFNA, and hexafluoropropylene oxide dimer acid and its ammonium salt (HFPO-DA) (PFAS compounds);
  - Locating the release areas where PFAS compounds in soil are linked to groundwater containing these compounds that are attributable to ARNG activities;
  - Evaluating site characteristics;
  - Determining if unacceptable risk or hazard to human health is presented by site related concentrations of PFAS compounds; and
  - Conducting a screening level ecological risk assessment (SLERA). If the potential for adverse effects on ecological receptors due to exposure to PFAS in soil or sediment and surface water is identified, then a risk management decision will be made by the team regarding the need for further ecological evaluations.

Grand Ledge AASF & Armory RI CSM (Slides 17-20)

- On the facility, surface water flows to the stormwater retention basin in the northwest corner of the site and north toward the Reed Drain.
- Based on the findings of the SI, groundwater flows toward the southeast.
- A diagram with the receptors and potentially complete pathways was presented.

Grand Ledge AASF & Armory RI Scope Summary (Slide 21):

- A total of 22 soil borings will be completed.
  - Up to three soil samples will be collected per location, at 0 to 2 feet bgs, 2 to 4 feet bgs, and 13 to 15 feet bgs.
- A total of 14 surface soil locations will be completed.
  - Up to two soil samples will be collected per location at 0 to 2 feet bgs and 2 to 4 feet bgs.
- A total of 45 monitoring wells (38 temporary and 7 permanent) will be installed.
  - Two to three groundwater samples will be collected via push point sampling per temporary monitoring well, at depths expected to range between 5 to 45 feet bgs.
  - One groundwater sample will be collected per permanent monitoring well, at depths ranging between 30 to 100 feet bgs.
    - The permanent wells will also undergo four quarters of sampling.
- A total of 7 surface water locations will be completed.
  - One surface water sample will be collected per location, at the middle of the water column.
- A total of 7 sediment will be completed.
  - One sediment sample will be collected per location, at 0 to 0.5 feet bgs.
- A total of 7 porewater locations will be completed.
  - One porewater sample will be collected per location, at 1.5 to 5 feet bgs.
  - Porewater samples may or may not be collocated with the sediment and surface water locations, based on the findings of the FTIR camera identifying groundwater seeps.

Grand Ledge AASF & Armory RI Sampling Approach (Slides 22-23):

- AOI 1
  - Samples surrounding the retention basin (AOI1-26, AOI1-47 through AOI1-57) are to determine if the path of migration of the PFAS compounds is via shallow groundwater or engineered structures. There are stormwater inlets near AOI1-55 and AOI1-54.
  - On the northern boundary, borings are placed to determine if PFAS is migrating onsite (AOI1-27 through AOI1-30)
  - Along the east side of the boundary, there is one soil grid to determine if there is a soil area (AOI1-59 through AOI1-70). Historically fire training activities occurred in this area, and it is largely undisturbed from construction activities.

  - The borings along the eastern portion of the facility are arranged to be near and downgradient of the two wells that had groundwater exceedances of the SLs in the area. These borings are to determine if there is a source area and to try to determine the extent (AOI1-31 through AOI1-38).
  - The borings on the south side of the facility have two purposes. There are strategically placed downgradient from the hangar with a fire suppression system equipped with AFFF, and to determine if PFAS migration is occurring off facility (AOI1-39 through AOI1-44).
  - One boring (AOI1-46) and surface soil locations (AOI1-71, AOI1-72) near the middle of facility are adjacent to the wash bay. These sampling points will determine if there is a source area as a result of the activities at the wash bay. Additionally, historically there was a ditch that ran north-south where AOI1-45 is located. This boring is located to determine if PFAS migrated in this ditch. There has been extensive construction in this area.
  - The existing monitor wells installed from the SI will also be sampled.
  - Further information on rationale of sample locations can be found in Table 17-1 of the UFP-QAPP.
- Ms. Patti Lyman (MIARNG) noted that PFAS were detected in the adjacent drain located north and upgradient of the former MIARNG boundary. Ms. Wolfe requested the results of the sampling event within the drain.

- AOI 2
  - There was an exceedance of SLs near the southern boundary of the facility. Soil borings are placed downgradient and upgradient to determine the source area. AOI 2 is the Annex building where bulk AFFF was stored.

- Ms. Packer inquired regarding the order in which the samples would be collected. Ms. Wolfe responded that the sequence of sample collection across the facility is currently being evaluated and discussed. Ms. Packer requested a follow-up meeting to discuss the order of sample collection, once developed.

- AOI 3
  - SI level sampling approach to evaluate if there are any source areas.
  - Borings along perimeter surrounding the existing facility, mainly located downgradient.
  - Location AOI3-10 is where firetrucks were frequently stored when this parcel of land was under control of the MIARNG.

Grand Ledge AASF & Armory RI Analytical Parameters (Slide 24):

- The samples will be analyzed for the 32-compound analyte list.
- All PFAS samples will be analyzed via LC/MS/MS Compliant with QSM 5.3 Table B-15.
- Analysis will be completed by Environmental Laboratory Accreditation Program (ELAP)/National Environmental Laboratory Accreditation Program (NELAP)-certified laboratory.
- Level IV data package will be received from the laboratory.
- Data will undergo Stage 2b validation as defined in the Department of Defense General Data Validation Guidelines.

Grand Ledge AASF & Armory RI Schedule (Slide 26):

- The schedule for the RI was discussed for both Mobilization 1 and Mobilization 2, including the QAPP, pre-mobilization, mobilization, field work, demobilization, data analysis and validation, and reporting.

Open Discussion (Slide 27):

- ARNG G-9 and EGLE discussed billing between EGLE and the federal government.

The presentation ended at 1615 and the phone line was closed.

Attachment A - TPP 1 and 2 Briefing Slides

Technical Project Planning Meeting 1 & 2
Grand Ledge AASF & Armory, Michigan

01 August 2022

Remedial Investigations (RI), Mobilization 1

Contract No. W912DR-19-D-0001
Task Order W912DR21F0349

Delivering a better world

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Agenda

Introductions

Safety Moment

TPP Meeting Goals

Army National Guard (ARNG) Comprehensive Environmental Response and Liability Act (CERCLA) Process Overview

Preliminary Assessment (PA) Overview

Site Inspection (SI) Results

RI Conceptual Site Model (CSM)

RI Goals

RI Sampling Approach

Schedule

Questions and Open Discussion

Introductions

ARNG G9

David Connolly, PFAS Program Manager

Bonnie Packer, Ph.D., Nationwide Project Manager

Michigan ARNG

Jonathan Edgerly, Environmental Manager

Patti Lyman, PFAS Remediation Manager

Amy Handley, PFAS Project Manager

United States Army Corp of Engineers (USACE)

Tim Peck, Nationwide Project Manager

Robin Sternberg, Ph.D. Biologist, Louisville District

Steve Kvaal, Project Manager, Louisville District

Environment, Great Lakes, and Energy (EGLE)

Kim Sakowski, Remediation & Redevelopment Division

AECOM

Claire Mitchell, Project Manager

Savannah Wolfe, RI Task Manager

Samuel Bartlett, RI Senior Lead

Safety Moment – Hand Safety

In 2018, over 120,000 hand injuries that involved days away from work were reported in the U.S. Approximately 47% of workplace hand injuries involve cuts, lacerations, and punctures.

Some Onsite Hazards That Cause Hand Injuries

- Hurrying to complete a task and not paying attention to the location of your hands.
- Loose clothing or hair getting caught in rotating parts or equipment.
- Not using the proper work procedures, tools, or safety gloves.
- Reaching into moving equipment and machinery.

How to Mitigate Risk for Hand Injury

- Plan the work: work that is planned and communicated to the work crews is more likely to be executed more efficiently and safely.
- Use the hierarchy of controls to determine if tasks can be done without the use of hands (mechanical means); if hands are the only means, then utilize safety tools (e.g., JSA, AHA) to ensure they stay out of the line of fire.
- Specify the exact glove to be used for the task.

TPP 1 & 2 - Meeting Goals

TPP 1 & 2 (July 2022):

- ARNG CERCLA program overview
- Provide overview of PA findings
- Present SI Results and revised CSM
- Present RI Uniform Federal Policy- Quality Assurance Project Plan (UFP-QAPP)
    - Goals
    - Planned approach for RI
- Discuss project schedule

Participants:

- ARNG G9, USACE, MIARNG, EGLE

TPP 3- Meeting Goals

TPP 3 (determined during reporting phase):

- Present findings of RI
- Gain concurrence on presentation of findings in RI Report

Participants:

- TPP 3: ARNG G9, USACE, MIARNG, EGLE, other local stakeholders

Program Overview – CERCLA Work Phases

- **Preliminary Assessment**
- **Site Inspection**
- **Remedial Investigation***
- Feasibility Study
- Proposed Plan
- Decision Document
- Remedial Design
- Remedial Action

Notes: *Current stage of activity

- Follows the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Process
- Preliminary Assessment and Site Inspection are complete
- An interim removal action (e.g., Time-Critical or Non-Time Critical Removal Action [TCRA or NTCRA]) can be conducted or a No Further Action determination can be made at any phase

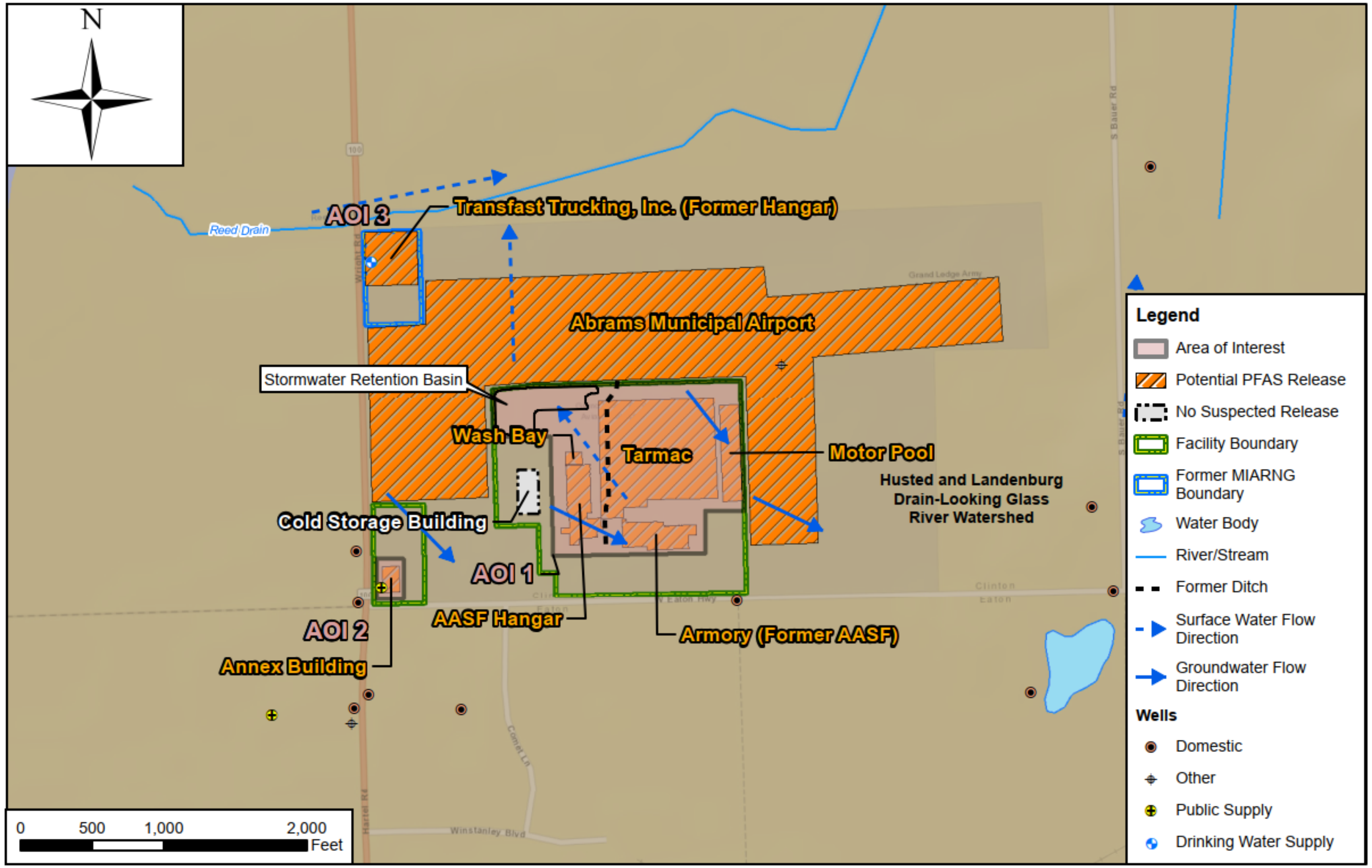
ARNG CERCLA Status Overview

- PA was completed in October 2019
- SI fieldwork was completed in May 2019 (Mobilization 1) and November-December 2020 (Mobilization 2)
- SI Report was completed in February 2021
- Draft Final RI UFP-QAPP provided to EGLE on 30 June 2022

Grand Ledge AASF & Armory PA

Summary of Findings

- Potential release areas: three identified during the PA and SI grouped into two areas of Interest (AOIs).
- PFAS releases attributed to aqueous film forming foam releases from fire training activities, fire suppression systems, and firetruck washing/ storage.
- The former AASF Hangar area currently owned by Transfast Trucking, was occupied by the MIARNG prior to the 1980s. This parcel of land was not investigated during the SI and will be included in the RI phase as AOI 3.



Grand Ledge AASF & Armory SI

Summary of Findings

- Soil[1]
  - PFOA, PFOS, PFBS, PFHxS and PFNA detected in soil, but at concentrations below the screening levels (SLs).
  - The highest PFOS concentration was 11.0 micrograms per kilogram (µg/kg) in surface soil at location AOI 1-19.

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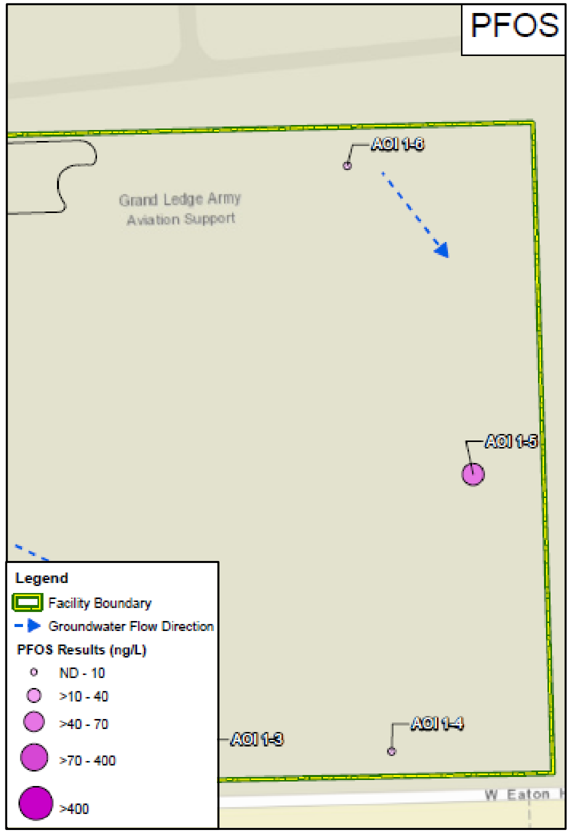
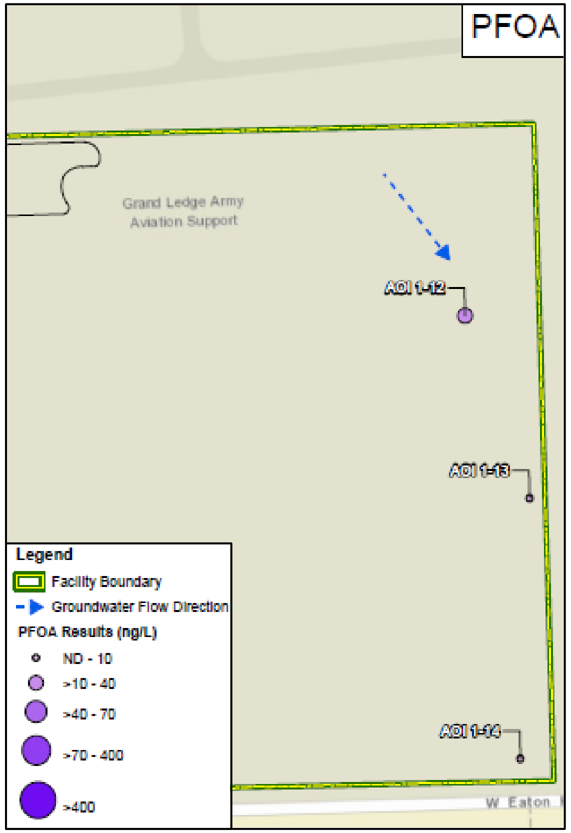
[1] SI results are compared to the updated EPA RSLs (May 2022)/ OSD SLs (July 2022)

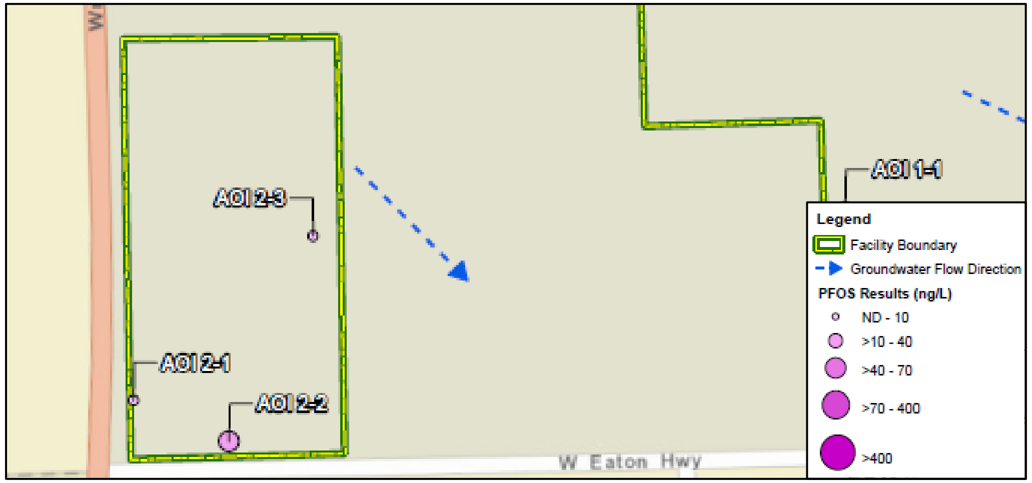
Grand Ledge AASF & Armory SI

Summary of Findings

- Groundwater[1]
  - PFOA, PFOS, PFBS, and PFHxS were detected in groundwater at all AOIs. PFNA was detected in AOI 1 only. PFBS and PFNA concentrations were below the SLs for all groundwater samples.
  - Exceedances at AOI 1:
    - PFOS exceeded the SL of 4 nanograms per liter (ng/L) with concentration of 60.0 ng/L at AOI 1-5
    - PFOA exceeded the SL of 6 ng/L, with concentrations of 53.0 ng/L and 28.2 ng/L, at AOI 1-5 and AOI 1-12, respectively
    - PFHxS exceeded the SL of 39 ng/L, with concentrations of 87.8 ng/L and 227 ng/L, at AOI 1-5 and AOI 1-12, respectively
    - PFNA and PFBS did not exceed the SLs at any location
  - Exceedances at AOI 2:
    - PFOS and PFHxS exceeded the SLs of 4 ng/L and 39 ng/L, with concentrations of 31.7 ng/L and 44.9 ng/L, respectively, at AOI 2-2







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[1] SI results are compared to the updated EPA RSLs (May 2022)/ OSD SLs (July 2022)

Grand Ledge AASF & Armory SI

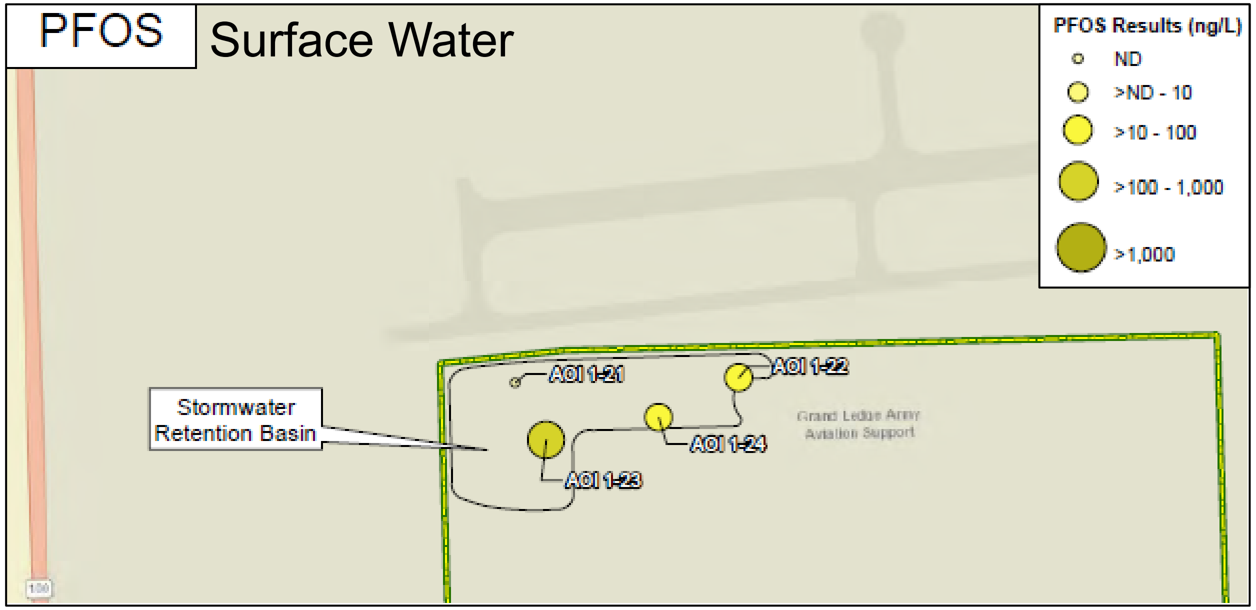
Summary of Findings

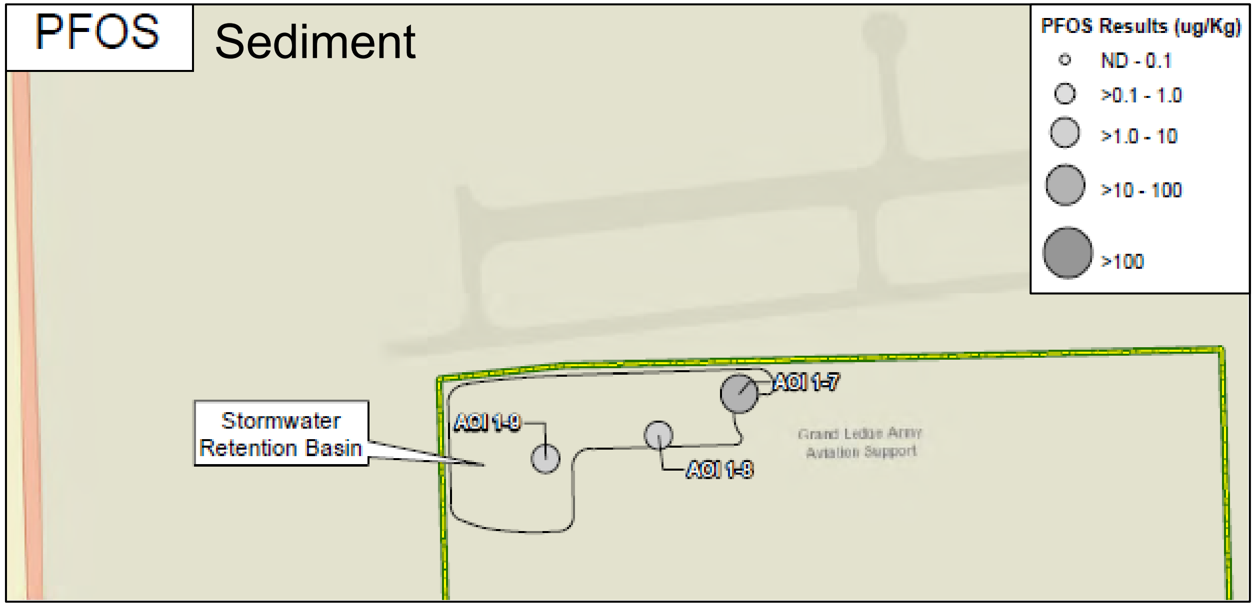
Sediment and Surface Water Findings

- There were detections of PFOA, PFOS, PFBS, PFNA, and PFHxS in sediment and surface water samples
- For sediment, the highest concentration detected was for PFOS, which had a range of 0.744 J to 26.3 J µg/kg
- For surface water, the highest concentration detected was for PFOS, which had a range of 4.66 J ng/L to 283 J+ ng/L
- There are no established OSD SLs for sediment and surface water.

Residential Well Water Findings

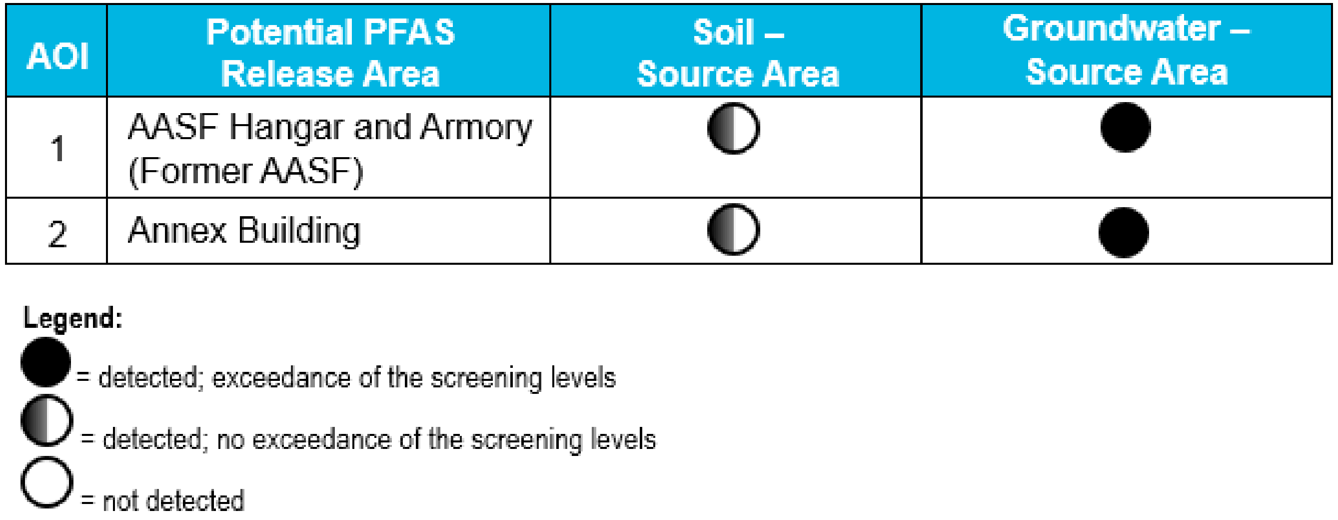
- No samples exceeded the SLs or the USEPA Health Advisory (HA) of 70 ng/L for PFOA and/or PFOS, and 23 of the 25 samples had no detections of PFAS.





Grand Ledge AASF & Armory SI

Path Forward



AOI	Potential PFAS Release Area	Soil – Source Area	Groundwater – Source Area
1	AASF Hangar and Armory (Former AASF)	◐	●
2	Annex Building	◐	●

Legend:

● = detected; exceedance of the screening levels

◐ = detected; no exceedance of the screening levels

○ = not detected

- AOI 1 move forward to RI, based on the results of the SI
- AOI 2 move forward to RI, based on the updated USEPA RSLs (May 2022)/ OSD SLs (July 2022)
- Since the former AASF Hangar (currently owned by Transfast Trucking, Inc.) was occupied by the MIARNG prior to the 1980s, an additional AOI will be included in the RI, AOI 3: Former AASF Hangar. SI level data will be collected at AOI 3.

CERCLA RI/FS

Introduction

Purpose of RI

- Mechanism for collecting data to characterize site conditions, determine the nature of the contamination, assess risk to human health and the environment
- Gather information sufficient to support an informed risk management decision regarding which remedy appears to be most appropriate for a given site

Purpose of FS

- Mechanism for the development, screening, and detailed evaluation of alternative remedial actions
- Determination of ARARs will occur at this stage

CERCLA RI/FS

Introduction

Adopting a traditional approach to characterizing nature and extent is complicated by the unique challenges of PFAS:

- Very low drinking water and groundwater action levels
- High mobility
- No soil action levels and the changing regulations
- Some states regulating additional PFAS compounds
- Ubiquitous in the environment

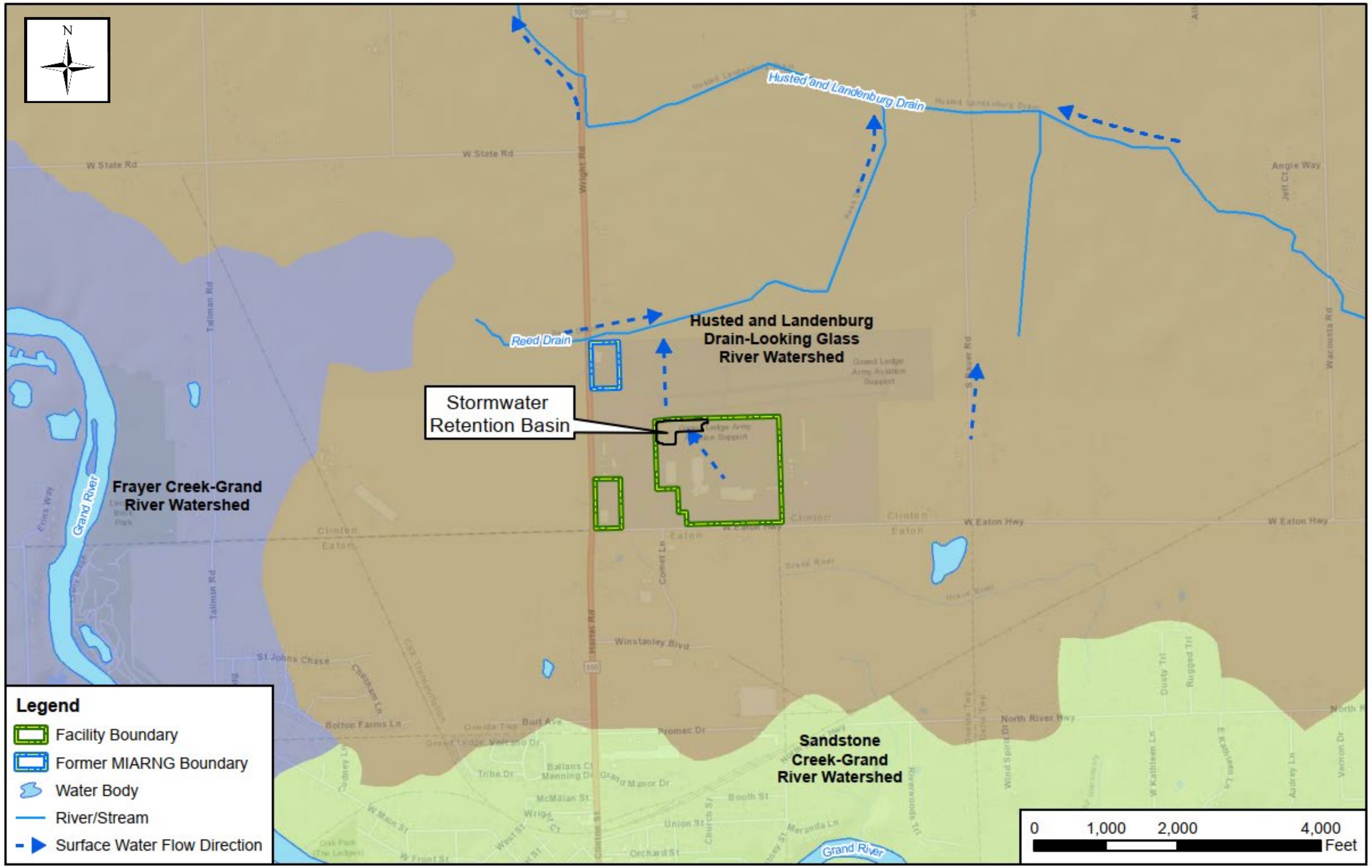
CERCLA RI/FS

Goals

- Refine the extent of PFOS, PFOA, PFBS, PFHxS, PFNA, and HFPO-DA in groundwater attributable to ARNG activities at concentrations above the SLs.
- Within an established AOI, locate the release areas where PFOS, PFOA, PFBS, PFHxS, PFNA, and HFPO-DA in soil are linked to groundwater containing these compounds that are attributable to ARNG activities. Refine occurrence of PFOS, PFOA, and PFBS in soil to the soil screening criteria.
- Evaluate site characteristics that influence PFOS, PFOA, PFBS, PFHxS, PFNA, and HFPO-DA fate and transport and potential remedial alternatives evaluation.
- Determine if unacceptable risk or hazard to human health is presented by site related concentrations of PFOS, PFOA, PFBS, PFHxS, PFNA, and HFPO-DA in soil, groundwater, sediment, and surface water in accordance with U.S. Environmental Protection Agency (USEPA) CERCLA methods by conducting a human health risk assessment (HHRA).
- Conduct a screening level ERA (SLERA) in accordance with USEPA and Army risk assessment guidance for PFOS, PFOA, PFBS, PFHxS, PFNA, and HFPO-DA, as well as other PFAS with relevant ecological screening values (e.g., perfluorododecanoic acid [PFDoA], perfluoroundecanoic acid [PFUdA], perfluorodecanoic acid [PFDA], perfluoroheptanoic acid [PFHpA], perfluorohexanoic acid [PFHxA], perfluoropentanoic acid [PFPeA], and perfluorobutanoic acid [PFBA]). If the SLERA and subsequent SLERA refinement (Step 3a in the USEPA ERA process) identify the potential for adverse effects on ecological receptors due to exposure to PFAS in soil or sediment and surface water, then a risk management decision will be made by the team regarding the need for further ecological evaluations.

Grand Ledge AASF & Armory RI CSM

Surface Water Features



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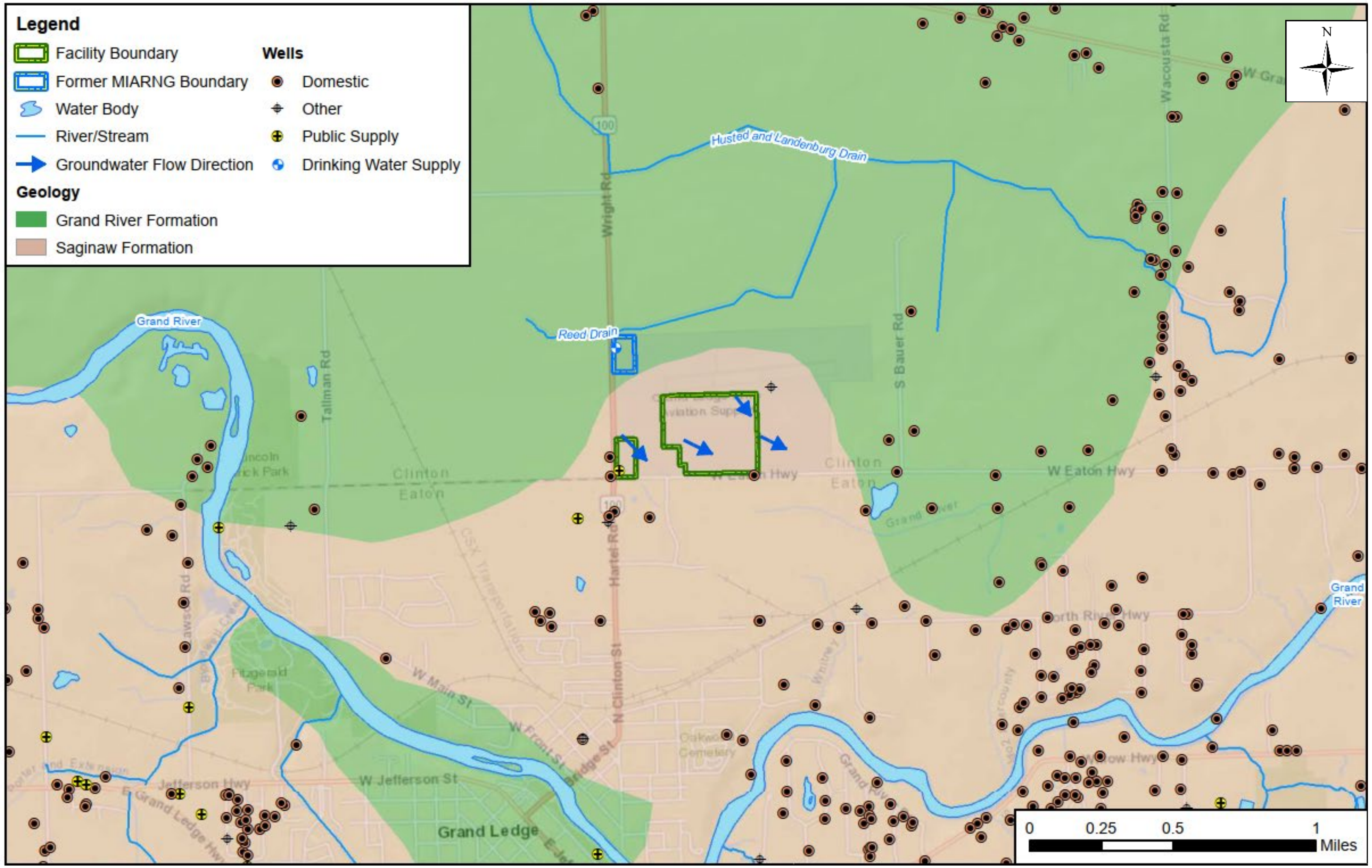
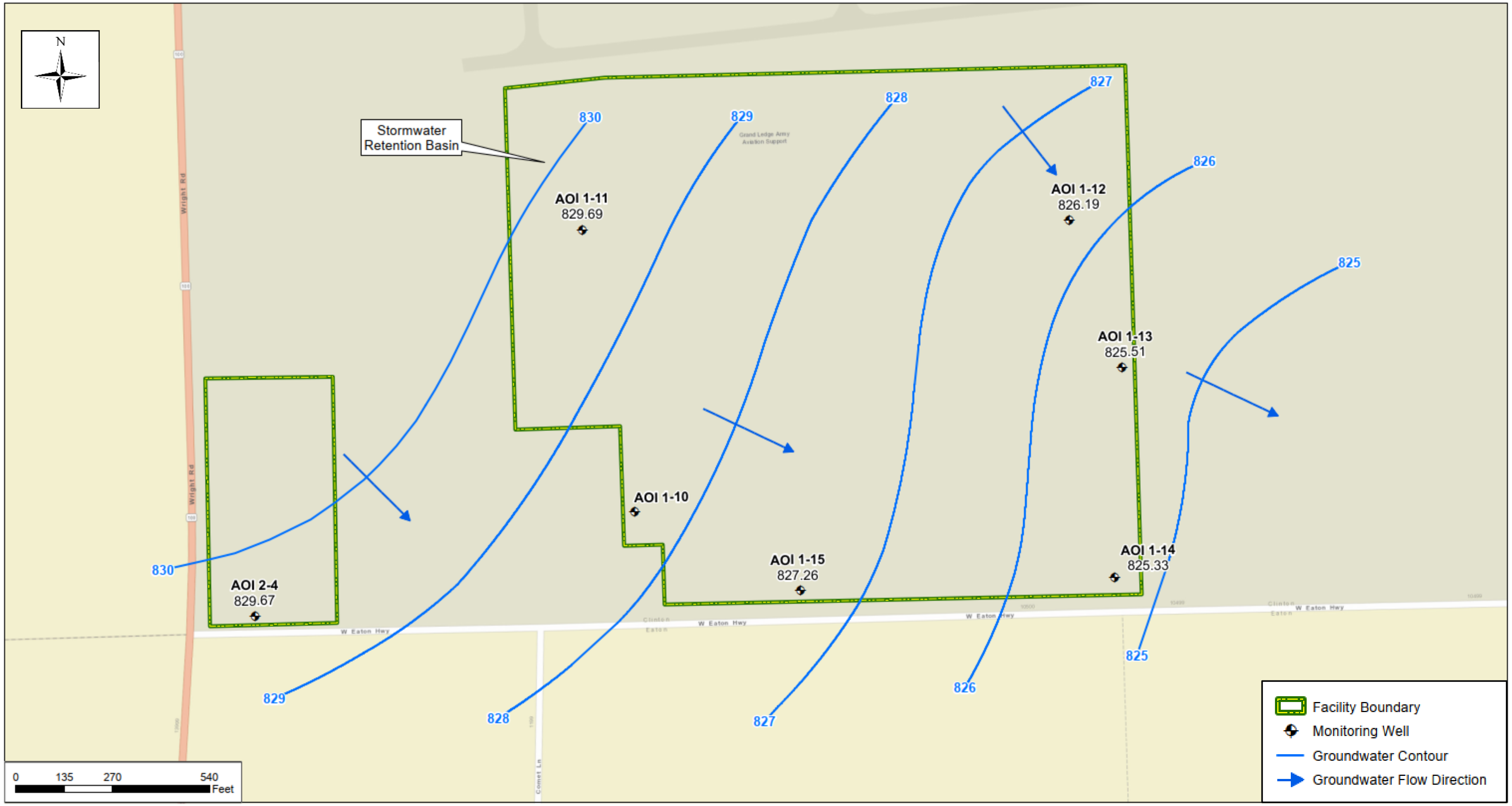
Grand Ledge AASF & Armory RI CSM

Groundwater Features



Grand Ledge AASF & Armory RI CSM

Groundwater Contours – January 2020



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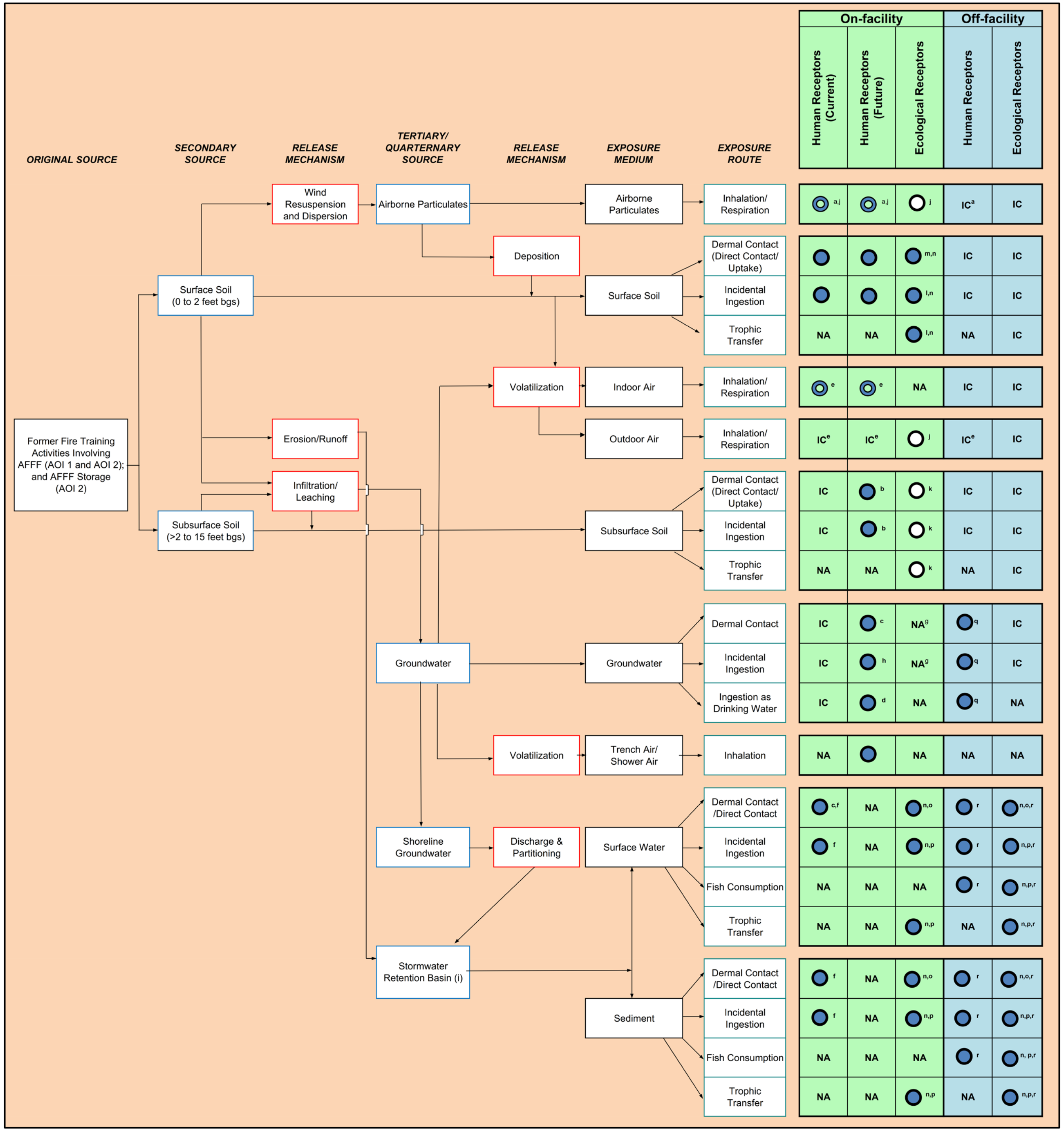
Grand Ledge
AASF & Armory RI
CSM



EXPOSURE MEDIUM	EXPOSURE ROUTE	On-facility: Human Receptors (Current)	On-facility: Human Receptors (Future)	On-facility: Ecological Receptors	Off-facility: Human Receptors	Off-facility: Ecological Receptors
Airborne Particulates	Inhalation/ Respiration	◎^{a,j}	◎^{a,j}	○^{j}	IC^{a}	IC
Surface Soil	Dermal Contact (Direct Contact/ Uptake)	●	●	●^{m,n}	IC	IC
	Incidental Ingestion	●	●	●^{l,n}	IC	IC
	Trophic Transfer	NA	NA	●^{l,n}	NA	IC
Indoor Air	Inhalation/ Respiration	◎^{e}	◎^{e}	NA	IC	IC
Outdoor Air	Inhalation/ Respiration	IC^{e}	IC^{e}	○^{j}	IC^{e}	IC
Subsurface Soil	Dermal Contact (Direct Contact/ Uptake)	IC	●^{b}	○^{k}	IC	IC
	Incidental Ingestion	IC	●^{b}	○^{k}	IC	IC
	Trophic Transfer	NA	NA	○^{k}	NA	IC
Groundwater	Dermal Contact	IC	●^{c}	NA^{g}	●^{q}	IC
	Incidental Ingestion	IC	●^{h}	NA^{g}	●^{q}	IC
	Ingestion as Drinking Water	IC	●^{d}	NA	●^{q}	NA
Trench Air/ Shower Air	Inhalation	NA	●	NA	NA	NA
Surface Water	Dermal Contact /Direct Contact	●^{c,f}	NA	●^{n,o}	●^{r}	●^{n,o,r}
	Incidental Ingestion	●^{f}	NA	●^{n,p}	●^{r}	●^{n,p,r}
	Fish Consumption	NA	NA	NA	●^{r}	●^{n,p,r}
	Trophic Transfer	NA	NA	●^{n,p}	NA	●^{n,p,r}
Sediment	Dermal Contact /Direct Contact	●^{f}	NA	●^{n,o}	●^{r}	●^{n,o,r}
	Incidental Ingestion	●^{f}	NA	●^{n,p}	●^{r}	●^{n,p,r}
	Fish Consumption	NA	NA	NA	●^{r}	●$^{n, p,r}$
	Trophic Transfer	NA	NA	●^{n,p}	NA	●^{n,p,r}

Legend

- ● **Potentially complete pathway**
- ◎ **Potentially complete pathway; but not quantitatively evaluated, as discussed in the report text.**
- ○ **Minor or insignificant pathway**
- **IC Incomplete**
- **NA Not Applicable**
- ☐ **Source Medium**
- ☐ **Release Mechanism**
- ☐ **Exposure Route**

Abbreviations

> - greater than.
AFFF - Aqueous film forming foams.
bgs - below ground surface.
PFAS - Per- and polyfluoroalkyl substances.

Grand Ledge AASF & Armory RI

Scope Summary

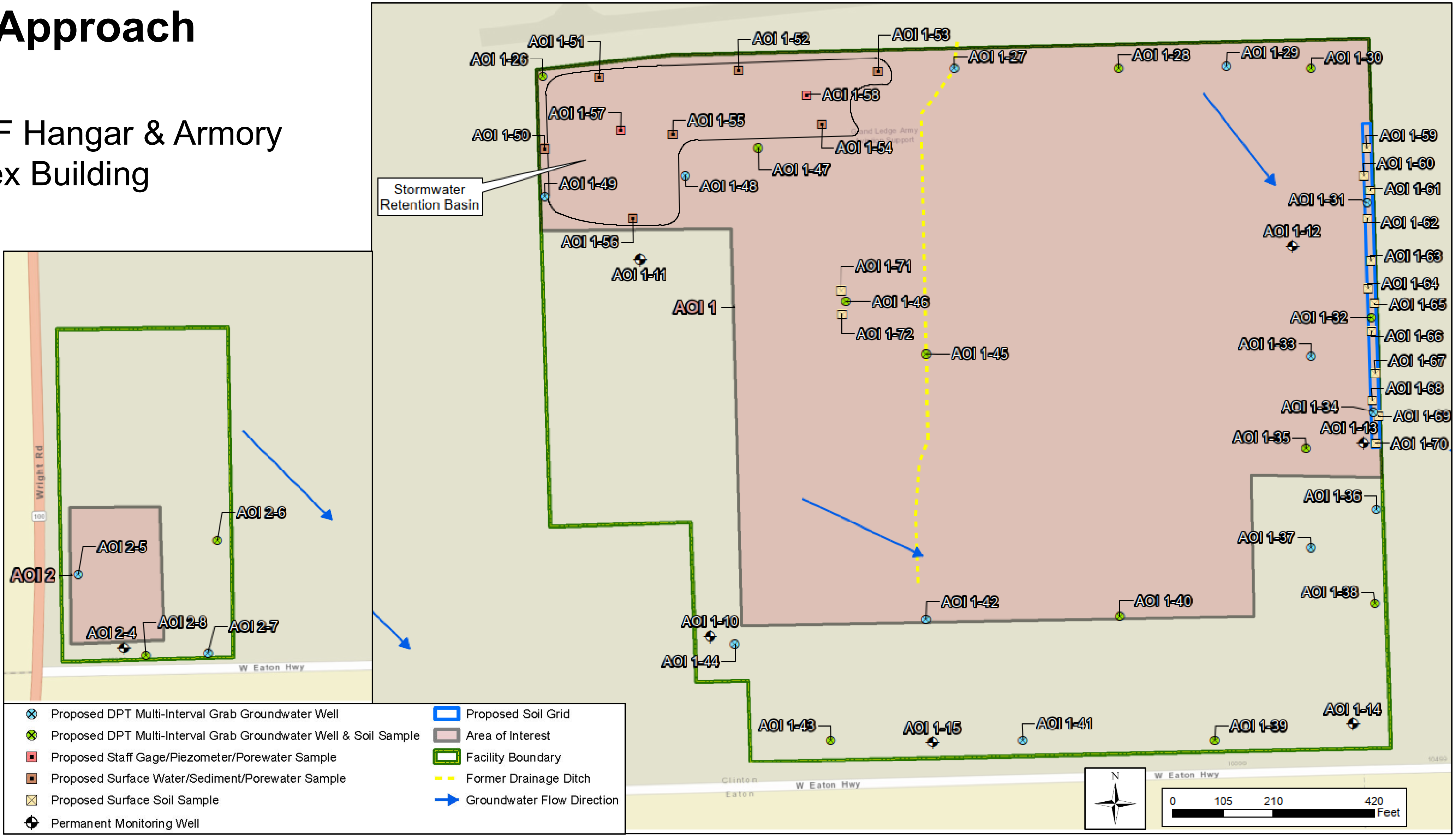
Media	# of Locations	# of Samples per Location	Depth (ft bgs)
Soil Borings	22	3	0-2; 2-4; 13-15
Surface soil	14	2	0-2; 2-4
Groundwater	38 temporary wells	2 to 3	Varies; ranging 5 to 45
	7 permanent wells	1*	Varies; ranging 30 to 100
Surface Water	7	1	Middle of water column
Sediment	7	1	0-0.5
Porewater	7	1	1.5-5

*Permanent wells will undergo four quarters of sampling

Grand Ledge AASF & Armory RI

Sampling Approach

AOI 1 – AASF Hangar & Armory
AOI 2 – Annex Building



⊗	Proposed DPT Multi-Interval Grab Groundwater Well	▭	Proposed Soil Grid
⊗	Proposed DPT Multi-Interval Grab Groundwater Well & Soil Sample	▭	Area of Interest
▣	Proposed Staff Gage/Piezometer/Porewater Sample	▭	Facility Boundary
▣	Proposed Surface Water/Sediment/Porewater Sample	- -	Former Drainage Ditch
⊠	Proposed Surface Soil Sample	→	Groundwater Flow Direction
⊕	Permanent Monitoring Well		

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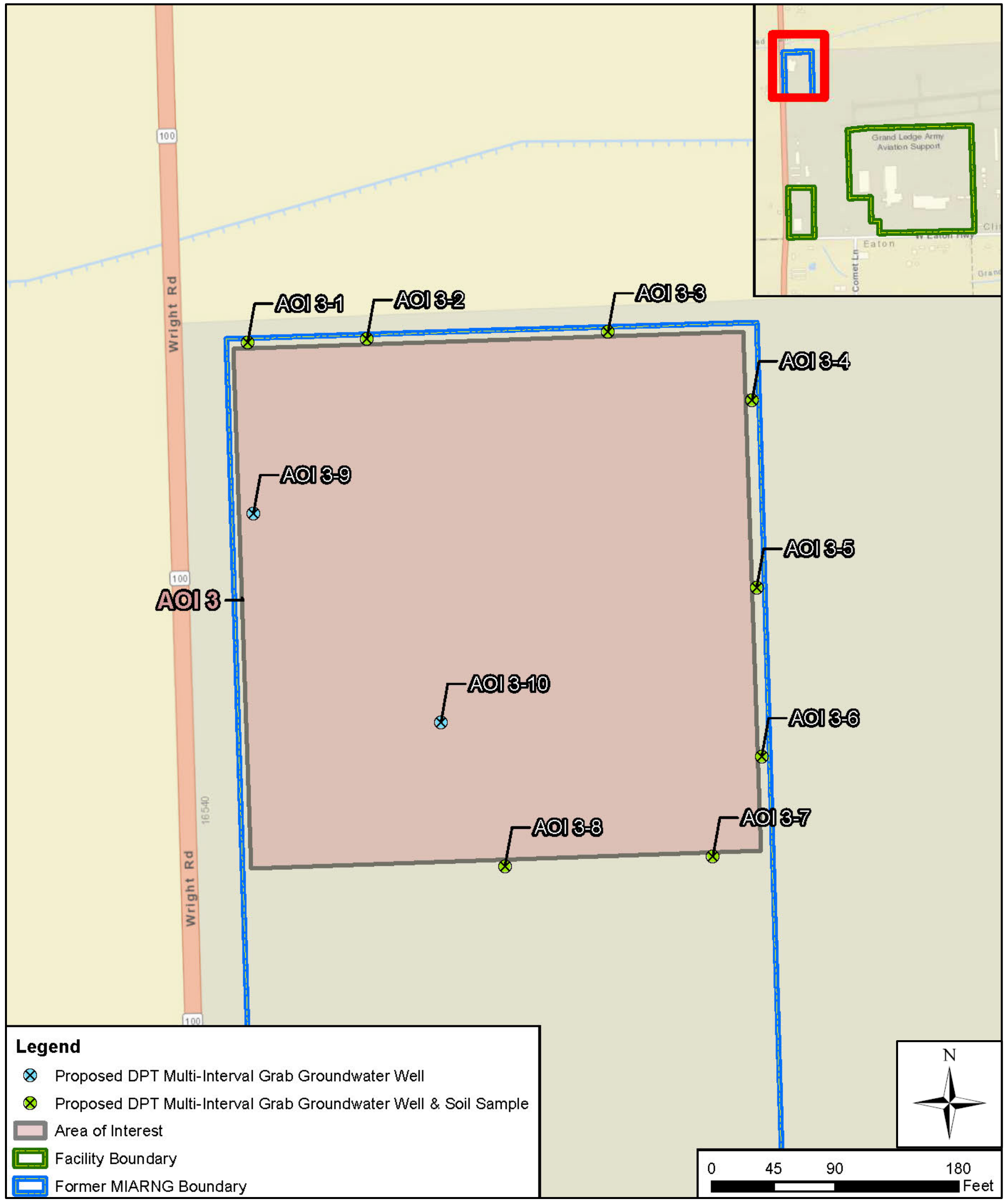
Grand Ledge AASF & Armory RI

Sampling Approach

SI Level Sampling:
AOI 3 – Former Hangar
(Transfast Trucking)



Grand Ledge AASF & Armory RI

Analytical Parameters

- 32-compound analyte list
- All PFAS samples will be analyzed via LC/MS/MS Compliant with QSM 5.3 Table B-15
- Analysis completed by Environmental Laboratory Accreditation Program (ELAP)/ National Environmental Laboratory Accreditation Program (NELAP)-certified laboratory
- Level IV data package will be received from the laboratory
- Data will undergo Stage 2b validation as defined in the Department of Defense General Data Validation Guidelines
- *See next slide for analyte list*

Grand Ledge AASF & Armory RI

Analytical Parameters

Analyte	Abbreviation	CAS Number
Perfluorobutanoic acid	PFBA	375-22-4
Perfluorobutanesulfonic acid	PFBS	375-73-5
Perfluoropentanoic acid	PFPeA	2706-90-3
Perfluorohexanoic acid	PFHxA	307-24-4
Perfluorohexanesulfonic acid	PFHxS	355-46-4
Perfluoroheptanoic acid	PFHpA	375-85-9
Perfluoroheptanesulfonic acid	PFHpS	375-92-8
Perfluorooctanoic acid	PFOA	335-67-1
Perfluorooctanesulfonic acid	PFOS	1763-23-1
Perfluorooctanesulfonamide	PFOSA	754-91-6
Fluorotelomer sulfonic acid 6:2	FTS 6:2	27619-97-2
Perfluorononanoic acid	PFNA	375-95-1
Perfluorodecanoic acid	PFDA	335-76-2
Perfluorodecanesulfonic acid	PFDS	335-77-3
Fluorotelomer sulfonic acid 8:2	FTS 8:2	39108-34-4
Perfluoroundecanoic acid	PFUdA	2058-94-8
Perfluorododecanoic acid	PFDoA	307-55-1
Perfluorotridecanoic acid	PFTrDA	72629-94-8
Perfluorotetradecanoic acid	PFTeA	376-06-7
2-(N-Ethylperfluorooctanesulfonamido) acetic acid	N-EtFOSAA	2991-50-6
2-(N-Methylperfluorooctanesulfonamido) acetic acid	N-MeFOSAA	2355-31-9
Fluorotelomer sulfonic acid 4:2	FTS 4:2	757124-72-4
Perfluorononanesulfonic acid	PFNS	68259-12-1
Perfluoropentanesulfonic acid	PFPeS	2706-91-4
N-ethyl perfluorooctane sulfonamide	EtFOSA	5141-50-2
N-ethyl perfluorooctane sulfonamido ethanol	EtFOSE	1691-99-2
N-methyl perfluorooctane sulfonamide	MeFOSA	31506-32-8
N-methyl perfluorooctane sulfonamido ethanol	MeFOSE	24448-09-7
Hexafluoropropylene oxide dimer acid	HFPO-DA	2062-98-8
11-Chloroeicosafluoro-3-oxaundecane-1-sulfonic acid	11 CL-PF3ONS	763051-92-9
9-Chlorohexadecafluoro-3-oxanonane-1-sulfonic acid	9CL-PF3ONS	756426-58-1
4,8-dioxa-3H-perfluorononanoate	ADONA	919005-14-4

Grand Ledge AASF & Armory RI

Schedule

Task	Start Date	End Date
RI QAPP (Mobilization 1)	November 2021	July/August 2022
Pre-mobilization (Mobilization 1)	July 2022	August 2022
Mobilization (Mobilization 1)	August 2022	September 2022
Field Work (Mobilization 1)	September 2022	September 2022
Demobilization (Mobilization 1)	September 2022	September 2022
Data Analysis/Data Validation (Mobilization 1)	September 2022	November 2022
RI QAPP (Mobilization 2)	November 2022	March 2023
Pre-mobilization (Mobilization 2)	March 2023	April 2023
Field Work (Mobilization 2)	April 2023	April 2023
Demobilization (Mobilization 2)	April 2023	April 2023
Data Analysis/Data Validation (Mobilization 2)	April 2023	June 2023
Reporting	June 2023	April 2024

Open Discussion

Questions? Comments?

Acronyms

AASF – Army Aviation Support Facility
AOI – Area of Interest
ARNG G9 – Army National Guard
bgs – below ground surface
CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act
CSM – conceptual site model
DD – Decision Documents
DQO – data quality objective
ERA – Ecological Risk Assessment
FS – Feasibility Study
HHRA – Human Health Risk Assessment
EGLE – Michigan Department of Environment, Great Lakes, and Energy
MIARNG – Michigan ARNG
ng/L – nanograms per liter
PA – Preliminary Assessment
PFAS – per- and polyfluoroalkyl substances
PFBA – perfluorobutanoic acid
PFBS – perfluorobutanesulfonic acid
PFDA – perfluoroundecanoic acid
PFDoA – perfluorododecanoic acid
PFNA – perfluorononanoic acid
PFHpA – perfluoroheptanoic acid
PFHxA – perfluorohexanoic acid
PFHxS – perfluorohexanesulphonic acid
PFOA – perfluorooctanoic acid
PFOS – perfluorooctanesulfonic acid
PFPeA – perfluoropentanoic acid
PFUdA – perfluoroundecanoic acid
RI – Remedial Investigation
RSC – rapid site characterization
SLERA - screening level ERA
SL – screening level
SI – Site Inspection
SU – sampling unit
SW/SD/PO – surface water, sediment, pore water
TPP – Technical Project Planning
TCRA/NTCRA – Time Critical / Non-Time Critical Removal Actions
UFP-QAPP – Uniform Federal Policy- Quality Assurance Project Plan
USACE – U.S. Army Corp of Engineers
USEPA – U.S. Environmental Protection Agency
µg/kg – micrograms per kilogram

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Thank you.

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Appendix B
SI Analytical Data Tables

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Appendix B
PFAS Detections in Residential Drinking Water
Site Inspection Report, Grand Ledge AASF and Armory

	Area of Interest	Off-Facility Private Potable Water Wells																			
	Sample ID	POTABLE-01		POTABLE-02		POTABLE-03		POTABLE-04		POTABLE-04-FD		POTABLE-05		POTABLE-06		POTABLE-07		POTABLE-08		POTABLE-09	
	Sample Date	01/22/2020		01/22/2020		01/22/2020		01/22/2020		01/22/2020		01/22/2020		01/22/2020		01/22/2020		01/22/2020		01/22/2020	
Analyte	**EPA HA [a]**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**
Water, PFAS via EPA 537.1 (ng/L)																					
PFHxA	-	ND		ND		ND		ND		ND		ND		ND		ND		ND		ND	
PFOS	70	ND		ND		ND		ND		ND		ND		ND		ND		ND		ND	
Total PFOA+PFOS	70	ND		ND		ND		ND		ND		ND		ND		ND		ND		ND	

Grey Fill	Detected concentration exceeded EPA HA

References

a. United States Environmental Protection Agency (EPA). 2016. Drinking Water Health Advisory for Perfluorooctanoic Acid (PFOA). Office of Water (4304T). Health and Ecological Criteria Division, Washington, DC 20460. EPA Document Number: 822-R-16-005. May 2016. / EPA. 2016. Drinking Water Health Advisory for Perfluorooctane Sulfonate (PFOS). Office of Water (4304T). Health and Ecological Criteria Division, Washington, DC 20460. EPA Document Number: 822-R-16-004. May 2016.

Interpreted Qualifiers

J = Estimated concentration

Chemical Abbreviations

PFHxA	perfluorohexanoic acid
PFOA	perfluorooctanoic acid
PFOS	perfluorooctanesulfonic acid

Acronyms and Abbreviations

FD/DUP	Duplicate
EPA	United States Environmental Protection Agency
GL	Grand Ledge
HA	Health Advisory
Qual	Interpreted Qualifier
ng/L	nanogram per liter
-	Not applicable

Appendix B
PFAS Detections in Residential Drinking Water
Site Inspection Report, Grand Ledge AASF and Armory

	Area of Interest	Off-Facility Private Potable Water Wells																			
	Sample ID	POTABLE-10		POTABLE-11		GL-POTABLE-12		GL-POTABLE-12-DUP		GL-POTABLE-13		GL-POTABLE-14		GL-POTABLE-15		GL-POTABLE-16		GL-POTABLE-18		GL-POTABLE-19	
	Sample Date	01/23/2020		01/23/2020		07/28/2020		07/28/2020		07/28/2020		07/29/2020		07/29/2020		07/28/2020		07/28/2020		07/29/2020	
Analyte	**EPA HA [a]**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**
Water, PFAS via EPA 537.1 (ng/L)																					
PFHxA	-	ND		ND		ND		ND		ND		2.37	J	ND		ND		ND		ND	
PFOS	70	ND		3.38	J	ND		ND		ND		ND		ND		ND		ND		ND	
Total PFOA+PFOS	70	ND		3.38	J	ND		ND		ND		ND		ND		ND		ND		ND	

Grey Fill	Detected concentration exceeded EPA HA

References

a. United States Environmental Protection Agency (EPA). 2016. Drinking Water Health Advisory for Perfluorooctanoic Acid (PFOA). Office of Water (4304T). Health and Ecological Criteria Division, Washington, DC 20460. EPA Document Number: 822-R-16-005. May 2016. / EPA. 2016. Drinking Water Health Advisory for Perfluorooctane Sulfonate (PFOS). Office of Water (4304T). Health and Ecological Criteria Division, Washington, DC 20460. EPA Document Number: 822-R-16-004. May 2016.

Interpreted Qualifiers

J = Estimated concentration

Chemical Abbreviations

PFHxA	perfluorohexanoic acid
PFOA	perfluorooctanoic acid
PFOS	perfluorooctanesulfonic acid

Acronyms and Abbreviations

FD/DUP	Duplicate
EPA	United States Environmental Protection Agency
GL	Grand Ledge
HA	Health Advisory
Qual	Interpreted Qualifier
ng/L	nanogram per liter
-	Not applicable

Appendix B
PFAS Detections in Residential Drinking Water
Site Inspection Report, Grand Ledge AASF and Armory

	Area of Interest	Off-Facility Private Potable Water Wells															
	Sample ID	GL-POTABLE-20		GL-POTABLE-21		GL-POTABLE-21-DUP		GL-POTABLE-22		GL-POTABLE-23		GL-POTABLE-24		GL-POTABLE-25		GL-POTABLE-26	
	Sample Date	07/28/2020		07/29/2020		07/29/2020		07/28/2020		07/28/2020		07/28/2020		07/29/2020		07/29/2020	
Analyte	**EPA HA**[a]	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**
Water, PFAS via EPA 537.1 (ng/L)																	
PFHxA	-	ND		ND		ND		ND		ND		ND		ND		ND	
PFOS	70	ND		ND		ND		ND		ND		ND		ND		ND	
Total PFOA+PFOS	70	ND		ND		ND		ND		ND		ND		ND		ND	

Grey Fill	Detected concentration exceeded EPA HA

References

a. United States Environmental Protection Agency (EPA). 2016. Drinking Water Health Advisory for Perfluorooctanoic Acid (PFOA). Office of Water (4304T). Health and Ecological Criteria Division, Washington, DC 20460. EPA Document Number: 822-R-16-005. May 2016. / EPA. 2016. Drinking Water Health Advisory for Perfluorooctane Sulfonate (PFOS). Office of Water (4304T). Health and Ecological Criteria Division, Washington, DC 20460. EPA Document Number: 822-R-16-004. May 2016.

Interpreted Qualifiers

J = Estimated concentration

Chemical Abbreviations

PFHxA	perfluorohexanoic acid
PFOA	perfluorooctanoic acid
PFOS	perfluorooctanesulfonic acid

Acronyms and Abbreviations

FD/DUP	Duplicate
EPA	United States Environmental Protection Agency
GL	Grand Ledge
HA	Health Advisory
Qual	Interpreted Qualifier
ng/L	nanogram per liter
-	Not applicable

Appendix B
PFAS Detections in Groundwater
Site Inspection Report, Grand Ledge AASF and Armory

Area of Interest		AOI1																	
Sample ID		AOI-1-1-GW-7-12		AOI-1-2-GW-5-10		AOI-1-3-GW-4-9		AOI-1-3-GW-4-9-DUP		AOI-1-4-GW-17-22		AOI-1-5-GW-5-10		AOI-1-6-GW-15-20		AOI1-10-GW-89		AOI1-10-GW-89-D	
Sample Date		05/09/2019		05/08/2019		05/08/2019		05/08/2019		05/08/2019		05/09/2019		05/08/2019		11/19/2019		11/19/2019	
Analyte	**OSD Screening Level [a]**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**
Water, PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 (ng/L)																			
6:2 FTS	-	ND		ND		ND	UJ	ND		ND		ND		87.0		1.69	J+	1.73	J+
PFBA	-	28.6		154		ND	UJ	ND		3.26	J	34.0		59.2		ND		2.86	J
PFBS	40000	1.58	J	5.36	J	ND	UJ	ND		2.66	J	13.5		46.1		ND		ND	
PFDoA	-	ND		ND		ND	UJ	ND		ND		ND		ND		ND		ND	
PFHpA	-	ND		ND		ND	UJ	ND		ND		36.7		65.9		ND		ND	
PFHxA	-	ND		6.83	J	ND	UJ	ND		ND		42.9		168		1.77	J	ND	
PFHxS	-	ND		5.08	J	ND	UJ	ND		4.47	J	87.8		12.1		ND		ND	
PFNA	-	ND		ND		ND	UJ	ND		ND		5.37	J	ND		ND		ND	
PFOA	40	ND		ND		ND	UJ	ND		ND		53.0		ND		ND		ND	
PFOS	40	ND		ND		ND	UJ	ND		ND		60.0		ND		ND		ND	
PFPeA	-	ND		9.09	J	ND	UJ	ND		ND		54.1		189		ND		ND	
PFTeDA	-	ND	UJ	ND	UJ	ND	UJ	ND	UJ	ND	UJ	ND	UJ	ND		ND		ND	

Grey Fill	Detected concentration exceeded OSD Screening Levels

References

a. Assistant Secretary of Defense, 2019. Risk Based Screening Levels Calculated for PFOS, PFOA, PFBS in Groundwater or Soil using USEPA's Regional Screening Level Calculator. HQ=0.1. 15 October 2019. Groundwater screening levels based on residential scenario for direct ingestion of groundwater.

Interpreted Qualifiers

J = Estimated concentration

J+ = Estimated concentration, biased high

UJ = The analyte was not detected at a level greater than or equal to the adjusted DL. However, the reported adjusted DL is approximate and may be inaccurate or imprecise.

Chemical Abbreviations

6:2 FTS	6:2 fluorotelomer sulfonate
PFBA	perfluorobutanoic acid
PFBS	perfluorobutanesulfonic acid
PFDA	perfluorodecanoic acid
PFDoA	perfluorododecanoic acid
PFHpA	perfluoroheptanoic acid
PFHxA	perfluorohexanoic acid
PFHxS	perfluorohexanesulfonic acid
PFNA	perfluorononanoic acid
PFOA	perfluorooctanoic acid
PFOS	perfluorooctanesulfonic acid
PFPeA	perfluoropentanoic acid
PFTeDA	perfluorotetradecanoic acid

Acronyms and Abbreviations

AOI	Area of Interest
D/DUP	Duplicate
GW	Groundwater
HQ	Hazard quotient
LCMSMS	liquid chromatography with tandem mass spectrometry
LOD	Limit of Detection
ND	Analyte not detected above the LOD
OSD	Office of the Secretary of Defense
QSM	Quality Systems Manual
Qual	Interpreted Qualifier
USEPA	United States Environmental Protection Agency
ng/L	nanogram per liter
-	Not applicable

Appendix B
PFAS Detections in Groundwater
Site Inspection Report, Grand Ledge AASF and Armory

	Area of Interest	AOI1										AOI2							
	Sample ID	AOI 1-11-GW-35		AOI 1-12-GW-42		AOI 1-13-GW-47		AOI 1-14-GW-55		AOI 1-15-GW-67.50		AOI-2-1-GW-5-10		AOI-2-2-GW-5-10		AOI-2-3-GW-5-10		AOI 2-4-GW-30	
	Sample Date	12/18/2019		12/20/2019		12/19/2019		12/19/2019		12/19/2019		05/09/2019		05/09/2019		05/10/2019		12/18/2019	
Analyte	**OSD Screening Level [a]**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**
Water, PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 (ng/L)																			
6:2 FTS	-	ND		327		ND		ND		ND		ND		ND		ND		ND	
PFBA	-	1.97	J	43.1		7.32	J	ND		ND		2.35	J	7.40	J	6.03	J	ND	
PFBS	40000	ND		70.7		ND		ND		ND		ND		4.21	J	ND		ND	
PFDoA	-	3.38	J+	ND	UJ	ND	UJ	ND		ND		ND		ND		ND		ND	UJ
PFHpA	-	ND		66.6		ND		ND		ND		ND		ND		ND		ND	
PFHxA	-	ND		160		4.45	J	ND		ND		ND		3.19	J	2.07	J	ND	
PFHxS	-	ND		227		ND		ND		ND		ND		44.9		ND		ND	
PFNA	-	ND		ND		ND		ND		ND		ND		ND		ND		ND	
PFOA	40	ND		28.2		ND		ND		ND		ND		4.10	J	ND		ND	
PFOS	40	1.97	J	ND		ND		ND		ND		3.46	J	31.7		ND		ND	
PFPeA	-	ND		153		16.1		ND		ND		ND		ND		ND		ND	
PFTeDA	-	40.1	J+	ND		ND	UJ	ND	UJ	ND		ND		ND	UJ	ND		ND	UJ

Grey Fill	Detected concentration exceeded OSD Screening Levels

References

a. Assistant Secretary of Defense, 2019. Risk Based Screening Levels Calculated for PFOS, PFOA, PFBS in Groundwater or Soil using USEPA's Regional Screening Level Calculator. HQ=0.1. 15 October 2019. Groundwater screening levels based on residential scenario for direct ingestion of groundwater.

Interpreted Qualifiers

J = Estimated concentration

J+ = Estimated concentration, biased high

UJ = The analyte was not detected at a level greater than or equal to the adjusted DL. However, the reported adjusted DL is approximate and may be inaccurate or imprecise.

Chemical Abbreviations

6:2 FTS	6:2 fluorotelomer sulfonate
PFBA	perfluorobutanoic acid
PFBS	perfluorobutanesulfonic acid
PFDA	perfluorodecanoic acid
PFDoA	perfluorododecanoic acid
PFHpA	perfluoroheptanoic acid
PFHxA	perfluorohexanoic acid
PFHxS	perfluorohexanesulfonic acid
PFNA	perfluorononanoic acid
PFOA	perfluorooctanoic acid
PFOS	perfluorooctanesulfonic acid
PFPeA	perfluoropentanoic acid
PFTeDA	perfluorotetradecanoic acid

Acronyms and Abbreviations

AOI	Area of Interest
D/DUP	Duplicate
GW	Groundwater
HQ	Hazard quotient
LCMSMS	liquid chromatography with tandem mass spectrometry
LOD	Limit of Detection
ND	Analyte not detected above the LOD
OSD	Office of the Secretary of Defense
QSM	Quality Systems Manual
Qual	Interpreted Qualifier
USEPA	United States Environmental Protection Agency
ng/L	nanogram per liter
-	Not applicable

Appendix B
PFAS Detections in Sediment
Site Inspection Report, Grand Ledge AASF and Armory

Area of Interest	AOI1																			
Sample ID	AOI-1-7-SD-0-1		AOI-1-7-SD-0-1-DUP		AOI-1-8-SD-0-1		AOI-1-9-SD-0-1		AOI 1-21-SD-0-0.5		AOI 1-22-SD-0-0.5		AOI 1-22-SD-0-0.5D		AOI 1-23-SD-0-0.5		AOI 1-24-SD-0-0.5		AOI 1-25-SD-0-0.5	
Sample Date	05/07/2019		05/07/2019		05/07/2019		05/07/2019		11/05/2019		11/05/2019		11/05/2019		11/05/2019		11/05/2019		11/06/2019	
Depth	0 - 1 ft		0 - 1 ft		0 - 1 ft		0 - 1 ft		0 - 0.5 ft		0 - 0.5 ft		0 - 0.5 ft		0 - 0.5 ft		0 - 0.5 ft		0 - 0.5 ft	
Analyte	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual
Sediment, PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 (ug/Kg)																				
6:2 FTS	53.2		60.1	J+	0.153	J	0.049	J	ND		1.67	J	1.40	J	ND		ND		ND	
8:2 FTS	149		158	J+	0.183	J	ND		ND		3.03		2.55	J	ND		ND		ND	
NEtFOSAA	4.73	J	3.98	J+	ND		ND		ND		ND		ND		ND		ND		ND	
PFBA	ND		ND	UJ	0.221	J	0.077	J	ND		ND		ND		ND		ND		ND	
PFBS	ND		ND	UJ	0.225	J	0.00473	J	ND		ND		ND		ND		ND		ND	
PFDA	14.2	J	17.1	J+	0.164	J	ND		ND		ND		ND		ND		ND		ND	
PFDoA	33.0	J+	26.1	J+	ND		ND		ND		0.536	J	0.676	J+	ND		ND		ND	
PFHpA	ND		ND	UJ	ND		0.00688	J	ND		ND		ND		ND		ND		ND	
PFHxA	ND		ND	UJ	0.312	J	0.057	J	ND		ND		ND		ND		ND		ND	
PFHxS	ND		ND	UJ	1.91	J	ND		ND		ND		ND		ND		0.233	J	ND	
PFOA	7.15	J	6.58	J+	0.265	J	0.030	J	ND		ND		ND		ND		ND		ND	
PFOS	26.3	J	ND	UJ	5.31	J+	6.32		ND		0.744	J	1.15	J	5.89	J-	ND		ND	
PFPeA	ND		ND	UJ	ND		0.047	J	ND		ND		ND		ND		ND		ND	
PFTeDA	37.3	J+	28.2	J+	0.077	J	ND		ND		1.13	J+	0.843	J+	ND		ND	UJ	ND	
PFTrDA	18.2	J+	10.7	J+	0.096	J	ND		ND		3.09	J+	0.772	J+	ND		ND	UJ	ND	
PFUnDA	10.5	J+	ND	UJ	ND		ND		ND		ND		ND		ND		ND		ND	

Interpreted Qualifiers

J = Estimated concentration

J- = Estimated concentration, biased low

J+ = Estimated concentration, biased high

UJ = The analyte was not detected at a level greater than or equal to the adjusted DL. However, the reported adjusted DL is approximate and may be inaccurate or imprecise.

Chemical Abbreviations

6:2 FTS	6:2 fluorotelomer sulfonate
8:2 FTS	8:2 fluorotelomer sulfonate
NEtFOSAA	N-ethyl perfluorooctane- sulfonamidoacetic acid
PFBA	perfluorobutyrate
PFBS	perfluorobutane sulfonate
PFDA	perfluorodecanoate
PFDoA	perfluorododecanoic acid
PFHpA	perfluoroheptanoic acid
PFHxA	perfluorohexanoic acid
PFHxS	perfluorohexanesulfonic acid
PFOA	perfluorooctanoic acid
PFOS	perfluorooctane sulfonate
PFPeA	perfluoropentanoic acid
PFTeDA	perfluorotetradecanoic acid
PFTrDA	perfluorotridecanoic acid
PFUnDA	perfluoro-n-undecanoic acid

Acronyms and Abbreviations

AOI	Area of Interest
D/DUP	Duplicate
ft	feet
LCMSMS	liquid chromatography with tandem mass spectrometry
LOD	Limit of Detection
ND	Analyte not detected above the LOD
QSM	Quality Systems Manual
Qual	Interpreted Qualifier
SD	Sediment
ug/Kg	micrograms per Kilogram

Appendix B
PFAS Detections in Deep Subsurface Soil
Site Inspection Report, Grand Ledge AASF and Armory

Area of Interest	AOI1			
Sample ID	AOI-1-4-SB-17-19		AOI-1-4-SB-17-19-DUP	
Sample Date	05/07/2019		05/07/2019	
Depth	17 - 19 ft		17 - 19 ft	
Analyte	**Result**	**Qual**	**Result**	**Qual**
Soil, PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 (ug/Kg)				
PFBA	0.068	J	0.046	J
PFDA	ND		0.012	J
PFHxA	0.032	J	ND	

Interpreted Qualifiers

J = Estimated concentration

Chemical Abbreviations

PFBA	perfluorobutyrate
PFDA	perfluorodecanoate
PFHxA	perfluorohexanoic acid

Acronyms and Abbreviations

AOI	Area of Interest
D/DUP	Duplicate
ft	feet
LCMSMS	liquid chromatography with tandem mass spectrometry
LOD	Limit of Detection
ND	Analyte not detected above the LOD
QSM	Quality Systems Manual
Qual	Interpreted Qualifier
SB	Soil boring
ug/Kg	micrograms per Kilogram

Appendix B
PFAS Detections in Shallow Subsurface Soil
Site Inspection Report, Grand Ledge AASF and Armory

	Area of Interest	AOI 1														AOI 2			
	Sample ID	AOI-1-1-SB-5-7		AOI-1-2-SB-2-4		AOI-1-3-SB-2-4		AOI-1-4-SB-8-10		AOI-1-5-SB-2-4		AOI-1-6-SB-2-4		AOI-1-6-SB-5-7		AOI-2-2-SB-2-4		AOI-2-2-SB-2-4-DUP	
	Sample Date	05/08/2019		05/09/2019		05/10/2019		05/07/2019		05/08/2019		05/09/2019		05/08/2019		05/09/2019		05/09/2019	
	Depth	5 - 7 ft		2 - 4 ft		2 - 4 ft		8 - 10 ft		2 - 4 ft		2 - 4 ft		5 - 7 ft		2 - 4 ft		2 - 4 ft	
Analyte	**OSD Screening Level [a]**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**
Soil, PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 (ug/Kg)																			
8:2 FTS	-	ND		ND		ND		ND		ND		0.023	J	ND		ND		ND	
PFBA	-	0.033	J	0.052	J	0.032	J	0.055	J	0.130	J	0.029	J	0.040	J	0.033	J	0.035	J
PFBS	1600000	ND		ND		ND		ND		0.00917	J	ND		ND		ND		ND	
PFDA	-	ND		0.016	J	ND		0.00876	J	0.013	J	ND		ND		ND		0.013	J
PFDoA	-	ND		ND		ND		ND		ND		0.010	J	ND		ND		ND	
PFHpA	-	ND		ND		0.00825	J	ND		0.179	J	0.018	J	ND		ND		ND	
PFHxA	-	ND		0.043	J	ND		0.028	J	0.261	J	0.064	J	0.038	J	ND		0.040	J
PFHxS	-	ND		ND		ND		ND		0.199	J	ND		ND		ND		0.011	J
PFNA	-	ND		ND		ND		ND		0.062	J	ND		ND		ND		ND	
PFOA	1600	ND		0.031	J	ND		0.00784	J	0.171	J	0.017	J	ND		0.017	J	0.016	J
PFOS	1600	ND		0.285	J	ND		ND		0.541	J	0.018	J	ND		0.196	J	0.123	J
PFPeA	-	ND		ND		ND		ND		0.321	J	ND		ND		ND		ND	
PFTeDA	-	ND		0.014	J	ND		ND		ND		ND		ND		ND		ND	
PFUnDA	-	0.00497	J	0.00847	J	ND		ND		ND		ND		ND		ND		ND	

Grey Fill	Detected concentration exceeded OSD Screening Levels

References

a. Assistant Secretary of Defense, 2019. Risk Based Screening Levels Calculated for PFOS, PFOA, PFBS in Groundwater or Soil using USEPA's Regional Screening Level Calculator. HQ=0.1. 15 October 2019. Soil screening levels based on industrial/commercial composite worker scenario for incidental ingestion of contaminated soil.

Interpreted Qualifiers

J = Estimated concentration

Chemical Abbreviations

8:2 FTS	8:2 fluorotelomer sulfonate
PFBA	perfluorobutanoic acid
PFBS	perfluorobutanesulfonic acid
PFDA	perfluorodecanoic acid
PFDoA	perfluorododecanoic acid
PFHpA	perfluoroheptanoic acid
PFHxA	perfluorohexanoic acid
PFHxS	perfluorohexanesulfonic acid
PFNA	perfluorononanoic acid
PFOA	perfluorooctanoic acid
PFOS	perfluorooctanesulfonic acid
PFPeA	perfluoropentanoic acid
PFTeDA	perfluorotetradecanoic acid
PFUnDA	perfluoro-n-undecanoic acid

Acronyms and Abbreviations

AOI	Area of Interest
DUP	Duplicate
ft	feet
HQ	Hazard quotient
LCMSMS	Liquid Chromatography Mass Spectrometry
LOD	Limit of Detection
ND	Analyte not detected above the LOD
OSD	Office of the Secretary of Defense
QSM	Quality Systems Manual
Qual	Interpreted Qualifier
SB	Soil boring
USEPA	United States Environmental Protection Agency
ug/Kg	micrograms per Kilogram
-	Not applicable

Appendix B
PFAS Detections in Surface Soil
Site Inspection Report, Grand Ledge AASF and Armory

	Area of Interest	AOI 1																			
	Sample ID	AOI-1-1-SB-0-2		AOI-1-2-SB-0-2		AOI-1-3-SB-0-2		AOI-1-4-SB-0-2		AOI-1-5-SB-0-2		AOI-1-6-SB-0-2		AOI 1-16-SS-0-2		AOI 1-17-SS-0-2		AOI 1-18-SS-0-2		AOI 1-18-SS-0-2D	
	Sample Date	05/09/2019		05/09/2019		05/10/2019		05/10/2019		05/08/2019		05/09/2019		11/06/2019		11/06/2019		11/06/2019		11/06/2019	
	Depth	0 - 2 ft		0 - 2 ft		0 - 2 ft		0 - 2 ft		0 - 2 ft		0 - 2 ft		0 - 2 ft		0 - 2 ft		0 - 2 ft		0 - 2 ft	
Analyte	**OSD Screening Level ^{a}**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**
Soil, PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 (ug/Kg)																					
NEtFOSAA	-	ND		ND		ND		ND		0.030	J	ND		ND		ND		ND		ND	
NMeFOSAA	-	ND		ND		0.00530	J	ND		0.028	J	ND		ND		ND		ND		ND	
PFBA	-	0.129	J	0.116	J	0.046	J	0.204	J	0.098	J	0.051	J	ND		ND		ND		ND	
PFBS	130000	0.00424	J	ND		ND		ND		ND		ND		ND		ND		ND		ND	
PFDA	-	ND		0.031	J	ND		0.045	J	ND		ND		ND		ND		ND		ND	
PFHpA	-	ND		0.057	J	0.011	J	0.056	J	0.057	J	0.027	J	ND		ND		ND		ND	
PFHxA	-	0.044	J	0.085	J	0.043	J	0.105	J	0.078	J	0.048	J	ND		0.282	J	0.209	J	ND	
PFHxS	-	ND		ND		ND		0.043	J	ND		0.032	J	0.213	J	1.09	J	0.223	J	0.216	J
PFNA	-	ND		0.052	J	ND		0.097	J	0.152	J	ND		ND		ND		0.113	J	ND	
PFOA	130	0.015	J	0.123	J	0.018	J	0.157	J	0.171	J	0.039	J	ND		0.212	J	0.182	J	0.181	J
PFOS	130	ND		0.936	J	0.033	J	0.444	J	2.22	J+	0.032	J	0.802	J	4.27		3.62		2.73	
PFPeA	-	ND		ND		ND		ND		ND		ND		ND		ND		ND		ND	
PFTeDA	-	ND		ND		ND		ND		ND		ND		ND		ND		ND		ND	
PFTrDA	-	ND		ND		ND		ND		ND		ND		ND		ND		ND		ND	
PFUnDA	-	0.00519	J	0.019	J	ND		0.031	J	0.012	J	ND		ND		ND		ND		ND	

▨ Grey Fill	Detected concentration exceeded OSD Screening Levels

References

a. Assistant Secretary of Defense, 2019. Risk Based Screening Levels Calculated for PFOS, PFOA, PFBS in Groundwater or Soil using USEPA's Regional Screening Level Calculator. HQ=0.1. 15 October 2019. Soil screening levels based on residential scenario for direct ingestion of contaminated soil.

Interpreted Qualifiers

J = Estimated concentration

J+ = Estimated concentration, biased high

Chemical Abbreviations

NEtFOSAA	N-ethyl perfluorooctane- sulfonamidoacetic acid
NMeFOSAA	N-methyl perfluorooctanesulfonamidoacetic acid
PFBA	perfluorobutanoic acid
PFBS	perfluorobutanesulfonic acid
PFDA	perfluorodecanoic acid
PFHpA	perfluoroheptanoic acid
PFHxA	perfluorohexanoic acid
PFHxS	perfluorohexanesulfonic acid
PFNA	perfluorononanoic acid
PFOA	perfluorooctanoic acid
PFOS	perfluorooctanesulfonic acid
PFPeA	perfluoropentanoic acid
PFTeDA	perfluorotetradecanoic acid
PFTrDA	perfluorotridecanoic acid
PFUnDA	perfluoro-n-undecanoic acid

Acronyms and Abbreviations

AOI	Area of Interest
D	Duplicate
ft	feet
HQ	Hazard quotient
LCMSMS	Liquid Chromatography Mass Spectrometry
LOD	Limit of Detection
ND	Analyte not detected above the LOD
OSD	Office of the Secretary of Defense
QSM	Quality Systems Manual
Qual	Interpreted Qualifier
SB	Soil boring
SS	Surface Soil
USEPA	United States Environmental Protection Agency
ug/Kg	micrograms per Kilogram
-	Not applicable

Appendix B
PFAS Detections in Surface Soil
Site Inspection Report, Grand Ledge AASF and Armory

	Area of Interest	AOI 1				AOI 2					
	Sample ID	AOI 1-19-SS-0-2		AOI 1-20-SS-0-2		AOI-2-1-SB-0-2		AOI-2-2-SB-0-2		AOI-2-3-SB-0-2	
	Sample Date	11/06/2019		11/06/2019		05/09/2019		05/09/2019		05/09/2019	
	Depth	0 - 2 ft		0 - 2 ft		0 - 2 ft		0 - 2 ft		0 - 2 ft	
Analyte	**OSD Screening Level [a]**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**
Soil, PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 (ug/Kg)											
NEtFOSAA	-	ND		ND		ND		0.026	J	ND	
NMeFOSAA	-	ND		ND		ND		ND		ND	
PFBA	-	0.186	J	ND		0.095	J	0.046	J	0.110	J
PFBS	130000	ND		ND		0.014	J	ND		0.011	J
PFDA	-	ND		ND		ND		0.018	J	0.028	J
PFHpA	-	0.225	J	ND		0.045	J	ND		0.028	J
PFHxA	-	0.492	J	0.237	J	0.094	J	ND		0.056	J
PFHxS	-	2.01		0.372	J	0.041	J	ND		0.011	J
PFNA	-	0.175	J	ND		0.029	J	ND		0.048	J
PFOA	130	0.331	J	ND		0.117	J	ND		0.069	J
PFOS	130	11.0		1.09	J	0.486	J	ND		0.175	J
PFPeA	-	ND		ND		0.078	J	ND		ND	
PFTeDA	-	ND		ND		0.019	J	ND		ND	
PFTrDA	-	ND		ND		ND		ND		0.014	J
PFUnDA	-	ND		ND		0.016	J	ND		0.018	J

Grey Fill	Detected concentration exceeded OSD Screening Levels

References

a. Assistant Secretary of Defense, 2019. Risk Based Screening Levels Calculated for PFOS, PFOA, PFBS in Groundwater or Soil using USEPA's Regional Screening Level Calculator. HQ=0.1. 15 October 2019. Soil screening levels based on residential scenario for direct ingestion of contaminated soil.

Interpreted Qualifiers

J = Estimated concentration

J+ = Estimated concentration, biased high

Chemical Abbreviations

NEtFOSAA	N-ethyl perfluorooctane- sulfonamidoacetic acid
NMeFOSAA	N-methyl perfluorooctanesulfonamidoacetic acid
PFBA	perfluorobutanoic acid
PFBS	perfluorobutanesulfonic acid
PFDA	perfluorodecanoic acid
PFHpA	perfluoroheptanoic acid
PFHxA	perfluorohexanoic acid
PFHxS	perfluorohexanesulfonic acid
PFNA	perfluorononanoic acid
PFOA	perfluorooctanoic acid
PFOS	perfluorooctanesulfonic acid
PFPeA	perfluoropentanoic acid
PFTeDA	perfluorotetradecanoic acid
PFTrDA	perfluorotridecanoic acid
PFUnDA	perfluoro-n-undecanoic acid

Acronyms and Abbreviations

AOI	Area of Interest
D	Duplicate
ft	feet
HQ	Hazard quotient
LCMSMS	Liquid Chromatography Mass Spectrometry
LOD	Limit of Detection
ND	Analyte not detected above the LOD
OSD	Office of the Secretary of Defense
QSM	Quality Systems Manual
Qual	Interpreted Qualifier
SB	Soil boring
SS	Surface Soil
USEPA	United States Environmental Protection Agency
ug/Kg	micrograms per Kilogram
-	Not applicable

Appendix B
PFAS Detections in Surface Water
Site Inspection Report, Grand Ledge AASF and Armory

Area of Interest	AOI 1																			
Sample ID	AOI-1-7-SW-0-1		AOI-1-7-SW-0-1-DUP		AOI-1-8-SW-0-1		AOI-1-9-SW-0-1		AOI 1-21-SW-0-0.5		AOI1-21-SW-0-0.5		AOI 1-22-SW-0-0.5		AOI 1-22-SW-0-0.5D		AOI1-22-SW-0-0.5		AOI 1-23-SW-0-0.5	
Sample Date	05/07/2019		05/07/2019		05/07/2019		05/07/2019		11/05/2019		11/21/2019		11/05/2019		11/05/2019		11/21/2019		11/05/2019	
Analyte	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**
Water, PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 (ng/L)																				
6:2 FTS	143		146		ND		35.5		10.1		27.9	J+	189		201		15.8	J+	122	
8:2 FTS	7.99	J	9.64		ND		7.64	J	ND		3.14	J+	2.89	J	3.23	J	ND		20.8	J
PFBA	16.0		17.3		19.8	J-	9.28	J+	14.1		18.6		20.0		20.5		3.63	J	26.0	J-
PFBS	3.39	J	3.87	J	6.66	J	1.82	J	6.22	J	3.56	J	3.75	J	4.10	J	ND		ND	
PFDA	ND		ND		ND		ND		ND		5.54	J	ND		ND		ND		ND	
PFHpA	18.2		18.6		ND		4.85	J	18.9		23.1		24.0		23.2		3.29	J	34.8	J-
PFHxA	34.1		35.2		7.34	J	11.2		43.4		50.1		44.2		45.6		6.78	J	43.4	J+
PFHxS	19.5		19.0		12.6		18.1		17.7		13.2		23.5		27.3		3.56	J	45.1	
PFNA	1.44	J	1.84	J	ND		ND		ND		2.72	J	ND		ND		ND		ND	
PFOA	10.6		10.8		1.64	J	5.59	J	8.69		20.5		12.5		13.2		1.85	J	17.0	J
PFOS	21.2		20.6		4.66	J	141		ND		16.3	J+	19.0		23.2		ND		283	J+
PFPeA	58.0		60.2		4.05	J	8.29	J	97.2		101		81.6		76.2		8.64		82.4	
PFTeDA	ND	UJ	ND		ND	UJ	ND		ND	UJ	ND		ND	UJ	ND	UJ	3.14	J	ND	
PFTrDA	ND	UJ	ND		ND	UJ	ND		ND	UJ	ND		ND	UJ	ND	UJ	2.62	J	ND	
PFUnDA	ND		ND		ND		ND		ND		ND		ND		ND	UJ	ND		8.79	J

Interpreted Qualifiers

J = Estimated concentration

J- = Estimated concentration, biased low

J+ = Estimated concentration, biased high

UJ = The analyte was not detected at a level greater than or equal to the adjusted DL. However, the reported adjusted DL is approximate and may be inaccurate or imprecise.

Chemical Abbreviations

6:2 FTS	6:2 fluorotelomer sulfonate
8:2 FTS	8:2 fluorotelomer sulfonate
PFBA	perfluorobutanoic acid
PFBS	perfluorobutanesulfonic acid
PFDA	perfluorodecanoic acid
PFHpA	perfluoroheptanoic acid
PFHxA	perfluorohexanoic acid
PFHxS	perfluorohexanesulfonic acid
PFNA	perfluorononanoic acid
PFOA	perfluorooctanoic acid
PFOS	perfluorooctanesulfonic acid
PFPeA	perfluoropentanoic acid
PFTeDA	perfluorotetradecanoic acid
PFTrDA	perfluorotridecanoic acid
PFUnDA	perfluoro-n-undecanoic acid

Acronyms and Abbreviations

AOI	Area of Interest
D/DUP	Duplicate
LCMSMS	liquid chromatography with tandem mass spectrometry
LOD	Limit of Detection
ND	Analyte not detected above the LOD
QSM	Quality Systems Manual
Qual	Interpreted Qualifier
SW	Surface water
ng/L	nanogram per liter

Appendix B
PFAS Detections in Surface Water
Site Inspection Report, Grand Ledge AASF and Armory

Area of Interest	AOI 1					
Sample ID	AOI1-23-SW-0-0.5		AOI 1-24-SW-0-0.5		AOI1-24-SW-0-0.5	
Sample Date	11/21/2019		11/05/2019		11/21/2019	
Analyte	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**
Water, PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 (ng/L)						
6:2 FTS	17.7	J+	ND		ND	
8:2 FTS	9.35	J+	ND		ND	
PFBA	3.05	J	ND		4.06	J
PFBS	ND		ND		1.41	J
PFDA	1.53	J	ND		3.51	J
PFHpA	2.07	J	ND		ND	
PFHxA	4.45	J	ND		2.49	J
PFHxS	4.64	J	8.95	J	3.33	J
PFNA	ND		7.48	J	ND	
PFOA	2.05	J	ND		ND	
PFOS	51.1	J+	53.2		ND	
PFPeA	2.09	J	ND		ND	
PFTeDA	ND		ND	UJ	ND	
PFTrDA	ND		ND	UJ	ND	
PFUnDA	ND		ND		ND	

Interpreted Qualifiers

J = Estimated concentration

J- = Estimated concentration, biased low

J+ = Estimated concentration, biased high

UJ = The analyte was not detected at a level greater than or equal to the adjusted DL. However, the reported adjusted DL is approximate and may be inaccurate or imprecise.

Chemical Abbreviations

6:2 FTS	6:2 fluorotelomer sulfonate
8:2 FTS	8:2 fluorotelomer sulfonate
PFBA	perfluorobutanoic acid
PFBS	perfluorobutanesulfonic acid
PFDA	perfluorodecanoic acid
PFHpA	perfluoroheptanoic acid
PFHxA	perfluorohexanoic acid
PFHxS	perfluorohexanesulfonic acid
PFNA	perfluorononanoic acid
PFOA	perfluorooctanoic acid
PFOS	perfluorooctanesulfonic acid
PFPeA	perfluoropentanoic acid
PFTeDA	perfluorotetradecanoic acid
PFTrDA	perfluorotridecanoic acid
PFUnDA	perfluoro-n-undecanoic acid

Acronyms and Abbreviations

AOI	Area of Interest
D/DUP	Duplicate
LCMSMS	liquid chromatography with tandem mass spectrometry
LOD	Limit of Detection
ND	Analyte not detected above the LOD
QSM	Quality Systems Manual
Qual	Interpreted Qualifier
SW	Surface water
ng/L	nanogram per liter

Appendix C
Analytical Laboratory Documentation

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Appendix D
Field Standard Operating Procedures

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Utility Clearance

Procedure 3-01

1.0 Purpose and Scope

1.1 This standard operating procedure (SOP) describes the process for determining the presence of subsurface utilities and other cultural features at locations where planned site activities involve the physical disturbance of subsurface materials.

1.2 This procedure is the Program-approved professional guidance for work performed by AECOM under the client contract.

1.3 The procedure applies to the following activities: soil gas surveying, excavating, trenching, drilling of borings and installation of monitoring and extraction wells, use of soil recovery or slide-hammer hand augers, and all other intrusive sampling activities.

1.4 The primary purpose of the procedure is to minimize the potential for damage to underground utilities and other subsurface features, which could result in physical injury, disruption of utility service, or disturbance of other subsurface cultural features.

1.5 If there are procedures, whether it be from AECOM, state, and/or federal, that are not addressed in this SOP and are applicable to utility clearance, those procedures should be added as an appendix to the project specific Quality Assurance Project Plan (QAPP).

1.6 As guidance for specific activities, this procedure does not obviate the need for professional judgment. Deviations from this procedure while planning or executing planned activities must be approved in accordance with Program requirements for technical planning and review.

2.0 Safety

2.1 Field and subcontractor personnel shall adhere to a site-specific health and safety plan (HASP).

3.0 Terms and Definitions

3.1 Utility

For the proposes of this SOP, a utility is defined as a manmade underground line or conduit, cable, pipe, vault or tank that is, or was, used for the transmission of material or energy (e.g., gas, electrical, telephone, steam, water or sewage, product transfer lines, or underground storage tanks).

3.2 As-Built Plans

As-built plans are plans or blueprints depicting the locations of structures and associated utilities on a property.

3.3 One-Call

The Utility Notification Center is the one-call agency for nationwide call before you dig. The Utility Notification Center is open 24 hours a day and accepts calls from anyone planning to dig. The phone number 811 is the designated call before you dig phone number that directly connects you to your local one-call center. Additional information can be found at www.call811.com.

Calling before you dig ensures that any publicly owned underground lines will be marked so that you can dig around them safely. Having the utility lines marked not only prevents accidental damage to the lines but prevents property damage and personal injuries that could result in breaking a line.

The following information will need to be provided when a call is placed to One-Call:

- Your name, phone number, company name (if applicable), and mailing address.
- What type or work is being done.
- Who the work is being done for.
- The county and city the work is taking place in.
- The address or the street where the work is taking place.
- Marking instructions, (specific instructions as to where the work is taking place).

Under normal circumstances it takes between 2 to 5 days from the time you call (not counting weekends or holidays) to have the underground lines marked. Because these laws vary from state to state, exactly how long it will take depends on where your worksite is located. You will be given an exact start time and date when your locate request is completed, which will comply with the laws in your area.

In the event of an emergency (any situation causing damage to life or property, or a service outage), lines can be marked sooner than the original given time if requested.

3.4 Toning

Toning is the process of surveying an area utilizing one or more surface geophysical methods to determine the presence or absence of underground utilities. Typically, toning is conducted after identifying the general location of utilities and carefully examining all available site utility plans. Each location is marked according to the type of utility being identified. In addition, areas cleared by toning are flagged or staked to indicate that all identified utilities in a given area have been toned.

4.0 Training and Qualifications

4.1 The **Task Order (TO) Manager** is responsible for verifying that these utility locating procedures are performed prior to the initiation of active subsurface exploration.

4.2 The **Program Quality Manager** is responsible for ensuring overall compliance with this procedure.

4.3 The **Field Manager** is responsible for ensuring that all utility locating activities are performed in accordance with this procedure.

4.4 All **Field Personnel** are responsible for the implementation of this procedure.

5.0 Equipment and Supplies

5.1 Equipment and supplies necessary for locating subsurface utilities will be provided by the subcontractor; however, the project **Field Manager/Field Personnel** will provide any additional equipment and supplies as needed as well as maintain information regarding the utility clearance activities in the field logbook.

6.0 Procedure

Proceed with the following steps where subsurface exploration will include excavations, drilling, or any other subsurface investigative method that could damage utilities at a site. In addition to the steps outlined below, always exercise caution while conducting subsurface exploratory work.

6.1 Prepare Preliminary Site Plan

- Prepare a preliminary, scaled site plan depicting the proposed exploratory locations as part of the project specific QAPP. Include as many of the cultural and natural features as practical in this plan.

6.2 Review Background Information

- Search existing plan files to review the as-built plans to identify the known location of utilities at the site. Plot the locations of utilities identified onto a preliminary, scaled site plan. Inform the TO Manager if utilities lie within close proximity to a proposed exploration or excavation location. The TO Manager will determine if it is necessary to relocate proposed sampling or excavation locations.
- Include the utility location information gathered during previous investigations (e.g., remedial investigation or remedial site evaluation) in the project design documents for removal or remedial actions. In this manner, information regarding utility locations collected during implementation of a TO can be shared with the subcontractor during implementation of a particular task order. In many instances, this will help to reduce the amount of additional geophysical surveying work the subcontractor may have to perform.
- Conduct interviews with onsite and facility personnel familiar with the site to obtain additional information regarding the known and suspected locations of underground utilities. In addition, if appropriate, contact shall be made with local utility companies to request their help in locating underground lines. Pencil in the dimensions, orientation, and depth of utilities, other than those identified on the as-built plans, at their approximate locations on the preliminary plans. Enter the type of utility, the personnel who provided the information, and the date the information was provided into the field log.
- During the pre-field work interviewing process, the interviewer will determine which site personnel should be notified in the event of an incident involving damage to existing utilities. Record this information in the field logbook with the corresponding telephone numbers and addresses.

6.3 Site Visit/Locate Utilities/Toning

- Prior to the initiation of field activities, the Field Task Manager or similarly qualified field personnel shall visit the site and note existing structures and evidence of associated utilities, such as fire hydrants, irrigation systems, manhole and vault box covers, standpipes, telephone switch boxes, free-standing light poles, gas or electric meters, pavement cuts, and linear depression. Compare notes of the actual site configuration to the preliminary site plan. Note deviations in the field logbook and on the preliminary site plan. Accurately locate or survey and clearly mark with stakes, pins, flags, paint, or other suitable devices all areas where subsurface exploration is proposed. These areas shall correspond with the locations drawn on the preliminary site plan.
- Following the initial site visit by the Field Task Manager, a trained utility locating subcontractor will locate, identify, and tone all utilities depicted on the preliminary site plan. The Field Task Manager or similarly qualified field personnel shall visit the site and identify the areas of subsurface disturbance with white spray paint, chalk, white pin flags or some other easily identifiable marking. The utility locator should utilize appropriate sensing equipment to attempt to locate utilities that might not have appeared on the as-built plans. At a minimum, the utility subcontractor should utilize a metal detector and/or magnetometer; however, it is important to consider the possibility that non-metallic utilities or tanks might be present at the site. Use other appropriate surface geophysical methods such as Ground Penetrating Radar, Radio detection, etc. as appropriate. Clear proposed exploration areas of all utilities in the immediate area where subsurface exploration is proposed. Clearly tone all anomalous areas. Clearly identify all toned areas on the preliminary site plan. All utilities near the area of subsurface disturbance should also be marked out by the utility subcontractor using the universal colors for subsurface utilities (i.e., red – electric; blue – water; green – sewer; yellow – gas; etc.). After toning the site and plotting all known or suspected buried utilities on the preliminary site plan, the utility locator shall provide the Field Task Manager with a copy of the completed preliminary site plan. Alternatively, the Field Task Manager or designee shall document the results of the survey on the preliminary site plan.
- Report to the Field Task Manager anomalous areas detected and toned that are in close proximity to the exploration or excavation areas. The Field Task Manager shall determine the safe distance to maintain from the known or suspected utility. It may be necessary to relocate the proposed

exploration or excavation areas. If this is required, the Field Task Manager or designee shall relocate them and clearly mark them using the methods described above. Completely remove the markings at the prior location. Plot the new locations on the site plan and delete the prior locations from the plan. In some instances, such as in areas extremely congested with subsurface utilities, it may be necessary to dig by hand or use techniques such as air knife to determine the location of the utilities.

6.4 Prepare Site Plan

- Prior to the initiation of field activities, draft a final site plan that indicates the location of subsurface exploration areas and all known or suspected utilities present at the site. Provide copies of this site plan to the client, the TO Manager, and the subcontractor who is to conduct the subsurface exploration/excavation work. Review the site plan with the client to verify its accuracy prior to initiating subsurface sampling activities.

7.0 Quality Control and Assurance

7.1 Utility locating must incorporate quality control measures to ensure conformance to these and the project requirements.

8.0 Records, Data Analysis, Calculations

8.1 A bound field logbook will be kept detailing all activities conducted during the utility locating procedure.

8.2 The logbook will describe any changes and modifications made to the original exploration plan. The trained utility locator shall prepare a report and keep it in the project file. Also, a copy of the final site plan will be kept in the project file.

9.0 Attachments or References

Department of Defense, United States (DoD). 2005. *Uniform Federal Policy for Quality Assurance Project Plans, Part 1: UFP-QAPP Manual.* Final Version 1. DoD: DTIC ADA 427785, EPA-505-B-04-900A. In conjunction with the U. S. Environmental Protection Agency and the Department of Energy. Washington: Intergovernmental Data Quality Task Force. March. On-line updates available at: http://www.epa.gov/fedfac/pdf/ufp_qapp_v1_0305.pdf.

Author	Reviewer	Revisions (Technical or Editorial)
Caryn DeJesus Senior Scientist	Bob Shoemaker Senior Scientist	Rev 0 – Initial Issue (June 2012)
Ken O’Donnell, PG Geologist	Claire Mitchell, PE, PMP Senior Engineer	Rev 1 – PFAS sampling update (July 2019)

Logbooks

Procedure 3-02

1.0 Purpose and Scope

1.1 This standard operating procedure (SOP) describes the activities and responsibilities pertaining to the identification, use, and control of logbooks and associated field data records.

1.2 As guidance for specific activities, this procedure does not obviate the need for professional judgment. Deviations from this procedure while planning or executing planned activities must be approved in accordance with Program requirements for technical planning and review.

2.0 Safety

2.1 In order to keep the logbook clean, store it in a clean location and use it only when outer gloves used for PPE have been removed.

3.0 Terms and Definitions

3.1 Logbook

A logbook is a bound field notebook with consecutively numbered, non-water-repellent binding or pages that is clearly identified with the name of the relevant activity, the person assigned responsibility for maintenance of the logbook, and the beginning and ending dates of the entries.

3.2 Data Form

A data form is a predetermined format utilized for recording field data that may become, by reference, a part of the logbook (e.g., soil boring logs, trenching logs, surface soil sampling logs, groundwater sample logs, and well construction logs are data forms).

4.0 Training and Qualifications

4.1 The **Task Order (TO) Manager** or **designee** is responsible for determining which team members shall record information in field logbooks and for obtaining and maintaining control of the required logbooks. The **TO Manager** shall review the field logbook on at least a monthly basis. The **TO Manager** or **designee** is responsible for reviewing logbook entries to determine compliance with this procedure and to ensure that the entries meet the project requirements.

4.2 A knowledgeable individual such as the **Field Manager**, **TO Manager**, or **Program Quality Manager** shall perform a technical review of each logbook at a frequency commensurate with the level of activity (weekly is suggested, or, at a minimum, monthly). Document these reviews by the dated signature of the reviewer on the last page or page immediately following the material reviewed.

4.3 The **Program Quality Manager** is responsible for ensuring overall compliance with this procedure.

4.4 The **Field Manager** is responsible for ensuring that all **field personnel** follow these procedures and that the logbook is completed properly and daily. The **Field Manager** is also responsible for submitting copies to the **TO Manager**, who is responsible for filing them and submitting a copy (if required by the TO Statement of Work).

4.5 The **logbook user** is responsible for recording pertinent data into the logbook to satisfy project requirements and for attesting to the accuracy of the entries by dated signature. The **logbook user** is also responsible for safeguarding the logbook while having custody of it.

NOTE: SOPs have been updated for PFAS sampling activities; however, AECOM's internal PFAS sampling guidance supersedes materials and methods described in SOPs.

4.6 All **field personnel** are responsible for the implementation of this procedure.

5.0 Equipment and Supplies

5.1 Field logbooks shall be bound field notebooks with non-water-repellent binding or pages.

5.2 Ballpoint pens shall have indelible black ink.

6.0 Procedure

6.1 The field logbook serves as the primary record of field activities. Make entries chronologically and in sufficient detail to allow the writer or a knowledgeable reviewer to reconstruct the applicable events. Store the logbook in a clean location and use it only when outer gloves used for personal protective equipment (PPE) have been removed.

6.2 Individual data forms may be generated to provide systematic data collection documentation. Entries on these forms shall meet the same requirements as entries in the logbook and shall be referenced in the applicable logbook entry. Individual data forms shall reference the applicable logbook and page number. At a minimum, include names of all samples collected in the logbook even if they are recorded elsewhere.

6.3 Enter field descriptions and observations into the logbook, as described in Attachment 1, using indelible black ink.

6.4 Typical information to be entered includes the following:

- Dates (month/day/year) and times (military) of all on-site activities and entries made in logbooks/forms;
- Site name and description;
- Site location by longitude and latitude, if known;
- Weather conditions, including temperature and relative humidity;
- Fieldwork documentation, including site entry and exit times;
- Descriptions of, and rationale for, approved deviations from the Quality Assurance Project Plan (QAPP) or field sampling plan;
- Field instrumentation readings;
- Names, job functions, and organizational affiliations of on-site personnel;
- Photograph references;
- Site sketches and diagrams made on site;
- Identification and description of sample morphology, collection locations, and sample numbers;
- Sample collection information, including dates (month/day/year) and times (military) of sample collections, sample collection methods and devices, station location numbers, sample collection depths/heights, sample preservation information, sample pH (if applicable), analysis requested (analytical groups), etc., as well as chain of custody (CoC) information such as sample identification numbers cross-referenced to COC sample numbers;
- Sample naming convention;
- Field quality control (QC) sample information;
- Site observations, field descriptions, equipment used, and field activities accomplished to reconstruct field operations;

- Meeting information;
- Important times and dates of telephone conversations, correspondence, or deliverables;
- Field calculations;
- PPE level;
- Calibration records;
- Contractor and subcontractor information (address, names of personnel, job functions, organizational affiliations, contract number, contract name, and work assignment number);
- Equipment decontamination procedures and effectiveness;
- Laboratories receiving samples and shipping information, such as carrier, shipment time, number of sample containers shipped, and analyses requested; and
- User signatures.

6.5 The logbook shall reference data maintained in other logs, forms, etc. Correct entry errors by drawing a single line through the incorrect entry, then initialing and dating this change. Enter an explanation for the correction if the correction is more than for a mistake.

6.6 At least at the end of each day, the person making the entry shall sign or initial each entry or group of entries.

6.7 Enter logbook page numbers on each page to facilitate identification of photocopies.

6.8 If a person's initials are used for identification, or if uncommon acronyms are used, identify these on a page at the beginning of the logbook.

6.9 At least weekly and preferably daily, the **preparer** shall photocopy and retain the pages completed during that session for backup. This will prevent loss of a large amount of information if the logbook is lost.

7.0 Quality Control and Assurance

7.1 Review per Section 4.2 shall be recorded.

8.0 Records, Data Analysis, Calculations

8.1 Retain the field logbook as a permanent project record. If a particular TO requires submittal of photocopies of logbooks, perform this as required.

8.2 Deviations from this procedure shall be documented in field records. Significant changes shall be approved by the **Program Quality Manager**.

9.0 Attachments or References

9.1 Attachment 1 – Description of Logbook Entries

9.2 Department of Defense, United States (DoD). 2005. *Uniform Federal Policy for Quality Assurance Project Plans, Part 1: UFP-QAPP Manual*. Final Version 1. DoD: DTIC ADA 427785, EPA-505-B-04-900A. In conjunction with the U. S. Environmental Protection Agency and the Department of Energy. Washington: Intergovernmental Data Quality Task Force. March. On-line updates available at: http://www.epa.gov/fedfac/pdf/ufp_qapp_v1_0305.pdf.

Author	Reviewer	Revisions (Technical or Editorial)
Mark Kromis Program Chemist	Chris Barr Program Quality Manager	Rev 0 – Initial Issue
Ken O'Donnell, PG Geologist	Claire Mitchell, PE, PMP Senior Engineer	Rev 1 – PFAS sampling update (July 2019)

Attachment 1
Description of Logbook Entries

Logbook entries shall be consistent with Section A.1.4 *Field Documentation SOPs* of the UFP-QAPP Manual (DoD 2005) and contain the following information, as applicable, for each activity recorded. Some of these details may be entered on data forms, as described previously.

Name of Activity	**For example, Asbestos Bulk Sampling, Charcoal Canister Sampling, Aquifer Testing.**
Task Team Members and Equipment	Name all members on the field team involved in the specified activity. List equipment used by serial number or other unique identification, including calibration information.
Activity Location	Indicate location of sampling area as indicated in the field sampling plan.
Weather	Indicate general weather and precipitation conditions.
Level of PPE	Record the level of PPE (e.g., Level D).
Methods	Indicate method or procedure number employed for the activity.
Sample Numbers	Indicate the unique numbers associated with the physical samples. Identify QC samples.
Sample Type and Volume	Indicate the medium, container type, preservative, and the volume for each sample.
Time and Date	Record the time and date when the activity was performed (e.g., 0830/08/OCT/89). Use the 24-hour clock for recording the time and two digits for recording the day of the month and the year.
Analyses	Indicate the appropriate code for analyses to be performed on each sample, as specified in the WP.
Field Measurements	Indicate measurements and field instrument readings taken during the activity.
CoC and Distribution	Indicate CoC for each sample collected and indicate to whom the samples are transferred and the destination.
References	If appropriate, indicate references to other logs or forms, drawings, or photographs employed in the activity.
Narrative (including time and location)	Create a factual, chronological record of the team's activities throughout the day including the time and location of each activity. Include descriptions of general problems encountered and their resolution. Provide the names and affiliations of non-field team personnel who visit the site, request changes in activity, impact the work schedule, request information, or observe team activities. Record any visual or other observations relevant to the activity, the contamination source, or the sample itself. It should be emphasized that logbook entries are for recording data and chronologies of events. The logbook author must include observations and descriptive notations, taking care to be objective and recording no opinions or subjective comments unless appropriate.
Recorded by	Include the signature of the individual responsible for the entries contained in the logbook and referenced forms.
Checked by	Include the signature of the individual who performs the review of the completed entries.

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Recordkeeping, Sample Labeling, and Chain of Custody

Procedure 3-03

1.0 Purpose and Scope

1.1 The purpose of this standard operating procedure is to establish standard protocols for all field personnel for use in maintaining field and sampling activity records, writing sample logs, labeling samples, ensuring that proper sample custody procedures are utilized, and completing chain of custody (CoC) /analytical request forms.

1.2 As guidance for specific activities, this procedure does not obviate the need for professional judgment. Deviations from this procedure while planning or executing planned activities must be approved in accordance with Program requirements for technical planning and review.

2.0 Safety

Not applicable.

3.0 Terms and Definitions

3.1 Logbook

A logbook is a bound field notebook with consecutively numbered, non-water-repellent binding or pages that is clearly identified with the name of the relevant activity, the person responsible for maintenance of the logbook, and the beginning and ending dates of the entries.

3.2 Chain of Custody

A CoC is documentation of the process of custody control. Custody control includes possession of a sample from the time of its collection in the field to its receipt by the analytical laboratory, and through analysis and storage prior to disposal.

4.0 Training and Qualifications

4.1 The **Task Order (TO) Manager** is responsible for determining which team members shall record information in the field logbook and for checking sample logbooks and CoC forms to ensure compliance with these procedures. The **TO Manager** shall review CoC forms on a monthly basis at a minimum.

4.2 The **TO Manager** and **Program Quality Manager** are responsible for evaluating project compliance with the Project Procedures Manual.

4.3 The **Program Quality Manager** is responsible for ensuring overall compliance with this procedure.

4.4 The **Laboratory Project Manager** or **Sample Control Department Manager** is responsible for reporting any sample documentation or CoC problems to the **TO Manager** or **TO Laboratory Coordinator** within 24 hours of sample receipt.

4.5 The **Field Manager** is responsible for ensuring that all **field personnel** follow these procedures. The **TO Laboratory Coordinator** is responsible for verifying that the CoC/analytical request forms have been completed properly and match the sampling and analysis plan. The **TO Manager** or **TO Laboratory Coordinator** is responsible for notifying the **laboratory**, **data managers**, and **data validators** in writing if analytical request changes are required as a corrective action. These small changes are different from change orders, which involve changes to the scope of the subcontract with the laboratory and must be made in accordance with a respective contract (e.g., client remedial action contract).

4.6 All **field personnel** are responsible for following these procedures while conducting sampling activities. **Field personnel** are responsible for recording pertinent data into the logbook to satisfy project requirements and for attesting to the accuracy of the entries by dated signature.

5.0 Procedure

This procedure provides standards for documenting field activities, labeling the samples, documenting sample custody, and completing CoC/analytical request forms. The standards presented in this section shall be followed to ensure that samples collected are maintained for their intended purpose and that the conditions encountered during field activities are documented.

5.1 Recordkeeping

The field logbook serves as the primary record of field activities. Make entries chronologically and in sufficient detail to allow the writer or a knowledgeable reviewer to reconstruct each day's events. Field logs such as soil boring logs and ground-water sampling logs will also be used. These procedures are described in Procedure 3-02, *Logbooks*.

5.2 Sample Labeling

Affix a sample label with adhesive backing to each individual sample container. Place clear tape over each label (preferably prior to sampling) to prevent the labels from tearing off, falling off, being smeared, and to prevent loss of information on the label. Record the following information with a ballpoint pen or pre-printed text on each label:

- Project name or number (optional);
- CoC sample number;
- Date and time of collection;
- Sampler's initials;
- Matrix (optional);
- Sample preservatives (if applicable); and
- Analysis to be performed on sample (this shall be identified by the method number or name identified in the subcontract with the laboratory).

These labels may be obtained from the analytical laboratory or printed from a computer file onto adhesive labels.

5.3 Custody Procedures

For samples intended for chemical analysis, sample custody procedures shall be followed through collection, transfer, analysis, and disposal to ensure that the integrity of the samples is maintained. Maintain custody of samples in accordance with the U.S. Environmental Protection Agency (EPA) CoC guidelines prescribed in EPA *NEIC Policies and Procedures*, National Enforcement Investigations Center, Denver, Colorado, revised May 1986; EPA *RCRA Ground Water Monitoring Technical Enforcement Guidance Document* (TEGD); *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA OSWER Directive 9355 3-01); Appendix 2 of the *Technical Guidance Manual for Solid Waste Water Quality Assessment Test (SWAT) Proposals and Reports*; and *Test Methods for Evaluating Solid Waste* (EPA SW-846)

A description of sample custody procedures is provided below.

5.3.1 Sample Collection Custody Procedures

According to the U.S. EPA guidelines, a sample is considered to be in custody if one of the following conditions is met:

- It is in one's actual physical possession or view;
- It is in one's physical possession and has not been tampered with (i.e., it is under lock or official seal);
- It is retained in a secured area with restricted access; and
- It is placed in a container and secured with an official seal such that the sample cannot be reached without breaking the seal.

Place custody seals on sample containers immediately after sample collection and on shipping coolers if the cooler is to be removed from the sampler's custody. Place custody seals in such a manner that they must be broken to open the containers or coolers. Label the custody seals with the following information:

- Sampler's name or initials; and
- Date and time that the sample/cooler was sealed.

These seals are designed to enable detection of sample tampering. An example of a custody seal is shown in Attachment 1.

Field personnel shall also log individual samples onto CoC forms (carbon copy or computer generated) when a sample is collected. These forms may also serve as the request for analyses. Procedures for completing these forms are discussed in Section 5.4, indicating sample identification number, matrix, date and time of collection, number of containers, analytical methods to be performed on the sample, and preservatives added (if any). The **samplers** will also sign the CoC form signifying that they were the personnel who collected the samples. The CoC form shall accompany the samples from the field to the laboratory. When a cooler is ready for shipment to the analytical laboratory, the **person delivering the samples for transport** will sign and indicate the date and time on the accompanying CoC form. One copy of the CoC form will be retained by the **sampler** and the remaining copies of the CoC form shall be placed inside a self-sealing bag and taped to the inside of the cooler. Each cooler must be associated with a unique CoC form. Whenever a transfer of custody takes place, **both parties** shall sign and date the accompanying carbon copy CoC forms, and the **individual relinquishing the samples** shall retain a copy of each form. One exception is when the samples are shipped; the **delivery service personnel** will not sign or receive a copy because they do not open the coolers. The **laboratory** shall attach copies of the completed CoC forms to the reports containing the results of the analytical tests. An example CoC form is provided in Attachment 2.

5.3.2 Laboratory Custody Procedures

The following custody procedures are to be followed by an **independent laboratory** receiving samples for chemical analysis; the procedures in their Naval Facilities Engineering Service Center-evaluated Laboratory Quality Assurance Plan must follow these same procedures. A **designated sample custodian** shall take custody of all samples upon their arrival at the analytical laboratory. The **custodian** shall inspect all sample labels and CoC forms to ensure that the information is consistent, and that each is properly completed. The **custodian** will also measure the temperature of the temperature blank in the coolers upon arrival using either a National Institute for Standards and Technology calibrated thermometer or an infra-red temperature gun. The **custodian** shall note the condition of the samples including:

- If the samples show signs of damage or tampering;
- If the containers are broken or leaking;
- If headspace is present in sample vials;
- If proper preservation of samples has occurred (made by pH measurement, except volatile organic compounds [VOCs] and purgeable total petroleum hydrocarbons [TPH] and temperature). The pH of VOC and purgeable TPH samples will be checked by the **laboratory analyst** after the sample aliquot has been removed from the vial for analysis; and
- If any sample holding times have been exceeded.

All of the above information shall be documented on a sample receipt sheet by the **custodian**.

Discrepancies or improper preservation shall be noted by the **laboratory** as an out-of-control event and shall be documented on an out-of-control form with corrective action taken. The out-of-control form shall be signed and dated by the **sample control custodian** and **any other persons** responsible for corrective action. An example of an out-of-control form is included as Attachment 4.

The **custodian** shall then assign a unique laboratory number to each sample and distribute the samples to secured storage areas maintained at 4 degrees Celsius (soil samples for VOC analysis are to be stored in a frozen state until analysis). The unique laboratory number for each sample, CoC sample number, client name, date and time received, analysis due date, and storage shall also be manually logged onto a sample receipt record and later entered into the laboratory's computerized data management system. The **custodian** shall sign the shipping bill and maintain a copy.

Laboratory personnel shall be responsible for the care and custody of samples from the time of their receipt at the laboratory through their exhaustion or disposal. Samples should be logged in and out on internal laboratory CoC forms each time they are removed from storage for extraction or analysis.

5.4 Completing CoC/Analytical Request Forms

CoC form/analytical request form completion procedures are crucial in properly transferring the custody and responsibility of samples from field personnel to the laboratory. This form is important for accurately and concisely requesting analyses for each sample; it is essentially a release order from the analysis subcontract.

Attachment 2 is an example of a generic CoC/analytical request form that may be used by **field personnel**. Multiple copies may be tailored to each project so that much of the information described below need not be handwritten each time. Attachment 3 is an example of a completed site-specific CoC/analytical request form, with box numbers identified and discussed in text below.

CoC forms tailored to each TO can be drafted and printed onto multi-ply forms. This eliminates the need to rewrite the analytical methods column headers each time. It also eliminates the need to write the project manager, name, and number; QC Level; TAT; and the same general comments each time.

Complete one CoC form per cooler. Whenever possible, place all VOC analyte vials into one cooler in order to reduce the number of trip blanks. Complete all sections and be sure to sign and date the CoC form. One copy of the CoC form must remain with the field personnel.

Box 2 **Bill To:** List the name and address of the person/company to bill only if it is not in the subcontract with the laboratory.

Box 3 **Sample Disposal Instructions:** These instructions will be stated in the Master Service Agreement or each TO statement of work with each laboratory.

Shipment Method: State the method of shipment (e.g., hand carry or air courier via FedEx or DHL).

Comments: This area shall be used by the field team to communicate observations, potential hazards, or limitations that may have occurred in the field or additional information regarding analysis (e.g., a specific metals list, samples expected to contain high analyte concentrations).

Box 4 **Cooler No.:** This will be written on the inside or outside of the cooler and shall be included on the CoC. Some laboratories attach this number to the trip blank identification, which helps track samples for VOC analysis. If a number is not on the cooler, field personnel shall assign a number, write it on the cooler, and write it on the CoC.

QC Level: Enter the reporting quality control (QC) requirements (e.g., Full Data Package, Summary Data Package).

Turnaround time (TAT): TAT will be determined by a sample delivery group (SDG), which may be formed over a 14-day period, not to exceed 20 samples. Once the SDG has been completed, standard TAT is 21 calendar days from receipt of the last sample in the SDG. Entering NORMAL or STANDARD in this field will be acceptable. If quicker TAT is required, it shall be in the subcontract with the laboratory and reiterated on each CoC to remind the laboratory.

Box 5 **Type of Containers:** Write the type of container used (e.g., 1-liter glass amber, for a given parameter in that column).

Preservatives: Field personnel must indicate on the CoC the correct preservative used for the analysis requested. Indicate the pH of the sample (if tested) in case there are buffering conditions found in the sample matrix.

Box 6 **Sample Identification (ID) Number:** This is typically a five-character alphanumeric identifier used by the contractor to identify samples. The use of this identifier is important since the laboratories are restricted to the number of characters they are able to use. Sample numbering shall be in accordance with the project-specific sampling and analysis plan.

Description (Sample ID): This name will be determined by the location and description of the sample, as described in the project-specific sampling and analysis plan. This sample identification should not be submitted to the laboratory, but should be left blank. If a computer CoC version is used, the sample identification can be input, but printed with this block black. A cross-referenced list of the CoC Sample Number and sample identification must be maintained separately.

Date Collected: Record the collection date in order to track the holding time of the sample. Note: For trip blanks, record the date it was placed in company with samples.

Time Collected: When collecting samples, record the time the sample is first collected. Use of the 24-hour military clock will avoid a.m. or p.m. designations (e.g., 1815 instead of 6:15 p.m.). Record local time; the laboratory is responsible for calculating holding times to local time.

Lab ID: This is for laboratory use only.

Box 7	**Matrix/QC:** Identify the matrix (e.g., water, soil, air, tissue, fresh water sediment, marine sediment, or product). If a sample is expected to contain high analyte concentrations (e.g., a tank bottom sludge or distinct product layer), notify the laboratory in the comment section. Mark an "X" for the sample(s) that have extra volume for laboratory QC matrix spike/matrix spike duplicate (MS/MSD) purposes. The sample provided for MS/MSD purposes is usually a field duplicate.
Box 8	**Analytical Parameters:** Enter the parameter by descriptor and the method number desired (e.g., BTEX 8260B, PAHs 8270C, etc.). Whenever practicable, list the parameters as they appear in the laboratory subcontract to maintain consistency and avoid confusion. If the CoC does not have a specific box for number of sample containers, use the boxes below the analytical parameter, to indicate the number of containers collected for each parameter.
Box 9	**Sampler's Signature:** The person who collected samples must sign here. **Relinquished By:** The person who turned over the custody of the samples to a second party other than an express mail carrier, such as FedEx or DHL, must sign and date here. **Received By:** Typically, a representative of the receiving laboratory signs and dates here. Or, a field crew member who delivered the samples in person from the field to the laboratory might sign here. A courier, such as FedEx or DHL, does not sign here because they do not open the coolers. It must also be used by the prime contracting laboratory when samples are to be sent to a subcontractor. **Relinquished By:** In the case of subcontracting, the primary laboratory will sign and date the Relinquished By space and fill out an additional CoC to accompany the samples being subcontracted. **Received By (Laboratory):** This space is for the final destination (e.g., at a subcontracted laboratory). A representative of the final destination (e.g., subcontracted laboratory) must sign and date here.
Box 10	**Lab No. and Questions:** This box is to be filled in by the laboratory only.
Box 11	**Control Number:** This number is the "CoC" followed by the first contractor identification number in that cooler or contained on that CoC. This control number must be unique (i.e., never used twice). Record the date the CoC is completed. It should be the same date the samples are collected.
Box 12	**Total # of Containers:** Sum the number of containers in that row.
Box 13	**Totals:** Sum the number of containers in each column. Because CoC forms contain different formats depending on who produced the form, not all of the information listed in items 1 to 13 may be recorded; however, as much of this information as possible shall be included.

6.0 Quality Control and Assurance

6.1 Recordkeeping, sample labeling, and CoC activities must incorporate quality control measures to ensure accuracy and completeness.

6.2 Deviations from this procedure or the project-specific TO Quality Assurance Project Plan (QAPP) shall be documented in field records. Significant changes shall be approved by the **Program Quality Manager**.

7.0 Records, Data Analysis, Calculations

7.1 The CoC/analytical request form shall be faxed approximately daily to the **TO Laboratory Coordinator** for verification of accuracy. Following the completion of sampling activities, the sample logbook and CoC forms will be transmitted to the **TO Manager** for storage in project files. The **data validators** shall receive a copy also. The original CoC/analytical request form shall be submitted by the **laboratory** along with the data delivered. Any changes to the analytical requests that are required shall be made in writing to the laboratory. A copy of this written change shall be sent to the data validators and placed in the project files. The reason for the change shall be included in the project files so that recurring problems can be easily identified.

7.2 Deviations from this procedure or the project-specific sampling and analysis plan shall be documented in the records. Significant changes shall be approved by the **Program Quality Manager**.

8.0 Attachments or References

8.1 Attachment 1 – Chain-of-Custody Seal

8.2 Attachment 2 – Generic Chain-of-Custody/Analytical Request Form

8.3 Attachment 3 – Sample Completed Chain-of-Custody

8.4 Attachment 4 – Sample Out-of-Control Form

8.5 Environmental Protection Agency, United States (EPA). 1988. *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA.* Interim Final. EPA/540/G-89/004. Office of Emergency and Remedial Response. October.

8.6 EPA. 1992. *RCRA Groundwater Monitoring Draft Technical Guidance*. EPA/530/R-93/001. Office of Solid Waste. November.

8.7 EPA. 1997. Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846. 3rd ed., Final Update IIIA. Office of Solid Waste.

8.8 Water Resources Control Board, State of California. 1988. *Technical Guidance Manual for Solid Waste Water Quality Assessment Test (SWAT) Proposals and Reports*. August.

8.9 Procedure 3-02, *Logbooks.*

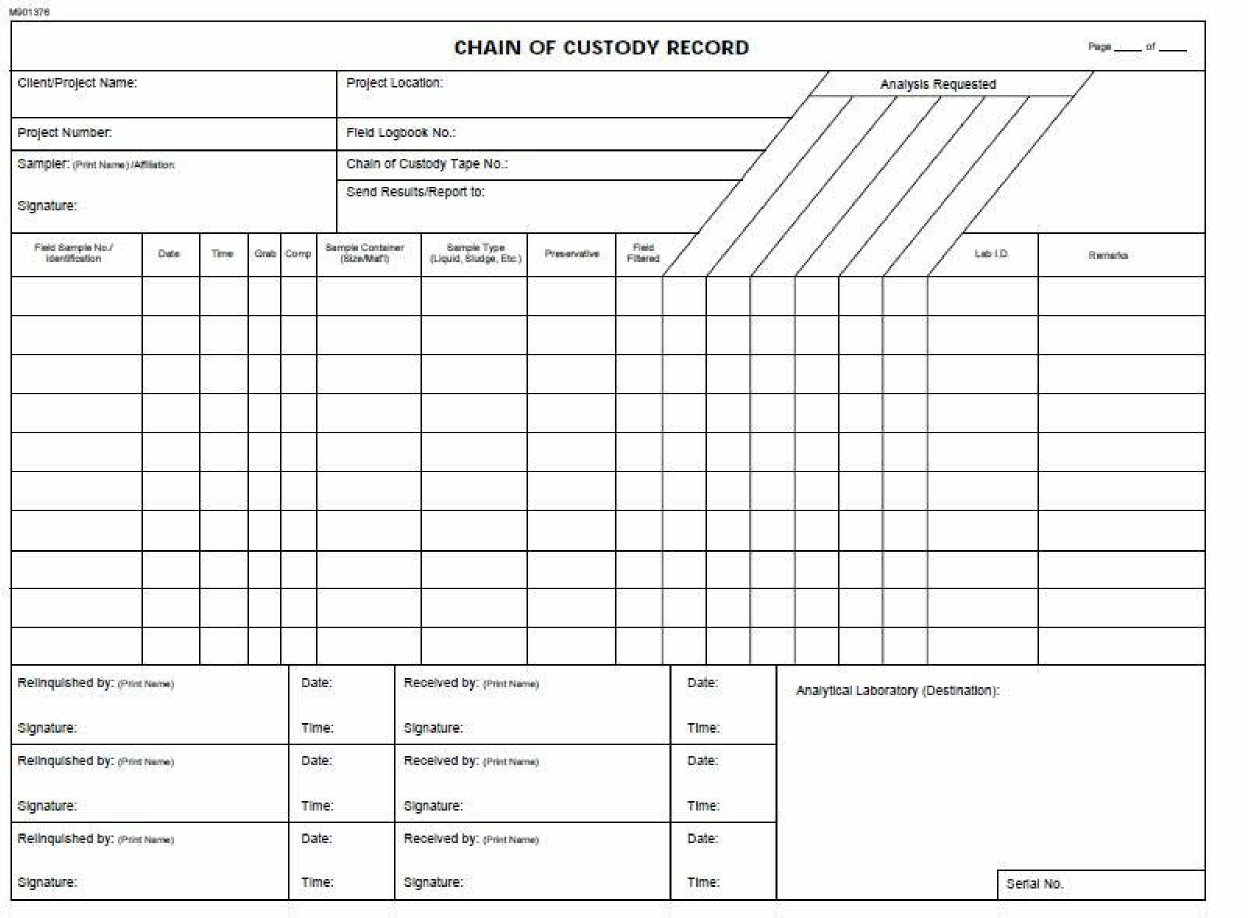
Author	Reviewer	Revisions (Technical or Editorial)
Mark Kromis Program Chemist	Chris Barr Program Quality Manager	Rev 0 – Initial Issue
Ken O'Donnell, PG Geologist	Claire Mitchell, PE, PMP Senior Engineer	Rev 1 – PFAS sampling update (July 2019)

Attachment 1
Chain of Custody Seal

CHAIN-OF-CUSTODY SEAL

[LABORATORY]	SAMPLE NO.	DATE	SEAL BROKEN BY
	SIGNATURE		DATE
	PRINT NAME AND TITLE *(Inspector, Analyst or Technician*		

Attachment 2
Generic Chain of Custody/Analytical Request Form



M901376

CHAIN OF CUSTODY RECORD

Page ____ of ____

Client/Project Name:

Project Location:

Analysis Requested

Project Number:

Field Logbook No.:

Sampler: (Print Name) /Affiliation:

Signature:

Chain of Custody Tape No.:

Send Results/Report to:

Field Sample No./ Identification	Date	Time	Grab	Comp	Sample Container (Size/Mat'l)	Sample Type (Liquid, Sludge, Etc.)	Preservative	Field Filtered							Lab I.D.	Remarks

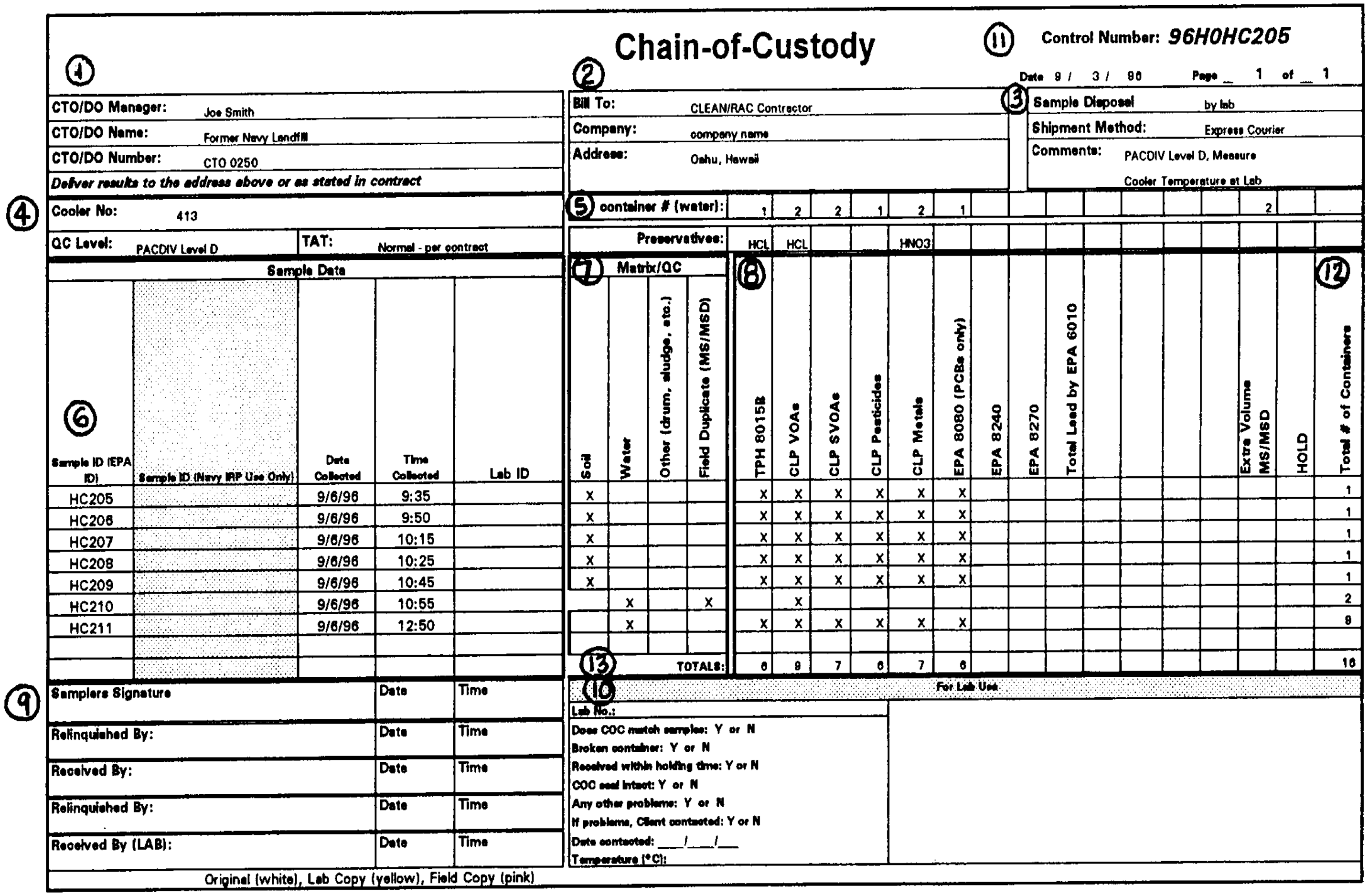
Relinquished by: (Print Name) Signature:	Date: Time:	Received by: (Print Name) Signature:	Date: Time:
Relinquished by: (Print Name) Signature:	Date: Time:	Received by: (Print Name) Signature:	Date: Time:
Relinquished by: (Print Name) Signature:	Date: Time:	Received by: (Print Name) Signature:	Date: Time:

Analytical Laboratory (Destination):

Serial No.

NOTE: SOPs have been updated for PFAS sampling activities; however, AECOM's internal PFAS sampling guidance supersedes materials and methods described in SOPs.

Attachment 3
Sample Completed Chain of Custody



Chain-of-Custody

Control Number: 96H0HC205

Date 9 / 3 / 96 Page 1 of 1

CTO/DO Manager: Joe Smith
CTO/DO Name: Former Navy Landfill
CTO/DO Number: CTO 0250
Deliver results to the address above or as stated in contract
Cooler No: 413
QC Level: PACDIV Level D
TAT: Normal - per contract

Bill To: CLEAN/RAC Contractor
Company: company name
Address: Oahu, Hawaii

Sample Disposal by lab
Shipment Method: Express Courier
Comments: PACDIV Level D, Measure Cooler Temperature at Lab

Sample ID (EPA ID)	Sample ID (Navy IRP Use Only)	Date Collected	Time Collected	Lab ID	Soil	Water	Other (drum, sludge, etc.)	Field Duplicate (MS/MSD)	TPH 8015B	CLP VOAs	CLP SVOAs	CLP Pesticides	CLP Metals	EPA 8080 (PCBs only)	EPA 8240	EPA 8270	Total Lead by EPA 6010					Extra Volume MS/MSD	HOLD	Total # of Containers
container # (water):									1	2	2	1	2	1								2		
Preservatives:									HCL	HCL			HNO3											
HC205		9/6/96	9:35		X				X	X	X	X	X	X										1
HC206		9/6/96	9:50		X				X	X	X	X	X	X										1
HC207		9/6/96	10:15		X				X	X	X	X	X	X										1
HC208		9/6/96	10:25		X				X	X	X	X	X	X										1
HC209		9/6/96	10:45		X				X	X	X	X	X	X										1
HC210		9/6/96	10:55			X		X		X														2
HC211		9/6/96	12:50			X			X	X	X	X	X	X										9
								TOTALS:	6	9	7	6	7	6										16

Samplers Signature	Date	Time
Relinquished By:	Date	Time
Received By:	Date	Time
Relinquished By:	Date	Time
Received By (LAB):	Date	Time

For Lab Use

Lab No.:
Does COC match samples: Y or N
Broken container: Y or N
Received within holding time: Y or N
COC seal intact: Y or N
Any other problems: Y or N
If problems, Client contacted: Y or N
Date contacted: ____/____/____
Temperature (°C):

Original (white), Lab Copy (yellow), Field Copy (pink)

Attachment 4
Sample Out-of-Control Form

OUT OF CONTROL FORM	Status	Date	Initial
	Noted OOC		
	Submit for CA*		
	Resubmit for CA*		
	Completed		

Date Recognized:	By:
Dated Occurred:	Matrix
Parameter (Test Code):	Method:
Analyst:	Supervisor:
1. Type of Event (Check all that apply)	2. Corrective Action (CA)* (Check all that apply)
☐ Calibration Corr. Coefficient <0.995	☐ Repeat calibration
☐ %RSD>20%	☐ Made new standards
☐ Blank >MDL	☐ Reran analysis
☐ Does not meet criteria:	☐ Sample(s) redigested and rerun
☐ Spike	☐ Sample(s) reextracted and rerun
☐ Duplicate	☐ Recalculated
☐ LCS	☐ Cleaned system
☐ Calibration Verification	☐ Ran standard additions
☐ Standard Additions	☐ Notified
☐ MS/MSD	☐ Other (please explain)
☐ BS/BSD	
☐ Surrogate Recovery	
☐ Calculations Error	
☐ Holding Times Missed	
☐ Other (Please explain	Comments:

Samples Affected (List by Accession AND Sample No.)

3. Results of Corrective Action
☐ Return to Control (indicated with)
☐ Corrective Actions Not Successful - DATA IS TO BE FLAGGED with _____________.

Analyst:	Date:
Supervisor:	Date:
QA Department:	Date:

Sample Handling, Storage, and Shipping

Procedure 3-04

1.0 Purpose and Scope

1.1 This standard operating procedure describes the actions to be used by personnel engaged in handling, storing, and transporting samples. The objective is to obtain samples of actual conditions with as little alteration as possible.

1.2 As guidance for specific activities, this procedure does not obviate the need for professional judgment. Deviations from this procedure while planning or executing planned activities must be approved in accordance with Program requirements for technical planning and review.

2.0 Safety

2.1 Avoid lifting heavy coolers with back muscles; instead, use leg muscles or dollies.

2.2 Wear powderless nitrile gloves, as defined in the project-specific health and safety plan, when handling sample containers to avoid contacting any materials that may have spilled out of the sample containers.

3.0 Terms and Definitions

None.

4.0 Training and Qualifications

4.1 The **Task Order (TO) Manager** and the **Laboratory Project Manager** are responsible for identifying instances of non-compliance with this procedure and ensuring that future sample transport activities comply with this procedure.

4.2 The **Field Manager** is responsible for ensuring that all samples are shipped according to this procedure.

4.3 **Field personnel** are responsible for the implementation of this procedure.

4.4 The **Program Quality Manager** is responsible for ensuring that sample handling, storage, and transport activities conducted during all TOs comply with this procedure.

4.5 All **field personnel** are responsible for the implementation of this procedure.

5.0 Procedure

5.1 Handling and Storage

Immediately following collection, label all samples according to Procedure 3-03, *Recordkeeping, Sample Labeling, and Chain of Custody*. The lids of the containers shall not be sealed with duct tape but may be covered with custody seals or placed directly into self-sealing polyethylene (e.g., Ziploc brand) bags. Place the sample containers in an insulated cooler with water ice in double, sealed self-sealing Ziploc bags. Samples should occupy the lower portion of the cooler, while the ice should occupy the upper portion. Place an absorbent material (e.g., proper absorbent cloth material) on the bottom of the cooler to contain liquids in case of spillage. Fill all empty space between sample containers with PFAS-free fill material. Prior to shipping, wrap glass sample containers on the sides, tops, and bottoms with polyethylene plastic wrap or other appropriate padding and/or surround them in Styrofoam to prevent breakage during transport. Pack all glass containers for water samples in an upright position, never

NOTE: SOPs have been updated for PFAS sampling activities; however, AECOM's internal PFAS sampling guidance supersedes materials and methods described in SOPs.

stacked or on their sides. Prior to shipment, replace the ice in the coolers so that samples will be maintained as close to 4 degrees Celsius (°C) as possible from the time of collection through transport to the analytical laboratory. Ship samples within 24 hours or on a schedule allowing the laboratory to meet holding times for analyses. The procedures for maintaining sample temperatures at 4°C pertain to all field samples.

5.2 Shipping

Follow all appropriate U.S. Department of Transportation regulations (e.g., 49 Code of Federal Regulations [CFR], Parts 171-179) for shipment of air, soil, water, and other samples. Elements of these procedures are summarized below.

5.2.1 Hazardous Materials Shipment

Field personnel must state whether any sample is suspected to be a hazardous material. A sample should be assumed hazardous unless enough evidence exists to indicate it is non-hazardous. If not suspected to be hazardous, shipments may be made as described in the Section 5.2.2 for non-hazardous materials. If hazardous, follow the procedures summarized below.

Any substance or material that is capable of posing an unreasonable risk to life, health, or property when transported is classified as hazardous. Perform hazardous materials identification by checking the list of dangerous goods for that particular mode of transportation. If not on that list, materials can be classified by checking the Hazardous Materials Table (49 CFR 172.102 including Appendix A) or by determining if the material meets the definition of any hazard class or division (49 CFR Part 173), as listed in Attachment 2.

All **persons shipping hazardous materials** must be properly trained in the appropriate regulations, as required by HM-126F, Training for Safe Transportation of Hazardous Materials (49 CFR HM-126F Subpart H). The training covers loading, unloading, handling, storing, and transporting of hazardous materials, as well as emergency preparedness in the case of accidents. **Carriers**, such as commercial couriers, must also be trained. Modes of shipment include air, highway, rail, and water.

When shipping hazardous materials, including bulk chemicals or samples suspected of being hazardous, the proper shipping papers (49 CFR 172 Subpart C), package marking (49 CFR 172 Subpart D), labeling (49 CFR 172 Subpart E), placarding (49 CFR 172 Subpart F, generally for carriers), and packaging must be used. Attachment 1 shows an example of proper package markings. Refer to a copy of 49 CFR each time hazardous materials/potentially hazardous samples are shipped.

According to Section 2.7 of the International Air Transport Association Dangerous Goods Regulations publication, very small quantities of certain dangerous goods may be transported without certain marking and documentation requirements as described in 49 CFR Part 172; however, other labeling and packing requirements must still be followed. Attachment 2 shows the volume or weight for different classes of substances. A “Dangerous Goods in Excepted Quantities” label must be completed and attached to the associated shipping cooler (Attachment 3). Certain dangerous goods are not allowed on certain airlines in any quantity.

As stated in item 4 of Attachment 4, the Hazardous Materials Regulations do not apply to hydrochloric acid (HCl), nitric acid (HNO_3), sulfuric acid (H_2SO_4), and sodium hydroxide (NaOH) added to water samples if their pH or percentage by weight criteria is met. These samples may be shipped as non-hazardous materials as discussed below.

5.2.2 Non-Hazardous Materials Shipment

If the samples are suspected to be non-hazardous based on previous site sample results, field screening results, or visual observations, if applicable, then samples may be shipped as non-hazardous.

When a cooler is ready for shipment to the laboratory, place two copies of the chain of custody (CoC) form inside a self-sealing polyethylene (e.g., Ziploc brand) bag and tape it to the inside of the insulated cooler. Then, seal the cooler with waterproof tape and label it with “Fragile,” “This-End-Up” (or directional arrows pointing up), or other appropriate notices. Place custody seals on the coolers as discussed in Procedure 3-03, *Recordkeeping, Sample Labeling, and Chain of Custody*.

5.2.3 Shipments from Outside the Continental United States

Shipment of sample coolers to the United States from locations outside the continental United States is controlled by the U.S. Department of Agriculture (USDA) and is subject to their inspection and regulation. A “USDA Soil Import Permit” is required to prove that the receiving analytical laboratory is certified by the USDA to receive and properly dispose of soil. In addition, all sample coolers must be inspected by a **USDA representative**, affixed with a label indicating that the coolers contain environmental samples, and accompanied by shipping forms stamped by the **USDA inspector** prior to shipment.

In addition, the U.S. Customs Service must clear samples shipped from U.S. territorial possessions or foreign countries upon entry into the United States. As long as the commercial invoice is properly completed (see below), shipments typically pass through U.S. Customs Service without the need to open coolers for inspection.

Completion and use of proper paperwork will, in most cases, minimize or eliminate the need for the USDA and U.S. Customs Service to inspect the contents. Attachment 5 shows an example of how paperwork may be placed on the outside of coolers for non-hazardous materials. For hazardous materials, refer to Section 5.2.1.

In summary, tape the paperwork listed below to the outside of the coolers to accompany sample shipments. If a shipment is made up of multiple pieces (e.g., more than one cooler), the paperwork need only be attached to one cooler, provided that the **courier** agrees. All other coolers in the shipment need only to be taped and have the address and custody seals affixed.

1. **Courier Shipping Form & Commercial Invoice:** See Attachment 6 and Attachment 7 for examples of the information to be included on the commercial invoices for soil and water, respectively. Place the courier shipping form and commercial invoice inside a clear, plastic, adhesive-backed pouch that adheres to the package (typically supplied by the courier) and place it on the cooler lid as shown in Attachment 5.
2. **Soil Import Permit (soil only):** See Attachment 8 and Attachment 9 for examples of the soil import permit and soil samples restricted entry labels, respectively. The **laboratory** shall supply these documents prior to mobilization. The USDA often stops shipments of soil without these documents. Staple together the 2-inch × 2-inch USDA label (described below) and soil import permit and place them inside a clear plastic pouch. The **courier** typically supplies the clear, plastic, adhesive-backed pouches that adhere to the package.

   Placing one restricted entry label as shown in Attachment 5 (covered with clear packing tape) and one stapled to the actual permit is suggested.

   The USDA does not control water samples, so the requirements for soil listed above do not apply.
3. **Custody Seals:** The **laboratory** should supply the seals. **TO personnel** must sign and date these. At least two seals should be placed in such a manner that they stick to both the cooler lid and body. Placing the seals over the tape (as shown in Attachment 5), then covering it with clear packing tape is suggested. This prevents the seal from coming loose and enables detection of tampering.
4. **Address Label:** Affix a label stating the destination (laboratory address) to each cooler.
5. **Special Requirements for Hazardous Materials:** See Section 5.2.1.

Upon receipt of sample coolers at the laboratory, the **sample custodian** shall inspect the sample containers as discussed in Procedure 3-03, *Recordkeeping, Sample Labeling, and Chain of Custody*. The samples shall then be immediately extracted and/or analyzed, or stored in a refrigerated storage area until they are removed for extraction and/or analysis. Whenever the samples are not being extracted or analyzed, they shall be returned to refrigerated storage.

6.0 Quality Control and Assurance

6.1 Sample handling, storage, and shipping must incorporate quality control measures to ensure conformance to these and the project requirements.

7.0 Records, Data Analysis, Calculations

7.1 Maintain records as required by implementing these procedures.

7.2 Deviations from this procedure or the project-specific sampling and analysis plan shall be documented in field records. Significant changes shall be approved by the **Program Quality Manager**.

8.0 Attachments or Reference

8.1 Attachment 1 – Example Hazardous Material Package Marking

8.2 Attachment 2 – Packing Groups

8.3 Attachment 3 – Label for Dangerous Goods in Excepted Quantities

8.4 Attachment 4 – SW-846 Preservative Exception

8.5 Attachment 5 – Non-Hazardous Material Cooler Marking Figure for Shipment from Outside the Continental United States

8.6 Attachment 6 – Commercial Invoice – Soil

8.7 Attachment 7 – Commercial Invoice – Water

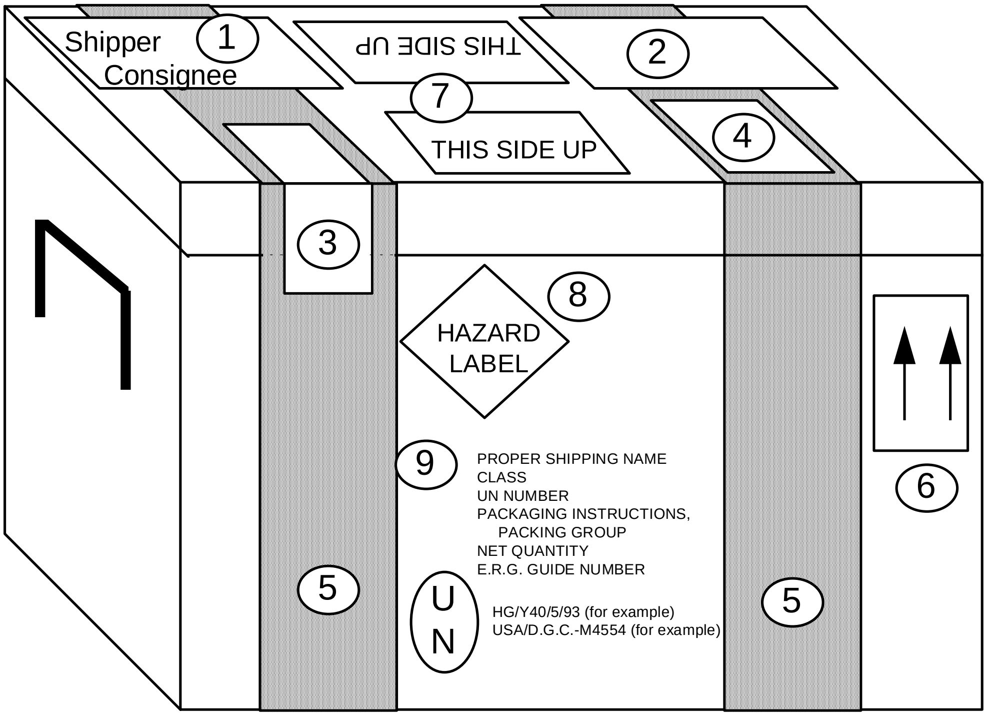
8.8 Attachment 8 – Soil Import Permit

8.9 Attachment 9 – Soil Samples Restricted Entry Labels

8.10 Procedure 3-03, *Recordkeeping, Sample Labeling, and Chain of Custody*.

Author	Reviewer	Revisions (Technical or Editorial)
Mark Kromis Program Chemist	Chris Barr Program Quality Manager	Rev 0 – Initial Issue
Ken O’Donnell, PG Geologist	Claire Mitchell, PE, PMP Senior Engineer	Rev 1 – PFAS sampling update (July 2019)

Attachment 1
Example Hazardous Material Package Marking



① **AIR BILL/COMMERCIAL INVOICE**

② **USDA PERMIT (Letter to Laboratory from USDA)**

③ **CUSTODY SEAL**

④ **USDA 2" X 2" SOIL IMPORT PERMIT**

⑤ **WATERPROOF STRAPPING TAPE**

⑥ **DIRECTION ARROWS STICKER - TWO REQUIRED**

⑦ **THIS SIDE UP STICKERS**

⑧ **HAZARD LABEL**

⑨ **HAZARDOUS MATERIAL INFORMATION**

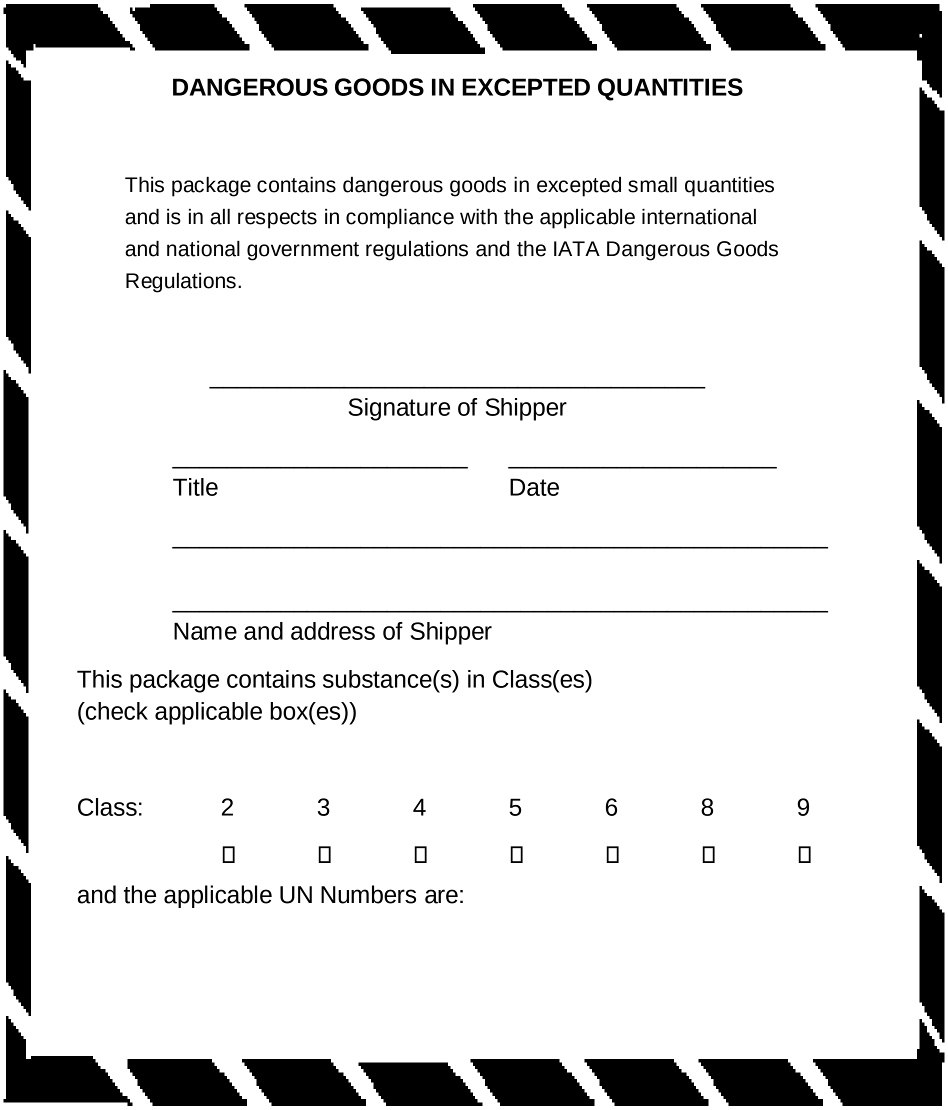
⑩ **PACKAGE SPECIFICATIONS**

Attachment 2
Packing Groups

PACKING GROUP OF THE SUBSTANCE	PACKING GROUP 1		PACKING GROUP II		PACKING GROUP III	
CLASS or DIVISION of PRIMARY or SUBSIDIARY RISK	Packagings		Packagings		Packagings	
	Inner	Outer	Inner	Outer	Inner	Outer
1: Explosives	---------------------------- Forbidden (Note A) ----------------------------------					
2.1: Flammable Gas	---------------------------- Forbidden (Note B) ----------------------------------					
2.2: Non-Flammable, non-toxic gas	---------------------------- See Notes A and B ----------------------------------					
2.3: Toxic gas	---------------------------- Forbidden (Note A) ----------------------------------					
3. Flammable liquid	30 mL	300 mL	30 mL	500 mL	30 mL	1 L
4.1 Self-reactive substances	Forbidden		Forbidden		Forbidden	
4.1: Other flammable solids	Forbidden		30 g	500 g	30 g	1 kg
4.2: Pyrophoric substances	Forbidden		Not Applicable		Not Applicable	
4.2 Spontaneously combustible substances	Not Applicable		30 g	500 g	30 g	1 kg
4.3: Water reactive substances	Forbidden		30 g or 30 mL	500 g or 500 mL	30 g or 30 mL	1 kg or 1 L
5.1: Oxidizers	Forbidden		30 g or 30 mL	500 g or 500 mL	30 g or 30 mL	1 kg or 1 L
5.2: Organic peroxides (Note C)	See Note A		30 g or 30 mL	500 g or 250 mL	Not Applicable	
6.1: Poisons - Inhalation toxicity	Forbidden		1 g or 1 mL	500 g or 500 mL	30 g or 30 mL	1 kg or 1 L
6.1: Poisons - oral toxicity	1 g or 1 mL	300 g or 300 mL	1 g or 1 mL	500 g or 500 mL	30 g or 30 mL	1 kg or 1 L
6.1: Poisons - dermal toxicity	1 g or 1 mL	300 g or 300 mL	1 g or 1 mL	500 g or 500 mL	30 g or 30 mL	1 kg or 1 L
6.2: Infectious substances	---------------------------- Forbidden (Note A) ----------------------------------					
7: Radioactive material (Note D)	---------------------------- Forbidden (Note A) ----------------------------------					
8: Corrosive materials	Forbidden		30 g or 30 mL	500 g or 500 mL	30 g or 30 mL	1 kg or 1 L
9: Magnetized materials	---------------------------- Forbidden (Note A) ----------------------------------					
9: Other miscellaneous materials (Note E)	Forbidden		30 g or 30 mL	500 g or 500 mL	30 g or 30 mL	1 kg or 1 L

Note A: *Packing groups are not used for this class or division.*
Note B: *For inner packagings, the quantity contained in receptacle with a water capacity of 30 mL. For outer packagings, the sum of the water capacities of all the inner packagings contained must not exceed 1 L.*
Note C: *Applies only to Organic Peroxides when contained in a chemical kit, first aid kit or polyester resin kit.*
Note D: *See 6.1.4.1, 6.1.4.2, and 6.2.1.1 through 6.2.1.7, radioactive material in excepted packages.*
Note E: *For substances in Class 9 for which no packing group is indicated in the List of Dangerous Goods, Packing Group II quantities must be used.*

Attachment 3
Dangerous Goods in Excepted Quantities



DANGEROUS GOODS IN EXCEPTED QUANTITIES

This package contains dangerous goods in excepted small quantities and is in all respects in compliance with the applicable international and national government regulations and the IATA Dangerous Goods Regulations.

____
Signature of Shipper

______________________ ____________________
Title Date

____

____
Name and address of Shipper

This package contains substance(s) in Class(es)
(check applicable box(es))

Class:	2	3	4	5	6	8	9
	☐	☐	☐	☐	☐	☐	☐

and the applicable UN Numbers are:

Attachment 4
SW-846 Preservative Exception

Measurement	Vol. Req. (mL)	Container[2]	Preservative[3,4]	Holding Time[5]
MBAS	250	P, G	Cool, 4ºC	48 Hours
NTA	50	P, G	Cool, 4ºC	24 Hours

1. More specific instructions for preservation and sampling are found with each procedure as detailed in this manual. A general discussion on sampling water and industrial wastewater may be found in ASTM, Part 31, p. 72-82 (1976) Method D-3370.

2. Plastic (P) or Glass (G). For metals, polyethylene with a polypropylene cap (no liner) is preferred.

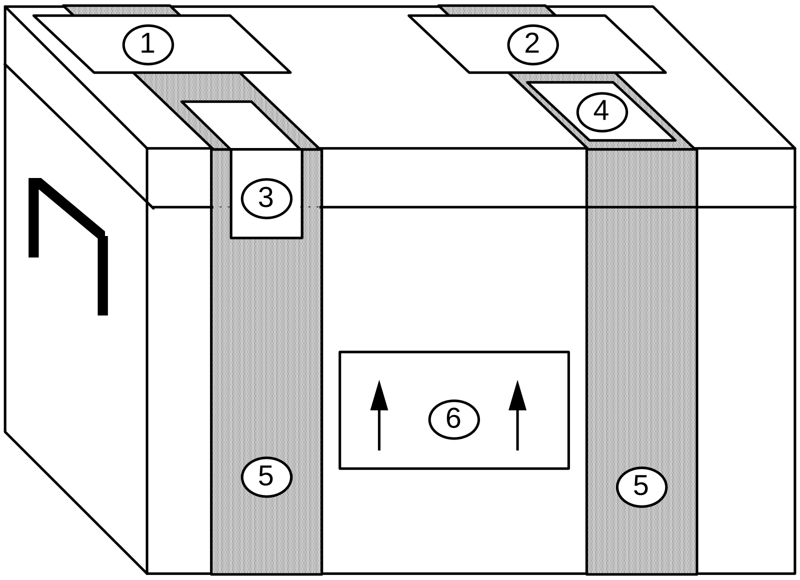
3. Sample preservation should be performed immediately upon sample collection. For composite samples each aliquot should be preserved at the time of collection. When use of an automated sampler makes it impossible to preserve each aliquot, then samples may be preserved by maintaining at 4ºC until compositing and sample splitting is completed.

4. When any sample is to be shipped by common carrier or sent through the United States Mail, it must comply with the Department of Transportation Hazardous Materials Regulations (49 CFR Part 172). The person offering such material for transportation is responsible for ensuring such compliance. for the preservation requirements of Table 1, the Office of Hazardous Materials, Materials Transportation Bureau, Department of Transportation has determined that the Hazardous Materials regulations do not apply to the following materials: Hydrochloric acid (HCl) in water solutions at concentration of 0.04% by weight or less (pH about 1.96 or greater); Nitric acid (HNO_3) in water solutions at concentrations of 0.15% by weight or less (pH about 1.62 or greater); Sulfuric acid (H_2SO_4) in water solutions at concentrations of 0.35% by weight or less (pH about 1.15 or greater); Sodium hydroxide (NaOH) in water solutions at concentrations of 0.080% by weight or less (pH about 12.30 or less).

5. Samples should be analyzed as soon as possible after collection. The times listed are the maximum times that samples may be held before analysis and still considered valid. Samples may be held for longer periods only if the permittee, or monitoring laboratory, has data on file to show that the specific types of sample under study are stable for the longer time, and has received a variance from the Regional Administrator. Some samples may not be stable for the maximum time period given in the table. A permittee, or monitoring laboratory, is obligated to hold the sample for a shorter time if knowledge exists to show this is necessary to maintain sample stability.

6. Should only be used in the presence of residual chlorine.

Attachment 5
Non-Hazardous Material Cooler Marking Figure for Shipment from Outside the Continental United States



① **AIR BILL/COMMERCIAL INVOICE**
② **USDA PERMIT (Letter to Laboratory from USDA)**
③ **CUSTODY SEAL**
④ **USDA 2" X 2" SOIL IMPORT PERMIT**
⑤ **WATERPROOF STRAPPING TAPE**
⑥ **DIRECTION ARROWS STICKER - TWO REQUIRED**

NOTE: SOPs have been updated for PFAS sampling activities; however, AECOM's internal PFAS sampling guidance supersedes materials and methods described in SOPs.

Attachment 6
Commercial Invoice – Soil

DATE OF EXPORTATION 1/1/94	EXPORT REFERENCES (i.e., order no., invoice no., etc.) <TO #>
SHIPPER/EXPORTER (complete name and address) Joe Smith Ogden c/o <hotel name> <hotel address>	CONSIGNEE Sample Receipt <Lab Name> <Lab Address>
COUNTRY OF EXPORT Guam, USA	IMPORTER - IF OTHER THAN CONSIGNEE
COUNTRY OF ORIGIN OF GOODS Guam, USA	
COUNTRY OF ULTIMATE DESTINATION USA	

INTERNATIONAL AIR WAYBILL NO.		(NOTE: All shipments must be accompanied by a Federal Express International Air Waybill)

MARKS/NOS	NO. OF PKGS	TYPE OF PACKAGING	FULL DESCRIPTION OF GOODS	QTY	UNIT OF MEASURE	WEIGHT	UNIT VALUE	TOTAL VALUE
	3	coolers	Soil samples for laboratory analysis only				$1.00	$3.00
	TOTAL NO. OF PKGS.					TOTAL WEIGHT		TOTAL INVOICE VALUE
	3							$3.00
								Check one ☐ F.O.B. ☐ C&F ☐ C.I.F.

THESE COMMODITIES ARE LICENSED FOR THE ULTIMATE DESTINATION SHOWN.

DIVERSION CONTRARY TO UNITED STATES LAW IS PROHIBITED.

I DECLARE ALL THE INFORMATION CONTAINED IN THIS INVOICE TO BE TRUE AND CORRECT

SIGNATURE OF SHIPPER/EXPORTER (Type name and title and sign)

Name/Title	Signature	Date
Joe Smith, Ogden	Joe Smith	1/1/94

Attachment 7
Commercial Invoice – Water

DATE OF EXPORTATION 1/1/94	EXPORT REFERENCES (i.e., order no., invoice no., etc.) <TO #>
SHIPPER/EXPORTER (complete name and address) Joe Smith Ogden c/o <hotel name> <hotel address>	CONSIGNEE Sample Receipt <Lab Name> <Lab Address>
COUNTRY OF EXPORT Guam, USA	IMPORTER - IF OTHER THAN CONSIGNEE
COUNTRY OF ORIGIN OF GOODS Guam, USA	
COUNTRY OF ULTIMATE DESTINATION USA	

INTERNATIONAL AIR WAYBILL NO.		(NOTE: All shipments must be accompanied by a Federal Express International Air Waybill)

MARKS/NOS	NO. OF PKGS	TYPE OF PACKAGING	FULL DESCRIPTION OF GOODS	QTY	UNIT OF MEASURE	WEIGHT	UNIT VALUE	TOTAL VALUE
	3	coolers	Water samples for laboratory analysis only				$1.00	$3.00
	TOTAL NO. OF PKGS.					TOTAL WEIGHT		TOTAL INVOICE VALUE
	3							$3.00
								Check one ☐ F.O.B. ☐ C&F ☐ C.I.F.

THESE COMMODITIES ARE LICENSED FOR THE ULTIMATE DESTINATION SHOWN.

DIVERSION CONTRARY TO UNITED STATES LAW IS PROHIBITED.

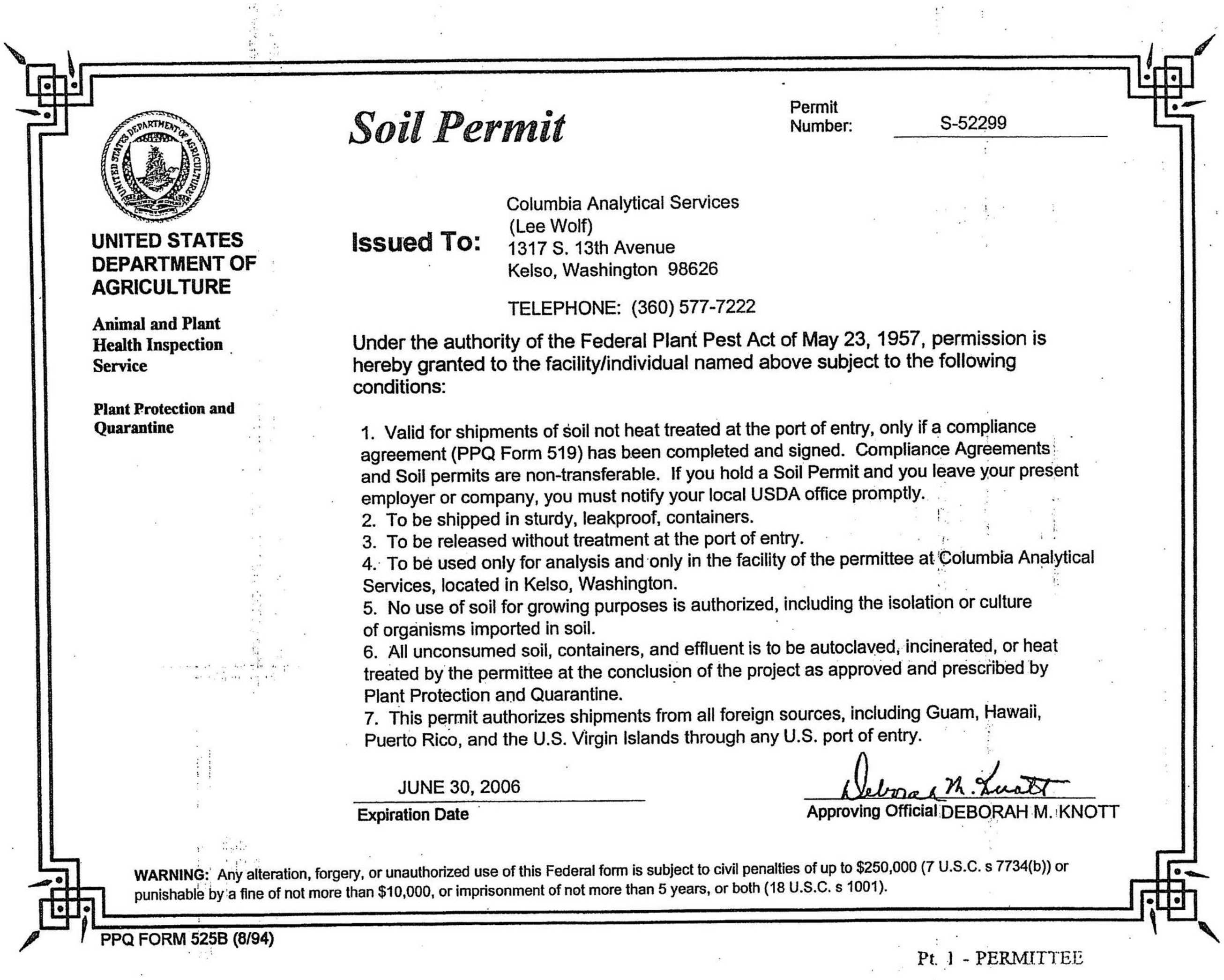
I DECLARE ALL THE INFORMATION CONTAINED IN THIS INVOICE TO BE TRUE AND CORRECT

SIGNATURE OF SHIPPER/EXPORTER (Type name and title and sign)

Joe Smith, Ogden	Joe Smith	1/1/94

NOTE: SOPs have been updated for PFAS sampling activities; however, AECOM's internal PFAS sampling guidance supersedes materials and methods described in SOPs.

Attachment 8
Soil Import Permit



UNITED STATES DEPARTMENT OF AGRICULTURE

Animal and Plant Health Inspection Service

Plant Protection and Quarantine

Soil Permit

Permit Number: S-52299

Issued To:
Columbia Analytical Services
(Lee Wolf)
1317 S. 13th Avenue
Kelso, Washington 98626

TELEPHONE: (360) 577-7222

Under the authority of the Federal Plant Pest Act of May 23, 1957, permission is hereby granted to the facility/individual named above subject to the following conditions:

1. Valid for shipments of soil not heat treated at the port of entry, only if a compliance agreement (PPQ Form 519) has been completed and signed. Compliance Agreements and Soil permits are non-transferable. If you hold a Soil Permit and you leave your present employer or company, you must notify your local USDA office promptly.
2. To be shipped in sturdy, leakproof, containers.
3. To be released without treatment at the port of entry.
4. To be used only for analysis and only in the facility of the permittee at Columbia Analytical Services, located in Kelso, Washington.
5. No use of soil for growing purposes is authorized, including the isolation or culture of organisms imported in soil.
6. All unconsumed soil, containers, and effluent is to be autoclaved, incinerated, or heat treated by the permittee at the conclusion of the project as approved and prescribed by Plant Protection and Quarantine.
7. This permit authorizes shipments from all foreign sources, including Guam, Hawaii, Puerto Rico, and the U.S. Virgin Islands through any U.S. port of entry.

JUNE 30, 2006
Expiration Date

Deborah M. Knott
Approving Official DEBORAH M. KNOTT

WARNING: Any alteration, forgery, or unauthorized use of this Federal form is subject to civil penalties of up to $250,000 (7 U.S.C. s 7734(b)) or punishable by a fine of not more than $10,000, or imprisonment of not more than 5 years, or both (18 U.S.C. s 1001).

PPQ FORM 525B (8/94)

Pt. 1 - PERMITTEE

Attachment 9
Soil Samples Restricted Entry Labels

U.S. DEPARTMENT OF AGRICULTURE

ANIMAL AND PLANT HEALTH INSPECTION SERVICE

PLANT PROTECTION AND QUARANTINE

HYATTSVILLE, MARYLAND 20782

SOIL SAMPLES

RESTRICTED ENTRY

The material contained in this package is imported under authority of the Federal Plant Pest Act of May 23, 1957.

For release without treatment if addressee is currently listed as approved by Plant Protection and Quarantine.

PPQ FORM 550 *Edition of 12/77 may be used*

(JAN 83)

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Investigation Derived Waste Management

Procedure 3-05

1.0 Purpose and Scope

This standard operating procedure (SOP) describes activities and responsibilities of the client with regard to management of investigation-derived waste (IDW). The purpose of this procedure is to provide guidance for the minimization, handling, labelling, temporary storage, inventory, classification, and disposal of IDW generated under the client contract. This procedure will also apply to personal protective equipment (PPE), sampling equipment, decontamination fluids, non-IDW trash, non-indigenous IDW, and hazardous waste generated during implementation of removal or remedial actions. The information presented will be used to prepare and implement work plans (WPs) for IDW-related field activities. The results from implementation of WPs will then be used to develop and implement final IDW disposal plans.

If there are procedures whether it be from AECOM, state and/or federal that are not addressed in this SOP and are applicable to IDW then those procedures may be added as an appendix to the project specific SAP.

This procedure shall serve as management-approved professional guidance for the client and is consistent with protocol in the Uniform Federal Policy-Quality Assurance Project Plan (DoD 2005). As professional guidance for specific activities, this procedure is not intended to obviate the need for professional judgment during unforeseen circumstances. Deviations from this procedure while planning or executing planned activities must be approved by both the Task Order (TO) Manager and the Quality Assurance (QA) Manager or Technical Director and documented.

This procedure was developed to serve as management-approved professional guidance for the management of IDW generated under the client contract. It focuses on the requirements for minimizing, segregating, handling, labeling, storing, and inventorying IDW in the field. Certain drum inventory requirements related to the screening, sampling, classification, and disposal of IDW are also noted in this procedure.

2.0 Safety

The health and safety considerations for the work associated with this SOP, including both potential physical and chemical hazards, will be addressed in the project Health and Safety Plan (HASP). In the absence of a HASP, work will be conducted according to the TO WP and/or direction from the **Site Safety Officer (SSO)**.

All **Field Personnel** responsible for IDW management must adhere to the HASP and must wear the PPE specified in the site-specific HASP. Generally, this includes, at a minimum, steel-toed boots or steel-toed rubber boots, safety glasses, American National Standards Institute-standard hard hats, and hearing protection (if heavy equipment is in operation). If safe alternatives are not achievable, discontinue site activities immediately.

3.0 Terms and Definitions

None.

4.0 Training and Qualifications

4.1 The **TO Manager** is responsible for ensuring that IDW management activities comply with this procedure. The **TO Manager** is responsible for ensuring that all personnel involved in IDW management shall have the appropriate education, experience, and training to perform their assigned tasks.

4.2 The **Program Quality Manager** is responsible for ensuring overall compliance with this procedure.

4.3 The **Field Manager** is responsible for ensuring that all IDW is managed according to this procedure.

4.4 All **Field Personnel** are responsible for the implementation of this procedure.

All AECOM personnel who will perform any duties related to management of Resource Conservation and Recovery Act (RCRA) hazardous wastes or shipping of Department of Transportation (DOT) Hazardous Materials will be properly trained in accordance with 40 CFR § 262.34 and §265.16 for RCRA Waste Generators, as well as 49 CFR § 172.704 for DOT Hazardous Materials Shippers. All RCRA Hazardous Wastes are by definition DOT Hazardous Materials. See Section 6.1 for details on determining the IDW waste classification.

5.0 Equipment and Supplies

The equipment and supplies required for implementation of this SOP include the following:

- Containers for waste (e.g., [U.S. Department of Transportation] DOT approved 55-gallon open and closed top drums) and material to cover waste to protect from weather (e.g., plastic covering);
- Hazardous /non-hazardous waste drum labels (weatherproof);
- Permanent marking pens;
- Inventory forms for project file;
- Plastic garbage bags, zip lock storage bags, roll of plastic sheeting; and
- Steel-toed boots, chemical resistant gloves, coveralls, safety glasses, and any other PPE required in the HASP.

6.0 Procedure

The following procedures are used to handle the IDW.

6.1 Drum Handling

6.1.1 IDW shall be containerized using DOT approved drums. The drums shall be made of steel or polyethylene, be completely painted or opaque, and have removable lids (i.e., United Nations Code 1A2 or 1H2). Always consider IDW physical and chemical characterises to make sure the drum material is compatible. Typically, 55-gallon drums are used, however small drums may be used depending on the amount of waste generated. Large overpack drums may be used if smaller drums become damaged. New drums are preferred. The use of recycled drums should be avoided.

6.1.2 Recycled drums should not be used for hazardous waste, PCBs or other regulated shipments. For short-term storage of liquid IDW prior to discharge, double-walled bulk steel or plastic storage tanks may be used. For this scenario, consider the scheduling and cost-effectiveness of this type of bulk storage, treatment, and discharge system versus longer-term drum storage.

6.1.3 For long-term IDW storage at other project locations, the DOT approved drums with removable lids are recommended. Verify the integrity of the foam or rubber sealing ring located on the underside of some drum lids prior to sealing drums containing IDW liquids.

6.1.4 If the sealing ring is only partially attached to the drum lid, or if a portion of the sealing ring is missing, select another drum lid with a sealing ring that is in sound condition.

6.1.5 To prevent damage to drums, loss of drum integrity/containment, and/or presenting hazards to drum handlers, the following “Rules-of-Thumb” should be applied when filling drums.

- Liquid, soil, PPE/plastics, and construction debris must be segregated by media into individual drums.
- A **void space of 4 to 6 inches** from the top of the drum (the upper drum ring on most drums) will be left in the drum to allow room for ice expansion when filling drums with water or oil/water emulsions. Under freezing temperatures, expanding ice in a full drum can deform the bottom of a drum such that it is no longer DOT compliant, cause ruptures and/or dislodge the drum lid and present a containment breach. The consequences of this damage can be both economic and environmental.
- Compatibility between the chemical component(s) of the IDW and the drum material must be considered before choosing the type of drum/container to use. Steel drums are susceptible to corrosion and loss of integrity when in contact with high pH water. Lime-based products (cement, concrete, grout, etc.) should not be disposed in steel drums containing water or soil water mixtures, and liquid IDW should not be disposed in steel drums used to mix lime-based products (separate reusable containers for mixing should be used when possible). If high (>12) or low (<2) pH conditions are possible, IDW liquids should be monitored for pH using a calibrated pH meter or pH test strips. The use of plastic drum liners or polyethylene drums is also recommended for high or low pH liquid IDW.
- Soil drums will be filled to no more than two thirds of the drum capacity. Drums completely full of soil can weigh over 600 pounds. Although drum handling tools and carts provide some assistance, moving such excessive weights present significant hazards, including; muscle strain, crushing (foot and fingers), and loss of drum control, such as sliding off of lift gates.
- Drums should not be overfilled filled with PPE and plastic (tubing, old macrocores) such that the material is excessively compacted. Pinch points are presented as the drum is closed under force, and the compressed material can spring up when the drums are opened.

6.1.6 Stacking full or partially full drums is prohibited.

6.1.7 To prepare IDW drums for labelling, wipe clean the outer wall surfaces and drum lids of all material that might prevent legible and permanent labelling. If potentially contaminated material adheres to the outer surface of a drum, wipe that material from the drum, and segregate the paper towel or rag used to remove the material with visibly soiled PPE and disposable sampling equipment. Label all IDW drums and place them on pallets prior to storage.

6.2 Labelling

6.2.1 Containers used to store IDW must be properly labelled. Two general conditions exist: 1) from previous studies or on-site data, waste characteristics are known to be either hazardous or nonhazardous; or 2) waste characteristics are unknown until additional data are obtained.

6.2.2 For situations where the waste characteristics are known, the waste containers should be packaged and labelled in accordance with state regulations and any federal regulations that may govern the labelling of waste.

6.2.3 The following information shall be placed on all non-hazardous waste labels:

- Description of waste (i.e., purge water, soil cuttings);
- Contact information (i.e., contact name and telephone number);
- Date when the waste was first accumulated.

6.2.4 The following information shall be placed on all hazardous waste labels:

- Description of waste (i.e., purge water, soil cuttings);
- Generator information (i.e., name, address, contact telephone number);
- EPA identification number (supplied by on-site client representative);
- Date when the waste was first accumulated.

6.2.5 When the final characterization of a waste is unknown, a notification label should be placed on the drum with the words “waste characterization pending analysis” and the following information included on the label:

- Description of waste (i.e., purge water, soil cuttings);
- Contact information (i.e., contact name and telephone number);
- Date when the waste was first accumulated.

6.2.6 Once the waste has been characterized, the label should be changed as appropriate for a nonhazardous or hazardous waste.

6.2.7 Waste labels should be constructed of a weatherproof material and filled out with a permanent marker to prevent being washed off or becoming faded by sunlight (faded entries should be remarked during inspections performed as specified in Section 6.2.4). It is recommended that waste labels be placed on the side of the container, since the top is more subject to weathering. However, when multiple containers are accumulated together, it may also be helpful to include labels on the top of the containers to facilitate organization and disposal. In addition to a label, each drum should be numbered on the side and top with a paint pen or wax pencil for easy identification.

6.2.8 Each container of waste generated shall be recorded in the field notebook used by the person responsible for labelling the waste. After the waste is disposed of, either by transportation off-site or disposal on-site in an approved disposal area, an appropriate record shall be made in the same field notebook to document proper disposition of IDW.

6.3 Types of Site Investigation Waste

Several types of waste are generated during site investigations that may require special handling. These include solid, liquid, and used PPE, as discussed further below.

Solid Waste

Soil cuttings from boreholes will typically be placed in containers unless site specific requirements allow for soil cuttings to be placed back into the borehole after drilling is complete. Drilling mud generated during investigation activities shall be collected in containers. Covers should be included on the containers and must be secured at all times and only open during filling activities. The containers shall be labelled in accordance with this SOP. An inventory containing the source, volume, and description of material put in the containers shall be logged on prescribed forms and kept in the project file.

Non-hazardous solid waste can be disposed on-site in the designated site landfill or in a designated evaporation pond if it is liquefied. Hazardous wastes must be disposed off-site at an approved hazardous waste landfill.

Liquid Waste

Groundwater generated during monitoring well development, purging, and sampling can be collected in truck-mounted containers and/or other transportable containers (i.e., 55-gallon drums). Lids or bungs on drums must be secured at all times and only open during filling or pumping activities. The containers shall be labelled in accordance with this SOP. Non-hazardous liquid waste can be disposed of in one of the designated lined evaporation ponds on-site. Hazardous wastes must be handled separately and disposed off-site at an approved hazardous waste facility.

Personal Protective Equipment

PPE that is generated throughout investigation activities shall be placed in plastic garbage bags. If the solid or liquid waste that was being handled is characterized as hazardous waste, then the corresponding PPE should also be disposed as hazardous waste. If not, all PPE should be disposed as non-hazardous waste in the designated on-site landfill. Trash that is generated as part of field activities may be disposed of in the landfill as long as the trash was not exposed to hazardous media.

6.1 IDW Waste Classification

State and federal regulations require specific handling and storage requirements for wastes classified as hazardous, such as secondary containment and waste removal deadlines (see Section 6.2.2). The Site owner/operator must determine whether the IDW may contain a listed hazardous waste based on the source of contamination, contaminants, and waste manifests or any other documentation of wastes generated at the Site. It is presumed that the IDW will be considered a solid waste (40 CFR 261.2) but this should be verified during the work plan development. If the available documentation indicates that a listed hazardous waste was generated at the Site, then the IDW will be considered a hazardous waste regulated under RCRA.

If there is inconclusive documentation concerning the IDW generated at the Site, then the U.S. EPA has stated the IDW is not a listed hazardous waste. However, in this case, further evaluation is necessary to evaluate whether the IDW in question exhibits a characteristic of hazardous waste. This is determined by analytical testing or knowledge. An IDW that may be characteristically hazardous should be evaluated for the following hazardous characteristics:

- Characteristic of ignitability (40 CFR §261.21)
- Characteristic of corrosivity (40 CFR §261.22)
- Characteristic of reactivity (40 CFR §261.23)
- Characteristic of toxicity (40 CFR §261.24)

If the RDW contains a listed hazardous waste, then U.S. EPA's contained-in policy (53 FR 31138, 31142, 31148, 57 FR 21453, 61 FR 18795) for contaminated environmental media should be evaluated. U.S. EPA considers IDW to contain hazardous waste:

- when it exhibits a characteristic of hazardous waste; or
- when it is impacted with concentrations of hazardous constituents from listed hazardous wastes that are above health-based levels.

Generally, IDW that does not (or no longer) contain hazardous waste are not subject to RCRA, but in some circumstances, the IDW that contained hazardous waste when first generated remain subject to land disposal restrictions (LDR) (40 CFR §268.45). There are also special LDR standards specific to contaminated debris (40 CFR §268.45).

6.2 Waste Accumulation On-Site

6.2.1 Solid, liquid, or PPE waste generated during investigation activities that are classified as nonhazardous or "characterization pending analysis" should be disposed of as soon as possible. Until off-site transport and disposal is arranged, drums should be moved to a staging location accessible by pickup by truck. This location should be relatively flat, have a hard surface (densely compact dirt, concrete, or asphalt), and be secure (by a fence or building).

6.2.2 Solid, liquid, or PPE waste generated during investigation activities that are classified as hazardous **shall not** be accumulated on-site longer than **90 days**. All hazardous waste containers shall be stored in a secured storage area. The following requirements for the hazardous waste storage area must be implemented:

- Proper hazardous waste signs shall be posted as required by any state or federal statutes that may govern the labelling of waste;
- Secondary containment to contain spills;
- Spill containment equipment must be available;
- Fire extinguisher;
- Adequate aisle space for unobstructed movement of personnel.

6.2.3 When possible, drums should be segregated in the storage area by media and or classification (liquid, solid, non-hazardous, hazardous, etc.) to facilitate type identification during characterization sampling and pickup and reduce the need to rearrange drums if multiple pickups by type are required.

6.2.4 Throughout the project, an inventory shall be maintained to itemize the type and quantity of the waste generated. During active site work, weekly storage area inspections should be performed and documented to ensure compliance with the requirements specified above. Monthly storage area inspections should be performed following the completion of active site work and the date the IDW is removed from the storage area by the waste hauler. Containers should be inventoried and inspected regularly. Labels should be checked to make sure they remain legible. Inspection notes should include the condition of the staging area as this will be important when coordinating the labour and equipment the waste hauler will require. Anomalies should be documented and photographed.

6.3 Waste Disposal

6.3.1 Solid, liquid, and PPE waste will be characterized for disposal through the use of client knowledge, laboratory analytical data created from soil or groundwater samples gathered during the field activities, and/or composite samples from individual containers. The selected disposal facility will prepare a waste profile based on the characterization results. The waste generator (Navy representative or authorized agent) will review and sign the profile.

6.3.2 All waste generated during field activities will be stored, transported, and disposed of according to applicable state, federal, and local regulations. All wastes classified as hazardous will be disposed of at a licensed treatment storage and disposal facility or managed in other approved manners.

6.3.3 Disposal facilities for waste generated during activities under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) will require EPA approval under the Off-Site Rule (OSR) procedures (40 CFR 300.440) to ensure the facility is operating in compliance with RCRA or other Federal and State requirements. After the waste profile is finalized, the generator will submit it with an OSR request form to the EPA project manager for approval. An example OSR request form is provided in Attachment A. IDW may not be shipped to the facility until approval is granted by the EPA. OSR approvals per waste profile are valid for 90 days.

6.3.4 In general, waste disposal should be carefully coordinated with the facility receiving the waste. Facilities receiving waste have specific requirements that vary even for non-hazardous waste, so characterization should be conducted to support both applicable regulations and facility requirements.

6.4 Regulatory Requirements

The following federal and state regulations shall be used as resources for determining waste characteristics and requirements for waste storage, transportation, and disposal:

- Code of Federal Regulations (CFR), Title 40, Part 261;
- CFR, Title 49, Parts 172, 173, 178, and 179.

6.5 Waste Transport

A state-certified hazardous waste hauler shall transport all wastes classified as hazardous. Typically, the facility receiving any waste can coordinate a hauler to transport the waste. Shipped hazardous waste shall be disposed of in accordance with all RCRA/USEPA requirements. All waste manifests or bills of lading will be signed either by the client or the client's designee.

7.0 Quality Control and Assurance

7.1 Management of IDW must incorporate quality control measures to ensure conformance to these and the project requirements.

8.0 Records, Data Analysis, Calculations

8.1 Maintain records as required by implanting the procedures in this SOP.

8.2 Deviations from this procedure or the sampling and analysis plan shall be documented in field records. Significant changes shall be approved by the **Program Quality Manager**.

9.0 Attachments or References

Department of Defense, United States (DoD). 2005. *Uniform Federal Policy for Quality Assurance Project Plans, Part 1: UFP-QAPP Manual.* Final Version 1. DoD: DTIC ADA 427785, EPA-505-B-04-900A. In conjunction with the U. S. Environmental Protection Agency and the Department of Energy. Washington: Intergovernmental Data Quality Task Force. March. On-line updates available at: http://www.epa.gov/fedfac/pdf/ufp_qapp_v1_0305.pdf.

Department of Energy, United States (DOE). 1994. *The Off-Site Rule*. EH-231-020/0194. Office of Environmental Guidance. March.

1999. *Management of Remediation Waste under the Resource Conservation and Recovery Act (RCRA)*. Office of Environmental Policy and Assistance. 20 December.

Environmental Protection Agency, United States (EPA). 1991. *Management of Investigative-Derived Wastes During Site Inspections*. Office of Emergency and Remedial Response. EPA/540/G-91/009. May.

1992a. *Guidance for Performing Site Inspections under CERCLA*. EPA/540/R-92/021. Office of Emergency and Remedial Response. September.

1992b. *Guide to Management of Investigative-Derived Wastes*. Quick reference fact sheet. OSWER Dir. 9345.3-03FS. Office of Solid Waste and Emergency Response. January.

1997a. *Sending Wastes Off Site? OSC and RPM Responsibilities under the Off-Site Rule*. EPA/540-F-97-006, Office of Solid Waste and Emergency Response. September.

1997b. *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846.* 3rd ed., Final Update IIIA. Office of Solid Waste. Updates available: www.epa.gov/epaoswer/hazwaste/test/new-meth.htm.

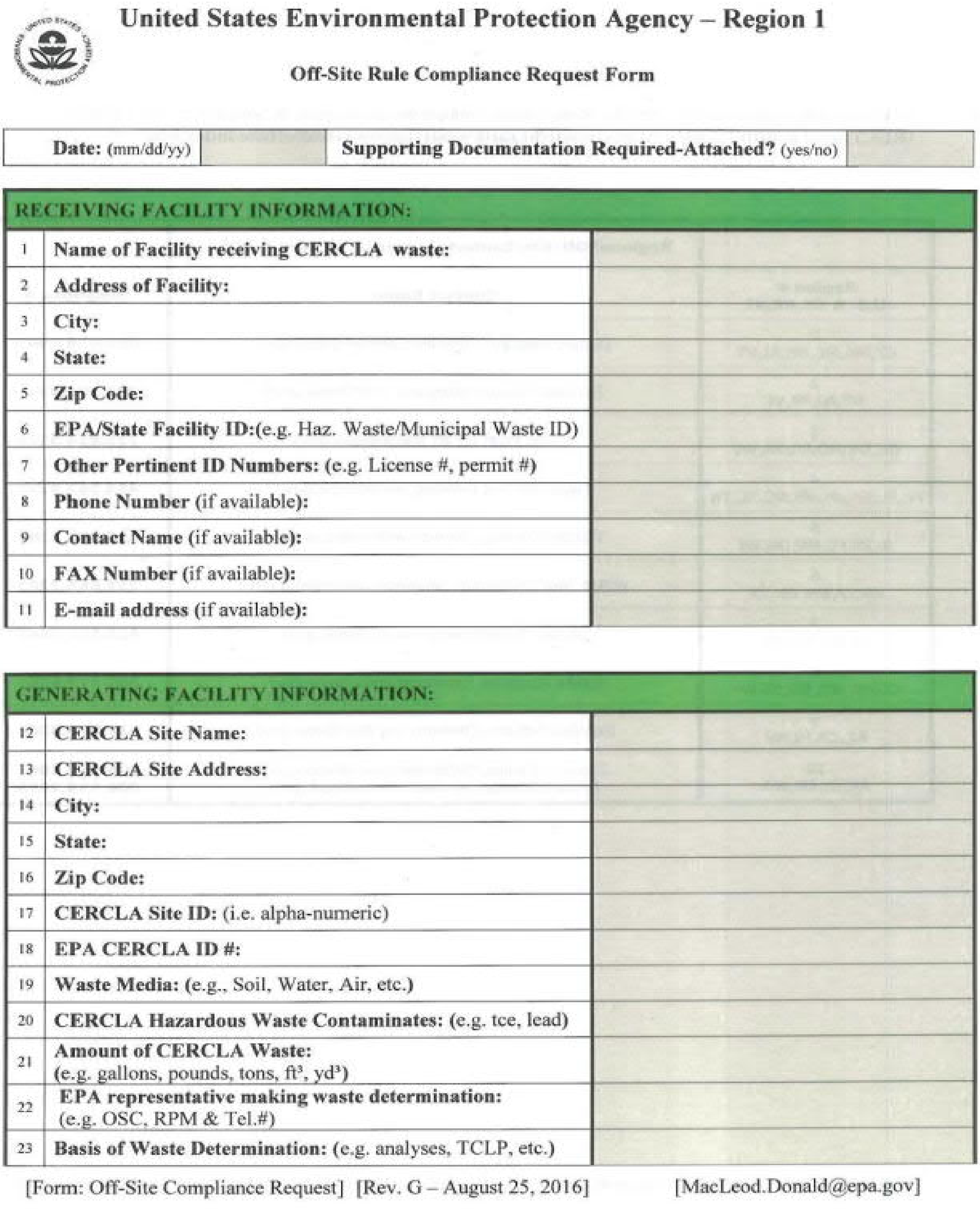
1998. *Management of Remediation Waste under RCRA*. EPA/530-F-98-026. Office of Solid Waste and Emergency Response. October.

(No Date). *Compliance with the Off-Site Rule During Removal Actions.* Office of Regional Counsel (Region 3). Hendershot, Michael.

Author	Reviewer	Revisions (Technical or Editorial)
Mark Kromis Program Chemist	Chris Barr Program Quality Manager	Rev 0 – Initial Issue (May 2012)
Joshua Millard Senior Geologist	Andrew Borden Geologist	Rev 1 – Technical (Jan 2017)
Ken O’Donnell, PG Geologist	Claire Mitchell, PE, PMP Senior Engineer	Rev 2 – PFAS sampling update (July 2019)

ATTACHMENT A – OFF SITE RULE REQUEST FORM

NOTE: SOPs have been updated for PFAS sampling activities; however, AECOM's internal PFAS sampling guidance supersedes materials and methods described in SOPs.



United States Environmental Protection Agency – Region 1

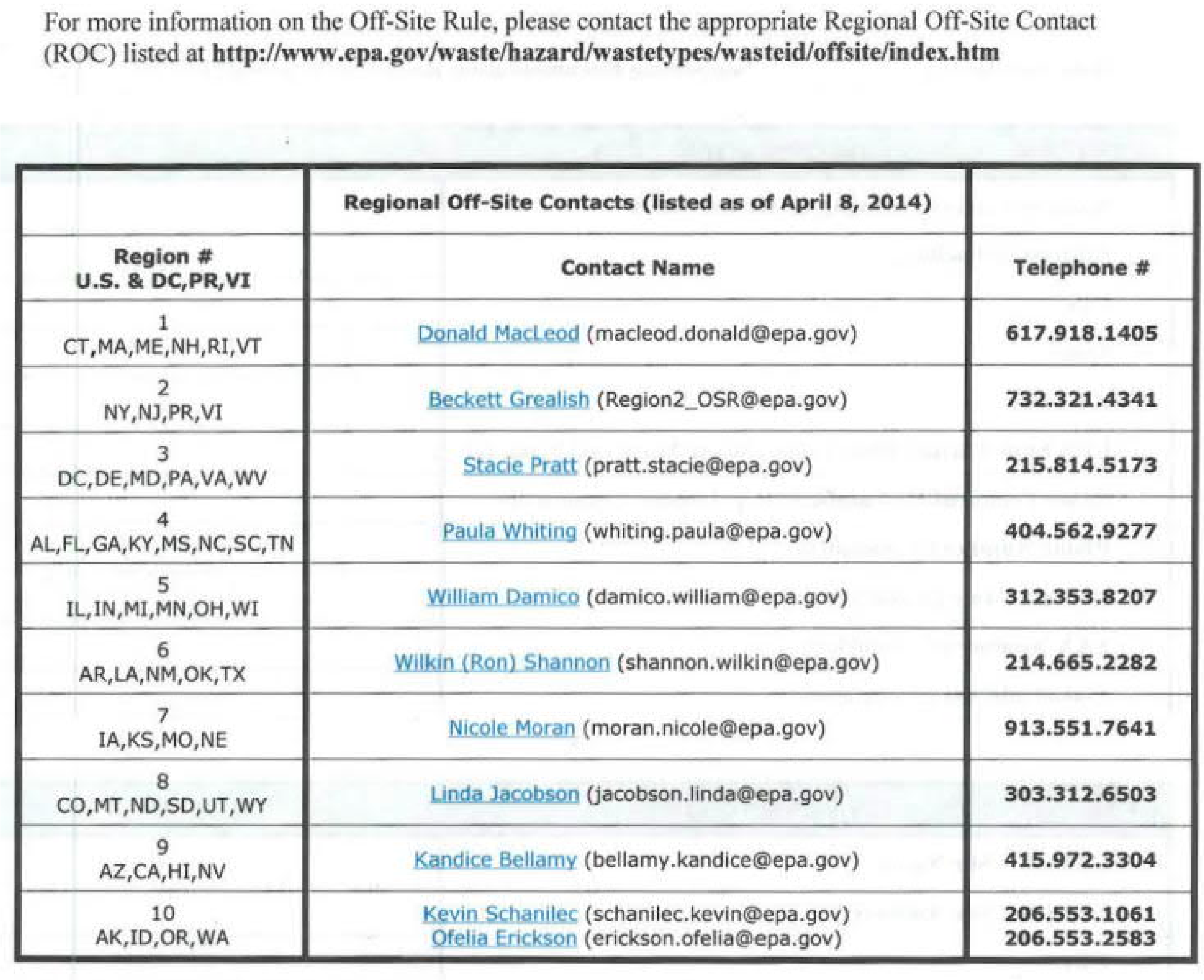
Off-Site Rule Compliance Request Form

Date: (mm/dd/yy)		**Supporting Documentation Required-Attached?** (yes/no)	

RECEIVING FACILITY INFORMATION:		
1	**Name of Facility receiving CERCLA waste:**	
2	**Address of Facility:**	
3	**City:**	
4	**State:**	
5	**Zip Code:**	
6	**EPA/State Facility ID:**(e.g. Haz. Waste/Municipal Waste ID)	
7	**Other Pertinent ID Numbers:** (e.g. License #, permit #)	
8	**Phone Number** (if available):	
9	**Contact Name** (if available):	
10	**FAX Number** (if available):	
11	**E-mail address** (if available):	

GENERATING FACILITY INFORMATION:		
12	**CERCLA Site Name:**	
13	**CERCLA Site Address:**	
14	**City:**	
15	**State:**	
16	**Zip Code:**	
17	**CERCLA Site ID:** (i.e. alpha-numeric)	
18	**EPA CERCLA ID #:**	
19	**Waste Media:** (e.g., Soil, Water, Air, etc.)	
20	**CERCLA Hazardous Waste Contaminates:** (e.g. tce, lead)	
21	**Amount of CERCLA Waste:** (e.g. gallons, pounds, tons, ft^3, yd^3)	
22	**EPA representative making waste determination:** (e.g. OSC, RPM & Tel.#)	
23	**Basis of Waste Determination:** (e.g. analyses, TCLP, etc.)	

[Form: Off-Site Compliance Request] [Rev. G – August 25, 2016] [MacLeod.Donald@epa.gov]



For more information on the Off-Site Rule, please contact the appropriate Regional Off-Site Contact (ROC) listed at **http://www.epa.gov/waste/hazard/wastetypes/wasteid/offsite/index.htm**

	Regional Off-Site Contacts (listed as of April 8, 2014)	
Region # U.S. & DC,PR,VI	**Contact Name**	**Telephone #**
1 CT,MA,ME,NH,RI,VT	Donald MacLeod (macleod.donald@epa.gov)	**617.918.1405**
2 NY,NJ,PR,VI	Beckett Grealish (Region2_OSR@epa.gov)	**732.321.4341**
3 DC,DE,MD,PA,VA,WV	Stacie Pratt (pratt.stacie@epa.gov)	**215.814.5173**
4 AL,FL,GA,KY,MS,NC,SC,TN	Paula Whiting (whiting.paula@epa.gov)	**404.562.9277**
5 IL,IN,MI,MN,OH,WI	William Damico (damico.william@epa.gov)	**312.353.8207**
6 AR,LA,NM,OK,TX	Wilkin (Ron) Shannon (shannon.wilkin@epa.gov)	**214.665.2282**
7 IA,KS,MO,NE	Nicole Moran (moran.nicole@epa.gov)	**913.551.7641**
8 CO,MT,ND,SD,UT,WY	Linda Jacobson (jacobson.linda@epa.gov)	**303.312.6503**
9 AZ,CA,HI,NV	Kandice Bellamy (bellamy.kandice@epa.gov)	**415.972.3304**
10 AK,ID,OR,WA	Kevin Schanilec (schanilec.kevin@epa.gov) Ofelia Erickson (erickson.ofelia@epa.gov)	**206.553.1061** **206.553.2583**

Equipment Decontamination

Procedure 3-06

1.0 Purpose and Scope

1.1 This standard operating procedure (SOP) describes methods of equipment decontamination, to be used for activities where samples for chemical analysis are collected or where equipment will need to be cleaned before leaving the site or before use in subsequent activities.

1.2 As guidance for specific activities, this procedure does not obviate the need for professional judgment. Deviations from this procedure while planning or executing planned activities must be approved in accordance with Program requirements for technical planning and review.

2.0 Safety

It is the responsibility of the **Site Safety and Health Officer (SSHO)** to set up the site zones (i.e., exclusion, transition, and clean) and decontamination areas. Generally, the decontamination area is located within the transition zone, upwind of intrusive activities, and serves as the washing area for both personnel and equipment to minimize the spread of contamination into the clean zone. Typically, for equipment, a series of buckets are set up on a visqueen-lined bermed area. Separate spray bottles containing cleaning solvents as described in this procedure or the Task Order (TO) Quality Assurance Project Plan (QAPP) and deionized water are used for final rinsing of equipment. Depending on the nature of the hazards and the site location, decontamination of heavy equipment, such as augers, pump drop pipe, and vehicles, may be accomplished using a variety of techniques.

All **Field Personnel** responsible for equipment decontamination must adhere to the site-specific Accident Prevention Plan (APP)/Site Safety and Health Plan (SSHP) and must wear the personal protective equipment (PPE) specified in the site-specific APP/SSHP. Generally, this includes, at a minimum, Tyvek® coveralls, steel-toed boots with boot covers or steel-toed rubber boots, safety glasses, American National Standards Institute-standard hard hats, and hearing protection (if heavy equipment is in operation). Air monitoring by the **SSHO** may result in an upgrade to the use of respirators and cartridges in the decontamination area; therefore, this equipment must be available on site. If safe alternatives are not achievable, discontinue site activities immediately.

In addition to the aforementioned precautions, the following sections describe safe work practices that will be employed.

2.1 Chemical Hazards associated with Equipment Decontamination

- Avoid skin contact with and/or incidental ingestion of decontamination solutions and water.
- Utilize PPE as specified in the site-specific APP/SSHP to maximize splash protection.
- Refer to material safety data sheets, safety personnel, and/or consult sampling personnel regarding appropriate safety measures (i.e., handling, PPE including skin and respiratory).
- Take the necessary precautions when handling detergents and reagents.

2.2 Physical Hazards associated with Equipment Decontamination

- To avoid possible back strain, it is recommended to raise the decontamination area 1 to 2 feet above ground level.

NOTE: SOPs have been updated for PFAS sampling activities; however, AECOM's internal PFAS sampling guidance supersedes materials and methods described in SOPs.

- To avoid heat stress, over exertion, and exhaustion, it is recommended to rotate equipment decontamination among all site personnel.
- Take necessary precautions when handling field sampling equipment.

3.0 Terms and Definitions

None.

4.0 Training and Qualifications

4.1 The **TO Manager** is responsible for ensuring that decontamination activities comply with this procedure. The **TO Manager** is responsible for ensuring that all personnel involved in equipment decontamination shall have the appropriate education, experience, and training to perform their assigned tasks.

4.2 The **Program Quality Manager** is responsible for ensuring overall compliance with this procedure.

4.3 The **Field Manager** is responsible for ensuring that all field equipment is decontaminated according to this procedure.

4.4 All **Field Personnel** are responsible for the implementation of this procedure.

5.0 Procedure

Decontamination of equipment used in soil/sediment sampling, groundwater monitoring, well drilling and well development, as well as equipment used to sample groundwater, surface water, sediment, waste, wipe, asbestos, and unsaturated zone, is necessary to prevent cross-contamination and to maintain the highest integrity possible in collected samples. Planning a decontamination program requires consideration of the following factors:

- Location where the decontamination procedures will be conducted
- Types of equipment requiring decontamination
- Frequency of equipment decontamination
- Cleaning technique and types of cleaning solutions appropriate to the contaminants of concern
- Method for containing the residual contaminants and wash water from the decontamination process
- Use of a quality control measure to determine the effectiveness of the decontamination procedure

The following subsections describe standards for decontamination, including the frequency of decontamination, cleaning solutions and techniques, containment of residual contaminants and cleaning solutions, and effectiveness.

5.1 Decontamination Area

Select an appropriate location for the decontamination area at a site based on the ability to control access to the area, the ability to control residual material removed from equipment, the need to store clean equipment, and the ability to restrict access to the area being investigated. Locate the decontamination area an adequate distance away and upwind from potential contaminant sources to avoid contamination of clean equipment.

5.2 Types of Equipment

Drilling equipment that must be decontaminated includes drill bits, auger sections, drill-string tools, drill rods, split barrel samplers, tremie pipes, clamps, hand tools, and steel cable. Decontamination of monitoring well development and groundwater sampling equipment includes submersible pumps, bailers, interface probes, water level meters, bladder pumps, airlift pumps, peristaltic pumps, and lysimeters. Other sampling equipment that requires decontamination includes, but is not limited to, hand trowels, hand augers, slide hammer samplers, shovels, stainless-steel spoons and bowls, soil sample liners and caps, wipe sampling templates, composite liquid waste samplers, and dippers. Equipment with a porous surface, such as rope, cloth hoses, and wooden blocks, cannot be thoroughly decontaminated and shall be properly disposed of after one use.

5.3 Frequency of Equipment Decontamination

Decontaminate down-hole drilling equipment and equipment used in monitoring well development and purging prior to initial use and between each borehole or well. Down-hole drilling equipment, however, may require more frequent cleaning to prevent cross-contamination between vertical zones within a single borehole. When drilling through a shallow contaminated zone and installing a surface casing to seal off the contaminated zone, decontaminate the drilling tools prior to drilling deeper. Initiate groundwater sampling by sampling groundwater from the monitoring well where the least contamination is suspected. Decontaminate groundwater, surface water, and soil sampling devices prior to initial use and between collection of each sample to prevent the possible introduction of contaminants into successive samples.

5.4 Cleaning Solutions and Techniques

Decontamination can be accomplished using a variety of techniques and fluids. The preferred method of decontaminating major equipment, such as drill bits, augers, drill string, and pump drop-pipe, is steam cleaning. To steam clean, use a portable, high-pressure steam cleaner equipped with a pressure hose and fittings. For this method, thoroughly steam wash equipment and rinse it with potable tap water to remove particulates and contaminants.

A rinse decontamination procedure is acceptable for equipment such as bailers, water level meters, new and re-used soil sample liners, and hand tools. The decontamination procedure shall consist of the following: (1) wash with a PFAS-free detergent (Alconox®, Liquinox®, or other suitable detergent) and deionized water solution, and (2) rinse in triplicate with deionized water. If possible, disassemble equipment prior to cleaning. Add an additional wash as needed at the beginning of the process if equipment is very soiled.

Decontaminating submersible pumps requires additional effort because internal surfaces become contaminated during usage. Decontaminate these pumps by washing and rinsing the outside surfaces using the procedure described for small equipment or by steam cleaning. Decontaminate the internal surfaces by recirculating fluids through the pump while it is operating. This recirculation may be done using a relatively long (typically 4 feet) large-diameter pipe (4-inch or greater) equipped with a bottom cap. Fill the pipe with the decontamination fluids, place the pump within the capped pipe, and operate the pump while recirculating the fluids back into the pipe. The decontamination sequence shall include: (1) detergent and deionized water solution, and (2) rinse in triplicate with deionized water rinse. Change the decontamination fluids after each decontamination cycle.

Solvents other than isopropyl alcohol may be used, depending upon the contaminants involved. For example, if polychlorinated biphenyls or chlorinated pesticides are contaminants of concern, hexane may be used as the decontamination solvent; however, if samples are also to be analyzed for volatile organics, hexane shall not be used. In addition, some decontamination solvents have health effects that must be considered. Decontamination water shall consist of deionized water. Decontamination solvents to be used during field activities will be specified in the TO QAPP.

Rinse equipment used for measuring field parameters, such as pH (indicates the hydrogen ion concentration – acidity or basicity), temperature, specific conductivity, and turbidity with deionized water after each measurement. Also wash new, unused soil sample liners and caps with a fresh detergent solution and rinse them with deionized water to remove any dirt or cutting oils that might be on them prior to use.

5.5 Containment of Residual Contaminants and Cleaning Solutions

A decontamination program for equipment exposed to potentially hazardous materials requires a provision for catchment and disposal of the contaminated material, cleaning solution, and wash water.

When contaminated material and cleaning fluids must be contained from heavy equipment, such as drill rigs and support vehicles, the area must be properly floored, preferably with a concrete pad that slopes toward a sump pit. If a concrete pad is impractical, planking can be used to construct solid flooring that is then covered by a nonporous surface and sloped toward a collection sump. If the decontamination area lacks a collection sump, use plastic sheeting and blocks or other objects to create a bermed area for collection of equipment decontamination water. Situate items, such as auger flights, which can be placed on metal stands or other similar equipment, on this equipment during decontamination to prevent contact with fluids generated by previous equipment decontamination. Store clean equipment in a separate location to prevent recontamination. Collect decontamination fluids contained within the bermed area and store them in secured containers as described below.

Use wash buckets or tubs to catch fluids from the decontamination of lighter-weight drilling equipment and hand-held sampling devices. Collect the decontamination fluids and store them on site in secured containers, such as U.S. Department of Transportation-approved drums, until their disposition is determined by laboratory analytical results. Label containers in accordance with Procedure 3-05, *IDW Management*.

6.0 Quality Control and Assurance

A decontamination program must incorporate quality control measures to determine the effectiveness of cleaning methods. Quality control measures typically include collection of equipment blank samples or wipe testing. Equipment blanks consist of analyte-free deionized water that has been poured over or through the sample collection equipment after its final decontamination rinse. Wipe testing is performed by wiping a PFAS-free cotton cloth over the surface of the equipment after cleaning. These quality control measures provide "after-the fact" information that may be useful in determining whether or not cleaning methods were effective in removing the contaminants of concern.

7.0 Records, Data Analysis, Calculations

Any project where sampling and analysis is performed shall be executed in accordance with an approved sampling and analysis plan. This procedure may be incorporated by reference or may be incorporated with modifications described in the plan.

Deviations from this procedure or the sampling and analysis plan shall be documented in field records. Significant changes shall be approved by the **Program Quality Manager**.

8.0 Attachments or References

8.1 ASTM Standard D5088. 2008. *Standard Practice for Decontamination of Field Equipment Used at Waste Sites.* ASTM International, West Conshohocken, PA. 2008. DOI: 10.1520/D5088-02R08. www.astm.org.

8.2 Procedure 3-05, *IDW Management*.

Author	Reviewer	Revisions (Technical or Editorial)
Mark Kromis Program Chemist	Chris Barr Program Quality Manager	Rev 0 – Initial Issue
Ken O'Donnell, PG Geologist	Claire Mitchell, PE, PMP Senior Engineer	Rev 1 – PFAS sampling update (July 2019)

NOTE: SOPs have been updated for PFAS sampling activities; however, AECOM's internal PFAS sampling guidance supersedes materials and methods described in SOPs.

Land Surveying

Procedure 3-07

1.0 Purpose and Scope

1.1 The purpose of this document is to define the standard operating procedure (SOP) for acquiring land surveying data to facilitate the location and mapping of geologic, hydrologic, geotechnical data, and analytical sampling points and to establish topographic control over project sites.

1.2 This procedure is the Program-approved professional guidance for work performed by AECOM under the client contract.

1.3 As guidance for specific activities, this procedure does not obviate the need for professional judgment. Deviations from this procedure while planning or executing planned activities must be approved in accordance with Program requirements for technical planning and review. If there are procedures whether it be from Resolution Consultants, state and/or federal that are not addressed in this SOP and are applicable to surface water sampling then those procedures may be added as an appendix to the project-specific Quality Assurance Project Plan (QAPP).

1.4 It is fully expected that the procedures outlined in this SOP will be followed. Procedural modifications may be warranted depending upon field conditions, equipment limitations, or limitations imposed by the procedure. Substantive modification to this SOP will be approved in advance by the Program Quality Manager. Deviations to this SOP will be documented in the field records.

1.5 If there are procedures, whether it be from Resolution Consultants, state and/or federal, that are not addressed in this SOP and are applicable to land surveying then those procedures may be added as an appendix to the project-specific QAPP.

2.0 Safety

2.1 Depending upon the site-specific contaminants, various protective programs must be implemented prior to conducting fieldwork. All **field sampling personnel** must review the project-specific Accident Prevention Plan (APP)/Site Safety and Health Plan (SSHP) paying particular attention to the control measures planned for the specific field tasks. Conduct preliminary area monitoring to determine the potential hazard to field sampling personnel. If significant contamination is observed, minimize contact with potential contaminants in both the vaper and liquid phase through the use of respirators and disposable clothing.

2.2 In addition, observe standard health and safety practices according to the project-specific APP/SSHP. Suggested minimum protection includes inner disposable vinyl gloves, outer chemical-protective nitrile gloves, rubberized steel-toed boots, and an American National Standards Institute-standard hard hat. Half-face respirators and cartridges and Tyvek® suits may be necessary depending on the contaminant concentrations, and shall always be available on site.

2.3 Daily safety briefs will be conducted at the start of each working day before any work commences. These daily briefs will be facilitated by the **Site Safety and Health Officer (SSHO)** or designee to discuss the day’s events and any potential health risk areas covering every aspect of the work to be completed. Weather conditions are often part of these discussions. As detailed in the APP/SSHP, everyone on the field team has the authority to stop work if an unsafe condition is perceived until the conditions are fully remedied to the satisfaction of the SSHO.

2.4 The health and safety considerations for the work associated with land surveying include:

- Slip, trips and falls associated with work in the field;

- Biological hazards associated with work in the field; and,
- Potential hazards associated with chemicals of concern (COCs) that may be located in the survey area,

3.0 Terms and Definitions

3.1 Boundary Survey

Boundary surveys are conducted by Certified Land Surveyors in order to delineate a legal property line for a site or section of a site.

3.2 Global Positioning System

A global positioning system (GPS) is a system of satellites, computers, and receivers that is able to determine the latitude and longitude of a receiver on Earth by calculating the time difference for signals from different satellites to reach the receiver.

4.0 Interferences

4.1 Commercially available GPS units typically have real-time sub-meter accuracy. Field corrections can be made as described in Section 8.3 below.

5.0 Training and Qualifications

5.1 Qualifications and Training

5.1.1 The individual executing these procedures must have read, and be familiar with, the requirements of this SOP.

5.2 Responsibilities

5.2.1 The **Task Order (TO) Manager** is responsible for ensuring that land surveying activities comply with this procedure. The TO Manager is responsible for ensuring that all field sampling personnel involved in land surveying shall have the appropriate education, experience, and training to perform their assigned tasks.

5.2.2 The **Program Quality Manager** is responsible for ensuring overall compliance with this procedure.

5.2.3 The **Site Supervisor (SS)** is responsible for ensuring that all field personnel follow these procedures. In virtually all cases, subcontractors will conduct these procedures. The SS or designee is responsible for overseeing the activities of the subcontractor and ensuring that sampling points and topographic features are properly surveyed.

6.0 Equipment and Supplies

6.1 The following equipment list contains materials that may be needed in carrying out the procedures outlined in this SOP. 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 by the APP/SSHP;
- Commercially available GPS unit; and,
- Field Logbook.

7.0 Calibration or Standardization

7.1 An authorized manufacturer’s representative shall inspect and calibrate survey instruments in accordance with the manufacturer's specifications regarding procedures and frequencies. At a minimum, instruments shall be calibrated no more than six months prior to the start of the survey work.

7.2 Standards for all survey work shall be in accordance with National Oceanic and Atmospheric Administration standards and, at a minimum, with accuracy standards set forth below. The horizontal accuracy for the location of all grid intersection and planimetric features shall be (±) 0.1 feet. The horizontal accuracy for boundary surveys shall be 1 in 10,000 feet (1:10,000). The vertical accuracy for ground surface elevations shall be (±) 0.1 feet. Benchmark elevation accuracy and elevation of other permanent features, including monitoring wellheads, shall be (±) 0.01 feet.

8.0 Procedure

8.1 Theodolite/Electronic Distance Measurement (EDM)

Follow the procedures listed below during theodolite/EDM land surveying:

- A land surveyor registered in the state or territory in which the work is being performed shall directly supervise all surveying work.
- Reference surveys to the local established coordinate systems.
- Reference surveyed points to site designated vertical datum, such as Mean Sea Level (Lower Low Water Level) and North American Vertical Datum of 1988 (NAVD 88).
- Jointly determine appropriate horizontal and vertical control points prior to the start of survey activities. If discrepancies in the survey (e.g., anomalous water level elevations) are observed, the surveyor may be required to verify the survey by comparison to a known survey mark. If necessary, a verification survey may be conducted by a qualified third party.
- All field notes, sketches, and drawings shall clearly identify the horizontal and vertical control points by number designation, description, coordinates, and elevations. Map all surveyed locations using a base map or other site mapping, as specified by the project Quality Assurance Project Plan (QAPP).
- Begin and end all surveys at the designated horizontal and vertical control points to determine the degree of accuracy of the surveys.
- Iron pins used to mark control points shall be made of reinforcement steel or an equivalent material and shall be 18 inches long with a minimum diameter of 5/8 inch. Drive pins to a depth of 18 inches into the soil.
- Stakes used to mark survey lines and points shall be made from 3-foot lengths of 2-inch by 2-inch lumber and pointed at one end. Clearly mark them with brightly coloured weatherproof flagging and paint.
- Clearly mark the point on a monitoring well casing or well riser that is surveyed by filing grooves into the casing/riser on either side of the surveyed point, or by marking the riser with a permanent ink marker.

8.2 Global Positioning System to Conduct Land Survey

Follow the procedures listed below during land surveying using GPS:

- A land surveyor registered in the state or territory in which the work is being performed shall directly supervise all surveying work.
- Reference surveys to the local established coordinate systems.
- All field notes, sketches, and drawings shall clearly identify the horizontal and vertical control points by number designation, description, coordinates, and elevations. Map all surveyed locations using a base map or other site mapping, as specified in the project QAPP.
- Begin and end all surveys at the designated horizontal and vertical control points (as applicable) to determine the degree of accuracy of the surveys.

- Iron pins used to mark control points shall be made of reinforcement steel or an equivalent material and shall be 18 inches long with a minimum diameter of 5/8 inch. Drive pins to a depth of 18 inches into the soil.
- Stakes used to mark survey lines and points shall be made from 3-foot lengths of 2-inch by 2-inch lumber and pointed at one end. Clearly mark them with brightly coloured weatherproof flagging and paint.
- Clearly mark the point on a monitoring well casing that is surveyed by filing grooves into the casing on either side of the surveyed point.

8.3 Global Positioning System to Position Sample Locations or Locate Site Features

Experienced field personnel may use a GPS system unit to position sample locations (e.g. grid positioned samples, soil boring locations) at a site. The decision to use field personnel or a licensed land surveyor will depend on the objectives of the survey (e.g. vertical elevation is not required) and the levels of precision required. Typically, when a level of accuracy greater than 0.03 meter is required, a licensed surveyor will be required. When a level of accuracy of (±) 1 meter is sufficient to meet project requirements (i.e. when laying sampling grids, identifying significant site features, or locating features identified in geographic information system [GIS] figures) experienced field personnel may use commercially available, consumer-grade GPS units. Follow the procedures listed below to locate samples or site features using GPS:

- A commercially available Trimble Geo 7X high-accuracy Global Navigation Satellite System.
- If waypoints are to be imported into a GIS database, the same grid projection system should be used.
- If a permanent reference point near the site is available, it is recommended that a waypoint at this location be taken every day waypoints are stored.
- When laying out a sampling grid from a GIS map, upload the coordinates from GIS to the GPS unit, including coordinates for an easily identified, permanent, nearby feature (i.e. building corner, roadway intersection, or United States Geological Survey benchmark).
- If during the initial site walk, the permanent feature identified does not overlay within (±) 1 meter as identified in the GPS unit, field corrections of the waypoints should be made.
- Field corrections can be made by adding/subtracting the difference in x,y coordinates between the field measurement of the permanent site feature and the anticipated x,y coordinates. This correction should then be applied to the x,y coordinates for each sampling location to be marked. Corrected x,y coordinates can then be uploaded into the GPS unit.
- Sampling points and site features can then be located in the field using the GPS units “Go To” function. When the distance to the sampling point or feature remains close to zero, the location can be marked.
- If no field corrections to the sampling location need to be made, or if sampling locations are to be surveyed by a licensed surveyor at a later date, no additional waypoints need to be taken. If significant changes to the sampling location are made, GPS coordinates at the corrected location shall be stored and labelled.
- GPS files containing field coordinates must be uploaded to a storage device such as PC at the end of each day. A new GPS file must be created for each day in the field.
- Field logs shall indicate manufacturer and model number for GPS unit used, map datum and projection used, and any field corrections made. If the GPS unit cannot lock onto a Wide Area Augmentation System (WAAS) system at the site, this should also be noted.

9.0 Quality Control and Assurance

GPS field data to be differentially corrected and imported into GIS and checked for accuracy on a daily basis.

10.0 Data and Records Management

The surveyor shall record field notes daily using generally accepted practices. The data shall be neat, legible, in indelible ink, and easily reproducible. Copies of the surveyor's field notes and calculation forms generated during the work shall be obtained and placed in the project files.

Surveyor's field notes shall, at a minimum, clearly indicate:

- The date of the survey;
- General weather conditions;
- The name of the surveying firm;
- The names and job titles of personnel performing the survey work;
- Equipment used, including serial numbers; and,
- Field book designations, including page numbers.

A land surveyor registered in the state or territory in which the work was done shall sign, seal, and certify the drawings and calculations submitted by the surveyor.

Dated records of land surveying equipment calibration shall be provided by the surveyor and placed in the project files. Equipment serial numbers shall be provided in the calibration records.

11.0 Attachments or References

Department of Defense, United States (DoD). 2005. *Uniform Federal Policy for Quality Assurance Project Plans, Part 1: UFP-QAPP Manual*. Final Version 1. DoD: DTIC ADA 427785, EPA-505-B-04-900A. In conjunction with the U. S. Environmental Protection Agency and the Department of Energy. Washington: Intergovernmental Data Quality Task Force. March. On-line updates available at: http://www.epa.gov/fedfac/pdf/ufp_qapp_v1_0305.pdf.

Author	Reviewer	Revisions (Technical or Editorial)
Robert Shoemaker Senior Scientist	Naomi Ouellette, Project Manager	Rev 0 – Initial Issue
Joshua Millard Geologist	James Bourdeau GIS Specialist	Rev 1 – Technical
Ken O'Donnell, PG Geologist	Claire Mitchell, PE, PMP Senior Engineer	Rev 2 – PFAS sampling update (July 2019)

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Surface Water Sampling

Procedure 3-10

1.0 Purpose and Scope

1.1 The purpose of this document is to define the standard operating procedure (SOP) for use in sampling surface water. This SOP describes the equipment, field procedures, materials, and documentation procedures necessary to surface water samples from shallow and deep water using a variety of samplers. Specific information regarding coring locations can be found in the associated Quality Assurance Project Plan (QAPP).

1.2 This procedure is the Program-approved professional guidance for work performed by AECOM under the client contract.

1.3 As guidance for specific activities, this procedure does not obviate the need for professional judgment. Deviations from this procedure while planning or executing planned activities must be approved in accordance with Program requirements for technical planning and review. If there are procedures whether it be from AECOM, state and/or federal that are not addressed in this SOP and are applicable to surface water sampling then those procedures may be added as an appendix to the project specific QAPP.

1.4 It is fully expected that the procedures outlined in this SOP will be followed. Procedural modifications may be warranted depending upon field conditions, equipment limitations, or limitations imposed by the procedure. Substantive modification to this SOP will be approved in advance by the Program Quality Manager. Deviations to this SOP will be documented in the field records.

2.0 Safety

2.1 Depending upon the site-specific contaminants, various protective programs must be implemented prior to sampling the first surface water sampling location. All **field sampling personnel** responsible for sampling activities must review the project-specific health and safety plan (HASP) paying particular attention to the control measures planned for the sampling tasks. Conduct preliminary area monitoring to determine the potential hazard to field sampling personnel. If significant contamination is observed, minimize contact with potential contaminants in both the vapor and liquid phase through the use of respirators and disposable clothing.

2.2 In addition, observe standard health and safety practices according to the project-specific HASP. Suggested minimum protection during well sampling activities includes protective eyewear, powder-free nitrile gloves, rubberized steel-toed boots, and an American National Standards Institute-standard hard hat. Half-face respirators and cartridges and Tyvek® suits may be necessary depending on evaluation for PFAS and on the contaminant concentrations.

2.3 Daily safety briefs will be conducted at the start of each working day before any work commences. These daily briefs will be facilitated by the **Site Safety Officer (SSO)** or designee to discuss the day's events and any potential health risk areas covering every aspect of the work to be completed. Weather conditions are often part of these discussions. As detailed in the HASP, everyone on the field team has the authority to stop work if an unsafe condition is perceived until the conditions are fully remedied to the satisfaction of the SSO.

2.4 The health and safety considerations for the work associated with surface water sampling include:

- Proper selection of personal protective equipment for work around water bodies (e.g., personal flotation devices [PFDs]), as specified in the project-specific HASP.

- Appropriate health and safety protocols for working in a boat (if applicable), as specified in the project-specific HASP.
- Proper lifting techniques when retrieving surface water samplers, large muscles of the legs should be used, not the back.
- Stay clear of all moving equipment and avoid wearing loose fitting clothing.
- To avoid slip/trip/fall hazards as a result of working on wet surfaces, wear work boots/work boot covers with textured soles.
- To avoid heat/cold stress as a result of exposure to extreme temperatures and PPE, drink electrolyte replacement fluids (1 to 2 cups per hour is recommended), and in cases of extreme cold, wear fitted insulated clothing

3.0 Terms and Definitions

None.

4.0 Interferences

None.

5.0 Training and Qualifications

5.1 Qualifications and Training

5.1.1 The individual executing these procedures must have read, and be familiar with, the requirements of this SOP.

5.2 Responsibilities

5.2.1 The **Task Order (TO) Manager** is responsible for ensuring that surface water sampling activities comply with this procedure. The TO Manager or designee shall review all surface water sampling forms on a minimum monthly basis. The TO Manager is responsible for ensuring that all field sampling personnel involved in surface water sampling shall have the appropriate education, experience, and training to perform their assigned tasks.

5.2.2 The **Program Quality Manager** is responsible for ensuring overall compliance with this procedure.

5.2.3 The **Field Manager** is responsible for ensuring that all field sampling personnel follow these procedures.

5.2.4 **Field sampling personnel** are responsible for the implementation of this procedure. Minimum qualifications for field sampling personnel require that one individual on the field team shall have a minimum of 6 months of experience with surface water sampling.

5.2.5 The **field sampler and/or task manager** is responsible for directly supervising the surface water sampling procedures to ensure that they are conducted according to this procedure, and for recording all pertinent data collected during sampling. If deviations from the procedure are required because of anomalous field conditions, they must first be approved by the Program Quality Manager and then documented in the field logbook and associated report or equivalent document.

6.0 Equipment and Supplies

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

- Work Plan
- Maps/Plot plan
- Tape measure
- Survey stakes, flags, or buoys
- Camera and film
- Stainless steel, HDPE, or other appropriate composition (i.e., PFAS-free) bucket
- Laboratory supplied sampling containers
- Ziploc plastic bags for samples, and HDPE sample jars
- Non-water repellent logbook
- Labels
- Chain of Custody (COC) forms
- Site description forms
- Cooler(s)
- Wet Ice
- Equipment/Apparatus
- Decontamination supplies/equipment
- Spade or shovel
- Spatula
- Scoop
- Trowel
- Task specific surface water sampling equipment

7.0 Calibration or Standardization

None.

8.0 Procedure

8.1 Selection of Sampling Techniques

Proper selection of sampling points and collection methodology are essential to meeting the objectives of a surface water sampling program. Sampling points should be selected for collection of surface water samples on the basis of characteristics of the body of surface water body to be monitored, the location of the body of surface water, and its hydrologic boundaries with respect to the site. Other considerations include the contaminants of concern, logistical considerations, such as access to the surface water body, the direction of flow, and determination of a background location.

Methods of collecting surface water samples vary from hand sampling procedures at a single point to sophisticated, multipoint sampling techniques. The number and type of samples to be collected depends on the characteristics of the body of water, the amount of suspended sediment that a moving body carries, the size of the discharge area at the site, and other factors. Multipoint sampling techniques apply to larger bodies of water; the samples are composited to provide a more representative sample.

Whenever possible, the sampling device, either disposable or constructed of HDPE, should hold at least 500 milliliters to minimize the number of times the liquid must be disturbed, thus reducing agitation of any sediment layers. A 1-liter HDPE beaker with a pour spout and handle works well. Any sampling device might contribute contaminants to a sample. The correct sampling device will not compromise the integrity of the sample and will give the desired analytical results.

8.1.1 Shallow Water Body Surface Water Sample Collection

A dip or grab sample is appropriate for a small body of water, or for collecting near-surface samples in a larger surface water body. The sampling method involves filling a sample container by submerging it either just below the surface, or by lowering the container to a desired depth by using a weighted holder. For shallow bodies of surface water, hold the sample container carefully just beneath the water surface to avoid disturbing the streambed and stirring the sediment. Position the container's mouth so that it faces upstream, while the sampling personnel are standing downstream. Any preservative added to the sample should be added after sample collection to avoid loss of preservative. Alternatively, a transfer device may be dipped into the water, and then the contents transferred to the appropriate container containing the preservative. For near-surface sample collection in a large surface water body, a pond sampler may be used if an extended reach is required to collect a representative sample. A pond sampler consists of a single use sample container attached to a telescoping, heavy-duty, aluminium pole via an adjustable clamp attached to the end. The collection technique for shallow surface water samples can be used for near-surface samples in a large surface water body.

8.1.2 Deep Surface Water Sample Collection

For deeper surface water bodies, either sample containers or transfer devices may be used to collect a sample. A weighted holder that allows either a sample transfer device or a sample container to be lowered, opened for filling, closed, and returned to the surface is suggested for sampling deeper surface water bodies. This is because concentrations of constituents near the surface of a deeper body of surface water might differ from the total concentration distributed throughout the water column cross section and thus a surface sample would not be representative of the water body. An open container that is lowered and raised to the surface at a uniform rate so that the bottle is just filled on reaching the surface is appropriate for deeper stagnant water bodies, however this method does not collect a truly representative sample in deeper flowing surface water bodies.

Kemmerer Samplers. Collect samples near the shore unless sampling from a boat is feasible and permitted. If a boat is used, the body of water should be cross-sectioned, and samples should be collected at various depths across the water in accordance with the project specific QAPP. The Kemmerer Sampler consists of a HDPE, a weighted sinker, a bottle stopper, and a line that is used to open the bottle and to lower and raise the sampler during sampling. The general procedure for using the sampler is as follows (or refer to manufacturer’s instructions):

1. Obtain the sampler and check the knot at the bottom of the sampler for tightness and size. The knot should be sufficiently large so that it will not pull through the central tube of the sampler.
2. Assemble the weighted bottle sampler for making the cast by pulling the trip head into the trip plate. This can be done by holding the top and bottom stoppers and giving a short, hard pull to the bottom stopper.
3. Measure and mark the desired depth on the sampling line. Tie the free end of the line to the railing of the vessel to prevent accidental dropping of the sampler.
4. Gently lower the sampler to the desired depth so as not to remove the stopper prematurely.
5. Pull out the stopper with a sharp jerk of the sampler line or by lowering a messenger down the line to trip the stoppers.
6. Allow the bottle to fill completely, as evidenced by the cessation of air bubbles.

7. Raise the sampler and cap the bottle. Untie the line from the railing and carry the sampler to your sampling station.
8. Transfer water into appropriate sample containers. Preserve the sample, if necessary, following guidelines in the project-specific QAPP. In most cases, place preservatives in sample containers before sample collection to avoid overexposure of samples and overfilling of bottles during collection.
9. Secure the HDPE or polypropylene cap tightly.
10. Fill out the sample label and record all relevant information in the sample collection form, the field logbook, and/or the field laptop/tablet. In addition, the chain of custody form should be filled out as soon as possible. These procedures should be done in accordance with SOP 3-03 Recordkeeping, Sample Labeling, and Chain of Custody.
11. Immediately place the properly labeled sample bottle(s) in a cooler with wet ice.
12. Wipe the sample clean and decontaminate for the collection of additional samples. Decontaminate according to the procedures in SOP 3-06 Equipment Decontamination.
13. Always store the sampler in the open position (stoppers not in the tube).

Peristaltic Pump. Another method of extending the reach of sampling efforts is to use a small peristaltic pump. In this method, the sample is drawn through HDPE tubing and pumped directly into the sample container. This system allows the operator to reach into the liquid body, sample from depth, or sweep the width of narrow streams.

If medical-grade silicon tubing is used in the peristaltic pump, the system is suitable for sampling almost any analyte, including most organics. Some volatile stripping may occur; due to the relatively high flow rate of the pump. Therefore, avoid pumping methods for sampling volatile organics. Battery-operated peristaltic pumps are available and can be easily carried by hand or with a shoulder sling, as needed. It is necessary in most situations to change both the HDPE suction line and the silicon pump tubing between sampling locations to avoid cross contamination. This action requires maintaining a sufficiently large stock of material to avoid having to clean the tubing in the field.

Peristaltic pumps work especially well for sampling large bodies of water when a near-surface sample will not sufficiently characterize the body as a whole. When sampling a liquid stream that exhibits a considerable flow rate, it may be necessary to weight the bottom of the suction line.

Use the following procedures for collecting samples using peristaltic pumps:

1. Install clean, silicone tubing in the pump head, per the manufacturer's instructions. Pharmaceutical-grade silicone tubing (e.g., PharMed tubing) may be required for some projects depending on the analyses required. Refer to the project specific QAPP for specific tubing requirements. Allow sufficient tubing on the discharge side to facilitate convenient dispensation of liquid into sample bottles, but only enough on the suction end for attachment to the intake line. This practice will minimize sample contact with the silicone pump tubing. Some types of thinner HDPE tubing may be used.
2. Select the length of suction intake tubing necessary to reach the required sample depth and attach it to the tubing on the intake side of the pump. If necessary, a small weight composed of inert material (e.g., stainless steel) which will not react with chemicals of concern may be used to weight the intake tubing. HDPE tubing of a diameter equal to the required pump tubing will suit most applications. (A heavier wall will allow for a slightly greater lateral reach.)
3. A purge volume that is at a minimum equal to the tubing volume should be passed through the system prior to sample collection. Collect this purge volume in a bucket. Once the sample has been collected, the purged water volume can be returned to the water body.

4. Fill necessary sample bottles by allowing pump discharge to flow gently down the side of bottle with smooth laminar flow and minimal entry turbulence. Cap each bottle as it is filled.
5. Preserve the sample, if necessary, following guidelines in the project-specific QAPP. In most cases, place preservatives in sample containers before sample collection to avoid overexposure of samples and overfilling of bottles during collection.
6. Secure the HDPE or polypropylene cap tightly.
7. Fill out the sample label and record all relevant information in the sample collection form, the field logbook, and/or the field laptop/tablet. In addition, the chain of custody form should be filled out as soon as possible. These procedures should be done in accordance with SOP 3-03 Recordkeeping, Sample Labeling, and Chain of Custody.
8. Immediately place the properly labeled sample bottle in a cooler with wet ice.
9. Allow the system to drain thoroughly, and then disassemble.

8.2 Transfer Devices

Samples from various locations and depths can be composited if project quality objectives indicate that it is appropriate; otherwise, collect separate samples. Identify approximate sampling points on a sketch of the water body. Use the following procedures for collecting samples using transfer devices:

1. Submerge a stainless steel dipper or other suitable device, causing minimal disturbance to the surface of the water and the sediment at the floor of the surface water body. Note the approximate depth and location of the sample source (e.g., 1 foot up from bottom or just below the surface).
2. Allow the device to fill slowly and continuously.
3. Retrieve the dipper or device from the surface water with minimal disturbance.
4. Remove the cap from the sample bottle and slightly tilt the mouth of the bottle below the dipper or device edge.
5. Empty the dipper or device slowly, allowing the sample stream to flow gently down the side of the bottle with smooth laminar flow and minimal entry turbulence.
6. Continue delivery of the sample until the bottle is filled.
7. If necessary, preserve the sample according to guidelines in the project-specific QAPP. In most cases, place preservatives in sample containers before sample collection to avoid overexposure of samples and overfilling of bottles during collection.
8. Secure the HDPE or polypropylene cap tightly.
9. Fill out the sample label and record all relevant information in the sample collection form, the field logbook, and/or the field laptop/tablet. In addition, the chain of custody form should be filled out as soon as possible. These procedures should be done in accordance with SOP 3-03 Recordkeeping, Sample Labeling, and Chain of Custody.
10. Dismantle the sampler and decontaminate according to the procedures in SOP 3-06 Equipment Decontamination.

Multipoint sampling techniques that represent both dissolved and suspended constituents and both vertical and horizontal distributions are applicable to larger bodies of water. Subsequent to sample collection, multipoint sampling techniques may require a compositing and sub-sampling process to homogenize all the individual samples into the number of subsamples required to perform the analyses of interest. Homogenizing samples is discouraged for samples collected for volatile organic analysis, because aeration causes a loss of volatile compounds. If collection of composite samples is required, then include the procedure for compositing in the project-specific work plan.

The sampling devices selected must not compromise sample integrity. Collect samples with either disposable devices, or devices constructed of a nonreactive material, such as stainless steel, polypropylene, of HDPE. The device must have adequate capacity to minimize the number of times the liquid must be disturbed, reducing agitation of any sediment layers. Further, the device must be able to transfer the water sample into the sample container without loss of volatile compounds. A single- or double-check valve or stainless-steel bailer equipped with a bottom discharging device may be utilized.

All equipment used for sample collection must be decontaminated before and after use in accordance with Procedure 3-06 – Equipment Decontamination.

9.0 Quality Control and Assurance

9.1 Field personnel will follow specific quality assurance (QA) guidelines as outlined in the project-specific QAPP. The goal of the QA program should be to ensure precision, accuracy, representativeness, completeness, and comparability in the project sampling program.

9.2 Quality Control (QC) requirements for sample collection are dependent on project-specific sampling objectives. The project-specific QAPP will provide requirements for sample preservation, holding times, container types, as well as various QC samples such as trip blanks, field blanks, equipment blanks, and field duplicates.

10.0 Data and Records Management

10.1 Field notes will be kept during sampling activities in accordance with SOP 3-03 – Recordkeeping, Sample Labeling, and Chain of Custody. During the completion of sampling activities, fill out the sample logbook and transmit forms to the TO Manager for storage in project files.

10.2 Deviations to the procedures detailed in the SOP should be recorded in the field logbook.

11.0 Attachments or References

Department of Defense, United States (DoD). 2005. *Uniform Federal Policy for Quality Assurance Project Plans, Part 1: UFP-QAPP Manual*. Final Version 1. DoD: DTIC ADA 427785, EPA-505-B-04-900A. In conjunction with the U. S. Environmental Protection Agency and the Department of Energy. Washington: Intergovernmental Data Quality Task Force. March. On-line updates available at: http://www.epa.gov/fedfac/pdf/ufp_qapp_v1_0305.pdf.

Environmental Protection Agency, United States (EPA). 1987. *A Compendium of Superfund Field Operations Methods*. EPA/540/P-87/001, EPA, Office of Emergency and Remedial Response, Washington, D.C.

Author	Reviewer	Revisions (Technical or Editorial)
Robert Shoemaker Senior Scientist	Naomi Ouellette, Project Manager	Rev 0 – Initial Issue
Ken O'Donnell, PG Geologist	Claire Mitchell, PE, PMP Senior Engineer	Rev 1 – PFAS sampling update (July 2019)

Monitoring Well Installation

Procedure 3-12

1.0 Purpose and Scope

1.1 This standard operating procedure (SOP) describes the methods to be used during the installation of groundwater monitoring wells. It describes the components of monitoring well design and installation and sets forth the rationale for use of various well installation techniques in specific situations.

1.2 As guidance for specific activities, this procedure does not obviate the need for professional judgment. Deviations from this procedure while planning or executing planned activities must be approved in accordance with Program requirements for technical planning and review.

2.0 Safety

2.1 The health and safety considerations for the work associated with this SOP, including both potential physical and chemical hazards, will be addressed in the project Accident Prevention Plan (APP)/Site Safety and Health Plan (SSHP). Additionally, work will be conducted according to the Task Order (TO) Quality Assurance Project Plan (QAPP) and/or direction from the **Site Safety and Health Officer (SSHO)**.

2.2 Before well installation commences, appropriate entities (e.g., DigSafe, local public works departments, company facilities) must be contacted to assure the anticipated well locations are marked for utilities, including electrical, telecommunications, water, sewer, and gas.

2.3 Physical Hazards Associated with Well Installation

- Stay clear of all moving equipment and avoid wearing loose fitting clothing.
- When using an approved retractable-blade knife, always cut away from oneself and make sure there are no other people in the cutting path or the retractable-blade knife.
- To avoid slip/trip/fall conditions during drilling activities, keep the area clear of excess soil cuttings and groundwater. Use textured boots/boot cover bottoms in muddy areas.
- To avoid heat/cold stress as a result of exposure to extreme temperatures and personal protective equipment (PPE), drink electrolyte replacement fluids (1 to 2 cups per hour is recommended) and, in cases of extreme cold, wear fitted insulating clothing.
- To avoid hazards associated with subsurface utilities, ensure all sampling locations have been properly surveyed as described in SOP 3-01, Utility Clearance.
- Be aware of restricted mobility caused by PPE.

3.0 Terms and Definitions

3.1 **Annulus:** The annulus is the down-hole space between the borehole wall and the well casing and screen.

3.2 **Bridge:** A bridge is an obstruction in the drill hole or annulus. A bridge is usually formed by caving of the wall of the well bore, by the intrusion of a large boulder, or by the placement of filter pack materials during well completion. Bridging can also occur in the formation during well development.

3.3 **Filter Pack:** Filter pack is sand or gravel that is smooth, uniform, clean, well-rounded, and siliceous. It is placed in the annulus of the well between the borehole wall and the well screen to prevent formation materials from entering the well and to stabilize the adjacent formation.

3.4 **Grout:** Grout is a fluid mixture of cement and water that can be forced through a tremie pipe and emplaced in the annular space between the borehole and casing to form an impermeable seal. Various additives, such as sand, bentonite, and polymers, may be included in the mixture to meet certain requirements.

3.5 **Heaving (Running) Sands:** Loose sands in a confined water-bearing zone or aquifer which tend to rise up into the drill stem when the confining unit is breached by the drill bit. Heaving sands occur when the water in the aquifer has a pressure head great enough to cause upward flow into the drill stem with enough velocity to overcome the weight of the sand.

3.6 **Sieve Analysis:** Sieve analysis is the evaluation of the particle-size distribution of a soil, sediment, or rock by measuring the percentage of the particles that will pass through standard sieves of various sizes.

4.0 Interferences

4.1 Heaving sands may be problematic in unconsolidated sands encountered below the water table.

4.2 Rotary drilling methods requiring bentonite-based drilling fluids should be used with caution to drill boreholes that will be used for monitoring well installation. The bentonite mud builds up on the borehole walls as a filter cake and permeates the adjacent formation, potentially reducing the permeability of the material adjacent to the well screen.

4.3 Drill rigs and accessory equipment (e.g., compressors, decontamination units, drill rods, plastic sleeving, etc.) should be evaluated and all PFAS-bearing parts or materials (e.g., O-rings, Teflon tape, etc.) replaced with confirmed PFAS-free parts. Special attention should be placed on evaluation of lubricants or greases used for the equipment.

4.4 If water or other drilling fluids have been introduced into the boring during drilling or well installation, samples of these fluids should be obtained and analyzed for chemical constituents that may be of interest at the site. In addition, an attempt should be made to recover the quantity of fluid or water that was introduced, either by flushing the borehole prior to well installation and/or by overpumping the well during development.

4.5 Track-mounted drill rigs are suitable for travelling on many types of landscapes that truck-mounted units cannot access, but may have limitations on extremely uneven or soft terrain.

4.6 Care should be taken to prevent cross-contamination between well locations. All drilling equipment coming in contact with potentially contaminated soil and/or groundwater will be decontaminated by the drilling subcontractor prior to initial drilling activities and between drilling locations in accordance with SOP 3-06, Equipment Decontamination.

5.0 Training and Qualifications

5.1 Qualifications and Training

The individual executing these procedures must have read, and be familiar with, the requirements of this SOP.

5.2 Responsibilities

5.2.1 **TO Managers** are responsible for issuing a Quality Assurance Project Plan (QAPP) that reflects the procedures and specifications presented in this procedure. Individual municipalities, county agencies, and possibly state regulatory agencies enforce regulations that may include well construction and installation requirements. The **TO Manager** shall be familiar with current local and state regulations, and ensure that these regulations are followed. The **TO Manager** is responsible for ensuring that all personnel involved in monitoring well installation shall have the appropriate education, experience, and training to perform their assigned tasks.

5.2.2 The **Program Quality Manager** is responsible for ensuring overall compliance with this procedure.

5.2.3 The **Site Supervisor (SS)** is responsible for direct supervision of the installation of monitoring wells and ensuring that procedures and specifications are implemented in the field in accordance with the approved QAPP and well installation permits. The qualifications for the **SS** must be in accordance with local jurisdictions with authority over the operations conducted.

5.2.4 All field personnel are responsible for the implementation of this procedure.

5.2.5 The on-site hydrogeologist/engineer is expected to obtain a description of the lithologic samples obtained during the excavation and construction of a monitoring well. These data are often required to provide guidance regarding the installation of specific components of the monitoring well. Guidance for lithologic sample collection and sample description is contained within SOP 3-16, Soil and Rock Classification.

6.0 Equipment and Supplies

6.1 Materials provided by the drilling contractor may include:

- Confirmed PFAS-free Drill rig, drill rods, hollow stem augers, etc.
- PFAS-free lubricants and greases
- Decontamination equipment (e.g., steam cleaner, high-pressure washer, brushes, etc.)
- Decontamination pad materials
- Well screen/riser pipe with flush-threaded couplings including riser and bottom caps
- Clean, filter sand
- Bentonite chips or pellets
- Cement grout and tremie pipe
- Portland cement for well pad completion
- Stainless steel protective riser covers and locking caps
- Weighted calibrated tape
- Split-spoon samplers
- 55-gallon drums or containers for drill cuttings, decontamination fluids, etc.

6.2 In addition to those materials provided by the drilling contractor, equipment and materials required by the project geologist/engineer may include, but is not limited to, the following:

- Photoionization Detector (PID)
- Spill kit, including at a minimum sorbent pads and shovel (if not provided by subcontractor)
- Polyethylene plastic sheeting
- Teaspoon or spatula
- Resealable polyethylene (e.g., Ziploc brand) plastic bags
- Boring Log Records
- Decontamination materials (per SOP No. 3-06 - Equipment Decontamination)
- Weighted Teflon-free measuring tape for depth measurement

- Soil logging materials (e.g. United Soil Classification System classification field card, millimeter rule, hand lens, etc.)
- Survey lathes or pin flags
- Digital camera
- PPE as required by the APP/SSHP and QAPP
- Planning documents including the site-specific APP/SSHP and QAPP
- Large indelible ink or paint pen
- Field logbook/field forms/site maps (non-water-repellent)

7.0 Procedure

7.1 General Procedures

- Specific drilling, sampling, and installation equipment and methodology will be dictated by the type of well to be installed (e.g., single case [Type II], double case [Type III], bedrock, etc.), geologic characteristics of the site, the type of contaminants being monitored, and local and state regulations.
- For access to locations when travelling over difficult terrain, an appropriate line should be chosen before mobilizing the drill rig or other support vehicles. If clearing of trees or ground cover is required, perform these activities in advance to avoid down time. Avoid wet or soft areas where possible or use ground mats and/or timbers to aid in supporting the rig as it travels. If drilling on soft material, place geomatting and ground mats under the rig tracks or stabilizers prior to drilling.
- A utility locate must be conducted to identify all underground utilities at the site prior to drilling (refer to SOP 3-01, Utility Clearance*)*. Proper clearance procedures for aboveground/overhead utilities must also be followed as specified in the APP/SSHP.
- Although new well materials (well screen and riser pipe) generally arrive at the site boxed and sealed within plastic bags, it is sometimes necessary to decontaminate the materials prior to their use. Well materials should be inspected by the project geologist/engineer upon delivery to check for cleanliness. If the well materials appear dirty, or if local or regional regulatory guidance requires decontamination, then well material decontamination should be performed by the drilling subcontractor in accordance with SOP 3-06, Equipment Decontamination.
- The diameter of the borehole must be a minimum of 2 inches greater than the outside diameter of the well screen or riser pipe used to construct the well. This is necessary so that sufficient annular space is available to install filter packs, bentonite seals, and grout seals, and allow the passage of tremie pipe where grouting at depth is required. Bedrock wells may require reaming after coring in order to provide a large enough borehole diameter for well installation.
- When soil sampling is required (refer to the QAPP), soil samples will be collected for visual logging by advancing split-spoon samplers through the augers. The soil will be visually logged by a field geologist and include lithologic characteristics (i.e., soil type, color, density, moisture content, etc.) using the methods described in SOP 3-16, Soil and Rock Classification. This information will be recorded on a boring/well log form, along with well construction details.

7.2 Drilling Techniques

Drilling of monitoring well boreholes may be accomplished by a variety of methods as described below. Preferred methods include those that temporarily case the borehole during drilling (i.e., hollow stem auger and sonic methods) using an override system. Drill rig components, drilling fluids, and consumable equipment will be evaluated for PFAS prior to the start of drilling activities, with special

NOTE: SOPs have been updated for PFAS sampling activities; however, AECOM's internal PFAS sampling guidance supersedes materials and methods described in SOPs.

attention placed on evaluating any lubricants and greases used during drilling. Other methods can be used where specific subsurface conditions or well design criteria dictate.

- Hollow stem auger (HSA) – Borings are advanced by rotating steel hollow stem augers with an attached cutting head. Soil cuttings are displaced by the cutting head and transported to the surface via continuous spiral flights attached to each auger stem. This method is widely used for unconsolidated soils that have a tendency to collapse within the boring. A bottom plug can be placed in the bottom auger to prevent soils from entering and clogging the auger, especially in the case of heaving sands. However, a bottom plug cannot be used when soil samples are to be collected through the augers. Soil plugs that accumulate in the bottom of the auger must be removed or knocked out prior to sampling or well installation.
- Solid stem auger – This type of drilling method is similar to HSA drilling using a solid stem or sealed hollow stem auger flights to advance the boring. Solid stem, continuous flight auger use is limited to semi-consolidated sediments or to cohesive or semi-cohesive unconsolidated sediments that don't have a tendency to collapse when disturbed.
- Sonic methods – Sonic drilling consists of advancing concentric hollow drill casings (inner and outer) using rotation in conjunction with axial vibration of the drill casing. Once the casings are advanced to the appropriate depth, the inner string is removed with a core of drill cuttings while the outer casing remains in place to keep the borehole open. Cuttings are removed from the inner casing relatively intact for logging or sampling purposes. This drilling method is used for a variety of soil types, from heaving sands to consolidated or indurated formations. Smearing of the formation along the borehole walls is minimal since moderate vibration and rotation techniques are used to advance the casings. Since the total borehole diameter in sonic drilling is only incrementally larger than the inner casing diameter, care should be taken during installation of the monitoring well to ensure the well is centered and adequate space is available for annular materials.
- Rotary methods (water or mud) – Rotary drilling methods consist of drill rods coupled to a drill bit that rotates and cuts through the soils to advance the borehole. Water or drilling fluid ("mud") is forced through the hollow drill rods and drill bit as the rods are rotated. The soil cuttings are forced up the borehole with the drilling fluids to the surface and the fluids recirculated. The drilling fluid provides a hydrostatic pressure that reduces or prevents the borehole from collapsing. Clean, potable, PFAS-free water must be used for water-rotary drilling to prevent introducing trace contaminants. A sample of the potable water should be collected during the course of well installation for analysis of the same parameters defined for the groundwater samples. If mud-rotary is used to advance boreholes, only potable, PFAS-free water and bentonite drilling mud should be used. No chemical additives shall be mixed in the drilling fluid to alter viscosity or lubricating properties. Adequate well development is essential for removal of drilling mud and fluids from the formation materials and ensure collection of representative groundwater samples.
- Rotary methods (Air) – Air rotary methods are similar to water rotary but use high air velocities in place of drilling fluids to rotate the drill bit and carry the soil cuttings up the borehole to the surface. Care must be taken to ensure that contaminants are not introduced into the air stream from compressor oils, etc. Most compressor systems are compatible with a coalescing filter system. Cuttings exiting the borehole under pressure must be controlled, especially when drilling in a zone of potential contamination. This can be accomplished by using an air diverter with hose or pipe to carry the cuttings to a waste container. Letting the cuttings blow uncontrolled from the borehole is not acceptable.

7.3 Well Construction and Installation

- If rotary drilling techniques are used, the borehole should be flushed or blown free of material prior to well installation. If hollow stem augers are used, the soil or bottom plug should be removed and the augers raised approximately six inches above the bottom of the borehole, while slowly rotating the augers to remove cuttings from the bottom of the boring. The depth of the borehole should be confirmed with a weighted, calibrated tape.

- The riser pipe and screen should be connected with flush-threaded joints and assembled wearing clean, disposable gloves. No solvent or anti-seize compound should be used on the connections. The full length of the slotted portion of the well screen and unslotted riser pipe should be measured and these measurements recorded on a well construction form (Attachment 1).
- If placed in an open borehole, the assembled well should be carefully lowered and centered in the borehole so that the well is true, straight, and vertical throughout. Centering can also be accomplished with the use of centralizers, if necessary. However, centralizers should be placed so that they do not inhibit the installation of filter sand, bentonite seal, and annular grout. Wells less than 50 deep generally do not require centralizers.
- If hollow stem augers are used, the well should be lowered through the augers and each auger flight removed incrementally as the filter sand, bentonite seal, and grout are tremied or poured into the annular space of the well. The well should be temporarily capped before filter sand and other annular materials are installed.
- Clean, silica sand should be placed around the well screen to at least 1 foot above the top of the screen. The filter sand should be appropriately graded and compatible with the selected screen size and surrounding formation materials. In general, the filter pack should not extend more than 3 feet above the top of the screen to limit the thickness of the monitoring zone. As the filter pack is placed, a weighted tape should be lowered in the annular space to verify the depth to the top of the layer. This measurement will be recorded on the well construction form (Attachment 1). If necessary, to eliminate possible bridging or creation of voids, placement of the sand pack may require the use of a tremie pipe. Tremie pipe sandpack installations are generally suggested for deeper wells and for wells which are screened some distance beneath the water table.
- A minimum 2-foot thick layer of bentonite pellets or slurry seal will be installed immediately above the filter sand to prevent vertical flow within the boring from affecting the screened interval. Bentonite chips/pellets must be hydrated if place above the water table prior to grouting. If bridging is of concern as in the case of deep wells, powdered bentonite may be mixed with water into a very thick slurry and a tremie pipe used to place the seal to the desired depth. Placement of the bentonite seal in the borehole will be recorded on the well construction form (Attachment 1).
- The remaining annular space around the well will be grouted from the top of the bentonite seal to the surface with a grout composed of neat cement, a bentonite cement mixture, or high solids sodium bentonite grout.
- Each well riser will be secured with an expandable, locking cap (vented if possible). Optionally, a hole can be drilled in the upper portion of the riser to allow venting of the well.
- The well will be completed within a concrete well pad consisting of a Portland cement/sand mixture. Well pads are generally 3 feet by 3 feet square but may be larger or smaller depending on site conditions and state-specific well construction standards. Round concrete well pads are also acceptable. A minimum of 1 inch of the finished pad should be below grade to prevent washing and undermining by soil erosion.
- If completed as a flush-mount well, the well riser will be cut off approximately 4 to 6 inches below ground surface and an expandable, locking cap placed on the well riser. The area around the riser is dug out and a steel well vault or manhole cover placed over the riser and set almost flush to the ground to protect the well. The manhole cover should be water-tight and secured with bolts to prevent casual access. The well pad will then be constructed around the well vault and slightly mounded at the center and sloping away to prevent surface water from accumulating in the well vault.
- If completed as a stick-up well, the well riser is cut approximately 2.5 to 3 feet above the ground surface and an expandable, locking cap placed on the well riser. A steel guard pipe with hinged, locking cap is placed over the well riser as a protective casing. The bottom of the guard pipe will be set approximately 2 feet below ground surface and sealed by pouring concrete from the top of the annular grout around

the pipe to grade. The concrete well pad should be completed at the same time. Weep holes will be drilled in the base of the guard pipe to facilitate draining of rainwater or purge water from inside the guard pipe.

- Bumper posts or bollards may be necessary for additional well protection, especially in high traffic areas. The bumper posts should be placed around the well pad in a configuration that provides maximum protection to the well and extend a minimum of 3 feet above the ground.

7.4 Double Cased Wells

Under certain site conditions, the use of a double-cased or telescoping (Type III) well may be necessary. Installation of double-cased wells may be required to prevent the interconnection of two separate aquifers, seal off a perched aquifer without creating a vertical hydraulic conduit, prevent cross-contamination during construction of wells in deeper aquifers hydro-stratigraphically below impacted aquifers, or case off highly impacted soils present above the aquifer to prevent potential “dragging down” of contaminants.

Similar to conventional wells, construction of double-cased wells can be accomplished using a variety of drilling methods. Well construction is initiated by “keying” a large diameter, outer casing into a stratigraphic zone of low permeability (clay layer or bedrock). The size of the outer casing should be a minimum of 2 inches greater than the outside diameter of the inner casing to allow installation of annular seal materials during well completion. A pilot borehole should be drilled through the overburden soil and/or contaminated zone into a clay confining layer or bedrock. The borehole for the outer casing should be of sufficient size to contain the outer casing with a minimum of 2 inches around the outside diameter to allow sufficient annular space for tremie or pressure grouting. The boring should extend a minimum of 2 feet into a clay layer and a minimum of 1 foot into bedrock, if possible, to ensure an adequate seal. The boring should never breach a confining layer or keyed zone under any circumstances.

Once the boring is completed, the outer casing can be set in the borehole and sealed with grout. The outer casing can be set two ways, with or without a bottom cap. If no bottom cap is applied, the casing is usually driven approximately 6 inches into the clay confining unit. A grout plug is generally placed in the bottom of the casing and once set, standing water in the casing is evacuated prior to drilling below the casing. As an alternative, a cap can be placed on the bottom of the casing and if set below the water table, the casing can be filled with clean, potable water to hold down the casing in the boring. Grouting should be conducted using tremie-grouting or pressure-grouting methods by pumping grout into the annular space between the outer casing and the borehole wall from the bottom of the casing to the ground surface. Grout around the casing should be allowed to cure at least 24 hours before attempting to drill through the bottom.

Once the grout is cured, a smaller diameter drill pipe/bit is used to bore through the grout plug or bottom cap to the desired well depth. The well is then constructed as described in Section 7.3 above.

7.5 Post Installation Procedures

- Wells should be permanently labelled or marked for identification. Well tags can be used to record the site name, well number, total depth, installation date, etc. At a minimum, the well number will be written in paint on both the outside of the protective casing and inside beneath the casing lid, as well as on the riser pipe.
- A measuring point will be marked on the top of the riser pipe for taking water level measurements. The measuring point can be notched using a knife or saw. The measuring point will also be the point which will be surveyed for vertical elevation data.
- Upon completion, the following measurements will be taken by the field geologist/engineer and recorded on the well construction diagram.
    - Depth to static water level
    - Depth of non-aqueous phase liquid (NAPL), if present
    - Total depth of well measured from top of casing (TOC)

    - Height of well casing above ground surface
    - Height of protective casing above ground surface
- All monitoring wells will be surveyed for horizontal and vertical control by a licensed surveyor.
- Investigation-derived waste (IDW) including drill cuttings, spent materials (e.g., PPE), and decontamination water should be properly managed in accordance with SOP 3-05, IDW Management.

8.0 Quality Control and Assurance

8.1 Field personnel will follow specific quality assurance (QA) guidelines as outlined in the QAPP. Certain quality control (QC) measures should be taken to ensure proper well installation and construction in accordance with this SOP, project specific QAPP, and applicable well standards.

8.2 The borehole will be checked for total open depth, and extended by further drilling or shortened by backfilling, as required before installation of the well materials.

8.3 Water level and NAPL presence will be checked during well installation to ensure that the positions of well screen, filter sand, and seals relative to water level conform to project requirements

8.4 The depth to top of each layer of annular materials (i.e., filter sand, bentonite, grout) will be verified and adjusted as necessary for proper placement.

9.0 Records, Data Analysis, Calculations

All field information will be recorded in the field logbook and/or standardized field forms by field personnel. Field data recorded will include drilling contractor information, drilling methods, well material and construction information provided on the boring logs and well construction forms, observations or problems encountered during drilling, fluid level data, and any deviations from the procedures in this SOP and other project plans. Well Construction Forms (Attachment 1) will provide visual and descriptive information the monitoring well and are often the most critical form of documentation generated during the installation of a monitoring well. The field logbook is kept as a general log of activities and should not be used in place of the boring log.

10.0 Attachments or References

10.1 Attachment 1 – Monitoring Well Construction Form

10.2 Environmental Protection Agency, United States (EPA). 1987. *A Compendium of Superfund Field Operations Methods*. Office of Solid Waste and Emergency Response. EPA/540/P-87/001.

10.3 EPA. 1990. *Handbook of Suggested Practices for the Design and Installation of Groundwater Monitoring Wells*. EPA/600/4-89/034. Office of Research and Development, Washington. March.

10.4 EPA. 1992. *RCRA Groundwater Monitoring Draft Technical Guidance*. EPA/530/R-93/001. Office of Solid Waste. November.

10.5 EPA, 2008. SESD Operating Procedure SESDGUID-101-R0: *Design and Installation of Monitoring Wells*. USEPA, Science and Ecosystem Support Division (SESD), Athens, Georgia. Effective Date February 18, 2008.

10.6 U.S. Army Corps of Engineers. 2008. Manual No. EM 385-1-1. *Safety and Health Requirements*. 15 November 2008. http://140.194.76.129/publications/eng-manuals/em385-1-1/2008_English/toc.html.

10.7 SOP 3-01, *Utility Clearance*.

10.8 SOP 3-05, *IDW Management*

10.9 SOP 3-06, *Equipment Decontamination*.

10.10 SOP 3-16, *Soil and Rock Classification.*

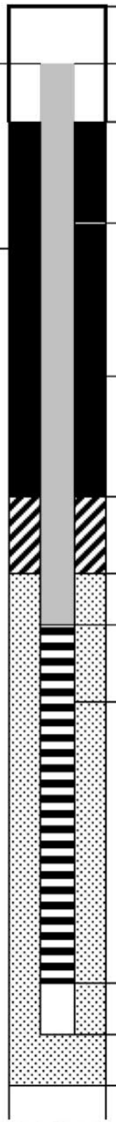
Author	***Reviewer***	***Revisions (Technical or Editorial)***
Mark Kromis Program Chemist	Chris Barr Program Quality Manager	Rev 0 – Initial Issue (May 2012)
Ken O'Donnell, PG Geologist	Claire Mitchell, PE, PMP Senior Engineer	Rev 1 – PFAS sampling update (July 2019)

NOTE: SOPs have been updated for PFAS sampling activities; however, AECOM's internal PFAS sampling guidance supersedes materials and methods described in SOPs.

Attachment 1
Monitoring Well Construction Form

	Client:	***WELL ID:***
	Project Number:	
	Site Location:	*Date installed:*
	Well Location: *Coords:*	*Inspector:*
	Method:	*Contractor:*

MONITORING WELL CONSTRUCTION DETAIL



_____ % Cement

_____ % Bentonite

_____ % Native Materials

	Depth from G.S. (feet)	Elevation(feet) Datum _________
Top of Steel Guard Pipe		
Top of Riser Pipe		
Ground Surface (G.S.)	0.0	
Top of Bentonite		
Top of Sand		
Top of Screen		
▼ Stabilized Water Level		
Bottom of Screen		
Bottom of Tail Pipe:		
Bottom of Borehole		

Riser Pipe:
Length _________
Inside Diameter (ID) _________
Type of Material _________

Bottom of Steel Guard Pipe

Bentonite Seal Thickness _____________

Screen:
Length _________
Inside Diameter (ID) _________
Slot Size _________
Type of Material _________

Type/Size of sand _________
Sand Pack Thickness _________

Bottom of Tail Pipe:
Length _________

Borehole Diameter _____

Approved:

Signature _______________ Date _______________

Describe Measuring Point:

____

Monitoring Well Development

Procedure 3-13

1.0 Purpose and Scope

1.1 This standard operating procedure (SOP) describes the procedures used for developing newly installed monitoring wells and/or redeveloping existing wells.

1.2 The purpose of well development is to remove interferences from a well to provide better connection between the well and the formation, to improve pumping performance of the well, and to be able to collect more representative information from the well (e.g., samples, test results, etc.). Proper well development will:

- Remove drilling residuals (e.g., water, mud) from the borehole and surrounding formations;
- Improve or restore hydraulic conductivity of the surrounding formations which may have been disturbed during the drilling process;
- Remove residual fines from the well screen and sand pack (filter pack) materials, thus reducing turbidity of groundwater and permitting the collection of more representative groundwater samples.

1.3 There may be circumstances where well development is not desirable, for example, in the presence of non-aqueous phase liquids (NAPL) or other significant contamination if development could worsen the contaminant impact. If NAPL begins to intrude during development, the development process will be halted. This situation will be considered a cause for sample modification requiring approval by the Task Order (TO) Manager and other stakeholders, as applicable.

1.4 The applicable well development procedures for a particular site may be subject to State or local regulatory requirements. In all cases, the project team should consult their local regulatory requirements and document the selected well development procedure in the project-specific Quality Assurance Project Plan (QAPP). For project-specific information refer to the QAPP, which takes precedence over these procedures.

1.5 This procedure is the Program-approved professional guidance for work performed by AECOM under the client contract.

1.6 As guidance for specific activities, this procedure does not obviate the need for professional judgment. Deviations from this procedure while planning or executing planned activities must be approved in accordance with Program requirements for technical planning and review.

2.0 Safety

2.1 The health and safety considerations for the work associated with this SOP, including both potential physical and chemical hazards, will be addressed in the project Accident Prevention Plan (APP)/Site Safety and Health Plan (SSHP). Work will be conducted according to the TO QAPP and/or direction from the Site Safety and Health Officer (SSHO).

2.2 Monitoring well development may involve chemical hazards associated with potential contaminants in the soil or aquifer being characterized and may involve physical hazards associated with use of well development equipment.

3.0 Terms and Definitions

None.

4.0 Interferences

4.1 Equipment/materials used for development may react with the groundwater during development. Appropriate development equipment has been selected for the anticipated condition of the groundwater.

4.2 Appropriate development methods such as using a surge-block to flush suspended fines in the groundwater in and out of the well screen can improve the yield of wells and improve their potential to be developed successfully. However, the effectiveness of development can be significantly reduced in wells that do not yield sufficient water to allow this flushing to take place.

4.3 For formations with a significant content of fine-grained materials (silts and clays), or wells with improperly sized screens, it may not be possible to reduce turbidity to commonly acceptable levels. Possible solutions may include collecting a sample even if excessively turbid, or installing a replacement well.

4.4 Development itself disturbs the surrounding formation and disrupts equilibrium conditions within the well. Groundwater samples will not be collected until a minimum of 24 hours after a well is developed to allow conditions to stabilize. For sites with fine-grained formations (silts and clays) and highly sorptive contamination, a longer time period between development and sampling should be considered.

5.0 Training and Qualifications

5.1 Qualifications and Training

The individual executing these procedures must have read, and be familiar with, the requirements of this SOP.

5.2 Responsibilities

5.2.1 The **TO Manager** is responsible for ensuring that well development activities comply with this procedure. The **TO Manager** is responsible for ensuring that all personnel involved in well development shall have the appropriate education, experience, and training to perform their assigned tasks.

5.2.2 The **Program Quality Manager** is responsible for ensuring overall compliance with this procedure.

5.2.3 The **Site Supervisor (SS)** is responsible for ensuring that all well development activities are conducted according to the either this procedure or the applicable procedure presented in the project-specific QAPP.

5.2.4 **Field sampling personnel** are responsible for the implementation of this procedure.

5.2.5 The field sampler and/or task manager is responsible for directly supervising the well development procedures to ensure that they are conducted according to this procedure and for recording all pertinent data collected during sampling.

6.0 Equipment and Supplies

6.1 This equipment list was developed to aid in field organization and should be used in planning and preparation. Depending on the site-specific requirements and the development method selected, additional or alternative material and equipment may be necessary. In addition, for sites where groundwater is expected to be contaminated, the materials to be placed down the well and in contact with groundwater should be evaluated so that they are compatible with the chemical conditions expected in the well.

6.2 Equipment and materials used for well development may include, but is not limited to:

Well development equipment

- Surge block
- Disposable HDPE bailers, appropriate to the diameter of the well(s): 1-inch to 1.5-inch for 2-inch inside diameter (ID) monitoring wells.
- Watterra® footvalve
- PFAS-free (e.g., Teflon-free) electric submersible pump
- 12-volt power source for electric pump
- High density polyethylene (HDPE) tubing appropriately sized for Watterra® footvalve and/or electric submersible pump
- Drums or containers for storage of purge water
- Nephelometer to measure turbidity
- Multi-parameter water quality meter(s) to measure temperature, potential of hydrogen (pH), conductivity, dissolved oxygen (DO), and oxidation reduction potential (ORP)
- Instrument calibration solutions
- Teflon-free water level meter
- Oil/water interface probe

General equipment

- Project-specific plans including the site-specific APP/SSHP and QAPP
- Non-water-repellent field notebook/field forms/site maps
- Ball point pens or fine-point indelible marker
- 5-gallon HDPE or polypropylene buckets

Equipment decontamination supplies (refer to SOP 3-06, Equipment Decontamination)

- Health and safety supplies, including personal protective equipment (PPE) as specified by the APP/SSHP
- Appropriate hand tools
- Keys or combinations to access monitoring wells
- PFAS-free deionized water supply
- Disposable bailer string (polypropylene)
- Plastic trash bags

7.0 Procedure

Development generally consists of removing water and entrained sediment from the well until the water is clear (to the extent feasible) and the turbidity is reduced, which indicates the well is in good hydraulic connection with the surrounding formation. In addition to simply removing water, development can be improved when flushing through the well screen and gravel pack takes place in both directions, that is, both into the well and into the formation. This action breaks down sediment bridges that can occur in the formation or sand pack, which reduce the connection between the well and the formation

7.1 General Preparation

- All down-well equipment should be decontaminated prior to use and between well locations in accordance with SOP 3-06, Equipment Decontamination
- Although equipment is decontaminated between well locations, if wells are known or suspected to be contaminated based on observations during well installation, it is recommended that well

development be conducted in order from the least contaminated to the most contaminated well to minimize the chances of cross-contamination.

- Management of investigation-derived waste (IDW), including development purge water and miscellaneous expendable materials generated during the development process, will be conducted in accordance with SOP 3-05, IDW Management.
- Prior to accessing the well, the wellhead should be cleared of debris and/or standing water. Nothing from the ground surface should be allowed to enter the well.
- The depth to water and total well depth should be measured with a Teflon-free water level meter and recorded in the field logbook or on a Well Development Record (Attachment 1). This information will be used to calculate the volume of standing water (i.e., the well volume) within the well, and plan the specific details of the well development. If wells are suspected to contain NAPL, an oil/water interface probe should be used to measure liquid levels and depth to bottom of the well.
- Permanent monitoring wells will be developed no sooner than 24 hours after well installation is completed in order to allow well completion materials to set properly.

7.2 Monitoring Well Development Procedures

Generally, development will begin by gently surging the well with a surge block or bailer as described in Sections 7.2.1 and 7.2.2, respectively. Surging can become more vigorous as development progresses but initially the well must be gently surged to allow material blocking the screen to become suspended without damaging the well. Next, a bailer can be used to remove the sediment settled at the base of the well. A bailer, Watterra® pump, or electric submersible pump will then be used to purge the well, per Sections 7.2.2, 7.2.3, or 7.2.4, respectively. The well will be purged until the removed water becomes less turbid or per the requirements of the project-specific QAPP, or State or local requirements. At this point the well will be surged again with a surge block or bailer. The well can be surged more vigorously at this point. After surging, the well will be purged again until the turbidity once again decreases. The surge/purge cycle should be completed at least three times during the development process. After the last surge, the well will be purged until the development completion criteria outlined in 7.3.2 or per the project-specific QAPP are met.

7.2.1 Surge Block

The default method of well development is the use of a surge block in conjunction with pumping or bailing to remove sediment-laden water.

- The construction of the surge block must be appropriate for the diameter of the well. The surge block must be mounted on rods or other stiff materials to extend it to the appropriate depths and to allow for the surge block to be moved up and down in the well.
- Insert the surge block into the well and lower it slowly to the screened or open interval below the static water level. Start the surge action by slowly and gently moving the surge block up and down in the well. A slow initial surging, using plunger strokes of approximately 1 meter or 3 feet, will allow material which is blocking the screen to separate and become suspended.
- After 5 to 10 plunger strokes, remove water from the well using a separate bailer (Section 7.2.2) or pumping techniques (Sections 7.2.3 or 7.2.4). The returned water should be heavily laden with suspended fines. The water will be discharged to 5-gallon buckets or 55-gallon drums to be managed per the requirements presented in the project-specific QAPP.
- In some cases, the bailer or Watterra® foot valve can act as a surge block, flushing water in and out of the well screen as groundwater is removed.
- Repeat the process of surging and pumping/bailing. As development continues, slowly increase the depth of surging to the bottom of the well screen. Surging within the riser portion of the well is neither necessary nor effective.

7.2.2 Bailer

- Tie a string or other cable securely to the bailer. Lower it to the screened or open interval of the monitoring well below the static water level.
- The bailer may be raised and lowered repeatedly within the screened interval to attempt to simulate the action of a surge block by pulling fines through the well screen and pushing water out into the formation to break down bridging.
- With the bailer full of water, remove it from the well and discharge the water into 5-gallon buckets or 55-gallon drums to be managed per the requirements presented in the project-specific QAPP.
- The Watterra® system (Section 7.2.3) or electric submersible pump (Section 7.2.4) may be used as a complementary development method to the bailer, especially when removal of additional water at a faster rate is beneficial.
- Continue alternately surging and bailing, monitoring the purge water periodically (Section 7.3.1) until development completion criteria are met (Section 7.3.2).

7.2.3 Watterra® system

- Attach high-density polyethylene (HDPE) tubing to the decontaminated Watterra® pump foot valve
- Lower the foot valve and tubing assembly near the bottom of the well.
- Lift and lower the tubing to allow water to enter the Watterra® foot valve and travel up the tubing and discharge the water into 5-gallon buckets or 55-gallon drums to be managed per the requirements presented in the project-specific QAPP.
- The lifting and lowering action of the Watterra® system will cause some surging action to aid in breaking up fine material in the surrounding formation.
- A bailer (Section 7.2.2) may be used as a complementary development method to the Watterra® system, especially during the initial stages of development when a high volume of sediment may be required to be removed.
- An electric submersible pump (Section 7.2.4) may also be used as a complementary development method to the Watterra® system, especially when more volume of water is desired to be pumped or the turbidity criteria cannot be met due to the surging action of the Watterra® system.
- Continue alternately surging and pumping, monitoring the purge water periodically (Section 7.3.1) until well development completion criteria are met (Section 7.3.2).

7.2.4 Electric Submersible Pump

- Attach HDPE tubing to the decontaminated electric submersible pump.
- Lower the pump and tubing assembly near the bottom of the well, at least a few inches above the well total depth.
- Begin pumping, discharging the water into 5-gallon buckets or 55-gallon drums to be managed per the requirements presented in the project-specific QAPP.
- Continue alternately surging and pumping, monitoring the purge water discharge periodically (Section 7.3.1) until well development completion criteria are met (Section 7.3.2).

7.3 Discharge Monitoring

7.3.1 Monitoring the Progress of Development

The progress of the development is evaluated through visual observation of the suspended sediment load and measurement of the turbidity and other parameters in the purged discharge water. As development progresses, the water should become clearer, measured turbidity should decrease, and specific capacity (pumping rate divided by drawdown) should stabilize. Water quality parameters, including DO, conductivity, ORP, pH, temperature, and turbidity may be measured and recorded periodically to determine the progress of development using the criteria outlined in Section 7.3.2 or per the project-specific QAPP. Water quality parameters should be measured on each well volume removed.

7.3.2 Completion of Development

The well will be considered developed when the following criteria are met or per the criteria set forth in the project-specific QAPP:

- A minimum of three times the standing water volume in a well (to include the well screen and casing plus saturated annulus, assuming 30 percent porosity) is removed.
- Groundwater parameters for three consecutive standing water volumes are within the following:
  - pH – within ± 0.2 units
  - Specific conductivity – within ± 3%
  - ORP – within ± 10 mV
  - Temperature – within ±1 degree Celsius
  - Turbidity – at or below 10 nephelometric turbidity units (NTU) or within ± 10% if above 10 NTU.
- The sediment thickness remaining within the well is less than 1 percent of the screen length or less than 30 millimeters (0.1 ft) for screens equal to or less than 10 feet long.

Dissolved oxygen (DO) readings may be recorded but DO readings will not be used as development completion criteria because DO may not stabilize.

If the well has slow groundwater recharge and is purged dry, the well will be considered developed when bailed or pumped dry three times in succession and the turbidity has decreased, or per the requirements set forth in the project-specific QAPP. Water quality parameters may be recorded if feasible using the flow-through cell.

If any water is added to the well's borehole during development or drilling, three times the volume of water added will also be removed during well development, or per the requirements set forth in the project-specific QAPP.

7.4 Development of Wells with Low Yield

Water is the primary mechanism to remove fines and flush water through the gravel pack for effective development. Therefore, development can be a challenge in wells that do not yield sufficient water to recharge when water is removed. However, often these wells are the most in need of development to improve their performance as they are typically installed in low permeability formations with a high content of fines. Development of these wells can improve their yield.

The surging portion of the development can be successfully performed in a well with standing water regardless of its yield. It is the subsequent removal of fine materials that is hindered when insufficient water is recharged to the well. When wells go dry or drawdown significantly during development, development can be performed intermittently, allowing sufficient water to recharge prior conducting the next stage of surging. These intermittent procedures can take place hours or even days apart, depending on project-specific time constraints.

7.5 Wells containing NAPL

Additional care should be taken when planning development of wells that contain NAPL. If the NAPL is flammable, there are health and safety as well as handling issues to consider. If NAPL in excess of a persistent sheen is noted, the recharge rate will be evaluated through hand bailing. In most cases, it is generally preferable to remove NAPL by bailing to the extent practical prior to performing development. Groundwater parameters, excluding turbidity, will not be collected during well development if NAPL or excessive sheen is noticed in the purged water during development to ensure the meter probes are not fouled or destroyed. Well development will be halted.

Development by surging or pumping the well dry can result in the spreading of NAPL vertically in the soil column around the well. These methods can be used, if information exists describing the vertical thickness of the NAPL smear zone around the well, and if the methods do not result in mounding or drawdown that exceeds this thickness. Alternate methods such as bailing may also be used, but any method should not allow the well to be pumped dry or result in significant drawdown that would spread the NAPL vertically.

7.6 Temporary Well Points

For certain projects, temporary well points (TWPs) may be installed to collect groundwater samples at a site. Since no sand pack, bentonite chips, or bentonite grout are generally used in the construction of the TWPs, development can proceed as soon as sufficient water has entered the well to static conditions. Due to the small diameter of these wells, generally ¾-inch to 1-inch ID, development will be performed using either a small diameter (0.5-inch) bailer and/or a peristaltic pump with HDPE tubing. The TWPs will have minimal water column and may purge dry during development. However, attempts will be made to remove fines from the well prior to sampling. Purging and sampling may occur as soon as approximately 80% of the static water has re-entered the TWP, or per the requirements set forth in the project-specific QAPP.

8.0 Quality Control and Assurance

8.1 Field personnel will follow specific quality assurance (QA) guidelines as outlined in the project-specific QAPP.

8.2 Quality control (QC) requirements are dependent on project-specific sampling objectives. The project-specific QAPP will provide requirements for equipment decontamination (frequency and materials) and IDW handling.

9.0 Records, Data Analysis, Calculations

9.1 All data and information (e.g., development method used) must be documented on field data sheets (Attachment 1) or within site logbooks with permanent ink. Data recorded may include the following:

- Well Location
- Weather conditions
- Date and Time
- Purge Method
- Reading/measurements obtained

10.0 Attachments or References

Attachment 1 – Well Development Record

SOP 3-05, *IDW Management*.

SOP 3-06, *Equipment Decontamination*.

Author	Reviewer	Revisions (Technical or Editorial)
Shawn Dolan Senior Scientist	Chris Barr Program Quality Manager	Rev 0 – Initial Issue (June 2012)
Ken O'Donnell, PG Geologist	Claire Mitchell, PE, PMP Senior Engineer	Rev 1 – PFAS sampling update (July 2019)

Attachment 1
Well Development Record

Well/Piezometer Development Record

Well ID:

Client: ________

Project No: ________ Date: ________ Developer: ________

Site Location: ________

Well/Piezometer Data

Well ☐ Piezometer ☐ Diameter ________ Material ________

Measuring Point Description ________

Geology at Screen Interval (if known) ________

Depth to Top of Screen (ft.) ________

Depth to Bottom of Screen (ft.) ________

Time of Water Level Measurement ________

Total Well Depth (ft.) ________

Calculate Purge Volume (gal.) ________

Depth to Static Water Level (ft.) ________

Disposal Method ________

Headspace ________

Original Well Development ☐ Redevelopment ☐ Date of Original Development ________

DEVELOPMENT METHOD ________

PURGE METHOD ________

Time	Total Volume Purged (gal.)	Flow Rate (gpm)	Turbidity (NTU)	Color	pH	Temp	Other

ACCEPTANCE CRITERIA (from workplan)

Minimum Purge Volume Required _____ gallons
Maximum Turbidity Allowed _____ NTUs
Stabilization of parameters _____%

	Yes	No	N/A
Has required volume been removed	☐	☐	☐
Has required turbidity been reached	☐	☐	☐
Has parameters stabilized	☐	☐	☐

If no or N/A explain below:

____

____

____

Signature ________ Date: ________

Monitoring Well Sampling

Procedure 3-14

1.0 Purpose and Scope

1.1 This standard operating procedure (SOP) describes the actions to be used during monitoring well sampling activities and establishes the method for sampling groundwater monitoring wells for water-borne contaminants and general groundwater chemistry. The objective is to obtain groundwater samples that are representative of aquifer conditions with as little alteration to water chemistry as possible.

1.2 This procedure is the Program-approved professional guidance for work performed by AECOM under the client contract.

1.3 As guidance for specific activities, this procedure does not obviate the need for professional judgment. Deviations from this procedure while planning or executing planned activities must be approved in accordance with Program requirements for technical planning and review.

2.0 Safety

2.1 Depending upon the site-specific contaminants, various protective programs must be implemented prior to sampling the first well. All field sampling personnel responsible for sampling activities must review the project-specific Accident Prevention Plan (APP)/Site Safety and Health Plan (SSHP) paying particular attention to the control measures planned for the well sampling tasks. Conduct preliminary area monitoring of sampling wells to determine the potential hazard to field sampling personnel. If significant contamination is observed, minimize contact with potential contaminants in both the vapor phase and liquid matrix through the use of appropriate personal protective equipment (PPE).

2.2 Observe standard health and safety practices according to the project-specific APP/SSHP. Suggested minimum protection during well sampling activities includes inner disposable vinyl gloves, outer chemical-protective nitrile gloves and rubberized steel-toed boots. Half-face respirators and cartridges and Tyvek® suits may be necessary depending on evaluation for PFAS and on the contaminant concentrations. Refer to the project-specific APP/SSHP for the required PPE.

2.3 Physical Hazards associated with Well Sampling

- To avoid lifting injuries associated with pump and bailers retrieval, use the large muscles of the legs, not the back.
- Stay clear of all moving equipment, and avoid wearing loose fitting clothing.
- When using tools for cutting purposes, cut away from yourself. The use of appropriate, task specific cutting tools is recommended.
- To avoid slip/trip/fall conditions as a result of pump discharge, use textured boots/boot cover bottoms.
- To avoid heat/cold stress as a result of exposure to extreme temperatures and PPE, drink electrolyte replacement fluids (1 to 2 cups per hour is recommended) and, in cases of extreme cold, wear fitted insulating clothing.
- Be aware of restricted mobility due to PPE.

3.0 Terms and Definitions

None.

4.0 Interferences

4.1 Potential interferences could result from cross-contamination between samples or sample locations. Minimization of the cross-contamination will occur through the following:

- The use of clean sampling tools at each location as necessary.
- Avoidance of material that is not representative of the media to be sampled.

5.0 Training and Qualifications

5.1 Qualifications and Training

The individual executing these procedures must have read, and be familiar with, the requirements of this SOP.

5.2 Responsibilities

5.2.1 The **Task Order (TO) Manager** is responsible for ensuring that monitoring well sampling activities comply with this procedure. The **TO Manager** is responsible for ensuring that all field sampling personnel involved in monitoring well sampling shall have the appropriate education, experience, and training to perform their assigned tasks.

5.2.2 The **Program Quality Manager** is responsible for ensuring overall compliance with this procedure.

5.2.3 The **Field Manager** is responsible for ensuring that all field sampling personnel follow these procedures.

5.2.4 **Field sampling personnel** are responsible for the implementation of this procedure.

5.2.5 The field sampler and/or task manager is responsible for directly supervising the groundwater sampling procedures to ensure that they are conducted according to this procedure and for recording all pertinent data collected during sampling.

6.0 Equipment and Supplies

6.1 Purging and Sampling Equipment

- Pump (Peristaltic, Portable Bladder, Submersible)
- Polyethylene bladders (for portable bladder pumps)
- Bladder pump controller (for portable bladder pumps)
- Air compressor (for portable bladder pumps)
- Nitrogen cylinders (for portable bladder pumps)
- 12-volt power source
- Polyethylene inlet and discharge tubing
- Silicone tubing appropriate for peristaltic pump head
- HDPE bailer appropriately sized for well
- Disposable bailer string (polypropylene)
- Individual or multi-parameter water quality meter(s) with flow-through cell to measure temperature, pH, specific conductance, dissolved oxygen (DO), oxidation reduction potential (ORP), and/or turbidity
- Turbidity meter
- Teflon-free water level meter
- Oil/water interface probe

6.2 General Equipment

- Sample kit (i.e., bottles, labels, preservatives, custody records and tape, cooler, wet ice)
- Sample Chain-of-Custody (COC) forms
- Sample Collection Records
- Sample packaging and shipping supplies
- Fine-tipped Sharpie® marker
- Deionized water supply
- Polyethylene water dispenser bottles
- HDPE flow measurement cup or bucket
- 5-gallon buckets
- Instrument calibration solutions
- Stopwatch or watch
- Disposable, powderless Nitrile gloves
- Cotton towels
- Trash bags
- Zipper-lock (e.g., Ziploc brand) bags
- Equipment decontamination supplies (e.g., Alconox®, Liquinox®, NOT Decon 90™)
- Health and safety supplies (as required by the APP/SSHP)
- Approved plans such as: project-specific APP/SSHP and Quality Assurance Project Plan (QAPP)
- Well keys or combinations
- Monitoring well location map(s)
- Field project logbook/ballpoint pen

7.0 Calibration or Standardization

7.1 Field instruments will be calibrated daily according to the requirements of the QAPP and manufacturer's specifications for each piece of equipment. Equipment will be checked daily with the calibration solutions at the end of use of the equipment. Calibration records shall be recorded in the field logbook or appropriate field form.

7.2 If readings are suspected to be inaccurate, the equipment shall be checked with the calibration solutions and/or re-calibrated.

8.0 Procedure

8.1 Preparation

8.1.1 Site Background Information

Establish a thorough understanding of the purposes of the sampling event prior to field activities. Conduct a review of all available data obtained from the site and pertinent to the water sampling. Review well history data including, but not limited to, well locations, sampling history, purging rates, turbidity problems, previously used purging methods, well installation methods, well completion records, well development methods, previous analytical results, presence of an immiscible phase, historical water levels, and general hydrogeologic conditions.

Previous groundwater development and sampling logs give a good indication of well purging rates and the types of problems that might be encountered during sampling, such as excessive turbidity and low well yield. They may also indicate where dedicated pumps are placed in the water column. To help minimize the potential for cross-contamination, well purging and sampling and water level measurement collection shall proceed from the least contaminated to the most contaminated well as indicated by previous analytical results. This order may be changed in the field if conditions warrant it, particularly if dedicated sampling equipment is used. A review of prior sampling procedures and results may also identify which purging and sampling techniques are appropriate for the parameters to be tested under a given set of field conditions.

8.1.2 Groundwater Analysis Selection

Establish the requisite field and laboratory analyses prior to water sampling. Decide on the types and numbers of quality assurance/quality control (QA/QC) samples to be collected (refer to the project-specific QAPP), as well as the type and volume of sample preservatives, the type and number of sample containers, the number of coolers required, and the quantity of ice or other chilling materials. The field sampling personnel shall ensure that the appropriate number and size sample containers are brought to the site, including extras in case of breakage or unexpected field conditions. Refer to the project-specific QAPP for the project analytical requirements.

8.2 Groundwater Sampling Procedures

Groundwater sampling procedures at a site shall include:

1) An evaluation of the well security and condition prior to sampling;
2) Decontamination of equipment;
3) Measurement of well depth to groundwater;
4) Assessment of the presence or absence of an immiscible phase;
5) Assessment of purge parameter stabilization;
6) Purging of static water within the well and well bore; and
7) Obtaining a groundwater sample.

Each step is discussed in sequence below. Depending upon specific field conditions, additional steps may be necessary. As a rule, at least 24 hours should separate well development and well sampling events. In all cases, consult the State and local regulations for the site, which may require more stringent time separation between well development and sampling.

8.2.1 Well Security and Condition

At each monitoring well location, observe the conditions of the well and surrounding area. The following information may be noted on a Groundwater Sample Collection Record (Attachment 1) or in the field logbook:

- Condition of the well’s identification marker.
- Condition of the well lock and associated locking cap.
- Integrity of the well – well pad condition, protective outer casing, obstructions or kinks in the well casing, presence of water in the annular space, and the top of the interior casing.
- Condition of the general area surrounding the well.

8.2.2 Decontamination of Equipment

Where possible, dedicated supplies should be used at each well location to minimize the potential for cross-contamination and minimize the amount of investigation derived waste (IDW) fluids resulting from the decontamination process. If decontamination is necessary, establish a decontamination station before beginning sampling. The station shall consist of an area of at least 4 feet by 2 feet covered with PE plastic sheeting and be located upwind of the well being sampled. The station shall be large enough to fit the appropriate number of wash and rinse buckets, and have sufficient room to place equipment after decontamination. One central cleaning area may be used throughout the entire sampling event. The area around the well being sampled shall also be covered with plastic sheeting to prevent spillage. Further details are presented in SOP 3-06, Equipment Decontamination.

Decontaminate each piece of equipment prior to entering the well. Also, conduct decontamination prior to sampling at a site, even if the equipment has been decontaminated subsequent to its last usage. Additionally, decontaminate each piece of equipment used at the site prior to leaving the site. It is only necessary to decontaminate dedicated sampling equipment prior to installation within the well. Do not place clean sampling equipment directly on the ground or other contaminated surfaces prior to insertion into the well. Dedicated sampling equipment that has been certified by the manufacturer as being decontaminated can be placed in the well without on-site decontamination.

8.2.3 Measurement of Static Water Level Elevation

Before purging the well, measure water levels in all of the wells within the zone of influence of the well being purged. The best practice, if possible, is to measure all site wells (or wells within the monitoring well network) prior to sampling. If the well cap is not vented, remove the cap several minutes before measurement to allow water levels to equilibrate to atmospheric pressure.

Measure the depth to standing water and the total depth of the well to the nearest 0.01 foot to provide baseline hydrologic data, to calculate the volume of water in the well, and to provide information on the integrity of the well (e.g., identification of siltation problems). If not already present, mark an easily identified reference point for water level measurements which will become the measuring point for all water level measurements. This location and elevation must be surveyed.

The device used to measure the water level surface and depth of the well shall be sufficiently sensitive and accurate in order to obtain a measurement to the nearest 0.01 foot reliably. A Teflon-free electronic water level meter will usually be appropriate for this measurement; however, when the groundwater within a particular well is highly contaminated, an inexpensive weighted tape measure can be used to determine well depth to prevent adsorption of contaminants onto the meter tape. The presence of light, non-aqueous phase liquids (LNAPLs) and/or dense, non-aqueous phase liquids (DNAPLs) in a well requires measurement of the elevation of the top and the bottom of the product, generally using an interface probe. Water levels in such wells must then be corrected for density effects to accurately determine the elevation of the water table.

At each location, measure water levels several times in quick succession to ensure that the well has equilibrated to atmospheric conditions prior to recording the measurement. As stated above, measure all site wells (or wells within the monitoring well network) prior to sampling whenever possible. This will provide a water level database that describes water levels across the site at one time (a synoptic sampling). Prior to sampling, measure the water level in each well immediately prior to purging the well to ascertain that static conditions have been achieved prior to sampling.

8.2.4 Detection of Immiscible Phase Layers

Complete the following steps for detecting the presence of LNAPL and DNAPL before the well is purged for conventional sampling. These procedures may not be required for all wells. Consult the project-specific QAPP to determine if assessing the presence of LNAPL and/or DNAPL is necessary.

1) Sample the headspace in the wellhead immediately after the well is opened for organic vapors using either a PID or an organic vapor analyzer, and record the measurements.
2) Lower an interface probe into the well to determine the existence of any immiscible layer(s), LNAPL and/or DNAPL, and record the measurements.
3) Confirm the presence or absence of an immiscible phase by slowly lowering a clear bailer to the appropriate depth, then visually observing the results after sample recovery.
4) In rare instances, such as when very viscous product is present, it may be necessary to utilize hydrocarbon- and water-sensitive pastes for measurement of LNAPL thickness. This is accomplished by smearing adjacent, thin layers of both hydrocarbon- and water-sensitive pastes along a steel measuring tape and inserting the tape into the well. An engineering tape showing tenths and hundredths of feet is required. Record depth to water, as shown by the mark on the water-sensitive paste, and depth to product, as shown by the mark on the product-sensitive paste. In wells where the approximate depth to water and product thickness are not known, it is best to apply both pastes to the tape over a fairly long interval (5 feet or more). Under these conditions, measurements are obtained by trial and error and may require several insertions and retrievals of the tape before the paste-covered interval of the tape encounters product and water. In wells where approximate depths of air-product and product-water interfaces are known, pastes may be applied over shorter intervals. Water depth measurements should not be used in preparation of water table contour maps until they are corrected for depression by the product.
5) If the well contains an immiscible phase, it may be desirable to sample this phase separately. Section 8.2.6 presents immiscible phase sampling procedures. It may not be meaningful to conduct water sample analysis of water obtained from a well containing LNAPLs or DNAPLs. Consult the **TO Manager** and **Program Quality Manager** if this situation is encountered.

8.2.5 Purging Equipment and Use

General Requirements

The water present in a well prior to sampling may not be representative of in situ groundwater quality and shall be removed prior to sampling. Handle all groundwater removed from potentially contaminated wells in accordance with the IDW handling procedures in SOP 3-05, IDW Management. Purging shall be accomplished by methods as indicated in the project-specific QAPP or by those required by State requirements. For the purposes of this SOP, purging methods will be described by removing groundwater from the well using low-flow techniques.

According to the U.S. Environmental Protection Agency (EPA) (EPA, 1996), the rate at which groundwater is removed from the well during purging ideally should be less than 0.2 to 0.3 liters/minute. EPA further states that wells should be purged at rates below those used to develop the well to prevent further development of the well, to prevent damage to the well, and to avoid disturbing accumulated corrosion or reaction products in the well. EPA also indicates that wells should be purged at or below their recovery rate so that migration of water in the formation above the well screen does not occur.

Realistically, the purge rate should be low enough that substantial drawdown in the well does not occur during purging. In addition, a low purge rate will reduce the possibility of stripping volatile organic compounds (VOCs) from the water, and will reduce the likelihood of increasing the turbidity of the sample due to mobilizing colloids in the subsurface that are immobile under natural flow conditions.

The field sampler shall ensure that purging does not cause formation water to cascade down the sides of the well screen. Wells should not be purged to dryness if recharge causes the formation water to cascade down the sides of the screen, as this will cause an accelerated loss of volatiles. This problem should be anticipated based on the results of either the well development task or historical sampling events. In general, place the intake of the purge pump in the middle of the saturated screened interval within the well to allow purging and at the same time minimize disturbance/overdevelopment of the screened interval in the well. Water shall be purged from the well at a rate that does not cause recharge water to be excessively agitated unless an extremely slow recharging well is encountered where complete evacuation is unavoidable. During the well purging procedure, collect water level and/or product level measurements to assess the hydraulic effects of purging. Sample the well when it recovers sufficiently to provide enough water for the analytical parameters specified. If the well is purged dry, allow the well to recover sufficiently to provide enough water for the specified analytical parameters, and then sample it.

Evaluate water samples on a regular basis during well purging and analyze them in the field preferably using in-line devices (i.e., flow through cell) for temperature, pH, specific conductivity, dissolved oxygen (DO), and oxidation-reduction (redox) potential. Turbidity should be measured separately (outside of the flow-through cell) with a nephelometer or similar device.

Readings should be taken every 2 to 5 minutes during the purging process. These parameters are measured to demonstrate that the natural character of the formation waters has been restored.

Purging shall be considered complete per the requirements set forth in the project-specific QAPP, State requirements, or when three consecutive field parameter measurements of temperature, pH, specific conductivity, DO and ORP stabilize within approximately 10 percent and the turbidity is at or below 10 nephelometric turbidity units (NTU) or within ± 10% if above 10 NTU. This criterion may not be applicable to temperature if a submersible pump is used during purging due to the heating of the water by the pump motor. Enter all information obtained during the purging and sampling process into a groundwater sampling log. Attachment 1 shows an example of a groundwater sampling log and the information typically included in the form. Whatever form is used, all blanks need to be completed on the field log during field sampling.

Groundwater removed during purging shall be stored according to the project-specific QAPP or per SOP 3-05, IDW Management.

Purging Equipment and Methods

Submersible Pump

A stainless steel submersible pump may be utilized for purging both shallow and deep wells prior to sampling the groundwater for semivolatile and non-volatile constituents, but are generally not preferred for VOCs unless there are no other options (e.g., well over 200 feet deep). For wells over 200 feet deep, the submersible pump is one of the few technologies available to feasibly accomplish purging under any yield conditions. For shallow wells with low yields, submersible pumps are generally inappropriate due to overpumpage of the wells (<1 gallon per minute), which causes increased aeration of the water within the well.

Steam clean or otherwise decontaminate the pump and discharge tubing prior to placing the pump in the well. The submersible pump shall be equipped with an anti-backflow check valve to limit the amount of water that will flow back down the drop pipe into the well. Place the pump in the middle of the saturated screened interval within the well and maintain it in that position during purging.

Bladder Pump

A stainless-steel bladder pump can be utilized for purging and sampling wells up to 200 feet in depth for volatile, semivolatile, and non-volatile constituents. Use of the bladder pump is most effective in low to moderate yield wells and are often the preferred method for low-flow sampling. When sampling for VOCs and/or SVOCs and PFAS, polyethylene bladders and PFAS-free O-rings and pump accessories should be used.

Either compressed dry nitrogen or compressed dry air, depending upon availability, can operate the bladder pump. The driving gas utilized must be dry to avoid damage to the bladder pump control box. Decontaminate the bladder pump prior to use.

Centrifugal, Peristaltic, or Diaphragm Pump

A centrifugal, peristaltic, or diaphragm pump may be utilized to purge a well if the water level is within 20 feet of ground surface. New or dedicated HDPE tubing is inserted into the midpoint of the saturated screened interval of the well. Water should be purged at a rate that satisfies low-flow requirements (i.e., does not cause drawdown). Centrifugal, peristaltic, or diaphragm pump are generally discouraged for VOCs sampling; however, follow methods allowed per the project-specific QAPP or State requirements.

Air Lift Pump

Airlift pumps are not appropriate for purging or sampling.

Bailer

Avoid using a bailer to purge a well because it can result in overdevelopment of the well and create excessive purge rates. If a bailer must be used, the bailer should either be dedicated or disposable. An HDPE balier with polypropylene string mounted on a reel is recommended for lowering the bailer in and out of the well.

Lower the bailer below the water level of the well with as little disturbance of the water as possible to minimize aeration of the water in the well. One way to gauge the depth of water on the reel is to mark the depth to water on the bailer wire with a stainless steel clip. In this manner, less time is spent trying to identify the water level in the well.

8.2.6 Monitoring Well Sampling Methodologies

Sampling Light, Non-Aqueous Phase Liquids (LNAPL)

Collect LNAPL, if present, prior to any purging activities. The sampling device shall generally consist of a dedicated or disposable bailer equipped with a bottom-discharging device. Lower the bailer slowly until contact is made with the surface of the LNAPL, and to a depth less than that of the immiscible fluid/water interface depth as determined by measurement with the interface probe. Allow the bailer to fill with LNAPL and retrieve it.

When sampling LNAPLs, never drop bailers into a well and always remove them from the well in a manner that causes as little agitation of the sample as possible. For example, the bailer should not be removed in a jerky fashion or be allowed to continually bang against the well casing as it is raised. Teflon bailers should always be used when sampling LNAPL. The cable used to raise and lower the bailer shall be composed of an inert material (e.g., stainless steel) or coated with an inert material (e.g., Teflon).

Sampling Dense, Non-Aqueous Phase Liquids (DNAPL)

Collect DNAPL prior to any purging activities. The best method for collecting DNAPL is to use a double-check valve, stainless steel bailer, or a Kemmerer (discrete interval) sampler. The sample shall be collected by slow, controlled lowering of the bailer to the bottom of the well, activation of the closing device, and retrieval.

Groundwater Sampling Methodology

The well shall be sampled when groundwater within it is representative of aquifer conditions per the methods described in Section 8.2.5. Prior to sampling the flow-through cell shall be removed and the samples collected directly from the purge tubing. Flow rates shall not be adjusted once aquifer conditions are met. Additionally, a period of no more than 2 hours shall elapse between purging and sampling to prevent groundwater interaction with the casing and atmosphere. This may not be possible with a slowly recharging well. Measure and record the water level prior to sampling in order to monitor drawdown when using low-flow techniques and gauge well volumes removed and recharged when using non-low-flow techniques.

Sampling equipment (e.g., especially bailers) shall never be dropped into the well, as this could cause aeration of the water upon impact. Additionally, the sampling methodology utilized shall allow for the collection of a groundwater sample in as undisturbed a condition as possible, minimizing the potential for volatilization or aeration. This includes minimizing agitation and aeration during transfer to sample containers, minimizing exposure to sunlight, and immediately placing the sample on ice once collected.

Sampling equipment shall be constructed of inert material. Equipment with neoprene fittings, polyvinyl chloride (PVC) bailers, Tygon® tubing, silicon rubber bladders, neoprene impellers, polyethylene, and Viton® are not acceptable when sampling for organics and PFAS. If bailers are used, an inert cable/chain (e.g., polypropylene string or stainless steel wire or cable) shall be used to raise and lower the bailer. Dedicated equipment is highly recommended for all sampling programs.

Submersible Pumps

The submersible pump must be specifically designed for groundwater sampling (i.e., pump composed of stainless steel and HDPE, sample discharge lines composed of HDPE) and must have a controller mechanism allowing the required low-flow rate. Adjust the pump rate so that flow is continuous and does not pulsate to avoid aeration and agitation within the sample discharge lines. Run the pump for several minutes at the low-flow rate used for sampling to ensure that the groundwater in the lines was obtained at the low-flow rate.

Bladder Pumps

A gas-operated stainless steel bladder pump with adjustable flow control and equipped with a polyethylene bladder and HDPE tubing can be effectively utilized to collect a groundwater sample and is considered to be the best overall device for sampling inorganic and organic constituents. If only inorganics are being sampled, polyvinyl bladders and tubing may be used. Operate positive gas displacement bladder pumps in a continuous manner so that they minimize discharge pulsation that can aerate samples in the return tube or upon discharge.

When using a compressor, take several precautions. If the compressor is being powered by a gasoline generator, position the generator downwind of the well. Ground fault circuit interrupters (GFCIs) should always be used when using electric powered equipment. Do not connect the compression hose from the compressor to the pump controller until after the engine has been started.

When all precautions are completed and the compressor has been started, connect the compression hose to the pump controller. Slowly adjust the control knobs to discharge water in the shortest amount of time while maintaining a near constant flow. This does not mean that the compressor must be set to discharge the water as hard as possible. The optimal setting is one that produces the largest volume of purge water per minute (not per purge cycle) while maintaining a near constant flow rate.

Prior to sampling, adjust the flow rate (purge rate) to yield 100 to 300 mL/minute. Avoid settings that produce pulsating streams of water instead of a steady stream if possible. Operate the pump at this low flow rate for several minutes to ensure that drawdown is not occurring. At no time shall the sample flow rate exceed the flow rate used while purging.

For those samples requiring filtration, it is recommended to use an in-line high capacity filter after all non-filtered samples have been collected.

Peristaltic Pumps:

A peristaltic pump is a type of positive displacement pump that moves water via the process of peristalsis. The pump uses a flexible hose fitted inside a circular pump casing. A rotor with cams compresses the flexible tube as the rotor turns, which forces the water to be pumped to move through the tube. In peristaltic pumps, no moving parts of the pump are in contact with the water being pumped. Displacement is determined by tube size, so delivery rate can only be changed during operation by varying pump speed. Peristaltic pumps are simple and quite inexpensive for the flow rates they provide.

There are several methods available for transferring the sample into the laboratory containers. The selected method may vary based on State requirements and should be documented in the project-specific QAPP. Samples typically can be collected directly from the discharge end of the HDPE tubing, after it has been disconnected from the flow through cell. For volatile analyses, the sampler should make sure that the pump is set such that a smooth laminar flow is achieved. In all cases, the project team should consult their local regulatory requirements and document the selected sample collection procedure in the project-specific QAPP.

Bailers

A single- or double-check valve HDPE or stainless steel bailer equipped with a bottom discharging device can be utilized to collect groundwater samples. Bailers have a number of disadvantages, however, including a tendency to alter the chemistry of groundwater samples due to degassing, volatilization, and aeration; the possibility of creating high groundwater entrance velocities; differences in operator techniques resulting in variable samples; and difficulty in determining where in the water column the sample was collected. Therefore, use bailers for groundwater sampling only when other types of sampling devices cannot be utilized for technical, regulatory, or logistical reasons.

Dedicated or disposable bailers should always be used in order to eliminate the need for decontamination and to limit the potential of cross-contamination. Each time the bailer is lowered to the water table, lower it in such a way as to minimize disturbance and aeration of the water column within the well.

8.2.7 Sample Handling and Preservation

Many of the chemical constituents and physiochemical parameters to be measured or evaluated during groundwater monitoring programs are chemically unstable and require preservation. The U.S. EPA document entitled, *Test Methods for Evaluating Solid Waste – Physical/Chemical Methods (SW-846)* (EPA 1997)*,* includes a discussion of appropriate sample preservation procedures. In addition, SW-846 provides guidance on the types of sample containers to use for each constituent or common set of parameters. In general, check with specific laboratory or State requirements prior to obtaining field samples. In many cases, the laboratory will supply the necessary sample bottles and required preservatives. In some cases, the field sampling personnel may add preservatives in the field.

Improper sample handling may alter the analytical results of the sample. Therefore, transfer samples in the field from the sampling equipment directly into the container that has been prepared specifically for that analysis or set of compatible parameters as described in the project-specific QAPP. It is not an acceptable practice for samples to be composited in a common container in the field and then split in the laboratory, or poured first into a wide mouth container and then transferred into smaller containers.

Collect groundwater samples and place them in their proper containers in the order of decreasing volatility and increasing stability. A preferred collection order for some common groundwater parameters is:

1. VOCs and total organic halogens (TOX)
2. Dissolved gases, total organic carbon (TOC), total fuel hydrocarbons
3. Semivolatile organics, pesticides
4. Total metals, general minerals (unfiltered)
5. Dissolved metals, general minerals (filtered)
6. Phenols
7. Cyanide
8. Sulfate and chloride
9. Nitrate and ammonia
10. Radionuclides

When sampling for VOCs, collect water samples in vials or containers specifically designed to prevent loss of VOCs from the sample. The analytical laboratory performing the analysis shall provide these vials. Collect groundwater from the sampling device in vials by allowing the groundwater to slowly flow along the sides of the vial. Sampling equipment shall not touch the interior of the vial. Fill the vial above the top of the vial to form a positive meniscus with no overflow. No headspace shall be present in the sample container once the container has been capped. This can be checked by inverting the bottle once the sample is collected and tapping the side of the vial to dislodge air bubbles. Sometimes it is not possible to collect a sample without air bubbles, particularly water that has high concentrations of dissolved gasses. In these cases, the field sampling personnel shall document the occurrence in the field logbook and/or sampling worksheet at the time the sample was collected. Likewise, the analytical laboratory shall note in the laboratory analysis reports any headspace in the sample container(s) at the time of receipt by the laboratory.

Special Handling Considerations

In general, samples for organic analyses should not be filtered. However, high turbidity samples for PCB analysis may require filtering. Consult the project-specific QAPP for details on filtering requirements. Samples shall not be transferred from one container to another because this could cause aeration or a loss of organic material onto the walls of the container. TOX and TOC samples should be handled in the same manner as VOC samples.

When collecting total and dissolved metals samples, the samples should be collected sequentially. The total metals sample is collected from the pump unfiltered. The dissolved metals sample is collected after filtering with a 0.45-micron membrane in-line filter. Allow at least 500 mL of effluent to flow through the filter prior to sampling to ensure that the filter is thoroughly wetted and seated in the filter capsule. If required by the project-specific QAPP, include a filter blank for each lot of filters used and always record the lot number of the filters.

Because there is some evidence that PFOS may sorb onto glass fiber filters, it is preferred not to filter samples for PFAS analysis in the field or laboratory. Field filtration is generally prohibited unless specifically requested by a client. If filtering is required by client’s and regulatory agency’s request, it is recommended that the following be considered and discussed with the client and regulatory agency:

- Evaluate if filtered results are meaningful, and, therefore, if filtering in the field or laboratory is required.
- Consider use of low flow sampling in the field to reduce the need for sample filtering.
- Consider use of a centrifuge in the laboratory to reduce the need for sample filtering.
- If filtering is required, determine the nature of the filters used and do not use glass fiber filters.

Field Sampling Preservation

Preserve samples immediately upon collection. Ideally, sampling containers will be pre-preserved with a known concentration and volume of preservative. Certain matrices that have alkaline pH (greater than 7) may require more preservative than is typically required. An early assessment of preservation techniques, such as the use of pH strips after initial preservation, may therefore be appropriate. Guidance for the preservation of environmental samples can be found in the U.S. EPA *Handbook for Sampling and Sample Preservation of Water and Wastewater* (EPA 1982). Additional guidance can be found in other U.S. EPA documents (EPA 1992, 1996).

Field Sampling Log

A groundwater sampling log provided as Attachment 1 shall document the following:

- Identification of well
- Well depth

- Static water level depth and measurement technique
- Presence of immiscible layers and detection method
- Well yield
- Purge volume and pumping rate
- Time that the well was purged
- Sample identification numbers
- Well evacuation procedure/equipment
- Sample withdrawal procedure/equipment
- Date and time of collection
- Types of sample containers used
- Preservative(s) used
- Parameters requested for analysis
- Field analysis data
- Field observations on sampling event
- Name of sampler
- Weather conditions

9.0 Quality Control and Assurance

9.1 Field personnel will follow specific quality assurance (QA) guidelines as outlined in the project-specific QAPP. The goal of the QA program should be to ensure precision, accuracy, representativeness, completeness, and comparability in the project sampling program.

9.2 Quality control (QC) requirements for sample collection are dependent on project-specific sampling objectives. The project-specific QAPP will provide requirements for sample preservation and holding times, container types, sample packaging and shipment, as well as requirements for the collection of various QC samples such as trip blanks, field blanks, equipment rinse blanks, and field duplicate samples.

10.0 Data and records management

10.1 Records will be maintained in accordance with SOP 3-03, Recordkeeping, Sample Labelling, and Chain-of-Custody. Various forms are required to ensure that adequate documentation is made of the sample collection activities. These forms may include:

- Sample Collection Records;
- Non-water repellent field logbook;
- Chain-of-custody forms; and
- Shipping labels.

10.2 Sample collection records (Attachment 1) will provide descriptive information for the purging process and the samples collected at each monitoring well.

10.3 The field logbook is kept as a general log of activities and should not be used in place of the sample collection record.

10.4 Chain-of-custody forms are transmitted with the samples to the laboratory for sample tracking purposes.

10.5 Shipping labels are required is sample coolers are to be transported to a laboratory by a third party (courier service).

11.0 Attachments or References

Attachment 1 – Groundwater Sampling Collection Record

ASTM Standard D5088. 2008. *Standard Practice for Decontamination of Field Equipment Used at Waste Sites.* ASTM International, West Conshohocken, PA. 2008. DOI: 10.1520/D5088-02R08. www.astm.org.

Environmental Protection Agency, United States (EPA). 1982. *Handbook for Sampling and Sample Preservation of Water and Wastewater.* EPA-600/4-82-029. Cincinnati: EPA Office of Research and Development, Environmental Monitoring and Support Laboratory.

EPA. 1992. *RCRA Groundwater Monitoring Draft Technical Guidance*. EPA/530/R-93/001. Office of Solid Waste. November.

EPA. 1996. *Ground Water Issue: Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures*. EPA/540/S-95/504. Office of Solid Waste and Emergency Response. April.

EPA. 1997. *Test Methods for Evaluating Solid Waste, Physical/Chemical Method (SW-846)*. 3rd ed., Final Update IIIA. Office of Solid Waste. Online updates at: http://www.epa.gov/epaoswer/hazwaste/test/new-meth.htm.

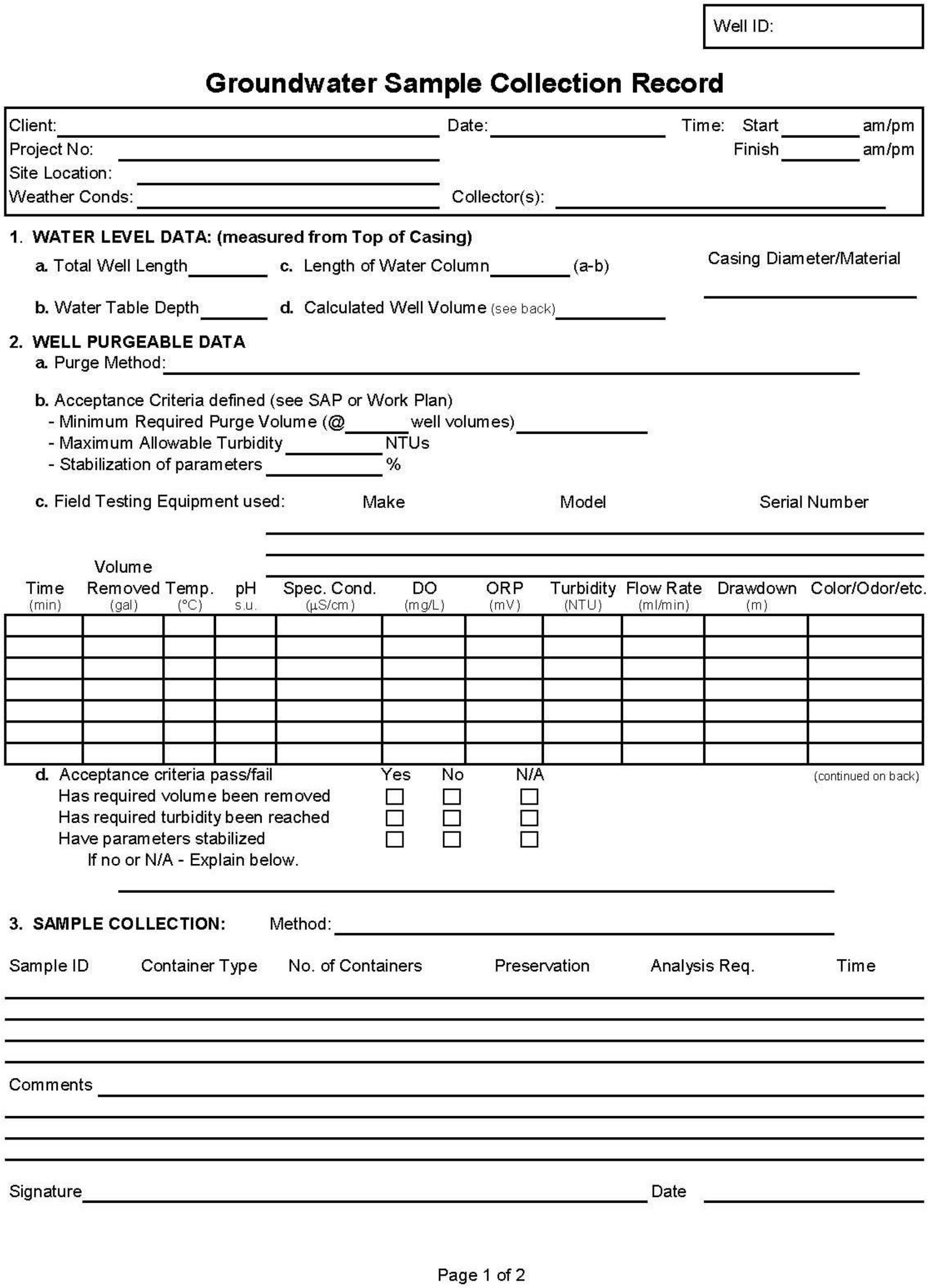
SOP 3-03, *Recordkeeping, Sample Labelling, and Chain-of-Custody*.

SOP 3-05, *IDW Management.*

SOP 3-06, *Equipment Decontamination*.

Author	Reviewer	Revisions (Technical or Editorial)
Mark Kromis Program Chemist	Chris Barr Program Quality Manager	Rev 0 – Initial Issue (May 2012)
Ken O'Donnell, PG Geologist	Claire Mitchell, PE, PMP Senior Engineer	Rev 1 – PFAS sampling update (July 2019)

Attachment 1
Groundwater Sample Collection Record



Well ID:

Groundwater Sample Collection Record

Client: ______________ Date: __________ Time: Start ______ am/pm
Project No: ______________ Finish ______ am/pm
Site Location: ______________
Weather Conds: ______________ Collector(s): ______________

1. WATER LEVEL DATA: (measured from Top of Casing)

a. Total Well Length ______ **c.** Length of Water Column ______ (a-b)

b. Water Table Depth ______ **d.** Calculated Well Volume (see back) ______

Casing Diameter/Material ______________

2. WELL PURGEABLE DATA

a. Purge Method: ______________

b. Acceptance Criteria defined (see SAP or Work Plan)
- Minimum Required Purge Volume (@______well volumes) ______
- Maximum Allowable Turbidity ______ NTUs
- Stabilization of parameters ______ %

c. Field Testing Equipment used:

	Make	Model	Serial Number

Time (min)	Volume Removed (gal)	Temp. (°C)	pH s.u.	Spec. Cond. (µS/cm)	DO (mg/L)	ORP (mV)	Turbidity (NTU)	Flow Rate (ml/min)	Drawdown (m)	Color/Odor/etc.

d. Acceptance criteria pass/fail	Yes	No	N/A
Has required volume been removed	☐	☐	☐
Has required turbidity been reached	☐	☐	☐
Have parameters stabilized	☐	☐	☐

If no or N/A - Explain below.

____

(continued on back)

3. SAMPLE COLLECTION: Method: ______________

Sample ID	Container Type	No. of Containers	Preservation	Analysis Req.	Time

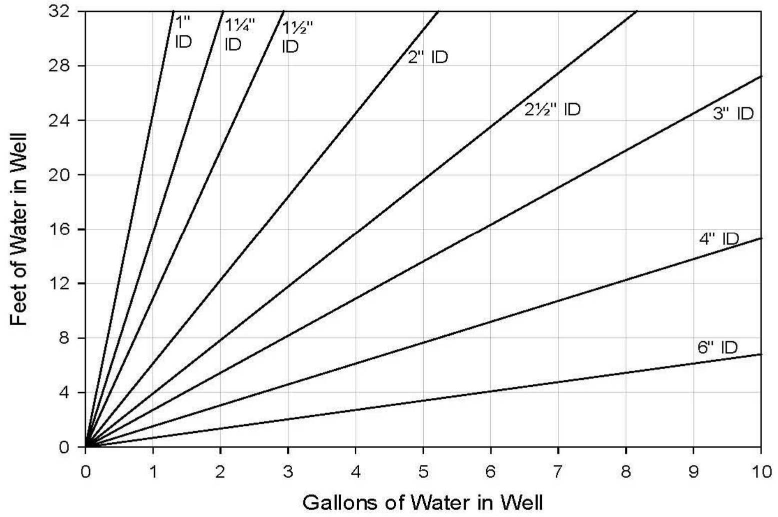
Comments ______________

Signature ______________ Date ______________

NOTE: SOPs have been updated for PFAS sampling activities; however, AECOM's internal PFAS sampling guidance supersedes materials and methods described in SOPs.

Purge Volume Computation

Well ID:



Volume / Linear Ft. of Pipe		
ID (in)	**Gallon**	**Liter**
¼	0.0025	0.0097
³/₈	0.0057	0.0217
½	0.0102	0.0386
¾	0.0229	0.0869
1	0.0408	0.1544
1¼	0.0637	0.2413
1½	0.0918	0.3475
2	0.1632	0.6178
2½	0.2550	0.9653
3	0.3672	1.3900
4	0.6528	2.4711
6	1.4688	5.5600

(continued from front)

Time (min)	Volume Removed (gal)	Temp. (°C)	pH s.u.	Spec. Cond. (μS/cm)	DO (mg/L)	ORP (mV)	Turbidity (NTU)	Flow Rate (ml/min)	Drawdown (m)	Color/Odor/etc.

Signature________________________________ Date ______________

Monitoring Well Abandonment

Procedure 3-15

1.0 Purpose and Scope

1.1 This standard operating procedure (SOP) describes the methods used for the abandonment of groundwater monitoring wells and peizometers.

1.2 This procedure is the Program-approved professional guidance for work performed by AECOM under the client contract.

1.3 As guidance for specific activities, this procedure does not obviate the need for professional judgment. Deviations from this procedure while planning or executing planned activities must be approved in accordance with Program requirements for technical planning and review.

2.0 Safety

2.1 The health and safety considerations for the work associated with this SOP, including both potential physical and chemical hazards, will be addressed in the project Accident Prevention Plan (APP)/Site Safety and Health Plan (SSHP). Work will be conducted according to the Task Order (TO) Quality Assurance Project Plan (QAPP) and/or direction from the Site Safety and Health Officer (SSHO).

2.2 Physical hazards associated with well installation include:

- To avoid lifting injuries associated with well abandonment practices, use the large muscles of the legs, not the back. The drilling contractor should use the drill rig wenching cables and appropriate heavy equipment to minimize manual lifting.
- Stay clear of all moving equipment and avoid wearing loose fitting clothing.
- When using an approved retractable-blade knife, cut away from one self.
- To avoid slip/trip/fall conditions during site activities, keep the area clear of excess soil cuttings and formation groundwater and use textured boots/boot cover bottoms in muddy areas.
- To avoid heat/cold stress because of exposure to extreme temperatures and personal protective equipment (PPE), drink electrolyte replacement fluids (1 - 2 cups per hour is recommended) and, in cases of extreme cold, wear fitted insulating clothing.
- Be aware of restricted mobility caused by PPE.

3.0 Terms and Definitions

3.1 **Annulus:** The annulus is the down-hole space between the borehole wall and the well casing and screen.

3.2 **Bridge:** A bridge is an obstruction in the drill hole or annulus. A bridge is usually formed by caving of the wall of the well bore, by the intrusion of a large boulder, or by the placement of filter pack materials during well completion. Bridging can also occur in the formation during well development.

3.3 **Filter Pack:** Filter pack is sand or gravel that is smooth, uniform, clean, well-rounded, and siliceous. It is placed in the annulus of the well between the borehole wall and the well screen to prevent formation materials from entering the well and to stabilize the adjacent formation.

3.4 **Grout:** Grout is a fluid mixture of cement and water that can be forced through a tremie pipe and emplaced in the annular space between the borehole and casing to form an impermeable seal. Various additives, such as sand, bentonite, and polymers, may be included in the mixture to meet certain requirements.

4.0 Interferences

4.1 The total depth of the monitoring well will be measured and the measurement will be compared to the original well completion log prior to abandonment.

4.2 A map with the location of the well to be abandoned and the surrounding wells, if any, will be utilized in the field to confirm the location of the well to be abandoned.

4.3 Information from the well identification tags/markings will be noted and the information compared to both the well completion log and the total depth measurement obtained in the field to confirm the identity of the well being abandoned.

5.0 Training and Qualifications

5.1 Qualifications and Training

The individual executing these procedures must have read, and be familiar with, the requirements of this SOP.

5.2 Responsibilities

5.2.1 The **TO Manager** is responsible for ensuring that well abandonment activities comply with this procedure. The **TO Manager** is responsible for ensuring that all personnel involved in well abandonment shall have the appropriate education, experience, and training to perform their assigned tasks.

5.2.2 The **Program Quality Manager** is responsible for ensuring overall compliance with this procedure.

5.2.3 The **Site Supervisor (SS)** is responsible for ensuring that all well abandonment activities are conducted according to the either this procedure or the applicable procedure presented in the project-specific QAPP.

5.2.4 **Field sampling personnel** are responsible for the implementation of this procedure.

5.2.5 The **field sampler and/or task manager** is responsible for directly supervising the well abandonment procedures to ensure that they are conducted according to this procedure and for recording all pertinent data collected during sampling.

6.0 Equipment and Supplies

6.1 Equipment and materials used during monitoring well and piezometer abandonment include the following:

- Drill rig or trailer-mounted mixer and grout pump
- Filter pack material
- Pure sodium bentonite with no additives
- Bentonite pellets/chips
- Bentonite grout
- Portland Type II cement
- Water from an approved source
- Weighted tape measure
- Flexible hose

- Tremie pipe (small-diameter, rigid polyvinyl chloride [PVC] pipe)
- Weatherproof bound field logbook with numbered pages
- Appropriate health and safety equipment

7.0 Procedure

7.1 General Procedures

The following procedure applies to the abandonment of wells aborted prior to completion and existing wells determined to be ineffective or otherwise in need of closure. Prior to abandoning any developed well, you may need to acquire a permit from the State or local governing body in which you are working. The permit application may require a detailed design of the well abandonment. In addition, prior to abandonment, all obstructions (e.g., pumps, lost equipment) must be removed from the well. Some States are strict in requiring the removal of all lost equipment prior to abandonment and will not allow the closure of a well with lost equipment in it. The State may require the removal of all objects to allow a proper seal during abandonment. Great lengths must be taken to reclaim lost items, such as the use of downhole video cameras to inspect and aid in the recovery of items. Prior to abandonment, confirm that the well selected for abandonment is properly located and identified to avoid abandoning the wrong well.

At locations where a well log is not available, the following procedure shall be implemented:

- The casing should be pulled, drilled out, or thoroughly pierced.
- With the use of a tremie pipe, grout should be placed from the bottom of the hole to within 3 feet of the ground surface.
- The material should be allowed to settle for 24 hours.
- The remainder of the hole should be filled with concrete.
- All historical sample data and abandonment procedures should be included in the records of work.

At locations where a well completion log is available, the following procedure shall be implemented:

- With the use of a tremie pipe, grout should be placed from the bottom of the hole to within 3 feet of the ground surface.
- The material should be allowed to settle for 24 hours.
- The remainder of the hole should be filled with concrete.
- All boring logs, historical sample data, completion records, and abandonment procedures should be included in the records of work.

Depending on the regulatory body under which you are working, the procedures listed above may differ. All work shall be performed by a licensed well driller in the State work is being performed. The licensed well driller is responsible for documenting the abandonment of the monitoring well with the appropriate State agency.

7.2 Replacement Wells

Replacement wells (if any) should normally be offset at least 15 feet from any abandoned well in an upgradient or crossgradient groundwater flow direction. Site-specific conditions may necessitate variation of this placement requiring the replacement well to be located either closer or further in proximity to the original well. To avoid potential issues related to grout migration into a well filter pack and/or screen section, replacement wells should be installed after the original/adjacent well is properly abandoned.

7.3 Grout

Bentonite grout is preferred for the abandonment of monitoring wells. Cement grout, if used for abandonment, should be composed of the following by weight:

- 20 parts cement (Portland cement, Type II or V)
- 0.4 to 1-part (maximum) (2 to 5 percent) bentonite
- 8 gallons (maximum) approved water per 94-pound bag of cement

Neither additives nor borehole cuttings should be mixed with the grout. Bentonite should be added after the required amount of cement has been mixed with the water. All grout material should be combined in an aboveground container and mechanically blended to produce a thick, lump-free mixture. The mixed grout should be recirculated through the grout pump prior to placement. The mixture can be combined and recirculated through a drill rig equipped for mud rotary drilling or through a mixer and grout pump mounted on a trailer.

Grout should be placed with the use of a commercially available grout pump and a rigid tremie pipe. Casing and grouting should be removed in stages, aquifer by aquifer, sealing the boring from the bottom to ground surface. This should be accomplished by placing a tremie pipe to the bottom and pumping grout through the pipe until undiluted grout reaches the bottom of the next higher section of casing or, for the topmost section, until grout flows from the boring at the ground surface.

After 24 hours, the abandoned drilling site should be checked for grout settlement. Any settlement depression should be filled with grout and rechecked 24 hours later. This process should be repeated until firm grout remains at the ground surface.

Be aware that when the drillers are finished, they will need a large supply of water to rinse out their equipment. This wash water must be containerized as IDW in accordance with SOP 3-05, *IDW Management*. Also, any materials (such as the removed protective casing, manhole covers, and concrete collars) shall be disposed of properly, or per the requirements of the project-specific QAPP.

8.0 Quality Control and Assurance

8.1 Field personnel will follow specific quality assurance (QA) guidelines as outlined in the project-specific QAPP.

8.2 Quality Control (QC) measures should be taken to ensure proper well abandonment in accordance with this SOP, project-specific QAPP, and applicable well standards.

9.0 Records, Data Analysis, Calculations

9.1 All field information must be documented in the field logbook and/or on field data sheets with permanent ink. Data recorded may include the following:

- Date/time
- Well/piezometer location
- Personnel/subcontractor on site
- Abandonment method
- Depth of well/piezometer
- Materials used to seal each stratum
- Detailed description of procedure
- Date/time of return visit(s)
- Activities performed on return visit(s)
- Observations or problems encountered during abandonment

10.0 Attachments or References

Environmental Protection Agency, United States (EPA). 1987*. A Compendium of Superfund Field Operations Methods*. Office of Solid Waste and Emergency Response. EPA/540/P-87/001.

SOP 3-05, *IDW Management*.

Author	Reviewer	Revisions (Technical or Editorial)
Shawn Dolan Senior Scientist	Chris Barr Program Quality Manager	Rev 0 – Initial Issue (June 2012)
Ken O’Donnell, PG Geologist	Claire Mitchell, PE, PMP Senior Engineer	Rev 1 – PFAS sampling update (July 2019)

Soil and Rock Classification

Procedure 3-16

1.0 Purpose and Scope

1.1 The purpose of this document is to define the standard operating procedure (SOP) to thoroughly describe the physical characteristics of the sample and classify it according to the Unified Soil Classification System (USCS).

1.2 This procedure is the Program-approved professional guidance for work performed by AECOM under the client contract.

1.3 As guidance for specific activities, this procedure does not obviate the need for professional judgment. Deviations from this procedure while planning or executing planned activities must be approved in accordance with Program requirements for technical planning and review. If there are procedures whether it be from AECOM, state and/or federal that are not addressed in this SOP and are applicable to surface water sampling then those procedures may be added as an appendix to the project-specific Quality Assurance Project Plan (QAPP).

1.4 It is fully expected that the procedures outlined in this SOP will be followed. Procedural modifications may be warranted depending upon field conditions, equipment limitations, or limitations imposed by the procedure. Substantive modification to this SOP will be approved in advance by the Program Quality Manager. Deviations to this SOP will be documented in the field records.

2.0 Safety

2.1 Depending upon the site-specific contaminants, various protective programs must be implemented prior to sampling. All **field sampling personnel** responsible for sampling activities must review the project-specific Accident Prevention Plan (APP)/Site Safety and Health Plan (SSHP), paying particular attention to the control measures planned for the sampling tasks. Conduct preliminary area monitoring to determine the potential hazard to field sampling personnel. If significant contamination is observed, minimize contact with potential contaminants in both the vapor and liquid phase through the use of respirators and disposable clothing.

2.2 In addition, observe standard health and safety practices according to the project-specific APP/SSHP. Suggested minimum protection during well sampling activities includes inner disposable vinyl gloves, outer chemical-protective nitrile gloves, rubberized steel-toed boots, and an American National Standards Institute-standard hard hat. Half-face respirators and cartridges and Tyvek® suits may be necessary depending on the contaminant concentrations, and shall always be available on site.

2.3 Daily safety briefs will be conducted at the start of each working day before any work commences. These daily briefs will be facilitated by the **Site Safety and Health Officer (SSHO)** or designee to discuss the day’s events and any potential health risk areas covering every aspect of the work to be completed. Weather conditions are often part of these discussions. As detailed in the APP/SSHP, everyone on the field team has the authority to stop work if an unsafe condition is perceived until the conditions are fully remedied to the satisfaction of the SSHO.

2.4 The health and safety considerations for the work associated with soil classification include:

- At no time during classification activities are personnel to reach for debris near machinery that is in operation, place any samples in their mouth, or come in contact with the soils/rocks without the use of gloves.

- Stay clear of all moving equipment and be aware of pinch points on machinery. Avoid wearing loose fitting clothing.
- When using cutting tools, cut away from yourself. The use of appropriate, task specific cutting tools is recommended.
- To avoid heat/cold stress as a result of exposure to extreme temperatures and PPE, drink electrolyte replacement fluids (1 to 2 cups per hour is recommended) and in case of extreme cold, wear insulating clothing.

3.0 Terms and Definitions

None.

4.0 Interference

None.

5.0 Training and Qualifications

5.1 The **Task Order (TO) Manager** is responsible for ensuring that the soil and rock classification procedures comply with this procedure. The **TO Manager** is responsible for ensuring that all personnel involved in soil and rock classification shall have the appropriate education, experience, and training to perform their assigned tasks.

5.2 The **Program Quality Manager** is responsible for ensuring overall compliance with this procedure.

5.3 The **Site Supervisor (SS)** is responsible for ensuring that all project **field personnel** follow these procedures.

5.4 Field personnel are responsible for the implementation of this procedure. Minimum qualifications for **field sampling personnel** require that one individual on the field team shall have a minimum of 6 months of experience with soil and rock classification.

5.5 The **project geologist** and/or **task manager** is responsible for directly supervising the soil and rock classification procedures to ensure that they are conducted according to this procedure, and for recording all pertinent data collected. If deviations from the procedure are required because of anomalous field conditions, they must first be approved by the **Program Quality Manager** and then documented in the field logbook and associated report or equivalent document.

6.0 Equipment and Supplies

6.1 The following equipment list contains materials which may be needed in carrying out the procedures outlined in this SOP. 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 by the APP/SSHP
- Field log book and pen with indelible ink
- Boring log
- Munsell Soil Color Chart
- Scoopula, spatula, and/or other small hand tools
- California Sampler
- Hand-held penetrometer

7.0 Calibration or Standardization

None.

8.0 Procedure

8.1 Soil Classification

The basic purpose of the classification of soil is to thoroughly describe the physical characteristics of the sample and to classify it according to an appropriate soil classification system. The USCS was developed so that soils could be described on a common basis by different investigators and serve as a "shorthand" description of soil. A classification of a soil in accordance with the USCS includes not only a group symbol and name, but also a complete word description.

Describing soil on a common basis is essential so that soil described by different site qualified personnel is comparable. Site individuals describing soil as part of site activities *must* use the classification system described herein to provide the most useful geologic database for all present and future subsurface investigations and remedial activities.

The site geologist or other qualified individual shall describe the soil and record the description in a boring log, logbook, and/or electronic field data collection device. The essential items in any written soil description are as follows:

- Classification group name (e.g., silty sand)
- Color, moisture, and odor
- Range of particle sizes and maximum particle size
- Approximate percentage of boulders, cobbles, gravel, sand, and fines
- Plasticity characteristics of the fines
- In-place conditions, such as consistency, density, and structure
- USCS classification symbol

The USCS serves as ”shorthand“ for classifying soil into 15 basic groups:

GW[1]	Well graded (poorly sorted) gravel (>50 percent gravel, <5percent fines)
GP[1]	Poorly graded (well sorted) gravel (>50percent gravel, <5percent fines)
GM[1]	Silty gravel (>50 percent gravel, >15 percent silt)
GC[1]	Clayey gravel (>50 percent gravel, >15 percent clay)
SW[1]	Well graded (poorly sorted) sand (>50 percent sand, <5 percent fines)
SP[1]	Poorly graded (well sorted) sand (>50 percent sand, <5 percent fines)
SM[1]	Silty sand (>50 percent sand, >15 percent silt)
SC[1]	Clayey sand (>50 percent sand, >15 percent clay)
ML[2]	Inorganic, low plasticity silt (slow to rapid dilatancy, low toughness, and plasticity)

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[1] If percentage of fine is 5 percent to 15 percent, a dual identification shall be given (e.g., a soil with more than 50 percent poorly sorted gravel and 10 percent clay is designated GW-GC.

CL[2]	Inorganic, low plasticity (lean) clay (no or slow dilatancy, medium toughness and plasticity)
MH[2]	Inorganic elastic silt (no to slow dilatancy, low to medium toughness and plasticity)
CH[2]	Inorganic, high plasticity (fat) clay (no dilatancy, high toughness, and plasticity)
OL	Organic low plasticity silt or organic silty clay
OH	Organic high plasticity clay or silt
PT	Peat and other highly organic soil

Figure8-1 defines the terminology of the USCS. Flow charts presented in Figure 8-2 and indicate the process for describing soil. The particle size distribution and the plasticity of the fines are the two properties of soil used for classification. In some cases, it may be appropriate to use a borderline classification (e.g., SC/CL) if the soil has been identified as having properties that do not distinctly place the soil into one group.

8.1.1 Estimation of Particle Size Distribution

One of the most important factors in classifying a soil is the estimated percentage of soil constituents in each particle size range. Being proficient in estimating this factor requires extensive practice and frequent checking. The steps involved in determining particle size distribution are listed below:

1. Select a representative sample (approximately 1/2 of a 6-inch long by 2.5-inch diameter sample liner).
2. Remove all particles larger than 3 inches from the sample. Estimate and record the percent by volume of these particles. Only the fraction of the sample smaller than 3 inches is classified.
3. Estimate and record the percentage of dry mass of gravel (less than 3 inches and greater than 1/4 inch).
4. Considering the rest of the sample, estimate, and record the percentage of dry mass of sand particles (about the smallest particle visible to the unaided eye).
5. Estimate and record the percentage of dry mass of fines in the sample (do not attempt to separate silts from clays).
6. Estimate percentages to the nearest 5 percent. If one of the components is present in a quantity considered less than 5 percent, indicate its presence by the term “trace”.
7. The percentages of gravel, sand, and fines must add up to 100 percent. “Trace” is not included in the 100 percent total.

8.1.2 Soil Dilatancy, Toughness, and Plasticity

8.1.2.1 Dilatancy

To evaluate dilatancy, follow these procedures:

1. From the specimen, select enough material to mold into a ball about 1/2 inch (12 millimeters [mm]) in diameter. Mold the material, adding water if necessary, until it has a soft, but not sticky, consistency.
2. Smooth the soil ball in the palm of one hand with the blade of a knife or small spatula. Shake horizontally, striking the side of the hand vigorously against 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

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[2] If the soil is estimated to have 15 percent to 25 percent sand or gravel, or both, the words “with sand” or “with gravel” (whichever predominates) shall be added to the group name (e.g., clay with sand, CL; or silt with gravel, ML). If the soil is estimated to have 30 percent or more sand or gravel, or both, the words “sandy” or “gravely” (whichever predominates) shall be added to the group name (e.g., sandy clay, CL). If the percentage of sand is equal to the percent gravel, use “sandy.”

pinching the soil between the fingers, and note the reaction as none, slow, or rapid in accordance with the criteria in Table 8-1. The reaction is the speed with which water appears while shaking and disappears while squeezing.

Table 8-1: Criteria for Describing Dilatancy

Description	Criteria
None	No visible change in 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.

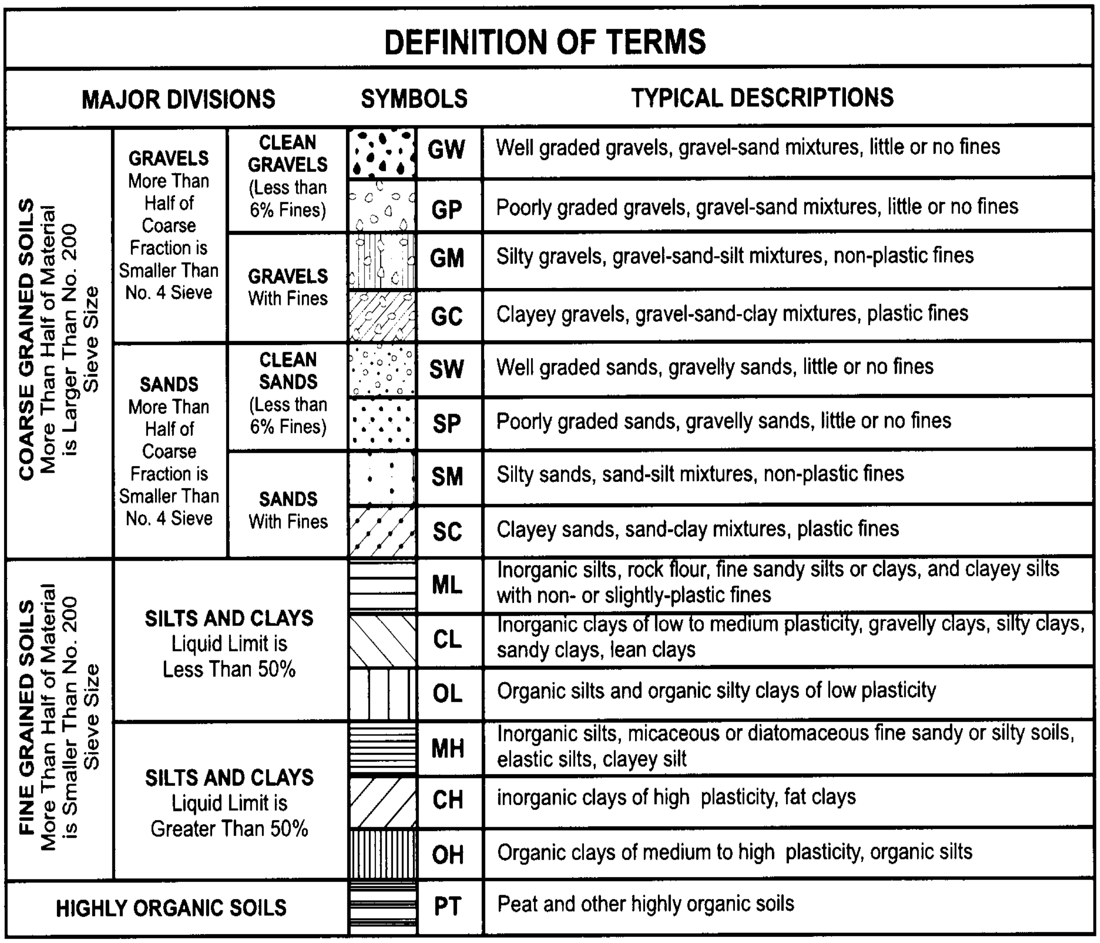
8.1.2.2 Toughness

Following the completion of the dilatancy test, shape the test specimen into an elongated pat and roll it 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, spread it into a thin layer and allow it to lose some water by evaporation.) Fold the sample threads and re-roll repeatedly until the thread crumbles at a diameter of about 1/8 inch. The thread will crumble at a diameter of 1/8 inch when the soil is near the plastic limit. Note the pressure required to roll the thread near the plastic limit. Also, note the strength of the thread. After the thread crumbles, lump the pieces together and knead it until the lump crumbles. Note the toughness of the material during kneading. Describe the toughness of the thread and lump as low, medium, or high in accordance with the criteria in Table 8-2.

Table 8-2: Criteria for Describing Toughness

Description	Criteria
Low	Only slight pressure is required to roll the thread near the plastic limit. The thread and the lump are weak and soft.
Medium	Medium pressure is required to roll the thread near the plastic limit. The thread and the lump have medium stiffness.
High	Considerable pressure is required to roll the thread near the plastic limit. The thread and the lump have very high stiffness.

Figure8-1: Unclassified Soil Classification System (USCS)



DEFINITION OF TERMS

MAJOR DIVISIONS			SYMBOLS	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS More Than Half of Material is Larger Than No. 200 Sieve Size	**GRAVELS** More Than Half of Coarse Fraction is Smaller Than No. 4 Sieve	**CLEAN GRAVELS** (Less than 6% Fines)	**GW**	Well graded gravels, gravel-sand mixtures, little or no fines
			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines
		GRAVELS With Fines	**GM**	Silty gravels, gravel-sand-silt mixtures, non-plastic fines
			GC	Clayey gravels, gravel-sand-clay mixtures, plastic fines
	SANDS More Than Half of Coarse Fraction is Smaller Than No. 4 Sieve	**CLEAN SANDS** (Less than 6% Fines)	**SW**	Well graded sands, gravelly sands, little or no fines
			SP	Poorly graded sands, gravelly sands, little or no fines
		SANDS With Fines	**SM**	Silty sands, sand-silt mixtures, non-plastic fines
			SC	Clayey sands, sand-clay mixtures, plastic fines
FINE GRAINED SOILS More Than Half of Material is Smaller Than No. 200 Sieve Size	**SILTS AND CLAYS** Liquid Limit is Less Than 50%		**ML**	Inorganic silts, rock flour, fine sandy silts or clays, and clayey silts with non- or slightly-plastic fines
			CL	Inorganic clays of low to medium plasticity, gravelly clays, silty clays, sandy clays, lean clays
			OL	Organic silts and organic silty clays of low plasticity
	SILTS AND CLAYS Liquid Limit is Greater Than 50%		**MH**	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts, clayey silt
			CH	inorganic clays of high plasticity, fat clays
			OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS			**PT**	Peat and other highly organic soils

GRAIN SIZES

SILTS AND CLAYS	SAND			GRAVEL		COBBLES	BOULDERS
	FINE	MEDIUM	COARSE	FINE	COARSE		

200 40 10 4 3/4“ 3“ 12“

U.S. STANDARD SERIES SIEVE CLEAR SQUARE SIEVE OPENINGS

Figure 8-2: Flow Chart for Fine Grain Soil Classification

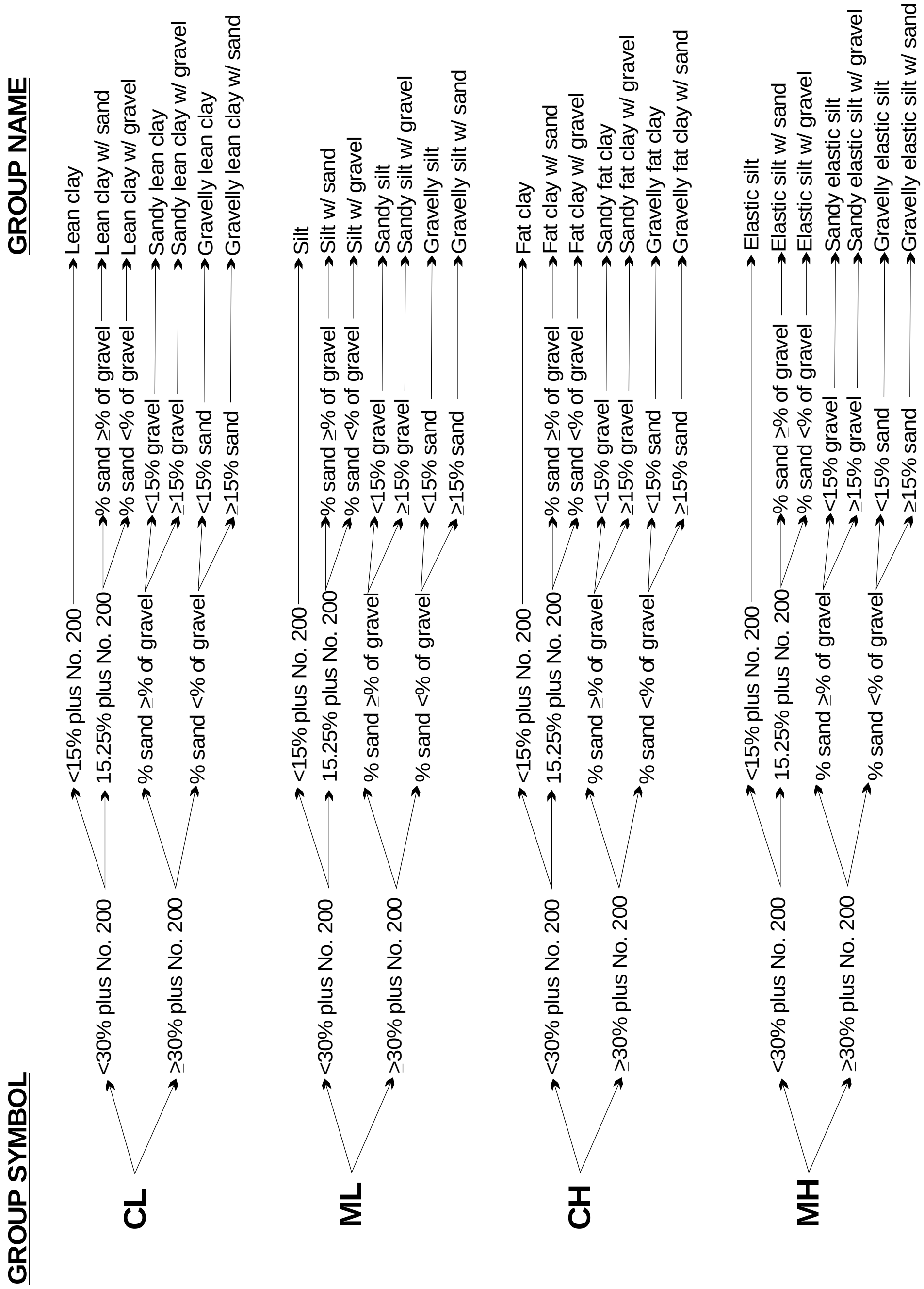
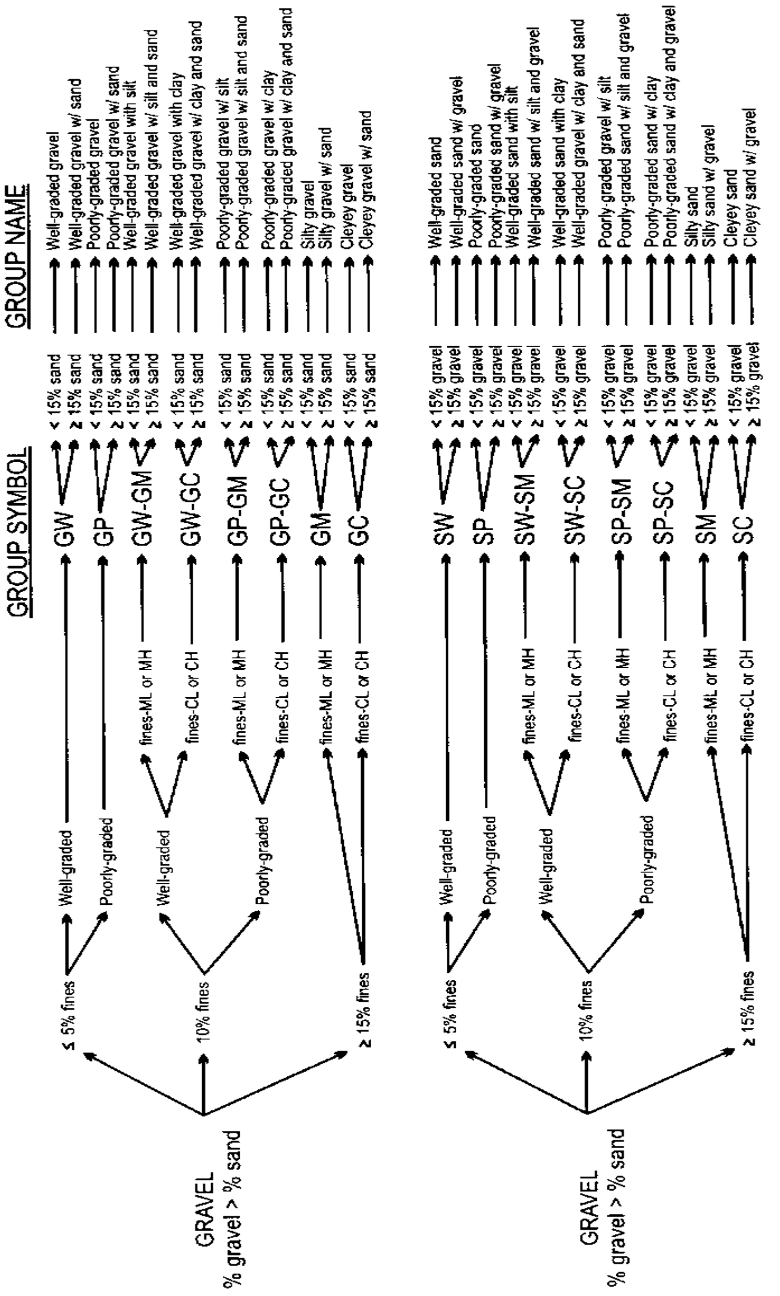


Figure 8-3: Flow Chart for Soil with Gravel



8.1.2.3 Plasticity

The plasticity of a soil is defined by the ability of the soil to deform without cracking, the range of moisture content over which the soil remains in a plastic state, and the degree of cohesiveness at the plastic limit. The plasticity characteristic of clays and other cohesive materials is defined by the liquid limit and plastic limit. The liquid limit is defined as the soil moisture content at which soil passes from the liquid to the plastic state as moisture is removed. The test for the liquid limit is a laboratory, not a field, analysis.

The plastic limit is the soil moisture content at which a soil passes from the plastic to the semi-solid state as moisture is removed. The plastic limit test can be performed in the field and is indicated by the ability to roll a 1/8-inch (0.125-inch) diameter thread of fines, the time required to roll the thread, and the number of times the thread can be re-rolled when approaching the plastic limit.

The plasticity tests are not based on natural soil moisture content, but on soil that has been thoroughly mixed with water. If a soil sample is too dry in the field, add water prior to performing classification. If a soil sample is too sticky, spread the sample thin and allow it to lose some soil moisture.

Table 8-3 presents the criteria for describing plasticity in the field using the rolled thread method.

Table 8-3: Criteria for Describing Plasticity

Description	Criteria
Non-Plastic	A 1/8-inch thread cannot be rolled.
Low Plasticity	The thread can barely be rolled.
Medium Plasticity	The thread is easy to roll and not much time is required to reach the plastic limit.
High Plasticity	It takes considerable time rolling the thread to reach the plastic limit.

8.1.3 Angularity

The following criteria describe the angularity of the coarse sand and gravel particles:

- **Rounded** particles have smoothly-curved sides and no edges.
- **Subrounded** particles have nearly plane sides but have well-rounded corners and edges.
- **Subangular** particles are similar to angular but have somewhat rounded or smooth edges.
- **Angular** particles have sharp edges and relatively plane sides with unpolished surfaces. Freshly broken or crushed rock would be described as angular.

8.1.4 Color, Moisture, and Odor

The natural moisture content of soil is very important. Table **8-4** shows the terms for describing the moisture condition and the criteria for each.

Table 8-4: Soil Moisture Content Qualifiers

Qualifier	Criteria
Dry	Absence of moisture, dry to the touch
Moist	Damp but no visible water
Wet	Visible water, usually soil is below water table

Color is described by hue and chroma using the Munsell Soil Color Chart (Munsell 2000). For uniformity, all site geologists shall utilize this chart for soil classification. Doing so will facilitate correlation of geologic units between boreholes logged by different geologists. The Munsell Color Chart is a small booklet of numbered color chips with names like “5YR 5/6, yellowish-red.” Note mottling or banding of colors. It is particularly important to note and describe staining because it may indicate contamination.

In general, wear a respirator if strong organic odors are present. If odors are noted, describe them if they are unusual or suspected to result from contamination. An organic odor may have the distinctive smell of decaying vegetation. Unusual odors may be related to hydrocarbons, solvents, or other chemicals in the subsurface. An organic vapor analyzer may be used to detect the presence of volatile organic contaminants.

8.1.5 In-Place Conditions

Describe the conditions of undisturbed soil samples in terms of their density/consistency (i.e., compactness), cementation, and structure utilizing the following guidelines:

8.1.5.1 Density/Consistency

Density and consistency describe a physical property that reflects the relative resistance of a soil to penetration. The term “density” is commonly applied to coarse to medium-grained sediments (i.e., gravels, sands), whereas the term “consistency” is normally applied to fine-grained sediments (i.e., silts, clays). There are separate standards of measure for both density and consistency that are used to describe the properties of a soil.

The density or consistency of a soil is determined by observing the number of blows required to drive a 1 3/8-inch (35 mm) diameter split barrel sampler 18 inches using a drive hammer weighing 140 lbs. (63.5 kilograms [kg]) dropped over a distance of 30 inches (0.76 meters). Record the number of blows required to penetrate each 6 inches of soil in the field boring log during sampling. The first 6 inches of penetration is considered to be a seating drive; therefore, the blow count associated with this seating drive is recorded, but not used in determining the soil density/consistency. The sum of the number of blows required for the second and third 6 inches of penetration is termed the “standard penetration resistance,” or the “N-value.” The observed number of blow counts must be corrected by an appropriate factor if a different type of sampling device (e.g., Modified California Sampler with liners) is used. For a 2 3/8-inch inner diameter (I.D.) Modified California Sampler equipped with brass or stainless-steel liners and penetrating a cohesionless soil (sand/gravel), the N-value from the Modified California Sampler must be divided by 1.43 to provide data that can be compared to the 1 3/8-inch diameter sampler data.

For a cohesive soil (silt/clay), the N-value for the Modified California Sampler should be divided by a factor of 1.13 for comparison with 1 3/8-inch diameter sampler data.

Drive the sampler and record blow counts for each 6-inch increment of penetration until one of the following occurs:

- A total of 50 blows have been applied during any one of the three 6-inch increments; a 50-blow count occurrence shall be termed “refusal” and noted as such on the boring log.
- A total of 150 blows have been applied.
- The sampler is advanced the complete 18 inches without the limiting blow counts occurring, as described above.

If the sampler is driven less than 18 inches, record the number of blows per partial increment on the boring log. If refusal occurs during the first 6 inches of penetration, the number of blows will represent the N-value for this sampling interval. Table 8-5 8-5 and Table 8-6 present representative descriptions of soil density/consistency vs. N-values.

Table 8-5: Measuring Soil Density with a California Sampler – Relative Density (Sands, Gravels)

Description	Field Criteria (N-Value)	
	1 3/8 in. ID Sampler	2 in. ID Sampler using 1.43 factor
Very Loose	0–4	0–6
Loose	4–10	6–14
Medium Dense	10–30	14–43

Description	Field Criteria (N-Value)	
	1 3/8 in. ID Sampler	2 in. ID Sampler using 1.43 factor
Dense	30–50	43–71
Very Dense	> 50	> 71

Table 8-6: Measuring Soil Density with a California Sampler – Fine Grained Cohesive Soil

Description	Field Criteria (N-Value)	
	1 3/8 in. ID Sampler	2 in. ID Sampler using 1.13 factor
Very Soft	0–2	0–2
Soft	2–4	2–4
Medium Stiff	4–8	4–9
Stiff	8–16	9–18
Very Stiff	16–32	18–36
Hard	> 32	> 36

For undisturbed fine-grained soil samples, it is also possible to measure consistency with a hand-held penetrometer. The measurement is made by placing the tip of the penetrometer against the surface of the soil contained within the sampling liner or Shelby tube, pushing the penetrometer into the soil a distance specified by the penetrometer manufacturer, and recording the pressure resistance reading in pounds per square foot (psf). The values are as follows (Table 8-7):

Table 8-7: Measuring Soil Consistency with a Hand-Held Penetrometer

Description	Pocket Penetrometer Reading (psf)
Very Soft	0–250
Soft	250–500
Medium Stiff	500–1000
Stiff	1000–2000
Very Stiff	2000–4000
Hard	>4000

Consistency can also be estimated using thumb pressure using Table 8-8.

Table 8-8: Measuring Soil Consistency Using Thumb Pressure

Description	Criteria
Very Soft	Thumb will penetrate soil more than 1 inch (25 mm)
Soft	Thumb will penetrate soil about 1 inch (25 mm)
Firm	Thumb will penetrate soil about 1/4 inch (6 mm)
Hard	Thumb will not indent soil but readily indented with thumbnail
Very Hard	Thumbnail will not indent soil

8.1.5.2 Cementation

Cementation is used to describe the friability of a soil. Cements are chemical precipitates that provide important information as to conditions that prevailed at the time of deposition, or conversely, diagenetic effects that occurred following deposition. Seven types of chemical cements are recognized by Folk (1980). They are as follows:

- Quartz – siliceous

- Chert – chert-cemented or chalcedonic
- Opal – opaline
- Carbonate – calcitic, dolomitic, sideritic (if in doubt, calcareous should be used)
- Iron oxides – hematitic, limonitic (if in doubt, ferruginous should be used)
- Clay minerals – if the clay minerals are detrital or have formed by recrystallization of a previous clay matrix, they are not considered to be a cement. Only if they are chemical precipitates, filling previous pore space (usually in the form of accordion-like stacks or fringing radial crusts) should they be included as “kaolin-cemented,” “chlorite-cemented,” etc.
- Miscellaneous minerals – pyritic, collophane-cemented, glauconite-cemented, gypsiferous, anhydrite-cemented, baritic, feldspar-cemented, etc.

The degree of cementation of a soil is determined qualitatively by utilizing finger pressure on the soil in one of the sample liners to disrupt the gross soil fabric. The three cementation descriptors are as follows:

- Weak – friable; crumbles or breaks with handling or slight finger pressure
- Moderate – friable; crumbles or breaks with considerable finger pressure
- Strong – not friable; will not crumble or break with finger pressure

8.1.5.3 Structure

This variable is used to qualitatively describe physical characteristics of soil that are important to incorporate into hydrogeological and/or geotechnical descriptions of soil at a site. Appropriate soil structure descriptors are as follows:

- Granular – spherically shaped aggregates with faces that do not accommodate adjoining faces
- Stratified – alternating layers of varying material or color with layers at least 6 mm (1/4 inch) thick; note thickness
- Laminated – alternating layers of varying material or color with layers less than 6 mm (1/4 inch) thick; note thickness
- Blocky – cohesive soil that can be broken down into small angular or subangular lumps that resist further breakdown
- Lensed – inclusion of a small pocket of different soil, such as small lenses of sand, should be described as homogeneous if it is not stratified, laminated, fissured, or blocky. If lenses of different soil are present, the soil being described can be termed homogeneous if the description of the lenses is included
- Prismatic or Columnar – particles arranged about a vertical line, ped is bounded by planar, vertical faces that accommodate adjoining faces; prismatic has a flat top; columnar has a rounded top
- Platy – particles are arranged about a horizontal plane

8.1.5.4 Other Features

- Mottled – soil that appears to consist of material of two or more colors in blotchy distribution
- Fissured – breaks along definite planes of fracture with little resistance to fracturing (determined by applying moderate pressure to sample using thumb and index finger)
- Slickensided – fracture planes appear polished or glossy, sometimes striated (parallel grooves or scratches)

8.1.6 Development of Soil Description

Develop standard soil descriptions according to the following examples. There are three principal categories under which all soil can be classified. They are described below.

8.1.6.1 Coarse-grained Soil

Coarse-grained soil is divided into sands and gravels. A soil is classified as a sand if over 50 percent of the coarse fraction is “sand-sized.” It is classified as a gravel if over 50 percent of the coarse fraction is composed of “gravel-sized” particles.

The written description of a coarse-grained soil shall contain, in order of appearance: Typical name including the second highest percentage constituent as an adjective, if applicable (underlined); grain size of coarse fraction; Munsell color and color number; moisture content; relative density; sorting; angularity; other features, such as stratification (sedimentary structures) and cementation, possible formational name, primary USCS classification, secondary USCS classification (when necessary), and approximate percentages of minor constituents (i.e., sand, gravel, shell fragments, rip-up clasts) in parentheses.

Example: POORLY-SORTED SAND WITH SILT, medium- to coarse-grained, light olive gray, 5Y 6/2, saturated, loose, poorly sorted, subrounded clasts, SW/SM (minor silt with approximately 20 percent coarse-grained sand-sized shell fragments, and 80 percent medium-grained quartz sand, and 5 percent to 15 percent ML).

8.1.6.2 Fine-grained Soil

Fine-grained soil is further subdivided into clays and silts according to its plasticity. Clays are rather plastic, while silts have little or no plasticity.

The written description of a fine-grained soil should contain, in order of appearance: Typical name including the second highest percentage constituent as an adjective, if applicable (underlined); Munsell color; moisture content; consistency; plasticity; other features, such as stratification, possible formation name, primary USCS classification, secondary USCS classification (when necessary), and the percentage of minor constituents in parentheses.

Example: SANDY LEAN CLAY, dusky red, 2.5 YR 3/2, moist, firm, moderately plastic, thinly laminated, CL (70 percent fines, 30 percent sand, with minor amounts of disarticulated bivalves [about 5 percent]).

8.1.6.3 Organic Soil

For highly organic soil, describe the types of organic materials present as well as the type of soil constituents present using the methods described above. Identify the soil as an organic soil, OL/OH, if the soil contains enough organic particles to influence the soil properties. Organic soil usually has a dark brown to black color and may have an organic odor. Often, organic soils will change color, (e.g., from black to brown) when exposed to air. Some organic soils will lighten in color significantly when air-dried. Organic soils normally will not have a high toughness or plasticity. The thread for the toughness test will be spongy.

8.2 Example: ORGANIC CLAY, black, 2.5Y, 2.5/1, wet, soft, low plasticity, organic odor, OL (100 percent fines), weak reaction to HCl.

8.3 Rock Classification

The purpose of rock classification is to thoroughly describe the physical and mineralogical characteristics of a specimen and to classify it according to an established system. The generalized rock classification system described below was developed because, unlike the USCS for soils, there is no universally accepted rock classification system. In some instances, a more detailed and thorough rock classification system may be appropriate. Any modifications to this classification system, or the use of an alternate classification system should be considered during preparation of the site work plan. Both the TO Manager and the QA Manager or Technical Director must approve any modifications to this classification system, or the use of another classification system.

Describing rock specimens on a common basis is essential so that rocks described by different site geologists are comparable. Site geologists describing rock specimens as a part of investigative activities must use the classification system described herein, or if necessary, another more detailed classification system. Use of a common classification system provides the most useful geologic database for all present and future subsurface investigations and remedial activities.

In order to provide a more consistent rock classification between geologists, a rock classification template has been designated as shown in **Error! Reference source not found.**. The template includes classification of rocks by origin and mineralogical composition. When classifying rocks, all site geologists shall use this template.

The site geologist shall describe the rock specimen and record the description in a boring log or logbook. The items essential for classification include (i.e., metamorphic foliated):

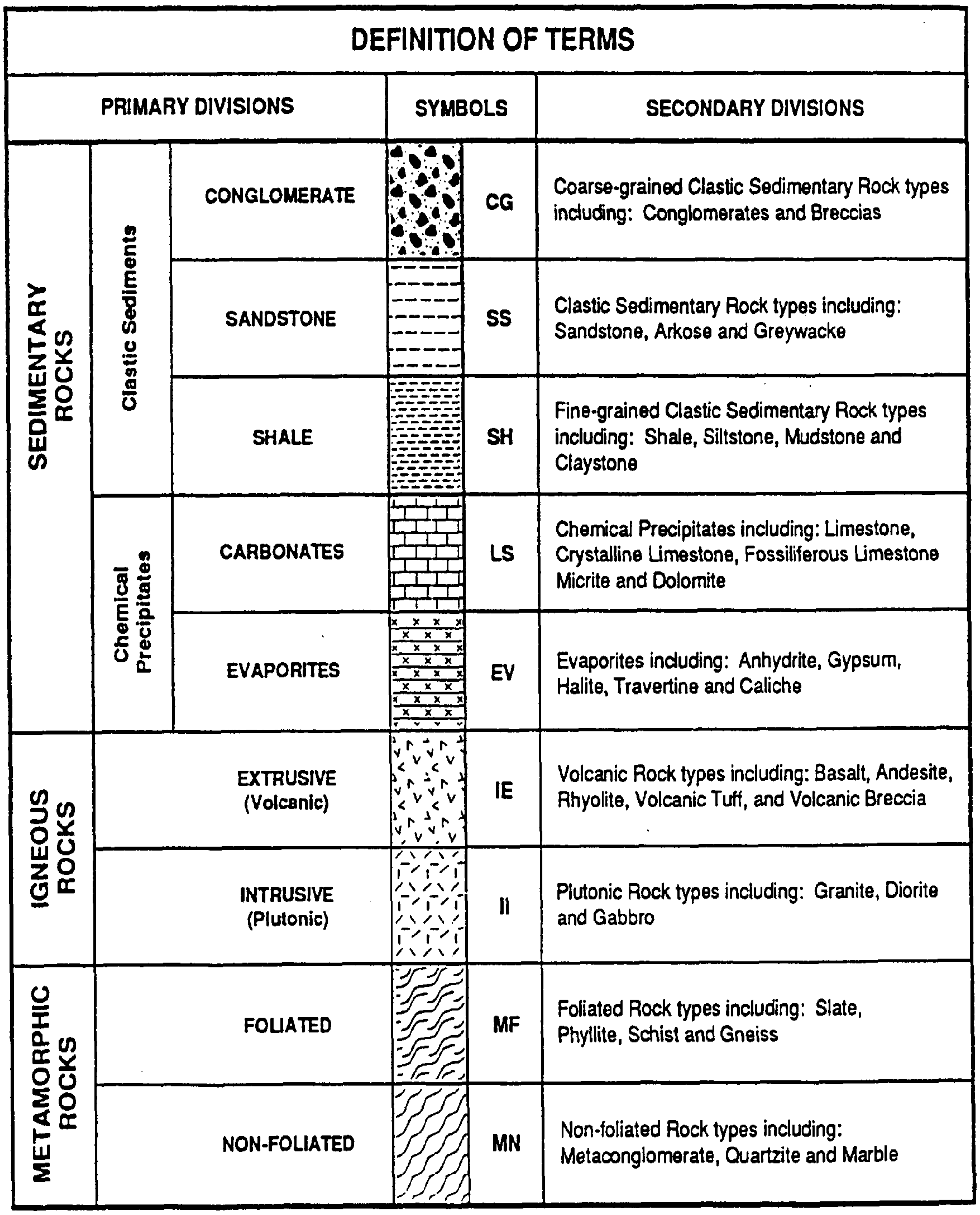
- Classification Name (i.e., schist)
- Color
- Mineralogical composition and percent
- Texture/Grain size (i.e., fine-grained, pegmatitic, aphlitic, glassy)
- Structure (i.e., foliated, fractured, lenticular)
- Rock Quality Designation (sum of all core pieces greater than two times the diameter of the core divided by the total length of the core run, expressed as a percentage)
- Classification symbol (i.e., MF)

Example: Metamorphic foliated schist: Olive gray, 5Y, 3/2, Garnet 25 percent, Quartz 45 percent, Chlorite 15 percent, Tourmaline 15 percent, Fine-grained with Pegmatite garnet, highly foliated, slightly wavy, MF.

9.0 Quality Control and Assurance

None

Figure 8-4: Rock Classification System



DEFINITION OF TERMS

PRIMARY DIVISIONS			SYMBOLS		SECONDARY DIVISIONS
SEDIMENTARY ROCKS	Clastic Sediments	CONGLOMERATE		CG	Coarse-grained Clastic Sedimentary Rock types including: Conglomerates and Breccias
		SANDSTONE		SS	Clastic Sedimentary Rock types including: Sandstone, Arkose and Greywacke
		SHALE		SH	Fine-grained Clastic Sedimentary Rock types including: Shale, Siltstone, Mudstone and Claystone
	Chemical Precipitates	CARBONATES		LS	Chemical Precipitates including: Limestone, Crystalline Limestone, Fossiliferous Limestone Micrite and Dolomite
		EVAPORITES		EV	Evaporites including: Anhydrite, Gypsum, Halite, Travertine and Caliche
IGNEOUS ROCKS		EXTRUSIVE (Volcanic)		IE	Volcanic Rock types including: Basalt, Andesite, Rhyolite, Volcanic Tuff, and Volcanic Breccia
		INTRUSIVE (Plutonic)		II	Plutonic Rock types including: Granite, Diorite and Gabbro
METAMORPHIC ROCKS		FOLIATED		MF	Foliated Rock types including: Slate, Phyllite, Schist and Gneiss
		NON-FOLIATED		MN	Non-foliated Rock types including: Metaconglomerate, Quartzite and Marble

10.0 Data and Records Management

10.1 Document soil classification information collected during soil sampling onto the field boring logs, field trench logs, and into the field notebook. Copies of this information shall be sent to the **TO Manager** for the project files.

10.2 Field notes will be kept during coring activities in accordance with SOP 3-03 – Recordkeeping, Sample Labeling, and Chain of Custody. The information pertinent to soil classification activities includes chronology of events, sample locations (x,y,z), time/date, sampler name, methods (including type of core liner/barrel, if applicable), sampler penetration and acceptability, sample observations, and the times and type of equipment decontamination. Deviations to the procedures detailed in the SOP should be recorded in the field logbook.

11.0 Attachments or References

American Society for Testing and Materials (ASTM). 2000. *Standard Practice for Description and Identification of Soils (Visual, Manual Procedure)*. D 2488-00. West Conshohocken, PA.

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Author	Reviewer	Revisions (Technical or Editorial)
Robert Shoemaker Senior Scientist	Naomi Ouellette, Project Manager	Rev 0 – Initial Issue
Ken O'Donnell, PG Geologist	Claire Mitchell, PE, PMP Senior Engineer	Rev 1 – PFAS sampling update (July 2019)

Direct Push Sampling Techniques

Procedure 3-17

1.0 Purpose and Scope

1.1 This standard operating procedure (SOP) provides guidance on the use of direct push techniques.

1.2 This procedure is the Program-approved professional guidance for work performed by AECOM under the client contract.

1.3 This procedure shall serve as management-approved professional guidance and is consistent with protocol in the Uniform Federal Policy-Quality Assurance Project Plan (UFP-QAPP; DoD 2005). As professional guidance for specific activities, this procedure is not intended to obviate the need for professional judgment during unforeseen circumstances. Deviations from this procedure while planning or executing planned activities must be approved by both the Task Order (TO) Manager and the Quality Assurance (QA) Manager or Technical Director, and documented.

1.4 If there are procedures whether it be from AECOM, state and/or federal that are not addressed in this SOP and are applicable to direct push sampling then those procedures may be added as an appendix to the project-specific QAPP.

2.0 Safety

2.1 Field personnel shall perform work in accordance with the Accident Prevention Plan (APP)/Site Safety and Health Plan (SSHP). During monitoring well installation, subcontractors in direct contact with potentially contaminated media shall wear the proper personal protective equipment (PPE) as outlined in the APP/SSHP. Failure to comply will result in disciplinary action.

2.2 If circumstances warrant, a real-time immediate response instrument, such as a Miniram Dust Monitor, organic vapor analyzer, HNu, Thermo, Draeger or Sensidyne tubes, or explosimeter, should be used to monitor the work area. When real/time instrument response exceeds the permissible exposure limit, personnel shall don the appropriate PPE and alternate control measures to ensure personnel safety. If safe control measures are not achievable, field activities shall be discontinued immediately. Company-specific APP/SSHPs offer guidelines on air surveillance and on selection of PPE. In addition, the site-specific APP/SSHP includes an air monitoring program and suggested PPE.

2.3 In addition to the aforementioned precautions and depending upon the type of contaminant expected, employ the following safe work practices:

Particulate, Metal Compounds, or PFAS/PFOS

1. Avoid skin contact and/or incidental ingestion of soil.
2. Wear protective clothing, steel-toed boots, powderless Nitrile gloves with non-water-repellent protective leather gloves, safety glasses, and hearing protection as warranted.

VOCs

1. Avoid breathing constituents venting from holes by approaching upwind, and/or by use of respiratory protection.
2. Pre-survey the area with a flame ionization detector (FID) or photoionization detector (PID) prior to sampling.
3. If monitoring results indicate organic vapors that exceed action levels as specified in the site-specific APP/SSHP, sampling activities may need to be conducted in Level C protection. At a

NOTE: SOPs have been updated for PFAS sampling activities; however, AECOM's internal PFAS sampling guidance supersedes materials and methods described in SOPs.

minimum, skin protection will be required by use of gloves and Tyvek or other media that is protective against the media being encountered.

Flammable or Explosive Conditions

1. Monitor explosive gases as continuously as possible using an explosimeter and oxygen meter.
2. Place all ignition sources upwind or crosswind of the borehole.
3. If explosive gases exceed the designated action levels as specified in the site-specific APP/SSHP, cease operations and evaluate conditions.

Physical Hazards Associated with Soil Sampling

1. To avoid possible back strain associated with sample collection, use the large muscles of the legs, not the back, when retrieving soil samplers.
2. Stay clear of all moving equipment, and avoid wearing loose fitting clothing.
3. To avoid slip/trip/fall hazards, be wary of open trenches, pits, or holes.
4. Be aware of restricted mobility due to PPE.
5. To avoid hand, wrist, arm, shoulder, and back trauma due to the use of slide hammers or hand augers, rotate sampling among field personnel

3.0 Terms and Definitions

3.1 Direct push techniques are methods for subsurface sampling or monitoring that involve the application of downward pressure (usually supplied through hydraulic means) without the benefit of cutting tool rotation to enter soil. A variety of systems are available under several trade names, such as GeoProbe®. Equipment may be skid-mounted, trailered, or mounted directly on the frame of a vehicle.

4.0 Interferences

4.1 Potential interferences could result from cross-contamination between samples or sample locations. Minimization of the cross contamination will occur through the following:

- The use of clean sampling tools at each location as necessary.
- Avoidance of material that is not representative of the media to be sampled.

5.0 Training and Qualifications

5.1 Qualifications and Training

The individual executing these procedures must have read, and be familiar with, the requirements of this SOP.

5.2 Responsibilities

5.2.1 The TO Manager is responsible for ensuring that these standard direct push technique procedures are followed during projects conducted under the ER Program and that a qualified individual conducts or supervises the projects. A qualified individual for subsurface sampling or monitoring using direct push techniques is defined as a person with a degree in geology, hydrogeology, or geotechnical/civil engineering with at least 1 year of experience supervising soil boring construction using conventional drilling or direct push techniques. The TO Manager or designee is responsible for ensuring that all personnel involved in direct push sampling techniques shall have the appropriate education, experience, and training to perform their assigned tasks as specified in Chief of Naval Operations Instruction 5090.1c (DON 2007).

5.2.2 The **Program Quality Manager** is responsible for ensuring overall compliance with this procedure.

5.2.3 The **Site Supervisor (SS)** is responsible for ensuring that all field personnel follow these procedures.

5.2.4 All **Field Personnel** are responsible for the implementation of this procedure.

5.2.5 The **Field Personnel** and/or **SS** are responsible for directly supervising the direct push sampling activities to ensure that they are conducted according to this procedure, and for recording all pertinent data collected during sampling.

6.0 Equipment and Supplies

In addition to those materials provided by the subcontractor, the project **SS/Field Personnel** will require:

- Boring Logs;
- Spoons or scoops;
- Sample kit (bottles, labels, custody records and tape, cooler, wet ice), if laboratory analysis is required;
- Sample collection pan;
- Folding rule or tape measure;
- Polyethylene plastic sheeting;
- Utility knife;
- Equipment decontamination materials (as described in SOP 3-06, *Equipment Decontamination*);
- Health and safety equipment (as required by APP/SSHP); and
- Non-water-repellent field project notebook/pen.

7.0 Procedure

Direct push techniques may be used as a cost-effective alternative to conventional drilling techniques for obtaining subsurface soil and groundwater samples and for monitoring subsurface conditions.

7.1 Method Selection

Base the decision to use direct push techniques on: (1) their ability to achieve the required information at the required level of quality control and (2) their cost-effectiveness compared to conventional drilling methods. Major limitations of direct push techniques are their inability to penetrate rock or cobbles and a shallow maximum depth of penetration. The capabilities of direct push systems vary significantly among vendors. Consider these differences in capabilities when evaluating the method for a subsurface exploration program.

Use direct push techniques to obtain groundwater samples for confirmatory analyses only if the screen placement method protects the screen from clogging during installation and allows the installation of a sand-pack around the exterior of the well screen.

7.2 Inspection of Equipment

Inspect direct push equipment prior to use for signs of fluid leakage, which could introduce contaminants to the soil. If, at any time during equipment operation, fluid is observed leaking from the rig, cease operations and immediately repair or contain the leak. Collect, containerize, and label soil and other materials affected by the leak for proper disposal (see SOP 3-05, *IDW Management*).

7.3 Preparation of Work Site

Inspect the work site prior to commencing operations to ensure that no overhead hazards exist that could impact the direct push equipment, and the work area should cleared and/or marked by the local underground utility locating service (e.g., DigSafe). In addition, clear locations planned for subsurface exploration using either geophysical methods and/or hand excavate locations to a depth of 2 to 3 feet prior to soil penetration, unless it is certain (by virtue of subsurface clearing activities) that no utilities or other hazardous obstructions will be encountered in the first 2 to 3 feet. Hand excavation may be waived when it is not practical.

Locate the direct push rig so that it is downslope from the penetration point, if the work is to be performed on a grade. Locate the rig downwind or crosswind of the penetration point, if possible. Cover the area surrounding, and in the vicinity of, the penetration point with plastic. Establish required exclusion zones using plastic tape or cones to designate the various areas.

7.4 Equipment Decontamination

To avoid cross-contamination, thoroughly decontaminate equipment used for direct push exploration and sampling as described in SOP 3-06, *Equipment Decontamination*. Decontaminate sampling tools and downhole equipment between each sampling event and between penetration points. At a minimum, steam clean or wash and rinse the equipment. Collect, containerize, and label all wash and rinse water for proper disposal. Clean equipment (e.g., drive rods and samplers) shall not come into contact with contaminated soils or other contaminated materials. Keep equipment on plastic or protect it in another suitable fashion. Store push rods and other equipment removed from a hole on plastic sheeting until properly decontaminated.

7.5 Soil Sampling

This SOP assumes that the subcontractor will perform sampling; therefore, detailed procedures regarding sample acquisition are not provided. Vendors of direct push equipment offer a variety of sampling systems designed specifically for their equipment. Both continuous and discreet soil samples may be obtained using sampling equipment similar to that described in Procedure 3-21, *Surface and Subsurface Soil Sampling*. The preferred methods for soil sampling using direct push techniques use stainless steel split-tube samplers that are driven through the horizon to be sampled. Use plastic sample tubes (e.g., Macro-Core Samplers) only for screening purposes or, in the case of confirmatory sampling, if samples will not be analyzed for volatile organic compounds (VOCs) or semivolatile organic compounds (SVOCs).

7.6 Groundwater Sampling

Direct push vendors offer numerous methods for obtaining groundwater samples. Key differences among methods involve: (1) the maximum well diameter achievable; (2) the ability to protect the well screen from exposure to contaminated overburden soils during installation; (3) the ability to install packing around the screen; (4) flexibility in the size, materials of construction, and design of well screens; and (5) the ability to convert sampling points into permanent monitoring wells. The limitations and abilities of a given system must be thoroughly understood and matched to the needs of the project before committing to the collection of groundwater samples using direct push techniques.

Use direct push techniques only to collect screening samples unless it is confirmed that the system:

1. Effectively protects the well screen from exposure to contaminated overburden soils during installation
2. Allows the installation of effective packing around the well screen
3. Allows the well screen to be effectively sealed against the downward infiltration of overlying groundwater or surface precipitation
4. Is constructed of materials compatible with the intended sampling and analysis goals of the project

5. Allows the use of a well screen properly sized and slotted for the needs of the project

Additional information on the collection of groundwater samples can be found in SOP 3-14 Monitoring Well Sampling.

It is the responsibility of the **TO Manager** to evaluate and determine the appropriateness of direct push systems prior to committing to their use on any project involving groundwater sampling. As part of this evaluation, it is recommended to obtain concurrence from regulatory authorities in advance for the method selection.

7.7 Borehole Abandonment

Methods for abandoning boreholes created with direct push systems will vary among vendors. Coordinate the desired method for abandonment with the vendor in the planning stages of the project to ensure proper abandonment.

Some direct push boreholes will close naturally as the drive rods and sampling tools are withdrawn. This may occur in loose, unconsolidated soils, such as sands. Close all boreholes using one of the procedures described in this procedure, unless natural caving precludes such closure.

The three methods for closing direct push boreholes are:

1. Add granulated or pelletized bentonite and hydrate in layers, proceeding from the bottom of the hole to the surface.
2. Pour premixed cement/water (or cement/water/bentonite) mixture into the hole.
3. Fill the entire hole with granular or pelletized bentonite and hydrate by means of a previously emplaced water tube that is gradually withdrawn as water is supplied to the bentonite.

The second method is recommended. For shallow holes less than 10 feet in depth, pour a cement/water/bentonite mix directly into the opening using a funnel. For deeper holes, use a conductor (tremie) pipe to carry the grout mix to the far reaches of the borehole. Lower the conductor pipe to within 2 inches of the bottom and gradually withdraw it as grout is added, keeping the lower end of the pipe submerged in grout at all times.

The recommended grout mixture for well abandonment is 7 to 9 gallons of water per 94-pound bag of Portland cement, with 3 percent to 5 percent by weight of powdered bentonite added to the mixture. Commercial products, such as Volcay are acceptable with pre-approval of the **TO Manager**.

Seal boreholes to within 0.5 to 2.0 feet of the surface. Inspect the abandoned borehole after 24 hours to ensure that grout shrinkage does not occur. If significant shrinkage has occurred, re-grout the borehole. Fill the remaining portion of the hole with local topsoil or appropriate paving materials.

8.0 Quality Control and Assurance

8.1 Collection of representative samples will be ensured through adherence to the procedures in this SOP and the sampling strategy outlined in the QAPP. The field quality control samples identified in the QAPP must be collected. These samples may include field duplicates, equipment rinsate blanks, trip blanks, and matrix spike/matrix spike duplicates

9.0 Records, Data Analysis, Calculations

9.1 Various forms are required to ensure that adequate documentation is made of the sample collection activities. These forms may include:

- Boring logs;
- Non-water-repellent field logbook;
- Sample collection records;

- Chain-of-custody forms; and
- Shipping labels.

9.2 Boring logs (Attachment 1) will provide visual and descriptive information for samples collected at each soil boring and are often the most critical form of documentation generated during a soil sampling program.

9.3 The field logbook is kept as a general log of activities and should not be used in place of the boring log.

9.4 Chain-of-custody forms are transmitted with the samples to the laboratory for sample tracking purposes.

9.5 Shipping labels are required is sample coolers are to be transported to a laboratory by a third party (courier service).

10.0 Attachments or References

10.1 Attachment 1 – Boring Log

10.2 Department of Defense, United States (DoD). 2005. *Uniform Federal Policy for Quality Assurance Project Plans, Part 1: UFP-QAPP Manual*. Final Version 1. DoD: DTIC ADA 427785, EPA-505-B-04-900A. In conjunction with the U. S. Environmental Protection Agency and the Department of Energy. Washington: Intergovernmental Data Quality Task Force. March. On-line updates available at: http://www.epa.gov/fedfac/pdf/ufp_qapp_v1_0305.pdf.

10.3 SOP 3-05, *IDW Management.*

10.4 SOP 3-06, *Equipment Decontamination.*

10.5 SOP 3-21, *Surface and Subsurface Soil Sampling.*

Author	Reviewer	Revisions (Technical or Editorial)
Mark Kromis Program Chemist	Chris Barr Program Quality Manager	Rev 0 – Initial Issue (May 2012)
Ken O'Donnell, PG Geologist	Claire Mitchell, PE, PMP Senior Engineer	Rev 1 – PFAS sampling update (July 2019)

Attachment 1
Boring Log

Boring ID:

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Project Name:	**Drilling Company:**	**Type of Surface Material:**
Project Number:	**Drilling Method:**	**Patching Material:**
Date Started Drilling:	**Rig Type:**	**Drilling Water Level:**
Date Finished Drilling:	**Core Size:**	**Boring Total Depth (bgs):**
Physical Location:		**Logged By:**

(Note: bgs = below ground surface)

Depth Range	**Re covery ft/ft**	**PID (ppm)**	**Moisture Content**	**GA Class.**	**USCS**	**GA Class: Garfield Avenue Sites classification & Modified Unified Soil Clasiffication System**	
						Ground Surface Cover and Thickness:	**Sample name & #:**
0-1							
1-2							
2-3							
3-4							
4-5							
5-6							
6-7							
7-8							
8-9							
9-10							
10-11							
11-12							
12-13							
13-14							
14-15							
15-16							
16-17							
17-18							
18-19							
19-20							

Stratigraphic Unit Intervals:		**Comments:**
1.)	**5.)**	
2.)	**6.)**	
5.)	**6.)**	

Operation and Calibration of a Photoionization Detector

Procedure 3-20

1.0 Purpose and Scope

1.1 Purpose and Applicability

1.1.1 This standard operating procedure (SOP) describes the procedures that will be followed by field staff for operation and calibration of a photoionization detector (PID). The PID is primarily used by AECOM personnel for safety and survey monitoring of ambient air, determining the presence of volatiles in soil and water, and detecting leakage of volatiles.

1.1.2 PIDs routinely used by field personnel include the Photovac Microtip, Thermoelectron 580EZ, MiniRAE 2000, and MiniRae 3000. Personnel responsible for using the PID should first read and thoroughly familiarize themselves with the instrument instruction manual.

1.2 Principle of Operation

1.2.1 The PID is a non-specific vapor/gas detector. The unit generally consists of a hand-held probe that houses a PID, consisting of an ultraviolet (UV) lamp, two electrodes, and a small fan which pulls ambient air into the probe inlet tube. The probe is connected to a readout/control box that consists of electronic control circuits, a readout display, and the system battery. Units are available with UV lamps having an energy from 9.5 electron volts (eV) to 11.7 eV.

1.2.2 The PID analyzer measures the concentration of trace gas present in the atmosphere by photoionization. Photoionization occurs when an atom or molecule absorbs a photon of sufficient energy to release an electron and become a positive ion. This will occur when the ionization potential of the molecule (in electron volts (eV) is less than the energy of the photon. The source of photons is an ultraviolet lamp in the probe unit. Lamps are available with energies ranging from 9.5 eV to 11.7 eV. All organic and inorganic vapor/gas compounds having ionization potentials lower than the energy output of the UV lamp are ionized and the resulting potentiometric change is seen as a positive reading on the unit. The reading is proportional to the concentration of organics and/or inorganics in the vapor.

1.2.3 Sample gases enter the probe through the inlet tube and enter the ion chamber where they are exposed to the photons emanating from the UV lamp. Ionization occurs for those molecules having ionization potentials near to or less than that of the lamp. A positive- biased polarizing electrode causes these positive ions to travel to a collector electrode in the chamber. Thus the ions create an electrical current which is amplified and displayed on the meter. This current is proportional to the concentration of trace gas present in the ion chamber and to the sensitivity of that gas to photoionization.

1.2.4 In service, the analyzer is first calibrated with a gas of known composition equal to, close to, or representative of that to be measured. Gases with ionization potentials near to or less than the energy of the lamp will be ionized. These gases will thus be detected and measured by the analyzer. Gases with ionization potentials greater than the energy of the lamp will not be detected. The ionization potentials of the major components of air, i.e., oxygen, nitrogen, and carbon dioxide, range from about 12.0 eV to 15.6 eV and are not ionized by any of the lamps available. Gases with ionization potentials near to or slightly higher than the lamp are partially ionized, with low sensitivity.

1.3 Specifications

1.3.1 Refer to the manufacturer's instructions for the technical specifications of the instrument being used. The operating concentration range is typically 0.1 to 2,000 ppm isobutylene equivalent.

2.0 Safety

2.1 The health and safety considerations for the work associated with this SOP, including both potential physical and chemical hazards, will be addressed in the project Accident Prevention Plan (APP)/Site Safety and Health Plan (SSHP). Work will also be conducted according to the Task Order (TO) Quality Assurance Project Plan (QAPP) and/or direction from the **Site Safety and Health Officer (SSHO)**.

2.2 Only PIDs stamped Division I Class I may be used in explosive atmospheres. Refer to the project APP/SSHP for instructions pertaining to instrument use in explosive atmospheres.

3.0 Terms and Definitions

None.

4.0 Interferences

4.1 Regardless of which gas is used for calibration, the instrument will respond to all analytes present in the sample that can be detected by the type of lamp used in the PID.

4.2 Moisture will generate a positive interference in the concentration measured for a PID and is characterized by a slow increase in the reading as the measurement is made. Care must be taken to minimize uptake of moisture to the extent possible. Refer to the manufacturers' instructions for care, cleaning, and maintenance.

4.3 Uptake of soil into the PID must be avoided as it will compromise instrument performance by blocking the probe, causing a positive interference, or dirtying the PID lamp. Refer to the manufacturers' instructions for care, cleaning, and maintenance.

4.4 The user should listen to the pitch of the sampling pump. Any changes in pitch may indicate a blockage and corrective action should be initiated.

5.0 Training and Qualifications

5.1 Qualifications and Training

The individual executing these procedures must have read, and be familiar with, the requirements of this SOP.

5.2 Responsibilities

5.2.1 The **TO Manager** is responsible for ensuring that the operation and calibration activities comply with this procedure. The **TO Manager** is responsible for ensuring that all personnel involved in the operation and calibration shall have the appropriate education, experience, and training to perform their assigned tasks.

5.2.2 The **Program Quality Manager** is responsible for ensuring overall compliance with this procedure.

5.2.3 The **Site Supervisor (SS)** is responsible for ensuring that all operation and calibration activities are conducted according to this procedure.

5.2.4 All **Field Personnel** are responsible for the implementation of this procedure.

6.0 Equipment and Supplies

- Calibration Gas: Compressed gas cylinder of isobutylene in air or similar stable gas mixture of known concentration. The selected gas should have an ionization potential similar to that of the vapors to be monitored, if known. The concentration should be at 50-75% of the range in which the instrument is to be calibrated;
- Regulator for calibration gas cylinder;

- Approximately 6 inches of Teflon® tubing;
- Tedlar bag (optional);
- Commercially-supplied zero grade air (optional);
- "Magic Marker" or “Sharpie” or other waterproof marker;
- Battery charger;
- Moisture traps;
- Spare lamps;
- Manufacturer’s instructions; and
- Field data sheets or logbook/pen.

7.0 Procedure

7.1 Preliminary Steps

7.1.1 Preliminary steps (battery charging, check-out, calibration, maintenance) should be conducted in a controlled or non-hazardous environment.

7.2 Calibration

7.2.1 The PID must be calibrated in order to display concentrations in units equivalent to ppm. First a supply of zero air (ambient air or from a supplied source), containing no ionizable gases or vapors is used to set the zero point. A span gas, containing a known concentration of a photoionizable gas or vapor, is then used to set the sensitivity.

7.2.2 Calibrate the instrument according to the manufacturer’s instructions. Record the instrument model and identification number, the initial and adjusted meter readings, the calibration gas composition and concentration, and the date and the time in the field records.

7.2.3 If the calibration cannot be achieved or if the span setting resulting from calibration is 0.0, then the lamp must be cleaned (Section 7.4).

7.3 Operation

7.3.1 Turn on the unit and allow it to warm up (minimum of 5 minutes). Check to see if the intake fan is functioning; if so, the probe will vibrate slightly and a distinct sound will be audible when holding the probe casing next to the ear. Also, verify on the readout display that the UV lamp is lit.

7.3.2 Calibrate the instrument as described in Section 7.2, following the manufacturer’s instructions. Record the calibration information in the field records.

7.3.3 The instrument is now operational. Readings should be recorded in the field records.

7.3.4 When the PID is not being used or between monitoring intervals, the unit may be switched off to conserve battery power and UV lamp life; however, a “bump” test should be performed each time the unit is turned on and prior to taking additional measurements. To perform a bump test, connect the outlet tubing from a Tedlar bag containing a small amount of span gas to the inlet tubing on the unit and record the reading. If the reading is not within the tolerance specified in the project plan, the unit must be recalibrated.

7.3.5 At the end of each day, recheck the calibration. The check will follow the same procedures as the initial calibration (Section 7.2) except that no adjustment will be made to the instrument. Record the information in the field records.

7.3.6 Recharge the battery after each use (Section 7.4).

7.3.7 When transporting, ensure that the instrument is packed in its stored condition in order to prevent damage.

7.4 Routine Maintenance

7.4.1 Routine maintenance associated with the use of the PID includes charging the battery, cleaning the lamp window, replacing the detector UV lamp, replacing the inlet filter, and replacing the sample pump. Refer to the manufacturer's instructions for procedures and frequency.

7.4.2 All routine maintenance should be performed in a non-hazardous environment.

7.5 Troubleshooting Tips

7.5.1 One convenient method for periodically confirming instrument response is to hold the sensor probe next to the tip of a magic marker. A significant reading should readily be observed.

7.5.2 Air currents or drafts in the vicinity of the probe tip may cause fluctuations in readings.

7.5.3 A fogged or dirty lamp, due to operation in a humid or dusty environment, may cause erratic or fluctuating readings. The PID should never be operated without the moisture trap in place.

7.5.4 Moving the instrument from a cool or air-conditioned area to a warmer area may cause moisture to condense on the UV lamp and produce unstable readings.

7.5.5 A zero reading on the meter should not necessarily be interpreted as an absence of air contaminants. The detection capabilities of the PID are limited to those compounds that will be ionized by the particular probe used.

7.5.6 Many volatile compounds have a low odor threshold. A lack of meter response in the presence of odors does not necessarily indicate instrument failure.

7.5.7 When high vapor concentrations enter the ionization chamber in the PID the unit can become saturated or "flooded". Remove the unit to a fresh air environment to allow the vapors to be completely ionized and purged from the unit.

8.0 Quality Control and Assurance

8.1 The end use of the data will determine the quality assurance requirements that are necessary to produce data of acceptable quality. These quality assurance requirements will be defined in the site-specific QAPP.

8.2 Calibration of the PID will be conducted at the frequency specified in the project plan. In the absence of project-specific guidance, calibration will be performed at the beginning of each day of sampling and will be checked at the end of the sampling day or whenever instrument operation is suspect. The PID will sample a calibration gas of known concentration. The instrument must agree with the calibration gas within ±10%. If the instrument responds outside this tolerance, it must be recalibrated.

8.3 Checks of the instrument response (Section 7.5) should be conducted periodically and documented in the field records.

9.0 Records, Data Analysis, Calculations

Safety and survey monitoring with the PID will be documented in a bound field logbook, or on standardized forms, and retained in the project files. The following information is to be recorded:

- Project name and number;
- Instrument manufacturer, model, and identification number;
- Operator's signature;

- Date and time of operation;
- Calibration gas used;
- Calibration check at beginning and end of day (meter readings before adjustment);
- Span setting after calibration adjustment;
- Meter readings (monitoring data obtained);
- Instances of erratic or questionable meter readings and corrective actions taken; and
- Instrument checks and response verifications – e.g., battery check, magic marker response (Section 7.5) or similar test.

10.0 Attachments or References

United States Environmental Protection Agency. Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM). USEPA, Region 4, SESD, Enforcement and Investigations Branch, Athens, GA. November 2001.

Author	Reviewer	Revisions (Technical or Editorial)
Robert Shoemaker Senior Scientist	Chris Barr Program Quality Manager	Rev 0 – Initial Issue (May 2012)
Ken O’Donnell, PG Geologist	Claire Mitchell, PE, PMP Senior Engineer	Rev 1 – PFAS sampling update (July 2019)

Surface and Subsurface Soil Sampling Procedures

Procedure 3-21

1.0 Purpose and Scope

1.1 This standard operating procedure (SOP) describes the procedures for soil sampling. The procedure includes surface and subsurface sampling by various methods using hand auguring, test pit, direct-push, sonic drilling, and split-spoon equipment.

1.2 For project specific information (e.g., sampling depths, equipment to be used, and frequency of sampling), refer to the Quality Assurance Project Plan (QAPP), which takes precedence over these procedures. Surface soil sampling, typically considered to be up to two feet below ground surface by United States Environmental Protection Agency (USEPA) standards, is typically accomplished using hand tools such as shovels or hand augers. Test pit samples are considered subsurface samples, although normally collected via hand tools similar to surface soil sampling or by excavation machinery. Direct-push and split-spoon sampling offer the benefit of collecting soil samples from a discrete or isolated subsurface interval without the need of extracting excess material above the target depth. These methods dramatically reduce time and cost associated with disposal of material from soil cuttings when compared to test pit sampling. In addition, direct-push, sonic drilling, and split-spoon sampling methods can obtain samples at targeted intervals greater than 15 feet in depth, allowing for discrete depth soil sampling while speeding up the sampling process. Direct-push methods work best in medium to fine-grained cohesive materials, such as medium to fine sands, silts, and silty clay soils. Sonic drilling sampling works well in all types of soil and bedrock. Split-spoon sampling works well in all types of soil but is somewhat slower than direct-push and sonic drilling methods. With the exception of volatile organic compounds (VOCs) samples, the soil sample interval is composited so that each sample contains a homogenized representative portion of the sample interval. Due to potential loss of analytes, samples for VOC analysis are not composited. Samples for chemical analysis can be collected by any of the above-mentioned sampling methods, as disturbed soil samples. Undisturbed samples are best collected with direct push or by Shelby Tube (not covered in this SOP). They are collected, sealed, and sent directly to the laboratory for analysis without homogenizing.

2.0 Safety

2.1 The health and safety considerations for the work associated with this SOP, including both potential physical and chemical hazards, will be addressed in the project Accident Prevention Plan (APP)/Site Safety and Health Plan. Work will also be conducted according to the Task Order (TO) QAPP and/or direction from the **Site Safety and Health Officer (SSHO)**.

2.2 Before soil sampling commences, appropriate entities (e.g. DigSafe, local public works departments, company facilities) must be contacted to assure the anticipated soil sampling locations are marked for utilities, including electrical, telecommunications, water, sewer, and gas.

3.0 Terms and Definitions

None.

4.0 Interferences

4.1 Low recovery of soil from sampling equipment will prevent an adequate representation of the soil profile and sufficient amount of soil sample. If low recovery is a problem, the hole may be offset and re-advanced, terminated, or continued using a larger diameter sampler.

NOTE: SOPs have been updated for PFAS sampling activities; however, AECOM's internal PFAS sampling guidance supersedes materials and methods described in SOPs.

4.2 Asphalt in soil samples can cause false positive results for hydrocarbons. To ensure samples are free of asphalt, do not collect samples that may contain asphalt. If the collection of samples potentially containing asphalt is unavoidable, note the sampling depths at which the presence of asphalt are suspected.

4.3 Instrumentation interferences addressed in SOPs for Calibration of the Photoionization Detector (PID), Headspace Screening for Total Volatile Organics, and Equipment Decontamination must also be considered.

4.4 Cross contamination from sampling equipment must be prevented by using sampling equipment constructed of stainless steel that is adequately decontaminated between samples.

5.0 Training and Qualifications

5.1 Qualifications and Training

The individual executing these procedures must have read, and be familiar with, the requirements of this SOP.

5.2 Responsibilities

5.2.1 The **TO Manager** is responsible for ensuring that soil sampling activities comply with this procedure. The TO Manager is responsible for ensuring that all personnel involved in soil sampling shall have the appropriate education, experience, and training to perform their assigned tasks.

5.2.2 The **Program Quality Manager** is responsible for ensuring overall compliance with this procedure.

5.2.3 The **Site Supervisor (SS)** is responsible for ensuring that all soil sampling activities are conducted according to this procedure.

5.2.4 All **Field Personnel** are responsible for the implementation of this procedure.

6.0 Equipment and Supplies

The depth at which samples will be collected and the anticipated method of sample collection (direct-push, split-spoon, hand auger, shovel, or test pits) will be presented in the QAPP. The following details equipment typically needed for soil sampling, based on the various methods. See the QAPP for specific detail of equipment and supply needs.

6.1 Depending on the nature of suspected contamination, field screening instrumentation may be used for direct sampling. Appropriate instrumentation and calibration standards should be available. If volatile organic contaminants are suspected and a PID will be used, refer to the equipment and instrumentation listed in SOP 3-20 Operation and Calibration of a Photoionization Detector. Equipment in this SOP includes but is not limited to:

- PID/FID;
- Calibration gas; and
- Tedlar® gas bags (for calibration).

6.2 If field screening methods include jar headspace screening for volatile organics, refer to the equipment and procedure in SOP 3-19 Headspace Screening for Total VOCs. Equipment in this SOP includes but is not limited to:

- Clean soil (“drillers jars”) jars;
- HDPE sample jars for PFAS/PFOS samples; and
- Aluminum foil for non-PFAS/PFOS sampling.

6.3 Appropriate decontamination procedures must be followed for sampling equipment. Refer to SOP 3-06 Equipment Decontamination. Equipment in this SOP includes but is not limited to:

- Alconox® or Liquinox®;
- Isopropyl Alcohol;
- Deionized Ultra-Filtered (DIUF) Water (confirmed PFAS-free);
- Plastic buckets or washbasins;
- Brushes; and
- Polyethylene sheeting.

6.4 The following general equipment is needed for all soil sampling, regardless of method:

- Stainless steel bowls;
- Stainless steel trowels;
- Appropriate sample containers for laboratory analysis;
- Personal Protective Equipment (PPE);
- Non-water-repellent logbook;
- Cooler and ice for preservation; and
- Stakes and flagging to document sampling location.

6.5 The following additional equipment is needed for volatile organic sampling:

- Electronic pan scale and weights for calibration; and
- Syringes or other discrete soil core samplers.

6.6 The following additional equipment may be needed for surface and test pit soil sampling:

- Hand Auger

6.7 The following additional equipment may be needed for soil sampling from direct push and/or split-spoon equipment:

- Tape measure or folding carpenter’s rule for recording the length of soil recovered.

Note: All subsurface drilling equipment will be provided and maintained by the subcontractor.

7.0 Procedure

7.1 General Soil Sampling Procedure for All Soil Sampling Methods

7.1.1 Record the weather conditions and other relevant on-site conditions.

7.1.2 Select the soil sampling location, clear vegetation, if necessary, and record the sampling location identification number and pertinent location details.

7.1.3 Verify that the sampling equipment is properly decontaminated, in working order, and situated at the intended sampling location.

7.1.4 Place polyethylene sheeting on the ground and assemble all necessary sampling equipment on top of it. Cover surfaces onto which soils or sampling equipment will be placed (i.e., tables with polyethylene sheeting).

7.1.5 Follow the appropriate procedures listed below for either surface, split-spoon, sonic drilling, direct push, or test pit sample collection (7.2, 7.3, 7.4, 7.5, and 7.6, respectively).

7.1.6 Collect soil samples according to procedures listed in Section 7.7 depending on project specific analyses.

7.1.7 Record date/time, sample ID, and sample descriptions in the field logbook or field form. A sketch or description of the location may also be recorded so the sample location can be re-constructed, especially if the location will not be recorded using global positioning satellite (GPS) equipment.

7.1.8 Immediately label the sample containers and place them on ice, if required for preservation. Complete the chain-of-custody form(s) as soon as possible.

7.1.9 Dispose of all excess excavated soil in accordance with the QAPP.

7.1.10 If required, mark the sample location with a clearly labelled wooden stake or pin flag. If the location is on a paved surface, the location may be marked with spray paint.

7.1.11 Decontaminate the sampling equipment according to SOP 3-06 Equipment Decontamination.

7.2 Surface Sampling

7.2.1 The criteria used for selecting surface soil locations for sampling may include the following:

- Visual observations (soil staining, fill materials);
- Other relevant soil characteristics;
- Site features;
- Screening results;
- Predetermined sampling approach (i.e., grid or random); and
- Sampling objectives as provided in the QAPP.

7.2.2 The following procedures are to be used to collect surface soil samples. Surface soils are considered to be soils that are up to two feet below ground surface, though state regulations and project objectives may define surface soils differently; therefore, the QAPP should be consulted for direction on the depth from which to collect the surface soil samples. Sampling and other pertinent data and information will be recorded in the field logbook and/or on field forms. Photographs may be taken as needed or as specified in the QAPP.

1. Gently scrape any vegetative covering until soil is exposed. Completely remove any pavement.
2. Remove soil from the exposed sampling area with a stainless-steel trowel, hand auger, or shovel. Put soils within the sampling interval in a stainless-steel bowl for homogenizing. Monitor the breathing zone and sampling area as required in the APP/SSHP.
3. For VOC analyses, collect representative soil samples directly from the recently-exposed soil using a syringe or other soil coring device (e.g., TerraCore®, EnCore®). Follow procedures in Section 7.7.1 for VOC sampling.
4. Collect sufficient soil to fill all remaining sample jars into a stainless-steel bowl. Homogenize the soil samples to obtain a uniform soil composition which is representative of the total soil sample collected according to the following procedure:
    a) Remove all rocks and non-soil objects using a stainless-steel spoon or scoop.

NOTE: SOPs have been updated for PFAS sampling activities; however, AECOM's internal PFAS sampling guidance supersedes materials and methods described in SOPs.

b) Form a cone shaped mound with the sample material, then flatten the cone and split the sample into quarters.

c) Use the stainless-steel spoon/scoop to mix the quarter samples that are opposite.

d) After mixing the opposite quarters, reform the cone shaped mound.

e) Repeat this procedure a minimum of five (5) times, removing any non-soil objects and breaking apart any clumps.

7.3 Split-Spoon Sampling

7.3.1 At each boring location, the frequency and depth of split-spoon samples will be determined from the QAPP. Split-spoon samples may be collected continuously, intermittently, or from predetermined depths.

7.3.2 Split-spoon samplers shall be driven into undisturbed soil by driving the spoon ahead of the drill augers/casing. In cohesive soils, or soils where the borehole remains open (does not collapse), two split-spoon samples may be taken prior to advancing the augers/casing.

7.3.3 After split-spoons are retrieved, open the split-spoon and measure the recovery of soil. If a PID will be used for screening, immediately scan the recovered sample for VOCs using the PID. Scan the recovered soil boring by making a hole in the soil with a decontaminated trowel and placing the PID inlet very close to the hole. Be very careful not to get soil on the tip of the PID. Take PID readings every 6 inches along the split-spoon and/or in any areas of stained or disturbed soil. Record the highest PID reading and the depth at which it was observed along with all other pertinent observations. If required in the QAPP, VOC and headspace samples should be collected (see Section 7.7.1) prior to logging the sample.

7.3.4 If headspace screening for VOCs is required in the QAPP, collect a soil sample (as defined in the QAPP) and perform headspace screening according to SOP 3-19 Headspace Screening for Total VOCs.

7.3.5 Soils collected using the split-spoon sampler will be logged by the field representative using the procedure required in the QAPP.

7.3.6 Collect the remainder of the sample volume required into a stainless-steel bowl. Homogenize the soil so the material is uniform in composition and representative of the total soil sample collected. Follow homogenizing techniques as described in Section 7.2.

7.3.7 The QAPP may specify that intervals to be sent to the laboratory be determined by visual observation and/or highest PID screening or headspace results, which can only be determined once the boring is complete. In this instance, a VOC sample should be collected at each interval. The remainder of the soil from that interval will be set aside in a clearly labelled stainless steel bowl covered with polyethylene sheeting. Once the boring has been completed and the sample interval has been determined, the remainder of the soil can be homogenized according to Section 7.2 and submitted for laboratory analysis.

7.3.8 Once a boring is complete and all required samples have been collected, the boring must be completed as specified in the QAPP (e.g., completed as a monitoring well, backfilled with bentonite, etc.).

7.4 Sonic Drilling Sampling

7.4.1 At each boring location, the frequency and depth of sonic drilling samples will be determined from the QAPP.

7.4.2 Sonic drilling methods, also known as vibratory drilling, use an eccentrically oscillating drill head to produce high-frequency vibratory energy that is then transmitted down a drill string to a core barrel to quickly advance through the subsurface. Sonic drilling utilizes a double-cased system using an inner core barrel and a larger override casing. This ensures that the borehole is continuously cased to the total depth, minimizing the potential for borehole collapse and providing the means to alter casing diameters to telescope through semi-confining units to prevent downhole cross contamination.

7.4.3 Upon retrieval of the core barrel, place the tubular plastic sleeve (confirmed PFAS-free) with sealed bottom over the bottom of the core barrel. The core barrel will then be vibrated, causing the soil sample to be extruded into the sleeve. Place the sleeve on the work surface (i.e. PFAS-free plastic covered table or ground). Open the sleeve and measure the recovery of soil.

7.4.4 If a PID will be used for screening, immediately scan the recovered sample for VOCs using the PID. Scan the recovered soil boring by making a hole in the soil with a decontaminated trowel and placing the PID inlet very close to the hole. Be very careful not to get soil on the tip of the PID. Take PID readings every 6 inches along the soil core and/or in any areas of stained or disturbed soil. Record the highest PID reading and the depth at which it was observed along with all other pertinent observations. If required in the QAPP, VOC and headspace samples should be collected (see Section 7.7.1) prior to logging the sample.

7.4.5 If headspace screening for VOCs is required in the QAPP, collect a soil sample (as defined in the QAPP) and perform headspace screening according to SOP 3-19 Headspace Screening for Total VOCs.

7.4.6 Soils collected using sonic drilling will be logged by the field representative using the procedure required in the QAPP.

7.4.7 Collect the remainder of the sample volume required into a stainless-steel bowl. Homogenize the soil so the material is uniform in composition and representative of the total soil sample collected. Follow homogenizing techniques as described in Section 7.2.

7.4.8 The QAPP may specify that intervals to be sent to the laboratory be determined by visual observation and/or highest PID screening or headspace results, which can only be determined once the boring is complete. In this instance, a VOC sample should be collected at each interval. The remainder of the soil from each interval will be set aside. Once the boring has been completed and the sample interval has been determined, the remainder of the soil can be homogenized according to Section 7.2 and submitted for laboratory analysis.

7.4.9 Once a boring is complete and all required samples have been collected, the boring must be completed as specified in the QAPP (e.g., completed as a monitoring well, backfilled with bentonite, etc.).

7.5 Direct Push Sampling

At each boring location, the frequency of direct-push samples will be determined from the QAPP. Typically, samples with direct-push equipment are collected in 4-foot (ft) intervals, but smaller (e.g., 2 ft) and larger (e.g., 5 ft) intervals are also possible.

1. Sample using Macro-Core samplers with acetate liners to obtain discrete soil samples at the depths specified in the QAPP.
2. Cut open the acetate liner. If required in the QAPP, immediately scan the recovered soil boring for VOCs using a PID by making a hole in the soil with a decontaminated trowel and placing the PID inlet very close to the hole. Be very careful not to get soil on the tip of the PID. Take PID readings every 6 inches along the split-spoon and/or in any areas of stained or disturbed soil. Record the highest PID reading and the depth at which it was observed along with all other pertinent observations. VOC and headspace samples, if required in the QAPP should be collected (see Section 7.7.1) prior to logging the sample.
3. If required in the QAPP, collect a soil sample (as defined in the QAPP) and perform headspace screening according to SOP 3-19 Headspace Screening for Total VOCs.
4. Soils collected using the direct-push sampler will be logged by the by the field representative using the procedure required in the QAPP.
5. Collect the remainder of the sample into a stainless-steel bowl. Homogenize the soil collected so that the material is uniform in composition and representative of the total soil sample collected. Follow homogenizing techniques as described in Section 7.2.

6. Once a boring is complete and all required samples have been collected, the boring must be completed as specified in the QAPP (e.g., completed as a monitoring well, backfilled with bentonite, etc.).

7.6 Test Pit Sampling

7.6.1 Excavate the test pit to the desired depth.

7.6.2 Using the excavator bucket, collect soil samples as specified in the QAPP. Collect a sample and perform screening analyses as required by the QAPP. If VOCs contamination is suspected, perform headspace screening according to SOP 3-19 Headspace Screening for Total VOCs.

7.6.3 Collect the sample from center of the bucket to avoid potential contamination from the bucket.

7.6.4 VOC samples should also be collected from an undisturbed section soil in the excavator bucket. The top layer of exposed soil should be scraped away just prior to collecting the VOC samples.

7.6.5 Collect the remainder of the sample volume required into a stainless-steel bowl. Homogenize the soil so the material is uniform in composition and representative of the total soil sample collected. Follow homogenizing techniques as described in Section 7.2.

7.6.6 Dispose of all excavated soil according to the QAPP.

7.7 Sample Collection Methods

7.7.1 Volatile Organics Sampling

For soils collected for analyses of volatile organics, including Volatile Petroleum Hydrocarbons (VPH) or other purgeable compounds, a closed system is maintained. From collection through analysis, the sample bottles are not opened. The bottle kit for a routine field sample for these analyses will typically include three 40-mL VOA vials and one soil jar. Two 40-mL VOA vials will contain either 5 mL reagent water or 5 mL sodium bisulfate and magnetic stir bars (i.e., low level vials). The third VOA vial will contain 15 mL methanol with no magnetic stir bar (i.e., high level vial). These vials are usually provided by the laboratory and are pre-weighed, with the tare weight recorded on the affixed sample label. No additional sample labels are affixed to the VOA vials, as addition of a label would alter the vial weight. All information is recorded directly on the sample label using an indelible marker. The soil jar is provided for percent solids determination. For VOC or VPH analyses, samples are collected prior to sample homogenization. Collect the VOC sample in accordance with the procedure described below.

1. Determine the soil volume necessary for the required sample weight, typically 5 grams:
    a) Prepare a 5 mL sampling corer (e.g., Terra Core®) or cut-off plastic syringe.
    b) Tare the sampler by placing it on the scale and zeroing the scale.
    c) Draw back the plunger to the 5-gram mark or 5mL (5cc) mark on cut-off syringe and insert the open end of the sampler into an undisturbed area of soil with a twisting motion, filling the sampler with soil. Note the location of the plunger with respect to the milliliter (cc) or other graduation printed on the sampler.
    d) Weigh the filled sampler and remove or add soil until the desired weight is obtained. Note the location of the plunger which corresponds to this weight. Do not use this sample for laboratory analysis.
2. Once the required soil volume has been determined, pull the plunger back to this mark and hold it there while filling the syringe for each sample.
3. Collect 5 grams of soil using the cut-off syringe or Terra Core® sample device. Extrude the 5-grams of soil into one of the low level 40-mL VOA vials. Quickly wipe any soil from the threads of the VOA vial with a clean Kimwipe® and immediately close the vial. It is imperative that the

threads be free from soil or other debris prior to replacing the cap on the vial in order to maintain the closed system necessary for the analysis.

4. Gently swirl the vial so that all of the soil is fully wetted with the preservative.
5. Fill the other low level 40 mL VOA vial in this manner.
6. Repeat the process for the high-level VOA vials, only for the high-level VOA vial three 5-gram aliquots (i.e., 15 grams total) should be extruded into the high-level VOA vial.

   NOTE: Depending on the laboratory, some high-level VOA vials only contain 5 mL or 10 mL of methanol. If this is the case, either 5 grams total or 10 grams total, respectively, should be extruded into the high-level VOA vial. In other words, the mass of soil in grams should be identical to the volume of methanol in mL (i.e., 1:1 ratio of soil to methanol).

7. Collect any additional QC sample collected (e.g., field duplicate, MS, and MSD) in the same manner as above.
8. Fill the 4-oz glass jar with soil from the same area for percent moisture determination.

7.7.2 Soil Sampling Method (All other analyses except VOC/VPH)

When all the required soil for a sampling location has been obtained, the soil can be homogenized as described in section 7.2. Collect sufficient volume to fill all of the remaining sample containers at least ¾ full for all other analyses. Homogenize the soil in a decontaminated stainless-steel bowl, removing rocks, sticks, or other non-soil objects and breaking apart any lumps of soil prior to filling the remaining sample containers.

NOTE: Soil samples must contain greater than 30% solids for the data to be considered valid.

8.0 Quality Control and Assurance

8.1 Sampling personnel should follow specific quality assurance guidelines as outlined in the QAPP. Proper quality assurance requirements should be provided which will allow for collection of representative samples from representative sampling points. Quality assurance requirements outlined in the QAPP typically suggest the collection of a sufficient quantity of field duplicate, field blank, and other samples.

8.2 Quality control requirements are dependent on project-specific sampling objectives. The QAPP will provide requirements for equipment decontamination (frequency and materials), sample preservation and holding times, sample container types, sample packaging and shipment, as well as requirements for the collection of various quality assurance samples such as trip blanks, field blanks, equipment blanks, and field duplicate samples.

9.0 Records, Data Analysis, Calculations

All data and information (e.g., sample collection method used) must be documented on field data sheets, boring logs, or within site logbooks with permanent ink. Data recorded may include the following:

- Weather conditions;
- Arrival and departure time of persons on site;
- Instrument type, lamp (PID), make, model and serial number;
- Calibration gas used;
- Date, time and results of instrument calibration and calibration checks;
- Sampling date and time;
- Sampling location;
- Samples collected;
- Sampling depth and soil type;
- Deviations from the procedure as written; and
- Readings obtained.

10.0 Attachments or References

SOP 3-06, *Equipment Decontamination*

SOP 3-19, *Headspace Screening for Total VOCs*

SOP 3-20, *Operation and Calibration of a Photoionization Detector*

Author	***Reviewer***	***Revisions (Technical or Editorial)***
Robert Shoemaker, PMP Senior Scientist	Chris Barr Program Quality Manager	Rev 0 – Initial Issue (May 2012)
Ken O’Donnell, PG Geologist	Claire Mitchell, PE, PMP Senior Engineer	Rev 1 – PFAS sampling update (July 2019)
Robert Shoemaker, PMP Senior Scientist	Josh Millard, PG, CPG	Rev 2 – Addition of Sonic Drilling Methods (January 2020)

Sediment Sampling

Procedure 3-22

1.0 Purpose and Scope

1.1 Sediment contamination is a widespread environmental problem that can pose a threat to a variety of aquatic ecosystems. Sediment functions as a reservoir for common contaminants, such as pesticides, herbicides, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), per- and polyfluoroalkyl compounds (PFAS), and metals, such as lead, mercury, and arsenic. Contaminated sediments represent a hazard to aquatic life through direct toxicity, as well as to aquatic life, wildlife, and human health through bioaccumulation. Accurate assessment of environmental hazards posed by sediment contamination depends in large part on the accuracy and representativeness of sediment collection and analyses (U.S. EPA, 2001).

1.2 Selection and proper use of sediment sampling equipment is essential to the collection of accurate, representative sediment data that will meet the project Data Quality Objectives (DQOs). Most sediment collection devices are designed to isolate and consistently retrieve a specified volume and surface area of sediment, from a required depth below the sediment surface, with minimal disruption of the integrity of the sample and no contamination of the sample. Maintaining the integrity of the collected sediment, for the purposes of the measurements intended, is a primary concern in most studies because disruption of the sediment's structure could change its physiochemical and biological characteristics, thereby influencing the bioavailability of contaminants and the potential toxicity of the sediment (U.S. EPA, 2001).

When selecting the type of sediment sampling equipment to be used for an event, the project DQOs as well as the sediment characteristics should be considered. Related to the project DQOs is the desired depth of sediment sampling. For monitoring and assessment studies where historical contamination is not the focus, the upper 10 to 15 centimeters (cm) is typically the horizon of interest, as this is the horizon that generally contains the most recently deposited sediments and most epifaunal and infaunal organisms (U.S. EPA, 2001). The 0-6 inches interval for sediments with less than two feet of water is also used for human health risk assessment purposes. Sampling of these horizons can usually be done with grab samplers. However, if sediment contamination is being related to organism exposures (e.g. benthic macroinvertebrates and/or fish), or if characterization of deeper sediments is important for comparison of recent surficial versus historical contamination, then more precise sampling of sediment depths might be needed, and a hand corer may be more suitable (U.S. EPA, 2001).

1.3 This standard operating procedure (SOP) describes the procedure for the collection of sediment samples using the Petite Ponar® Grab Sampler, Ekman Bottom Grab Sampler, and Wildco® Hand Corer (or similar sampling devices). The applicability of each of the sediment samplers is described below.

The Petite Ponar® Grab Sampler is used to collect sediment samples in:

- Firm, hard bottoms such as sand, gravel, consolidated marl, and clay
- Mixtures of sand, stones, and coarse debris
- Soft or mucky sediments

The Ekman Bottom Grab Sampler is used to collect sediment samples in:

- Soft, finely divided littoral bottoms free from vegetation and intermixtures of sand, stones, and other coarse debris
- Bottoms composed of finely divided mulch, mud, muck, or submerged fine peaty materials

The Wildco® Hand Corer is used:

- To collect sediment samples for geological characterizations and dating
- To collect sediment samples for programs where it is important to maintain an oxygen-free environment for the sample during collection
- To collect sediment samples from a deeper depth than a grab sampler, and to characterize the depth of contamination at a site
- To investigate the historical input of contaminants to aquatic systems
- To collect sediment samples in semi-consolidated and soft sediment

Pictures and exploded diagrams of the Petite Ponar Grab Sampler, Ekman Bottom Grab Sampler, and Wildco® Hand Corer are presented in Figures 1, 2, and 3, respectively.

1.4 This procedure is the Program-approved professional guidance for work performed by AECOM under the client contract.

1.5 As guidance for specific activities, this procedure does not obviate the need for professional judgment. Deviations from this procedure while planning or executing planned activities must be approved in accordance with Program requirements for technical planning and review.

2.0 Safety

2.1 Depending upon the site-specific contaminants, various protective programs must be implemented prior to sampling the first location. All **Field Personnel** responsible for sampling activities must review the project-specific Accident Prevention Plan (APP)/Site Safety and Health Plan (SSHP), paying particular attention to the control measures planned for the sampling tasks. Conduct preliminary area monitoring of sample locations to determine the potential hazard to **Field Personnel**. If significant contamination is observed, minimize contact with potential contaminants in both the vapor phase and solid or liquid matrix through the use of respirators and disposable clothing.

2.2 Observe standard health and safety practices according to the project-specific APP/SSHP. Suggested minimum protection during sediment sampling activities includes inner disposable vinyl gloves, outer chemical-protective powderless nitrile gloves, and PFAS-free waders (if applicable). Refer to the project-specific APP/SSHP for the required PPE.

2.3 Handle all sediments removed from potentially contaminated locations in accordance with the IDW handling procedures in SOP 3-05, IDW Management.

2.4 Depending upon the type of contaminant expected or determined in previous sampling efforts, employ the following safe work practices:

- If sampling from a boat, all **Field Personnel** should wear personal flotation devices (PFDs) when in the boat and should follow all health and safety protocols for working in a boat presented in the project-specific APP/SSHP.
- Lifting the samplers into the boat, dumping its contents, and washing those contents may require leaning over the side of the boat. Care should be taken to keep the boat in proper balance at all times during sampling.
- Severe injury to fingers or hands can be caused by movement of the lever arms of the Petite Ponar® Grab Sampler. Do not handle or move the Petite Ponar® Grab Sampler unless the safety pin is fully inserted in the locking holes.
- Severe injury to fingers or hands can be caused by the closing of the sharpened scoops of the Ekman Bottom Grab Sampler. Handle the Ekman Bottom Grab Sampler very carefully when the springs are set and the cable loops are hooked (armed) on the Twin-Pin™ pins on the release mechanism. Do not "arm" the Ekman Bottom Grab Sampler until the sampler is ready to be used. The Ekman Bottom Grab Sampler spring-loaded jaws are potentially dangerous; extreme care must

be exercised when setting the jaws. To prevent injury (and to extend the life of the springs), unhook both springs from their scoop buttons after each sampling session.

3.0 Terms and Definitions

None.

4.0 Training and Qualifications

4.1 The **Task Order (TO) Manager** is responsible for ensuring that sediment sampling activities comply with this procedure. The **TO Manager** is responsible for ensuring that **Field Personnel** involved in sediment sampling shall have the appropriate education, experience, and training to perform their assigned tasks.

4.2 The **Program Quality Manager** is responsible for ensuring overall compliance with this procedure.

4.3 The **Site Supervisor (SS)** is responsible for ensuring that **Field Personnel** follow these procedures.

4.4 **Field Personnel** are responsible for the implementation of this procedure.

4.5 The **Field Personnel** and/or **TO Manager** are responsible for directly supervising the sediment sampling procedures to ensure that they are conducted according to this procedure, and for recording all pertinent data collected during sampling.

5.0 Equipment and Supplies

5.1 For sediment sampling using all types of equipment, the following supplies are required:

- Stainless steel bowls
- Stainless steel hand trowels, spoons, spatulas, and scoops
- Munsell Color Chart
- Particle size chart

5.2 Petite Ponar® Grab Sampler

- 3/16" braided polyester line
- Auxiliary weights

5.3 Ekman Bottom Grab Sampler

- 11 oz split messenger
- 3/16" braided polyester line
- Extension Handle
- Auxiliary weights

5.4 Wildco® Hand Corer

- 3/16" braided polypropylene line
- Extension handle
- Stainless steel core catchers (for normal sediments)
- Eggshell™ core catchers (for wet sediments)
- Stainless steel nose piece
- Cellulose acetate butyrate (CAB) liners

NOTE: SOPs have been updated for PFAS sampling activities; however, AECOM's internal PFAS sampling guidance supersedes materials and methods described in SOPs.

- Core liner end caps
- Core liner cutter
- Geologists table
- Auxiliary weights

6.0 Procedure

6.1 Depending on the characteristics of the site being investigated, sediment samples may be collected from a boat, or by **Field Personnel** in waders. In all instances, sediment sampling should begin from the most downstream location and proceed to the most upstream location. If sediment samples are collocated with surface water samples, the surface water sample should be collected prior to the sediment sample in order to avoid increased turbidity from displaced sediment. Regardless of the type of sediment sampling equipment used, documentation of field observations and collection activities should be recorded on the sediment sampling sheet or electronic data collection device. The following observations should be recorded on the sediment sampling form (see Attachment 1) for all sediment sampling activities:

- Sample location
- Weather conditions and other relevant site conditions
- Depth of water to the nearest 0.1 foot. A surveyor rod may be used. If the surveyor rod is used, minimize water turbulence and do not disturb any sediment.
- Physical characteristics of the water body, such as estimated current speed (stagnant, slow, medium, or fast) and direction, odor, color, presence of any dead vegetation, surface sheens, etc.
- Sediment color according to the Munsell Color Chart
- Sediment grain size according to a particle size chart

Specific procedures for the collection of sediment samples using the Petite Ponar® Grab Sampler, Ekman Bottom Grab Sampler, and Wildco® Hand Corer are presented below.

6.2 Petite Ponar® Grab Sampler

6.2.1 Inspect the sampler to ensure all parts are in good working condition.

6.2.2 Decontaminate the sampler according to the procedures in SOP 3-06, Equipment Decontamination.

6.2.3 Attach the 3/16" braided polypropylene line to the sampler by looping the line through the clevis at the top center of the lever arms and tying securely. Tie the other end of the line to the boat (if applicable), or make sure to hold on to the other end of the line. Strong, tight knots (e.g., bowline, two half hitches) are essential for operator safety and to prevent losing the sampler. If necessary, attach the auxiliary weights to the sampler according the manufacturer's directions.

6.2.4 Insert the Pinch-Pin™ into its hole in the lever arms, making sure to firmly push the Pinch-Pin™ into the hole. As long as the line is taut, the Pinch-Pin™ will stay in its place. When the line becomes the least bit slack (e.g., when the sampler hits the bottom), the Pinch-Pin™ spring will force the Pinch-Pin™ out of its hole, allowing the scoops to close.

6.2.5 Just before lowering the grab into the water, and with the line taut, remove the safety pin so the closing mechanism will release when the sampler is on the bottom. Make sure to keep the line taut, as any loss of tension in the line will cause the Pinch-Pin™ to pop out, closing the sampler.

6.2.6 Lower the sampler into the water in a slow and controlled fashion, especially during the final 1-2', such that the bow wave is minimized, thus minimizing the dispersal of fine material on the sediment surface. At no time should the sampler be allowed to "free fall" down through the water column.

6.2.7 Once the sampler has reached the bottom, release the tension on the line, and allow the sampler to sink into the sediment momentarily. The release of tension on the line will cause the Pinch-Pin™ to pop out.

6.2.8 Collect the sample by pulling on the line, which will cause the lever arms to drive the scoops into the sediment in a closing motion. Keep pulling on the line in a controlled fashion until the scoops drive through the sediment and close.

6.2.9 Once the sampler scoops have closed, continue pulling on the line in a controlled fashion in order to retrieve the sampler back to the surface. When the sampler reaches the surface, lift it clear and bring it above a decontaminated stainless-steel bowl. Inspect the sampler to ensure that an acceptable sample has been collected (See Figure 4). If the sample is not acceptable, discard the sample in an area that is not proximal or upstream to the area or subsequent areas that are being sampled.

6.2.10 Prior to sampling and sample homogenization, the overlying water in the sampler should be siphoned off, and not decanted (U.S. EPA 2001).

6.2.11 If acid volatile sulfide/simultaneously extracted metals (AVS/SEM) samples are to be collected, open the top screens of the sampler and collect the AVS/SEM sample directly from the sediment contained in the sampler according to the procedures specified in the project-specific Quality Assurance Project Plan (QAPP).

6.2.12 If volatile organic compound (VOC) samples are to be collected, open the top screens of the sampler and collect the VOC samples by inserting a syringe, Terra Core sampler, or other VOC sampling device directly into the undisturbed sediment contained within the sampler, making sure to follow all VOC sampling procedures specified in the project-specific QAPP. Once the VOC samples have been collected, collect an additional aliquot for the VOC percent solids sample directly from the undisturbed sediment contained within the sampler.

6.2.13 Once the AVS/SEM and VOC samples have been collected (or if AVS/SEM and VOC samples are not required), open the sampler by pulling the two scoops open, taking care to keep hands and fingers away from the sharpened edges of the scoops, and allow the sediment to exit the sampler into the decontaminated stainless-steel bowl.

6.2.14 If additional aliquots are necessary to provide adequate sample volume, repeat steps 6.2.3 through 6.2.12 until an adequate sample volume has been collected, taking care to deploy the sampler to an area that is proximal and upstream, but not on top of, the previous sample location.

6.2.15 Once an adequate sample volume has been collected, homogenize the sample in the stainless-steel bowl, record the sediment sample information on the Sediment Sample Collection Form (see Attachment 1), and collect the sediment samples according to the procedures specified in the project-specific QAPP (typically in order of decreasing volatility).

6.3 Ekman Bottom Grab Sampler with the 11 oz Split Messenger

6.3.1 Inspect the sampler to ensure all parts are in good working condition.

6.3.2 Decontaminate the sampler according to the procedures in SOP 3-06, Equipment Decontamination.

6.3.3 Attach the 3/16” braided polyester line to the sampler by passing the line through the trip mechanism and knotting it securely below the underlying plate. Thread the 11 oz split messenger on the line and tie the other end of the line to the boat (if applicable), or make sure to hold on to the other end of the line. Strong, tight knots (e.g. bowline, two half hitches) are essential to prevent losing the sampler. If necessary, attach the auxiliary weights to the sampler according the manufacturer’s directions.

6.3.4 Set the spring on the side of the sampler by hooking the end of the spring onto one scoop button and stretching the spring to reach the second scoop button. Repeat this procedure with the spring on the other side of the sampler.

6.3.5 Arm the scoops by hooking one cable loop to one Twin-Pin™ pin in the trip assembly on the top of the sampler. The white ball on the cable can be used as a hand grip to assist getting the cable loop hooked onto the Twin-Pin™ pin. Repeat for the opposite cable loop. The sampler is now armed and dangerous. Do not allow anything to come in contact with the trip assembly at the top of the sampler, as this may cause a sudden and unexpected closure of the sampler.

6.3.6 Lower the sampler into the water in a slow and controlled fashion, especially during the final 1-2', such that the bow wave is minimized, thus minimizing the dispersal of fine material on the sediment surface. At no time should the sampler be allowed to "free fall" down through the water column.

6.3.7 Once the sampler has reached the bottom, allow the sampler to settle momentarily. Once the sampler has settled, hold the line with just enough tension to keep it straight, and send the 11 oz split messenger down the line. Once the 11 oz split messenger impacts Twin-Pin™ strike pad in the trip assembly on the top of the sampler, the two cable loops will be released from the Twin-Pin™ pins, and the spring-loaded scoops of the sampler will automatically close.

6.3.8 Retrieve the sampler by pulling up the line in with a moderate, steady speed. When the sampler reaches the surface, lift it clear and bring it above a decontaminated stainless-steel bowl. Inspect the sampler to ensure that an acceptable sample has been collected (See Figure 4). If the sample is not acceptable, discard the sample in an area that is not proximal or upstream to the area or subsequent areas that are being sampled.

6.3.9 Prior to sampling and sample homogenization, the overlying water in the sampler should be siphoned off, and not decanted (U.S. EPA 2001).

6.3.10 If AVS/SEM samples are to be collected, open the top lids of the sampler and collect the AVS/SEM sample directly from the sediment contained in the sampler according to the procedures specified in the project-specific QAPP.

6.3.11 If VOC samples are to be collected, open the top lids of the sampler and collect the VOC samples by inserting a syringe, Terra Core sampler, or other VOC sampling device directly into the undisturbed sediment contained within the sampler, making sure to follow all VOC sampling procedures specified in the project-specific QAPP. Once the VOC samples have been collected, collect an additional aliquot for the VOC percent solids sample directly from the undisturbed sediment contained within the sampler.

6.3.12 Once the AVS/SEM and VOC samples have been collected (or if AVS/SEM and VOC samples are not required), open the sampler by pulling on the white balls on both cables, opening the spring-loaded scoops and allowing the sediment to exit the sampler into the decontaminated stainless-steel bowl. While the spring-loaded scoops are being held open, do not place hands or fingers inside or underneath the sampler.

6.3.13 If additional aliquots are necessary to provide adequate sample volume, repeat steps 6.3.4 through 6.3.11 until an adequate sample volume has been collected, taking care to deploy the sampler to an area that is proximal and upstream, but not on top of, the previous sample location.

6.3.14 Once an adequate sample volume has been collected, homogenize the sample in the stainless-steel bowl, record the sediment sample information on the Sediment Sample Collection Form (see Attachment 1), and collect the sediment samples according to the procedures specified in the project-specific QAPP (typically in order of decreasing volatility).

6.4 Ekman Bottom Grab Sampler with the Extension Handle

6.4.1 Inspect the sampler to ensure all parts are in good working condition.

6.4.2 Decontaminate the sampler according to the procedures in SOP 3-06, Equipment Decontamination.

6.4.3 Attach the extension handle to the top of the sampler with machine bolts.

6.4.4 Arm the sampler according to the procedures described in steps 6.3.3 and 6.3.4 above.

6.4.5 Using the extension handle, lower the sampler to a point 4-6” above the sediment surface, and drop the sampler to the sediment, keeping the sampler vertical at all times.

6.4.6 Trigger the trip assembly by depressing the button on the upper end of the extension handle. This will cause the two cable loops to be released from the Twin-Pin™ pins, and the spring-loaded scoops of the sampler will automatically close.

6.4.7 While keeping the sampler vertical, bring the sampler over to a decontaminated stainless-steel bowl. Inspect the sampler to ensure that an acceptable sample has been collected (See Figure 4). If the sample is not acceptable, discard the sample in an area that is not proximal or upstream to the area or subsequent areas that are being sampled.

6.4.8 Collect samples according to the procedures described in steps 6.3.8 through 6.3.13 above.

6.5 Wildco® Hand Corer with the Push Handles

6.5.1 Inspect the sampler to ensure all parts are in good working condition:

- Assemble and disassemble the core tube from the head and nose piece to make sure the threads are not binding. If the threads are binding, consult the manufacturer’s directions.
- Make sure that the CAB plastic liner can slide easily in and out of the core tube.
- Make sure the bottom edge of the core tube and nose piece are sharp and free from nicks or dents. If necessary, file smooth using a round file.
- Check the flutter valve for ease of movement.
- Check the flutter valve seat to make sure it is clear of any obstruction, disfigurement, grease, and/or oil that could prevent a tight closure.

6.5.2 Decontaminate the sampler according to the procedures in SOP 3-06, Equipment Decontamination.

6.5.3 Screw the corer head onto the core tube and screw the two handles onto the corer head.

6.5.4 Insert a CAB plastic liner into the core tube, insert a core catcher onto the end of the CAB plastic liner (stainless steel for normal sediments, Eggshell™ for wet sediments), and screw the stainless-steel nose piece onto the core tube. If using the hand corer from a boat, bridge, high dock, etc., be sure that the appropriate extension handle (5’, 10’ or 15’) is attached to the corer head.

6.5.5 Get in position over the sampling location. If wading in shallow water, be sure to approach the sample location from the downstream side. Line up the sampler, aiming it vertically for the point where the sample is being taken, and push the hand corer in a smooth continuous motion through the water and into the sediment. Increase the thrust as necessary to obtain the penetration desired. Do not hammer or pound the corer into the sediment.

6.5.6 Retrieve the sample by pulling straight up on the handles, keeping the corer as vertical as possible. If the corer has not been completely submerged, close the flutter valve by hand and press it shut while the sample is being retrieved. The flutter valve must be kept very wet if it is to seal properly and prevent sample washout. If the substrate is gripping the corer too tightly, gently rock the top of the corer back and forth horizontally to increase the size of the hole created by the corer and reduce the pull-out suction.

6.5.7 Unscrew the nose piece from the corer and cap the bottom end of the CAB core liner. Release the flutter valve to free the CAB core liner and slide the CAB core liner from the core tube. Cap the top of the CAB core liner and inspect the CAB core liner for recovery. If the recovery is adequate, proceed to step 6.5.8. If the recovery is not adequate, resample the location by repeating steps 6.5.3 through 6.5.7.

6.5.8 Bring the CAB core liner with the sediment sample over to the geologist table, keeping the core vertical. Place the CAB core liner on the geologist table and cut open with a core liner cutter. If AVS/SEM samples are to be collected, collect the AVS/SEM sample directly from the sediment contained in the core liner according to the procedures specified in the project-specific QAPP. If VOC samples are to be collected, collect the VOC samples by inserting a syringe, Terra Core sampler, or other VOC sampling device directly into the sediment core. Consult the project-specific QAPP for project-specific VOC sediment sampling procedures. Once the VOC samples have been collected, collect an additional aliquot for the VOC percent solids sample directly from the sediment core.

6.5.9 Once the AVS/SEM and VOC samples have been collected (or if AVS/SEM and VOC samples are not required), use a decontaminated stainless-steel spoon to transfer the remaining sediment core into a decontaminated stainless-steel bowl.

6.5.10 If additional aliquots are necessary to provide adequate sample volume, repeat steps 6.5.3 through 6.5.8 until an adequate sample volume has been collected, taking care to deploy the corer to an area that is proximal, but not on top of, the previous sample location.

6.5.11 Once an adequate sample volume has been collected, homogenize the sample in the stainless-steel bowl, record the sediment sample information on the Sediment Sample Collection Form (see Attachment 1), and collect the sediment samples according to the procedures specified in the project-specific QAPP (typically in order of decreasing volatility).

6.6 Wildco® Hand Corer with the Clevis and Line

6.6.1 Inspect the corer as described in step 6.5.1 above.

6.6.2 Decontaminate the sampler according to the procedures in SOP 3-06, Equipment Decontamination.

6.6.3 Screw the corer head onto the core tube. Attach the 3/16" braided polyester line to the corer by passing the line through the clevis in the corer head and knotting it securely. Strong, tight knots are essential to prevent losing the corer. If necessary, attach the auxiliary weights to the sampler according the manufacturer's directions.

6.6.4 Insert a CAB plastic liner into the core tube, insert a core catcher onto the end of the CAB plastic liner (stainless steel for normal sediments, Eggshell™ for soupy sediments), and screw the stainless-steel nose piece onto the core tube.

6.6.5 Position the corer over the drop point and steady momentarily, making sure to keep the corer vertical at all times. Make sure to arrange the 3/16" braided polyester line to run freely. Since the corer's penetration is by simple gravity, it is important that there be no restraint on the corer during descent by stricture on the line. Keep a firm hold on the free end of the line or tie it to the boat (if applicable) or some other permanent fixture.

6.6.6 Drop the corer into the water and allow the corer to free fall until it hits the sediment surface. The corer should not be dropped to depths greater than 20' to 30'. Dropping the corer to depths greater than 20' to 30' may result in the corer striking the sediment surface at an angle less than 90°, resulting in an unsatisfactory sample.

6.6.7 Once the corer has entered the sediment and is no longer falling, draw the line taut, and then pull on the line to pull the corer from the sediment. Once the corer has been pulled free from the sediment, bring the corer back to the surface by pulling up the line, using a smooth, hand-over-hand fashion. This movement automatically causes the flutter valve to close, preventing sample washout in all but the soupiest of sediments.

6.6.8 Once the corer has been returned to the surface, lift the corer clear of the water, being careful to keep the corer as vertical as possible at all times.

6.6.9 Collect the sediment sample according to the procedures outlined in steps 6.5.6 through 6.5.11 above.

7.0 Quality Control and Assurance

7.1 **Field Personnel** will follow specific quality assurance (QA) guidelines as outlined in the project-specific QAPP. The goal of the QA program should be to ensure precision, accuracy, representativeness, completeness, and comparability in the project sampling program.

7.2 Quality control (QC) requirements for sample collection are dependent on project-specific sampling objectives. The project-specific QAPP will provide requirements for sample preservation and holding times, container types, sample packaging and shipment, as well as requirements for the collection of various QC samples such as trip blanks, field blanks, equipment rinse blanks, and field duplicate samples.

8.0 Records, Data Analysis, Calculations

8.1 Records will be maintained in accordance with SOP 3-03, Recordkeeping, Sample Labelling, and Chain-of-Custody. Various forms are required to ensure that adequate documentation is made of the sample collection activities. These forms may include:

- Sample Collection Records;
- Field logbook;
- Chain-of-custody forms; and
- Shipping labels.

8.2 Sample collection records (Attachment 1) will provide descriptive information for the sediment samples collected at each location.

8.3 The field logbook is kept as a general log of activities and should not be used in place of the sample collection record.

8.4 Chain-of-custody forms are transmitted with the samples to the laboratory for sample tracking purposes.

8.5 Shipping labels are required is sample coolers are to be transported to a laboratory by a third party (courier service).

9.0 Attachments or References

Attachment 1 – Sediment Sample Collection Record

Figure 1 – Petite Ponar® Grab Sampler and Exploded Diagram

Figure 2 – Ekman Bottom Grab Sampler (Large, Tall, and Standard Sizes) and Exploded Diagram

Figure 3 – Wildco® Hand Corer (with Case and Accessories) and Exploded Diagram

Figure 4 – Illustrations of Acceptable and Unacceptable Grab Samples

U.S. Environmental Protection Agency (U.S. EPA). 2001. *Methods for Collection, Storage and Manipulation of Sediments for Chemical and Toxicological Analyses: Technical Manual.* October.

Wildlife Supply Company. 2003. 2424- Hand Corer Instructions.

Wildlife Supply Company. 2004. Ekman Bottom Grabs Instructions and Maintenance.

Wildlife Supply Company. 2004. 1728-G30/ 1728-G40 Petite Ponar® Grab.

SOP 3-05, *IDW Management*.

SOP 3-06, *Equipment Decontamination*.

Author	Reviewer	Revisions (Technical or Editorial)
Robert Shoemaker Senior Scientist	Chris Barr Program Quality Manager	Rev 0 – Initial Issue (May 2012)
Ken O'Donnell, PG Geologist	Claire Mitchell, PE, PMP Senior Engineer	Rev 1 – PFAS sampling update (July 2019)

Attachment 1

Sediment Sample Collection Record

SEDIMENT SAMPLE COLLECTION FORM

Project Name:

Date(s):

Project #:		**Date:**
Sample Location ID:		**Time:**
Sample #:		**Weather:**
Samplers:		

Sample Information:

Sample Depth:		**Sampling Device:**
Water Depth:		
Distance from River Bank:		
River Flow Rate:		
Field Decon:	Yes No Dedicated	**Sample Type:** Grab Composite

Munsell Color:

Sample Description:

Other physical characteristics of water body at sample location:
(Water color, turbidity, odor, presence of sheens, dead\stressed vegetation)

Sample Comments/Description:

NOTE: SOPs have been updated for PFAS sampling activities; however, AECOM's internal PFAS sampling guidance supersedes materials and methods described in SOPs.

Figure 1
Petite Ponar® Grab Sampler and Exploded Diagram

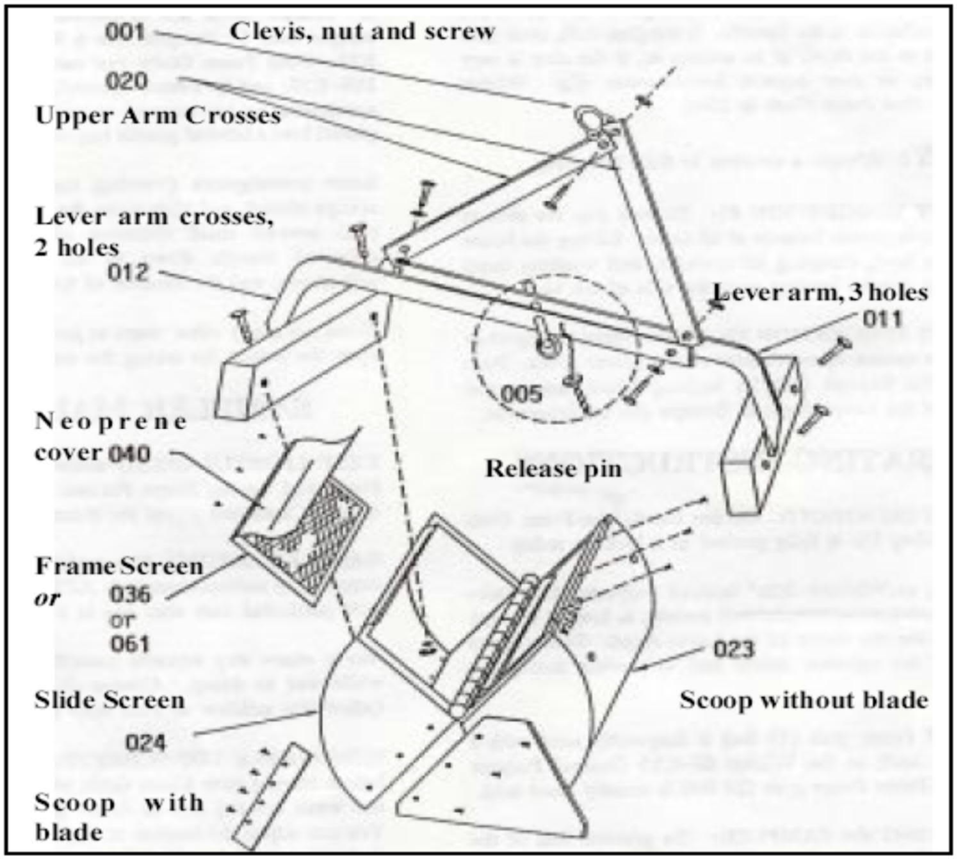


Figure 2

Ekman Bottom Grab Sampler (Large, Tall, and Standard Sizes) and Exploded Diagram

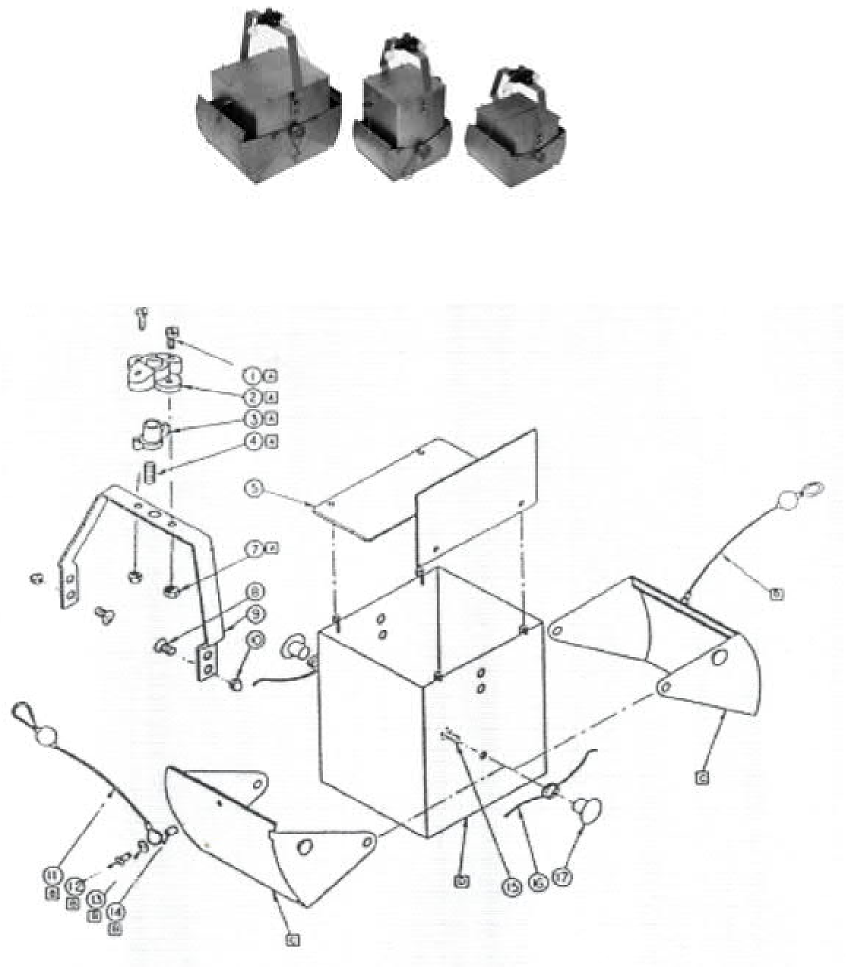
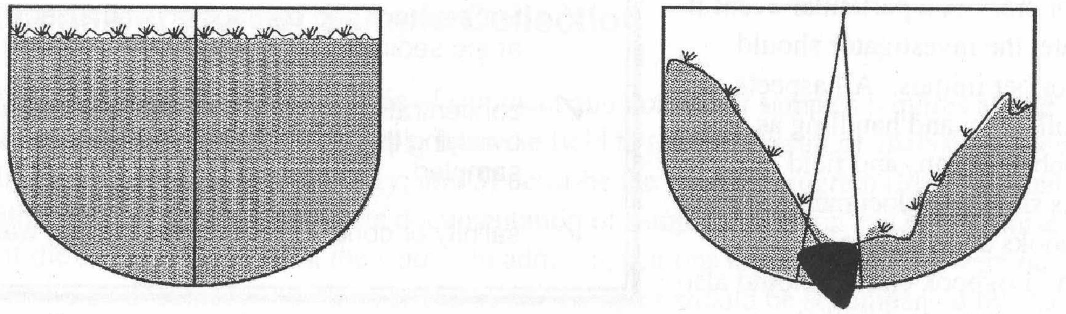


Figure 3
Wildco® Hand Corer (with Case and Accessories) and Exploded Diagram

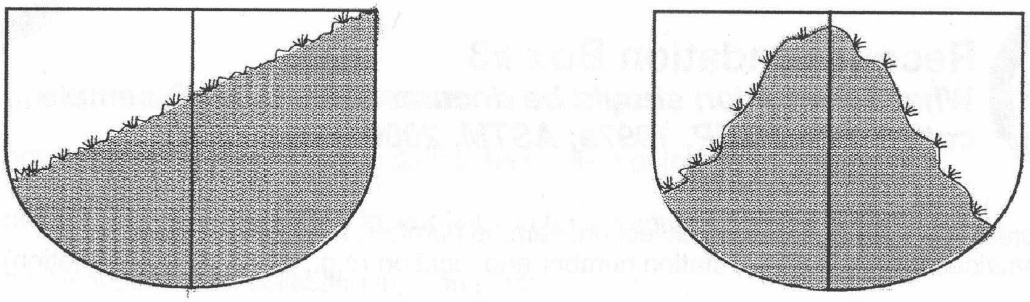
NOTE: SOPs have been updated for PFAS sampling activities; however, AECOM's internal PFAS sampling guidance supersedes materials and methods described in SOPs.

Figure 4
Illustrations of Acceptable and Unacceptable Grab Samples



Acceptable if Minimum Penetration Requirement Met and Overlying Water is Present

Unacceptable (Washed, Rock Caught in Jaws)



Unacceptable (Canted with Partial Sample)

Unacceptable (Washed)

Water Quality Parameter Testing

Procedure 3-24

1.0 Purpose and Scope

1.1 The purpose of this document is to define the standard operating procedure (SOP) for use water quality parameter testing for groundwater or surface water sampling. This SOP describes the equipment, field procedures, materials, and documentation procedures necessary to complete this task. Specific information regarding coring locations can be found in the associated Quality Assurance Project Plan (QAPP).

1.2 This procedure is the Program-approved professional guidance for work performed by AECOM under the client contract.

1.3 As guidance for specific activities, this procedure does not obviate the need for professional judgment. Deviations from this procedure while planning or executing planned activities must be approved in accordance with Program requirements for technical planning and review. If there are procedures whether it be from AECOM, state and/or federal that are not addressed in this SOP and are applicable to surface water sampling then those procedures may be added as an appendix to the project specific QAPP.

1.4 It is fully expected that the procedures outlined in this SOP will be followed. Procedural modifications may be warranted depending upon field conditions, equipment limitations, or limitations imposed by the procedure. Substantive modification to this SOP will be approved in advance by the **Task Order (TO) Manager** or **Program Quality Manager**. Deviations to this SOP will be documented in the field records.

2.0 Safety

2.1 Depending upon the site-specific contaminants, various protective programs must be implemented prior to sampling the first surface water sampling location. All **field sampling personnel** responsible for sampling activities must review the project-specific Accident Prevention Plan (APP) and Site Safety and Health Plan (SSHP), paying particular attention to the control measures planned for the sampling tasks. Conduct preliminary area monitoring to determine the potential hazard to field sampling personnel. If significant contamination is observed, minimize contact with potential contaminants in both the vapor and liquid phase through the use of respirators and disposable clothing.

2.2 In addition, observe standard health and safety practices according to the project-specific APP/SSHP. Suggested minimum protection during well sampling activities includes protective eyewear, powder-free nitrile gloves, rubberized steel-toed boots, and an American National Standards Institute-standard hard hat. Half-face respirators and cartridges and Tyvek® suits may be necessary depending on evaluation for PFAS and on the contaminant concentrations.

2.3 Daily safety briefs will be conducted at the start of each working day before any work commences. These daily briefs will be facilitated by the **Site Safety Officer (SSO)** or designee to discuss the day's events and any potential health risk areas covering every aspect of the work to be completed. Weather conditions are often part of these discussions. As detailed in the APP/SSHP, everyone on the field team has the authority to stop work if an unsafe condition is perceived until the conditions are fully remedied to the satisfaction of the SSO.

2.4 The health and safety considerations for the work associated with surface water sampling include:

- Proper selection of personal protective equipment for work around water bodies (e.g., personal flotation devices [PFDs]), as specified in the project-specific APP/SSHP.

NOTE: SOPs have been updated for PFAS sampling activities; however, AECOM's internal PFAS sampling guidance supersedes materials and methods described in SOPs.

- Appropriate health and safety protocols for working in a boat (if applicable), as specified in the project-specific APP/SSHP.
- Proper lifting techniques when retrieving surface water samplers, large muscles of the legs should be used, not the back.
- Stay clear of all moving equipment and avoid wearing loose fitting clothing.
- To avoid slip/trip/fall hazards as a result of working on wet surfaces, wear work boots/work boot covers with textured soles.
- To avoid heat/cold stress as a result of exposure to extreme temperatures and PPE, drink electrolyte replacement fluids (1 to 2 cups per hour is recommended), and in cases of extreme cold, wear fitted insulated clothing

3.0 Terms and Definitions

3.1 **Barometric Pressure (BP)**: The density of the atmosphere, which varies according to altitude and weather conditions.

3.2 **Conductivity/Specific Conductance**: A measure of the ability of water to pass electrical current, which increases with the amount of dissolved ionic substances (i.e., salts). Conductivity is inversely related to the resistance of a solution and is measured in units of mhos per centimeter (mhos/cm) (inverse ohms/cm, Siemens/cm). The conductivity of water increases with increasing temperature. Specific Conductance is corrected for 25 degrees Celsius (°C); for this reason, it is best to record Specific Conductance. If Conductivity is recorded, the temperature of the sample MUST recorded.

3.3 **Dissolved Oxygen (DO):** The amount of oxygen present in water and available for respiration. DO is typically measured in milligrams per liter (mg/L). Oxygen is less soluble in warm and salty waters, so the instrument compensates the apparent percent saturation for changes in temperature and conductivity. Most probes measure the current resulting from the electrochemical reduction of oxygen (at a gold cathode) diffusing through a selective membrane. Because oxygen is being removed from the sample to perform the measurement, sample flow is required to prevent false low readings due to depletion of oxygen in the solution in front of the probe. Optical DO probes do not remove oxygen from the sample and are less affected by salts. The common range of DO in groundwater is 0.0 to 3.0 mg/L. Measurements outside of this range suggest that the meter may not be operating correctly.

3.4 **Nephelometric Turbidity Unit (NTU):** The measurement of light passing through a sample based on the scattering of light caused by suspended particles.

3.5 **Potential of Hydrogen (pH):** A measure of acidity and alkalinity of a solution using a logarithmic scale on which a value of 7 represents neutrality, lower numbers indicate increasing acidity, and higher numbers are increasingly basic.

3.6 **Oxidation-Reduction Potential (ORP):** Also known as redox or eH, ORP is a measurement of the potential for a reaction to occur, which generally indicates the oxygen status of a sample. The probe consists of a platinum electrode, the potential of which is measured with respect to a reference electrode that rapidly equilibrates with the potential of the sample solution. A positive value indicates that oxygen is present. A negative value indicates an anaerobic environment or reducing condition. For this reason, negative ORP readings should be associated with DO readings of less than 0.5 mg/l; with negative ORP readings the water may exhibit a sulfur odor or gray color. Positive ORP readings should be associated with DO readings greater than 0.5 mg/L and lack of sulfur odors. Because of the complex relationship between ORP and temperature, no compensation is attempted; it is thus best to report both the ORP and temperature of a water sample.

3.7 **Total Dissolved Solids:** A measure of the quantity of materials in water that are either dissolved or too small to be filtered.

3.8 **Turbidity:** Measure of the clarity of water in NTUs. Potable water typically has NTU values between 0.0 and 0.3 NTUs, depending on the state or regulatory program.

4.0 Interferences

4.1 During field testing, water quality data that is documented from field testing equipment may be influenced by certain outside factors that are unrelated to the actual site water quality. Such parameters and equipment include the following:

4.2 **pH Meters:** Coatings of oils, greases, and particles may impair the electrode's response. Pat the electrode bulb dry with lint-free paper or cloth and rinse with de-ionized water. For cleaning hard-to-remove films, use isopropyl alcohol very sparingly so that the electronic surface is not damaged.

Poorly buffered solutions with low specific conductance (less than 200 microsiemens per centimeter) may cause fluctuations in the pH readings. Equilibrate electrode by immersing in several aliquots of sample before taking pH.

4.3 **Dissolved Oxygen**: Dissolved gases (e.g., hydrogen sulfide, halogens, sulfur dioxide) are a factor with the performance of DO probes. The effect is less pronounced on optical DO meters. Meter type and potential interferences should be considered based on potential sulfate/sulfide or nitrate/nitrite reducing environments.

Exposure of the sample to the atmosphere will cause elevated DO measurements.

4.4 **Turbidity Meter**: If the weather is warm and humidity is high, condensation may collect on the cuvet.

To avoid this, allow the sample to warm and dry the outside of the cuvet before making the measurement. One method used to accomplish this is to place the cuvet against one’s body (armpits work well).

4.5 **Temperature**: Sample temperature will change rapidly when there are significant differences between the sample and ambient air.

5.0 Training and Qualifications

5.1 Qualifications and Training

5.1.1 The individual executing these procedures must have read, and be familiar with, the requirements of this SOP.

5.2 Responsibilities

5.2.1 The **TO Manager** is responsible for ensuring that field activities comply with this procedure. The TO Manager or designee shall review all surface water sampling forms on a minimum monthly basis. The TO Manager is responsible for ensuring that all field sampling personnel involved in water quality parameter testing shall have the appropriate education, experience, and training to perform their assigned tasks.

5.2.2 The **Program Quality Manager** is responsible for ensuring overall compliance with this procedure.

5.2.3 The **Field Manager** is responsible for ensuring that all field sampling personnel follow these procedures.

5.2.4 **Field sampling personnel** are responsible for the implementation of this procedure. Minimum qualifications for field sampling personnel require that one individual on the field team shall have a minimum of 6 months of experience with water quality parameter testing.

5.2.5 The **field sampler and/or task manager** is responsible for directly supervising the surface water sampling procedures to ensure that they are conducted according to this procedure, and for recording all pertinent data collected during sampling. If deviations from the procedure are required because of anomalous field conditions, they must first be approved by the **Program Quality Manager** and then documented in the field logbook and associated report or equivalent document.

6.0 Equipment and Supplies

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

- QAPP
- Maps/Plot plan
- Non-water-repellent logbook
- Site description forms
- Pump (Peristaltic, Portable Bladder, Submersible)
- Polyethylene bladders (for portable bladder pumps)
- Bladder pump controller (for portable bladder pumps)
- Air compressor (for portable bladder pumps)
- Nitrogen cylinders (for portable bladder pumps)
- 12-volt power source
- Polyethylene inlet and discharge tubing
- Silicone tubing appropriate for peristaltic pump head
- HDPE bailer appropriately sized for well
- Disposable bailer string (polypropylene)
- Individual or multi-parameter water quality meter(s) with flow-through cell to measure temperature, pH, specific conductance, dissolved oxygen (DO), oxidation reduction potential (ORP), and/or turbidity
- Turbidity meter
- Teflon-free water level meter
- Oil/water interface probe

6.2 **Equipment/Apparatus**: Field personnel shall consult the site QAPP to review the equipment requirements for the sampling procedures to be followed during the sampling effort. The specific apparatus and materials required will depend on the water quality parameters being monitored. **Table 1** shows the common equipment used in water quality parameter testing.

Table 1
Water Quality Parameter Testing — Common Equipment

Water quality Parameter Instrument	Calibration Standards Required	Other Equipment
pH Meter	Yes - 2- or 3-Point Standards depending on groundwater range. Calibration must cover the range to be measured. If samples are above or below typical buffer standards (4, 7 and 10), special order buffers that fall outside groundwater pH range.	Container or flow thru cell for holding sample
Specific Conductance	Yes	Container or flow thru cell for holding sample
ORP Meter	Yes	Container or flow thru cell for holding sample
Turbidity Meter	Yes	Container or flow thru cell for holding sample
DO	No	Container or flow thru cell for holding sample
Thermometer	No	Container or flow thru cell for holding sample
Flow Rate	No	Container or flow thru cell for holding sample

Notes:
ORP = Oxidation Reduction Potential
DO = Dissolved Oxygen

7.0 Calibration or Standardization

7.1 Instrument or Method Calibration

Most monitoring instruments require calibration before use, and this calibration must be conducted in the field under the ambient climatic conditions that will be present during field sampling. Calibration of monitoring instruments shall be performed in accordance with the manufacturer's specifications and recorded in the provided form in Attachment 1. Site-specific instrument calibration requirements should be specified in the QAPP. The following minimum calibration requirements apply to the various types of meters used to gather water quality measurements.

Initial Calibration (IC): Before use, the instrument or meter electronics are adjusted (manually or automatically) to a theoretical value (e.g., DO saturation) or a known value of a calibration standard. An IC is performed in preparation for the first use of an instrument or if a calibration verification does not meet acceptance criteria.

Initial Calibration Verification (ICV): The instrument or meter calibration is checked or verified directly following IC by measuring a calibration standard of known value as if it were a sample and comparing the measured result to the calibration acceptance criteria for the instrument/parameter. If an ICV fails to meet acceptance criteria, immediately recalibrate the instrument using the applicable initial calibration procedure or remove it from service.

Continuing Calibration Verification (CCV): After use, the instrument or meter calibration is checked or verified by measuring a calibration standard of known value as if it were a sample and comparing the measured result to the calibration acceptance criteria for the instrument/parameter.

7.2 Calibration Checks

Calibration checks are conducted by measuring a known standard. They must be completed after calibration and should be performed at least one other time (i.e., after lunch) and anytime suspect measurements are encountered. Table 2 provides general acceptance ranges to be used during calibration checks. If a meter is found to be outside of the acceptance range, the meter must be recalibrated. If the meter remains out of range, the project manager and/or the supplier of the meter should be contacted to determine alternative measures.

Table 2
Calibration Check Acceptance Limits

Parameter	Acceptance Criteria
Dissolved Oxygen	±0.3 mg/L of the theoretical oxygen solubility
Oxidation-Reduction Potential	±10 mv from the theoretical standard value at that temperature
pH	±0.2 Standard pH Units
Specific Conductance	±5% of the standard
Turbidity	0.1 to 10 NTU: ±10% of the standard 11 to 40 NTU: ±8% of the standard 41 to 100 NTU: ±6.5% of the standard

Notes:
Mg/L = milligrams per liter
Mv = millivolts
NTU = nephelometric turbidity units

7.3 Possible and Suspected Ranges

The concentration for each parameter range should be known so that concentrations outside of the range can be noted. Table 3 presents the maximum range of the parameter in groundwater. The table also presents the suspected range. Measurements outside of the maximum/minimum range should be considered in error and the measurement method should be checked. Concentrations outside the normal range should be treated as suspect but may be the result of contaminant impact. For example, a pH of 2.0 would be out of the normally suspected range for groundwater but not at a site impacted with an acid.

Table 3
Minimum and Maximum Result Ranges

Parameter	Units	PossibleMin	Possible Max	Normal Min	Normal Max	Notes
Dissolved Oxygen	mg/L	0.0	14.6 (0°C) 10.1 (15°C) 8.3 (2°C)	0.0	5	The colder the sample, the higher the DO reading. DO greater than 1 mg/L, ORP positive should not have sulfur odor, sulfide, ferrous iron and/or gray color. DO less than 1 mg/L, ORP negative, may have sulfur odor, sulfide, ferrous iron and/or gray color.
pH	SU	0	14	5	9	pH values exceeding 10 could indicate grout contamination

NOTE: SOPs have been updated for PFAS sampling activities; however, AECOM's internal PFAS sampling guidance supersedes materials and methods described in SOPs.

Parameter	Units	Possible Min	Possible Max	Normal Min	Normal Max	Notes
ORP	mv					DO greater than 1 mg/L, ORP positive should not have sulfur odor, sulfide, ferrous iron and/or gray color. DO less than 1 mg/L, ORP negative, may have sulfur odor, sulfide, ferrous iron and/or gray color.
Specific Conductance	µS/cm			varies	varies	
Temperature	°C	0	100	5	30	
Turbidity	NTU	0	Greater than 1,000	0	Greater than 1,000	50 NTU or greater suggests cloudiness.

Notes:
mg/L = milligrams per liter
°C = degrees Celsius
DO = dissolved oxygen
SU = standard units
ORP = oxidation reduction potential
Mv = millivolts
mS/cm =micro Siemens per cm
NTU = nephelometric turbidity units

7.4 Field Instruments and Calibration Criteria

The calibration acceptance criteria for each instrument are summarized in Table 4 along with special considerations related to each field instrument.

Table 4
Calibration check Acceptance Limits

Parameter	Acceptance Criteria
Dissolved Oxygen	±0.3 mg/L of the theoretical oxygen solubility
Oxidation-Reduction Potential	±10 mv from the theoretical standard value at that temperature.
pH	±0.2 Standard pH Units
Specific Conductance	±5% of the standard
Turbidity	0.1 to 10 NTU: ±10% of the standard 11 to 40 NTU: ±8% of the standard 41 to 100 NTU: ±6.5% of the standard

Notes:
Mg/L = milligrams per liter
mv = millivolts
NTU = nephelometric turbidity units

7.4.1 pH Meters

For the most accurate of pH measurements, pH meters should receive a three-point calibration. However, if a two-point calibration will bracket the groundwater pH of the site, a two-point calibration is acceptable. Three-point calibrations typically include calibrating to solutions of pH 7.00, 4.00, and 10.00. If groundwater pH is outside the calibration range of the solution standards, special buffers must be ordered to bracket the pH. Some meters will report the slope of the calibration and this may be used in checking the meter calibration (refer to the meter's manual). When performing an ICV, the result must be within +/- 0.2 pH units of the stated buffer value.

pH meters should be calibrated across the range of values to be measured. The maximum and minimum calibration solutions shall be outside the range of anticipated values. For example, if the expected range is between 7.50 and 9.00, the 7.00 and the 10.00 standard should be used for calibration. Perform the IC using at least two buffers, and always use the pH 7.00 buffer first. A reading that is above the maximum (or below the minimum) calibration standard is an estimate only and is not valid. This condition requires obtaining a new standard that is above (or below) the reported value, depending on the measurement.

A percent slope of less than 90 percent indicates a bad electrode that must be changed or repaired. If percent slope cannot be determined, or the manufacturer's optimum specifications are different, follow the manufacturer’s recommendation for maintaining optimum meter performance.

7.4.2 Specific Conductivity Meters

For IC, when the sample measurements are expected to be 00 microsiemens per centimeter (µS/cm) or greater, use two standard potassium chloride (KCl) solutions that bracket the range of expected sample conductivities. Calibrate the instrument with the first standard. Verify the calibration of the instrument with the second standard, bracketing the range of expected sample values.

If the instrument can be calibrated with more than one standard, choose additional calibration standards within the range of expected sample values.

When the sample measurements are expected to be less than 100 µS/cm, a lower bracket is not required, but one standard (KCl) solution that is within the range of expected measurements must be used for the IC and the ICV.

Accept the calibration if the meter reads within +/- 5 percent of the value of any calibration standard used to verify the calibration.

Most field instruments read conductivity directly. Record all readings and calculations in the calibration records.

For CCV, check the meter with at least one KCl standard with a specific conductance in the range of conductivity measured in environmental samples. The reading for the calibration verification must also be within +/- 5 percent of the standard value.

If new environmental samples are encountered outside the range of the IC, verify the instrument calibration with two standards bracketing the range of sample values. If these calibration verifications fail, recalibrate the instrument.

7.5 Dissolved Oxygen Meters

Before calibrating, check the probe membrane for bubbles, tears, or wrinkles. These conditions require replacement of the membrane in accordance with the manufacturer’s directions.

If the meter provides readings that are off-scale, will not calibrate, or drift, check the leads, contacts, etc., for corrosion and/or short circuits. These conditions require replacement maintenance in accordance with the manufacturer’s directions.

Most DO meters must be calibrated based on an environment of 100 percent humidity and a known elevation and barometric pressure (BP).

For 100 percent humidity, place the probe in the calibration container with a moist towel and allow the probe to remain, undisturbed, for 10 to 20 minutes.

The IC is an air calibration at 100% saturation. Before use, verify the meter calibration in water-saturated air to make sure it is properly calibrated and operating correctly. Make a similar verification at the end of the day or sampling event. Follow the manufacturer’s instructions for your specific instrument. Allow an appropriate warm up period before IC. Wet the inside of the calibration chamber with water, pour out the excess water (leave a few drops), wipe any droplets off the membrane/sensor and insert the sensor into the chamber (this ensures 100 percent humidity). Allow adequate time for the DO sensor and the air inside the calibration chamber to equilibrate. Once the probe/calibration chamber is stable at ambient temperature, check the air temperature and determine from the DO versus temperature table (see Attachment 2) what DO should measure. The acceptance criterion for DO ICV is +/- 0.3 mg/L.

Use the same procedure as above for CCV.

7.6 ORP Meters

Verify electrode response before use in the field.

Equilibrate the standard solution to the temperature of the sample. The standard solution is based on a 25°C temperature; however, the calibration solution standard's value will require adjustment based on the temperature.

Immerse the electrodes and gently stir the standard solution in a beaker (or flow cell).

Turn the meter on, placing the function switch in the millivolt (mv) mode.

Let the electrode equilibrate and record the reading to the nearest millivolt. The reading must be within ±10 mv from the theoretical redox standard value at that temperature. If not, determine the problem and correct it before proceeding. Switch to temperature display and read the value.

Record the mv reading and temperature in the field notebook or in form. Rinse the electrode with distilled water and proceed with the sample measurement, unless using a flow cell. If a flow cell is used, rinse between sample locations.

7.7 Turbidity Meters

Perform an initial calibration using at least two primary standards.

If the instrument cannot be calibrated with two standards, calibrate the instrument with one standard and verify with a second standard.

Perform an ICV by reading at least one primary standard as a sample. The acceptance criterion for the ICV depends on the range of turbidity of the standard value:

1. Standard Value = 0.1 to 10 NTU: the response must be within 10 percent of the standard;
2. Standard Value = 11 to 40 NTU: the response must be within 8 percent of the standard;
3. Standard Value = 41 to 100 NTU: the response must be within 6.5 percent of the standard; and
4. Standard Value greater than 100 NTU: the response must be within 5 percent of the standard.

Determining the Values of Secondary Standards: Use only those certified by the manufacturer for a specific instrument. Secondary standards may be used for CCVs.

To initially determine the value of a secondary standard, assign the value that is determined immediately after an ICV or verification with primary standards. This is done by reading the secondary standard as a sample. This result must be within the manufacturer's stated tolerance range and +/- 10 percent of the assigned standard value. If the +/- 10 percent criterion is not met, assign this reading as the value of the standard. If the reading is outside the manufacturer's stated tolerance range, discard the secondary standard.

CCV: Perform a CCV using at least one primary or secondary standard. The calibration acceptance criteria are the same as those for an ICV.

8.0 Procedures

8.1 Purpose

The procedures will vary depending on parameters being measured, method of sampling, and the method of measurement used. The information here is a general guidance and the site-specific documents and manufacturer manuals supersede these procedures.

8.2 Cautions

Improper use of water quality testing equipment could result in equipment damage or compromised sampling results. Personnel should be trained to operate the test equipment being used for a field operation and should be trained in the proper techniques for collecting and logging water quality parameters. Personnel should also be able to recognize problems with test equipment and have someone available for basic troubleshooting and repair.

8.3 Direct Measurements

Direct measurements with meters are the most common methods and can be accomplished by placing a sample in a container with the probe or by allowing the water to flow past the probe in a flow cell. The use of a flow-through cell improves measurement quality by allowing the constant flow of water over the probes and reduces interaction of the sample with the atmosphere. Sample cups should be avoided. The quantity of samples, timing, and methodology should be described in the project QAPP.

Following calibration of required probes, connect the bottom flow-cell port to the discharge line of the pump. Connect the top port to a discharge line directed to a bucket to collect the purge water. Allow the flow cell to completely fill. As the water flows over the probe, record the measurements. Continue to record the measurements at regular intervals, as specified in the QAPP.

When the ambient air temperatures are much higher or lower than the temperature of the water sample, it is best to keep the length of tubing between the wellhead and the flow cell as short as possible to prevent heating or cooling of the water. Tubing and flow-through cell should not be exposed to direct sunlight, particularly in the summer, if at all possible, to avoid heating of water samples.

8.4 Data Acquisitions, Calculations, and Data Reduction

8.4.1 Specific Conductivity Correction Factions

If the meter does not automatically correct for temperature (i.e., read Specific Conductivity) record Conductivity and adjust for temperature upon returning to the office. The following equation can be used to convert Conductivity to Specific Conductivity.

$$K = \frac{(Km)(C))}{1 + 0.0191(\mathrm{T} - 25)}$$

Where:

K = Conductivity in µmhos/cm at 25°C

Km = Measured conductivity in µmhos/cm at T degrees Celsius

C = Cell constant

T = Measured temperature of the sample in degrees Celsius;

If the cell constant is 1, the formula for determining conductivity becomes:

$$K = \frac{(Km)}{1 + 0.0191(\mathrm{T} - 25)}$$

8.4.2 Percentage Difference Calculation

For evaluating slope of readings from either a flow cell or a sample cup.

$$\%Difference = \frac{(Highest\ Value - Lowest\ Value)}{(Highest\ Value)}\ x\ 100$$

8.4.3 Convert mm mercury (mmHG) to inches mercury (inHG)

$$mmHG = inHG\ x\ 25.4$$

8.4.4 True Barometric Pressure

For Converting BP obtained from a public domain source that is expressed in BP at sea level to BP at the subject site.

$$TrueBP = (BP) - \frac{(2.5\ x\ [Local\ Altitude])}{100}$$

Where: BP is in mmHG and Local Altitude is in feet

Example: BP at Site A is 30.49 inHG and elevation is 544 feet, calculate TrueBP

Convert inHG to mmgHG:

mmHG = 30.49 inHG x 25.4 = 774.4 mmHG

Calculate TrueBP:

TrueBP = (774.4 mmHG) – [2.5*(544/100)] = 774.4-13.6 = 760.mmHG.

9.0 Quality Control and Assurance

9.1 Field personnel will follow specific quality assurance (QA) guidelines as outlined in the project-specific QAPP. The goal of the QA program should be to ensure precision, accuracy, representativeness, completeness, and comparability in the project sampling program.

9.2 Quality Control (QC) requirements for sample collection are dependent on project-specific sampling objectives. The project-specific QAPP will provide requirements for sample preservation, holding times, container types, as well as various QC samples such as trip blanks, field blanks, equipment blanks, and field duplicates.

10.0 Data and Records Management

10.1 Field notes will be kept during sampling activities in accordance with *SOP 3-03 – Recordkeeping, Sample Labeling, and Chain of Custody*. During the completion of sampling activities, fill out the sample logbook and transmit forms to the TO Manager for storage in project files.

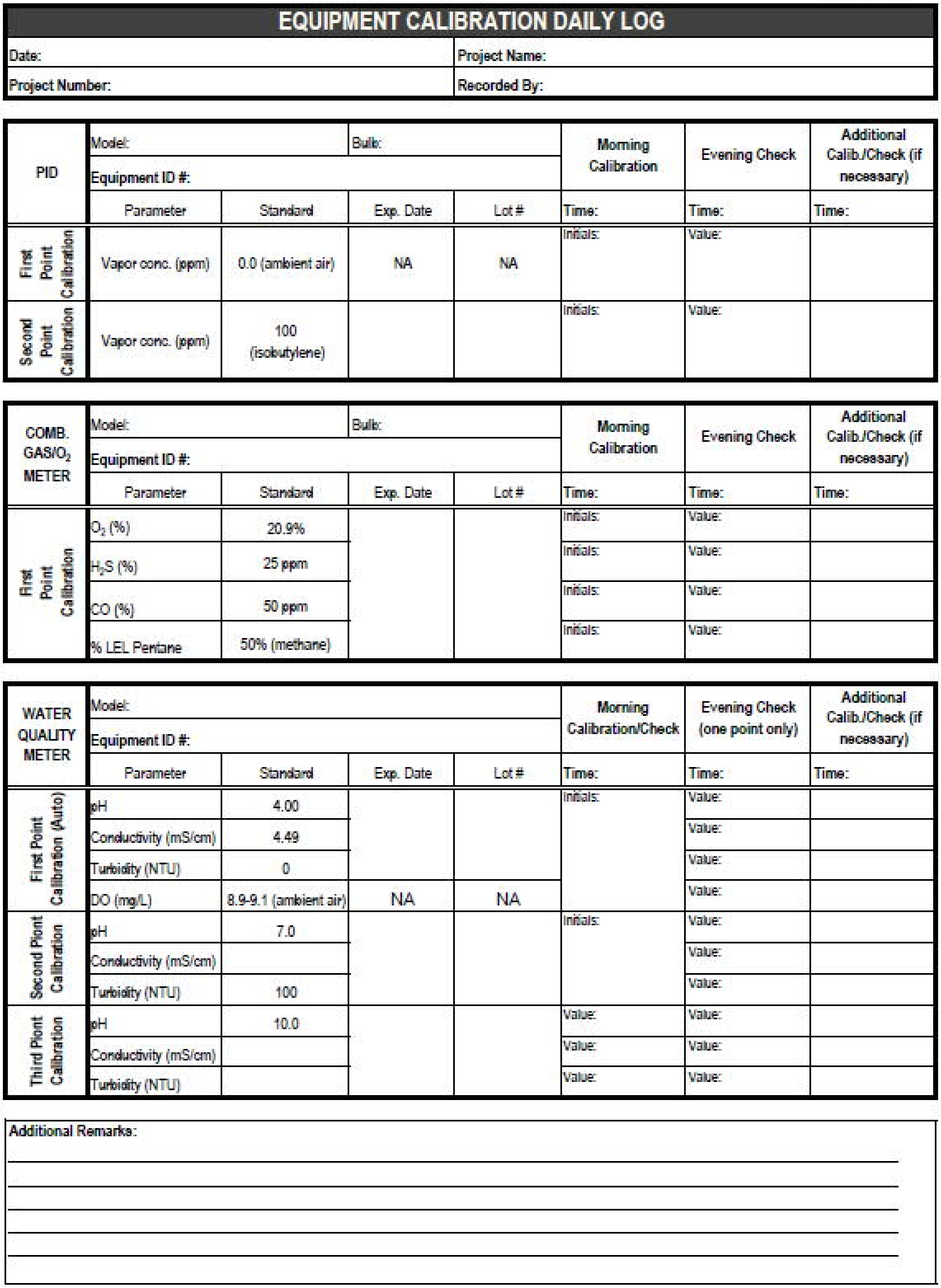
10.2 Deviations to the procedures detailed in the SOP should be recorded in the field logbook.

11.0 Attachments or References

Attachment 1: Example Field Instrument Calibration Form
Attachment 2: Solubility of Oxygen at Given Temperatures
Attachment 3: Example Field Data Form

Author	Reviewer	Revisions (Technical or Editorial)
Robert Shoemaker Senior Scientist	Naomi Ouellette, Project Manager	Rev 0 – Initial Issue
Amanda Martin Engineer	Claire Mitchell, PE, PMP Senior Engineer	Rev 1 – PFAS sampling update (July 2019)

Attachment 1
Example Field Instrument Calibration Form



EQUIPMENT CALIBRATION DAILY LOG	
Date:	Project Name:
Project Number:	Recorded By:

PID	Model:		Bulb:		Morning Calibration	Evening Check	Additional Calib./Check (if necessary)
	Equipment ID #:						
	Parameter	Standard	Exp. Date	Lot #	Time:	Time:	Time:
First Point Calibration	Vapor conc. (ppm)	0.0 (ambient air)	NA	NA	Initials:	Value:	
Second Point Calibration	Vapor conc. (ppm)	100 (isobutylene)			Initials:	Value:	

COMB. GAS/O_2 METER	Model:		Bulb:		Morning Calibration	Evening Check	Additional Calib./Check (if necessary)
	Equipment ID #:						
	Parameter	Standard	Exp. Date	Lot #	Time:	Time:	Time:
First Point Calibration	O_2 (%)	20.9%			Initials:	Value:	
	H_2S (%)	25 ppm			Initials:	Value:	
	CO (%)	50 ppm			Initials:	Value:	
	% LEL Pentane	50% (methane)			Initials:	Value:	

WATER QUALITY METER	Model:				Morning Calibration/Check	Evening Check (one point only)	Additional Calib./Check (if necessary)
	Equipment ID #:						
	Parameter	Standard	Exp. Date	Lot #	Time:	Time:	Time:
First Point Calibration (Auto)	pH	4.00			Initials:	Value:	
	Conductivity (mS/cm)	4.49				Value:	
	Turbidity (NTU)	0				Value:	
	DO (mg/L)	8.9-9.1 (ambient air)	NA	NA		Value:	
Second Plont Calibration	pH	7.0			Initials:	Value:	
	Conductivity (mS/cm)					Value:	
	Turbidity (NTU)	100				Value:	
Third Plont Calibration	pH	10.0			Value:	Value:	
	Conductivity (mS/cm)				Value:	Value:	
	Turbidity (NTU)				Value:	Value:	

Additional Remarks:

Attachment 2
Solubility of Oxygen at Given Temperatures

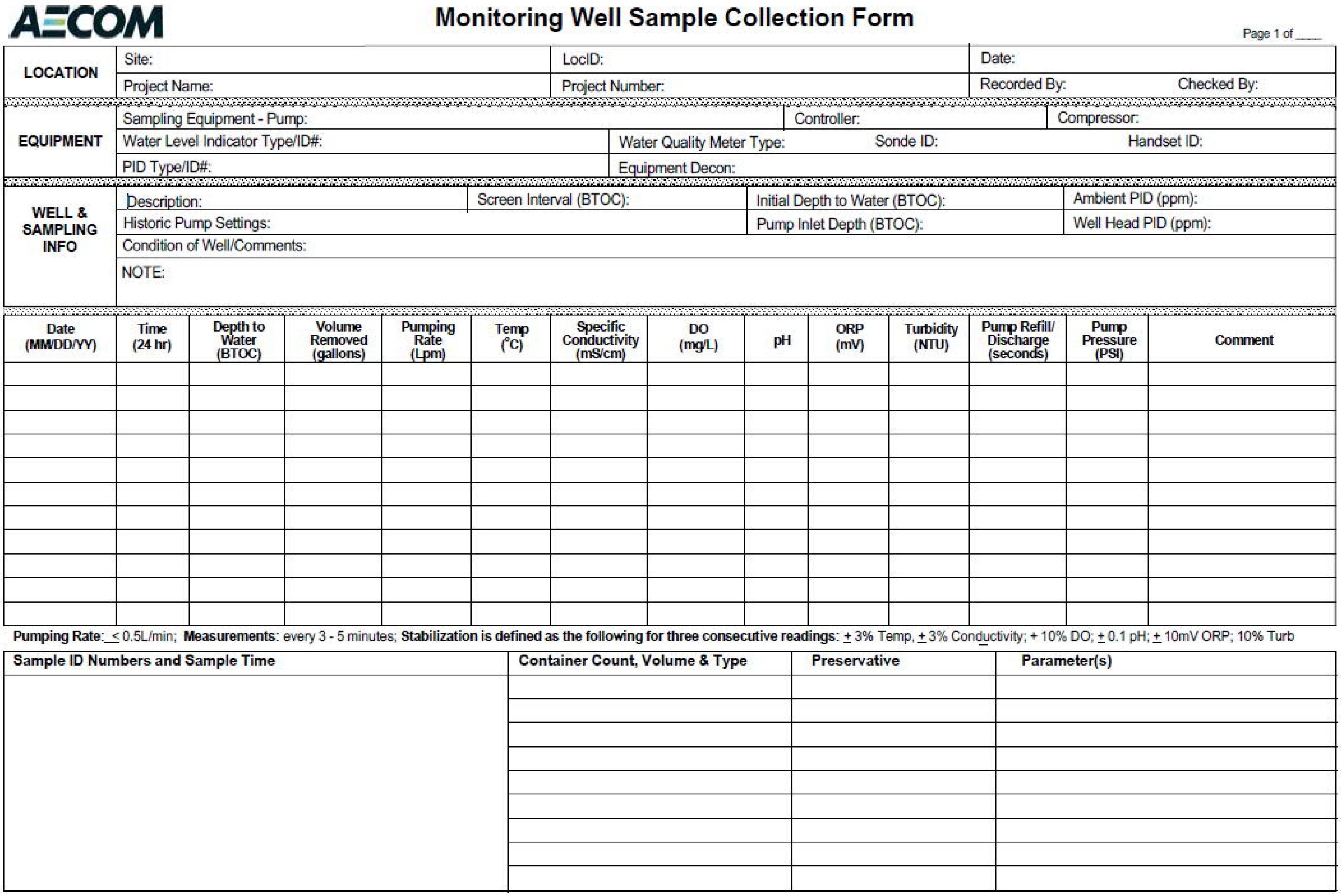
Field Measurement of Dissolved Oxygen

Solubility of Oxygen in Water at Atmospheric Pressure

Temperature °C	Oxygen Solubility mg/L	Temperature °C	Oxygen Solubility mg/L
0.0	14.621	26.0	8.113
1.0	14.216	27.0	7.968
2.0	13.829	28.0	7.827
3.0	13.460	29.0	7.691
4.0	13.107	30.0	7.559
5.0	12.770	31.0	7.430
6.0	12.447	32.0	7.305
7.0	12.139	33.0	7.183
8.0	11.843	34.0	7.065
9.0	11.559	35.0	6.950
10.0	11.288	36.0	6.837
11.0	11.027	37.0	6.727
12.0	10.777	38.0	6.620
13.0	10.537	39.0	6.515
14.0	10.306	40.0	6.412
15.0	10.084	41.0	6.312
16.0	9.870	42.0	6.213
17.0	9.665	43.0	6.116
18.0	9.467	44.0	6.021
19.0	9.276	45.0	5.927
20.0	9.092	46.0	5.835
21.0	8.915	47.0	5.744
22.0	8.743	48.0	5.654
23.0	8.578	49.0	5.565
24.0	8.418	50.0	5.477
25.0	8.263		

Notes:
The table provides three decimals to aid interpolation
Under equilibrium conditions, the partial pressure of oxygen in air-saturated water is equal to that of the oxygen in water saturated
°C = degrees Celsius
mg/L = milligrams per liter

Attachment 3
Example Field Data Form



Monitoring Well Sample Collection Form

Page 1 of ____

LOCATION
Site:
LocID:
Date:
Project Name:
Project Number:
Recorded By:
Checked By:

EQUIPMENT
Sampling Equipment - Pump:
Controller:
Compressor:
Water Level Indicator Type/ID#:
Water Quality Meter Type:
Sonde ID:
Handset ID:
PID Type/ID#:
Equipment Decon:

WELL & SAMPLING INFO
Description:
Screen Interval (BTOC):
Initial Depth to Water (BTOC):
Ambient PID (ppm):
Historic Pump Settings:
Pump Inlet Depth (BTOC):
Well Head PID (ppm):
Condition of Well/Comments:
NOTE:

Date (MM/DD/YY)	Time (24 hr)	Depth to Water (BTOC)	Volume Removed (gallons)	Pumping Rate (Lpm)	Temp (°C)	Specific Conductivity (mS/cm)	DO (mg/L)	pH	ORP (mV)	Turbidity (NTU)	Pump Refill/ Discharge (seconds)	Pump Pressure (PSI)	Comment

Pumping Rate: ≤ 0.5L/min; **Measurements:** every 3 - 5 minutes; **Stabilization is defined as the following for three consecutive readings:** ± 3% Temp, ± 3% Conductivity; + 10% DO; ± 0.1 pH; ± 10mV ORP; 10% Turb

Sample ID Numbers and Sample Time	Container Count, Volume & Type	Preservative	Parameter(s)

Grab Groundwater Sampling Techniques

Procedure 3-37

1.0 Purpose and Scope

1.1 This standard operating procedure (SOP) defines the procedures for collecting grab-groundwater samples from temporary well points installed using direct push or other drilling.

1.2 This procedure is the Program-approved professional guidance for work performed by AECOM under the client contract.

1.3 As guidance for specific activities, this procedure is not intended to obviate the need for professional judgment during unforeseen circumstances. Deviations from this procedure while planning or executing planned activities must be approved by both the **Task Order (TO) Manager** and the **Program Quality Manager** and documented.

1.4 If there are procedures, whether they be from AECOM, state, and/or federal that are not addressed in this SOP and are applicable to direct push sampling, then those procedures may be added as an appendix to the project-specific Quality Assurance Project Plan (QAPP).

2.0 Safety

2.1 **Field Personnel** shall perform work in accordance with the Accident Prevention Plan (APP) and Site Safety and Health Plan (SSHP). During grab groundwater collection, subcontractors in direct contact with potentially contaminated media shall wear the proper personal protective equipment (PPE) as outlined in the APP/SSHP. Failure to comply will result in disciplinary action.

3.0 Terms and Definitions

3.1 Grab groundwater collection techniques are designed to collect screening-level groundwater data in an efficient manner such that informed field decisions can be made when delineating contaminant plumes, inferring source areas, and identifying other potential soil sample locations and/or locations for permanent monitoring well installation.

4.0 Interferences

4.1 Contaminants that are known to adsorb to particulates, such as metals, polychlorinated biphenyls (PCBs), etc., will be impacted by elevated turbidity (i.e., >25 Nephelometric Turbidity Units [NTU]). For grab groundwater samples with turbidity above 25 NTU, AECOM may collect filtered samples using a 0.45-micron field filter as well as unfiltered samples, providing that the use of a filter does not potentially compromise sample quality.

4.2 Gas bubbles present in discharge tubing during purging and sampling are a problem; their presence indicates off-gassing from groundwater or poor purging connections in the airline or groundwater tubing. Sunlight can exacerbate this problem when low pumping rates are used. Check connections at the surface, and if bubbles persist, check connections at the pump. During purging and sampling, observe the flow of groundwater in the sample tubing and keep the tubing filled with groundwater, removing all air pockets and bubbles, to the extent possible. Gas bubbles may be reduced by increasing flow, if possible, and keeping tubing shaded.

4.3 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 volatile organic compounds (VOCs) and dissolved gases analyses.

5.0 Training and Qualifications

5.1 Qualifications and Training

The individual executing these procedures must have read, and be familiar with, the requirements of this SOP.

5.2 Responsibilities

5.2.1 The **TO Manager** is responsible for ensuring that these standard grab groundwater collection procedures are followed during projects conducted under the Program and that a qualified individual conducts or supervises the projects.

5.2.2 The **Program Quality Manage**r is responsible for ensuring overall compliance with this procedure.

5.2.3 The **Site Supervisor (SS)** is responsible for ensuring that all **Field Personnel** follow these procedures.

5.2.4 All **Field Personnel** are responsible for the implementation of this procedure.

5.2.5 The **Field Personnel** and/or **SS** are responsible for directly supervising the grab groundwater collection procedures to ensure that they are conducted according to this procedure, and for recording all pertinent data collected during sampling.

6.0 Equipment and Supplies

6.1 Bladder Pump

The bladder pump system contains the following components: a pressurized cylinder of inert gas (typically nitrogen), a pump controller, air intake and discharge lines, and bladder pumps. The controller regulates total flow of nitrogen from the pressurized nitrogen cylinder to the pump assembly located in the well. AECOM typically samples one well per nitrogen cylinder. Note that if the bladder pumps are placed at the same depth in each well, multiple wells may be sampled simultaneously with one nitrogen cylinder or air compressor. In this case, a three-way cross splitter with quick-connect air line fittings is attached to the tubing connected to the nitrogen cylinder. Up to three controllers can then be connected to the nitrogen cylinder. If nitrogen cylinders are not available, air compressors may be used to power the bladder pumps.

The tubing bundle connected to the pump has three components: an air line with fittings to the pump and the controller, a sample line, and a support cable. For pumps that use nipple tubing connectors, the support cable may not be necessary. The sample line, through which purge water is removed, must to be composed entirely of high-density polyethylene (HDPE) if samples for VOCs or PFAS are to be collected, depending on the project data quality objectives.

Temporary well points installed using direct push or other drilling methods are typically 1” or 0.75” in diameter. The diameter of the bladder pump should be sufficiently small (e.g., 0.850”, 0.675”, etc.) to allow for the easy deployment of the pump, associated tubing, and water level indicator.

6.2 Peristaltic Pump

Peristaltic pumps are not submerged in the well but remain outside of the well and function by pulling water to the surface. A peristaltic pump has a rotating pump head with stepless variable speed that compresses a short stretch of flexible Pharmaceutical-grade (e.g., Pharmed) silicone tubing to pull water up from the well using mechanical peristalsis. The sample water does not come into direct contact with the pump. HDPE tubing is connected to either end of the silicone tubing. The pumps typically used, the GeoTech GeoPump or GeoPump II, operate off an external 12-volt (V) battery or 120 V alternating current (AC) power source. Commercially available “JumpStart” 12 V batteries are typically preferred since electrical hookup is typically not available; since they are safe, easy to carry, and easy to recharge; and since the potential contamination issues associated with use of a generator are avoided. Peristaltic pumps cannot be used when the depth to water is greater than 27 feet.

6.3 Tubing

HDPE tubing is preferred for all parameters. Pharmaceutical-grade (e.g., Pharmed) silicon tubing may be required to be used around the rotor head of the peristaltic pump and, if necessary, as a connecting tubing to the flow-through cells. Inner tubing diameter should be kept to the smallest size possible to reduce the generation of air pockets during low flow. Tubing typically used with the peristaltic pumps is HDPE of 1/4-inch outside diameter and 3/16-inch inner diameter.

6.4 Electronic water level indicator: Solinst Model 101 or similar

Inner casing diameter and pump diameter should be considered when selecting a water level indicator that will fit into the well with the pump. A smaller diameter probe will be required for temporary well points. Electronic water level indicators will be confirmed with the vendor to be Teflon-free.

6.5 Flow controllers and compressed inert gases for submersible bladder pumps

QED Model MP-10 flow controller and nitrogen gas are typically used unless nitrogen is an analyte of interest. Portable air compressors may be used in place of compressed gas (e.g., QED Well Wizard).

6.6 Power Source

Marine battery, battery pack, compressed gas, portable air compressor, and a flow-controller are typically used.

6.6.1 Bladder Pumps

For bladder pump operation, the cylinders of inert compressed gas or portable air compressors function with the flow controller as the power source, although the flow controller requires batteries.

6.6.2 Peristaltic Pumps

The peristaltic pumps typically used by AECOM require an external 12 V battery or 120 V AC power source. Commercially available 12 V batteries designed for jump-starting a car battery (“JumpStart” or similar) are preferred since electrical hookup is typically not available; since they are safe, easy to carry, and easily rechargeable; and since the potential contamination issues associated with use of a generator are avoided.

6.7 Turbidity Meter

LaMotte 2020 turbidity meter or similar model.

7.0 Procedure

7.1 Pre-Sampling Activities

Place polyethylene sheeting on the ground and assemble all necessary sampling equipment on top of it. This process helps to prevent contamination of the sampling equipment by the ground surface, reduces wear on the sampling equipment, and reduces the likelihood that contaminated purge water will spill onto the ground surface.

Prior to beginning sampling activities, measure the depth to water and total depth by using the water level indicator and determine the amount of water in the temporary well point. Record this information in the field logbook. If the depth to water is greater than 27 feet, a bladder pump will have to be used.

Wells should be inspected for the presence of light non-aqueous phase liquid (LNAPL). Wells with LNAPL cannot be sampled using bladder pumps or peristaltic pumps and must be sampled with a bailer.

All non-dedicated down-well measuring devices will be thoroughly decontaminated before sampling and between monitoring locations.

7.2 Purging the Temporary Well Point

Temporary well points are typically single-use and are sampled shortly after installation. Purging of temporary well points is completed just prior to sampling in an effort to remove the first water that enters the open borehole.

The following procedures should be followed when collecting grab samples from temporary well points:

Connect all the tubing to the pump. Attach the water discharge line to a 5-gallon purge bucket or carboy using a squeeze clamp or similar device. Connect the pump to the power source (i.e., battery, pump controller and compressed gas cylinder, or air compressor). Lower the tubing or pump to the bottom of the well and begin slowly pumping.

- Note the purge start time.
- Start by surging the tubing up and down several times within the lower part of the screened interval to loft sediment from the bottom of the well. Immediately raise the tubing or pump to the mid-point of the screened interval to remove dislodged sediment from the well. Secure the tubing in place.
- The pump controller should be set to allow for adequate recharge such that a maximum flow rate with no drawdown is achieved and a smooth, laminar discharge flow is achieved. Measure the flow rate using a graduated cylinder and time piece and monitor the water level and pumping rate.
- If drawdown cannot be reasonably controlled at any point during purging, especially to the extent that the well begins to purge dry, collect the groundwater sample immediately.
- If sufficient recharge is available, continue purging. Once drawdown has stabilized and an acceptable flow rate established, begin monitoring turbidity every 5 minutes and continue monitoring flow rate and water level. Water quality parameters should be monitored concurrently using an in-line device (i.e., multi-parameter probe and flow through cell) separate from the turbidity meter at the discharge end of the tubing. Field measurements should be taken after a visible ‘break’ in turbidity is noted in order to avoid running sediment-laden water, which may foul the sensors, through the field meters.
- Purge the temporary well for a period of 20 minutes or until a target turbidity reading of ≤ 25 NTU is achieved, whichever occurs first. Turbidity readings should be collected at a minimum of every 5 minutes.
- If the target turbidity has not been achieved at the end of 20 minutes, assess whether a decreasing turbidity trend exists (i.e., consecutive decreasing readings of >10%). If turbidity is decreasing, continue purging for another 20 minutes. Repeat this process until the target turbidity is achieved or for a maximum purge time of 1 hour (three 20-minute cycles).
- If, at the end of a 20-minute cycle, turbidity readings are not observed to be significantly decreasing and appear instead to stabilize (i.e., three consecutive readings with ±10%), the sample may be collected. The final turbidity must be noted at the time of sample collection.

7.3 Sampling

In keeping with convention, samples should be collected in order of decreasing volatility and reactivity so that the most volatile or reactive samples are collected first. The following are general guidelines.

- Gases (methane/ethane/ethene/hydrogen/CO_2)
- VOCs
- Semivolatile Organic Compounds (SVOCs)

- Pesticides
- PCBs
- Dioxins/furans
- Metals
- Per- and polyfluoroalkyl substances (PFAS)

During sample collection, allow the water to flow directly into and down the side of the sample container without allowing the tubing to touch the inside of the sample container or lid in order to minimize aeration and maintain sample integrity.

- If groundwater turbidity is above 25 NTU at the time of sampling, collect filtered and unfiltered samples using a 0.45-micron filter for analyses that may be impacted by the elevated turbidity (e.g., metals, PCBs). Do not collect filtered samples if the use of a filter may potentially compromise sample quality (e.g., PFAS).

8.0 Quality Control and Assurance

8.1 Collection of representative samples will be ensured through adherence to the procedures in this SOP and the sampling strategy outlined in the QAPP. The field quality control samples identified in the QAPP must be collected. These samples may include field duplicates, equipment rinsate blanks, trip blanks, and matrix spike/matrix spike duplicates.

9.0 Records, Data Analysis, Calculations

9.1 Various forms are required to ensure that adequate documentation is made of the sample collection activities. These forms may include:

- Non-waterproof field logbook;
- Sample collection records;
- Chain-of-custody (CoC) forms; and
- Shipping labels.

9.2 The field logbook is kept as a general log of activities and should not be used in place of the boring log.

9.3 CoC forms are transmitted with the samples to the laboratory for sample tracking purposes.

9.4 Shipping labels are required if sample coolers are to be transported to a laboratory by a third party (courier service).

Author	Reviewer	Revisions (Technical or Editorial)
Suzy Baird Project Scientist	Robert Shoemaker TO Manager	Rev 0 – Initial Issue (February 2013)
Ken O’Donnell, PG Geologist	Claire Mitchell, PE, PMP Senior Engineer	Rev 1 – PFAS sampling update (July 2019)
Matt Costakis, PG Geologist	Claire Mitchell, PE, PMP Senior Engineer	Rev 2 – Purging the Temporary Well Point update (January 2021)

NOTE: SOPs have been updated for PFAS sampling activities; however, AECOM’s internal PFAS sampling guidance supersedes materials and methods described in SOPs.

Per- and Polyfluoroalkyl Substance Field Sampling Protocol

Procedure 3-41

1.0 Purpose and Scope

1.1 This standard operating procedure (SOP) presents sampling practices to be used in the field at per- and polyfluoroalkyl substances (PFAS)-impacted Sites. The protocol is intended to supplement existing AECOM SOPs for field sampling and provide guidance in the collection of groundwater, soil, drinking water, surface water, sediment, soil, and biota samples without introducing cross-contaminants from personnel protective equipment (PPE), sampling equipment, or other field supplies used during sampling. This procedure applies to all qualified personnel and subcontractors who collect or otherwise handle field samples for PFAS analysis. This SOP should be reviewed by **Task Order (TO) Managers**, **Field Personnel**, and **Project Chemists** on projects where samples will be analyzed for PFAS prior to implementation of field activities, including during the planning stage, and prior to submitting a Quality Assurance Project Plan (QAPP).

1.2 This procedure is the program-approved professional guidance for work performed by AECOM under the client contract.

1.3 Use of this SOP does not replace the need for pre-field mobilization planning and discussion. The **TO Manager** and **Site Supervisor (SS)** should use this SOP in the development of planning documents and emphasize the procedures during kick-off meetings prior to the start of field mobilization.

2.0 Safety

2.1 It is the responsibility of the **TO Manager**, **SS**, **Site Safety and Health Officer (SSHO)**, and **Field Personnel** to be aware of the physical, chemical, and biological hazards associated with the Site. The mitigation of potential hazards will be documented in the project Accident Prevention Plan (APP) and Site Safety and Health Plan (SSHP), which will include Task Hazard Assessments (THAs) and incorporated into daily tailgate safety meetings to reinforce the message. The ubiquitous nature of PFAS presents several constraints to specific types of PPE which are commonly used to mitigate health and safety concerns. As a result, the following PPE should not to be used or worn during PFAS sampling events:

- Coated Tyvek® suits;
- New clothing or water resistant, waterproof, or stain-treated clothing; clothing containing Gore-Tex™ , unless the items have been pre-screened;
- Clothing that has been washed with fabric softener;
- Boots containing Gore-Tex™; and
- Nitrile gloves containing dry powder.

Non-coated Tyvek® may be used if required; however, collection of an equipment blank prior to non-coated Tvyek use is recommended.

2.2 Field sampling occurring during wet weather (e.g., rainfall and snowfall) should be conducted while wearing appropriate clothing that will not pose a risk for cross-contamination (see below **Section 7.1** on Field Clothing and PPE). Sampling programs that include PFAS should take these factors into consideration during the planning phase and be aware of field conditions prior to mobilization.

2.3 In addition to water resistant and waterproof clothing, chemically-treated clothing for bug resistance and UV protection should also be avoided for PFAS sampling programs, unless the items have been pre-screened. This particularly poses a health and safety hazard given the prevalence of biologic hazards (e.g., ticks) and risks to prolonged sun exposure. Field personnel should tuck pant legs into socks and/or boots and use duct tape and use pre-screened insect repellents to reduce the risk of being bitten by ticks. Furthermore, light-colored shirts and pants should be worn to easily identify ticks

NOTE: SOPs have been updated for PFAS sampling activities; however, AECOM's internal PFAS sampling guidance supersedes materials and methods described in SOPs.

during field activities. Light-colored clothing, long sleeves, and large-brimmed hats should also be worn to prevent sunburn, as many sunscreen products contain PFAS and should be avoided during PFAS sampling. Additional details pertaining to personal care products (e.g., sunscreen, moisturizer, make-up) are available in Section 9.0 below.

3.0 Terms and Conditions

3.1 Perfluoroakyl substances: A broad term for a class of synthetic fluorinated organic chemicals which all carbon molecules are fully fluorinated carbon atom. A chemical is considered a PFAS if all the hydrogen atoms attached to carbon atoms are replaced by fluorine atoms..

3.2 Polyfluoroakyl substances: A class of synthetic fluorinated organic chemicals which some carbon molecules are not fully fluorinated carbon atom (some carbons have hydrogen).

3.3 Perfluorooctane sulfonate (PFOS): Specific PFAS commonly found commercial and industrial products, such as Scotchgard® and aqueous film forming foam (AFFF).

3.4 Perfluorooctanoic acid (PFOA): Specific PFAS with similar uses as PFOS.

4.0 Interferences

4.1 See AECOM SOP 3-06 for general information regarding cross-contamination and equipment decontamination. Due to the potential for cross-contamination, this SOP describes additional precautionary procedures to be followed when collecting PFAS samples and decontaminating sampling equipment.

5.0 Training and Qualifications

5.1 See the following AECOM SOPs for general information regarding the qualifications and training required for collection of site media using various methodologies:

- AECOM SOP 3-14, Monitoring Well Sampling, for monitoring well sampling via low-flow methods as directed under the Environmental Protection Agency (EPA) guidance (EPA, 2010).
- AECOM SOP 3-10, Surface Water Sampling, for surface water sampling surface from shallow and deep water using a variety of samplers.
- AECOM SOP 3-17, Direct Push Sampling Techniques, for soil sampling using direct push sampling techniques.
- AECOM SOP 3-21, Surface and Subsurface Soil Sampling Procedures, for soil sampling by various methods using hand auguring, test pit, and split-spoon equipment.
- AECOM SOP 3-22, Sediment Sampling, for sediment sampling using the Petite Ponar® Grab Sampler, Ekman Bottom Grab Sampler, and Wildco® Hand Corer (or similar sampling devices).
- AECOM SOP 3-36, Benthic Grab Sampling, for the collection, handling, and packaging of benthic infaunal samples.
- AECOM SOP 3-37, Grab Groundwater Sampling, for collecting grab-groundwater samples from temporary well points installed using direct push or other drilling.

5.2 Additional protocols for sampling PFAS in drinking water is available are available under EPA method 537 (EPA, 2009).

5.3 Additional internal training for sampling PFAS in all media is provided for AECOM field and management personnel.

6.0 Equipment and Supplies

6.1 Sampling equipment will change depending on the site and scope of work. A general list of sampling equipment necessary are provided in the SOPs listed in Section 5.1. Specific instructions for equipment and supplies as it pertains to PFAS sampling are provided in Section 7.1 of this SOP.

7.0 Procedure

7.1 Given the low detection limits associated with PFAS analysis and the many potential sources of trace levels of PFAS, specific equipment and supplies may not be permitted or used during field sampling activities. As a result, it is important that **Field Personnel** are aware of these procedures and that they act on the side of caution by strictly following these procedures in the field.

7.2 Field Clothing and PPE

- A summary of the acceptable materials to use in the PFAS sampling environment is provided in **Table 1** of **Attachment A**. Additionally, personnel should complete the PFAS checklist prior to beginning field work each day (**Attachment A, Table 2**).
- Do not wear water resistant, waterproof, or stain-treated clothing during the field program. Field clothing made of synthetic and natural fibers (preferably cotton) are acceptable.
- Field clothing should be well laundered (a minimum of 6 times from time of purchase) as new clothing may contain PFAS-related treatments. Do not use new clothing or clothing that has been treated with fabric softener while sampling or sample handling.
- Do not wear clothing or boots containing Gore-Tex™ while sampling or sample handling as it contains a PFAS membrane.
- All safety footwear will consist of steel-toed boots made with polyurethane and polyvinyl chloride (PVC).
- Do not wear coated Tyvek® suits and clothing that contains Tyvek®, as these may contain fluorinated compounds. Non-coated Tyvek® may be used if required for safety concerns, but collection of an equipment blank prior to Tyvek® use is recommended.
- Powderless nitrile gloves must be worn at all times while collecting and handling samples. Nitrile gloves should be donned prior to the following activities at each sample location:
    - Decontamination of reusable sampling equipment,
    - Prior to contact with sample bottles or water containers,
    - Insertion of anything into the well (e.g., pump, tubing, bailer, etc.),
    - Insertion of silicon tubing into the peristaltic pump,
    - Completion of monitor well purging, prior to sample collection,
    - Handling of any quality assurance/quality control (QA/QC) samples, including field blanks and equipment blanks, and
    - After the handling of any non-dedicated sampling equipment, contact with non-decontaminated surfaces, or when judged necessary by field personnel.

7.3 Equipment and Supplies

- Do not use Teflon® containing materials (e.g., Teflon® tubing, bailers, tape, plumbing paste, or other Teflon® materials), as Teflon® contains fluorinated compounds. Before sampling, check pump materials (check valves, O-rings, and values) for fluoropolymer materials.
- High-density polyethylene (HDPE), and medical grade silicon materials are acceptable for sampling (i.e., tubing). Do not use any bonded tubing, as the bonding material is Teflon®-based.
- Do not use waterproof field books (Rite in the Rain®), as these may contain a plastic coating or adhesive containing PFAS. Field notes should be documented in untreated Composite® notebooks or on loose paper on Masonite or aluminum clipboards (i.e., plastic clipboards, binders, or spiral hard cover notebooks are not acceptable).
- Post-It Notes® are not allowed on project sites.
- Sharpies® are acceptable to use in PFAS sampling programs if they are fine-tipped and used in the staging area only. Ballpoint pens should be used when documenting field activities in field notebooks or on field forms, as well as, labeling sample containers and preparing chains of custody (CoCs).

- Do not use chemical (blue) ice packs during the sampling program. This includes the use of ice packs for the storage of food and/or samples. Only wet ice (water ice) should be used during the sampling program.
- Do not use aluminum foil during sampling or sample handling.
- Do not use a vehicle with seat covers with water proofing such as Scotchgard®.

7.4 Sample Containers and Handling

- Samples should be collected in laboratory-provided polypropylene or HDPE bottles fitted with an unlined (no Teflon®), polypropylene or HDPE screw cap. Teflon-lined bottleware may not be used in sample collection. LDPE bottles should not be used for sample containers.
- Glass containers should also be avoided due to potential loss of analyte through adsorption.
- For each item in the sampling envionrment that is questionable or absence of PFAS was not previously documented, equipment blanks should be collected by passing lab-certified deionized blank water over and through equipment used for sampling.
- If possible, collect field blank samples. These can be prepared by using a bottle-to-bottle transfer of lab-certified deionized blank water in order to assess contaminants in the blank water and/or the atmosphere surrounding sample collection.

8.0 Equipment Decontamination

8.1 It is highly recommended that disposable equipment be utilized when collecting samples for PFAS analysis. However, if equipment re-use is performed, field sampling equipment, including oil/water interface meters and water level indicators, that are utilized at each sample location will require cleaning between uses in accordance with AECOM SOP 3-06. Several additional procedures should be followed by field personnel regarding decontamination.

- Alconox® and Liquinox® soap is acceptable for use since the Safety Data Sheets (SDS) do not list fluoro-surfactants as an ingredient. However, Decon 90 must not be used during decontamination activities.
- Water used for the decontamination of sampling equipment will be laboratory-certified "PFAS-free" deionized water.
- Cotton towels will be used to decontaminate equipment before and after each sample is collected. Recycled paper towels will not be used during sample collection or in the immediate sampling environment.

9.0 Additional Considerations

9.1 Outside of sampling equipment, PFAS could be introduced to collected samples through personal care products. Additionally, food and snack products are packaged in wrappers treated with perfluorochemicals.

9.2 Personnel Hygiene

- Field personnel should not use cosmetics, moisturizers, hand cream, or other related products as part of their personal cleaning/showering routine on the morning of a sampling event. These products may contain surfactants and represent a potential source of PFAS.
- Many manufactured sunblock and insect repellants contain PFAS and should not be brought or used on-site. Sunblock and insect repellants that are used on-site should consist of 100% natural ingredients. As mentioned in Section 2, steps can be taken to reduce the hazards associated with bugs and prolonged sun exposure.
- The following products are acceptable for use as sunscreen and/or insect repellent when sampling for PFAS:
  - Sunscreens - Alba Organics Natural Sunscreen, Yes To Cucumbers, Aubrey Organics, Jason Natural Sun Block, Kiss my face, and baby sunscreens that are “free” or “natural”

  - Insect Repellents - Jason Natural Quit Bugging Me, Repel Lemon Eucalyptus Insect repellant, Herbal Armor, California Baby Natural Bug Spray, BabyGanics

9.3 Food Considerations

- Many food snack products are packaged in wrappers treated with PFAS. Therefore, hands must be thoroughly washed after handling fast food, carry-out food, or snacks. Pre-wrapped food or snacks (e.g., candy bars, microwave popcorn, etc.) must not be in the possession of field personnel during sampling.
- Food and drink will be handled and consumed only outside of the sampling environment.

10.0 References

10.1 EPA, 2010. EPA Document #: EQASOP-GW 001, Low Stress (low flow) Purging and Sampling Procedure for the Collection of Groundwater Samples from Monitoring Wells. Version 3. January 19, 2010.

10.2 EPA, 2009. EPA Document #: EPA/600/R-08/092, Method 537. Determination of Selected Perfluorinated Alkyl Acids in Drinking Water by Solid Phase Extraction and Liquid Chromatography/Tandem Mass Spectrometry (LC/MS/MS). Version 1.1. September.

10.3 AECOM SOP 3-06, Equipment Decontamination

10.4 AECOM SOP 3-10, Surface Water Sampling

10.5 AECOM SOP 3-14, Monitoring Well Sampling

10.6 AECOM SOP 3-17, Direct Push Sampling Techniques

10.7 AECOM SOP 3-21, Surface and Subsurface Soil Sampling Procedures

10.8 AECOM SOP 3-22, Sediment Sampling

10.9 AECOM SOP 3-36, Benthic Grab Sampling

10.10 AECOM SOP 3-37, Grab Groundwater Sampling

Author	Reviewer	Revisions (Technical or Editorial)
Ken O'Donnell, PG Geologist	Claire Mitchell, PE, PMP Senior Engineer	Rev 1 – PFAS sampling update (July 2019)

Table 1- Summary of the Acceptability of Materials for Use in the PFAS Sampling Environment

Do Not Use or Have in the Immediate Sampling Environment	Evaluate Prior to Use, Doing, or Having at the Sampling Event	Acceptable for Use or Action in the Sampling Environment
Polytetrafluoroethylene (PTFE) items, sample containers or equipment that contains PTFE parts that will be in direct contact with sampling media, such as Teflon®; no Teflon® lined bottle caps; no Teflon-bearing plumber's tape		
Low-density polyethylene (LDPE) items or equipment that contains LDPE parts and that will be in direct contact with the sampling media		Items or equipment made of polypropylene (PP); high-density polyethylene (HDPE); polyurethane, polyvinyl chloride (PVC); silicon, stainless steel
	All equipment rented for a project (must be verified to have no PFAS-bearing parts prior to use)	
	Equipment with moving parts that may be lubricated with PFAS containing lubricants or greases	Crisco® or other vegetable-based greases for lubricating parts
Any item in the ingredient list or SDS that includes the term "fluoro" or items containing flurorsurfactants		
Viton® o-rings in pressure washers	Internal valves and equipment parts (pumps, pressure, washers, etc.)	
Glass sample containers (jars) and glass fiber filters		
Decon 90	Water for decontamination must be PFAS-free	Alconox®, Citronex®, LIquinox®, Methanol®
Aluminum foil	Bulk sample containers must be evaluted	Polyethylene plastic bags (e.g., Ziploc® bags)
Recycled paper towels		Cotton towels
Water-proof (Rite in the Rain®) field notebooks; Post-it notes®		
Any type of makers- all prohibited in the immediate sampling environment	Non-brand name markers	Fine point Sharpie®- okay for use in the staging area only; ball point pens and pencils can be used in the immediate sampling environment, pencils can be used for pre-labeling but must be written over with pen or marker; using pre-labeled bottles can avoid labeling in the field all together.
Blue or chemical ice		Wet ice
	Drilling fluids	
	Water for blanks and decontamination	Lab-certified PFAS-free water and site or PWS supplies that have been verified to be PFAS-free (as defined for project) prior to use
PPE which contains PFAS	PPE for constituents of concern other than PFAS	PFAS-free PPE
		Powderless nitrile gloves
GoreTex® treated fabrics or clothes; new and unwashed clothing (fabric treatment may contain PFAS)	Clothes described as waterproof, water-resistant, or stain-resistant	Neoprene, clothing made of waxed fabric, synthetic and natural fibers (preferably cotton); well laundered clothes (washed several times after purchase)
Clothing that has been washed with fabric softener	Tyvek® or coated Tyvek®	Well-washed (washed several times) cotton coveralls

Table 2- PFAS Daily Sampling Checklist

Project No.:
Project Location:
Signature:
Date:

Team Members

Yes	**No**	**Description**
		Has AECOM PFAS Sampling guidance been reviewed by all team members?
		Comments:
Yes	**No**	Has AECOM field sampling staff received needed training certification?
		Comments:
Yes	**No**	Was a briefing held for field sampling staff?
		Comments:
Yes	**No**	Were additional PFAS sampling instructions given to field sampling staff?
		Comments:
Yes	**No**	Have personal clothing and PPE requirements been followed by all field sampling staff?
		Comments:
Yes	**No**	Were lotions and sunscreen used for field sampling staff?
		Comment:

Sample Collection

Yes	**No**	Has a PFAS-free water source been identified?
		Comment
		Source of PFAS-free water:
Yes	**No**	Have all sampling items, parts and equipment been inspected to be free of PFAS?
		Comment:
Yes	**No**	Has sampling location sequence been communicated to avoid cross-contaminations?
		Comment:
Yes	**No**	Have drilling fluids been evaluated and shown to be free of PFAS?
		Comment:
Yes	**No**	Use of PFAS-free decontamination solution?
		Brand name of decontamination solution:
Yes	**No**	Have all field logs, notebooks, pens, labels been inspected, and do they meet AECOM PFAS sampling guidance requirements?
		Comment:
Yes	**No**	Have all sample shipping materials (ice, Ziploc® bags) been inspected, and do they meet AECOM PFAS sampling guidance requirements?
		Comment:
Yes	**No**	Have all blanks arrived at the site and will they be collected to verify cross-contamination?
		Comment:

Document Control

Yes	**No**	Have all variances from sampling guidance been documented?
		Comment:

Other Comments:

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Porewater Sampling

Procedure 3-43

1.0 Purpose and Scope

1.1 The purpose of this document is to define the standard operating procedure (SOP) for use in sampling porewater at sites impacted with per- and polyfluoralkyl substances (PFAS). This SOP describes the equipment, field procedures, materials, and documentation procedures necessary for collection of porewater samples. Specific information regarding sample locations can be found in the associated Quality Assurance Project Plan (QAPP).

1.2 As guidance for specific activities, this procedure does not obviate the need for professional judgment. Deviations from this procedure while planning or executing planned activities must be documented. If there are other procedures whether it be from state, federal or other relevant stakeholders that are not addressed in this SOP and are applicable to porewater sampling then those procedures may be added as an appendix to the QAPP.

1.3 It is fully expected that the procedures outlined in this SOP will be followed. Procedural modifications may be warranted depending upon field conditions, equipment limitations, or limitations imposed by the procedure. Substantive modification to this SOP will be approved in advance by the Program Quality Manager. Deviations to this SOP will be documented in the field records.

2.0 Safety

2.1 The health and safety considerations for the work associated with this SOP, including physical, chemical, and biological hazards are addressed in the project Accident Prevention Plan (APP)/Site Safety and Health Plan. The major health and safety considerations for the work associated with porewater sample collection are the near and on-water safety aspects of the program.

2.2 Daily safety briefs should be conducted at the start of each working day before any work commences. These daily briefs will be facilitated by the **Site Safety and Health Officer (SSHO)** or his/her designee to discuss the day's events and any potential health risks of the work to be completed. Weather conditions are often part of these discussions. As detailed in the APP/SSHP, everyone on the field team has the authority to stop work if an unsafe condition is perceived until the conditions are remedied to the satisfaction of the SSHO.

3.0 PFAS Sampling Certification

3.1 All field staff must have completed the AECOM PFAS sampling education and training sessions and be up to date on their AECOM PFAS Sampling Certification. Field staff must review and be familiar with the Michigan Department of Environment, Great Lakes, and Energy (EGLE), formerly the Michigan Department of Environmental Quality (MDEQ), document entitled "*General PFAS Sampling Guidance*" (MDEQ, 2018).

4.0 Interferences

4.1 Cross-contamination of samples may result if sampling equipment is inappropriate or improperly decontaminated (MDEQ, 2018).

4.2 Contamination of samples may result if samples are exposed to certain environmental conditions. Exposure to potential sources of contamination (e.g., exhaust fumes) should be minimized. Compared to sampling at other sites, special considerations are required when conducting PFAS sampling (MDEQ, 2018).

4.3 Care must be taken to avoid surface water intrusion during sampling. Water will flow in a path of least resistance. If space is created around the sides of the sampling end of the porewater collection device during deployment, surface water may flow down the outside of the device to the screened area and into the intended sample. The porewater device should be used with a sampling flange, especially when collecting porewater near the sediment-surface water interface.

4.4 When investigating PFAS sites, inappropriate sampling equipment, waterproof rain gear and equipment, and other unsuspecting specific sources, may contaminate samples (MDEQ, 2018). The following materials are acceptable for PFAS sampling equipment: silicon tubing, polypropylene plastic, high density polyethylene (HDPE) plastic, or stainless steel. The laboratory must supply appropriate sample bottles: polypropylene or HDPE sample bottles fitted with an unlined (no PTFE "Teflon"), polypropylene, or HDPE screw cap (MDEQ, 2018).

4.5 The following materials are not acceptable for PFAS sampling: low density polyethylene (LDPE), fluorinated polymer plastics such as polytetrafluoroethylene (PTFE) "Teflon" (MDEQ, 2018).

5.0 Training and Qualifications

5.1 Qualifications and Training

5.1.1 The individual executing these procedures must have read, and be familiar with, the requirements of this SOP.

5.2 Responsibilities

5.2.1 The **Site Supervisor (SS)** is responsible for ensuring that porewater sampling activities comply with this procedure. The SS or designee shall review all porewater sampling forms on a minimum monthly basis. The SS is responsible for ensuring that all field sampling personnel involved in porewater sampling shall have the appropriate education, experience, and training to perform their assigned tasks.

5.2.2 The **TO Manager** is responsible for ensuring overall compliance with this procedure.

5.2.3 Field sampling personnel are responsible for the implementation of this procedure. Minimum qualifications for field sampling personnel require that every individual on the field team shall have experience with environmental sampling techniques.

5.2.4 The field sampler and/or SS is responsible for directly supervising the porewater sampling procedures to ensure that they are conducted according to this procedure, and for recording all pertinent data collected during sampling. If deviations from the procedure are required because of anomalous field conditions, they must first be approved by the SS and then documented in the field logbook and associated report or equivalent document.

6.0 Equipment and Supplies

The following equipment list contains materials that may be needed in carrying out the procedures outlined in this SOP. Not all equipment listed below may be necessary for a specific activity. Additional equipment may be required, pending field conditions. All equipment must be PFAS-approved as specified in the EGLE PFAS Sampling Guidance document (MDEQ, 2018).

- Approved plans, including target sampling locations
- GPS
- Stainless steel porewater push-point sampler (i.e., Henry Sampler)
- Peristaltic pump with appropriate battery
- Polypropylene, HDPE, or silicon tubing necessary for peristaltic pump
- Syringe (polypropylene or HDPE)
- Multi-parameter data sonde (YSI or equivalent)
- Laboratory supplied PFAS sampling containers
- Ziploc plastic bags for samples and sample bottles
- PFAS-free project-specific field log book, standardized field forms and pens
- Labels (PFAS free)

- Chain of Custody (CoC) forms
- Life Vest
- Waders
- Boat with all applicable safety equipment (anchor, etc.)
- Cooler(s)
- Ice (no blue ice)
- Decontamination supplies/equipment

7.0 Calibration or Standardization

The multiparameter water quality meter should be calibrated daily per the manufacturer's instructions.

8.0 Procedure

Porewater samples will be collected and handled in accordance with USEPA Region 4 SOP for Porewater Sampling (SESDPROC-513-R2, dated February 28, 2013).

8.1 Flange/Push-Point/Peristaltic Pump/Tubing Set-up

Navigate to the sample location using a GPS. The flange is first placed at the desired sampling point with the push-point removed to allow water to escape from under the flange. The flange rim should be carefully worked into the sediment until the flange is flush with the sediment surface. The porewater push-point device should then be inserted through the compression adapter on the flange and into the sediment as carefully as possible. When the sampler is inserted to the desired depth, the compression adapter should be tightened. If sampling through a significant amount of surface water, the flange should be connected to the push-point sampler prior to deployment such that the correct depth can be sampled for porewater. The flange and push-point sampler set up are shown in Attachment 1.

Connect tubing from push-point sampler through peristaltic pump and connect the pump to an appropriate battery. Sampling set up is shown on Attachment 2. The tubing should be new and dedicated to the sample location. Install clean, silicone tubing in the pump head, per the manufacturer's instructions. Pharmaceutical-grade silicone tubing (e.g., PharMed tubing) may be required for some projects depending on the analyses required. Allow sufficient tubing on the discharge side to facilitate convenient dispensation of liquid into sample bottles but only enough on the suction end for attachment to the intake line. This practice will minimize sample contact with the silicone pump tubing.

If the push-point sampler becomes easily clogged such that porewater cannot be extracted via the sampler, a syringe (HDPE) can be used to extract the sample instead of a peristaltic pump.

8.1.1 Sample Collection

In general, the volume of porewater that can be collected at a given location is limited. Collecting large volumes of porewater will ultimately result in the collection of water from the overlying water body. Therefore, a set of field parameters (color, pH, specific conductivity, temperature, turbidity, salinity, oxidation-reduction potential, and dissolved oxygen) from the surface water located immediately above the sediment/water interface and from the porewater that is initially extracted will be collected prior to sample collection. If porewater volume is limited, dissolved oxygen and conductivity will be the priority field parameters for the porewater. The porewater sample will only be collected if the dissolved oxygen and conductivity in the porewater and overlying surface water are significantly different. If possible, a final set of field parameters will be collected from the porewater after sample collection.

The samples will be numbered and labelled as described in the project specific QAPP. Following collection, samples will be placed in coolers on ice until transport to the laboratory.

Sample collection information will be recorded at the time of collection in the field logbook and on the form in Attachment 3. This information will include, but not be limited to, the station ID, sample ID, time and date of sample collection, sample collection depth, the sampler's name, description of any sample processing, and any pertinent observations. Initial and final porewater and overlying surface water field parameters should also be recorded.

Samples will be stored cold (6°C) until they are packaged for transport/shipment to the laboratories. Samples will be packaged in ice and will be hand delivered or shipped to the appropriate laboratories.

9.0 Quality Control and Assurance

9.1 Field personnel will follow specific quality assurance (QA) guidelines as outlined in the project-specific QAPP. The goal of the QA program should be to ensure precision, accuracy, representativeness, completeness, and comparability in the project sampling program.

9.2 Quality Control (QC) requirements for sample collection are dependent on project-specific sampling objectives. The project-specific QAPP will provide requirements for sample preservation, holding times, container types, as well as various QC samples such as trip blanks, field reagent blanks, equipment rinsate blanks, and field duplicates.

10.0 Data and Records Management

10.1 Field notes will be kept during sampling activities in accordance with SOP 3-03: Recordkeeping, Sample Labeling, and Chain of Custody. During the completion of sampling activities, fill out the sample logbook and transmit forms to the SS for storage in project files.

10.2 Deviations to the procedures detailed in the SOP should be recorded in the field logbook.

11.0 Attachments or References

11.1 United States Environmental Protection Agency (USEPA). 1987. A Compendium of Superfund Field

11.2 Operations Methods. USEPA/540/P-87/001, USEPA, Office of Emergency and Remedial Response,

11.3 Washington, D.C.

11.4 USEPA. 2013. Operating Procedure, Porewater.

11.5 Number SESDPROC-513-R2, EPA, Region 4, Science and Ecosystems Support Division, Athens, GA.

11.6 MDEQ. 2018. General PFAS Sampling Guidance, October 2018.

Author	***Reviewer***	***Revisions (Technical or Editorial)***
Daniel Folan, PhD, PG, LSP	Claire Mitchell, PE, PMP Senior Engineer	Rev 0 – Initial Issue (February 2021)

Appendix E
SI Mobilizations 1 and 2 Boring Logs

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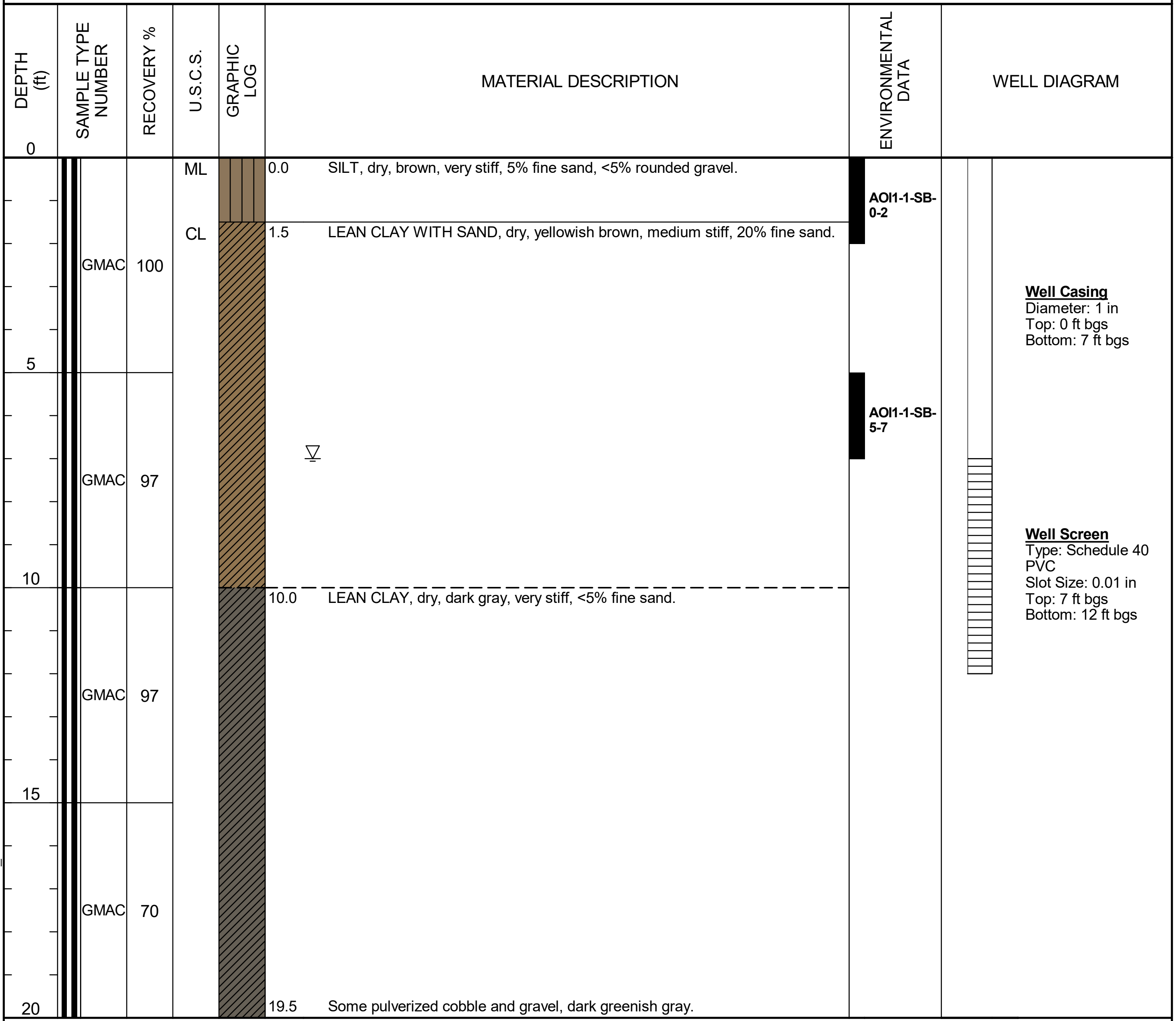
AECOM AECOM

WELL NUMBER AOI 1-1

TOTAL DEPTH 20 FT BGS
PAGE 1 OF 1

CLIENT ARNG, USACE Baltimore District
PROJECT NUMBER 60552172
DATE STARTED 5/8/19 **COMPLETED** 5/8/19
DRILLING CONTRACTOR Cascade
DRILLING EQUIPMENT Geoprobe
DRILLING METHOD Direct Push
LOGGED BY M Glinski **CHECKED BY** N/A

PROJECT NAME Grand Ledge Army Aviation Support Facility and Armory SI
SITE NAME AOI1
EASTING -84.73488487 **NORTHING** 42.77142757
GROUND ELEVATION N/A **HOLE SIZE** 2 inches
GROUND WATER LEVELS:
▽ **AT TIME OF DRILLING** 7.00 ft
AT END OF DRILLING ---



DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	MATERIAL DESCRIPTION	ENVIRONMENTAL DATA
0	GMAC	100	ML	0.0 SILT, dry, brown, very stiff, 5% fine sand, <5% rounded gravel.	AOI1-1-SB-0-2
			CL	1.5 LEAN CLAY WITH SAND, dry, yellowish brown, medium stiff, 20% fine sand.	
5	GMAC	97		▽	AOI1-1-SB-5-7
10	GMAC	97		10.0 LEAN CLAY, dry, dark gray, very stiff, <5% fine sand.	
15	GMAC	70			
20				19.5 Some pulverized cobble and gravel, dark greenish gray.	

WELL DIAGRAM

Well Casing
Diameter: 1 in
Top: 0 ft bgs
Bottom: 7 ft bgs

Well Screen
Type: Schedule 40 PVC
Slot Size: 0.01 in
Top: 7 ft bgs
Bottom: 12 ft bgs

Bottom of borehole at 20.0 feet.

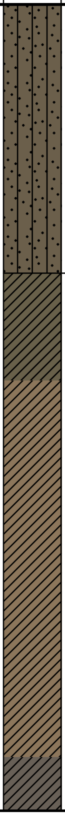
Notes:
1. Headspace screening values represent total volatile organic vapors (referenced to an isobutylene standard) measured with a Photoionization Detector (PID) with 10.6 eV lamp.
2. Coordinates and elevation data in NAVD88 for vertical datum and NAD83/91 for horizontal datum in Michigan State Plane.

AECOM AECOM

WELL NUMBER AOI 1-2

TOTAL DEPTH 15 FT BGS
PAGE 1 OF 1

CLIENT ARNG, USACE Baltimore District
PROJECT NAME Grand Ledge Army Aviation Support Facility and Armory
PROJECT NUMBER 60552172
SI **SITE NAME** AOI1
DATE STARTED 5/7/19 **COMPLETED** 5/7/19
EASTING -84.73387606 **NORTHING** 42.77059223
DRILLING CONTRACTOR Cascade
GROUND ELEVATION N/A **HOLE SIZE** 2 inches
DRILLING EQUIPMENT Geoprobe
GROUND WATER LEVELS:
DRILLING METHOD Direct Push
AT TIME OF DRILLING ---
LOGGED BY M Glinski **CHECKED BY** N/A
AT END OF DRILLING ---

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	ENVIRONMENTAL DATA	WELL DIAGRAM
0	GMAC	100	ML		0.0 SANDY SILT, dry, dark grayish brown, loose, 30% fine sand, <5% fine to medium subangular gravel.	**AOI1-2-SB-0-2** **AOI1-2-SB-0-2 MS** **AOI1-2-SB-0-2 MSD** **AOI1-2-SB-2-4** **AOI1-2-SB-2-4 DUP**	 **Well Casing** Diameter: 1 in Top: 0 ft bgs Bottom: 5 ft bgs
5	GMAC	88	CL		5.0 LEAN CLAY, dry, olive gray, stiff, 5% very fine sand. 7.0 Changes to moist, brown, 10% sand.		**Well Screen** Type: Schedule 40 PVC Slot Size: 0.01 in Top: 5 ft bgs Bottom: 10 ft bgs
10	GMAC	93			14.0 Changes to dark gray.		
15							

Bottom of borehole at 15.0 feet.

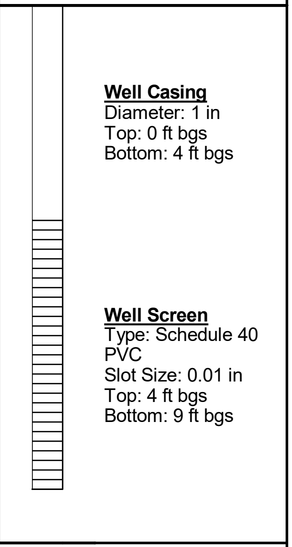
Notes:
1. Headspace screening values represent total volatile organic vapors (referenced to an isobutylene standard) measured with a Photoionization Detector (PID) with 10.6 eV lamp.
2. Coordinates and elevation data in NAVD88 for vertical datum and NAD83/91 for horizontal datum in Michigan State Plane.

WELL NUMBER AOI 1-3

AECOM

TOTAL DEPTH 10 FT BGS
PAGE 1 OF 1

CLIENT ARNG, USACE Baltimore District
PROJECT NAME Grand Ledge Army Aviation Support Facility and Armory SI
PROJECT NUMBER 60552172
SITE NAME AOI1
DATE STARTED 5/7/19 **COMPLETED** 5/7/19
EASTING -84.73253428 **NORTHING** 42.7705232
DRILLING CONTRACTOR Cascade
GROUND ELEVATION N/A **HOLE SIZE** 2 inches
DRILLING EQUIPMENT Geoprobe
GROUND WATER LEVELS:
DRILLING METHOD Direct Push
AT TIME OF DRILLING ---
LOGGED BY M Glinski **CHECKED BY** N/A
AT END OF DRILLING ---

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	ENVIRONMENTAL DATA	WELL DIAGRAM
0	GMAC	100	CL	▨	0.0 LEAN CLAY, dry, light olive brown, 10% fine sand.	**AOI1-3-SB-0-2** **AOI1-3-SB-2-4**	
5	GMAC	68	SC	▨	5.0 CLAYEY SAND, wet, light yellowish brown, loose.		
			CL	▨	6.0 LEAN CLAY WITH SAND, wet, yellowish brown, medium plasticity, 15% fine sand.		
10							

Bottom of borehole at 10.0 feet.

Notes:
1. Headspace screening values represent total volatile organic vapors (referenced to an isobutylene standard) measured with a Photoionization Detector (PID) with 10.6 eV lamp.
2. Coordinates and elevation data in NAVD88 for vertical datum and NAD83/91 for horizontal datum in Michigan State Plane.

WELL NUMBER AOI 1-4

AECOM AECOM

TOTAL DEPTH 22 FT BGS
PAGE 1 OF 1

CLIENT	ARNG, USACE Baltimore District	**PROJECT NAME**	Grand Ledge Army Aviation Support Facility and Armory SI
PROJECT NUMBER	60552172	**SITE NAME**	AOI1
DATE STARTED	5/7/19 **COMPLETED** 5/7/19	**EASTING**	-84.73100624 **NORTHING** 42.77058912
DRILLING CONTRACTOR	Cascade	**GROUND ELEVATION**	N/A **HOLE SIZE** 2 inches
DRILLING EQUIPMENT	Geoprobe	**GROUND WATER LEVELS:**	
DRILLING METHOD	Direct Push	**AT TIME OF DRILLING**	---
LOGGED BY	M Glinski **CHECKED BY** N/A	**AT END OF DRILLING**	---

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	ENVIRONMENTAL DATA	WELL DIAGRAM
0	GMAC	100	CL	▨	0.0 LEAN CLAY WITH SAND, dry, very dark grayish brown, stiff, medium plasticity, 15% fine sand.	AOI1-4-SB-0-2	
5	GMAC	97		▨	6.0 Changes to brown, 20% fine sand. 9.5 Changes to contain <5% subangular fine to coarse gravel.	AOI1-4-SB-8-10	**Well Casing** Diameter: 1 in Top: 0 ft bgs Bottom: 17 ft bgs
10	GMAC	97		▨			
15	GMAC	93	CH	▨	16.5 FAT CLAY, moist, gray, stiff, high plasticity, gradational upper boundary.	AOI1-4-SB-17-19	
			SP	▨	19.0 POORLY GRADED SAND, wet, yellowish brown, medium dense, fine sand.		**Well Screen** Type: Schedule 40 PVC Slot Size: 0.01 in Top: 17 ft bgs Bottom: 22 ft bgs
20	GMAC	67	CL	▨	21.0 LEAN CLAY WITH SAND, moist, gray, stiff, 15% fine sand.		

Bottom of borehole at 22.0 feet.

Notes:
1. Headspace screening values represent total volatile organic vapors (referenced to an isobutylene standard) measured with a Photoionization Detector (PID) with 10.6 eV lamp.
2. Coordinates and elevation data in NAVD88 for vertical datum and NAD83/91 for horizontal datum in Michigan State Plane.

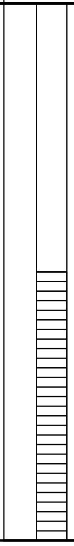
AECOM

WELL NUMBER AOI 1-5

TOTAL DEPTH 10 FT BGS
PAGE 1 OF 1

CLIENT ARNG, USACE Baltimore District
PROJECT NAME Grand Ledge Army Aviation Support Facility and Armory SI
PROJECT NUMBER 60552172
SITE NAME AOI1
DATE STARTED 5/8/19 **COMPLETED** 5/8/19
EASTING -84.73025492 **NORTHING** 42.7723008
DRILLING CONTRACTOR Cascade
GROUND ELEVATION N/A **HOLE SIZE** 2 inches
DRILLING EQUIPMENT Geoprobe
GROUND WATER LEVELS:
DRILLING METHOD Direct Push
AT TIME OF DRILLING ---
LOGGED BY M Glinski **CHECKED BY** N/A
AT END OF DRILLING ---

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	ENVIRONMENTAL DATA	WELL DIAGRAM
0	GMAC	100	ML		0.0 SILT WITH SAND, dry, yellowish brown, medium stiff, low plasticity, 25% fine sand.	**AOI1-5-SB-0-2** **AOI1-5-SB-0-2 MS** **AOI1-5-SB-0-2 MSD** **AOI1-5-SB-2-4**	**Well Casing** Diameter: 1 in Top: 0 ft bgs Bottom: 5 ft bgs
5	GMAC	90			4.8 Changes to contain <5% fine to medium gravel.		**Well Screen** Type: Schedule 40 PVC Slot Size: 0.01 in Top: 5 ft bgs Bottom: 10 ft bgs
10							



Bottom of borehole at 10.0 feet.

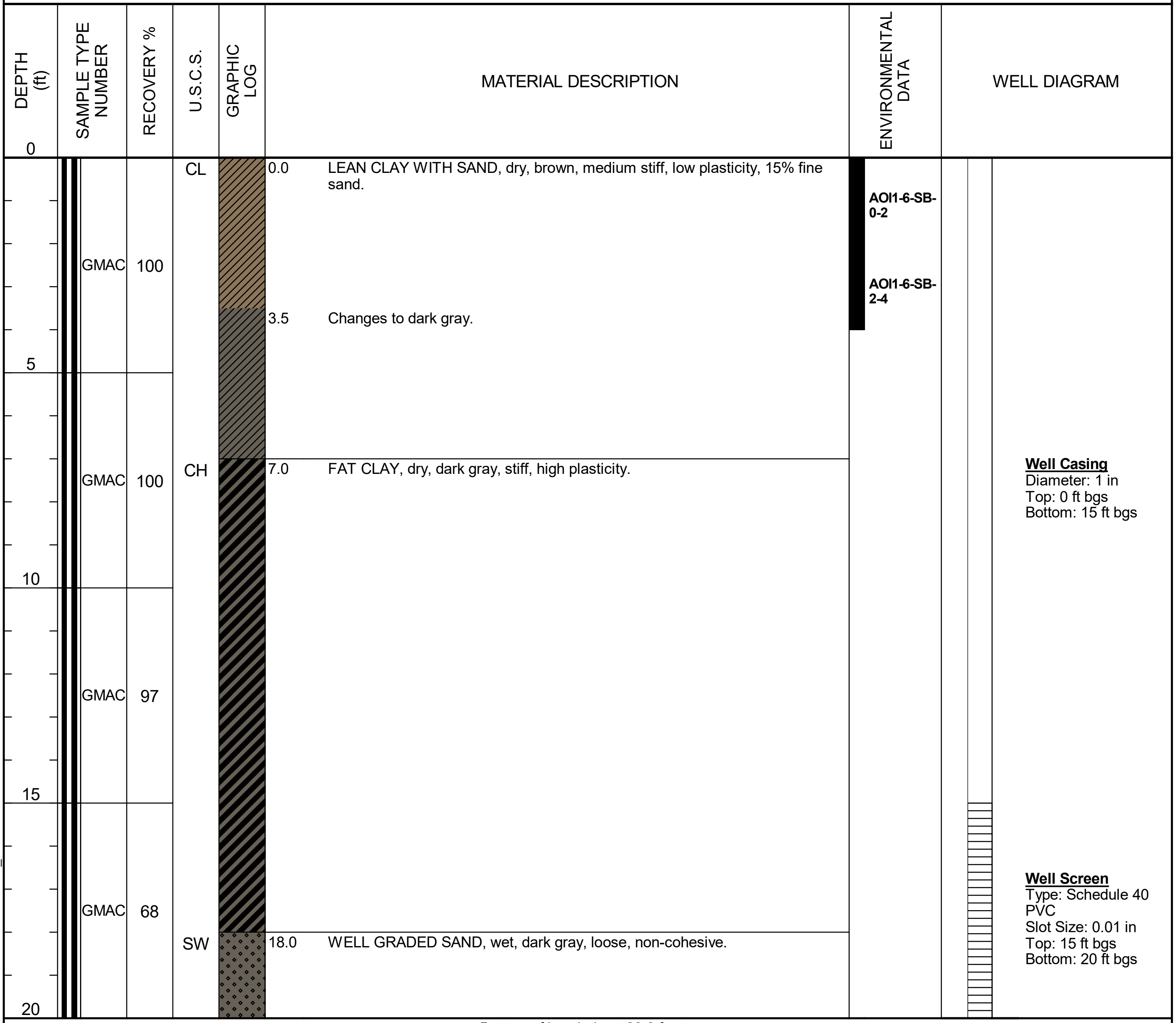
Notes:
1. Headspace screening values represent total volatile organic vapors (referenced to an isobutylene standard) measured with a Photoionization Detector (PID) with 10.6 eV lamp.
2. Coordinates and elevation data in NAVD88 for vertical datum and NAD83/91 for horizontal datum in Michigan State Plane.

AECOM AECOM

WELL NUMBER AOI 1-6

TOTAL DEPTH 20 FT BGS
PAGE 1 OF 1

CLIENT	ARNG, USACE Baltimore District	**PROJECT NAME**	Grand Ledge Army Aviation Support Facility and Armory SI
PROJECT NUMBER	60552172	**SITE NAME**	AOI1
DATE STARTED	5/8/19 **COMPLETED** 5/8/19	**EASTING**	-84.73124884 **NORTHING** 42.77424436
DRILLING CONTRACTOR	Cascade	**GROUND ELEVATION**	N/A **HOLE SIZE** 2 inches
DRILLING EQUIPMENT	Geoprobe	**GROUND WATER LEVELS:**	
DRILLING METHOD	Direct Push	**AT TIME OF DRILLING**	---
LOGGED BY	M Glinski **CHECKED BY** N/A	**AT END OF DRILLING**	---



DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	MATERIAL DESCRIPTION	ENVIRONMENTAL DATA
0.0	GMAC	100	CL	LEAN CLAY WITH SAND, dry, brown, medium stiff, low plasticity, 15% fine sand.	AOI1-6-SB-0-2 AOI1-6-SB-2-4
3.5				Changes to dark gray.	
5	GMAC	100			
7.0			CH	FAT CLAY, dry, dark gray, stiff, high plasticity.	
10	GMAC	97			
15	GMAC	68			
18.0			SW	WELL GRADED SAND, wet, dark gray, loose, non-cohesive.	
20					

WELL DIAGRAM

Well Casing
Diameter: 1 in
Top: 0 ft bgs
Bottom: 15 ft bgs

Well Screen
Type: Schedule 40 PVC
Slot Size: 0.01 in
Top: 15 ft bgs
Bottom: 20 ft bgs

Bottom of borehole at 20.0 feet.

Notes:
1. Headspace screening values represent total volatile organic vapors (referenced to an isobutylene standard) measured with a Photoionization Detector (PID) with 10.6 eV lamp.
2. Coordinates and elevation data in NAVD88 for vertical datum and NAD83/91 for horizontal datum in Michigan State Plane.

WELL NUMBER AOI1-10

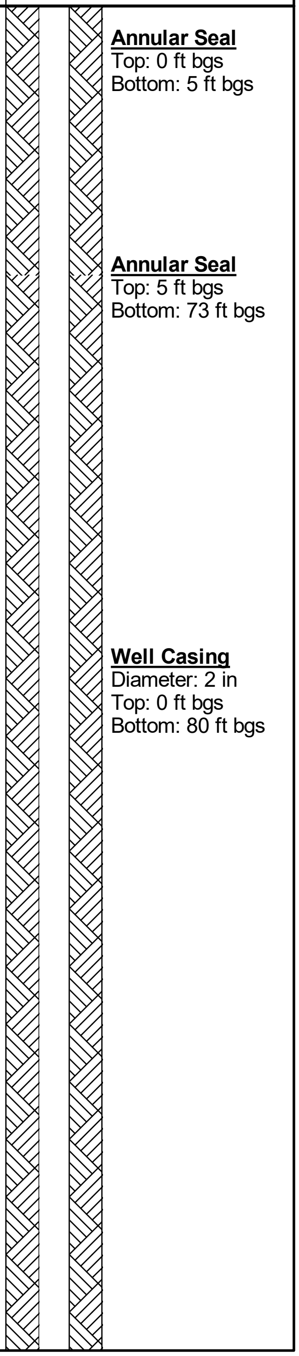
TOTAL DEPTH 100 FT BGS
PAGE 1 OF 4

AECOM

CLIENT ARNG, USACE Baltimore District		**PROJECT NAME** Grand Ledge AASF	
PROJECT NUMBER 60552172		**SITE NAME** AOI 1	
DATE STARTED 11/12/19	**COMPLETED** 12/5/19	**EASTING** 13024496.14	**NORTHING** 463461.05
DRILLING CONTRACTOR Cascade		**GROUND ELEVATION** N/A	**HOLE SIZE** 6 inches
DRILLING EQUIPMENT Geoprobe 8140LC		**GROUND WATER LEVELS:**	
DRILLING METHOD Rotary Sonic		**AT TIME OF DRILLING** ---	
LOGGED BY A. Shah	**CHECKED BY** J. Hollingsworth	▼ **AT TIME OF SAMPLING** 22.85 ft	

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	MATERIAL DESCRIPTION	ENVIRONMENTAL DATA
0.0		100		TOPSOIL.	
0.3			CL	LEAN CLAY WITH SAND, moist, dark brown to brown, medium plasticity with estimated 15-25% fine- to coarse-grained sand, trace amounts of subrounded gravel, and trace organics.	
5		100			
7.0				Changes to estimated 5-10% fine subrounded gravel.	
10.0		120		LEAN CLAY, moist, dark brown to brown, medium to high plasticity with estimated 5-10% fine- to coarse-grained sand and trace amounts of subrounded gravel.	
15.0		0		NO RECOVERY.	
20		0			
25					

WELL DIAGRAM



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AECOM

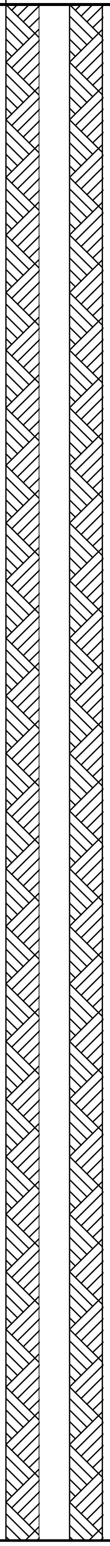
WELL NUMBER AOI1-10

TOTAL DEPTH 100 FT BGS
PAGE 2 OF 4

CLIENT ARNG, USACE Baltimore District
PROJECT NAME Grand Ledge AASF
PROJECT NUMBER 60552172
SITE NAME AOI 1

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	ENVIRONMENTAL DATA
25		0			15.0 NO RECOVERY. *(continued)*	
30		0				
35		0			39.5 Boulder encountered - switched to rock coring.	
40		0				
45					45.0 NO RECOVERY, potentially indicates boulder/cobbles.	
50		100	GW-GM		50.0 WELL-GRADED GRAVEL WITH SILT AND SAND, wet, dark brown to black, fine to coarse, subrounded to subangular with estimated 15-25% fine- to coarse-grained sand, 15-25% fines.	

WELL DIAGRAM



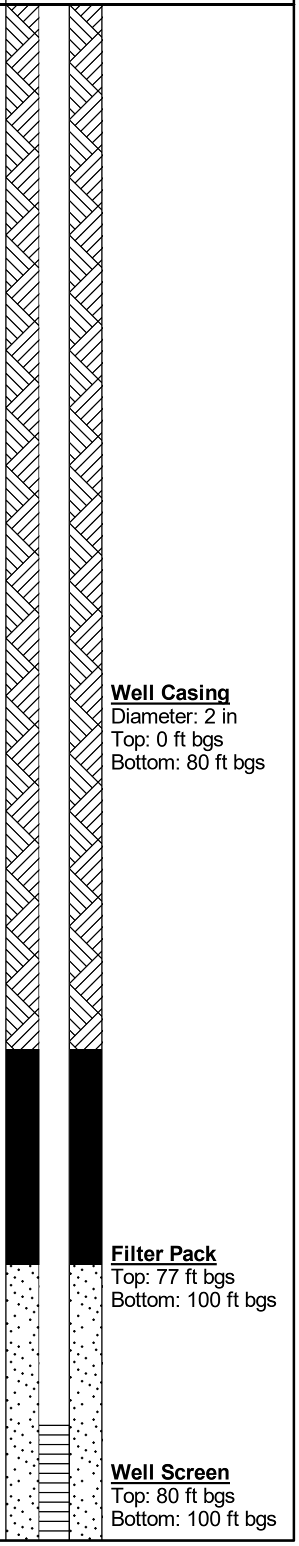
Well Casing
Diameter: 2 in
Top: 0 ft bgs
Bottom: 80 ft bgs

(Continued Next Page)

CLIENT ARNG, USACE Baltimore District
PROJECT NAME Grand Ledge AASF
PROJECT NUMBER 60552172
SITE NAME AOI 1

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	ENVIRONMENTAL DATA
55			GW-GM		50.0	
60		90	SM		55.0 SILTY SAND WITH GRAVEL, moist, dark brown to black, fine- to medium-grained with estimated 15-25% fines and 15-25% fine to medium, subangular gravel.	
65		100			60.0 SILTY SAND, moist, dark brown to black, fine- to medium-grained with estimated >15% fines and 5-10% fine, subangular gravel. Thin layers of poorly cemented, coarse-grained sandstone present.	
70		100			65.0 Changes to dry, dark brown. Contains 0.5" layers of coarse-grained, poorly cemented sandstone.	
75		70			70.0 Changes to moist, dark brown to dark gray with trace amounts of fine, subangular to angular gravel.	
80		100	ML		75.0 SANDY SILT, moist, dark gray, very dense with estimated 15-25% fine-grained sand and trace amounts of fine, subangular gravel. Contains light gray clay nodules and 0.5"-thick layers of poorly cemented sandstone.	
					80.5 Changes to contain 0.5-0.75" layers of coarse-grained, poorly cemented sandstone.	

WELL DIAGRAM



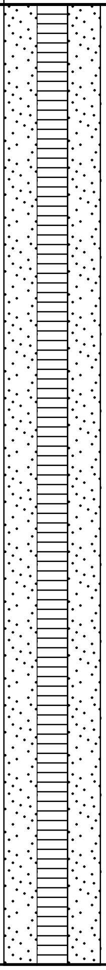
(Continued Next Page)

WELL NUMBER AOI1-10

TOTAL DEPTH 100 FT BGS

CLIENT ARNG, USACE Baltimore District
PROJECT NAME Grand Ledge AASF
PROJECT NUMBER 60552172
SITE NAME AOI 1

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	GRAPHIC LOG		MATERIAL DESCRIPTION	ENVIRONMENTAL DATA	WELL DIAGRAM
85		100	ML		75.0	SANDY SILT, moist, dark gray, very dense with estimated 15-25% fine-grained sand and trace amounts of fine, subangular gravel. Contains light gray clay nodules and 0.5"-thick layers of poorly cemented sandstone. *(continued)*		
90		100			85.0	Changes to contain 1-3" layers of coarse grained, poorly cemented sandstone.		
95		100			90.0	SANDSTONE, gray, coarse-grained, poorly cemented, moderately thin bedding, medium hardness, moderately to highly weathered.	**AOI1-10-GW-89**	**Well Screen** Top: 80 ft bgs Bottom: 100 ft bgs
100		100			95.0	Changes to medium- to coarse-grained, moderately weathered, hard.		



Bottom of borehole at 100.0 feet.

Notes:
1. Headspace screening values represent total volatile organic vapors (referenced to an isobutylene standard) measured with a Photoionization Detector (PID) with 10.6 eV lamp.
2. Coordinates and elevation data in NAVD88 for vertical datum and NAD83/91 for horizontal datum in Michigan State Plane.
3. No recovery from 15-50 ft bgs. Driller switched to flapper bit at 35 ft bgs. Switched to rock coring at 39.5 due to rock encounter. Switched to RQ core at 50 ft bgs.

WELL NUMBER AOI1-11

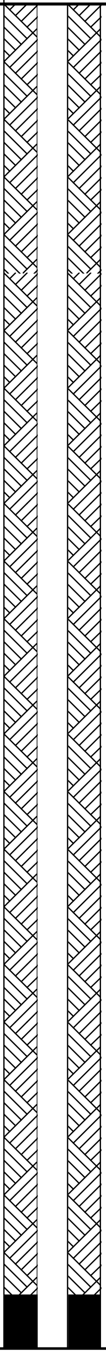
AECOM

TOTAL DEPTH 50 FT BGS
PAGE 1 OF 2

CLIENT ARNG, USACE Baltimore District
PROJECT NAME Grand Ledge AASF
PROJECT NUMBER 60552172
SITE NAME AOI 1
DATE STARTED 12/2/19 **COMPLETED** 12/5/19
EASTING 13024374.67 **NORTHING** 464250.05
DRILLING CONTRACTOR Cascade
GROUND ELEVATION N/A **HOLE SIZE** 6 inches
DRILLING EQUIPMENT Boart Longyear ProSonic T600
GROUND WATER LEVELS:
DRILLING METHOD Rotary Sonic
AT TIME OF DRILLING ---
LOGGED BY A. Shah **CHECKED BY** J. Hollingsworth
▼ **AT TIME OF SAMPLING** 13.30 ft

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	MATERIAL DESCRIPTION	ENVIRONMENTAL DATA
0.0				TOPSOIL.	
0.4		100	SM	SILTY SAND WITH GRAVEL, moist, brown with estimated >15% fines, 15-25% fine to coarse, angular gravel, and trace organics.	
5.0			SC	CLAYEY SAND, moist, brown with estimated 15-25% fine to coarse, angular gravel.	
9.5		100	GW-GM	WELL-GRADED GRAVEL WITH SILT AND SAND, moist, brown to light brown, estimated 15-25% fines and 15-25% fine- to medium-grained sand.	
15.0			SM	SILTY SAND, moist, brown to dark brown with estimated 5-10% fine to medium, angular gravel.	
17.0		100	CL	LEAN CLAY WITH GRAVEL, moist, brown to grayish brown, medium plasticity with estimated 15-25% fine to medium, subangular to subrounded gravel and 5-10% fine-grained sand.	
23.4				Changes to estimated 5-10% fine- to medium-grained sand.	

WELL DIAGRAM



Annular Seal
Top: 0 ft bgs
Bottom: 5 ft bgs

Annular Seal
Top: 5 ft bgs
Bottom: 24 ft bgs

Well Casing
Diameter: 2 in
Top: 0 ft bgs
Bottom: 30 ft bgs

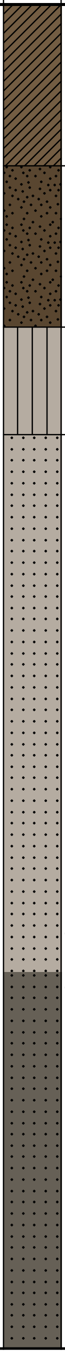
(Continued Next Page)

AECOM AECOM

WELL NUMBER AOI1-11

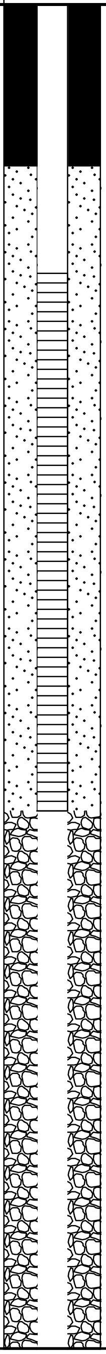
TOTAL DEPTH 50 FT BGS

CLIENT ARNG, USACE Baltimore District
PROJECT NAME Grand Ledge AASF
PROJECT NUMBER 60552172
SITE NAME AOI 1



DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	MATERIAL DESCRIPTION	ENVIRONMENTAL DATA
25			CL	17.0 LEAN CLAY WITH GRAVEL, moist, brown to grayish brown, medium plasticity with estimated 15-25% fine to medium, subangular to subrounded gravel and 5-10% fine-grained sand. *(continued)*	
		90	SP	28.0 POORLY GRADED SAND WITH GRAVEL AND COBBLES, moist, dark brown do dark gray with estimated 15-25% fine to coarse, subrounded to rounded gravel and 2-3" cobbles.	
30			ML	31.0 SILT WITH SAND, moist, light gray with estimated 15-25% fine-grained sand and trace amounts of gravel.	
				33.0 SANDSTONE, dry, light gray, coarse-grained, poorly cemented, severely weathered, no bedding, weak.	
35					AOI1-11-GW-35
		100		37.0 Contains medium to hard layers of sandstone to 38 ft bgs.	
40				42.0 Changes to very thin bedding.	
				43.0 Changes to dark gray with thin, contains 0.5" layers of moderately hard sandstone.	
45		100			
50					

WELL DIAGRAM



Well Casing
Diameter: 2 in
Top: 0 ft bgs
Bottom: 30 ft bgs

Filter Pack
Top: 28 ft bgs
Bottom: 40 ft bgs

Well Screen
Top: 30 ft bgs
Bottom: 40 ft bgs

Backfill
Top: 40 ft bgs
Bottom: 50 ft bgs

Bottom of borehole at 50.0 feet.

Notes:
1. Headspace screening values represent total volatile organic vapors (referenced to an isobutylene standard) measured with a Photoionization Detector (PID) with 10.6 eV lamp.
2. Coordinates and elevation data in NAVD88 for vertical datum and NAD83/91 for horizontal datum in Michigan State Plane.

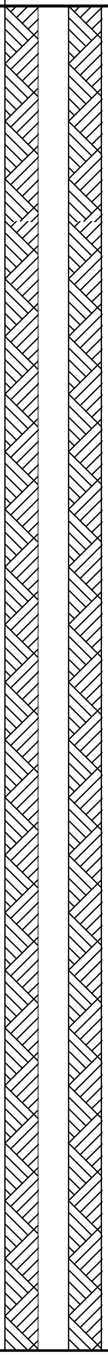
AECOM AECOM

WELL NUMBER AOI1-12

TOTAL DEPTH 57 FT BGS
PAGE 1 OF 3

CLIENT	ARNG, USACE Baltimore District	**PROJECT NAME**	Grand Ledge AASF
PROJECT NUMBER	60552172	**SITE NAME**	AOI 1
DATE STARTED	12/6/19 **COMPLETED** 12/6/19	**EASTING**	13025733.63 **NORTHING** 464235.8
DRILLING CONTRACTOR	Cascade	**GROUND ELEVATION**	N/A **HOLE SIZE** 6 inches
DRILLING EQUIPMENT	Boart Longyear ProSonic T600	**GROUND WATER LEVELS:**	
DRILLING METHOD	Rotary Sonic	**AT TIME OF DRILLING**	---
LOGGED BY	A. Shah **CHECKED BY** J. Hollingsworth	▼ **AT TIME OF SAMPLING**	16.91 ft

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	ENVIRONMENTAL DATA	WELL DIAGRAM
0		86	CL		0.0 TOPSOIL.		**Annular Seal** Top: 0 ft bgs Bottom: 4 ft bgs
					0.2 LEAN CLAY, moist, brown to light brown, low to medium plasticity with estimated 5-10% fine to coarse, subangular to subrounded gravel.		
5					4.4 LEAN CLAY WITH GRAVEL, moist, brown to light brown, medium plasticity with estimated 15-25% fine to coarse, subangular to subrounded gravel and 5-10% fine- to medium-grained sand.		**Annular Seal** Top: 4 ft bgs Bottom: 31 ft bgs
10		100			10.2 Changes to brown to dark brown.		**Well Casing** Diameter: 2 in Top: 0 ft bgs Bottom: 47 ft bgs
15					15.0 Changes to dark brown to gray.		
20		100					
25							



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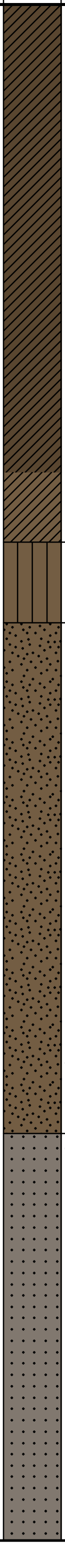
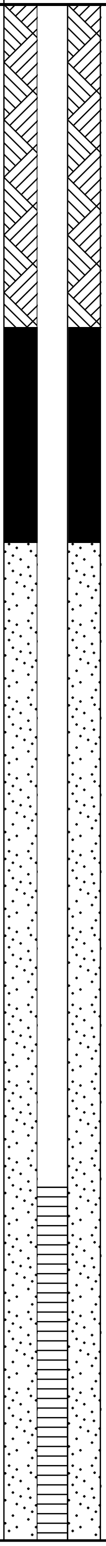
CLIENT ARNG, USACE Baltimore District
PROJECT NAME Grand Ledge AASF
PROJECT NUMBER 60552172
SITE NAME AOI 1

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	MATERIAL DESCRIPTION	ENVIRONMENTAL DATA
15.0				Changes to dark brown to gray. *(continued)*	
27.6		100		Changes to dark brown with estimated 5-10% fine- to coarse-grained sand.	
33.7				LEAN CLAY, moist, brown to dark brown with estimated 5-10% fine to coarse, subangular to subrounded gravel and 5-10% fine-grained sand.	
35.0			ML	SILT, moist, brown, low plasticity with estimated 5-10% gravel and 5-10% fine-grained sand.	
36.5		100	SP	POORLY GRADED SAND, moist, brown with estimated 5-10% fines and trace amounts of fine gravel.	AOI1-12-GW-42
44.4				Changes to estimated 5-10% fine-grained gravel.	
46.0		100		SANDSTONE, gray, coarse-grained, poorly cemented, no bedding, weak, severely weathered.	





WELL DIAGRAM

Filter Pack
Top: 35 ft bgs
Bottom: 57 ft bgs

Well Casing
Diameter: 2 in
Top: 0 ft bgs
Bottom: 47 ft bgs

Well Screen
Top: 47 ft bgs
Bottom: 57 ft bgs

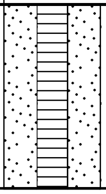
(Continued Next Page)

AECOM

WELL NUMBER AOI1-12

TOTAL DEPTH 57 FT BGS
PAGE 3 OF 3

CLIENT ARNG, USACE Baltimore District
PROJECT NAME Grand Ledge AASF
PROJECT NUMBER 60552172
SITE NAME AOI 1

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	ENVIRONMENTAL DATA	WELL DIAGRAM
55					46.0 54.0 SANDSTONE, gray, coarse-grained, poorly cemented, no bedding, weak, severely weathered. *(continued)* Changes to very thin bedding.		 **Well Screen** Top: 47 ft bgs Bottom: 57 ft bgs

Bottom of borehole at 57.0 feet.

Notes:
1. Headspace screening values represent total volatile organic vapors (referenced to an isobutylene standard) measured with a Photoionization Detector (PID) with 10.6 eV lamp.
2. Coordinates and elevation data in NAVD88 for vertical datum and NAD83/91 for horizontal datum in Michigan State Plane.

AECOM AECOM

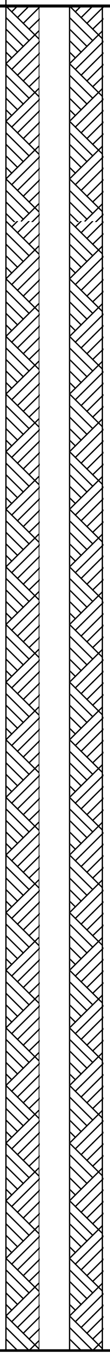
WELL NUMBER AOI1-13

TOTAL DEPTH 57 FT BGS

CLIENT	ARNG, USACE Baltimore District	**PROJECT NAME**	Grand Ledge AASF
PROJECT NUMBER	60552172	**SITE NAME**	AOI 1
DATE STARTED	12/5/19 **COMPLETED** 12/6/19	**EASTING**	13025868.19 **NORTHING** 463821.28
DRILLING CONTRACTOR	Cascade	**GROUND ELEVATION**	N/A **HOLE SIZE** 6 inches
DRILLING EQUIPMENT	Boart Longyear ProSonic T600	**GROUND WATER LEVELS:**	
DRILLING METHOD	Rotary Sonic	**AT TIME OF DRILLING**	---
LOGGED BY	A. Shah **CHECKED BY** J. Hollingsworth	▼ **AT TIME OF SAMPLING**	20.21 ft

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	GRAPHIC LOG		MATERIAL DESCRIPTION	ENVIRONMENTAL DATA
0				■	0.0	ASPHALT.	
		100	SW	▒	0.4	WELL-GRADED SAND WITH GRAVEL, moist, brown to dark brown with estimated 15-25% fine to coarse subangular to subrounded gravel.	
			CL	▨	2.5	LEAN CLAY WITH GRAVEL, moist, brown, low to medium-plasticity with estimated 15-25% fine to coarse, subangular to rounded gravel and 5-10% fine-grained sand.	
5							
10		100					
					12.4	Changes to brown to dark brown.	
15							
		100		▨	17.5	Changes to dark brown.	
					19.2	Changes to medium plasticity.	
20							
					21.0	Changes to low plasticity.	
					22.4	Changes to medium plasticity.	
25							

WELL DIAGRAM



Annular Seal
Top: 0 ft bgs
Bottom: 4 ft bgs

Annular Seal
Top: 4 ft bgs
Bottom: 36 ft bgs

Well Casing
Diameter: 2 in
Top: 0 ft bgs
Bottom: 42 ft bgs

(Continued Next Page)

AECOM AECOM

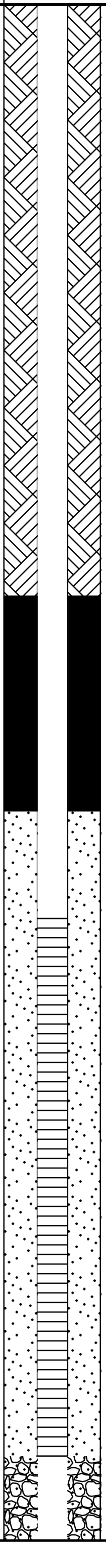
WELL NUMBER AOI1-13

TOTAL DEPTH 57 FT BGS
PAGE 2 OF 3

CLIENT ARNG, USACE Baltimore District
PROJECT NAME Grand Ledge AASF
PROJECT NUMBER 60552172
SITE NAME AOI 1

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	MATERIAL DESCRIPTION	ENVIRONMENTAL DATA
17.5				Changes to dark brown. *(continued)*	
29.5		100		Changes to brown to dark brown.	
35.0				Changes to dark brown and sand becomes fine- to medium-grained.	
39.5				Changes to medium to high plasticity.	
42.0		100	SP	POORLY GRADED SAND, moist, brown with estimated 5-10% fines and trace amounts of fine gravel.	
44.0				Contains 1" thick lean clay lens.	
44.5			SW	WELL-GRADED SAND WITH GRAVEL, moist, brown to dark brown with estimated 15-25% fine to coarse, subangular to subrounded gravel.	
46.0				Changes to estimated 30-45% gravel.	AOI1-13-GW-47
		100			
52.8			MH		

WELL DIAGRAM



Well Casing
Diameter: 2 in
Top: 0 ft bgs
Bottom: 42 ft bgs

Filter Pack
Top: 40 ft bgs
Bottom: 57 ft bgs

Well Screen
Top: 42 ft bgs
Bottom: 52 ft bgs

Backfill
Top: 52 ft bgs
Bottom: 57 ft bgs

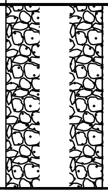
(Continued Next Page)

AECOM

WELL NUMBER AOI1-13

TOTAL DEPTH 57 FT BGS
PAGE 3 OF 3

CLIENT ARNG, USACE Baltimore District
PROJECT NAME Grand Ledge AASF
PROJECT NUMBER 60552172
SITE NAME AOI 1

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	ENVIRONMENTAL DATA	WELL DIAGRAM
					ELASTIC SILT WITH GRAVEL, moist, brown to light gray with estimated 15-25% fine to coarse gravel. *(continued)*		
55				54.0	SANDSTONE, gray, coarse-grained, poorly cemented, weak, severly weathered, no bedding present.		

Bottom of borehole at 57.0 feet.

Notes:
1. Headspace screening values represent total volatile organic vapors (referenced to an isobutylene standard) measured with a Photoionization Detector (PID) with 10.6 eV lamp.
2. Coordinates and elevation data in NAVD88 for vertical datum and NAD83/91 for horizontal datum in Michigan State Plane.

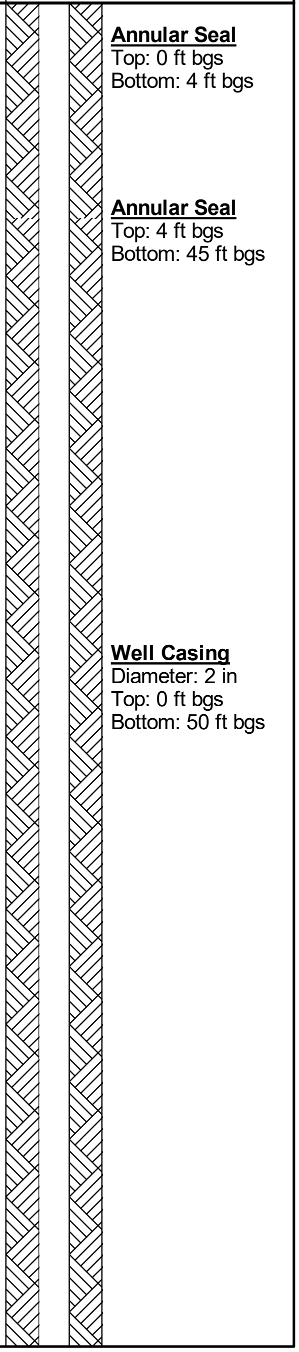
WELL NUMBER AOI1-14

TOTAL DEPTH 67 FT BGS
PAGE 1 OF 3

CLIENT	ARNG, USACE Baltimore District	**PROJECT NAME**	Grand Ledge AASF
PROJECT NUMBER	60552172	**SITE NAME**	AOI 1
DATE STARTED	12/4/19 **COMPLETED** 12/6/19	**EASTING**	13025828.79 **NORTHING** 463236.23
DRILLING CONTRACTOR	Cascade	**GROUND ELEVATION**	N/A **HOLE SIZE** 6 inches
DRILLING EQUIPMENT	Boart Longyear ProSonic T600	**GROUND WATER LEVELS:**	
DRILLING METHOD	Rotary Sonic	**AT TIME OF DRILLING**	---
LOGGED BY	A. Shah **CHECKED BY** J. Hollingsworth	▼ **AT TIME OF SAMPLING**	36.26 ft

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	GRAPHIC LOG		MATERIAL DESCRIPTION	ENVIRONMENTAL DATA
0					0.0	TOPSOIL.	
		100	CL		0.3	LEAN CLAY, moist, brown to reddish brown, low to medium plasticity with estimated 5-10% fine to medium, subrounded to rounded gravel and trace amounts of organics.	
5					4.5	LEAN CLAY WITH GRAVEL, moist, brown to dark brown, medium to high plasticity with estimated 15-25% fine to coarse, subrounded gravel and 5-10% fine-grained sand.	
10		100			12.0	Changes to brown.	
					13.5	Changes to brown to light brown, estimated 5-10% fine- to coarse-grained sand.	
15							
20					18.5	Changes to brown.	
		100			22.0	LEAN CLAY WITH GRAVEL AND COBBLES, moist, brown, medium to high plasticity with estimated 15-25% fine to coarse, subrounded gravel, 5-10% fine- to coarse-grained sand, and 2-4" cobbles.	
25							

WELL DIAGRAM



Annular Seal
Top: 0 ft bgs
Bottom: 4 ft bgs

Annular Seal
Top: 4 ft bgs
Bottom: 45 ft bgs

Well Casing
Diameter: 2 in
Top: 0 ft bgs
Bottom: 50 ft bgs

(Continued Next Page)

AECOM AECOM

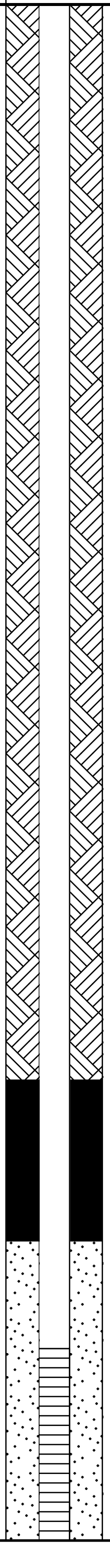
WELL NUMBER AOI1-14

TOTAL DEPTH 67 FT BGS
PAGE 2 OF 3

CLIENT ARNG, USACE Baltimore District
PROJECT NAME Grand Ledge AASF
PROJECT NUMBER 60552172
SITE NAME AOI 1

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	ENVIRONMENTAL DATA
25					22.0 LEAN CLAY WITH GRAVEL AND COBBLES, moist, brown, medium to high plasticity with estimated 15-25% fine to coarse, subrounded gravel, 5-10% fine- to coarse-grained sand, and 2-4" cobbles. *(continued)*	
					28.5 LEAN CLAY WITH GRAVEL, moist, brown, medium to high plasticity with estimated 15-25% fine to coarse, subrounded to rounded gravel and 5-10% fine- to coarse-grained sand.	
30					30.6 LEAN CLAY WITH GRAVEL AND COBBLES, moist, brown, medium to high plasticity with estimated 15-25% fine- to coarse-grained, subrounded to rounded gravel, 5-10% fine to coarse sand, and cobbles.	
		100				
35						
40						
		20				
45						
		100				
50			SW		50.0 WELL-GRADED SAND WITH GRAVEL, moist, brown to light gray with estimated 15-25% fine to coarse, subangular to rounded gravel.	

WELL DIAGRAM



Well Casing
Diameter: 2 in
Top: 0 ft bgs
Bottom: 50 ft bgs

Filter Pack
Top: 48 ft bgs
Bottom: 60 ft bgs

Well Screen
Top: 50 ft bgs
Bottom: 60 ft bgs

(Continued Next Page)

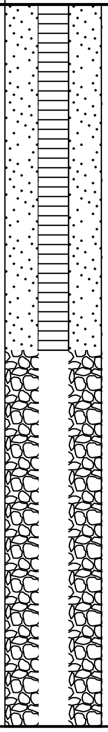
WELL NUMBER AOI1-14

TOTAL DEPTH 67 FT BGS
PAGE 3 OF 3

CLIENT ARNG, USACE Baltimore District
PROJECT NAME Grand Ledge AASF
PROJECT NUMBER 60552172
SITE NAME AOI 1

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	ENVIRONMENTAL DATA
55		100	SW	▨	50.0 WELL-GRADED SAND WITH GRAVEL, moist, brown to light gray with estimated 15-25% fine to coarse, subangular to rounded gravel. *(continued)*	AOI1-14-GW-55
					56.0 Changes to estimated 30-45% fine- to coarse, subrounded to rounded gravel.	
60		80				
					62.5 Changes to estimated 15-25% fine to coarse, rounded to subrounded gravel.	
65			CL	▨	65.0 LEAN CLAY, moist, light brown, low plasticity with estimated 5-10% fine-grained sand and trace amounts of fine gravel.	

WELL DIAGRAM



Well Screen
Top: 50 ft bgs
Bottom: 60 ft bgs

Backfill
Top: 60 ft bgs
Bottom: 67 ft bgs

Bottom of borehole at 67.0 feet.

Notes:
1. Headspace screening values represent total volatile organic vapors (referenced to an isobutylene standard) measured with a Photoionization Detector (PID) with 10.6 eV lamp.
2. Coordinates and elevation data in NAVD88 for vertical datum and NAD83/91 for horizontal datum in Michigan State Plane.
3. At 37 ft bgs, majority of recovery was washed out due to catcher malfunction.

AECOM AECOM

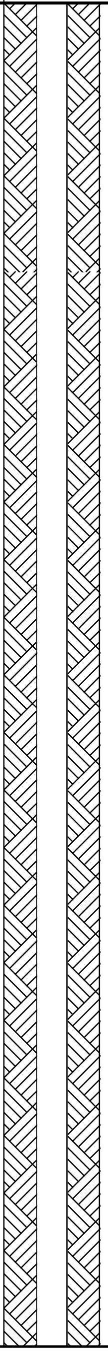
WELL NUMBER AOI1-15

TOTAL DEPTH 75 FT BGS
PAGE 1 OF 3

CLIENT ARNG, USACE Baltimore District
PROJECT NAME Grand Ledge AASF
PROJECT NUMBER 60552172
SITE NAME AOI 1
DATE STARTED 11/19/19 **COMPLETED** 12/5/19
EASTING 13024952.05 **NORTHING** 463225.07
DRILLING CONTRACTOR Cascade
GROUND ELEVATION N/A **HOLE SIZE** 6 inches
DRILLING EQUIPMENT Boart Longyear ProSonic T600
GROUND WATER LEVELS:
DRILLING METHOD Rotary Sonic
AT TIME OF DRILLING ---
LOGGED BY A. Shah **CHECKED BY** J. Hollingsworth
▼ **AT TIME OF SAMPLING** 27.50 ft

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	ENVIRONMENTAL DATA
0				0.0	TOPSOIL.	
		40	CL	0.3	SANDY LEAN CLAY, moist, brown, low plasticity with estimated 15-25% fine- to medium-grained sand, 5-10% fine to medium, subrounded to rounded gravel, and trace amounts of organics.	
5		40		5.0	Changes to fine to coarse, rounded gravel.	
10		60		10.0	Changes to brown to dark brown, medium plasticity with estimated 15-25% fine-grained sand and trace amounts of fine to coarse, subrounded to rounded gravel and organics.	
15		80		15.0	Changes estimated 5-10% fine to coarse, subrounded gravel and contains 0.1" layers of fine- to medium-grained sand interbedded with sandy lean clay.	
20		70		20.0	Changes to low plasticity with estimated 5-10% fine to coarse, subrounded to rounded gravel.	
25						

WELL DIAGRAM



Annular Seal
Top: 0 ft bgs
Bottom: 5 ft bgs

Annular Seal
Top: 5 ft bgs
Bottom: 55 ft bgs

Well Casing
Diameter: 2 in
Top: 0 ft bgs
Bottom: 60 ft bgs

(Continued Next Page)

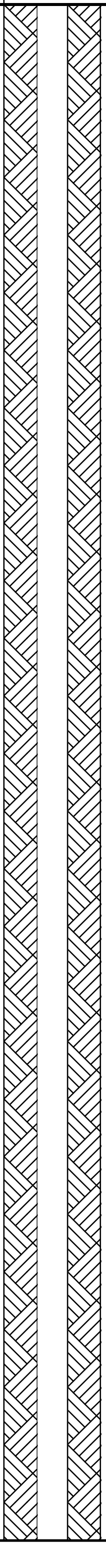
WELL NUMBER AOI1-15

AECOM AECOM

TOTAL DEPTH 75 FT BGS

CLIENT ARNG, USACE Baltimore District
PROJECT NAME Grand Ledge AASF
PROJECT NUMBER 60552172
SITE NAME AOI 1

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	GRAPHIC LOG		MATERIAL DESCRIPTION	ENVIRONMENTAL DATA	WELL DIAGRAM
25		100			25.0	SANDY LEAN CLAY WITH GRAVEL, moist, brown to dark brown, low to medium plasticity with estimated 15-25% fine- to medium-grained sand and 15-25% fine- to coarse-grained, subrounded to rounded gravel.		
30		100						
35		100						
40		100			40.0	Changes to dark brown to gray.		**Well Casing** Diameter: 2 in Top: 0 ft bgs Bottom: 60 ft bgs
45			SC		45.0	CLAYEY SAND WITH GRAVEL, moist, dark brown to gray, fine-grained with estimated 15-25% fines and 15-25% fine to coarse, subrounded gravel.		
					49.5	Contains 4" of sandstone, gray, coarse-grained, poorly cemented.		
50		100			50.0	SANDSTONE, moist, gray, medium- to coarse-grained, very poorly cemented, moderately thin bedding, no foliation, moderately hard, moderate to highly weathered.		
					53.0	Contains 1.5" layer of clayey sand with coarse gravel.		



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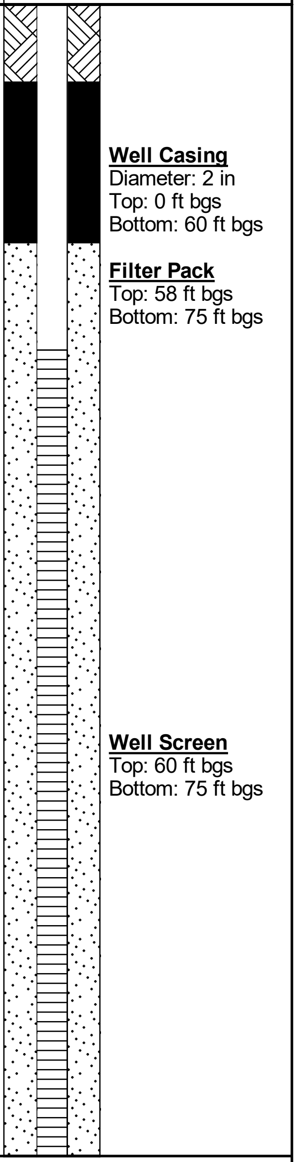
WELL NUMBER AOI1-15

TOTAL DEPTH 75 FT BGS

CLIENT ARNG, USACE Baltimore District
PROJECT NAME Grand Ledge AASF
PROJECT NUMBER 60552172
SITE NAME AOI 1

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	ENVIRONMENTAL DATA
50.0					SANDSTONE, moist, gray, medium- to coarse-grained, very poorly cemented, moderately thin bedding, no foliation, moderately hard, moderate to highly weathered. *(continued)*	
55.0		95			Changes to dry, highly weathered.	
57.0					Contains 1/2" to 1' layers of clayey sand with gravel from 57 to 60 feet bgs.	
65.0		100			Changes to coarse-grained, interbedded with gray clayey sand with gravel.	AOI1-15-GW-67.50

WELL DIAGRAM



Well Casing
Diameter: 2 in
Top: 0 ft bgs
Bottom: 60 ft bgs

Filter Pack
Top: 58 ft bgs
Bottom: 75 ft bgs

Well Screen
Top: 60 ft bgs
Bottom: 75 ft bgs

Bottom of borehole at 75.0 feet.

Notes:
1. Headspace screening values represent total volatile organic vapors (referenced to an isobutylene standard) measured with a Photoionization Detector (PID) with 10.6 eV lamp.
2. Coordinates and elevation data in NAVD88 for vertical datum and NAD83/91 for horizontal datum in Michigan State Plane.

WELL NUMBER AOI 2-1

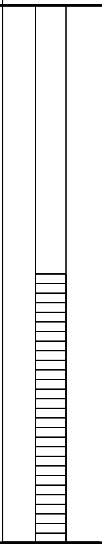
AECOM AECOM

TOTAL DEPTH 10 FT BGS
PAGE 1 OF 1

CLIENT ARNG, USACE Baltimore District
PROJECT NAME Grand Ledge Army Aviation Support Facility and Armory SI
PROJECT NUMBER 60552172
SITE NAME AOI2
DATE STARTED 5/7/19 **COMPLETED** 5/7/19
EASTING -84.73931046 **NORTHING** 42.77064037
DRILLING CONTRACTOR Cascade
GROUND ELEVATION N/A **HOLE SIZE** 2 inches
DRILLING EQUIPMENT Geoprobe
GROUND WATER LEVELS:
DRILLING METHOD Direct Push
AT TIME OF DRILLING ---
LOGGED BY M Glinski **CHECKED BY** N/A
AT END OF DRILLING ---

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	ENVIRONMENTAL DATA
0	GMAC	100	ML	▨	0.0 SILT WITH SAND, dry, dark brown, soft, slightly cohesive, 15% fine sand.	AOI2-1-SB-0-2
			CL	▨	4.0 LEAN CLAY WITH SAND, dry, light yellowish brown, stiff, medium plasticity, 15% fine to medium sand.	
5	GMAC	97		▨	7.0 Changes to brown.	
10						

WELL DIAGRAM



Well Casing
Diameter: 1 in
Top: 0 ft bgs
Bottom: 5 ft bgs

Well Screen
Type: Schedule 40 PVC
Slot Size: 0.01 in
Top: 5 ft bgs
Bottom: 10 ft bgs

Bottom of borehole at 10.0 feet.

Notes:
3. Headspace screening values represent total volatile organic vapors (referenced to an isobutylene standard) measured with a Photoionization Detector (PID) with 10.6 eV lamp.
4. Coordinates and elevation data in NAVD88 for vertical datum and NAD83/91 for horizontal datum in Michigan State Plane.

WELL NUMBER AOI 2-2

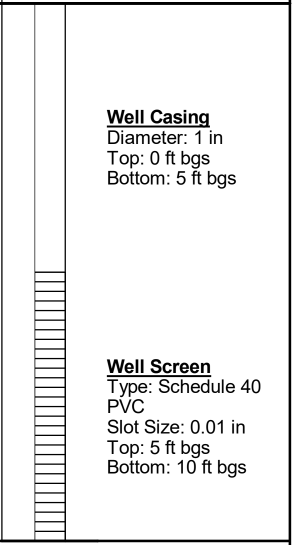
AECOM

TOTAL DEPTH 10 FT BGS
PAGE 1 OF 1

CLIENT ARNG, USACE Baltimore District
PROJECT NAME Grand Ledge Army Aviation Support Facility and Armory SI
PROJECT NUMBER 60552172
SITE NAME AOI2
DATE STARTED 5/7/19 **COMPLETED** 5/7/19
EASTING -84.73872822 **NORTHING** 42.77044474
DRILLING CONTRACTOR Cascade
GROUND ELEVATION N/A **HOLE SIZE** 2 inches
DRILLING EQUIPMENT Geoprobe
GROUND WATER LEVELS:
DRILLING METHOD Direct Push
AT TIME OF DRILLING ---
LOGGED BY M Glinski **CHECKED BY** N/A
AT END OF DRILLING ---

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	ENVIRONMENTAL DATA
0	GMAC	100	ML		0.0 SILT WITH SAND, dry, yellowish brown, soft, 20% fine sand.	AOI2-2-SB-0-2
			SP		1.5 POORLY GRADED SAND, dry, yellowish brown, loose, fine grained.	
			CL		2.0 LEAN CLAY WITH SAND, moist, brown, 25% fine sand.	AOI2-2-SB-2-4 AOI2-2-SB-2-4 DUP
5	GMAC	90	CL		5.5 LEAN CLAY, moist, brown, stiff, 10% fine sand.	
10						

WELL DIAGRAM



Well Casing
Diameter: 1 in
Top: 0 ft bgs
Bottom: 5 ft bgs

Well Screen
Type: Schedule 40 PVC
Slot Size: 0.01 in
Top: 5 ft bgs
Bottom: 10 ft bgs

Bottom of borehole at 10.0 feet.

Notes:
3. Headspace screening values represent total volatile organic vapors (referenced to an isobutylene standard) measured with a Photoionization Detector (PID) with 10.6 eV lamp.
4. Coordinates and elevation data in NAVD88 for vertical datum and NAD83/91 for horizontal datum in Michigan State Plane.

WELL NUMBER AOI 2-3

AECOM

TOTAL DEPTH 10 FT BGS
PAGE 1 OF 1

CLIENT	ARNG, USACE Baltimore District	**PROJECT NAME**	Grand Ledge Army Aviation Support Facility and Armory SI
PROJECT NUMBER	60552172	**SITE NAME**	AOI2
DATE STARTED	5/7/19 **COMPLETED** 5/7/19	**EASTING**	-84.73817303 **NORTHING** 42.77136182
DRILLING CONTRACTOR	Cascade	**GROUND ELEVATION**	N/A **HOLE SIZE** 2 inches
DRILLING EQUIPMENT	Geoprobe	**GROUND WATER LEVELS:**	
DRILLING METHOD	Direct Push	**AT TIME OF DRILLING**	---
LOGGED BY	M Glinski **CHECKED BY** N/A	**AT END OF DRILLING**	---

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	GRAPHIC LOG		MATERIAL DESCRIPTION	ENVIRONMENTAL DATA	WELL DIAGRAM
0	GMAC	100	SC	▨	0.0	CLAYEY SAND, dry, yellowish brown, medium dense, fine grained sand, 30% clay.	AOI2-3-SB-0-2	
					2.0	Coarsening sand.		**Well Casing** Diameter: 1 in Top: 0 ft bgs Bottom: 5 ft bgs
			CL	▨	4.5	LEAN CLAY WITH SAND, wet, dark grayish brown, 20% fine sand.		
5	GMAC	92						
					7.0	Changes to 5% subangular coarse sand.		**Well Screen** Type: Schedule 40 PVC Slot Size: 0.01 in Top: 5 ft bgs Bottom: 10 ft bgs
10								

Bottom of borehole at 10.0 feet.

Notes:

3. Headspace screening values represent total volatile organic vapors (referenced to an isobutylene standard) measured with a Photoionization Detector (PID) with 10.6 eV lamp.
4. Coordinates and elevation data in NAVD88 for vertical datum and NAD83/91 for horizontal datum in Michigan State Plane.

WELL NUMBER AOI2-4

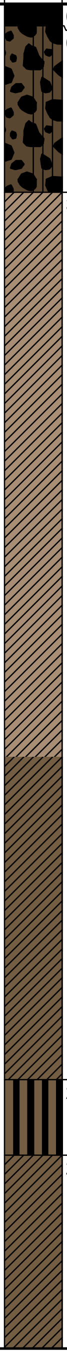
AECOM AECOM

TOTAL DEPTH 50 FT BGS
PAGE 1 OF 2

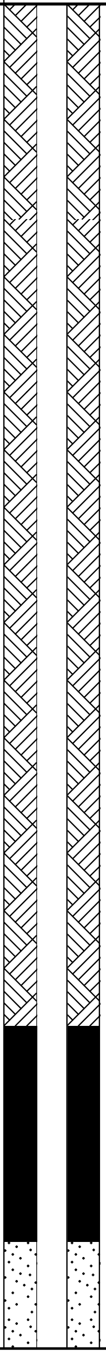
CLIENT	ARNG, USACE Baltimore District	**PROJECT NAME**	Grand Ledge AASF
PROJECT NUMBER	60552172	**SITE NAME**	AOI 2
DATE STARTED	12/3/19 **COMPLETED** 12/5/19	**EASTING**	-84.73886589 **NORTHING** 42.77044627
DRILLING CONTRACTOR	Cascade	**GROUND ELEVATION**	N/A **HOLE SIZE** 6 inches
DRILLING EQUIPMENT	Boart Longyear ProSonic T600	**GROUND WATER LEVELS:**	
DRILLING METHOD	Rotary Sonic	**AT TIME OF DRILLING**	---
LOGGED BY	A. Shah **CHECKED BY** J. Hollingsworth	▼ **AT TIME OF SAMPLING**	10.37 ft

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	MATERIAL DESCRIPTION	ENVIRONMENTAL DATA
0				0.0 ASPHALT.	
			GW-GM	0.4 WELL-GRADED GRAVEL WITH SILT AND SAND, moist, dark brown with estimated 15-25% fines, 15-25% fine- to medium-grained sand, and trace amounts of asphalt fragments. Possibly fill.	
			CL	3.5 LEAN CLAY WITH GRAVEL, moist, light brown, medium plasticity with estimated 15-25% fine to medium, subrounded gravel and 5-10% fine-grained sand.	
5		100			
10					
				14.0 Changes to brown, estimated 15-25% fine to coarse, subangular to subrounded gravel.	
15		100			
				18.2 Changes to estimated 5-10% fine- to coarse-grained sand.	
20			MH	20.0 ELASTIC SILT WITH GRAVEL, moist, brown, low plasticity with estimated 30-45% medium to coarse, subrounded gravel.	
			CL	21.4 LEAN CLAY, moist, brown, low to medium plasticity with estimated 5-10% fine to coarse, subrounded gravel.	
25					

GRAPHIC LOG



WELL DIAGRAM



Annular Seal
Top: 0 ft bgs
Bottom: 4 ft bgs

Annular Seal
Top: 4 ft bgs
Bottom: 19 ft bgs

Well Casing
Diameter: 2 in
Top: 0 ft bgs
Bottom: 25 ft bgs

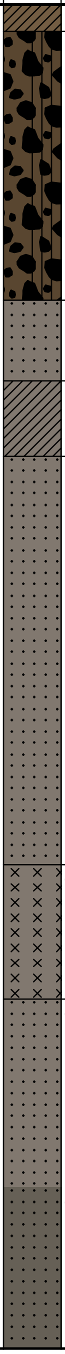
Filter Pack
Top: 23 ft bgs
Bottom: 35 ft bgs

(Continued Next Page)

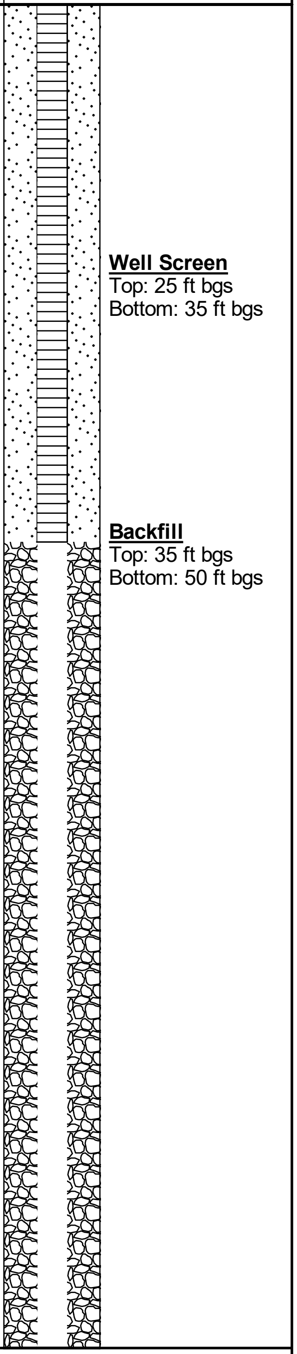
CLIENT ARNG, USACE Baltimore District
PROJECT NAME Grand Ledge AASF
PROJECT NUMBER 60552172
SITE NAME AOI 2

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	MATERIAL DESCRIPTION	ENVIRONMENTAL DATA
21.4		70			
25.5			GW-GM	WELL-GRADED GRAVEL WITH SILT, SAND, AND COBBLES, moist, dark brown with estimated 15-25% silt, 15-25% fine- to medium-grained sand, and cobbles up to 3" in diameter.	AOI2-4-GW-30
30.5		100		SANDSTONE, gray to dark gray, coarse-grained, poorly cemented, very thin bedding, weak, severly weathered.	
32.0			CL	LEAN CLAY WITH GRAVEL, gray with estimated 15-25% gravel.	
33.4				SANDSTONE, gray, coarse-grained, poorly cemented, very thin bedding, weak, severly weathered.	
41.0		80		SILTSTONE, gray, fine-grained, very thin bedding, weak, highly weathered.	
43.5				SANDSTONE, gray to dark gray, medium-grained, poorly cemented, thin bedding, weak, highly weathered.	
47.0				Changes to dark gray, fine- to medium-grained.	

GRAPHIC LOG



WELL DIAGRAM



Bottom of borehole at 50.0 feet.

Notes:
1. Headspace screening values represent total volatile organic vapors (referenced to an isobutylene standard) measured with a Photoionization Detector (PID) with 10.6 eV lamp.
2. Coordinates and elevation data in NAVD88 for vertical datum and NAD83/91 for horizontal datum in Michigan State Plane.