DRAFT FINAL
Remedial Investigation
Quality Assurance Project Plan
Camp Smith Training Facility
Cortlandt, New York

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

July 2022

Prepared for:

Army National Guard Bureau
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Acronyms and Abbreviations

%	percent
°C	degrees Celsius
°F	degrees Fahrenheit
3D	3-dimensional
µg/kg	micrograms per kilogram
µg/m^3	micrograms per cubic meter
AECOM	AECOM Technical Services, Inc.
AFFF	aqueous film forming foam
AFSA	Academy of Fire Science Annex
AHA	Activity Hazard Analysis
AOI	Area of Interest
APP	Accident Prevention Plan
ARARs	Applicable or Relevant and Appropriate Requirements
ARNG	Army National Guard
ASTM	American Society for Testing and Materials
BERA	Baseline Ecological Risk Assessment
bgs	below ground surface
Ca	calcium
CAMP	Community Air Monitoring Plan
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFMO	Construction and Facilities Management Officer
CFR	Code of Federal Regulations
CoC	chain of custody
COC	chemical of concern
COPC	chemical of potential concern
CPR	cardiopulmonary resuscitation
CSM	conceptual site model
CSMS	Combined Support Maintenance Shop
DA	Department of the Army (US)
DERP	Defense Environmental Restoration Program
DL	detection limit
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
ELAP	Environmental Laboratory Accreditation Program

124	ELCR	excess lifetime cancer risk
125	EM	Engineering Manual
126	EPC	exposure point concentration
127	ERA	Ecological Risk Assessment
128	ESS	Environmental Sequence Stratigraphy
129	ESTCP	Environmental Security Technology Certification Program
130	EtFOSA	N-ethyl perfluorooctane sulfonamide
131	EtFOSE	N-ethyl perfluorooctane sulfonamido ethanol
132	FD	field duplicate
133	FRB	field reagent blank
134	FS	Feasibility Study
135	FTA	fire training area
136	FTOH	fluorotelomer alcohol
137	FTS	fluorotelomer sulfonic acid
138	GAC	granular activated carbon
139	GIS	geographic information system
140	gpm	gallons per minute
141	GPS	global positioning system
142	HA	Health Advisory
143	HAZWOPER	Hazardous Waste Operations and Emergency Response
144	HDPE	high-density polyethylene
145	HHRA	Human Health Risk Assessment
146	HI	Hazard Index
147	IDQTF	Intergovernmental Data Quality Task Force
148	IDW	investigation-derived waste
149	INRMP	Integrated Natural Resources Management Plan
150	IPaC	Information, Planning, and Conservation System
151	ISC	instrument sensitivity check
152	ITRC	Interstate Technology Regulatory Council
153	K_{oc}	organic carbon-normalized distribution coefficients
154	LC/MS/MS	liquid chromatography tandem mass spectrometry
155	LOD	limit of detection
156	LOQ	limit of quantitation
157	MCLs	Maximum Contaminant Levels
158	MeFOSA	N-methyl perfluorooctane sulfonamide
159	MeFOSE	N-methyl perfluorooctane sulfonamido ethanol
160	mg/kg	milligrams per kilogram
161	MPC	measurement performance criteria
162	mph	miles per hour
163	MS	matrix spike
164	MSD	matrix spike duplicate
165	mV	millivolts
166	NCP	National Oil and Hazardous Substances Pollution Contingency Plan

N-EtFOSAA	2-(N-Ethylperfluorooctanesulfonamido) acetic acid
N-MeFOSAA	2-(N-Methylperfluorooctanesulfonamido) acetic acid
ng/L	nanograms per liter
NOAA	National Oceanic and Atmospheric Administration
NTU	nephelometric turbidity unit
NYARNG	New York Army National Guard
NYCRR	New York Codes, Rules, and Regulations
NYS	New York State
NYSDEC	New York State Department of Environmental Conservation
NYSDMNA	New York State Department of Military and Naval Affairs
NYSDOH	New York State Department of Health
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
PDT	project delivery team
PFAAs	perfluoroalkyl acids
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
PM10	particulate matter with a diameter of 10 micrometers
PPE	personal protective equipment
PRG	Preliminary Remediation Goal
PVC	poly-vinyl chloride
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
RSC	Rapid Site Characterization
RSL	Regional Screening Levels
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
SS	Site Supervisor
SSHO	Site Safety and Health Officer
SSHP	Site Safety and Health Plan
SUs	Sampling Units
T&E	threatened and endangered
TAT	turn-around time
TBs	trip blanks
TBD	to be determined
TCRA	time critical removal action
TIR	thermal infrared imagery
TO	task order
TOC	total organic carbon
TOGS	Technical and Operational Guidance Series
TPP	technical project planning
TSA	Technical System Audit
UCL	upper confidence limit
UCMR	Unregulated Contaminant Monitoring Rule
UFP	Uniform Federal Policy
US	United States
USACE	United States Army Corps of Engineers

253	USCS	Unified Soil Classification System
254	USEPA	United States Environmental Protection Agency
255	USFWS	United States Fish and Wildlife Service
256	USGS	United States Geological Survey
257	UU/UE	unlimited use/unrestricted exposure
258	VISL	Vapor Intrusion Screening Level
259	VSI	visual site inspection
260	VSP	Visual Sampling Plan
261	VOCs	volatile organic compounds
262	WWTP	wastewater treatment plant

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 Camp Smith Training Facility (Camp Smith; also referred to as the "facility"), in Cortlandt, New York.

The Army National Guard (ARNG) G-9 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 per- and polyfluoroalkyl substances (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 used PFAS. Based on the findings of the PA, Camp Smith moved forward to the SI phase. The SI concluded further evaluation of the Areas of Interest (AOIs) identified in the PA is warranted and determined the presence of perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS) 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 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 (also referred to as the "National Oil and Hazardous Substances Pollution Contingency Plan [NCP]"; 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 perfluorobutanesulfonic acid (PFBS), and the group of related compounds known in the industry as PFAS. The term PFAS will be used throughout this plan to encompass all PFAS chemicals being evaluated, including 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 AOIs identified in the PA where the presence of these PFAS was confirmed during the SI. Two additional potential release areas, Sludge Drying Beds and Gravel Pit, were added after the SI was completed to assess if PFAS-laden sludge was spread and to determine PFAS detections north (upgradient) of AOI 1. 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 but not limited to:

- 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 IDQTF'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

Facility-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
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

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: Camp Smith Training Facility, Cortlandt, New York

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.

Investigative Organization Project Manager Printed Name / Organization	Signature / Date Claire Mitchell / AECOM Project Manager
Investigative Organization Quality Manager Printed Name / Organization	Signature / Date Sarah Gettier / AECOM Project QC Officer
Army National Guard Printed Name / Organization	Signature / Date David Connolly / ARNG Program Manager
New York Army National Guard Printed Name / Organization	Signature / Date 1LT Steves Vanderpool / NYARNG Environmental Protection Specialist
Contract Organization Project Manager Printed Name / Organization	Signature / Date Timothy Peck / USACE, Baltimore District

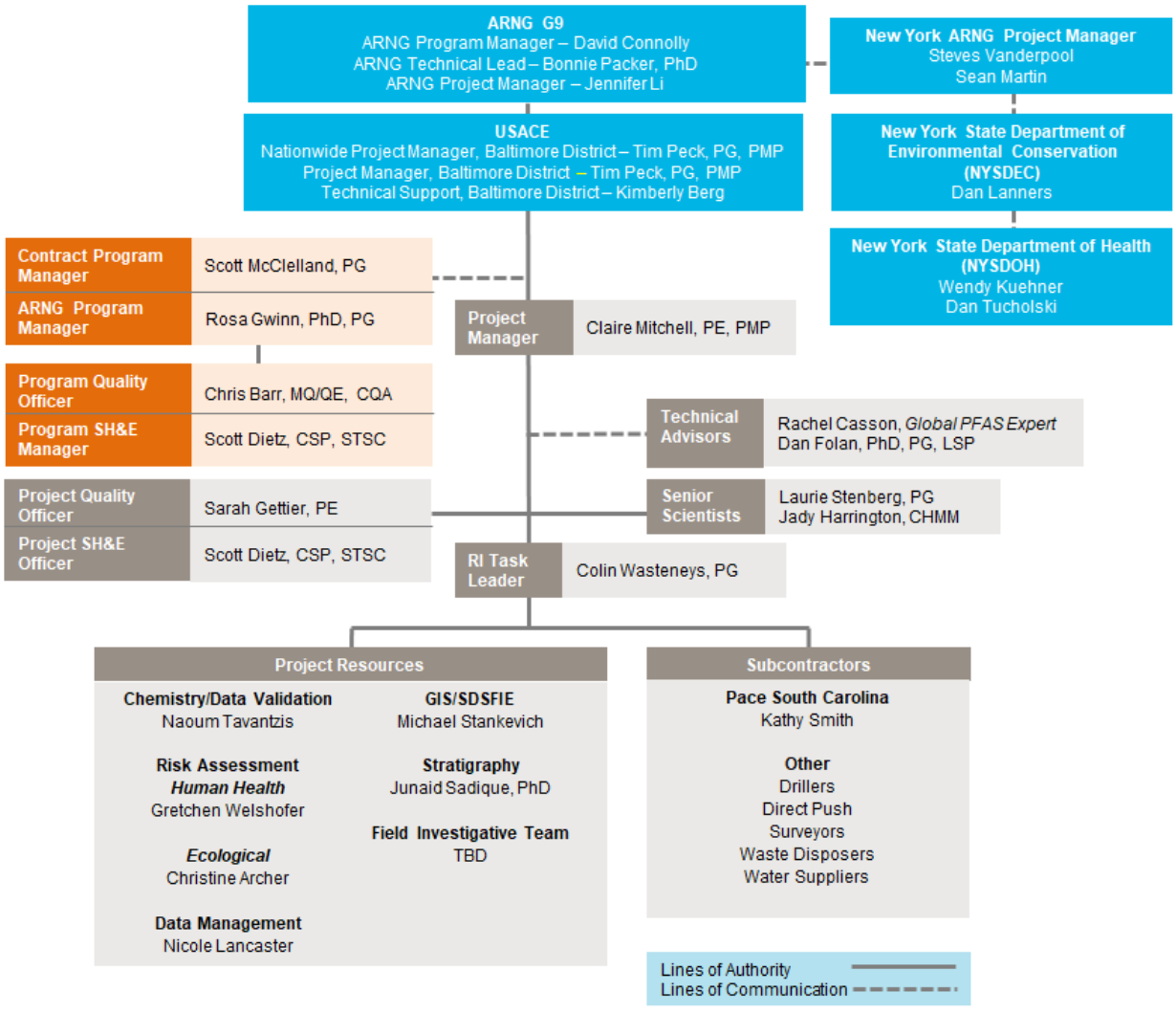
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QAPP Worksheets #3 & #5: Project Organization and QAPP Distribution

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	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
Colin Wasteneys, PG	AECOM	RI Task Manager	Education: BA, Geology Experience: 29+ years RI/FS and remedial construction experience for federal, state, and commercial/industrial clients. Managed multiple PFAS investigations in New York.	Professional Geologist, NY, CA AECOM Certified Project Manager AECOM Safety Qualified Supervisor OSHA 30hr Construction Manager OSHA 40hr HAZWOPER OSHA 8hr Refresher OSHA 8hr Supervisor 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.

Name	Organization	Project Role	Education/Experience	Specialized Training / Certifications	Signature/Date
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.
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.

Name	Organization	Project Role	Education/Experience	Specialized Training / Certifications	Signature/Date
Gretchen Welshofer	AECOM	Human Health Risk Assessor	Education: BA, Communication; MS, Environmental Science Experience: 29+ years; performing human health risk assessments; expertise in evaluating potential risks and hazards to human health posed by PFAS at DoD facilities; developed technical approach document that helps facilities manage PFAS-affected environmental media and waste streams; expertise in evaluating contaminant fate and transport for validity of exposure pathways.	OSHA 40hr HAZWOPER OSHA 8hr Refresher	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.
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.

Name	Organization	Project Role	Education/Experience	Specialized Training / Certifications	Signature/Date
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.
Kathy Smith	Pace South Carolina	Laboratory Project Manager	Education: B.S. Environmental Science. Experience: 20 years of laboratory experience	NA	Signature available upon request.

Notes:

AL = Alabama
ASQ = American Society for Quality
BA = Bachelor of Arts
BS = Bachelor of Science
CA = California
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
GIS = Geographic Information System
HAZWOPER = Hazardous Waste Operations and Emergency Response
hr = hour
IN = Indiana
KY = Kentucky
LSP = Licensed Site Professional
MA = Massachusetts
MBA = Master of Business Administration
MD = Maryland
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
NY = New York
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	Tim Peck, PG, PMP	410-962-3416 timothy.j.peck@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 Baltimore District Technical Lead	Tim Peck, PG, PMP	410-962-3416 timothy.j.peck@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. 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	Jennifer Li	301-717-6939 jennifer.j.li2.ctr@army.mil	The AECOM PM will obtain ARNG technical review and concurrence of the QAPP and project documents and any field modifications/QAPP changes. 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	NYARNG	Sean Martin Greg Austin	914-945-7377 sean.r.martin33.nfg@army.mil 518-786-4318 gregory.t.austin.nfg@army.mil	Communicate project scope/schedule and coordinate logistics between PDT and installation personnel on an as-needed basis, documented via phone records and emails.
Regulatory agency interface		1LT Steves Vanderpool	518-786-4367 Steves.vanderpool.mil@army.mil	Communicate technical approaches and decisions directly to regulatory agencies' representative(s) on an as-needed basis, documented via phone records and emails.

Communication Driver	Organization	Name	Contact Information	Procedure (Timing, Pathway, Documentation)
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. 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/FS Task Managers	Colin Wasteneys, PG	716-923-1164 colin.wasteneys@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 from ARNG/ USACE. All approved modifications will be included in non-conformance Reports.
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 South Carolina	Kathy Smith	803-791-9700 Kathy.Smith@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.

Communication Driver	Organization	Name	Contact Information	Procedure (Timing, Pathway, Documentation)
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
PDT = project delivery team
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 implemented into the QAPP (**Appendix A**).

AECOM will implement the TPP process as listed in Engineering Manual (EM) 200-1-2 (USACE, 2016), including facility 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), up to eight TPP meetings will be held, in person or via teleconference, as described below:

- Meeting 1 (RI; date to be determined [TBD]) - 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.
- Meeting 2 (RI; date TBD) - Present the facility-specific QAPP for RI, 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.
- Meeting 3 (RI) - Resolve comments or concerns about the facility-specific RI QAPP not already addressed during response to comments (date TBD).
- Meeting 4 (RI) - Present findings of the RI and gain concurrence on presentation of findings in the RI Report (date TBD).
- Meeting 5 (FS) - Discuss potential remedial action objectives and remedial alternatives to support development of the FS (date TBD).
- Meeting 6 (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 7 (as needed) - Additional meeting to address any unforeseen issue that requires further discussion (date TBD).
- Meeting 8 (as needed) - Additional meeting to address any unforeseen issue that requires further discussion (date TBD).

TPP meeting minutes will be prepared after each TPP meeting and added as an attachment to the corresponding document.

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QAPP Worksheet #10: Conceptual Site Model

10.1 Facility Location and Description

Camp Smith is in Cortlandt Manor, Westchester County, New York (**Figure 10-1**). Camp Smith borders Putnam County to the north, and the City of Peekskill to the southeast. The Hudson River lies west and south of Camp Smith. Camp Smith can be accessed directly from New York State (NYS) Route 202. Bear Mountain Bridge Road runs along the facility on the western and southern borders, and the US Military Academy at West Point is located across the Hudson River, approximately 10 miles north (NYS Department of Military and Naval Affairs [NYSDMNA], 2018).

Camp Smith comprises roughly 1,600 acres of training property for the New York ARNG (NYARNG). Approximately 94 percent (%) of Camp Smith is rugged, mountainous terrain, while the remaining 95-acre Camp Smith cantonment area consists of outdoor ranges, training simulation facilities, administrative buildings, and maintenance shops that sit on a plateau overlooking the Hudson River (**Figure 10-2**). Camp Smith has no air support facilities. Camp Smith is approximately 30 miles north of New York City and approximately 0.75 miles east of the Hudson River (NYSDMNA, 2018).

10.2 Facility Environmental Setting

Westchester County is a predominately suburban area largely consisting of rolling hills in the Hudson Valley region of New York. The terrain of the facility is consistent with the majority of Westchester County. The county has a total of 430.5 square miles. The nearest residential properties to the facility are along the northern property line. The Camp Smith trail head is approximately 0.5 miles to the west of the facility. Iona Island and the Iona Island Component Hudson River National Estuarine Research Reserve lie two miles to the west of the facility, across the Hudson River. The facility topography of Camp Smith is shown on **Figure 10-3**.

10.2.1 Geology

Camp Smith is east of the Hudson River, within the eastern geological region of the Hudson Highlands formation (NYARNG, 2015), a segment of the New England Uplands physiographic province. This region forms part of the Reading Prong, an extension of the Ridge and Valley province extending from Pennsylvania, through northern New Jersey and southern New York, and ending in Connecticut. The Hudson Highlands were formed as a result of periods of mountain building during Precambrian, Ordovician, and Devonian periods. These mountains were consequently scoured and leveled by glaciation events during the Pleistocene period.

Most of the 95-acre Camp Smith cantonment area lies in a shallow valley outwash plain. The majority of both the surface and underlying material of the northern section of Camp Smith are Pleistocene age unconsolidated glacial deposits, recent floodplain deposits, and lacustrine delta. These sediments consist of silts underlain by fine sands and gravels of variable thicknesses ranging between 40 to nearly 200 feet (Berkley et al., 1919; Isachsen et al., 2000). The Pleistocene age deposits overly Precambrian bedrock consisting of hornblende gneiss, which comprises two-thirds of all rock found at Camp Smith. The area geology is presented in **Figure 10-4**.

A previous NYARNG subsurface investigation indicated that the southern portion of Camp Smith contains intermixed layers of unconsolidated sand, silt, and clay, with variable amounts of gravel, peat, and organic clay (NYARNG, 2015). The majority of this southern portion is poorly drained Ipswich mucky peat (69.9%), well-drained Riverhead loam (24.8%), and somewhat poorly drained Udorthents (1.4%). The topography in the southern portion of the facility (at the Main Gate) drops

80 to 100 feet in elevation compared to the rest of the Camp Smith cantonment area; therefore, the overburden is thinner at the southern portion of the facility, and the lithology is reflective of low energy river and wetland deposits from the adjacent Hudson River and Annsville Creek.

On the southernmost boundary of Camp Smith, near the Hudson River, is exposed (or within 3 feet of surface) Precambrian bedrock, which travels north along the western boundary of the training facility (Eric et al., 1954). Many of the drinking water wells in the Hudson Valley come from bedrock; however, they do not yield as much as unconsolidated sediments.

During the SI phase, borings were drilled at depths ranging from 5 to 140 feet. The unconsolidated deposits ranged in composition from clays and silts to silty sands to poorly and well-graded sands. The unconsolidated overburden ranged in thickness from 18 to more than 140 feet. The overburden at the Camp Smith cantonment appears to thicken to the south and towards the middle of the valley. For example, the hornblende gneiss underlying the unconsolidated sediments was encountered at 18 feet bgs to the north of AOI 1 (CS-MW001) and 26 feet bgs at AOI 2 (AOI 2-SB1; interpreted based on refusal) to the east of the valley wall. Whereas bedrock was not encountered in the middle of the valley (CS-MW002D) despite terminating the borehole at 140 feet bgs. Further work in the RI will look at preferential pathways of groundwater in the overburden and within the fractured bedrock (**Worsheets #17 & 18**).

10.2.2 Hydrogeology

Based on the USEPA's map of Sole Source Aquifers, a sole source aquifer does not lie beneath Camp Smith. The NYS Department of Environmental Conservation (NYSDEC) *Map of Principal and Primary Aquifers in New York State* indicates that a primary aquifer does not lie beneath the Camp Smith cantonment area (US Geological Survey [USGS], 1998). Unconsolidated aquifers make up over 60 acres of the 95-acre Camp Smith cantonment area. Infiltration of precipitation and runoff is the sole source of recharge for aquifers at Camp Smith (USGS, 1995).

Unconsolidated glacial deposits of thick sand and gravel underlie flood plains and terraces along tributaries to the Hudson River and occupy many valleys (Chazen, 2003), yielding the largest supply to wells in Westchester County. However, more than 70% of the drinking water wells in Westchester County are gneiss or schist bedrock wells with yields averaging 30 gallons per minute (gpm). If limestone is tapped, yields can range from 2 to as much as 450 gpm.

Groundwater in the Camp Smith cantonment area generally flows from north to south, towards the Hudson River (**Figure 10-4**), or towards various creeks and surface water features that run south to the Hudson River. Two potable wells in the southern portion of the Camp Smith, Wells A and B, supply drinking water to the facility. The wells are located on the edge of the wetland area in the southern portion of Camp Smith. Well A is 80 feet deep, with a screen installed between 65 and 80 feet below ground surface (bgs), and Well B is 100 feet deep, with a screen installed between 82 and 100 feet bgs (NYARNG, 2015). Two different studies were performed in 2005 (Obrien & Gere, 2005) and 2008 (Ecology and Environment, 2008) to evaluate whether or not Wells A and B are under the influence of surface water. Both Assessments concluded that the potable water supply wells are not influenced by surface water. Well logs presented in the 2005 report indicate that the wells are screened within a sand and gravel aquifer that immediately overlies bedrock. The logs also indicate that layers of fine-grained silt and clay overlie the aquifer from which the supply wells draw their water. The fine-grained confining units identified in Well A logs are sandy clay extending from approximately 10 to 30 feet bgs and "blue clay" extending from approximately 40 to 46 feet bgs. The fine-grained confining units identified in Well B logs are fine gray silt extending from approximately 8 to 15 feet bgs and brown clay and "swamp bog" extending from approximately 15 to 27.5 feet bgs. Wells A and B draw water from the confined aquifer. It is possible that the clay layer thins out and is not present further upgradient in the northern portion of the Camp Smith cantonment area. This trend would potentially allow

upgradient surface water and groundwater to infiltrate the deeper aquifer from where groundwater is drawn. One other potentially potable well at Camp Smith is used for lavatory purposes. There are no drinking water fountains connected to this potentially potable well.

Depth to groundwater at the facility was observed to range from 0.5 to 22.2 feet bgs in December 2019 during SI Mobilization 1 field activities and 7.19 to 79.76 feet bgs during the July 2021 SI Mobilization 2 field activities. The observed depth to water at CS-MW002D (79.76 feet bgs) is significantly deeper than the other depths to water measured in monitoring wells across the facility. This difference could be due to semi-confined conditions at depth; however, results from the SI could not confirm. Additional deep borings and monitoring wells would be needed to evaluate the hydrogeology of the facility further. The groundwater contour map from Mobilization 2 (July 2021) is provided in **Figure 10-5**.

10.2.3 Hydrology

Camp Smith is in the Lower Hudson River watershed, which is a part of the 13,300-square mile Hudson River basin. The main channel of the Hudson River spans nearly 1,000 feet of Camp Smith's western and southern boundaries and forms a deep gorge through the Hudson Highlands in this area (NYARNG, 2015). Surface water resources at Camp Smith include natural streams, rivers, and open water features. Several unnamed intermittent tributaries and numerous vernal pools and wetlands are scattered throughout the facility. Surface runoff from the facility eventually drains into the Hudson River.

Dickiebusch Lake is on the northeastern end of Camp Smith (**Figure 10-6**). Dickiebusch Lake covers approximately 6 acres and is connected to several streams, one of which is Putnam Brook. The headwaters of Putnam Brook flow into the northern-most portion of Dickiebusch Lake, which then drains south bordering Camp Smith on the west before draining into the Annsville Creek impoundment. Annsville Creek borders Camp Smith on the eastern side of the facility before turning southwest to border the southern portion.

The confluence of the Annsville Creek and Putnam Brook at the Annsville Creek impoundment is tidally influenced, as this impoundment is connected to the Hudson River. This small bay/impoundment/tidal wetland was artificially created by a railroad berm.

10.2.4 Climate

The climate at Camp Smith and the surrounding Westchester County is predominantly continental, with an average annual temperature of 51.7 degrees Fahrenheit (°F). Seasonally, temperatures vary from an average summer high of 72.1°F, to average winter lows of 30.3°F (National Oceanic and Atmospheric Administration [NOAA], 2022). The annual average wind speed is 8.9 miles per hour (mph), although winter months can have gusts up to 35 mph. The total average annual precipitation is 50.62 inches. February is the driest month, with an average of 3.08 inches of precipitation, while October is the wettest month, with 4.99 inches of precipitation. Short, intense thunderstorms are the major sources of summer precipitation. The average annual snowfall is 55 inches.

10.2.5 Current and Future Land Use

Camp Smith is a private facility with one access point through a guarded security gate, off Route 202, that runs parallel to the Hudson River. The majority of the property is an NYARNG installation used for military training. Approximately 94% of Camp Smith is rugged, mountainous terrain. The remaining 95-acre Camp Smith cantonment area consists of outdoor ranges, training simulation facilities, administrative buildings, and maintenance shops that sit on a plateau overlooking the Hudson River (NYSDMNA, 2018). In general, the future use of the facility is not expected to

change. However, range construction is expected to occur in the next few years and will involve reworking the ranges and potentially filling in Dickiebusch Lake.

10.2.6 Sensitive Habitat and Threatened/ Endangered Species

The following species are listed as federally endangered, threatened, proposed, and/or candidate species within Camp Smith according to a query of the online US Fish and Wildlife Service (USFWS) Information, Planning, and Conservation System (IPaC) (USFWS, 2022):

- **Mammal**: Northern long-eared bat, *Myotis septentrionalis* (threatened)**;** Indiana bat, *Myotis sodalist* (endangered)
- **Reptile**: Bog turtle, *Clemmys muhlenbergii* (threatened)
- **Insects**: Monarch butterfly, *Danaus plexippus* (candidate)

The IPaC review did not identify any critical habitats within Camp Smith.

In addition to the federally listed species identified above, the draft Integrated Natural Resources Management Plan (INRMP) for Camp Smith identified the following state endangered or threatened species that have been historically documented to be present at Camp Smith (NYARNG, 2019)

- Plants: Spongy arrowhead, *Sagittaria calycina var. spongiosa* (threatened)
- Birds: Bald eagle, *Haliaeetus leucocephalus* (threatened)[1]
- Reptiles: Fence lizard, *Sceloporus undulatus* (threatened) and Timber rattlesnake, *Crotalus horridus* (threatened)

The draft INRMP indicated that a healthy population of the state threatened spongy arrowhead occurs in the tidal marsh near the confluence of Putnam Brook and Annsville Creek with approximately 50 to 100 plants observed during surveys conducted in 1996. No training occurs in or near the plant's habitat and the marsh has been identified as an area with a high protection priority (NYARNG, 2019).

As described in **Worksheet #14**, a habitat assessment will be performed as part of the RI. This habitat assessment will occur within the same timeframe as the field sampling within the AOIs and the offsite areas. Wildlife biologists will assess the available habitats in the vicinity of the sampling locations. The biologists will be familiar with the habitat requirements and appearance of these federally listed species. Any observations of relevant habitats or listed species, as well as other general habitat and species observations, will be recorded.

10.3 History of AFFF Use

Four potential PFAS release areas where AFFF may have been used or released historically were identified at Camp Smith during the PA (AECOM, 2019a). Overall, due to the lack of institutional knowledge, records, and documentation relating to AFFF, there is uncertainty regarding the history of PFAS use at Camp Smith. Each potential release area identified in the PA Report identified a level of uncertainty either relating to usage of AFFF-containing PFAS, of the dates of storage or use of AFFF onsite, or any recorded instances of usage of AFFF. At the Former Fire Pit, live fire training exercises occurred with some frequency. Presence or use of AFFF for these exercises could not be confirmed during the PA. At the Former Fire Station, firefighting equipment was mandated to be stored onsite and ready for use during refueling activities, but no firefighting

[1] The bald eagle is also federally protected under the Bald and Golden Eagle Protection Act.

equipment was observed during the PA. It is unknown if any of the training activities that occurred at the former airfield or former NYS Academy of Fire Science Annex (AFSA) included fire training with AFFF or other firefighting foams.

10.4 Historical PFAS Responses

10.4.1 NYARNG PFAS Drinking Water Sampling

Based on the USEPA Unregulated Contaminant Monitoring Rule 3 (UCMR 3) data, it was indicated that PFAS were detected in the New Windsor Consolidated Water District public water system above the USEPA lifetime Health Advisory (HA). The surface water intakes for New Windsor Consolidated Water District are located within 20 miles of the facility. As of 5 December 2014, PFOS and PFOA were detected at 128 and 21.5 nanograms per liter (ng/L), respectively (USEPA, 2017a). NYARNG began quarterly sampling of drinking water in April 2017 at Well A and Well B (approximate location shown on **Figure 10-4**). From April 2017 to April 2019, PFAS were consistently detected below the USEPA HA of 70 ng/L in both Well A and Well B. However, in the sampling event conducted in March 2020, the combined concentrations of PFOA and PFOS were above the USEPA HA, at 72.2 ng/L. Due to this exceedance, the NYARNG took several actions in response. The facility installed granular activated carbon (GAC) filtered drinking water stations and labeled them “safe for drinking and cooking” and labeled unfiltered water points “not safe for drinking and cooking”. Additionally, the facility has communicated through leadership and posted signs informing the full-time workforce, part-time work force, contractors, and visitors of locations where water can be used for drinking and cooking. Quarterly sampling at random filtered drinking water stations has demonstrated values of less than 10 ng/L of PFOS or PFOA. Finally, an upgrade to the water treatment plant has been bid and awarded which will install a GAC filter to remove PFOA and PFOS. The upgraded treatment plant is expected to be operational in September 2022.

10.4.2 Camp Smith PFAS Preliminary Assessment and Site Inspection

In 2019, the ARNG conducted a PA at Camp Smith that identified four potential PFAS release areas (AECOM, 2019a). The potential PFAS release areas were divided into three AOIs based on proximity of the potential release areas to one another and the assumed groundwater flow direction (**Figure 10-7**). Descriptions of the potential release areas and AOIs are presented as part of the preliminary conceptual site model (CSM) in **Section 10.5.** An SI was subsequently conducted to determine the presence or absence of PFOA, PFOS, and PFBS at or above SLs in the identified AOIs (AECOM, 2022). The SLs adopted for the SI were a memorandum from the OSD dated 15 September 2021 (Assistant Secretary of Defense, 2021). A summary of the results of the SI is as follows:

- At AOI 1, PFOA in groundwater exceeded the SL of 40 ng/L, with a maximum concentration of 58.4 ng/L at location AOI 1-GW3. Based on the results of the SI, further evaluation of AOI 1 is warranted in an RI.
- At AOI 2 and 3, PFOS in groundwater exceeded the SL of 40 ng/L, with a maximum concentration of 147 ng/L at location CS-MW003S. Based on the results of the SI, further evaluation of AOI 2 and 3 is warranted in a RI.
- The detected concentrations of PFOA, PFOS, and PFBS in soil at all AOIs were below the SLs.
- PFOA, PFOS, and PFBS were not detected in surface water. PFOA and PFOS were detected in sediment samples. There are no established SLs for sediment; therefore, these results are presented for informational purposes only.

- During SI Mobilization 2, additional information was obtained regarding the onsite wastewater treatment plant (WWTP) and the former Sludge Drying Beds. While there was no evidence to suggest the WWTP was a release area, the Sludge Drying Beds were identified as a potential secondary release area.
- Detections of PFOA, PFOS, and PFOS in groundwater in the northern portion of AOI 1 (north of the Former Burn Pit) at wells AOI 1-GW-3 and CS-MW001S/D indicate there may be a potential PFAS source north of AOI 1. Therefore, the Gravel Pit was identified as a potential PFAS release area.

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**.

10.5 Preliminary Conceptual Site Model

A summary of the preliminary CSM for the facility 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**. Finally, the potential receptors and exposure pathways are discussed in **Section 10.5.4**.

The preliminary CSM presents the current understanding of the facility 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 any possible AFFF releases, the average precipitation at the facility, and high degree of soil permeability, potential PFAS contamination at the AOIs may have leached from the soil to groundwater. Based on topography and past groundwater elevation data, surface water and groundwater for most of the Camp Smith cantonment area likely drains south to the Hudson River via Putnam Brook. One wetland complex is located at the southern boundary of Camp Smith adjacent the Hudson River. Therefore, as described in **Section 10.5.4**, human and ecological receptors may be exposed to PFAS in the onsite AOIs and in downgradient offsite surface water bodies.

Previous sampling activities have identified PFAS in groundwater at Camp Smith. Two potable wells in the southern portion of the Camp Smith cantonment area, Wells A and B, supply drinking water to the facility. The wells are located on the edge of the wetland area in the southern portion of Camp Smith. Well A is 80 feet deep, with a screen installed between 65 and 80 feet below ground surface (bgs), and Well B is 100 feet deep, with a screen installed between 82 and 100 feet bgs (NYARNG, 2015). The ingestion exposure pathway for groundwater is complete for onsite workers.

10.5.1 Summary of Potential Release Areas

The PA at Camp Smith identified four potential PFAS release areas (AECOM, 2018). The potential PFAS release areas were divided into three AOIs based on proximity of the potential release areas to one another and the assumed groundwater flow direction (**Figure 10-7**). Descriptions of the potential release areas and AOIs are presented below.

10.5.1.1 AOI 1

AOI 1 consists of one potential PFAS release area, the Former Fire Pit. The Former Fire Pit is on the northern end of the Camp Smith cantonment area, adjacent to Dickiebusch Lake, at geographic coordinates 41°18'36.96"N; 73°56'24.19"W. This area is approximately 184 feet long by 113 feet wide and is essentially a dirt expanse of sand and gravel on the eastern side of N. Camp Road.

During the visual site inspection (VSI) completed during the PA, a bare earthen patch was observed that appeared to have been smoothed and paved over multiple times in the past. Interviewees described patch as a former live fire training exercise area in which exercises occurred with some frequency, possibly once per month; however, the presence or use of AFFF for these exercises could not be confirmed during the VSI or interviews with NYARNG personnel.

The Former Fire Pit was the training ground for the Camp Smith fire fighters and emergency responders and was active between 1980 and 1996. If AFFF was used for fire training activities at this area, it may have contained PFAS; therefore, activities related to fire training at this AOI have the potential for PFAS releases. Additionally, it is unknown whether volatile organic compounds (VOCs) used as accelerants during fire training activities may have been released at AOI 1. Common fire training practice at the time included utilizing waste or surplus accelerants or fuels that were on hand at the facility; therefore, the presence or absence of VOCs at the Former Fire Pit will be determined during the RI Mobilization 1. Lastly, during a facility site visit in February 2022, it was observed that soil from AOI 2 was removed and stockpiled at the Former Fire Pit as part of active underground utility construction activities.

10.5.1.2 AOI 2

AOI 2 consists of one potential PFAS release area, the Former Fire Station. Based on aerial photographs, the Former Fire Station was approximately 500 feet east of the southern end of the former airfield runway, at geographic coordinates 41°18'10.01"N; 73°56'21.34"W, and was active between 1980 and 1996. When operational, the VSI interviewee stated that two trucks were parked inside the Former Fire Station: an old Chevy half-deuce water truck and an old Ford that was not operational.

In the Former Fire Station's last few years of operation, there were only civilian hourly employees onsite during the weekends. The interviewee indicated he was not aware of any AFFF use or storage at Camp Smith. After 1996, the former fire station was torn down and replaced with a parking lot. The two trucks were given to the Continental Village Fire Department, the municipal fire department for Westchester County, which provides emergency services for all major incidents at Camp Smith. Due to gaps in interviewee knowledge regarding use of AFFF on the firetrucks, the Former Fire Station is considered a potential PFAS release area.

10.5.1.3 AOI 3

AOI 3 consists of two potential PFAS release areas, the Former Airfield and the Former NYS AFSA. These areas are described in the subsections below.

Former Airfield

The Former Airfield is located at the southeastern end of Dickiebusch Lake, at geographic coordinates 41°18'31.19"N; 73°56'24.87"W, and approximately 2,500 feet in length running north to south. Aerial photographs confirm a runway was constructed sometime after 1955, but before 1960, and was later removed in the late-1970s. The Camp Smith Maintenance Equipment Mechanic, who has been working at Camp Smith since 1988, stated that the Former Airfield was possibly active during parts of the Korean and Vietnam Wars, but he was unaware of any incidents that occurred and required the use of AFFF. However, because fire training activities have historically been frequently conducted at the edges of runways, the Former Airfield is considered a potential PFAS release area.

Former NYS AFSA

During the VSI, an interview with the Construction and Facilities Management Officer (CFMO) was performed at the NYARNG headquarters in Latham, New York. The CFMO stated that a "former NYS fire inspection agency" was formerly located on-post, located slightly northwest of the new Combined Support Maintenance Shop (CSMS) building, and was associated with a cluster of former buildings, at the approximate geographic coordinates 41°18'20.85"N; 73°56'28.75"W. The duration of occupancy of the buildings by the "former fire inspection agency" is unclear; however, historical aerials indicate that the buildings were built sometime between 1974 and 1984 and demolished sometime between October 2014 and April 2016.

Additional research after submission of the Final PA Report confirmed that the facility complex was the NYS AFSA. Activities at the former NYS AFSA were described as including classroom training, fire services, forensics, and arson investigation. Because personnel with first-hand knowledge of training activities that occurred at the AFSA were not available for interviews during the PA, there were gaps in knowledge of AFFF use and storage at this location. It is unknown if any of the training activities that occurred at the facility included fire training with AFFF or other firefighting foams. As such, PFAS may have been released at the former NYS AFSA; therefore, the former NYS AFSA is a potential PFAS release area. The former NYS AFSA began operations in the late-1990's and ceased operation in September 2006.

Following demolition of the buildings in approximately 2014, nearly 8 feet of fill from the general area of the former NYS AFSA was removed and transported for use in the foundation of the new CSMS building. Because of this removal, soil potentially impacted with PFAS may have been spread from the source location to below the new CSMS building.

10.5.1.4 Sludge Drying Beds

During SI Mobilization 2, additional information was obtained regarding the onsite WWTP and former Sludge Drying Beds. The WWTP and Sludge Drying Beds are located between the identified AOIs and Wells A and B. The approximate geographic coordinates of the Sludge Drying Beds are 41°18'03.70"N; 73°56'33.87W. The Sludge Drying Beds are no longer in use but could be a potential secondary source given the presence of PFAS in the potable water source at the facility. There is no evidence to suggest the WWTP is a potential release area. At the time of the SI Mobilization 2, the team agreed to proceed with finalizing the mobilization and to investigate the Sludge Drying Bed as a potential new source during the RI.

10.5.1.5 Gravel Pit

The Gravel Pit was included after the SI as a result of the data collected during Mobilizations 1 and 2. PFOA, PFOS, and PFOS data in the northern portion of AOI 1 at AOI 1-GW-3 and CS-MW001S/D indicated there may be a potential PFAS source north of AOI 1. Based on aerial

imagery and reconnaissance during a site walk, the Gravel Pit is the most likely location for a potential upgradient release of PFAS. The Gravel Pit is located approximately 250 feet north of AOI 1 at the approximate geographic coordinates of 41°18'47.92"N; 73°56'27.10"W.

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**.

The DoD has adopted a policy within the CERCLA process to compare results against risk-based SLs for soil and groundwater, as described in a 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.

Additionally, the USEPA HA for PFOA and PFOS in May 2016 (USEPA 2016a; USEPA, 2016b). The SLs are shown in **Table 10-1**, below.

Table 10-1: PFAS 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, 2021b. 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
USEPA = United States Environmental Protection Agency

Figures 10-8 and **10-9** present detections in soil for PFOA for SI Mobilization's 1 and 2, respectively. **Figures 10-10** and **10-11** present detections in soil for PFOA for SI Mobilization 1 and 2, respectively. **Figures 10-12** and **Figure 10-13** present the detections in groundwater for PFOA and PFOS, respectively, for both SI Mobilization 1 and 2. Tables of results from the SI are provided in **Appendix B**. The SI results 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 soil at AOI 1; however, the detected concentrations were several orders of magnitude lower than the soil SLs. At location AOI 1-GW3, PFOA was detected in groundwater at concentrations that exceeded the SL of 40 ng/L and the combined SL of 70 ng/L for PFOA and PFOS. PFOS and PFBS were detected in groundwater at concentrations below the SL.

PFOS was the most frequently detected compound in soil, with a maximum detection of 0.396 J micrograms per kilogram (µg/kg) at sample location CS-MW001S from 0 to 2 feet bgs. The highest overall PFAS detection in AOI 1 soil was 0.919 J µg/kg PFOA at sample location AOI-1-SB3 from 1 to 2 feet bgs. PFBS was only detected at one location, CS-MW001S/D at depths of 0-2 feet bgs (0.034 J µg/kg) ad 8 to 10 feet bgs (0.025 J µg/kg).

During the SI, groundwater in AOI 1 was sampled from three temporary monitoring well locations, AOI 1-GW1 through AOI 1-GW3, and two permanent wells, CS-MW001S and CS-MW001D. All wells were installed in overburden soil with the exception of CS-MW001D which was installed in bedrock with a screen interval from 20 to 30 feet bgs. The SL of 40 ng/L for PFOA and 70 ng/L for the combined PFOA and PFOS were exceeded AOI 1-GW3 (15 to 20 feet bgs), with a maximum concentration of 58.4 ng/L PFOA and 70.9 ng/L for the combined PFOA and PFOS. PFOA was additionally detected in all four of the other monitoring wells, with concentrations ranging from 14.3 ng/L (CS-MW001S, 7 to 17 feet bgs) to 29 ng/L (AOI 1-GW1, 15 to 20 feet bgs). PFOS was detected in four of the five monitoring wells sampled, with concentrations ranging from 10.8 ng/L (CS-MW001D) to 37.8 ng/L (AOI 1-GW1). PFBS was detected in two of the five monitoring wells sampled, with concentrations ranging from 2.87 J ng/L (AOI 1-GW1) to 3.39 J ng/L (AOI 1-GW3, 0-5 feet bgs).

PFOA and PFOS were detected in most of the monitoring well locations associated with AOI 1. The highest concentration, detected in AOI 1-GW3, was located at the northern, upgradient limit of AOI 1 indicating that the extent of impacts likely extends further northward. The distribution of PFOA and PFOS detections in groundwater samples collected during the SI do not indicate a particular source area. The horizontal and vertical extent of PFOA and PFOS impacts has not been defined. Impacts were identified in both overburden and bedrock groundwater.

It is unknown whether VOCs used as accelerants during fire training activities may have been released at AOI 1. Therefore, the presence or absence of VOCs at the source areas will be determined during the RI.

10.5.2.2 AOI 2

Based on the SI findings, PFOA, PFOS, and PFBS were detected in soil at AOI 2 at concentrations below the soil OSD SLs. At location CS-MW003S, PFOS was detected in groundwater, at concentrations exceeding the SL of 40 ng/L and the combined SL of 70 ng/L for PFOA and PFOS. PFOA was detected in groundwater at concentrations below the SL, and PFBS was not detected in either of the two locations. Groundwater was not encountered immediately beneath AOI 2 in the overburden in temporary well AOI 2-GW1 due to shallow refusal due to bedrock.

At the Former Fire Station, soil was sampled from surface soil (0.5 to 2 feet bgs), shallow subsurface soil (2 to 13 feet bgs), and deep subsurface (21-42 feet bgs) from eight boring locations during SI Mobilizations 1 and 2. PFOA, PFOS, and PFBS were detected in soil at a range of concentrations. In the surface soil, PFOA was detected at one of five locations, at a concentration of 0.126 J µg/kg (AOI2-SB3-00-02). PFOS was detected in all five locations, with concentrations ranging from 0.099 J µg/kg (AOI2-SB5-00-02) to 34.2 µg/kg (AOI2-SB3-00-02). PFBS was not detected in any of the five locations.

In the shallow subsurface, PFOA was detected one of five locations, with a detected concentration of 0.588 J µg/kg (AOI2-SB3-02-04). PFOS was detected in four of the five locations, with concentrations ranging from 1.42 J- µg/kg (AOI2-SB5-02-04) to 191 µg/kg (AOI2-SB3-02-04). PFBS was not detected in any of the five locations.

Downgradient of the Former Fire Station potential PFAS release area, groundwater was sampled from two permanent wells CS-MW002D and CS-MW003S. The SL of 40 ng/L for PFOS and 70 ng/L for the combined PFOA and PFOS were exceeded at CS-MW003S, with a maximum concentration of 147 ng/L PFOS and 168 ng/L for the combined PFOA and PFOS. PFOA was detected in one of the two locations, at a concentration of 21.2 ng/L (CS-MW003S). PFOS was detected in both locations, with concentrations ranging from 37.7 ng/L (CS-MW002D) to 147 ng/L (CS-MW003S). PFBS was not detected in either of the two locations.

10.5.2.3 AOI 3

Based on the SI findings, PFOA, PFOS, and PFBS were detected in soil at AOI 3; however, the detected concentrations were several orders of magnitude lower than the soil SLs. At location CS-MW003S, PFOS was detected in groundwater, at concentrations exceeding the SL of 40 ng/L and the combined SL of 70 ng/L for PFOA and PFOS. PFOA and PFBS were detected in groundwater, at concentrations below the SL.

At AOI 3, soil was sampled from surface soil (0 to 2 feet bgs), shallow subsurface soil (7 to 9 feet bgs), and deep subsurface (15-17 feet bgs) from five borings during SI Mobilization 1 and 2. PFOA, PFOS, and PFBS were detected in soil, at concentrations several orders of magnitude lower than the SLs. In the surface soil, PFOA was detected in all three locations, at concentrations ranging from of 0.110 J µg/kg (CS-MW004S-SB-00-02) to 0.173 J µg/kg (AOI 3-SB-0.5-1). PFOS was detected in all three locations, at concentrations ranging from of 0.194 J µg/kg (AOI 3-SB1-0.5-1) to 1.02 J µg/kg (AOI 3-SB2-0.5-1). PFBS was not detected in any of the five locations. In the shallow subsurface, PFOA, PFOS, and PFBS were not detected in any of the three borings.

Within the Former Airfield and the Former NYS AFSA potential PFAS release area, groundwater was sampled from two temporary wells, AOI 3-GW1 (0 to 5 feet bgs) and AOI 3-GW2 (18 to 23 feet bgs), and three permanent wells: CS-MW002D (90 to 110 feet bgs), CS-MW003S (40 to 50 feet bgs), and CS-MW004S (7 to 17 feet bgs). The SL of 40 ng/L for PFOS and 70 ng/L for the combined PFOA and PFOS exceeded at CS-MW003S, with a maximum concentration of 147 ng/L PFOS and 168 ng/L for the combined PFOA and PFOS. PFOA was detected in the three of five locations and ranged in concentrations from 10.3 ng/L (AOI 3 GW-2) to 39.9 ng/L (AOI 3 GW-1). PFOS was detected in three of the five locations, with concentrations ranging from 14.8 ng/L (AOI 3 GW-1) to 147 ng/L (CS-MW003S). PFBS was detected in two of the five locations, with concentrations ranging from 2.66 ng/L (AOI 3 GW-2) to 3.77 ng/L (AOI 3 GW-1).

10.5.2.4 Facility-Wide Surface Water and Sediment

Surface water and sediment samples were collected from tributaries flowing to and from Dickiebusch Lake and along Putnam Brook. Sampling locations within these water bodies are downgradient of all three AOIs, except in cases noted. Based on the SI findings, PFOA and PFOS were detected in sediment at several locations across the facility. There are no established SLs for sediment; therefore, these results are presented for informational purposes only. PFBS was not detected in sediment, and PFOA, PFOS, and PFBS were not detected in surface water.

PFOA was detected in two of eight sediment sample locations, with concentrations ranging from 0.283 J µg/kg (CS-SD05) to 1.07 J µg/kg (CS-SD02). PFOS was detected in five of eight sediment sample locations, with concentrations ranging from 1.14 J µg/kg (CS-SD05) to 3.77 µg/kg (CS-SD06). The maximum detection was the PFOS concentration at location CS-SD06, which was

the most upgradient location in the tributary leading into Dickiebusch Lake. PFBS was not detected in any of the eight sediment sample locations. The most frequently detected compound was PFOS, which was detected in all five sediment samples where PFAS were detected. The occurrence and concentration of individual PFAS varied between sampling location.

No PFOA, PFOS, and PFBS were detected in surface water at locations CS-SW01 (surface water at the northern-most point of Dickiebusch Lake), CS-SW02 (surface water flowing into the northwest portion of Dickiebusch Lake), CS-SW03 (surface water flowing into the southwestern portion of Dickiebusch Lake), CS-SW04 (surface water from the underground surface water conveyance that flows out of the southeastern portion of Dickiebusch Lake), and CS-SW05 (surface water in Putnam Brook).

10.5.2.5 Data Gaps for PFAS

Based on the evaluation of available data in soil and groundwater, as presented above, the presence of PFAS has been confirmed in soil and groundwater within all three AOIs with exceedances of the SLs in groundwater. However, the exact locations of the PFAS releases to soil and the migration pathways between the release areas and boundaries are not fully understood for AOI 1, AOI 2, and AOI 3. Detailed descriptions of the approach for filling the PFAS data gaps, are presented in the sampling design and rationale tables in **Worksheet #17**.

10.5.2.6 Data Gaps for VOCs

It is unknown whether VOCs may have been used as accelerants during fire training activities at AOI 1 and subsequently released to the environment. Common fire training practice at the time included utilizing waste or surplus accelerants or fuels that were on hand at the facility; therefore, the presence or absence of VOCs at the source areas will be determined during the RI. The approach for filling the VOC data gaps is presented in the sampling design and rationale tables in **Worksheet #17**.

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 Camp Smith is likely AFFF from activities attributable to ARNG activities. 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, Day, and Field, 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/NAPL 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 former ARNG activities at three AOIs within Camp Smith. Also, RI Mobilization 1 field activities include sampling two additional potential release areas that were identified after the SI: Sludge Drying Beds and Gravel Pit. In addition, PFAS in these media may have migrated to surface water and sediment in downgradient waterbodies (e.g., streams, wetlands, Dickiebusch Lake) via stormwater flow and/or groundwater migration. Therefore, human and ecological receptors present within these AOIs and the downgradient waterbodies may be exposed to PFAS. PFAS are the only potential facility-related COPCs for the facility being evaluated under the scope of this RI. However, it is unknown whether VOCs were used as accelerants during fire training activities and may have been released at AOI 1.

The preliminary 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 10-14**. A Human Health Risk Assessment (HHRA) and a Screening-Level Ecological Risk Assessment (SLERA) will be conducted in accordance with CERCLA, USACE, and NYS risk assessment guidance. The results of the SLERA, in conjunction with the SLERA refinement (Step 3a) and the findings of the habitat assessment, will determine whether an optional Baseline Ecological Risk Assessment (BERA) is needed. **Appendix F** includes the Risk Work Plan, which provides further detail on the HHRA and SLERA/BERA processes.

Human Health

Land Use

Current human receptors at the facility include onsite workers, military personnel, and approved visitors of Camp Smith. It is also 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.

The northern portion is heavily wooded where access is open to the public. Several unnamed intermittent tributaries and numerous vernal pools and wetlands are scattered throughout the facility. Surface runoff from the facility eventually drains into the Hudson River. Surface water

features include Putnam Brook that flows into the northern-most portion of Dickiebusch Lake and then drains south bordering Camp Smith on the west before draining into the Annsville Creek impoundment. Therefore, it is assumed that recreational users may access the facility soil, surface water and sediment under a current and future use scenario.

Offsite media are not evaluated for the facility because most of the 95-acre Camp Smith cantonment area lies within a shallow valley outwash plain. As for surrounding land use, the nearest residential properties to the facility are along the northern property line. The Camp Smith trail head is approximately 0.5 miles to the west of the facility. Iona Island and the Iona Island Component Hudson River National Estuarine Research Reserve lie two miles to the west of the facility, across the Hudson River.

Two potable wells in the southern portion of the Camp Smith cantonment area, Wells A and B, supply drinking water to the facility. The wells are located on the edge of the wetland area in the southern portion of Camp Smith. From April 2017 to April 2019, PFAS were consistently detected below the USEPA HA of 70 ng/L in both Well A and Well B. The March 2020 sampling event identified a combined concentration of PFOA and PFOS that was above the USEPA HA, at 72.2 ng/L. The facility now provides filtered drinking water stations that are labeled “safe for drinking and cooking” and labeled unfiltered water points “not safe for drinking and cooking”. Also, the facility has communicated through leadership and posted signs informing the full-time workforce, part-time work force, contractors, and visitors of locations where water can be used for drinking and cooking. Quarterly sampling at random filtered drinking water stations and the water treatment plant (WTP) will be upgraded and operational in September 2022. Groundwater exposure for future onsite workers/military personnel and a future onsite hypothetical resident is potentially complete..

Reasonably anticipated future land use is not expected to change from the current land use described above. However, in addition to an offsite unlimited use/unrestricted exposure (UU/UE) scenario, the HHRA will also conservatively evaluate an onsite UU/UE scenario to inform future risk-management decisions and the FS, if applicable. A remedial response will not necessarily be taken based on the results of the future onsite UU/UE residential 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).

Potentially Complete Human Exposure Pathways

The receptors and potentially complete exposure pathways for a current and/or future use scenario, based on the preliminary Facility-specific CSM, are as follows. For purposes of the HHRA, it is conservatively assumed that future land-use scenarios may involve some level of construction to convert the area to the desired use. Under this scenario, it is assumed that current subsurface soils may be brought to the surface and mixed with surface soil for exposure by future receptors.

- Current Onsite Worker/Military Personnel
    - Exposure to surface soil (0 to 2 feet bgs) through incidental ingestion and dermal contact.
    - This scenario is protective of soldiers on temporary assignment who are spending time outdoors during training exercises, working indoors in an office capacity, and are living in the onsite barracks or hotel.

- Future Onsite Worker/Military Personnel
    - Exposure to onsite 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.
    - This scenario is protective of soldiers on temporary assignment who are spending time outdoors during training exercises, working indoors in an office capacity, and are living in the onsite barracks or hotel.
- Current Onsite Recreational User (Adult and Child)
    - Exposure to surface soil (0 to 2 feet bgs) through incidental ingestion and dermal contact.
    - Exposure to shallow sediment in Dickiebusch Lake as well as the intermittent streams (Putnam Brook), vernal pools and wetlands via incidental ingestion and dermal contact; exposure to surface water via incidental ingestion under a wading scenario due to the nature of the water bodies (e.g., heavily vegetated and may or may not contain very shallow surface water all year round).
- Future Onsite Recreational User (Adult and Child)
    - Exposure to onsite 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. (Future scenario assumes that development/construction of the facility, which may bring subsurface soils to the surface, occurs)
    - Exposure to shallow sediment in the intermittent streams (e.g., Putnam Brook), vernal pools and wetlands via incidental ingestion and dermal contact; exposure to surface water via incidental ingestion under a wading scenario due to the nature of the water bodies (e.g., heavily vegetated and may or may not contain very shallow surface water all year round).
- Future Onsite Construction/Utility Worker
    - Exposure to onsite 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 onsite shallow groundwater (to a maximum depth of 15 feet bgs) via incidental ingestion and inhalation of volatiles (if VOCs are detected in groundwater collected from permanent monitoring wells) in an excavation trench.
- Future Onsite Adolescent Trespasser
    - Exposure to onsite surface soil (0 to 2 feet bgs) through incidental ingestion and dermal contact. (This scenario represents a future scenario in which land-use remains the same; and development/construction of the facility, which may bring subsurface soils to the surface, does not occur).
    - Exposure to shallow sediment in the intermittent streams (e.g., Putnam Brook), vernal pools and wetlands via incidental ingestion and dermal contact; exposure to surface water via incidental ingestion under a wading scenario due to the nature of the water bodies (e.g., heavily vegetated and may or may not contain very shallow surface water all year round).

- Hypothetical Future Onsite Resident (Adult and Child)
    - Exposure to onsite 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 onsite groundwater via ingestion of drinking water and dermal contact during showering/bathing.
    - The adult resident scenario is protective of soldiers that live temporarily at Camp Smith in the barracks or at the hotel.

Based on currently available scientific data (Franko et al., 2012) and consistent with USEPA's approach for evaluation of PFOS and PFOA in water (USEPA, 2021b), 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 PFAS in water. Therefore, the dermal contact with water pathway will be qualitatively discussed for PFOS and PFOA in the uncertainty assessment. However, the dermal contact with PFBS in groundwater will be quantified in the HHRA if it is identified as a surface water and/or groundwater COPC.

Any potential exposure pathways associated with VOCs in groundwater will be examined after review of the AOI 1 RI Mobilization 1 groundwater sampling results. Potential exposure to airborne particles in outdoor air (from soil) will not be quantitatively evaluated in the HHRA 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 terrestrial habitats associated with the AOIs themselves are expected to be limited due to the continuing military land uses; however, the surrounding areas include rugged, mountainous terrain that is likely to support a variety of ecological receptors. Although the AOIs may not provide significant ecological habitat, it is conservatively assumed that the following potential exposure pathways exist for upland areas:

- Soil invertebrates, terrestrial plants, reptiles, and amphibians directly exposed to PFAS in surface soil (0 to 2 ft 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.

Potential aquatic habitat exists with a variety of natural streams, rivers, wetlands, and open water features present at Camp Smith and the Hudson River forms the western and southern boundaries of Camp Smith. Aquatic plants, benthic invertebrates, aquatic invertebrates, amphibians, reptiles (e.g., turtles), and fish are likely to be present in on-facility aquatic habitats and are expected to serve as food sources for birds and mammals foraging in these aquatic habitats. 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. Dickiebusch Lake, a 6-acre lake at the northeastern end of Camp Smith, is expected to provide habitat for fish, amphibians, turtles, invertebrates, birds and mammals and may receive surface run off and groundwater discharge from upgradient AOIs.

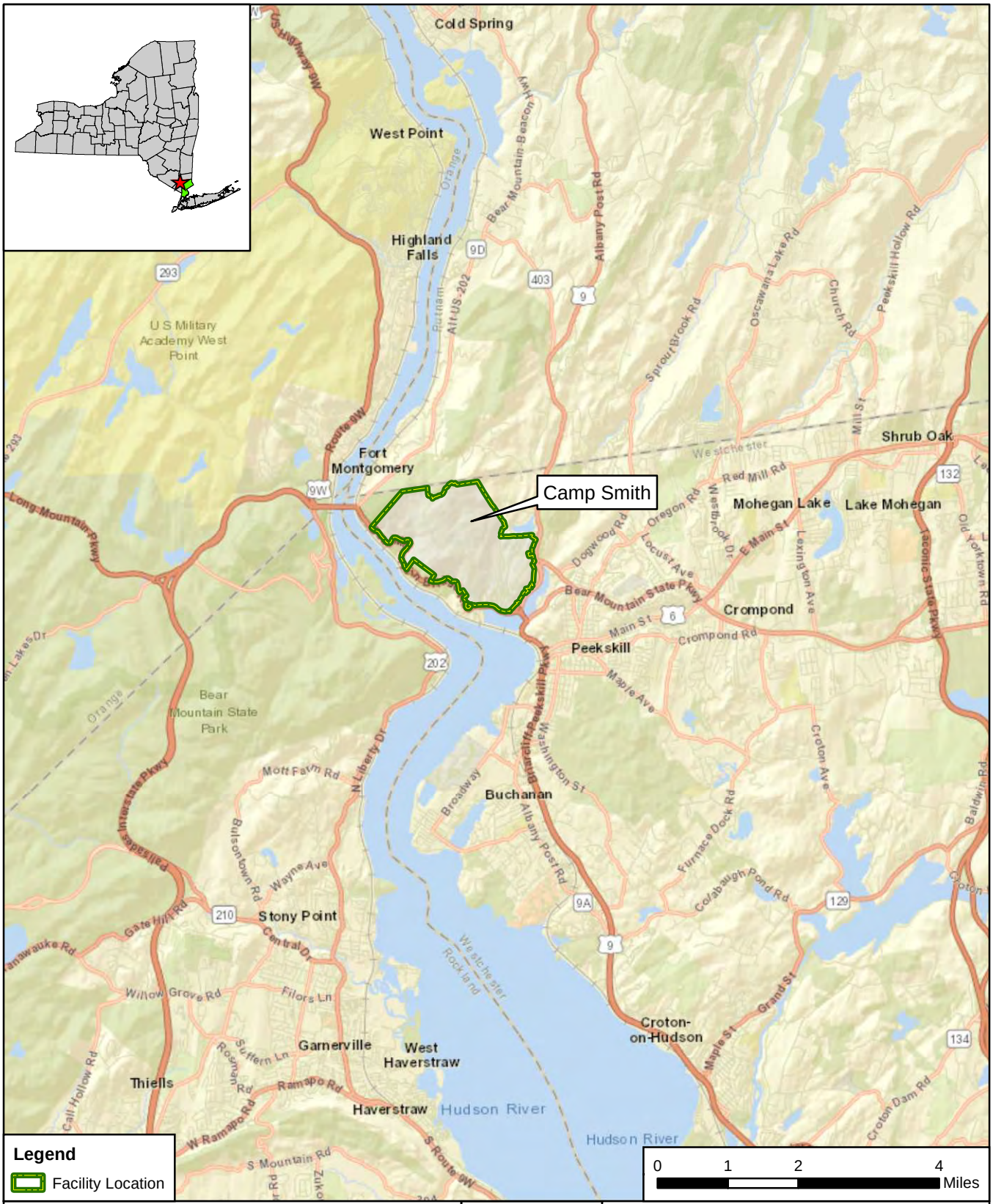
Based on existing data, the primary exposure pathways for aquatic habitats at Camp Smith include:

- Aquatic plants, amphibians, reptiles, aquatic invertebrates, and benthic invertebrates directly exposed to PFAS in surface sediment (including porewater) and/or surface water in streams, wetlands, and/or other waterbodies.

- 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 (including porewater) or surface water in streams, wetlands, and/or other waterbodies.

The Phase 1 evaluation will evaluate exposure to sediment and surface water from the on-facility waterbodies as a conservative surrogate for concentrations that have the potential to migrate into additional downgradient aquatic habitats. In cases where receptor-specific PFAS toxicity information is not available, potential impacts on receptors (e.g., reptiles) will be considered qualitatively.

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



CLIENT	ARNG			
NOTES	Remedial Investigation for PFAS at Camp Smith, NY			
REVISED	2/28/2022	GIS BY	MS	2/28/2022
SCALE	1:126,720	CHK BY	AB	2/28/2022
Base Map: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI,		PM	CM	2/28/2022

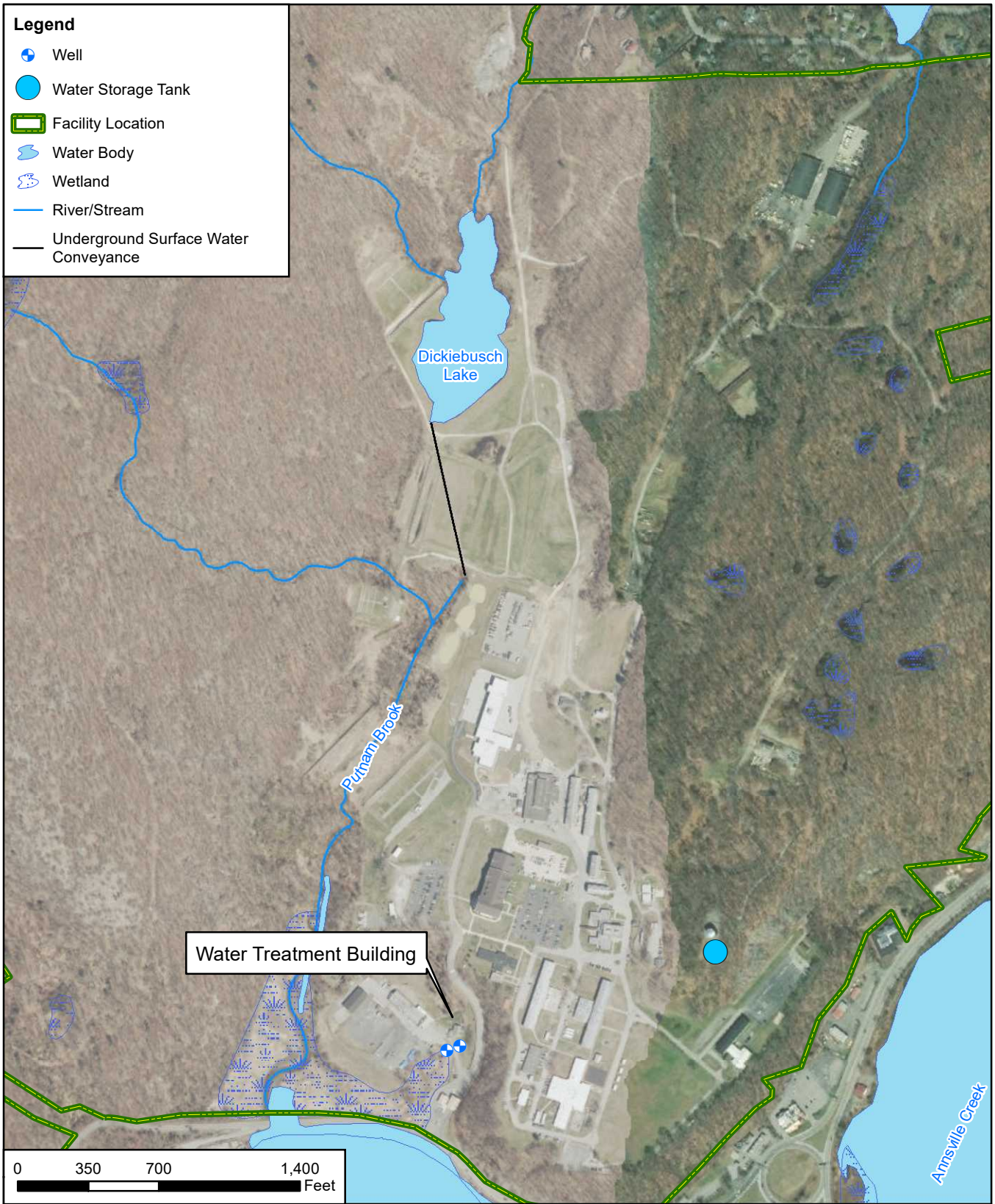
N

Facility Location

AECOM
12420 Milestone Center Drive
Germantown, MD 20876

Figure 10-1

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CLIENT	ARNG			
NOTES	Remedial Investigation for PFAS at Camp Smith, NY			
REVISED	2/28/2022	GIS BY	MS	2/28/2022
SCALE	1:8,400	CHK BY	AB	2/28/2022
Base Map: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS,		PM	CM	2/28/2022

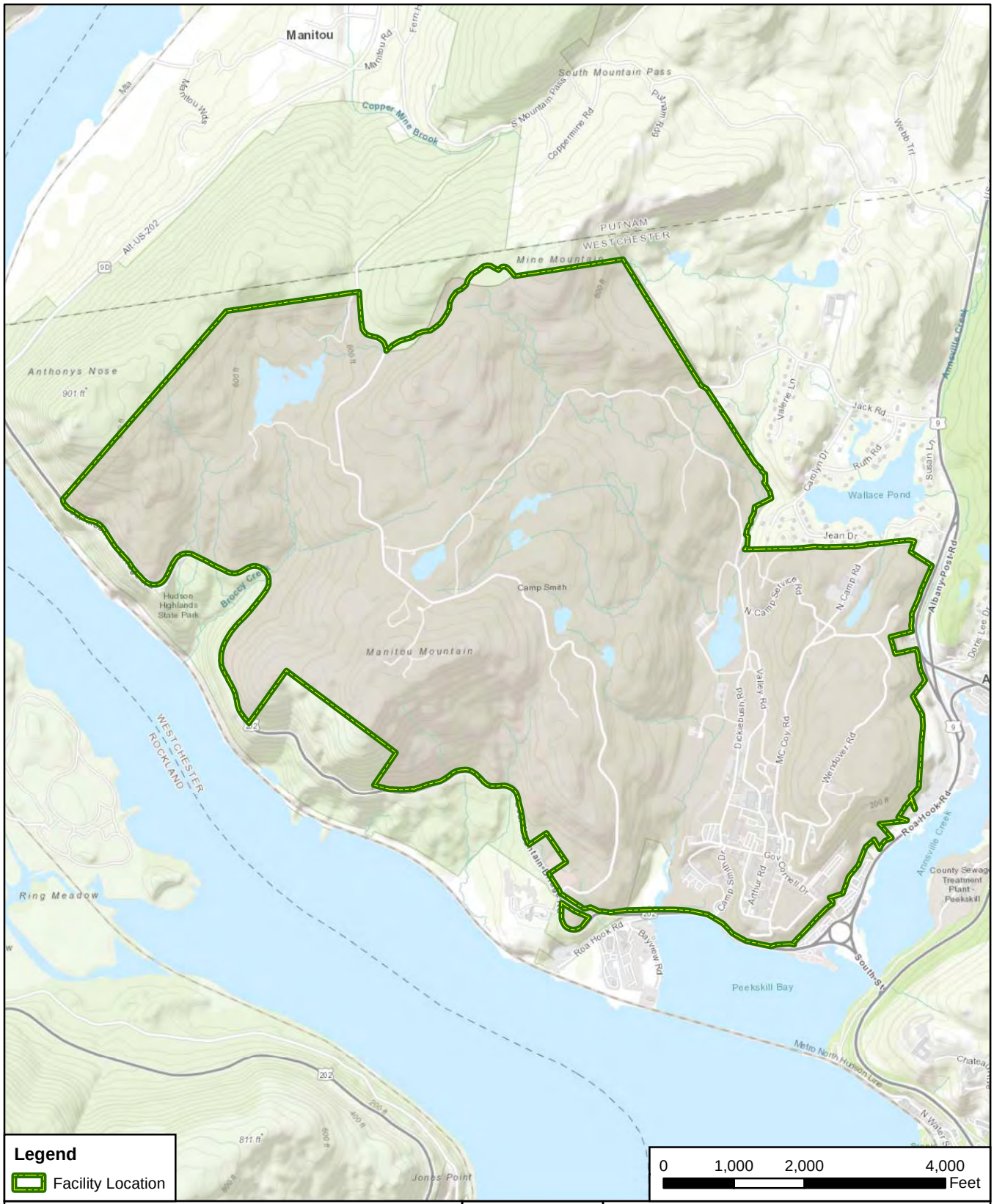
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Site Layout

AECOM
12420 Milestone Center Drive
Germantown, MD 20876

Figure 10-2

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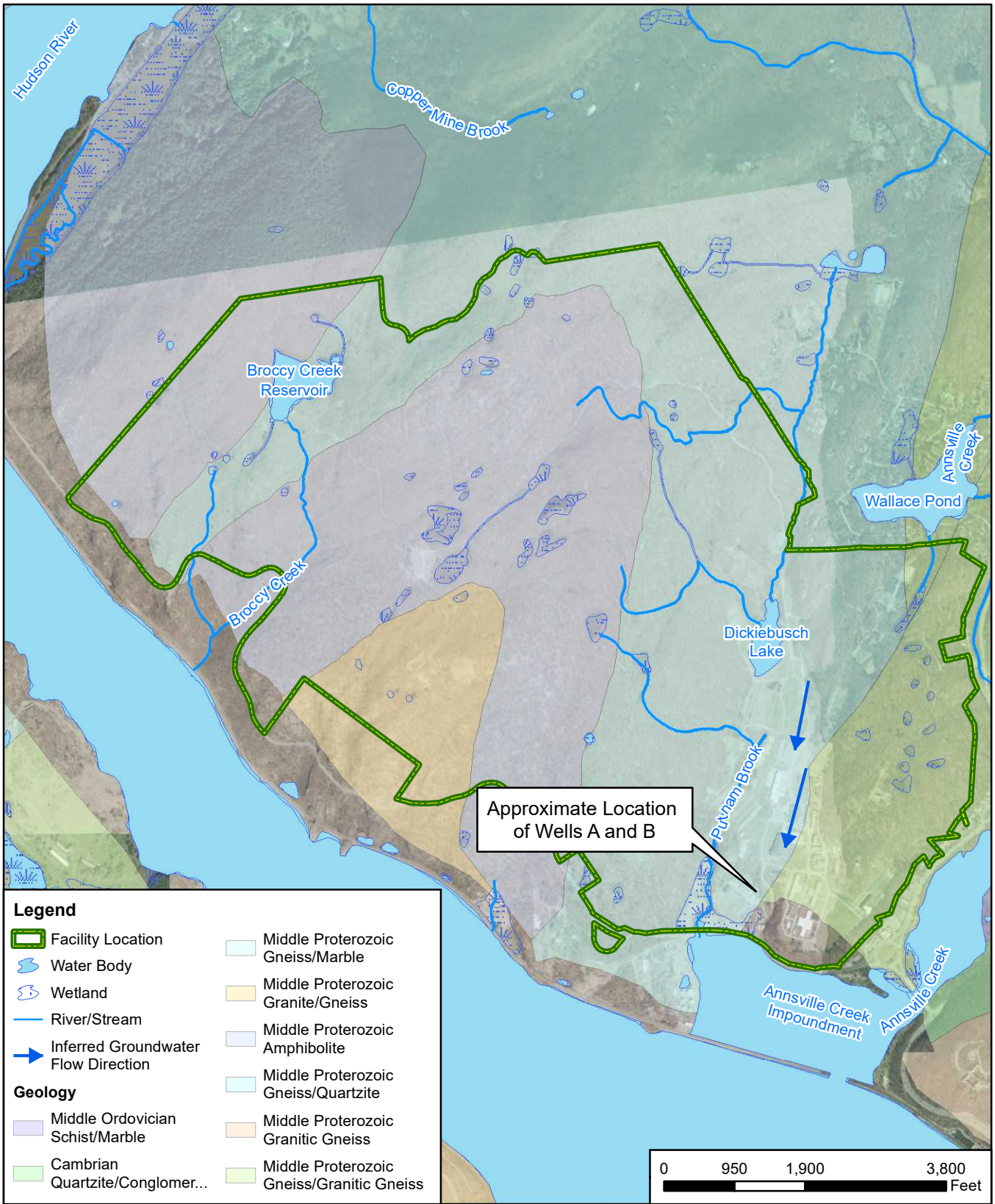
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SCALE	1:24,000	CHK BY	AB	2/28/2022
Base Map: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN,		PM	CM	2/28/2022

Facility Topography

AECOM
12420 Milestone Center Drive
Germantown, MD 20876

Figure 10-3

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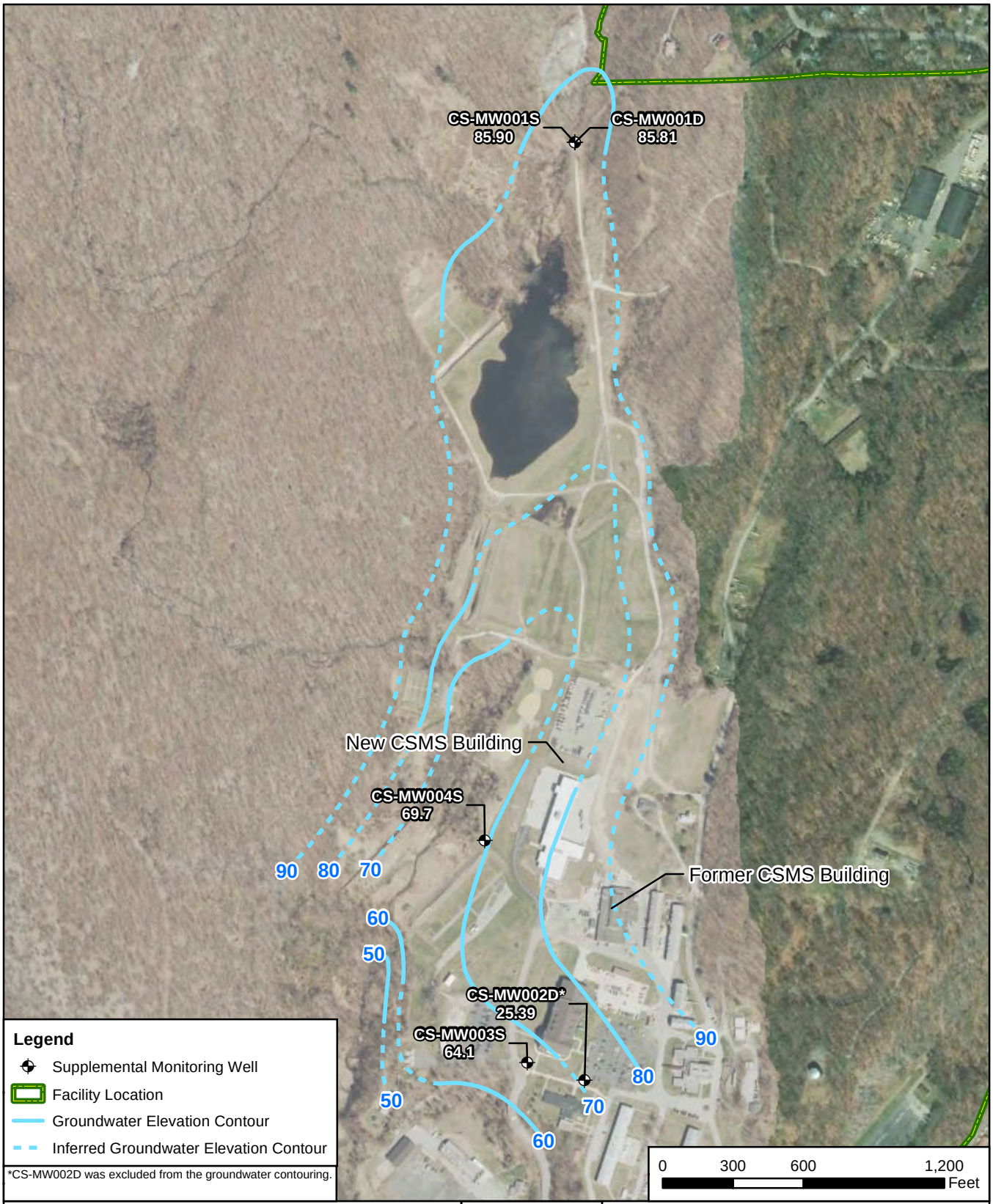
CLIENT	ARNG			
NOTES	Remedial Investigation for PFAS at Camp Smith, NY			
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SCALE	1:22,800	CHK BY	AB	2/28/2022
Base Map: NYS Digital Ortho-imagery Program (NYSDOP), 2016		PM	CM	2/28/2022

Groundwater Features

AECOM
12420 Milestone Center Drive
Germantown, MD 20876

Figure 10-4

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CLIENT	ARNG			
NOTES	Remedial Investigation for PFAS at Camp Smith, NY			
REVISED	2/28/2022	GIS BY	MS	2/28/2022
SCALE	1:7,200	CHK BY	AB	2/28/2022
Base Map: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS,		PM	CM	2/28/2022

Groundwater Elevations, July 2021

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Figure 10-5

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CLIENT	ARNG			
NOTES	Remedial Investigation for PFAS at Camp Smith, NY			
REVISED	2/28/2022	GIS BY	MS	2/28/2022
SCALE	1:22,800	CHK BY	AB	2/28/2022
Base Map: NYS Digital Ortho-imagery Program (NYSDOP), 2016		PM	CM	2/28/2022

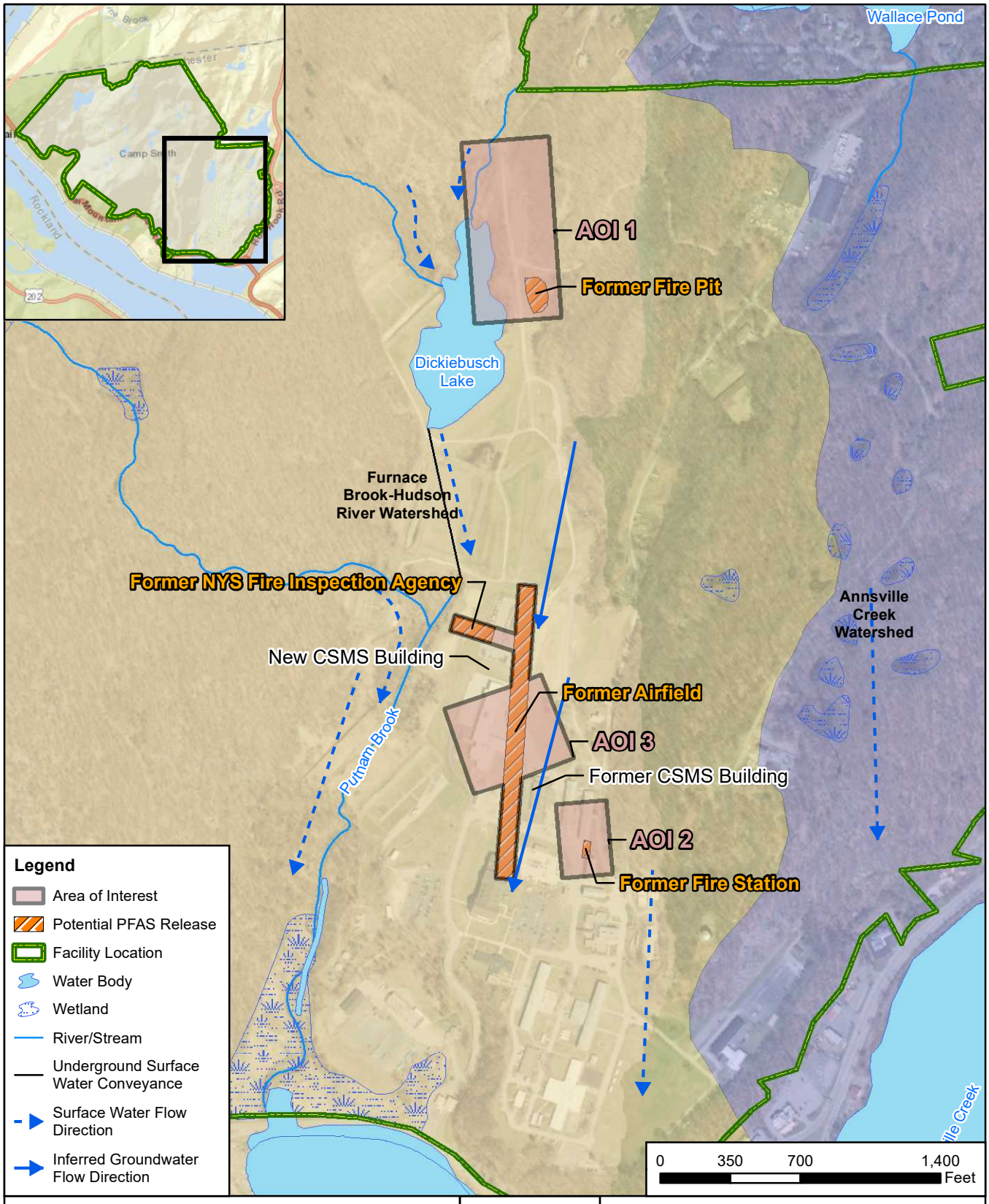
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Surface Water Features

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Germantown, MD 20876

Figure 10-6

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CLIENT	ARNG			
NOTES	Remedial Investigation for PFAS at Camp Smith, NY			
REVISED	2/28/2022	GIS BY	MS	2/28/2022
SCALE	1:8,400	CHK BY	AB	2/28/2022
Base Map: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS,		PM	CM	2/28/2022

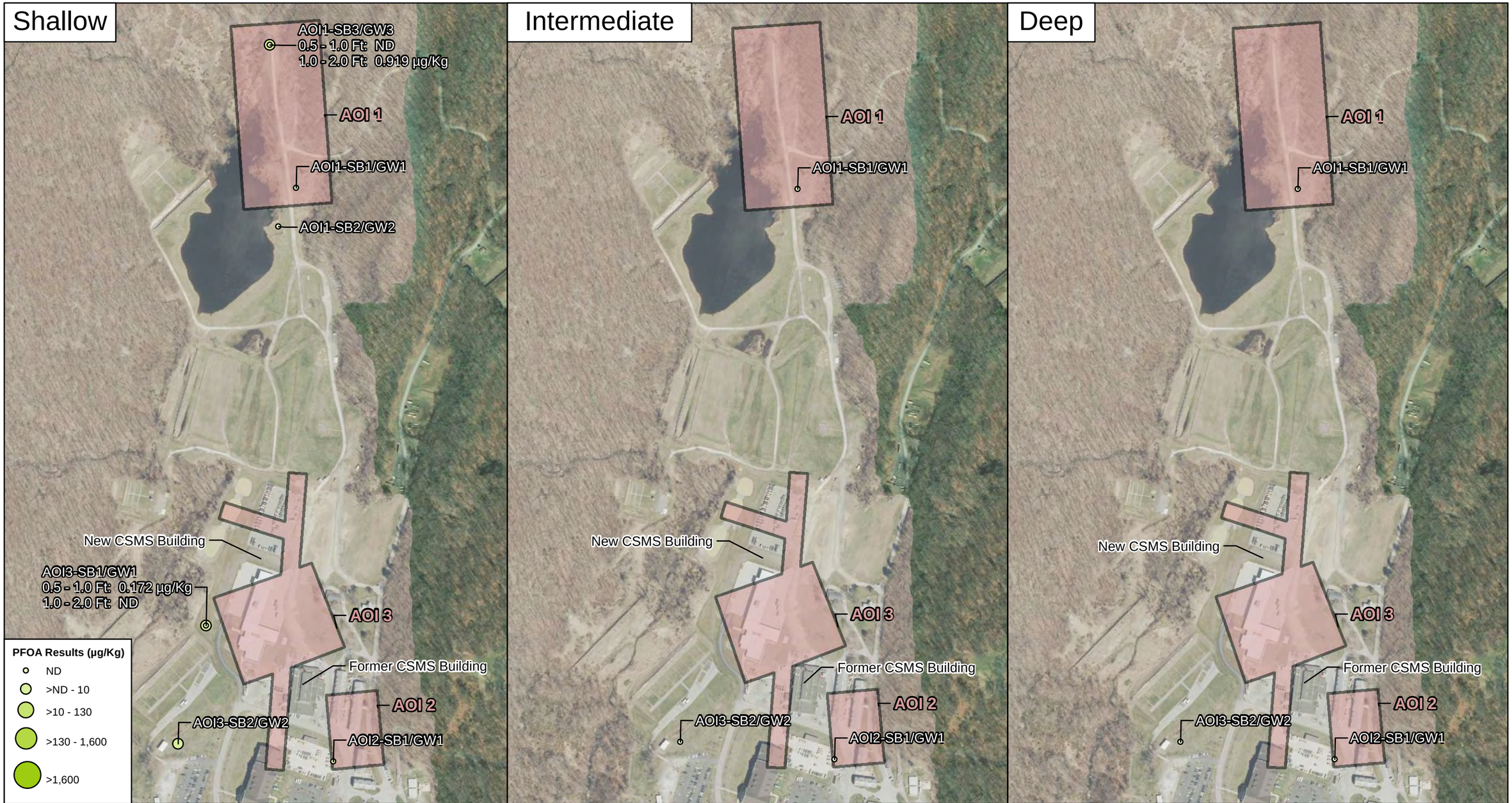
Areas of Interest

AECOM
12420 Milestone Center Drive
Germantown, MD 20876

Figure 10-7

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CLIENT	ARNG			
PROJECT	Remedial Investigation for PFAS at Camp Smith, NY			
REVISED	2/28/2022	GIS BY	MS	2/28/2022
SCALE	1:5,795	CHK BY	AB	2/28/2022
Base Map: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community		PM	CM	2/28/2022

Legend

- Area of Interest
- Facility Location

0 240 480 960 Feet

N

PFOA Detections in Soil, Mobilization 1

AECOM 12420 Milestone Center Drive Germantown, MD 20876

Figure 10-8

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Shallow

Intermediate

Deep

CS-MW001S

CS-MW001D

CS-MW003S

CS-MW002D

CS-MW004S

Putnam Brook

Dickiebusch Lake

AOI2-SB2

AOI2-SB3

AOI2-SB4

AOI2-SB5

0 100 200 400 Feet

0 150 300 600 Feet

PFOA Results (µg/Kg)

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

CLIENT	ARNG			
PROJECT	Remedial Investigation for PFAS at Camp Smith, NY			
REVISED	2/28/2022	GIS BY	MS	2/28/2022
SCALE	1:2,400	CHK BY	AB	2/28/2022
Base Map: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community		PM	CM	2/28/2022

Legend

- Facility Location
- Water Body
- Wetland
- River/Stream

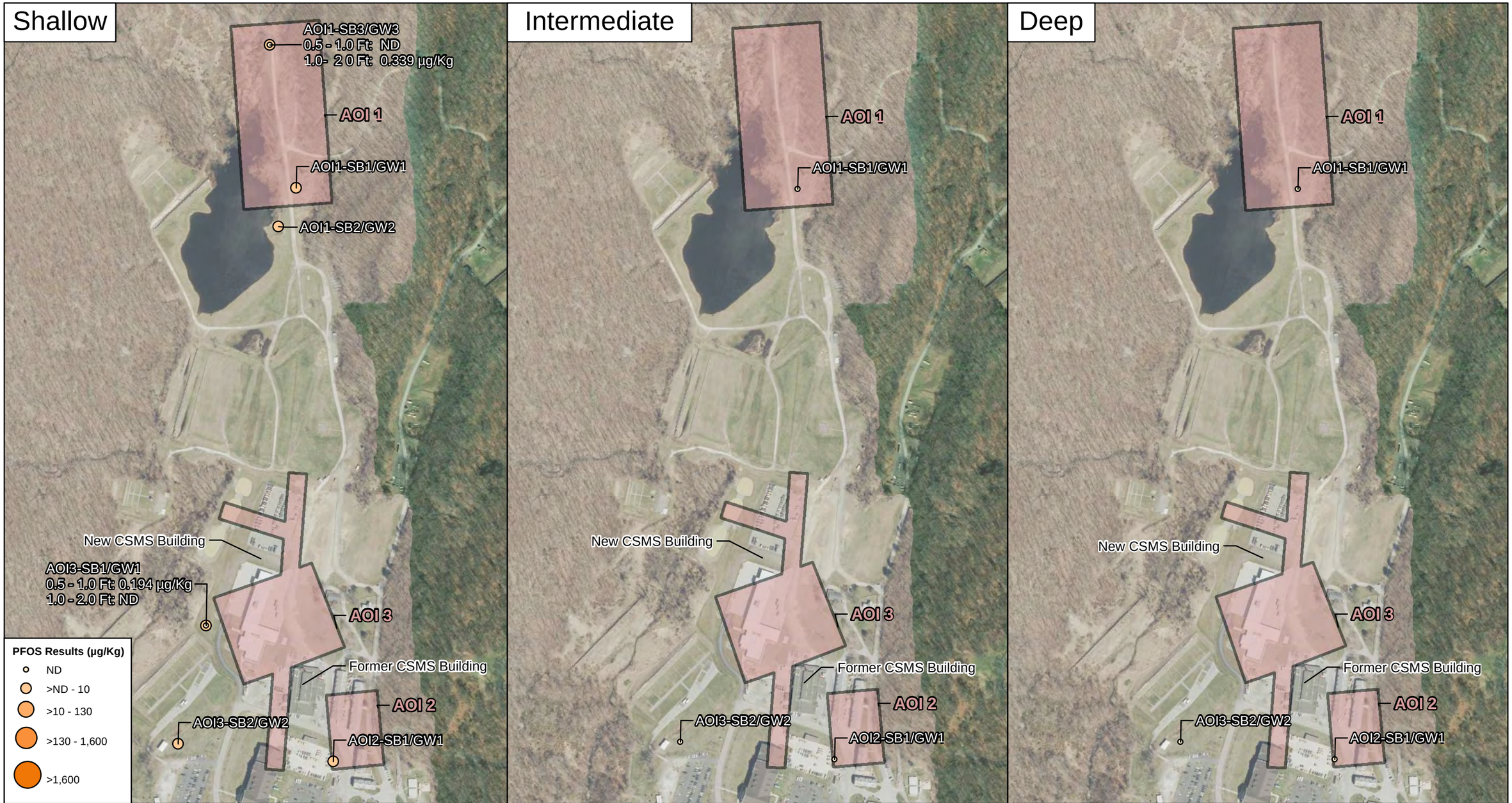
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PFOA Detections in Soil, Mobilization 2

AECOM
12420 Milestone Center Drive
Germantown, MD 20876

Figure 10-9

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CLIENT	ARNG			
PROJECT	Remedial Investigation for PFAS at Camp Smith, NY			
REVISED	2/28/2022	GIS BY	MS	2/28/2022
SCALE	1:5,795	CHK BY	AB	2/28/2022
Base Map: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community		PM	CM	2/28/2022

Legend

- Area of Interest
- Facility Location

0 240 480 960 Feet

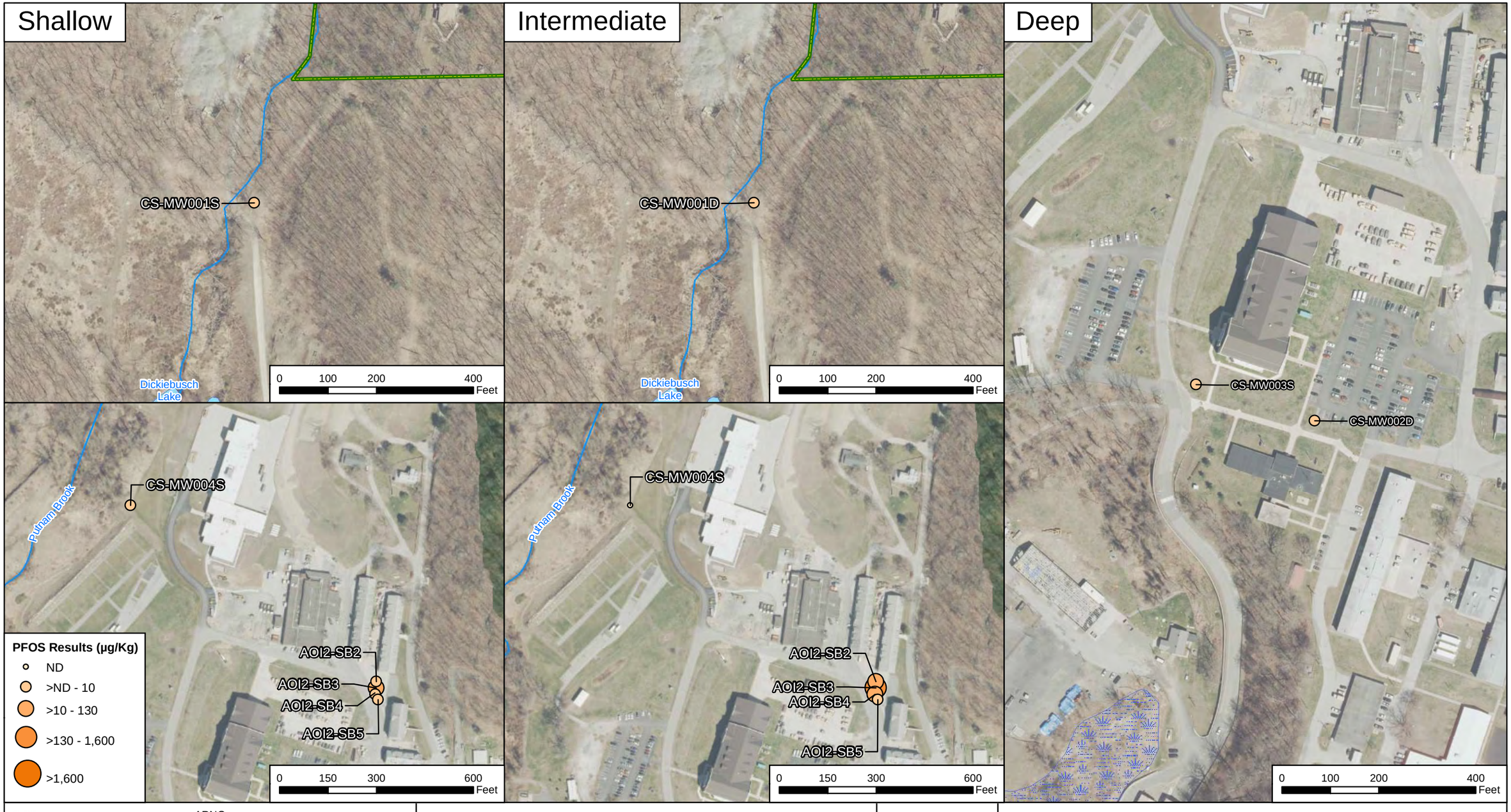
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PFOS Detections in Soil, Mobilization 1

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12420 Milestone Center Drive
Germantown, MD 20876

Figure 10-10

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CLIENT	ARNG			
PROJECT	Remedial Investigation for PFAS at Camp Smith, NY			
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SCALE	1:2,402	CHK BY	AB	2/28/2022
Base Map: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community		PM	CM	2/28/2022

Legend
- Facility Location
- Water Body
- Wetland
- River/Stream

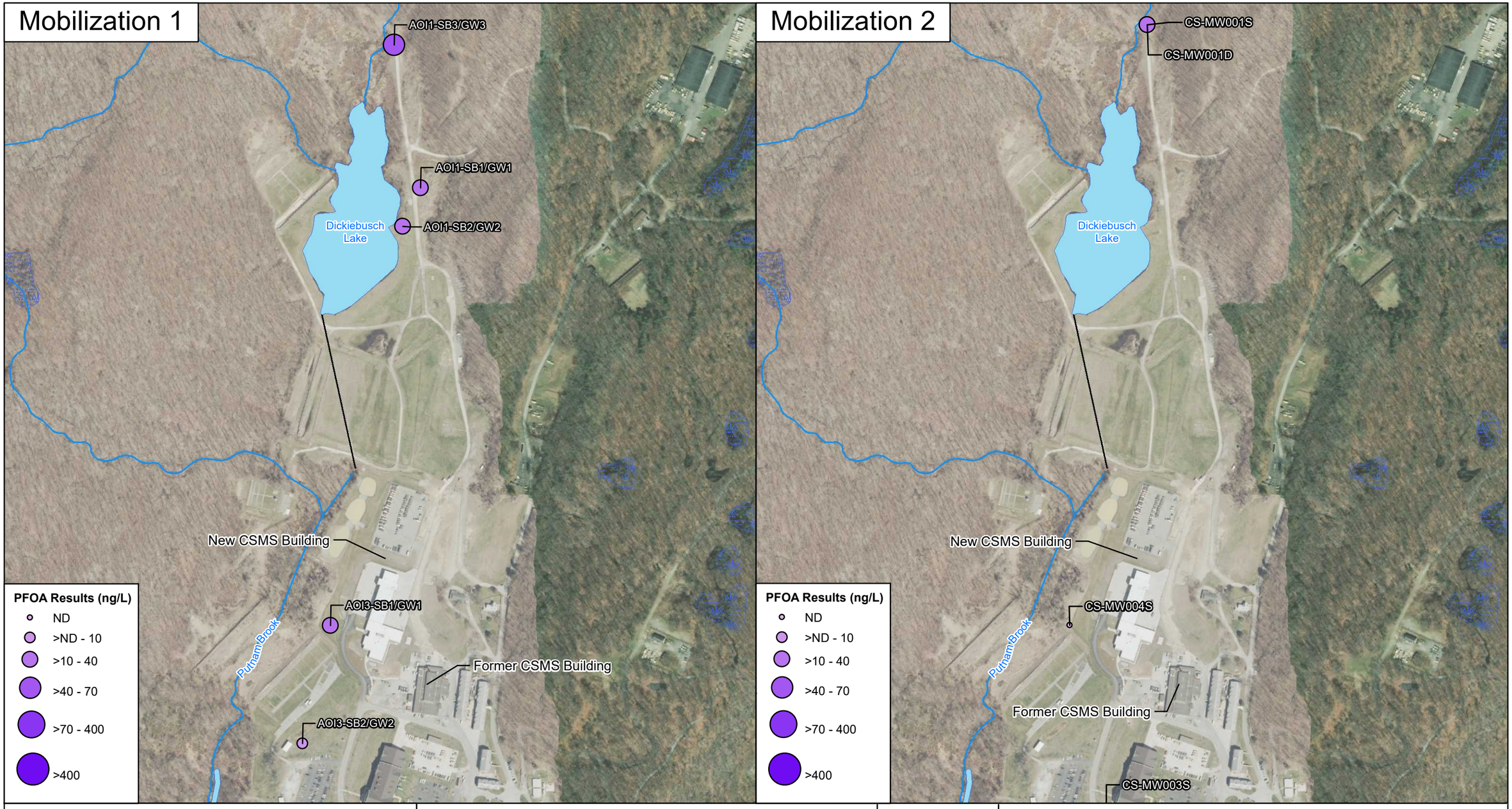
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PFOS Detections in Soil, Mobilization 2

AECOM
12420 Milestone Center Drive
Germantown, MD 20876

Figure 10-11

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CLIENT	ARNG			
PROJECT	Remedial Investigation for PFAS at Camp Smith, NY			
REVISED	2/28/2022	GIS BY	MS	2/28/2022
SCALE		CHK BY	AB	2/28/2022
Base Map: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community		PM	CM	2/28/2022

Legend

Facility Location
Water Body
Wetland
River/Stream
Underground Surface Water Conveyance

0 240 480 960 Feet

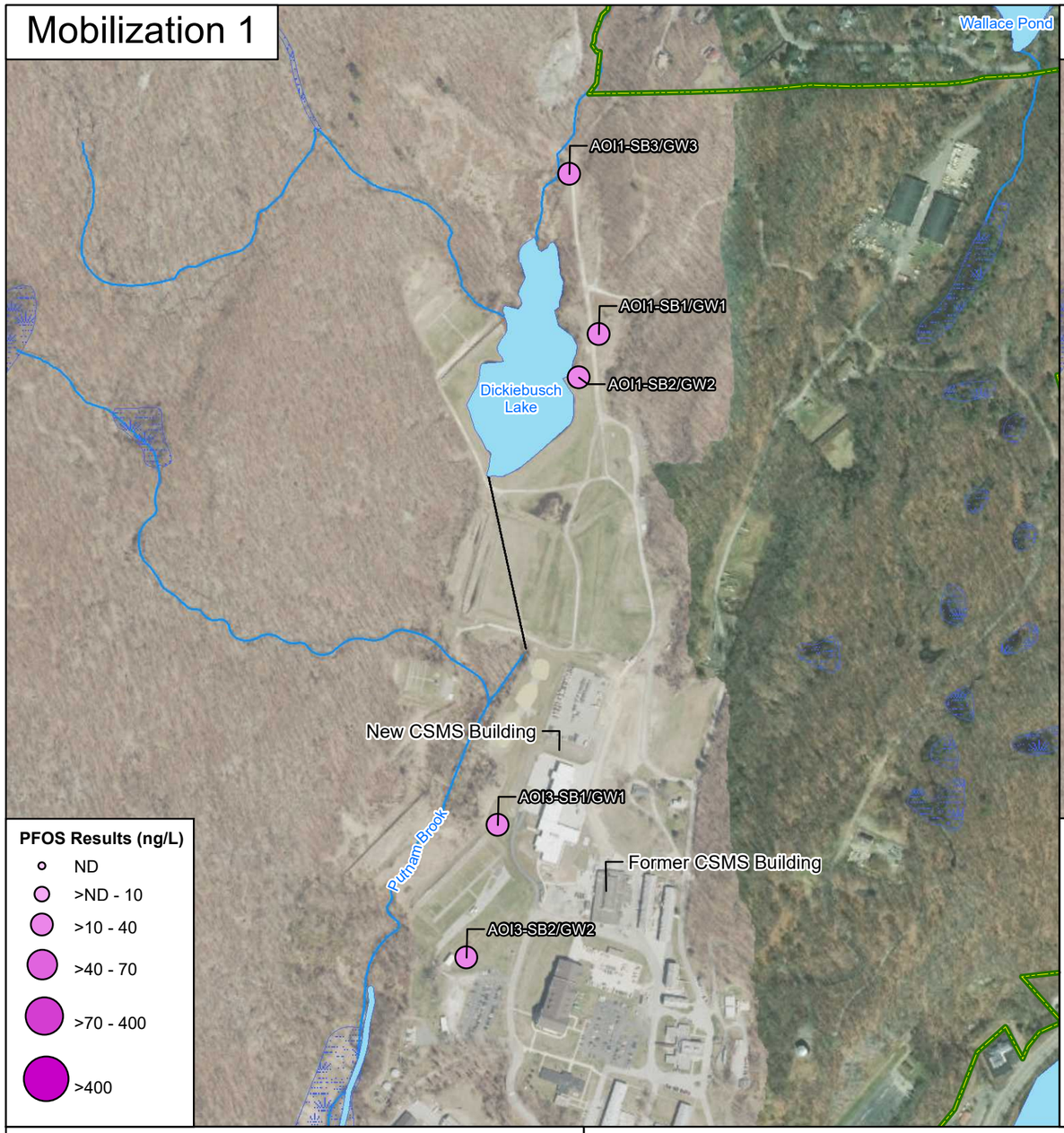
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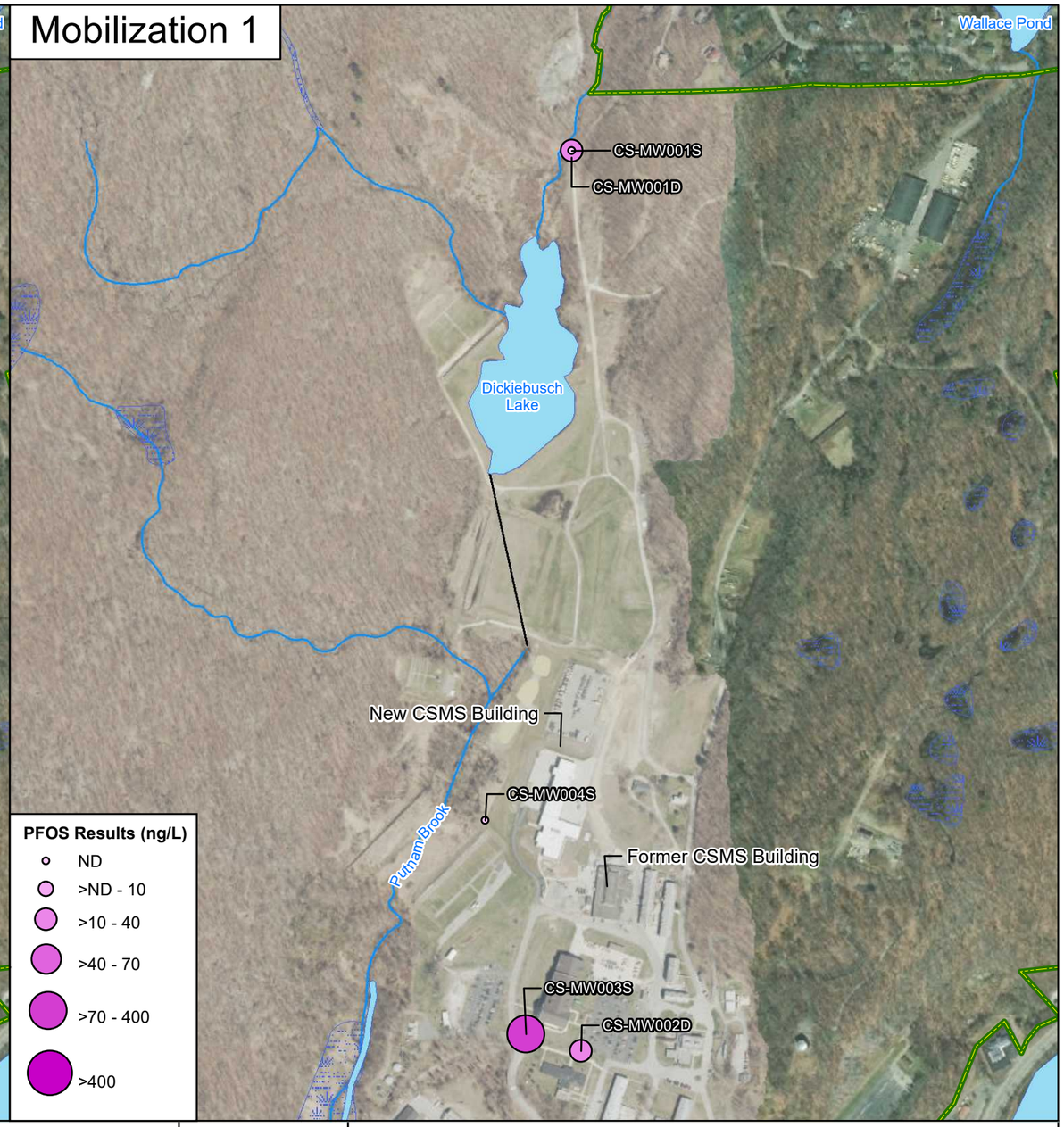
PFOA Detections in Groundwater, SI Mobilizations 1 and 2

AECOM
12420 Milestone Center Drive
Germantown, MD 20876

Figure 10-12

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CLIENT	ARNG			
PROJECT	Remedial Investigation for PFAS at Camp Smith, NY			
REVISED	2/28/2022	GIS BY	MS	2/28/2022
SCALE	1:7,200	CHK BY	AB	2/28/2022
Base Map: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community		PM	CM	2/28/2022

Legend

Facility Location — River/Stream

Water Body — Underground Surface Water Conveyance

Wetland

0 300 600 1,200 Feet

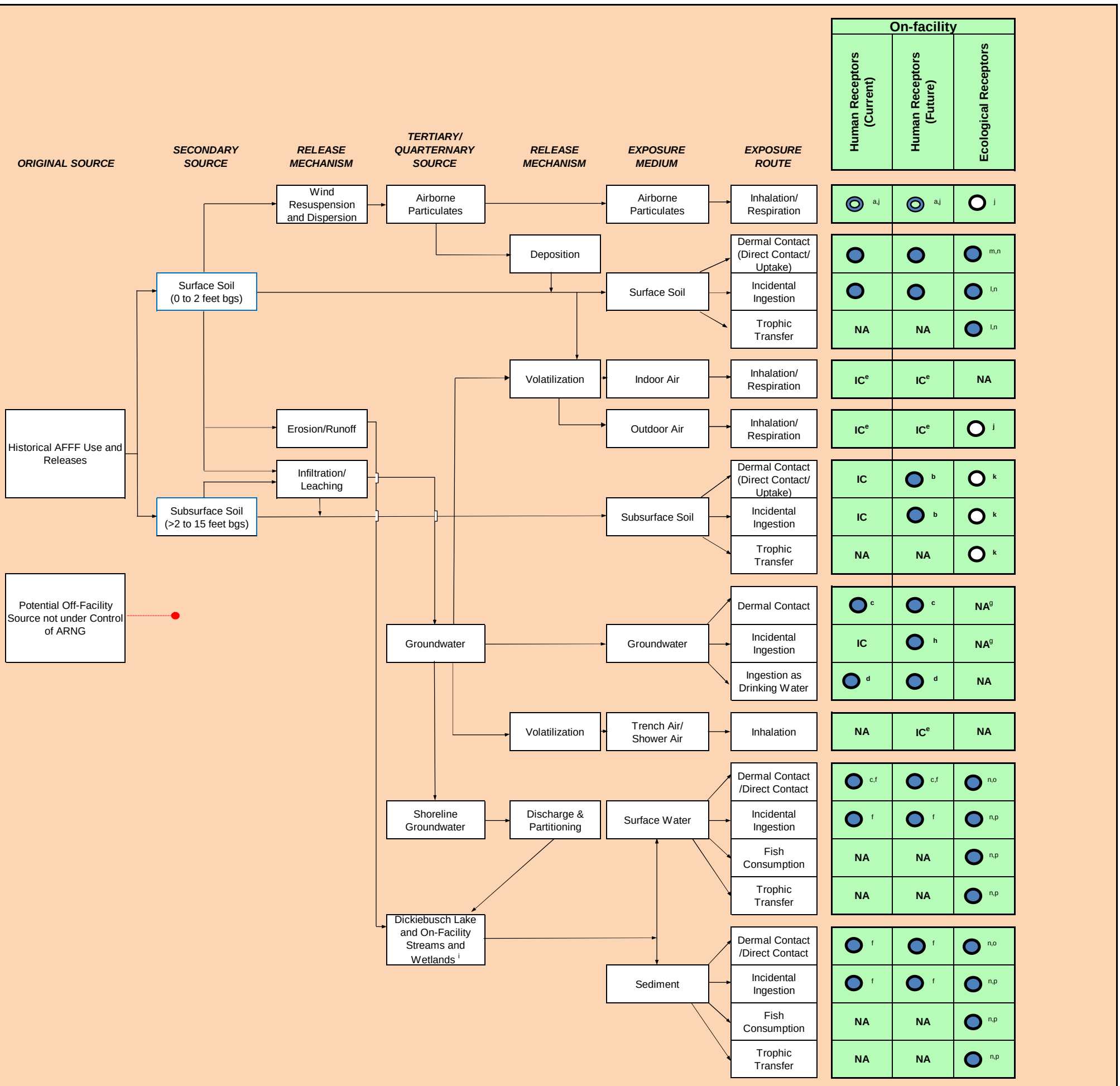
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PFOS Detections in Groundwater, SI Mobilizations 1 and 2

AECOM 12420 Milestone Center Drive Germantown, MD 20876

Figure 10-13

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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**
- **Flow-Chart Stops**

Abbreviations

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

Notes

The current investigation considers potential on-facility exposure pathways. If sampling identifies the potential for off-facility contaminant migration and exposure, then off-facility pathways will be considered in a later phase of investigation.

(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) Two potable wells in the southern portion of the Camp Smith cantonment area, Wells A and B, supply drinking water to the facility. The March 2020 sampling event identified a PFOA + PFOS concentration that was above the health advisory level of 70 parts per trillion. Now, the facility provides filtered drinking water stations. The facility water treatment plant is being upgraded with a granular activated carbon system that will be operational in September 2022.

(e) PFAS have low volatility and therefore are not considered to volatilize into air. PFAS are the only potential facility-related COPCs for the facility being evaluated under the scope of this Remedial Investigation (RI). However, groundwater sampling for VOCs will be conducted during RI Mobilization 1 at the wells installed at AOI 1. Inhalation of vapors exposure pathway will be revisited, if needed.

(f) Exposure to sediment and surface water in on-facility waterbodies by recreational and trespasser receptors.

(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 and sediment (including porewater) may be complete.

(h) Incidental ingestion of shallow groundwater may occur during soil disturbing activities by future construction/utility workers.

(i) Potential exposures will be evaluated for sediment and surface water for both human health and ecological receptors.

(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 and/or sediment are potentially complete for aquatic organisms, reptiles and amphibians and direct contact/uptake exposure pathways for sediment (including porewater) are also potentially complete for benthic invertebrates.

(p) Incidental ingestion/trophic transfer pathways for surface water and/or sediment are potentially complete for aquatic dependent wildlife.

Project No. 60591182		Preliminary Human Health and Ecological Receptors and Exposure Pathways	Figure 10-14
Camp Smith Training Facility Cortlandt, NY			

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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.

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 September 2021 (Assistant Secretary of Defense, 2021). The ARNG program under which the SI was performed follows this DoD policy. The policy indicates that if the maximum concentration for sampled media exceed 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, and PFBS.

The presence of PFOA and PFOS in excess of the OSD SLs has been confirmed at AOIs 1 through 3 at Camp Smith. In addition, PFAS were consistently detected below the USEPA HA of 70 ng/L in both potable water supply wells A and B in quarterly sampling since April 2017. However, in the sampling event conducted in March 2020, the combined concentrations of PFOA and PFOS were above the USEPA HA, at 72.2 ng/L. However, to what extent risk is posed to human health or the environment from PFAS in environmental media at the facility and downgradient of the facility is currently unknown. If the results of the risk assessment identify potential unacceptable risk as defined under the NCP (40 CFR Part 300.430; USEPA, 1994), then a FS will be recommended to evaluate remedial action alternatives.

Additionally, NYS has formally adopted new drinking water standards for public water systems that set maximum contaminant levels (MCLs) of 10 ng/L each for PFOA and PFOS. Although the NYS 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 onsite at Camp Smith.

Finally, it is unknown whether VOCs used as accelerants during fire training activities may have been released at AOI 1 Former Fire Pit. If VOCs are present in soil and groundwater at this AOI, whether, or to what extent, risk is posed to human health from VOCs is currently unknown. If VOCs are detected above SLs, as discussed in the goals below, further investigation for VOCs will be recommended under a separate contract to determine the nature and extent of VOC contamination in environmental media at the facility and downgradient of the facility.

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 are:

1. Conduct Rapid Site Characterization (RSC) of PFAS in surface soil within established AOIs to locate the PFAS release areas in soil where PFOA, PFOS, and PFBS are linked to groundwater containing these compounds that is attributable to ARNG activities. Collect surface soil samples using a grid approach. If decreasing concentrations in surface soil are observed in the four cardinal directions away from an area of elevated surface soil concentrations, then the local release area is assumed to have been identified. If increasing concentrations are observed, then additional RSC soil sampling may continue with “step-out” locations along the grid pattern until the data are sufficient to allow for source area identification, as described above. The RSC approach is detailed in **Section 17.1**.
2. Collect groundwater samples from onsite permanent monitoring wells for analysis of PFAS to refine the extent of PFOA, PFOS, and PFBS attributable to ARNG activities in groundwater at concentrations above the USEPA HAs, OSD SLs, and New York State Department of Health (NYSDOH) drinking water MCLs (USEPA, 2016a; USEPA, 2016b; Assistant Secretary of Defense, 2021; NYSDOH, 2020). Determine whether the concentrations of these compounds in groundwater are more than likely the result of ARNG activities. If PFOA, PFOS, and/ or PFBS are detected, conduct preliminary screening and evaluate the results in the HHRA as part of the comprehensive Phase 1 RI report that will be prepared following completion of Mobilization 1 and Mobilization 2, as indicated in **Section 14.6** and described in Goals 8 through 10 below.
3. Within the PFAS release areas identified by RSC, collect surface and subsurface soil samples using a grid approach to refine the occurrence of PFOA, PFOS, and PFBS in soil to the OSD SLs (Assistant Secretary of Defense, 2021). If PFOA, PFOS, and/ or PFBS are detected at concentrations exceeding the OSD SLs, continue to evaluate extent of these compounds in soil. If PFOA, PFOS, and/ or PFBS are detected, conduct preliminary screening and evaluate the results in the HHRA as part of the comprehensive Phase 1 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 through 10 below.
4. Collect surface water samples to determine the presence or absence of PFOA, PFOS, and PFBS within surrounding surface water bodies attributable to ARNG activities. If PFOA, PFOS, and/ or PFBS are detected, conduct preliminary screening and evaluate the results in the HHRA as part of the comprehensive Phase 1 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 through 10 below.
5. Collect sediment samples to evaluate PFOA, PFOS, and PFBS in sediment within surrounding surface water bodies where groundwater with PFAS impacts attributable to ARNG activities is discharging to surface water and where erosion/transportation of soil with PFAS impacts are deposited. If PFOA, PFOS, and/ or PFBS are detected, conduct preliminary screening and evaluate the results in the HHRA as part of the comprehensive Phase 1 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 through 10 below.
6. Collect data to evaluate facility characteristics that influence PFAS fate and transport, support refinement of the CSM, and inform the potential remedial alternatives evaluation.

7. Analyze groundwater samples for VOCs from onsite permanent monitoring wells within the given AOI. If VOCs are detected, further samples will be collected in RI Mobilization 2 for HHRA evaluation.
8. Conduct a facility-specific HHRA following Mobilization 2 in accordance with USEPA Risk Assessment Guidance for Superfund (RAGS) and DA risk assessment guidance and policies (DA, 1999; Assistant Secretary of Defense, 2021). 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 facility-related concentrations of PFOA, PFOS, and/or PFBS in soil, groundwater, sediment, and/or surface water, then an FS will be recommended to evaluate remedial action alternatives.
9. If the facility-specific HHRA (described in the Goal 8) identifies that facility-related concentrations of VOCs in onsite groundwater pose a potential unacceptable risk or hazard to human health, as defined in the NCP [40 CFR § 300.430] (USEPA, 1991; USEPA, 1994), this will be discussed in the HHRA for consideration of further investigation and assessment of VOCs during a separate RI.
10. If PFOA, PFOS, and/ or PFBS are detected in facility media at concentrations exceeding OSD SLs as described in Goals 2 and 3, a SLERA will be conducted following completion of Mobilization 2 data collection. The SLERA will be conducted in accordance with USEPA Ecological RAGS (USEPA, 1997) and DA risk assessment guidance (DA, 2010), as described in **Section 14.5** for PFOA, PFOS, and PFBS, 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. 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, sediment 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 PA completed for Camp Smith. This information was used to identify potential PFAS release areas and release mechanisms.
- Findings from the SI completed for Camp Smith, including PFAS analytical data from groundwater and soil from all three AOIs. 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, as described in **Worksheets #17 & #18**.
- PFAS analytical data from the RI, including groundwater, soil, surface water, and sediment data collected onsite. These data will be used to locate the PFAS release areas onsite and determine the nature and extent of contamination in these media onsite and offsite. Additionally, these data will be used to complete the HHRA and SLERA, as described in **Section 14.5**.

- VOC analytical data in groundwater from the RI collected onsite. These data will be used to confirm the presence or absence VOCs used as accelerants/ fuels during fire training activities within the established AOIs. If VOCs are detected in concentrations above the MCLs, additional samples will be collected during the RI Mobilization 2 in order to complete the HHRA, as described in **Section 14.5**.

- The habitat assessment completed as part of the RI. The findings of the habitat assessment will be used to help characterize the ecological receptors observed or expected to be present in the vicinity of the AOIs. Additionally, the findings of the habitat assessment will be used to help characterize the ecological receptors observed or expected to be present within the wetlands and the Hudson River.

- Field data collected during the SI and RI, including water quality parameters in groundwater and surface water, 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, which will be used to understand groundwater flow direction and gradient, and staff gauge data from the RI, which will aid in the interpretation of groundwater to surface water interaction. This information will also be used to refine the preliminary CSM.

- Hydraulic conductivity testing (slug testing) and geotechnical soil sample data collected during the RI, which will be used to determine aquifer permeability at select monitoring well locations. This information will also be used to refine the preliminary CSM.

- Data from 2017 to present that has been collected as part of the facility quarterly sampling at Wells A and B.

4. Define the Boundaries of the Study

The scope of the RI includes the property limits of Camp Smith and possible off-facility sampling locations depending on results of the initial RI sampling results. Where off-facility sampling is required, the proper stakeholders will be notified, and necessary proper right of entry (ROE) will be 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 NYSDOH PFAS-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 (DoD, 2019a) 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 data quality limits (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 sampling program for the RI will include:

- Surface and subsurface soil samples from AOI 1 through AOI 3, the Sludge Drying Beds, and the Gravel Pit;

- Groundwater from existing and newly-installed monitoring wells located on Camp Smith;
- Sediment and surface water sampling in Dickiebusch Lake, tributary creeks to Dickiebusch Lake, and Putnam Brook.
- Installation of staff gauges at nearby wetlands on Annsville Creek impoundment; and
- Collection of synoptic water levels in monitoring wells and at staff gauges.

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**.

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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% 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	S & A
Completeness	Completeness criteria will be considered met if 95% 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
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 90% 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 Groundwater
Analytical Group VOCs
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% 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	Detection Limits, Instrument Sensitivity Check	A
Completeness	Completeness criteria will be considered met if 95% of all planned sample data (as requested on CoC in lab reports and EDD; including requested re-analyses) are collected	NA.	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

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, quarterly sampling data for supply wells A and B	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, onsite 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 provide the project schedule and detail 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 Camp Smith will consist of multiple mobilizations. The RI Mobilization 1 will be conducted from August to September 2022. During Mobilization 1, grab soil samples will be collected for PFAS from multiple intervals at unbiased sampling locations within suspected potential release areas. Additionally, monitoring wells will be installed across the facility to determine nature and extent of PFAS in groundwater and to provide additional information on the geology and hydrogeology of the aquifer underlying the facility. RI Mobilization 2 will be conducted at a to be determined date to address data gaps from the RI Mobilization 1 and perform any additional sampling required for completion of the risk assessment.

This RI QAPP Addendum specifically addresses the activities to be performed during the RI Mobilization 1. The general approach for the RI Mobilization 1 is to start with the RSC soil sampling at suspected potential release areas. RSC of PFAS in surface and shallow subsurface soil will be used to determine the presence and extent of a source area and the placement of monitoring wells within the identified source areas. The RSC of PFAS will require an iterative approach, where data will be analyzed with 48-hour rapid turn-around time (TAT) and reviewed within a week to determine whether additional sample locations will be required. The project delivery team (PDT) will help guide the RSC if decisions are required to select new sample locations. Additional details are presented in the *RSC Coordination* portion of **Section 14.2** below.

Once the RSC is complete, the program will proceed to the collection of surface and subsurface soil samples for characterization of the PFAS release areas within Sampling Units (SUs), installation and development of new permanent multi-interval monitoring wells, collection of groundwater samples from permanent monitoring wells, and collection of surface water and sediment samples. 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**. The schedule for the RI is presented below in **Table 14-1**.

Table 14-1: RI Schedule

Task	Start Date	End Date
RI QAPP (Mobilization 1)	January 2022	August 2022
Pre-mobilization (Mobilization 1)	August 2022	August 2022
Mobilization (Mobilization 1)	September 2022	September 2022
Field Work (Mobilization 1)	September 2022	October 2022
Demobilization (Mobilization 1)	October 2022	October 2022
Data Review/Validation (Mobilization 1)	October 2022	February 2023
Data Analysis/Modeling (Mobilization 1)	February 2023	May 2023
RI QAPP (Mobilization 2) *	TBD	TBD
Pre-mobilization (Mobilization 2) *	TBD	TBD
Field Work (Mobilization 2) *	TBD	TBD
Demobilization (Mobilization 2) *	TBD	TBD
Data Review/ Validation (Mobilization 2) *	TBD	TBD
Reporting	TBD	TBD

* Depending on the results of Mobilization 1, it is possible Mobilization 2 will not be required. This will be determined once all Mobilization 1 data has been collected, validated, and reviewed.
TBD = to be determined

14.1 Mobilization

The following subsections present field tasks that may be completed as part of the Mobilization 1 activities.

Right of Entry Documentation Support

At this stage, ROEs are not anticipated to be needed for completion of Mobilization 1. However, ROEs may be necessary to complete future tasks, including monitoring well installation and sampling, well gauging, staff gauge installation, surface water, and sediment sampling. ROE documentation and property identification will be sent by USACE project manager at least 60 days prior to entry onto a property. ROE property data will include a property parcel number, legal description, owner name, address and phone number, and a map of the property. AECOM will provide support to USACE developing the parcel property maps.

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 facility 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 onsite during field activities. Training certificates for personnel (HAZWOPER 40-hour training; current HAZWOPER 8-hour refresher training; and first aid/CPR) will be maintained onsite.

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 facility 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 facility conditions, it will be established in the facility-specific SSHP. Detailed Activity Hazard Analysis (AHA) forms identifying the physical, chemical, and biological hazards that may be encountered at the facility and the associated mitigation methods are presented in the APP/SSHP.

Personnel and visitors who enter the facility 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 facility 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.

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 New York Dig Safe (811), the local one-call utility location system. Precautionary measures (e.g., geophysical survey, air knifing methods, hand-digging to 5 feet, etc.) will be implemented before any subsurface investigation work begins. 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**).

Facility 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 most vegetated areas at the facility are rough terrain generally inaccessible to a drill rig. Traffic control measures may be required to complete investigations near some AOIs at the facility. Procedures will be outlined in the SSHP.

Community Air Monitoring

Community air monitoring will be performed in accordance with the NYSDOH Generic Community Air Monitoring Plan (CAMP), Attachment 1A of the NYSDEC Division of Environmental Remediation-10 Technical Guidance for Site Investigation and Remediation (**Appendix E**). Air

monitoring activities will be implemented to protect the community from any potential airborne releases that could result from field activities associated with the SI (NYSDEC, 2010).

Continuous air monitoring will be performed in the vicinity of the drill rig when intrusive activities are underway. Air monitoring will consist of a dust monitor placed on a tripod adjacent to the work areas, in a downwind location. Background (upwind) levels will be measured each day prior to start-up of site activities and periodically throughout the day. If particulate levels (PM10) are greater than 100 micrograms per cubic meter (µg/m^3) above background for a 15-minute period, or if airborne dust is observed leaving the work area, dust suppression techniques will be employed. Work will continue with these suppression techniques provided that PM10 levels do not exceed 150 µg/m^3 above background and no visible dust is migrating from the work area. If PM10 exceeds 150 µg/m^3 over background, work will be stopped, and a re-evaluation of activities will be initiated.

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

A habitat assessment will be performed as part of the RI to identify representative habitats and species present in the vicinity of the sampling locations evaluated in the risk assessment. 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.

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, as well as other general habitat and species observations, will be recorded.

It is anticipated that the primary habitats of interest will be Dickiebusch Lake, Putnam Brook, and the forested areas surrounding the Camp Smith cantonment area. Based on the results of the habitat assessment and analytical results of RI Mobilization 1, additional assessment may be needed in another mobilization. These additional efforts could include wetland delineations, 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 Facility Water Supply Sampling and Sampling Equipment Acceptability

The potable water at Camp Smith was analyzed for PFAS and shown to exceed SLs. As a result, it cannot be used as a source for decontamination water and an offsite potable water source will be used instead. A sample from the offsite potable water source will be collected prior to mobilization to confirm that it is acceptable for use during field activities. The water source is acceptable for use if the detected concentrations are less than 1/5 the OSD SL. If the decontamination water has concentrations greater than 1/5 the SL, the PDT will determine whether the water is acceptable for its intended use based on facility-specific factors (i.e., drilling methodology, relevant sample media, etc.). If the water is deemed unacceptable, another source of water will be brought onsite 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).

RSC Coordination

The exact locations of the PFAS releases to soil and the migration pathways between the release areas and boundaries are not fully understood for the Gravel Pit and the Sludge Drying Bed. To address these data gaps, RSC methods will be utilized during RI Mobilization 1. The sampling design and rationale for the RSC program are outlined in **Worksheets #17 & #18**.

The RSC program involves an iterative approach where RSC soil samples will be collected prior to the installation of any groundwater monitoring wells. The RSC soil boring locations will be randomly placed within a grid overlapping potential release areas investigated during the SI and in areas where data gaps were identified. For each RSC soil boring sampling grid, a total of 24 samples will be initially collected. Based on the results of the RSC soil samples, additional RSC soil sampling may continue with "step-out" locations until the data are sufficient to allow for source area identification. The RSC soil samples for PFAS will be conducted via air knife/hang auger and analyzed for a short list of eight PFAS compounds. Additional details are provided in the *RSC PFAS Soil Sample Collection* section below.

Meetings will be hosted with the PDT as needed to review the available RSC data and make decisions on additional sampling locations. The general timing will be that analytical results will be received three days after sample collection and the determination of whether additional samples are warranted would be made approximately seven days after sample collection. For example, RSC soil samples collected on a Monday would arrive at the analytical laboratory on a Tuesday, AECOM would receive analytical results on Thursday, and AECOM would review and

evaluate the data by the following Monday to discuss with the PDT and recommend whether additional RSC soil samples for PFAS are needed.

Once RSC is complete, the program will proceed to collection of surface and subsurface soil samples for characterization of the PFAS release areas within SUs, installation and development of new permanent monitoring wells, collection of groundwater samples from permanent monitoring wells, and collection of surface water and sediment samples. Refer to **Worksheets #17 & #18** for additional details.

RSC PFAS Soil Sample Collection

RSC of soil will be conducted within the Gravel Pit and Sludge Drying Beds. Air knife and hand augers will be used at locations designated for collection of RSC soil samples at two depth ranges: 0 to 2 and 2 to 4 feet bgs. If a source area has been identified based on RSC soil PFAS data, nearby proposed permanent monitoring wells will be adjusted as necessary to delineate potential impacts to groundwater. Additionally, an SU grid will be developed centered on the highest detection identified with the RSC soil grid. For each rectangular RSC sampling grid, a total of 24 samples will be initially collected. The locations of these 12 boring locations are placed on a systematic grid in accordance with USEPA Guidance (USEPA, 2002). Refer to **Worksheets #17 & #18** for additional details on the sample design and rationale. Specific sampling locations are also identified in **Worksheets #17 & #18**. All sampling materials will be PFAS-free.

Where applicable, the soil cores will be logged for lithological descriptions by a field geologist using the Unified Soil Classification System (USCS). In accordance with the APP/SSHP (AECOM, 2019b; AECOM, 2019d), the soil core will be screened for VOCs with a photoionization detector (PID) immediately upon recovery. Details regarding the air monitoring procedures and specific action levels are provided in the APP. Observations and measurements will be recorded on field forms and in a non-treated field logbook. Photographs of the boring cores will also be taken. At a minimum, depth interval, recovery thickness, PID concentrations, moisture, relative density, color (using a Munsell soil color chart), and texture (using the USCS) will be recorded. Refer to *SOP 3-16: Soil and Rock Classification* and *Surface and Subsurface Soil Sampling Procedures* (**Appendix D**) for additional details.

Each RSC soil sample will be collected into laboratory-supplied bottleware and submitted to the laboratory for analysis. RSC soil samples will be analyzed under rapid 48-hour TAT for a shortlist of eight PFAS (liquid chromatography with tandem mass spectrometry [LC/MS/MS] compliant with QSM 5.3 Table B-15). The eight PFAS included in the shortlist are the compounds for which OSD has established SLs, in addition to five compounds to aid in identification of PFAS release areas. The RSC analyte list for soil is as follows:

- PFOA
- PFOS
- PFBS
- PFHxS
- N-ethyl perfluorooctane sulfonamide (EtFOSA)
- N-ethyl perfluorooctane sulfonamido ethanol (EtFOSE)
- N-methyl perfluorooctane sulfonamide (MeFOSA)
- N-methyl perfluorooctane sulfonamido ethanol (MeFOSE)

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.

RSC soil sample locations will be marked with a pin flag or spray paint with sample identification number, photo-documented, and recorded with a hand-held global positioning system (GPS). The surface at each sampling location will be restored to match the surrounding area.

Surface and Subsurface Soil Sample Collection from SUs

Following completion of the RSC soil sample collection, soil SUs may be located if PFAS release areas were identified during RSC sampling. The added SU grids will be centered on the highest detected concentrations from the RSC soil sampling results. SU-01 and SU-02 will not be informed by RSC soil sampling. Refer to **Worksheets #17 & #18** for the sampling design and rationale. A GeoProbe® DT45 or DT60 dual-tube sampling system (or equivalent) will be used to collect continuous soil cores to the target depth; however, hand augers will be used to clear the top 5 feet of the boring in accordance with AECOM utility clearance protocols. A total of three soil samples will be collected from each boring: one surface soil sample (0 to 2 feet bgs), one shallow subsurface soil sample from 2 to 4 feet bgs, and one subsurface soil sample approximately 2 feet above the groundwater table or from 13 to 15 feet bgs (whichever occurs first). Specific sampling locations and target boring depths are specified in **Worksheets #17 & #18**. All drilling materials will be PFAS-free.

Where applicable, the soil cores will be continuously logged for lithological descriptions by a field geologist using the USCS. In accordance with the APP/SSHP (AECOM, 2019b; AECOM, 2019d), the soil core will be screened for VOCs with a PID immediately upon recovery. Details regarding the air monitoring procedures and specific action levels are provided in the APP. Observations and measurements will be recorded on field forms and in a non-treated field logbook. Photographs of the boring cores will also be taken. At a minimum, depth interval, recovery thickness, PID concentrations, moisture, relative density, color (using a Munsell soil color chart), and texture (using the USCS) will be recorded. Additional observations to be recorded may include groundwater or perched water depth, organic material, or cultural debris. 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. Refer to *SOP 3-16: Soil and Rock Classification* and *SOP 3-17: Direct Push Sampling Techniques* (**Appendix D**) for additional details.

Each sample will be collected into laboratory-supplied bottleware and submitted to the laboratory for analysis of selected parameters. SU surface and subsurface samples will be analyzed under standard TAT for the target list of 28 PFAS (LC/MS/MS compliant with QSM 5.3 Table B-15). Additionally, other geochemical and physical parameters will be analyzed in a subset of SU soil samples to support evaluation of PFAS fate and transport, in addition to the remedial alternatives analysis. Two soil samples per depth interval at each SU (equivalent to 10%) will be analyzed for total organic carbon (TOC) (USEPA Method 9060A) and pH (USEPA Method 9045D). 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.

If a boring is required in asphalt, it 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. Borings into concrete will be avoided, if possible; however, if borings are advanced into concrete, the borings will be abandoned by backfilling with bentonite chips to approximately 6 inches bgs, and the remainder of the borehole will be filled with concrete to provide as flush a surface as possible. The surface at each location will be restored to match the surrounding area. SU soil sample locations will be marked with a pin flag or spray paint with sample identification number, photo-documented, and recorded with a hand-held GPS.

Permanent Monitoring Well Installation

New permanent monitoring wells will be installed across the facility during RI Mobilization 1. Well installation will be completed in accordance with NYS guidelines and *SOP 3-12: Monitoring Well Installation* (**Appendix D**). The specific monitoring locations and target screen intervals are specified in **Worksheets #17 & #18**.

An exclusion zone will be established with cones surrounding the drilling operation. Each well boring will be hand-cleared to 5 feet bgs prior to drilling in accordance with AECOM utility clearance procedures. The drilling team will place plastic sheeting under the sonic drill rig and will pull it up around the tracks to act as a containment barrier. The sonic drill will be advanced through a tub or surface casing at the ground surface.

The sonic drill rig will advance a 6-inch diameter core barrel to obtain continuous subsurface samples in 10-foot increments. After a soil core is obtained from the 6-inch core barrel, the 8-inch temporary override casing will be advanced to the same depth as the 6-inch core barrel. The 6-inch core barrel and temporary override casing will be advanced through the subsurface to the target depth specified in **Worksheets #17 & #18**.

The soil cores from sonic drilling will be continuously logged for lithological descriptions by a field geologist using the USCS. In accordance with the APP/SSHP (AECOM, 2019b; AECOM, 2019d), the soil core will be screened for VOCs with a PID immediately upon recovery. Details regarding the air monitoring procedures and specific action levels are provided in the APP. Observations and measurements will be recorded on field forms and in a non-treated field logbook. Photographs of the boring cores will also be taken. At a minimum, depth interval, recovery thickness, PID concentrations, moisture, relative density, color (using a Munsell soil color chart), and texture (using the USCS) will be recorded. Additional observations to be recorded may include groundwater or perched water depth, organic material, or cultural debris. Refer to *SOP 3-16: Soil and Rock Classification* (**Appendix D**) for additional details.

Individual monitoring wells will be constructed of 2-inch diameter, schedule 40 poly-vinyl chloride (PVC), 10 to 20-foot long 0.01-inch slotted screens, and 10-foot sections of schedule 40 PVC flush threaded riser pipe. A silica sand filter pack material will then be placed in the annulus between the well pipe and casing. The height of the filter pack above the top of the screen interval will be 2 feet. As the filter pack is placed in the borehole, the temporary casing will periodically be vibrated and pulled up, allowing the well materials to settle into the borehole. Time-release bentonite chips will be placed in the annulus, above the filter pack, and allowed to hydrate. The bentonite seal will be at least 2 feet thick. The hydration time will be per the recommendations of the bentonite manufacturer, which is 2 hours for typical types of bentonite chips. Once the bentonite seal has hydrated, cement-bentonite grout will be placed in the annulus from the top of the bentonite seal up to the ground surface. Cement-bentonite grout placement will continue until the outer casing is removed from the borehole.

Nested monitoring well construction will depend on the number of nested monitoring wells per boring, as specified in **Worksheets #17 & #18** or as determined based on the RSC results. Nested wells with up to two monitoring wells will be constructed of 2-inch diameter, schedule 40 PVC, 10 to 20-foot long 0.01-inch slotted screens, and 10-foot sections of schedule 40 PVC flush threaded riser pipe. All other material specifications will be the same. A 1-foot silica sand filter pack base will be placed at the bottom of the borehole, and the deepest nested well screen and riser will be placed in the borehole. The filter pack material will then be placed in the annulus between the well pipe and casing. The height of the sand above the top of the screen interval will be 3 feet. As the filter pack is placed in the borehole, the temporary casing will periodically be vibrated and pulled up, allowing the well materials to settle into the newly created borehole. Bentonite chips will be placed in the borehole and fill the annular space above the filter pack to 1 foot below the depth of the next screened interval. A one-foot filter pack will be placed on top of

the bentonite seal followed by the next nested well screen and riser. The remaining nested monitoring well construction will follow the same process described above until all nested well screens are in place. The bentonite seal above the most-shallow nested screen interval will be at least 2 feet thick. Once the last bentonite seal has hydrated, cement-bentonite grout will be placed in the annulus throughout the interval from the top of the bentonite seal up to the ground surface. Cement-bentonite grout placement will continue until the outer casing is removed from the borehole.

Monitoring wells will be completed as flushmounts using an 8-inch diameter, bolt-down manhole cover with 12-inch poly skirt in the Camp Smith cantonment area. Stick-up well casings will be used outside the Camp Smith cantonment area. The manhole/stand pipe will be centered in a 2-foot by 2-foot by 8-inch thick concrete pad.

Soil Sample Collection from Permanent Well Borings

During installation of permanent monitoring wells, borings will be advanced using sonic drilling as described above in the procedures for *Permanent Monitoring Well Installation*. All soil cores collected via sonic drilling for well installation will be logged for lithological descriptions. A total of three soil samples will be collected from each well location: one surface soil sample (0 to 2 feet bgs), one shallow subsurface soil sample from 2 to 4 feet bgs, and one subsurface soil sample approximately 2 feet above the groundwater table. Geotechnical soil samples will be collected to support the evaluation of aquifer permeability at select permanent monitoring wells (i.e., a total of 6 screen intervals at 6 locations), which correspond to the locations where hydraulic conductivity (slug) tests will be completed. The soil samples will be collected from a 2-foot interval within the corresponding target screen interval for each well, as specified in **Worksheets #17 & #18**.

Each sample will be collected into laboratory-supplied bottleware and submitted to the laboratory. Subsurface soil samples from permanent monitoring well borings will be analyzed under standard TAT for grain size analysis with sieve and hydrometer (American Society for Testing and Materials [ASTM] D-422). Additionally, one soil sample per location will be analyzed for TOC (USEPA Method 9060A) and pH (USEPA Method 9045D). 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.

Permanent Monitoring Well Development

Permanent monitoring wells will be developed at a minimum of 24 hours after completion of well installation. Development will be completed by a combination of surging with a surge block and over-pumping with a submersible monsoon pump or Waterra pump and associated high-density polyethylene (HDPE) tubing, in accordance with *SOP 3-13: Monitoring Well Development* (**Appendix D**).

Water clarity will be visually monitored and water quality parameters, including dissolved oxygen (DO), specific conductivity (SC), oxidation-reduction potential (ORP), pH, temperature, and turbidity will be measured using a flow-through cell (per *SOP 3-24: Water Quality Parameter Testing for Groundwater Sampling*) every 5 minutes during purging to determine progress of development. The 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. Each well will be developed until the well produces clear (silt-free) water with a minimum of 3 stable water quality readings as outlined below:

- pH – within ± 0.2 units
- DO – within ± 10%

- SC – within ± 3%
- ORP – within ± 10 millivolts (mV)
- Temperature – within ±1 degree Celsius (°C)
- Turbidity – at or below 10 nephelometric turbidity unit (NTU) or within ± 10% if above 10 NTU

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. 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. Groundwater generated during development will be containerized, managed, and disposed of as investigation-derived waste (IDW) as discussed below in *IDW Management* (**Section 14.2**). See *SOP 3-13: Monitoring Well Development* for more details.

Groundwater Sample Collection from Permanent Monitoring Wells

Permanent monitoring wells will be sampled a minimum of 24 hours after completion of well development, in accordance with *SOP 3-14: Groundwater Sampling* (**Appendix D**). 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.

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 3 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 28 PFAS (LC/MS/MS compliant with QSM 5.3 Table B-15). VOCs will additionally be sampled at nested monitoring well location CS-MW006, which is located at the Former Fire Pit potential release area where accelerants may have been used during fire training/burn activities.

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.

Hydraulic Conductivity (Slug) Tests

In-situ hydraulic conductivity test data, via rising or falling head slug tests, will be conducted at select permanent monitoring wells to assess the hydraulic conductivity of the soil surrounding the tested monitoring well. Hydraulic conductivity values can be used to estimate rates of groundwater flow, estimate responses of aquifers to applied stresses (such as pumping), estimate the rate of movement of various chemicals in subsurface zones, and construct and calibrate groundwater flow models. The specific monitoring well locations where slug tests will be completed are specified in **Worksheets #17 & #18**.

The slug testing will commence at least a week after installation, development, or sampling to allow the well to return to equilibrium. An initial round of static water level measurements will be collected prior to initiating the slug tests. Standard slug test techniques will be used at monitoring wells. The standard slug test will entail measurement of water level changes resulting from submergence or withdrawal of a solid cylinder of known volume. Water levels will be monitored and recorded until the water level returns to static conditions or sufficient data are collected to perform the hydraulic conductivity calculations.

The response of the water level will be monitored using an In-Situ Level Troll 700 Data Logger or equivalent. The datalogger will be lowered into each monitoring well and hung at a field-determined depth below top of casing. The datalogger depth will be set low enough to fully submerge the slug. Each datalogger will be programed using a Win-Situ Software application through use of an In-Situ Rugged Reader, laptop, or cell phone. Test results will be monitored in real-time in the field. Equipment that comes into contact with groundwater will be decontaminated between each test location. Hydraulic conductivity will be conducted in accordance with *SOP 3-35: In-Situ Hydraulic Conductivity Testing via Rising or Falling Head Slug Testing* (**Appendix D**).

Surface Water and Sediment Sample Collection

Surface water and sediment samples will be collected from surface water features across the facility, including the Dickiebusch Lake and Putnam Brook. Specific sampling locations are specified in **Worksheets #17 & #18**. Surface water and sediment samples will be collected in areas that are considered “wading” depths along the shoreline and will be co-located. Sample locations within Dickiebusch Lake that are not at wading depths will be accessed using a flat-bottomed boat. Sample locations will be photo-documented and recorded with a hand-held GPS.

Surface water and sediment samples will not be collected directly following a rain event. 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 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, sediment samples will be collected from 0 to 0.5 feet bgs using a hand-driven coring barrel. The sediment will be transferred to a 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 and sediment samples will be analyzed under standard TAT for the target list of 28 PFAS (LC/MS/MS compliant with QSM 5.3 Table B-15). Additionally, 25% of sediment samples will be analyzed for TOC (USEPA Method 9060A) and pH (USEPA Method 9045D). 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 select portions of Putnam Brook to aid in the evaluation of surface water/groundwater interaction. The staff gauges will be located in suspected areas of groundwater and surface water interaction. Therefore, the proposed staff gauge locations may be adjusted based on site walk and reconnaissance. The staff gauges will consist of 1.5-inch galvanized pipe and will be driven into the stream bottom using a slide hammer at targeted locations along the edge of the stream that is at wading depths. The depth of the gauge will be 1 to 3 feet below the stream 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 permanent 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 Putnam Book. The specific locations of groundwater and surface water level measurements are specific in **Worksheets #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 potable well samples. A temperature blank shall be placed in each cooler to ensure that samples are preserved at or below 4 °C during shipment. When groundwater samples are collected for VOC analysis, trip blanks (TBs) will be collected at a rate of one per cooler. 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**. **Worksheets #17 & #18** provides the sampling design and rationale. **Worksheets #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

DPT borings will be abandoned using bentonite chips at completion of sampling activities unless they are being converted into monitoring wells. If the boring is required in asphalt, it will be abandoned by backfilling with soil cuttings to approximately 6 inches bgs, and the remainder of the borehole will be patched with an asphalt cold patch. Borings into concrete will be avoided, if possible, to minimize the introduction of foreign object debris. However, if borings are advanced into concrete, the borings will be abandoned by backfilling with soil cuttings to approximately 6 inches bgs, and the remainder of the borehole will be filled with concrete to provide as flush a surface as possible. The surface at each location will be restored to match the surrounding area. The field team will make the necessary adjustments if state regulations dictate the use of bentonite or grout to abandon soil borings or monitoring wells. See *SOP 3-15: Monitoring Well and Borehole Abandonment* (**Appendix D**) for more details.

Facility Restoration

Following well installation activities, the ground surface will be restored to match the surrounding area (e.g., seeded with grass).

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. 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

Newly installed permanent monitoring wells and staff gauges will be surveyed by a state-registered surveyor to a horizontal accuracy of 0.1 feet and a vertical accuracy of 0.01 feet. A small notch will be cut on the northern side of the well casing, which will be surveyed. The top of casing and ground surface elevation will be surveyed for each newly installed well, and the horizontal location and elevation will be surveyed for each staff gauge. The data will be collected in the applicable North American Datum 1983 State Plane (horizontal) and North American Vertical Datum 1988 (vertical) See *SOP 3-07: Land Surveying* (**Appendix D**) for more details.

Sample locations which are not permanent monitoring wells (i.e., hand auger soil locations, surface water locations, and sediment locations) will be documented using a hand-held GPS (Trimble Geo 7 or equivalent).

Investigation-Derived Waste (IDW) Management

Currently, the disposal of PFAS IDW is not regulated. PFAS IDW is considered a non-hazardous waste and will be managed in accordance with USEPA, *Management of Investigation Derived Waste* (USEPA, 2014) and applicable state regulations, such as the NYSDEC Division of Environmental Remediation *Technical Guidance for Site Investigation and Remediation*. Containerized waste will also be managed in accordance with the Army Guidance for Addressing Releases of PFAS, Q18 (DA, 2018).

Non-hazardous solid IDW (i.e., soil and rock cuttings) generated during RI activities with no evidence of contamination (e.g., no visual or olfactory evidence of contamination, no elevated readings on the PID) will be returned to the ground surface on the downgradient side of the borehole or at an onsite location designated by the NYARNG. The solid IDW will not be sampled and will assume the PFAS characteristics of the associated soil samples. Although not anticipated, if elevated PID readings are observed, or if visual or olfactory evidence of petroleum contamination is observed, the soil IDW from the select boring location with impacts will be containerized in properly labeled 55-gallon drums (see SOP 3-05). The containerized IDW will be temporarily stored onsite at a location designated by the NYARNG. AECOM will coordinate transport and disposal of any containerized IDW with the NYARNG and NYSDEC to ensure proper disposal in accordance with Section 6 New York Codes, Rules, and Regulations (NYCRR) Part 364.

Liquid IDW (i.e., drilling slurry, well development/purge water, and decontamination fluids) generated during RI activities will either be containerized in properly labeled 55-gallon drums (see SOP 3-05) or in portable bulk storage tanks (e.g., frac tank). If in drums, liquid IDW will be containerized separately by location of generation. The containerized liquid IDW will be temporarily stored at a location designated by NYARNG until the analytical results are available. Liquid IDW drums will only be filled 70% to account for freeze/thaw cycles. Drums will be labeled with a paint pen and faced away from the south and west. RI groundwater sample analytical results for each location will be evaluated to determine if IDW treatment is required prior to discharge to ground. Liquid IDW from locations that exceed the NYSDOH MCL will be run through a GAC filter, and then sampled. Liquid IDW, either treated or not, exhibiting concentrations below NYSDOH MCLs will be discharged at an onsite location designated by the NYARNG. If liquid IDW is containerized in frac tanks, samples will be collected upon completion of waste accumulation to determine if treatment is required prior to discharge to ground. For any IDW not discharged to ground, AECOM will coordinate transport and disposal of any containerized IDW with the NYARNG and NYSDEC to ensure proper disposal in accordance with Section 6 NYCRR Part 364.

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 South Carolina, a DoD ELAP and NYSDOH 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. VOC analyses will be conducted in accordance with USEPA Method 8260D.

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 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 AECOM 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, electronic laboratory data will be verified for accuracy against the hardcopy laboratory report, and the QAPP will be established using the 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 the RI 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 BERA is needed. The Human Health and Ecological Risk Assessment Work Plan is presented in **Appendix F**.

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 PFOS, PFOA, and PFBS 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 (e.g., soil, sediment, surface water) 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 viable 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 facility-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 facility-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.

- Completion of Steps 3b through 7 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 facility-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, facility-specific background concentrations, calculated values based on food web modeling, and/or facility-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, laboratory analysis, and data validation, a comprehensive RI Report 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 facility-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 facility 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;
- Summary of the HHRA and SLERA/BERA; and
- Conclusions and summary of the RI findings.

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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, 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 NYS-specific criteria, USEPA HAs, 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. Facility-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 facility-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 28 PFAS has been established for the project. Additionally, four other PFAS have been added to the target analyte list (TAL) and include EtFOSA, EtFOSE, MeFOSA and 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).

In order to expedite RSC results from the analytical laboratory, RSC grab soil samples for PFAS will be analyzed for a shortlist of eight PFAS. The eight PFAS included in the shortlist for soil are the compounds for which OSD has established SLs (PFOA, PFOS, and PFBS), in addition to five compounds to aid in identification of PFAS release areas (PFHxS, EtFOSA, EtFOSE, MeFOSA, and MeFOSE). The RSC shortlist was specifically selected for identification of PFAS release areas, in addition to refining the extent of compounds with SLs in soil and groundwater.

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, as described in a 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 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.

Additionally, the USEPA HAs for PFOA and PFOS in May 2016 (USEPA 2016a; USEPA, 2016b) will be used as SLs for groundwater samples. The SLs are shown in **Table 10-1** (**Worksheet #10**).

Human health SLs for VOCs will include the USEPA MCLs (USEPA, 2022), USEPA tap water RSLs (USEPA, 2021b), and USEPA Vapor Intrusion Screening Levels (VISLs) for groundwater (USEPA, 2021d).

Ecological Screening Criteria for PFAS

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

New York Criteria for PFAS

The NYSDOH has formally adopted finished drinking water MCLs for PFOA and PFOS (NYSDOH, 2020 and NYCRR, 2022). The NYSDOH MCLs for PFAS 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 New York screening criteria, including the Technical and Operational Series (TOGS), 1.1.1. Groundwater Effluent Limitations (Table 5; Class A) (NYDEC, 1998, 1999, 2000, and 2004) for evaluating VOCs in groundwater, are included in the DQLs.

Laboratory: Pace South Carolina
Matrix: Groundwater
Analyte Group: PFAS (28 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	1.0	2.0	4.0
Perfluorobutanesulfonic acid	PFBS	375-73-5	600	HH; USEPA Tap Water	72	130	1.0	2.0	4.0
Perfluoropentanoic acid	PFPeA	2706-90-3	NA	--	72	129	1.0	2.0	4.0
Perfluorohexanoic acid	PFHxA	307-24-4	NA	--	72	129	1.0	2.0	4.0
Perfluorohexanesulfonic acid	PFHxS	355-46-4	NA	--	68	131	1.0	2.0	4.0
Perfluoroheptanoic acid	PFHpA	375-85-9	NA	--	72	130	1.0	2.0	4.0
Perfluoroheptanesulfonic acid	PFHpS	375-92-8	NA	--	69	134	1.0	2.0	4.0
Perfluorooctanoic acid	PFOA	335-67-1	10	HH; NYS DOH MCLs	71	133	1.0	2.0	4.0
Perfluorooctanesulfonic acid	PFOS	1763-23-1	10	HH; NYS DOH MCLs	65	140	1.0	2.0	4.0
Perfluorooctanesulfonamide	PFOSA	754-91-6	NA	--	67	137	1.0	2.0	4.0
Fluorotelomer sulfonic acid 6:2	FTS 6:2	27619-97-2	NA	--	64	140	2.0	4.0	8.0
Perfluorononanoic acid	PFNA	375-95-1	NA	--	69	130	1.0	2.0	4.0
Perfluorodecanoic acid	PFDA	335-76-2	NA	--	71	129	1.0	2.0	4.0
Perfluorodecanesulfonic acid	PFDS	335-77-3	NA	--	53	142	1.0	2.0	4.0
Fluorotelomer sulfonic acid 8:2	FTS 8:2	39108-34-4	NA	--	67	138	2.0	4.0	8.0
Perfluoroundecanoic acid	PFUdA	2058-94-8	NA	--	69	133	1.0	2.0	4.0
Perfluorododecanoic acid	PFDoA	307-55-1	NA	--	72	134	1.0	2.0	4.0
Perfluorotridecanoic acid	PFTrDA	72629-94-8	NA	--	65	144	1.0	2.0	4.0
Perfluorotetradecanoic acid	PFTeA	376-06-7	NA	--	71	132	1.0	2.0	4.0
2-(N-Ethylperfluorooctanesulfonamido) acetic acid	N-EtFOSAA	2991-50-6	NA	--	61	135	2.0	4.0	8.0
2-(N-Methylperfluorooctanesulfonamido) acetic acid	N-MeFOSAA	2355-31-9	NA	--	65	136	2.0	4.0	8.0
Fluorotelomer sulfonic acid 4:2	FTS 4:2	757124-72-4	NA	--	63	143	2.0	4.0	8.0
Perfluorononanesulfonic acid	PFNS	68259-12-1	NA	--	69	127	1.0	2.0	4.0
Perfluoropentanesulfonic acid	PFPeS	2706-91-4	NA	--	71	127	1.0	2.0	4.0
N-ethyl perfluorooctane sulfonamide	EtFOSA	5141-50-2	NA	--	70	130	1.0	4.0	8.0
N-ethyl perfluorooctane sulfonamido ethanol	EtFOSE	1691-99-2	NA	--	70	130	1.0	4.0	8.0
N-methyl perfluorooctane sulfonamide	MeFOSA	31506-32-8	NA	--	70	130	1.0	4.0	8.0
N-methyl perfluorooctane sulfonamido ethanol	MeFOSE	24448-09-7	NA	--	70	130	1.0	4.0	8.0

Notes:
1.) DQLs for groundwater were selected based on the lower of the following:
(a) New York State Department of Health Maximum Contaminant Levels (NYS DOH MCLs) Subpart 5-1.52 Tables, Table 3, Effective Date: January 19, 2022 (NYS DOH, 2022).

(b) USEPA's Lifetime Drinking Water HA levels for PFOS and PFOA (as individual chemicals and the combined PFOS + PFOA concentration) (USEPA 2016a; USEPA, 2016b).
(c) 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 (September 2021 version) 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, 2021c).

% = percent
CAS = Chemical Abstracts Service
DL = detection limit
DQL = data quality limit
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 South Carolina
Matrix: Surface Water (28 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	1.0	2.0	4.0
Perfluorobutanesulfonic acid	PFBS	375-73-5	400,000	Eco; Freshwater Chronic ESV Aquatic Life	72	130	1.0	2.0	4.0
Perfluoropentanoic acid	PFPeA	2706-90-3	140,000	Eco; Freshwater Chronic Aquatic Life RWQ RBSL	72	129	1.0	2.0	4.0
Perfluorohexanoic acid	PFHxA	307-24-4	28,800	Eco; Freshwater Chronic ESV Aquatic Life	72	129	1.0	2.0	4.0
Perfluorohexanesulfonic acid	PFHxS	355-46-4	5,500	Eco; Wildlife ESV	68	131	1.0	2.0	4.0
Perfluoroheptanoic acid	PFHpA	375-85-9	870,000	Eco; Freshwater Chronic Aquatic Life RWQ RBSL	72	130	1.0	2.0	4.0
Perfluoroheptanesulfonic acid	PFHpS	375-92-8	NA	--	69	134	1.0	2.0	4.0
Perfluorooctanoic acid	PFOA	335-67-1	4,400	Eco; Wildlife RBSL	71	133	1.0	2.0	4.0
Perfluorooctanesulfonic acid	PFOS	1763-23-1	75	Eco; Wildlife RBSL	65	140	1.0	2.0	4.0
Perfluorooctanesulfonamide	PFOSA	754-91-6	NA	--	67	137	1.0	2.0	4.0
Fluorotelomer sulfonic acid 6:2	FTS 6:2	27619-97-2	NA	--	64	140	2.0	4.0	8.0
Perfluorononanoic acid	PFNA	375-95-1	2,080	Eco; Wildlife ESV	69	130	1.0	2.0	4.0
Perfluorodecanoic acid	PFDA	335-76-2	660	Eco; Wildlife ESV	71	129	1.0	2.0	4.0
Perfluorodecanesulfonic acid	PFDS	335-77-3	NA	--	53	142	1.0	2.0	4.0
Fluorotelomer sulfonic acid 8:2	FTS 8:2	39108-34-4	NA	--	67	138	2.0	4.0	8.0
Perfluoroundecanoic acid	PFUdA	2058-94-8	NA	--	69	133	1.0	2.0	4.0
Perfluorododecanoic acid	PFDoA	307-55-1	72,000	Eco; Freshwater Chronic Aquatic Life RWQ RBSL	72	134	1.0	2.0	4.0
Perfluorotridecanoic acid	PFTrDA	72629-94-8	NA	--	65	144	1.0	2.0	4.0
Perfluorotetradecanoic acid	PFTeA	376-06-7	NA	--	71	132	1.0	2.0	4.0
2-(N-Ethylperfluorooctanesulfonamido) acetic acid	N-EtFOSAA	2991-50-6	NA	--	61	135	2.0	4.0	8.0
2-(N-Methylperfluorooctanesulfonamido) acetic acid	N-MeFOSAA	2355-31-9	NA	--	65	136	2.0	4.0	8.0
Fluorotelomer sulfonic acid 4:2	FTS 4:2	757124-72-4	NA	--	63	143	2.0	4.0	8.0
Perfluorononanesulfonic acid	PFNS	68259-12-1	NA	--	69	127	1.0	2.0	4.0
Perfluoropentanesulfonic acid	PFPeS	2706-91-4	NA	--	71	127	1.0	2.0	4.0
N-ethyl perfluorooctane sulfonamide	EtFOSA	5141-50-2	NA	--	70	130	2.0	4.0	8.0

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)
N-ethyl perfluorooctane sulfonamido ethanol	EtFOSE	1691-99-2	NA	--	70	130	2.0	4.0	8.0
N-methyl perfluorooctane sulfonamide	MeFOSA	31506-32-8	NA	--	70	130	2.0	4.0	8.0
N-methyl perfluorooctane sulfonamido ethanol	MeFOSE	24448-09-7	NA	--	70	130	2.0	4.0	8.0

Notes:

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

(a) Risk-based surface water SLs protective of incidental ingestion by recreational users. Values were calculated using the USEPA RSL Calculator (November 2021 version; USEPA, 2021b) 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, 2021c).

(b) 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 final chronic value.

(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 surface water for aquatic wildlife.
- Freshwater chronic screening levels for aquatic life RWQ RBSL

(d) 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.

% = percent
CAS = Chemical Abstracts Service
DL = detection limit
DQL = data quality limit
Eco = ecological based DQL
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 South Carolina
Matrix: Soil
Analyte Group: PFAS (28 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	0.20	0.50	1.0
Perfluorobutanesulfonic acid	PFBS	375-73-5	817	Eco; Mammalian Soil ESV	72	128	0.20	0.50	1.0
Perfluoropentanoic acid	PFPeA	2706-90-3	NA	--	69	132	0.20	0.50	1.0
Perfluorohexanoic acid	PFHxA	307-24-4	6,200	Eco; Mammalian Soil ESV	70	132	0.20	0.50	1.0
Perfluorohexanesulfonic acid	PFHxS	355-46-4	2.8	Eco; Mammalian Soil ESV	67	130	0.20	0.50	1.0
Perfluoroheptanoic acid	PFHpA	375-85-9	1,000	Eco; Invertebrates NOEC Soil SL	71	132	0.20	0.50	1.0
Perfluoroheptanesulfonic acid	PFHpS	375-92-8	NA	--	70	132	0.20	0.50	1.0
Perfluorooctanesulfonic acid	PFOS	1763-23-1	8.7	Eco; Mammalian Soil ESV	68	136	0.20	0.50	1.0
Fluorotelomer sulfonic acid 6:2	FTS 6:2	27619-97-2	NA	--	64	140	0.50	1.0	2.0
Perfluorooctanoic acid	PFOA	335-67-1	84	Eco; Plants NOEC Soil SL	69	133	0.20	0.50	1.0
Perfluorooctanesulfonamide	PFOSA	754-91-6	NA	--	67	137	0.20	0.50	1.0
Perfluorononanoic acid	PFNA	375-95-1	24.2	Eco; Mammalian Soil ESV	72	129	0.20	0.50	1.0
Perfluoroundecanoic acid	PFUdA	2058-94-8	NA	--	64	136	0.20	0.50	1.0
Perfluorodecanoic acid	PFDA	335-76-2	67.7	Eco; Mammalian Soil ESV	69	133	0.20	0.50	1.0
Perfluorodecanesulfonic acid	PFDS	335-77-3	NA	--	59	134	0.20	0.50	1.0
Fluorotelomer sulfonic acid 8:2	FTS 8:2	39108-34-4	NA	--	65	137	0.50	1.0	2.0
Perfluorododecanoic acid	PFDoA	307-55-1	NA	--	69	135	0.20	0.50	1.0
Perfluorotridecanoic acid	PFTrDA	72629-94-8	NA	--	66	139	0.20	0.50	1.0
Perfluorotetradecanoic acid	PFTeA	376-06-7	NA	--	69	133	0.20	0.50	1.0
2-(N-Ethylperfluorooctanesulfonamido) acetic acid	N-EtFOSAA	2991-50-6	NA	--	61	139	0.50	1.0	2.0
2-(N-Methylperfluorooctanesulfonamido) acetic acid	N-MeFOSAA	2355-31-9	NA	--	63	144	0.50	1.0	2.0

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)
Fluorotelomer sulfonic acid 4:2	FTS 4:2	757124-72-4	NA	--	62	145	0.50	1.0	2.0
Perfluorononanesulfonic acid	PFNS	68259-12-1	NA	--	69	125	0.20	0.50	1.0
Perfluoropentanesulfonic acid	PFPeS	2706-91-4	NA	--	73	123	0.20	0.50	1.0
N-ethyl perfluorooctane sulfonamide	EtFOSA	5141-50-2	NA	--	70	130	0.50	1.0	2.0
N-ethyl perfluorooctane sulfonamido ethanol	EtFOSE	1691-99-2	NA	--	70	130	0.50	1.0	2.0
N-methyl perfluorooctane sulfonamide	MeFOSA	31506-32-8	NA	--	70	130	0.50	1.0	2.0
N-methyl perfluorooctane sulfonamido ethanol	MeFOSE	24448-09-7	NA	--	70	130	0.50	1.0	2.0

Notes:

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

(a) 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 (September 2021 version) 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, 2021c).

(b) 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 (September 2021 version) 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, 2021c).

(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). Recommended Toxicity Benchmarks for Terrestrial Plants and Invertebrates; based on NOECs.

(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 soil for terrestrial wildlife.
- NOEC-based soil screening level for plants.
- NOEC-based soil screening level for invertebrates.

(e) 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
ESV = ecological screening value
FTS = fluorotelomer sulfonic acid
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 South Carolina
Matrix: Soil
Analyte Group: PFAS (8 Compound RSC Shortlist)
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)
Perfluorobutanesulfonic acid	PFBS	375-73-5	817	Eco; Mammalian Soil ESV	72	128	1.0	2.0	4.0
Perfluorohexanesulfonic acid	PFHxS	355-46-4	28	Eco; Mammalian Soil ESV	67	130	1.0	2.0	4.0
Perfluorooctanesulfonic acid	PFOS	1763-23-1	8.7	Eco; Mammalian Soil ESV	68	136	1.0	2.0	4.0
Perfluorooctanoic acid	PFOA	335-67-1	84	Eco; Plants NOEC Soil SL	69	133	1.0	2.0	4.0
N-ethyl perfluorooctane sulfonamide	EtFOSA	5141-50-2	NA	--	70	130	2.0	4.0	8.0
N-ethyl perfluorooctane sulfonamido ethanol	EtFOSE	1691-99-2	NA	--	70	130	2.0	4.0	8.0
N-methyl perfluorooctane sulfonamide	MeFOSA	31506-32-8	NA	--	70	130	2.0	4.0	8.0
N-methyl perfluorooctane sulfonamido ethanol	MeFOSE	24448-09-7	NA	--	70	130	2.0	4.0	8.0

Notes:

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

(a) 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 (September 2021 version) 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, 2021c).

(b) 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 (September 2021 version) 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, 2021c).

(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). Recommended Toxicity Benchmarks for Terrestrial Plants and Invertebrates; based on NOECs.

(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 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
ESV = ecological screening value
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 South Carolina
Matrix: Sediment
Analyte Group: PFAS (28 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; Wildlife RBSL	71	135	0.20	0.50	1.0
Perfluorobutanesulfonic acid	PFBS	375-73-5	730	Eco; Wildlife RBSL	72	128	0.20	0.50	1.0
Perfluoropentanoic acid	PFPeA	2706-90-3	NA	--	69	132	0.20	0.50	1.0
Perfluorohexanoic acid	PFHxA	307-24-4	1,800	Eco; Wildlife RBSL	70	132	0.20	0.50	1.0
Perfluorohexanesulfonic acid	PFHxS	355-46-4	NA	--	67	130	0.20	0.50	1.0
Perfluoroheptanoic acid	PFHpA	375-85-9	NA	--	71	132	0.20	0.50	1.0
Perfluoroheptanesulfonic acid	PFHpS	375-92-8	NA	--	70	132	0.20	0.50	1.0
Perfluorooctanesulfonic acid	PFOS	1763-23-1	1.4	Eco; Wildlife RBSL	68	136	0.20	0.50	1.0
Fluorotelomer sulfonic acid 6:2	FTS 6:2	27619-97-2	NA	--	64	140	0.50	1.0	2.0
Perfluorooctanoic acid	PFOA	335-67-1	6	Eco; Wildlife RBSL	69	133	0.20	0.50	1.0
Perfluorooctanesulfonamide	PFOSA	754-91-6	NA	--	67	137	0.20	0.50	1.0
Perfluorononanoic acid	PFNA	375-95-1	10	Eco; Wildlife RBSL	72	129	0.20	0.50	1.0
Perfluoroundecanoic acid	PFUdA	2058-94-8	NA	--	64	136	0.20	0.50	1.0
Perfluorodecanoic acid	PFDA	335-76-2	NA	--	69	133	0.20	0.50	1.0
Perfluorodecanesulfonic acid	PFDS	335-77-3	NA	--	59	134	0.20	0.50	1.0
Fluorotelomer sulfonic acid 8:2	FTS 8:2	39108-34-4	NA	--	65	137	0.50	1.0	2.0
Perfluorododecanoic acid	PFDoA	307-55-1	NA	--	69	135	0.20	0.50	1.0
Perfluorotridecanoic acid	PFTrDA	72629-94-8	NA	--	66	139	0.20	0.50	1.0
Perfluorotetradecanoic acid	PFTeA	376-06-7	NA	--	69	133	0.20	0.50	1.0
2-(N-Ethylperfluorooctanesulfonamido) acetic acid	N-EtFOSAA	2991-50-6	NA	--	61	139	0.50	1.0	2.0

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)
2-(N-Methylperfluorooctanesulfonamido) acetic acid	N-MeFOSAA	2355-31-9	NA	--	63	144	0.50	1.0	2.0
Fluorotelomer sulfonic acid 4:2	FTS 4:2	757124-72-4	NA	--	62	145	0.50	1.0	2.0
Perfluorononanesulfonic acid	PFNS	68259-12-1	NA	--	69	125	0.20	0.50	1.0
Perfluoropentanesulfonic acid	PFPeS	2706-91-4	NA	--	73	123	0.20	0.50	1.0
N-ethyl perfluorooctane sulfonamide	EtFOSA	5141-50-2	NA	--	70	130	0.50	1.0	2.0
N-ethyl perfluorooctane sulfonamido ethanol	EtFOSE	1691-99-2	NA	--	70	130	0.50	1.0	2.0
N-methyl perfluorooctane sulfonamide	MeFOSA	31506-32-8	NA	--	70	130	0.50	1.0	2.0
N-methyl perfluorooctane sulfonamido ethanol	MeFOSE	24448-09-7	NA	--	70	130	0.50	1.0	2.0

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 (November 2021 version; USEPA, 2021b) 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, 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, 2021c).

(b) 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.

(c) 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 µg/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 South Carolina
Matrix: Groundwater
Analyte Group: VOCs
Method: USEPA 8260D

Analyte	CAS Number	DQL (µg/L)[1,2]	DQL Source	LOQ (µg/L)	LOD (µg/L)	DL (µg/L)	Accuracy Control Limit (%R)	Precision Control Limit RPD
1,1,1-Trichloroethane	71-55-6	200	SDECUSEPA MCL	1.00	0.80	0.40	74-131	≤20
1,1,2,2-Tetrachloroethane	79-34-5	0.076	USEPA Tapwater RSL	1.00	0.80	0.40	71-121	≤20
1,1,2-Trifluoro-1,2,2-trichloroethane	76-13-1	24.2	USEPA VISL	1.00	0.84	0.42	70-136	≤20
1,1-Dichloroethene	75-35-4	7	USEPA MCL	1.00	0.80	0.40	71-131	≤20
1,2,4-Trichlorobenzene	120-82-1	0.4	USEPA Tapwater RSL	1.00	0.80	0.40	69-130	≤20
1,2-Dibromo-3-chloropropane	96-12-8	0.00033	USEPA Tapwater RSL	1.00	0.80	0.40	62-128	≤20
1,2-Dibromoethane	106-93-4	0.0075	USEPA Tapwater RSL	1.00	0.80	0.40	77-121	≤20
1,2-Dichlorobenzene	95-50-1	5	NYSDEC TOGS	1.00	0.80	0.40	80-119	≤20
1,2-Dichloroethane	107-06-2	0.17	USEPA Tapwater RSL	1.00	0.80	0.40	73-128	≤20
1,2-Dichloropropane	78-87-5	0.82	USEPA Tapwater RSL	1.00	0.80	0.40	78-122	≤20
1,3-Dichlorobenzene	541-73-1	5	NYSDEC TOGS	1.00	0.80	0.40	80-119	≤20
1,4-Dichlorobenzene	106-46-7	0.48	USEPA Tapwater RSL	1.00	0.80	0.40	79-118	≤20
2-Butanone	78-93-3	560	USEPA Tapwater RSL	10	4.0	2.0	56-143	≤20
2-Hexanone	591-78-6	3.8	USEPA Tapwater RSL	10	4.0	2.0	57-139	≤20
4-Methyl-2-pentanone	108-10-1	630	USEPA Tapwater RSL	10	4.0	2.0	67-130	≤20
Acetone	67-64-1	1800	USEPA Tapwater RSL	20	10	5.0	39-160	≤20
Benzene	71-43-2	0.46	USEPA Tapwater RSL	1.0	0.80	0.40	79-120	≤20
Bromodichloromethane	75-27-4	0.13	USEPA Tapwater RSL	1.0	0.80	0.40	79-125	≤20
Bromoform	75-25-2	3.3	USEPA Tapwater RSL	1.0	0.80	0.40	66-130	≤20
Bromomethane	74-83-9	0.75	USEPA Tapwater RSL	2.0	0.80	0.40	53-141	≤20
Carbon disulfide	75-15-0	8181	USEPA Tapwater RSL	1.0	0.80	0.40	64-133	≤20
Carbon tetrachloride	56-23-5	0.415	USEPA VISL	1.0	0.80	0.40	72-136	≤20
Chlorobenzene	108-90-7	5	NYSDEC TOGS	1.0	0.80	0.40	82-118	≤20
Chloroethane	75-00-3	830	USEPA Tapwater RSL	2.0	0.80	0.40	60-138	≤20
Chloroform	67-66-3	0.22	USEPA Tapwater RSL	1.0	0.80	0.40	79-124	≤20
Chloromethane	74-87-3	19	USEPA Tapwater RSL	2.0	1.0	0.50	50-139	≤20
cis-1,2-Dichloroethene	156-59-2	3.6	USEPA Tapwater RSL	1.0	0.80	0.40	78-123	≤20
cis-1,3-Dichloropropene	10061-01-5	0.47	USEPA Tapwater RSL	1.0	0.80	0.40	75-124	≤20
Cyclohexane	110-82-7	102	USEPA VISL	1.0	0.80	0.40	71-130	≤20
Dibromochloromethane	124-48-1	0.87	USEPA Tapwater RSL	1.0	0.80	0.40	74-126	≤20
Dichlorodifluoromethane	75-71-8	0.744	USEPA VISL	2.0	1.2	0.60	32-152	≤20
Ethylbenzene	100-41-4	1.5	USEPA Tapwater RSL	1.0	0.80	0.40	79-121	≤20

Analyte	CAS Number	DQL (µg/L)[1,2]	DQL Source	LOQ (µg/L)	LOD (µg/L)	DL (µg/L)	Accuracy Control Limit (%R)	Precision Control Limit RPD
Isopropylbenzene (Cumene)	98-82-8	45	USEPA Tapwater RSL	1.0	0.80	0.40	72-131	≤20
m&p-Xylene	136777-61-2	19	USEPA Tapwater RSL	1.0	0.80	0.40	80-121	≤20
Methyl Acetate	79-20-9	2000	USEPA Tapwater RSL	1.0	0.80	0.40	56-136	≤20
Methylcyclohexane	108-87-2	NA	--	5.0	0.80	0.40	72-132	≤20
Methylene chloride	75-09-2	5	USEPA MCL	1.0	0.80	0.40	74-124	≤20
tert-Butyl methyl ether (MTBE)	1634-04-4	414	USEPA Tapwater RSL	1.0	0.80	0.40	71-124	≤20
o-Xylene	95-47-6	19	USEPA Tapwater RSL	1.0	0.80	0.40	78-122	≤20
Styrene	100-42-5	100	USEPA MCL	1.0	0.82	0.41	78-123	≤20
Tetrachloroethene	127-18-4	4.1	USEPA Tapwater RSL	1.0	0.80	0.40	74-129	≤20
Toluene	108-88-3	110	USEPA Tapwater RSL	1.0	0.80	0.40	80-121	≤20
trans-1,2-Dichloroethene	156-60-5	6.8	USEPA Tapwater RSL	1.0	0.80	0.40	75-124	≤20
trans-1,3-Dichloropropene	10061-02-6	0.47	USEPA Tapwater RSL	1.0	0.80	0.40	73-127	≤20
Trichloroethene	79-01-6	0.28	USEPA Tapwater RSL	1.0	0.80	0.40	79-123	≤20
Trichlorofluoromethane	75-69-4	520	USEPA Tapwater RSL	1.0	0.80	0.40	65-141	≤20
Vinyl chloride	75-01-4	0.019	USEPA Tapwater RSL	1.0	0.80	0.40	58-137	≤20
Xylene (total)	1330-20-7	19	USEPA Tapwater RSL	1.0	0.80	0.40	79-121	≤20

Notes:

1.) Italics indicate the target analytes where the DQL is lower than the DL. The DL will be the DQL in instances where the DQL is not analytically achievable. The LOD will be used as the DQL for non-detects. The risk assessments will include screens of the detection limits against the applicable screening levels and will discuss any uncertainties associated with cases where the detection limits are above the screening levels.

2.) DQLs for groundwater were selected based on the lower of the following:

(a) USEPA Regional Screening Levels (RSLs) for tap water (November 2021 version; USEPA, 2021b), based on a target hazard quotient of 0.1 and a target risk level of 1E-06.

(b) USEPA Vapor Intrusion Screening Levels (VISLs) (November 2021 version; USEPA, 2021e) for a residential scenario, target groundwater concentrations, based on a target hazard quotient of 0.1 and a target risk level of 1E-06 and the default ambient groundwater temperature of 25 degrees Centigrade.

(c) USEPA Maximum Contaminant Levels (MCLs). National Primary Drinking Water Regulations (USEPA, 2022).

(d) New York State Technical and Operational Guidance Series (TOGS), 1.1.1. Groundwater Effluent Limitations, Table 5 (Class SC), dated June 1998, January 1999 Errata Sheet, April 2000 Addendum, and June 2004 Addendum (NYSDEC, 1998, 1999, 2000, and 2004).

%R = percent recovery
µg/L = micrograms per Liter
CAS = Chemical Abstracts Service
DL = detection limit
DQL = data quality limit
GCC = Generic Cleanup Criteria
LOD = limit of detection
LOQ = limit of quantitation
MCL = Maximum Contaminant Level
NA = not available
NYCRR = New York Codes, Rules, and Regulations
RPD = relative percent difference
RSL = Regional Screening Level
TOGS = Technical and Operational Guidance Series
USEPA = United States Environmental Protection Agency
VISL = Vapor Intrusion Screening Level

Laboratory: Pace Green Bay
Matrix: Solid (Soil/ Sediment)
Analyte Group: TOC
Method: Lloyd Kahn

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	100,000	100,000	50,000	80-120	≤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 South Carolina
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

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

Worksheets #17 & #18 provide the sampling design and rationale, in addition to the sampling locations and methods, for the Camp Smith RI. The sampling program was designed to meet the DQOs established in **Worksheet #11**, while considering the preliminary CSM summarized in **Worksheet #10**. As discussed in **Worksheet #10**, three AOIs were identified at Camp Smith during the SI (AECOM, 2022) and two additional potential release areas were identified after the SI:

- AOI 1: Former Fire Pit;
- AOI 2: Former Fire Station;
- AOI 3: Former Airfield and Former NYS Academy of Fire Science Annex;
- Sludge Drying Beds; and
- Gravel Pit.

The RI Mobilization 1 sampling program was designed to refine the nature and extent of PFAS in soil at each release area and downgradient within the investigation area, conduct preliminary screening and evaluate the results as part of the comprehensive HHRA and ERA, and define more precise boundaries for potential response actions during the FS, if warranted. Analytical data from the SI (AECOM, 2022) were used to refine the approach for the RI. Data collected during the RI Mobilization 1 will be used to refine the approach for additional monitoring well installation and groundwater and soil sampling during the RI Mobilization 2, should all data quality objectives not be met during Mobilization 1.

The sampling program for the RI Mobilization 1 will include:

- Collection of RSC surface and shallow subsurface soil samples for analysis of the shortlist of eight PFAS under rapid 48-hour TAT at Camp Smith at the Gravel Pit and the Sludge Drying Beds;
- Collection of surface and subsurface soil samples for analysis of PFAS (target list of 28 PFAS) for characterization of the PFAS release areas using a sampling grid approach within SUs;
- Installation of new permanent nested monitoring wells onsite at Camp Smith;
- Collection of groundwater samples for analysis of PFAS (target list of 28 PFAS) and VOCs (only at the Former Fire Pit) from existing and new permanent monitoring wells and two supply wells onsite at Camp Smith;
- Hydraulic conductivity testing (slug testing) and geotechnical soil sample collection to determine aquifer permeability at select monitoring well locations;
- Collection of surface water and sediment samples for analysis of PFAS (target list of 28 PFAS) from downgradient surface water features, including nearby tributaries of Dickiebusch Lake, Dickiebusch Lake, and Putnam Brook; and
- Collection of synoptic water levels in monitoring wells and gauging of surface water levels.

The following subsections provide the specific sampling design and rationale for the selection of sampling locations for the RI. The proposed locations of samples to be collected as part of the RI are presented on **Figure 17-1** through **Figure 17-7**. The specific design rationale for each task, in addition to the sampling locations and methods, are included in **Table 17-1** through **Table 17-5**. 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 Manager, USACE, and ARNG.

17.1 Rapid Site Characterization of Soil

Based on the evaluation of available data in soil and groundwater, as presented in **Section 10.5**, the presence of PFAS has been confirmed in soil and groundwater within or downgradient of all three AOIs, with exceedances of the SLs in groundwater. Additionally, PFAS were confirmed upgradient of AOI 1 in groundwater and soil, and a new potential PFAS release area, Sludge Drying Beds, has been identified after the SI was performed. The exact locations and extent of the PFAS release upgradient to AOI 1 and the presence/absence of PFAS at the Sludge Drying Beds, as well as the migration pathways between these potential release areas and boundaries, are not fully understood.

To address these data gaps, RSC methods, including surface and shallow subsurface soil sampling, will be utilized during RI Mobilization 1. The RSC surface soil sampling program will refine the understanding of the suspected release areas at the Camp Smith using an efficient and cost-effective approach by limiting the number of subsequent mobilizations required to achieve DQOs. In accordance with the goals of the project outlined in **Worksheet #11**, the RSC methods will aid in the identification of PFAS release areas, new locations for permanent monitoring wells, and placement of the soil SUs for collection of surface and subsurface soil data for use in the risk assessments. RSC surface and shallow subsurface soil samples will be analyzed by the laboratory under a rapid TAT of 48 hours.

The rationale for the proposed RSC program is based on quickly identifying the presence of a potential PFAS release and defining the extent of that release. Since PFAS contain a wide variety of compounds with different structures and reactive moieties, some PFAS compounds tend to sorb well to soils when released at the surface, and others are highly mobile and may move to the subsurface. Elevated surface soil concentrations of the less-mobile PFAS compounds are good indicators of a release area.

PFAS RSC of Surface and Shallow Subsurface Soil

RSC of surface and shallow subsurface soil will be conducted at the Gravel Pit and the Sludge Drying Beds. Based on the existing data collected during the SI, the PFAS releases are not adequately defined to the north of AOI 1. The Gravel Pit was identified as a potential PFAS release area to the north of AOI 1 based on aerial imagery and a site walk. Additionally, RSC of surface soil at the Sludge Drying Beds will assess if PFAS-laden sludge was spread and created a secondary release area.

An initial total of 24 RSC surface soil samples (not including QC samples) will be collected within the Gravel Pit (RSC01) and the Sludge Drying Beds (RSC02). Visual Sample Plan (VSP) version 7 software, developed by the Pacific Northwest National Laboratory, was used to generate a statistical sampling plan for RSC sampling within each established area (VSP Development Team, 2020). For each RSC sampling grid, a total of 24 samples will be initially collected from 12 boring

locations at 0 to 2 and 2 to 4 feet bgs. The locations of these 12 borings 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 that 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.

The initial RSC sample grid locations are shown on **Figure 17-1**. The specific surface soil sample locations for RSC01 and RSC02 are shown on **Figure 17-2** and **Figure 17-3**. The rationale for the RSC soil sample locations is provided in **Table 17-1**. RSC soil samples will be analyzed for a shortlist of eight PFAS by LC/MS/MS compliant with QSM 5.3 Table B-15, as specified in **Worksheet #15**, under rapid 48-hour TAT. The eight PFAS included in the shortlist are the compounds for which OSD has established SLs (PFOA, PFOS, and PFBS; Assistant Secretary of Defense, 2021), in addition to five precursor compounds to aid in identification of PFAS release areas (PFHxS, EtFOSA, EtFOSE, MeFOSA, and MeFOSE). RSC soil samples will be collected in accordance with the procedures presented in **Worksheet #14** and further detailed in *SOP 3-21: Surface and Subsurface Soil Sampling Procedures* (**Appendix D**).

Based on the results of the designated RSC surface soil samples for each potential release area, additional RSC surface soil sampling may continue with “step-out” locations until the data are sufficient to allow for source area identification. RSC surface soil data are considered adequate when a local release area has been identified or decreasing concentrations below the soil SLs in surface soil are observed in the four cardinal directions away from an area of elevated surface soil concentrations. If PFAS release areas are identified with concentrations above the soil SLs, the locations of the SUs will be selected for surface and subsurface soil characterization of the release areas, as defined in **Section 17.2**. Additionally, permanent monitoring wells may be moved or reallocated, as defined in **Section 17.3**. If concentrations at a potential release area are below the soil SLs, the site characterization will be considered complete, and the potential release area will not be sampled as a soil SU.

17.2 Soil Sampling Unit Design and Rationale

Surface and subsurface soil characterization of the PFAS release areas will be completed using a sampling grid approach within 0.5 to 1-acre SUs. The SUs were designed to refine the nature and extent of PFAS in soil at each release area, conduct preliminary screening and evaluate the results as part of the comprehensive HHRA and ERA, and define more precise boundaries for potential response actions during the FS, if warranted. Representative exposure areas for all risk scenarios, human and ecological, were considered in determining the size of the SUs.

The locations of two SUs within AOI 1 and AOI 2, the Former Fire Burn Pit (SU01) and Former Fire Station (SU02), have already been identified. As previously described, the release areas associated with these two SUs have been identified based on historical knowledge of the releases at these two areas in conjunction with the existing data collected during the first and second mobilizations during the SI. However, the exact locations of the PFAS releases to soil and the migration pathways between the release areas and boundaries are not fully understood for AOI 3. Following completion of the Mobilization 1 groundwater sampling (**Section 17.3**), additional soil SUs may be placed within AOI 3 as applicable. Furthermore, it is unknown if PFAS were released to soil at the Gravel Pit and the Sludge Drying beds. Following completion of the RSC soil sampling, additional SUs may be placed at these areas in RI Mobilization 1. Any additional SU grids will be centered on the highest detected concentrations from the RSC surface soil sampling results.

Within each SU, an unbiased statistical soil sampling plan will be generated using VSP version 7 software (VSP Development Team, 2020). For each SU, samples will be collected from a total of 12 boring locations, as recommended by the ProUCL guidance document (USEPA, 2015) that recommends a minimum of 8 to 10 samples should be collected to provide a robust estimate of the 95% upper confidence limit (UCL). The 95% UCL is often used as an estimate of exposure point concentration (EPC) for risk assessments or other environmental characterizations. The locations of these 12 borings 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 that 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.

Borings will be advanced using DPT at locations designated for subsurface soil sample collection; however, air knife/hand augers will be used to clear the top 5 feet of the boring in accordance with AECOM utility clearance protocols. A GeoProbe® DT45 or DT60 dual-tube sampling system (or equivalent) will be used to collect continuous soil cores to the target depth. A total of three soil samples will be collected from each boring: one surface soil sample (0 to 2 feet bgs), subsurface soil from 2 to 4 feet bgs, and one subsurface sample approximately 2 feet above the groundwater table if depth to water is less than 15 feet or from 13 to 15 feet bgs if the depth to water is greater than 15 feet deep. Soil samples will be collected in accordance with the procedures presented in **Worksheet #14** and further detailed in *SOP 3-17: Direct Push Sampling Techniques* (**Appendix D**).

The soil SU design and rationale are provided in **Table 17-2**. The currently identified SU locations, SU01 and SU02, are shown on **Figure 17-1**. The soil sampling locations within SU01 and SU02 are on **Figure 17-4** and **Figure 17-5**, respectively. Soil samples will be analyzed under standard TAT for the target list of 28 PFAS by LC/MS/MS compliant with QSM 5.3 Table B-15, as specified in **Worksheet #15**. Additionally, other geochemical and physical parameters will be analyzed in a subset of samples to support evaluation of PFAS fate and transport, in addition to the remedial alternatives analysis. Two soil samples per depth interval at each SU (equivalent to 10%) will be analyzed for TOC (USEPA Method 9060A) and pH (USEPA Method 9045D).

17.3 Groundwater Sampling Design and Rationale

During RI Mobilization 1, groundwater samples will be collected from existing and newly installed monitoring wells onsite at Camp Smith. During the SI, five monitoring wells were installed across the facility to evaluate potential PFAS releases from AOI 1 through 3. The wells were designated as shallow or deep wells and the well screen intervals varied in depth from 18 to 140 feet bgs (AECOM, 2022). The existing monitoring well network is shown on **Figure 17-1**. The groundwater sampling rationale and monitoring well screen intervals for existing onsite wells are presented in **Table 17-3**.

PFAS Groundwater Sampling

In order to fill data gaps in both the horizontal and vertical distribution of PFAS in groundwater, nested monitoring wells will be installed onsite at Camp Smith during the RI Mobilization 1. The rationale for the new monitoring wells and the target screen intervals is provided in **Table 17-3**. The proposed new permanent monitoring well locations are shown on **Figure 17-6**. The horizontal location and the screen intervals of the proposed new monitoring wells may be adjusted in the field based on the RSC soil samples and other lithologic observations (i.e., the presence of clay confining layers).

At Camp Smith, 40 permanent nested monitoring wells are proposed at 18 locations. At each location, two to three nested wells will be installed as a shallow, intermediate or deep well. The shallow wells will be installed at the top of groundwater in the overburden. Deep wells will either be screened in the deep overburden or the bedrock. In select locations, an intermediate well will be installed in the overburden. Monitoring well screen intervals and rationale are presented on **Table 17-3**. If groundwater is not encountered until bedrock, only one monitoring well will be installed. Permanent monitoring wells will be installed in accordance with the procedures presented in **Worksheet #14** and further detailed in *SOP 3-12: Monitoring Well Installation* (**Appendix D**).

During RI Mobilization 1, groundwater samples will be collected from all newly installed wells and existing wells as established in **Table 17-3**. Based on the results of RI Mobilization 1, additional monitoring wells may be installed in RI Mobilization 2 to further delineate the potential PFAS releases. Groundwater samples will be analyzed under standard TAT for the target list of 28 PFAS by LC/MS/MS compliant with QSM 5.3 Table B-15, as specified in **Worksheet #15**. Groundwater samples will be collected in accordance with the procedures presented in **Worksheet #14** and further detailed in *SOP 3-14: Monitoring Well Sampling* (**Appendix D**).

Two additional rounds of groundwater sampling for PFAS will be completed quarterly after the RI Mobilization 2 as part of groundwater monitoring (three additional rounds if RI Mobilization 2 is not necessary). The permanent monitoring wells included in the groundwater monitoring events will be determined based on the results of RI Mobilization 2 and will be presented in a separate QAPP Addendum with the relevant QAPP worksheets.

VOC Groundwater Sampling

It is unknown whether VOCs used as accelerants during fire training activities may have been released at AOI 1. To address this data gap, groundwater sampling for VOCs will be conducted during RI Mobilization 1 at the wells installed at AOI 1 (CS-MW006S/D). If the detected concentration of any VOC exceeds the USEPA MCLs, additional groundwater samples will be collected for VOC analysis during the RI Mobilization 2. The newly installed wells and existing wells potentially slated for VOC analysis are identified in **Table 17-3**.

Groundwater samples will be analyzed under standard TAT for VOCs, as specified in **Worksheet #15**. Groundwater samples will be collected in accordance with the procedures presented in **Worksheet #14** and further detailed in *SOP 3-14: Monitoring Well Sampling* (**Appendix D**).

17.4 Soil Boring Sampling Design and Rationale

Soil borings will be advanced using sonic drilling techniques at locations designated for permanent monitoring well installation. The purpose of the soil boring sampling is to supplement the SU soil sampling with additional subsurface soil data to conduct preliminary screening and evaluate the results as part of the comprehensive HHRA and ERA.

A sonic dual-tube sampling system (or equivalent) will be used to collect continuous soil cores to the target depth; however, air knife/hand augers will be used to clear the top 5 feet of the boring in accordance with AECOM utility clearance protocols. A total of three soil samples will be collected from each well location: one surface soil sample (0 to 2 feet bgs), subsurface soil from 2 to 4 feet bgs, and one subsurface sample approximately 2 feet above the groundwater table if depth to water is less than 15 feet or from 13 to 15 feet bgs if the depth to water is greater than 15 feet deep. If refusal is encountered or the boring is terminated due to shallow groundwater at 6 feet bgs or shallower, only two samples will be collected per boring: one surface soil (0 to 2 feet bgs) and one sample approximately 1 foot above refusal. Additionally, geotechnical soil samples will be collected to support the evaluation of aquifer permeability from the shallow and deep

screen intervals at the permanent monitoring well locations where slug testing will be completed. Soil samples will be collected in accordance with the procedures presented in **Worksheet #14** and further detailed in *SOP 3-17: Direct Push Sampling Techniques* (**Appendix D**).

The selected locations of the geotechnical soil sample collection are presented in **Table 17-4**. The proposed boring locations are on **Figure 17-6**. Soil samples will be analyzed under standard TAT for the target list of 28 PFAS by LC/MS/MS compliant with QSM 5.3 Table B-15, as specified in **Worksheet #15**. Geotechnical soil samples will not be collected at the bedrock wells where slug testing will occur. Soil samples will be analyzed under standard TAT for grain size analysis with sieve and hydrometer (ASTM D-422). Additionally, one soil sample per location will be analyzed for TOC (USEPA Method 9060A) and pH (USEPA Method 9045D). Soil samples will be collected in accordance with the procedures presented in **Worksheet #14** and further detailed in *SOP 3-21: Surface and Subsurface Soil Sampling Procedures* (**Appendix D**).

17.5 Hydraulic Conductivity Testing Design and Rationale

Slug testing (aquifer testing) will be completed to evaluate aquifer permeability in three screen intervals: the shallow groundwater interval (top of groundwater), deep interval (above bedrock), and bedrock interval. Each interval will be evaluated at six monitoring well locations. Slug testing at the shallow and deep screen intervals will occur in nested pairs to allow for evaluation between the different depths of the aquifer. The selected well locations and screen intervals for slug testing are included in **Table 17-3**. The well locations are shown on **Figure 17-1**. As described in **Section 17.3**, the target screen intervals for select permanent monitoring wells are TBD based on the top of groundwater in the shallow wells and depth to bedrock in many of the deep wells.

A minimum of three slug tests (rising or falling head) will be performed at each well by using different initial displacements. Both rising and falling head tests will be conducted, if possible. Falling head tests will be not performed in wells screened at the top of the water table. A pressure transducer and data-logger will be employed to record the head changes. Data will be evaluated using the approach recommended by Butler (Butler, 2020). Plots of head displacement versus time and estimates of hydraulic conductivity will be generated. The field procedures for slug testing are presented in **Worksheet #14**. For additional details, refer to *SOP 3-35: In-Situ Hydraulic Conductivity Testing via Rising or Falling Head Slug Testing* (**Appendix D**).

17.6 Surface Water and Sediment Sampling Design and Rationale

Surface water and sediment samples will be collected from surface water features at Camp Smith, including Dickiebusch Lake, unnamed tributaries of Dickiebusch Lake, and Putnam Brook. Surface water and sediment sample locations will be evaluated as four separate exposure areas: Dickiebusch Lake, the two unnamed tributaries of Dickiebusch Lake (one exposure area), the brackish wetland portion of Putnam Brook, and the upgradient portion of Putnam Brook (i.e., north of the brackish wetland). One additional sample will be collected directly from the wastewater treatment plant outfall. The sampling design for these media was established such that the number of samples shall be sufficient for calculation of a 95% UCL per area. Within each of the four surface water exposure areas being evaluated, a minimum of six samples per media will be collected (including samples collected during the SI) in order to refine the nature and extent of PFAS within the surface water features and calculate robust EPCs during the human health and ecological risk assessments (the exception to this is the brackish wetland portion Putnam Brook).

The approximate locations of the surface water and sediment samples are shown on **Figure 17-7**; however, the locations may be adjusted in the field based on existing field conditions**.** The rationale for the sample locations and sample depths are provided in **Table 17-5**. Surface water and sediment samples will be analyzed under standard TAT for the target list of 28 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 procedures for the collection of surface water and sediment samples are presented in **Worksheet #14**. The sampling procedures are further detailed in *SOP 3-10: Surface Water Sampling* and *SOP 3-22: Sediment Sampling* (**Appendix D**).

17.7 Synoptic Groundwater and Surface Water Level Gauging Design and Rationale

Groundwater levels will be collected from existing and newly installed permanent groundwater monitoring wells. The existing and proposed monitoring well locations are shown on **Figure 17-1**. The procedures for collection of water levels from monitoring wells are presented in **Worksheet #14**. The groundwater gauging round will be conducted within as short a time period as reasonably feasible and will follow a period of little to no precipitation.

Additionally, water levels will be collected from staff gauges installed in the brackish portion of Putnam Brook. Two staff gauges will be installed at the wastewater treatment plant outfall and to the south of the outfall. The purpose of the staff gauges is to aid in the interpretation of groundwater to surface water interaction and overall groundwater flow through the system. The procedures for the installation of staff gauges and collection of water levels from staff gauges are presented in **Worksheet #14**. The surface water level gauging event will be conducted on a day when little to no precipitation is forecasted. The surface water levels will fluctuate with high and low tide; therefore, the surface water levels will be measured at the two staff gauge locations during high and low tide. In addition, the closest monitoring wells (nested monitoring wells CS-MW015, CS-MW016, CS-MW 018, and CS-MW019) will be gauged synoptically to better understand groundwater to surface water interaction.

17.8 Potable Well Sampling Design and Rationale

As part of the RI, samples will be collected from the two onsite facility supply wells (Well A and Well B). Sample collection will occur in RI Mobilizations 1 and 2 and the additionally quarterly sampling rounds as described in **Section 17.3**. The results of the previous sampling performed by NYARNG will be evaluated for inclusion in the RI.

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Table 17-1: Rapid Site Characterization Soil Sampling Design and Rationale

Potential Release Area	Reference Figure	Location Identifier	Sample Identifier	Number of Samples	Target Sample Depth (feet bgs)	Matrix	Sampling Tool	Analyte Group	Rationale
Gravel Pit	Figure 17-2	RSC01-SB01	RSC01-SB01-[start depth]-[end depth]	24	0-2 2-4	Surface Soil, Shallow Subsurface Soil	Air Knife	PFAS, 8 Compound Shortlist (LC/MS/MS compliant with QSM 5.3 Table B-15)	During the SI, PFAS was detected in groundwater and soil upgradient of the AOI 1 Former Fire Pit release area. Detections of PFOA in groundwater at temporary monitoring well AOI01-GW3 exceeded the screening level while the northernmost monitoring wells (CS-MW001D/1S) had detections of PFOA and PFOS. These wells are located within the AOI 1 boundary, but are north of the identified potential release area (Former Fire Pit) indicating a potential upgradient release area exists outside the AOI 1 boundary. The clearing north of the AOI 1 boundary (Gravel Pit) appears to have been in use for several decades and may have some history of PFAS or AFFF use or release that are the source of detections north of the Former Fire Pit. The proposed sample locations will determine whether the detected concentrations of PFAS extend further to the north (beyond CS-MW001D/1S pair) and whether any detected concentrations of PFAS constitute a new potential release area.
		RSC01-SB02	RSC01-SB02-[start depth]-[end depth]						
		RSC01-SB03	RSC01-SB03-[start depth]-[end depth]						
		RSC01-SB04	RSC01-SB04-[start depth]-[end depth]						
		RSC01-SB05	RSC01-SB05-[start depth]-[end depth]						
		RSC01-SB06	RSC01-SB06-[start depth]-[end depth]						
		RSC01-SB07	RSC01-SB07-[start depth]-[end depth]						
		RSC01-SB08	RSC01-SB08-[start depth]-[end depth]						
		RSC01-SB09	RSC01-SB09-[start depth]-[end depth]						
		RSC01-SB10	RSC01-SB10-[start depth]-[end depth]						
		RSC01-SB11	RSC01-SB11-[start depth]-[end depth]						
		RSC01-SB12	RSC01-SB12-[start depth]-[end depth]						
Sludge Drying Beds	Figure 17-3	RSC02-SB01	RSC02-SB01-[start depth]-[end depth]	24			Hand Auger		The Sludge Drying Beds were added as a potential release area after the completion of the SI field work. Purpose of the RSC is to quickly identify and delineate any potential PFAS releases that may have occurred from spreading sludge from the wastewater treatment plant.
		RSC02-SB02	RSC02-SB02-[start depth]-[end depth]						
		RSC02-SB03	RSC02-SB03-[start depth]-[end depth]						
		RSC02-SB04	RSC02-SB04-[start depth]-[end depth]						
		RSC02-SB05	RSC02-SB05-[start depth]-[end depth]						
		RSC02-SB06	RSC02-SB06-[start depth]-[end depth]						
		RSC02-SB07	RSC02-SB07-[start depth]-[end depth]						
		RSC02-SB08	RSC02-SB08-[start depth]-[end depth]						
		RSC02-SB09	RSC02-SB09-[start depth]-[end depth]						
		RSC02-SB10	RSC02-SB10-[start depth]-[end depth]						
		RSC02-SB11	RSC02-SB11-[start depth]-[end depth]						
		RSC02-SB12	RSC02-SB12-[start depth]-[end depth]						
			Total (not including QC):	**48**					

Notes:

1.) RSC surface soil samples will be analyzed for a shortlist of 8 PFAS, as specified in **Worksheet #15**.

2.) The quantity of RSC surface soil samples included in this table includes the 24 proposed RSC locations. Up to 20 additional step out locations may be warranted based on the results of the proposed RSC locations.

AOI = area of interest
bgs = below ground surface
FTA = fire training area
MW = monitoring well
LC/MS/MS = liquid chromatography tandem mass spectrometry
PFAS = per- and polyfluoroalkyl substances
PFOA = perfluorooctanoic acid
PFOS = perfluorooctanesulfonic acid
QC = quality control
QSM = Quality Systems Manual
RSC = rapid site characterization
SI = Site Inspection

Table 17-2: Soil Sampling Unit Design and Rationale

Area of Interest	Potential Release Area	Sampling Unit	Reference Figure	Location Identifier	Sample Identifier	Number of Samples	Target Sample Depths (feet bgs)	Matrix	Sampling Tool	Analyte Group	Rationale
AOI 1	Former Fire Pit	SU01	Figure 17-4	SU01-SB01	SU01-SB01-[Start Depth]-[End Depth]	36	0-2, 2-4, 2 feet above groundwater (or 13-15 if groundwater is deeper than 15 feet)	Surface and Shallow Subsurface Soil	Air Knife and DPT	PFAS, Target 28 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)	This 1-acre SU was designed to capture the area where fire training activities took place between 1980 and 1996. During the SI, groundwater concentrations at the Former Fire Pit were detected just below the screening levels of 40 ng/L for PFOA and PFOS at 29.0 and 37.8 ng/L, respectively.
				SU01-SB02	SU01-SB02-[Start Depth]-[End Depth]						
				SU01-SB03	SU01-SB03-[Start Depth]-[End Depth]						
				SU01-SB04	SU01-SB04-[Start Depth]-[End Depth]						
				SU01-SB05	SU01-SB05-[Start Depth]-[End Depth]						
				SU01-SB06	SU01-SB06-[Start Depth]-[End Depth]						
				SU01-SB07	SU01-SB07-[Start Depth]-[End Depth]						
				SU01-SB08	SU01-SB08-[Start Depth]-[End Depth]						
				SU01-SB09	SU01-SB09-[Start Depth]-[End Depth]						
				SU01-SB10	SU01-SB10-[Start Depth]-[End Depth]						
				SU01-SB11	SU01-SB11-[Start Depth]-[End Depth]						
				SU01-SB12	SU01-SB12-[Start Depth]-[End Depth]						
AOI 2	Former Fire Station	SU02	Figure 17-5	SU02-SB01	SU02-SB01-[Start Depth]-[End Depth]	36			Hand Auger and DPT		This 1-acre SU was designed to capture the area around the Former Fire Station was located. During the second mobilization for the SI, shallow subsurface soil contined up to 191 microgram per kilogram PFOS. Sampling designed to further evaluate and delineate the potential release. Concrete around the SU is reinforced and sample locations may be adjusted by a few feet to avoid hitting the rebar.
				SU02-SB02	SU02-SB02-[Start Depth]-[End Depth]						
				SU02-SB03	SU02-SB03-[Start Depth]-[End Depth]						
				SU02-SB04	SU02-SB04-[Start Depth]-[End Depth]						
				SU02-SB05	SU02-SB05-[Start Depth]-[End Depth]						
				SU02-SB06	SU02-SB06-[Start Depth]-[End Depth]						
				SU02-SB07	SU02-SB07-[Start Depth]-[End Depth]						
				SU02-SB08	SU02-SB08-[Start Depth]-[End Depth]						
				SU02-SB09	SU02-SB09-[Start Depth]-[End Depth]						
				SU02-SB10	SU02-SB10-[Start Depth]-[End Depth]						
				SU02-SB11	SU02-SB11-[Start Depth]-[End Depth]						
				SU02-SB12	SU02-SB12-[Start Depth]-[End Depth]						
					Total (not including QC)	**72**					

Notes:

AFFF = aqueous film forming foam
AOI = area of interest
bgs = below ground surface
DPT = direct-push technology
LC/MS/MS = liquid chromatography tandem mass spectrometry
MW = monitoring well
ng/L = nanograms per liter
pH = potential of hydrogen
QC = quality control
QSM = Quality Systems Manual
SB = soil boring
SI = Site Inspection
SU = sampling unit
TBD = to be determined

Table 17-2: Soil Sampling Unit Design and Rationale

Area of Interest	Potential Release Area	Sampling Unit	Reference Figure	Location Identifier	Sample Identifier	Number of Samples	Target Sample Depths (feet bgs)	Matrix	Sampling Tool	Analyte Group	Rationale

PFAS = per- and polyfluoroalkyl substances
PFOS = perfluorooctanesulfonic acid
TOC = total organic carbon
USEPA = United States Environmental Protection Agency

Table 17-3: Groundwater Sampling Design and Rationale

Area of Interest	Location Identifier	Well ID	Well Status	Target Screen Interval (feet bgs)	Well Type	Synoptic Gauging	Slug Testing	Sample Identifier	Number of Samples	Matrix	Sampling Tool	Analyte Group	Rationale
AOI 1	CS-MW001	CS-MW001S	existing	7-17	Overburden	X		CS-MW001S-[MMDDYY]	4	Groundwater	Bladder Pump	PFAS, Target 28 Compound List (LC/MS/MS compliant with QSM 5.3 Table B-15)	Evaluate groundwater in northern portion of AOI 1, north of the Former Fire Pit.
		CS-MW001D	existing	20-30	Bedrock	X		CS-MW001D-[MMDDYY]	4				
	CS-MW005	CS-MW005S	proposed	top of groundwater	Overburden	X		CS-MW005S-[MMDDYY]	4				These well locations will be selected based on the findings of the RSC soil sampling at the Gravel Pit
		CS-MW005D	proposed	bedrock	Bedrock	X		CS-MW005D-[MMDDYY]	4				
	CS-MW006	CS-MW006S	proposed	top of groundwater	Overburden	X	X	CS-MW006S-[MMDDYY]	4			PFAS, Target 28 Compound List (LC/MS/MS compliant with QSM 5.3 Table B-15) and VOCs (SW846 8260C)	Evaluate groundwater at AOI 1 Former Fire Pit
		CS-MW006D	proposed	bedrock	Bedrock	X	X	CS-MW006D-[MMDDYY]	4				
	CS-MW007	CS-MW007S	proposed	top of groundwater	Overburden	X		CS-MW007S-[MMDDYY]	4				Evaluate groundwater downgradient of Gravel Pit and northern portion of AOI 1 Former Fire Pit
		CS-MW007D	proposed	bedrock	Bedrock	X		CS-MW007D-[MMDDYY]	4				
AOI 2	CS-MW012	CS-MW012S	proposed	top of groundwater	Overburden	X	X	CS-MW012S-[MMDDYY]	4				Evaluate groundwater at AOI 2 Former Fire Station. If groundwater is not encountered before bedrock, only a bedrock well will be installed
		CS-MW012D	proposed	bedrock	Bedrock	X	X	CS-MW012D-[MMDDYY]	4				
	CS-MW013	CS-MW013S	proposed	top of groundwater	Overburden	X		CS-MW013S-[MMDDYY]	4				Evaluate groundwater downgradient to the southwest of AOI 2
		CS-MW013I	proposed	90-110	Overburden	X		CS-MW013I-[MMDDYY]	4				
		CS-MW013D	proposed	130-140	Overburden	X		CS-MW013D-[MMDDYY]	4				
	CS-MW014	CS-MW014S	proposed	top of groundwater	Overburden	X		CS-MW014S-[MMDDYY]	4				Evaluate groundwater downgradient to the south of AOI 2
		CS-MW014D	proposed	90-100	Overburden	X		CS-MW014D-[MMDDYY]	4				
AOI 3	CS-MW004	CS-MW004S	existing	7-17	Overburden	X		CS-MW004S-[MMDDYY]	4			PFAS, Target 28 Compound List (LC/MS/MS compliant with QSM 5.3 Table B-15)	Evaluate groundwater at AOI 3
	CS-MW008	CS-MW008S	proposed	top of groundwater	Overburden	X		CS-MW008S-[MMDDYY]	4				Evaluate groundwater upgradient of AOI 3
		CS-MW008D	proposed	55-65	Overburden	X		CS-MW008D-[MMDDYY]	4				
	CS-MW009	CS-MW009S	proposed	top of groundwater	Overburden	X	X	CS-MW009S-[MMDDYY]	4				Evaluate groundwater at AOI 3 Former New York State Academy of Fire Science Annex
		CS-MW009D	proposed	55-65	Overburden	X	X	CS-MW009D-[MMDDYY]	4				
	CS-MW010	CS-MW010S	proposed	top of groundwater	Overburden	X		CS-MW010S-[MMDDYY]	4				Evaluate groundwater at AOI 3
		CS-MW010D	proposed	55-65	Overburden	X		CS-MW010D-[MMDDYY]	4				Evaluate groundwater at AOI 3
	CS-MW011	CS-MW011S	proposed	top of groundwater	Overburden	X		CS-MW011S-[MMDDYY]	4				Evaluate groundwater at AOI 3
		CS-MW011D	proposed	65-75	Overburden	X		CS-MW011D-[MMDDYY]	4				Evaluate groundwater at AOI 3
Downgradient of AOI 2 and AOI 3	CS-MW002	CS-MW002D	existing	90-110	Overburden	X		CS-MW002D-[MMDDYY]	4				Evaluate groundwater downgradient of AOIs 2 and 3
	CS-MW003	CS-MW003S	existing	40-50	Overburden	X		CS-MW003S-[MMDDYY]	4				Evaluate groundwater downgradient of AOIs 2 and 3
	CS-MW015	CS-MW015S	proposed	top of groundwater	Overburden	X		CS-MW015S-[MMDDYY]	4				Evaluate groundwater downgradient of AOI 2 and AOI 3 at the shallow (top of groundwater), intermediate, and deep (bedrock) intervals. Monitoring wells CS-MW015 through CS-MW017 are intended to provide transect of hydrogeological data across the site. Groundwater from all AOIs will flow through this transect.
		CS-MW015I	proposed	90-110	Overburden	X		CS-MW015I-[MMDDYY]	4				
		CS-MW015D	proposed	bedrock	Bedrock	X		CS-MW015D-[MMDDYY]	4				
	CS-MW016	CS-MW016S	proposed	top of groundwater	Overburden	X		CS-MW016S-[MMDDYY]	4				
		CS-MW016I	proposed	90-110	Overburden	X		CS-MW016I-[MMDDYY]	4				
		CS-MW016D	proposed	bedrock	Bedrock	X		CS-MW016D-[MMDDYY]	4				
	CS-MW017	CS-MW017S	proposed	top of groundwater	Overburden	X		CS-MW017S-[MMDDYY]	4				
		CS-MW017I	proposed	90-110	Overburden	X		CS-MW017I-[MMDDYY]	4				
		CS-MW017D	proposed	bedrock	Bedrock	X		CS-MW017D-[MMDDYY]	4				
	CS-MW018	CS-MW018S	proposed	top of groundwater	Overburden	X		CS-MW018S-[MMDDYY]	4				Evaluate groundwater near the Sludge Drying Beds. Locations can be changed based on the RSC soil sampling results
		CS-MW018D	proposed	90-100	Overburden	X		CS-MW018D-[MMDDYY]	4				
	CS-MW019	CS-MW019S	proposed	top of groundwater	Overburden	X	X	CS-MW019S-[MMDDYY]	4				Evaluate groundwater at the facility boundary. Locations can be changed based on the RSC soil sampling results
		CS-MW019D	proposed	90-100	Overburden	X	X	CS-MW019D-[MMDDYY]	4				

Table 17-3: Groundwater Sampling Design and Rationale

Area of Interest	Location Identifier	Well ID	Well Status	Target Screen Interval (feet bgs)	Well Type	Synoptic Gauging	Slug Testing	Sample Identifier	Number of Samples	Matrix	Sampling Tool	Analyte Group	Rationale
Downgradient of AOI 2 and AOI 3	CS-MW020	CS-MW020S	proposed	top of groundwater	Overburden	X		CS-MW020S-[MMDDYY]	4	Groundwater	Bladder Pump	PFAS, Target 28 Compound List (LC/MS/MS compliant with QSM 5.3 Table B-15)	Evaluate groundwater at the facility boundary
		CS-MW020D	proposed	170-180	Overburden	X		CS-MW020D-[MMDDYY]	4				
	CS-MW021	CS-MW021S	proposed	top of groundwater	Overburden	X		CS-MW021S-[MMDDYY]	4				Evaluate groundwater at the facility boundary
		CS-MW021D	proposed	170-180	Overburden	X		CS-MW021D-[MMDDYY]	4				
	CS-MW022	CS-MW022S	proposed	top of groundwater	Overburden	X		CS-MW022S-[MMDDYY]	4				Evaluate groundwater downgradient of the Former CSMS Building.
		CS-MW022D	proposed	65-75	Overburden	X		CS-MW022D-[MMDDYY]	4				
Supply Wells	Well A	Well A	existing	65-80	Overburden			WellA-[MMDDYY]	4		Spigot		Evaluate groundwater being sourced by the facility supply wells.
	Well B	Well B	existing	82-100	Overburden			WellB-[MMDDYY]	4				
				Total		**45**	**8**	**Total Samples (not including QC)**	**188**				

Notes:

1.) The number of slug tests included in this table includes 8 planned tests from the proposed monitoring wells.

2.) The total quantity of groundwater samples includes 4 rounds of quarterly sampling. One round of samples is 56 samples, which includes the QC samples

AOI = area of interest
bgs = below ground surface
CS = Camp Smith
CSMS = Combined Support Maintenance Shop
LC/MS/MS = liquid chromatography tandem mass spectrometry
MW = monitoring well
MM/DD/YY = Month/Day/Year
PFAS = per- and polyfluoroalkyl substances
QC = quality control
QSM = Quality Systems Manual
RSC = rapid site characterization
SI = Site Inspection
TBD = to be determined

Table 17-4: Monitoring Well Soil Sampling Design and Rationale

Area of Interest	Location Identifier	Well ID	Well Status	Target Screen Interval (feet bgs)	Well Type	Number of Samples	Sample Identifier	Matrix	Sampling Tool	Analyte Group	Rationale
AOI 1	CS-MW005	CS-MW005S	proposed	top of groundwater	Overburden	3	CS-MW005S-[Start Depth]-[End Depth]	Surface and shallow subsurface soil	Airknife, hand auger, and rotosonic	PFAS, Target 28 Compound List (LC/MS/MS compliant with QSM 5.3 Table B-15) Limited Sample Selection (One sample per well location): TOC (USEPA Method 9060A) pH (USEPA Method 9045D) Limited Sample Selection (At intervals where slug testing will occur): Grain Size Analysis (ASTM D-422)	These well locations will be selected based on the findings of the RSC soil sampling at the Gravel Pit
		CS-MW005D	proposed	bedrock	Bedrock		CS-MW005D-[Start Depth]-[End Depth]				
	CS-MW006	CS-MW006S	proposed	top of groundwater	Overburden	3	CS-MW006S-[Start Depth]-[End Depth]				Evaluate groundwater at AOI 1 Former Fire Pit
		CS-MW006D	proposed	bedrock	Bedrock		CS-MW006D-[Start Depth]-[End Depth]				
	CS-MW007	CS-MW007S	proposed	top of groundwater	Overburden	3	CS-MW007S-[Start Depth]-[End Depth]				Evaluate groundwater downgradient of Gravel Pit and northern portion of AOI 1 Former Fire Pit
		CS-MW007D	proposed	bedrock	Bedrock		CS-MW007D-[Start Depth]-[End Depth]				
AOI 2	CS-MW012	CS-MW012S	proposed	top of groundwater	Overburden	3	CS-MW012S-[Start Depth]-[End Depth]				Evaluate groundwater at AOI 2 Former Fire Station. If groundwater is not encountered before bedrock, only a bedrock well will be installed
		CS-MW012D	proposed	bedrock	Bedrock		CS-MW012D-[Start Depth]-[End Depth]				
	CS-MW013	CS-MW013S	proposed	top of groundwater	Overburden	3	CS-MW013S-[Start Depth]-[End Depth]				Evaluate groundwater downgradient to the southwest of AOI 2
		CS-MW013I	proposed	90-110	Overburden		CS-MW013I-[Start Depth]-[End Depth]				
		CS-MW013D	proposed	130-140	Overburden		CS-MW013D-[Start Depth]-[End Depth]				
	CS-MW014	CS-MW014S	proposed	top of groundwater	Overburden	3	CS-MW014S-[Start Depth]-[End Depth]				Evaluate groundwater downgradient to the south of AOI 2
		CS-MW014D	proposed	90-100	Overburden		CS-MW014D-[Start Depth]-[End Depth]				
AOI 3	CS-MW008	CS-MW008S	proposed	top of groundwater	Overburden	3	CS-MW008S-[Start Depth]-[End Depth]				Evaluate groundwater upgradient of AOI 3
		CS-MW008D	proposed	55-65	Overburden		CS-MW008D-[Start Depth]-[End Depth]				
	CS-MW009	CS-MW009S	proposed	top of groundwater	Overburden	3	CS-MW009S-[Start Depth]-[End Depth]				Evaluate groundwater at AOI 3 Former New York State Academy of Fire Science Annex
		CS-MW009D	proposed	55-65	Overburden		CS-MW009D-[Start Depth]-[End Depth]				
	CS-MW010	CS-MW010S	proposed	top of groundwater	Overburden	3	CS-MW010S-[Start Depth]-[End Depth]				Evaluate groundwater at AOI 3
		CS-MW010D	proposed	55-65	Overburden		CS-MW010D-[Start Depth]-[End Depth]				Evaluate groundwater at AOI 3
	CS-MW011	CS-MW011S	proposed	top of groundwater	Overburden	3	CS-MW011S-[Start Depth]-[End Depth]				Evaluate groundwater at AOI 3
		CS-MW011D	proposed	65-75	Overburden		CS-MW011D-[Start Depth]-[End Depth]				Evaluate groundwater at AOI 3
Downgradient of AOI 2 and AOI 3	CS-MW015	CS-MW015S	proposed	top of groundwater	Overburden	3	CS-MW015S-[Start Depth]-[End Depth]				Evaluate groundwater downgradient of AOI 2 and AOI 3 at the shallow (top of groundwater), intermediate, and deep (bedrock) intervals. Monitoring wells CS-MW015 through CS-MW017 are intended to provide transect of hydrogeological data across the site. Groundwater from all AOIs will flow through this transect.
		CS-MW015I	proposed	90-110	Overburden		CS-MW015I-[Start Depth]-[End Depth]				
		CS-MW015D	proposed	bedrock	Bedrock		CS-MW015D-[Start Depth]-[End Depth]				
	CS-MW016	CS-MW016S	proposed	top of groundwater	Overburden	3	CS-MW016S-[Start Depth]-[End Depth]				
		CS-MW016I	proposed	90-110	Overburden		CS-MW016I-[Start Depth]-[End Depth]				
		CS-MW016D	proposed	bedrock	Bedrock		CS-MW016D-[Start Depth]-[End Depth]				
	CS-MW017	CS-MW017S	proposed	top of groundwater	Overburden	3	CS-MW017S-[Start Depth]-[End Depth]				
		CS-MW017I	proposed	90-110	Overburden		CS-MW017I-[Start Depth]-[End Depth]				
		CS-MW017D	proposed	bedrock	Bedrock		CS-MW017D-[Start Depth]-[End Depth]				
	CS-MW018	CS-MW018S	proposed	top of groundwater	Overburden	3	CS-MW018S-[Start Depth]-[End Depth]				Evaluate groundwater near the Sludge Drying Beds. Locations can be changed based on the RSC soil sampling results
		CS-MW018D	proposed	90-100	Overburden		CS-MW018D-[Start Depth]-[End Depth]				
	CS-MW019	CS-MW019S	proposed	top of groundwater	Overburden	3	CS-MW019S-[Start Depth]-[End Depth]				Evaluate groundwater at the facility boundary. Locations can be changed based on the RSC soil sampling results
		CS-MW019D	proposed	90-100	Overburden		CS-MW019D-[Start Depth]-[End Depth]				
	CS-MW020	CS-MW020S	proposed	top of groundwater	Overburden	3	CS-MW020S-[Start Depth]-[End Depth]				Evaluate groundwater at the facility boundary
		CS-MW020D	proposed	170-180	Overburden		CS-MW020D-[Start Depth]-[End Depth]				
	CS-MW021	CS-MW021S	proposed	top of groundwater	Overburden	3	CS-MW021S-[Start Depth]-[End Depth]				Evaluate groundwater at the facility boundary
		CS-MW021D	proposed	170-180	Overburden		CS-MW021D-[Start Depth]-[End Depth]				
	CS-MW022	CS-MW022S	proposed	top of groundwater	Overburden	3	CS-MW022S-[Start Depth]-[End Depth]				Evaluate groundwater downgradient of the Former CSMS Building.
		CS-MW022D	proposed	65-75	Overburden		CS-MW022D-[Start Depth]-[End Depth]				
			Total Samples (not including QC)			**54**					

Notes:

1.) Grain size analyses will be collected at the same locations and intervals where slug testing will occur, as indicated by Table 17-3. Grain size analyses will not be collected from bedrock wells.

AOI = area of interest
bgs = below ground surface
CS = Camp Smith
CSMS = Combined Support Maintenance Shop
LC/MS/MS = liquid chromatography tandem mass spectrometry
MW = monitoring well
MM/DD/YY = Month/Day/Year

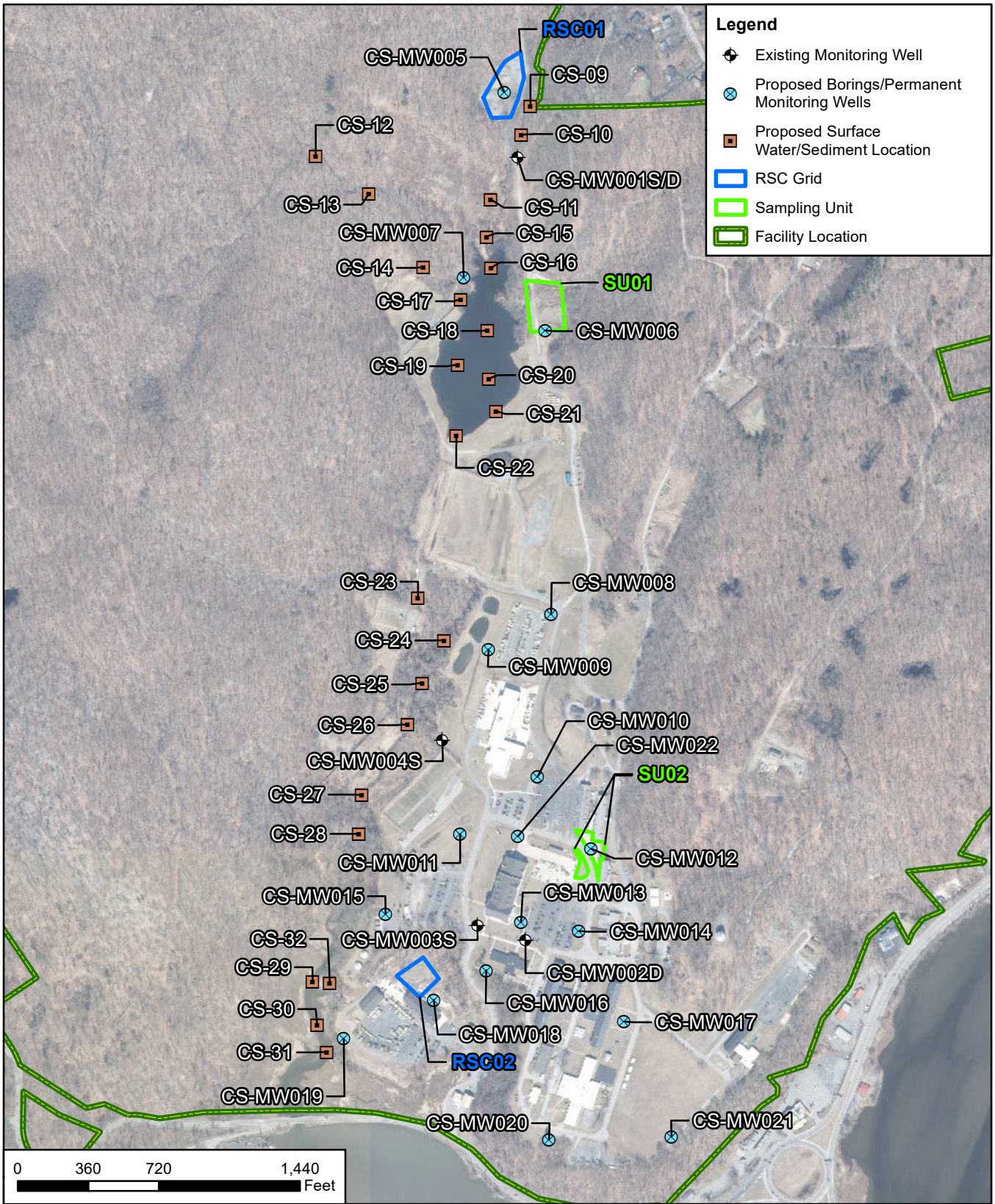
Table 17-5: Surface Water and Sediment Sampling Design and Rationale

Exposure Area	Location Identifier	Sample Identifier	Number of Sample Locations	Target Sample Depth (feet bgs)	Matrix	Sampling Tool	Analyte Group	Rationale
Dickiebusche Lake Tributaries	CS-09	CS-09-SW or CS-09-SD	6	Middle of water column / 0 to 6 inches	Surface Water/ Sediment	Dip Sampler / Sediment Coring Device	PFAS, Target 28 Compound List (LC/MS/MS compliant with QSM 5.3 Table B-15) TOC (USEPA Method 9060A), pH (USEPA Method 9045D), and grain size (ASTM D-422) (25% of sediment only)	Evaluate surface water and sediment upgradient of Dickibusche Lake and AOI 1 Former Fire Pit
	CS-10	CS-10-SW or CS-10-SD						Evaluate surface water and sediment upgradient of Dickibusche Lake and AOI 1 Former Fire Pit
	CS-11	CS-11-SW or CS-11-SD						Evaluate surface water and sediment upgradient of Dickibusche Lake and AOI 1 Former Fire Pit
	CS-12	CS-12-SW or CS-12-SD						Evaluate surface water and sediment upgradient of Dickibusche Lake
	CS-13	CS-13-SW or CS-13-SD						Evaluate surface water and sediment upgradient of Dickibusche Lake
	CS-14	CS-14-SW or CS-14-SD						Evaluate surface water and sediment upgradient of Dickibusche Lake
Dickiebusche Lake	CS-15	CS-15-SW or CS-15-SD	8					Evaluate surface water and sediment at tributary discharge point into Dickiebusche Lake
	CS-16	CS-16-SW or CS-16-SD						Evaluate surface water and sediment in Dickiebusche Lake
	CS-17	CS-17-SW or CS-17-SD						Evaluate surface water and sediment at tributary discharge point into Dickiebusche Lake
	CS-18	CS-18-SW or CS-18-SD						Evaluate surface water and sediment in Dickiebusche Lake
	CS-19	CS-19-SW or CS-19-SD						Evaluate surface water and sediment in Dickiebusche Lake
	CS-20	CS-20-SW or CS-20-SD						Evaluate surface water and sediment in Dickiebusche Lake
	CS-21	CS-21-SW or CS-21-SD						Evaluate surface water and sediment in Dickiebusche Lake
	CS-22	CS-22-SW or CS-22-SD						Evaluate surface water and sediment in Dickiebusche Lake at the point of discharge
Putnam Brook	CS-23	CS-23-SW or CS-23-SD	6					Evaluate surface water and sediment in Putnam Brook downgradient of Dickiebusche Lake
	CS-24	CS-24-SW or CS-24-SD						Evaluate surface water and sediment in Putnam Brook downgradient of Dickiebusche Lake and AOI 3
	CS-25	CS-25-SW or CS-25-SD						Evaluate surface water and sediment in Putnam Brook downgradient of Dickiebusche Lake and AOI 3
	CS-26	CS-26-SW or CS-26-SD						Evaluate surface water and sediment in Putnam Brook downgradient of Dickiebusche Lake and AOI 3
	CS-27	CS-27-SW or CS-27-SD						Evaluate surface water and sediment in Putnam Brook downgradient of Dickiebusche Lake and AOI 3
	CS-28	CS-28-SW or CS-28-SD						Evaluate surface water and sediment in Putnam Brook downgradient of Dickiebusche Lake and AOI 3
Putnam Brook - Brackish	CS-29	CS-29-SW or CS-29-SD	3					Evaluate surface water and sediment in brackish portion of Putnam Creek prior to facility boundary where surface water discharges into the Hudson River
	CS-30	CS-30-SW or CS-30-SD						Evaluate surface water and sediment in brackish portion of Putnam Creek prior to facility boundary where surface water discharges into the Hudson River
	CS-31	CS-31-SW or CS-31-SD						Evaluate surface water and sediment in brackish portion of Putnam Creek prior to facility boundary where surface water discharges into the Hudson River
WWTP Effluent	CS-32	CS-32-SW	1	Directly from outfall	Surface Water	Dip Sampler	PFAS, Target 28 Compound List (LC/MS/MS compliant with QSM 5.3 Table B-15)	Evaluate PFAS concentrations discharged from the wastewater treatment plant into Putnam Brook.
Total Samples per Media (not including QC)			**24**					

Notes:

AOI = area of interest
ASTM = American Society for Testing and Materials
bgs = below ground surface
CS = Camp Smith
LC/MS/MS = liquid chromatography tandem mass spectrometry
NYARNG = New York Army National Guard
QC = quality control
QSM = Quality Systems Manual
SD = sediment
SW = surface water
TOC = total organic carbon
USEPA = United States Environmental Protection Agency

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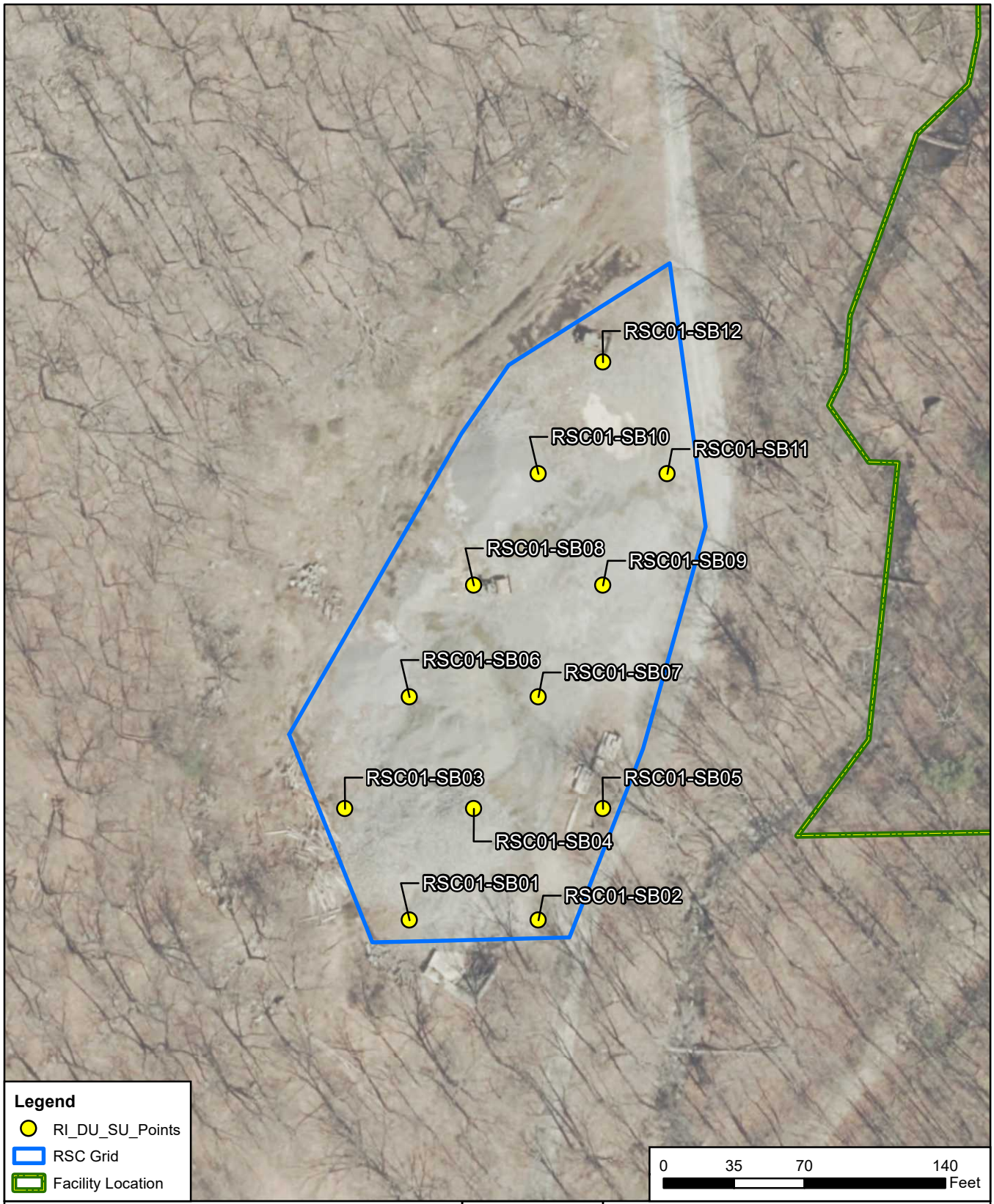
CLIENT	ARNG			
NOTES	Remedial Investigation for PFAS at Camp Smith, NY			
REVISED	4/29/2022	GIS BY	MS	4/29/2022
SCALE	1:8,640	CHK BY	AB	4/29/2022
Base Map: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS,		PM	CM	4/29/2022

Camp Smith RI – Proposed Sample Locations

AECOM
12420 Milestone Center Drive
Germantown, MD 20876

Figure 17-1

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CLIENT	ARNG			
NOTES	Remedial Investigation for PFAS at Camp Smith, NY			
REVISED	2/9/2022	GIS BY	MS	2/9/2022
SCALE	1:840	CHK BY	CW	2/9/2022
Base Map: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS,		PM	CM	2/9/2022

N

Camp Smith RI – RSC Grid 1

AECOM
12420 Milestone Center Drive
Germantown, MD 20876

Figure 17-2

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CLIENT	ARNG			
PROJECT	Remedial Investigation for PFAS at Camp Smith, NY			
REVISED	2/9/2022	GIS BY	MS	2/9/2022
SCALE	1:720	CHK BY	CW	2/9/2022
Base Map: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community		PM	CM	2/9/2022

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Camp Smith RI – RSC Grid 2

AECOM
12420 Milestone Center Drive
Germantown, MD 20876

Figure 17-3



CLIENT	ARNG			
NOTES	Remedial Investigation for PFAS at Camp Smith, NY			
REVISED	2/9/2022	GIS BY	MS	2/9/2022
SCALE	1:840	CHK BY	CW	2/9/2022
Base Map: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS,		PM	CM	2/9/2022

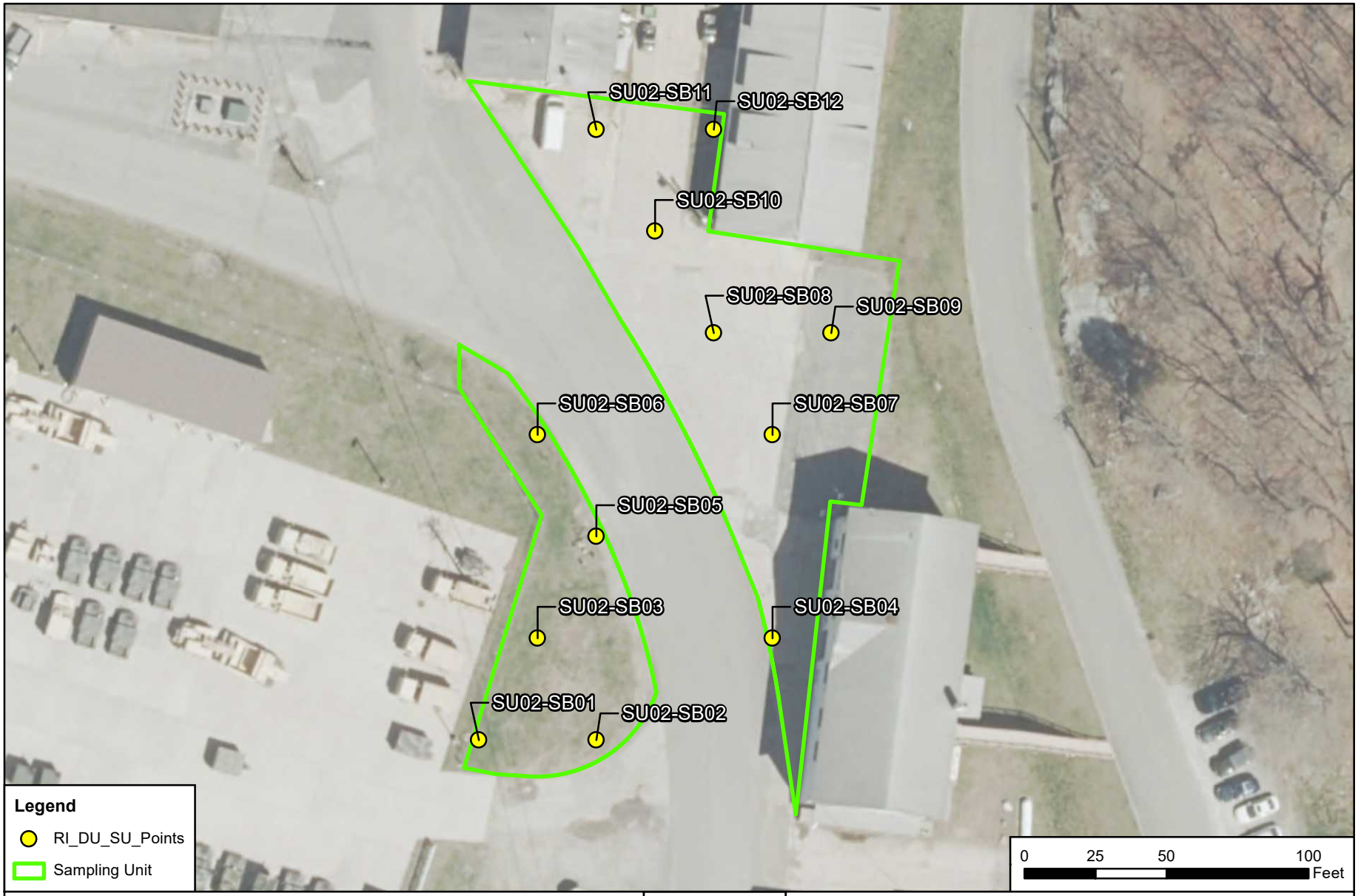
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Camp Smith RI – Sampling Unit 1

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Germantown, MD 20876

Figure 17-4

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CLIENT	ARNG			
PROJECT	Remedial Investigation for PFAS at Camp Smith, NY			
REVISED	2/10/2022	GIS BY	MS	2/10/2022
SCALE	1:600	CHK BY	CW	2/10/2022
Base Map: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community		PM	CM	2/10/2022

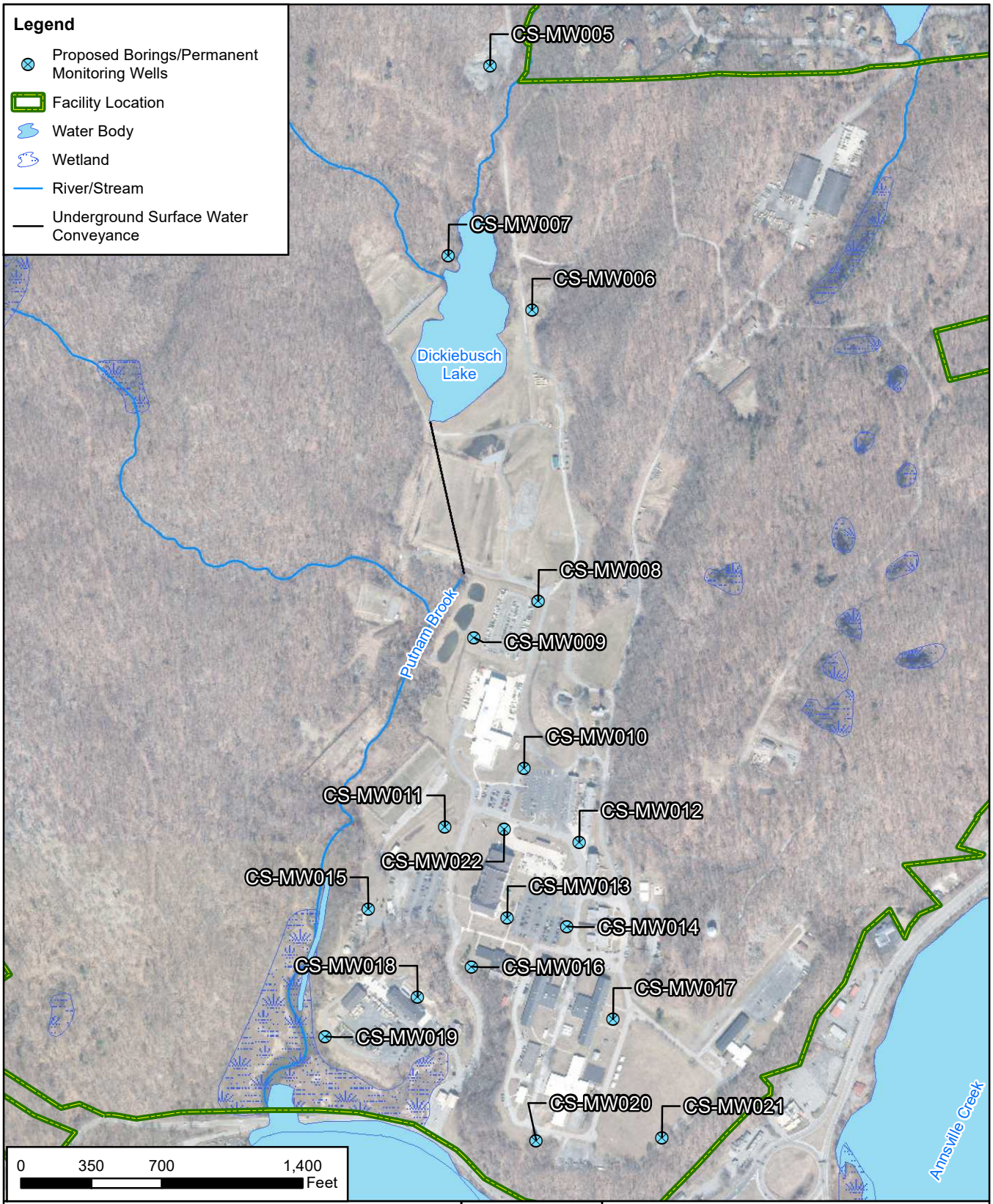
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Camp Smith RI – Sampling Unit 2

AECOM 12420 Milestone Center Drive Germantown, MD 20876

Figure 17-5

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CLIENT	ARNG			
NOTES	Remedial Investigation for PFAS at Camp Smith, NY			
REVISED	4/29/2022	GIS BY	MS	4/29/2022
SCALE	1:8,400	CHK BY	AB	4/29/2022
Base Map: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS,		PM	CM	4/29/2022

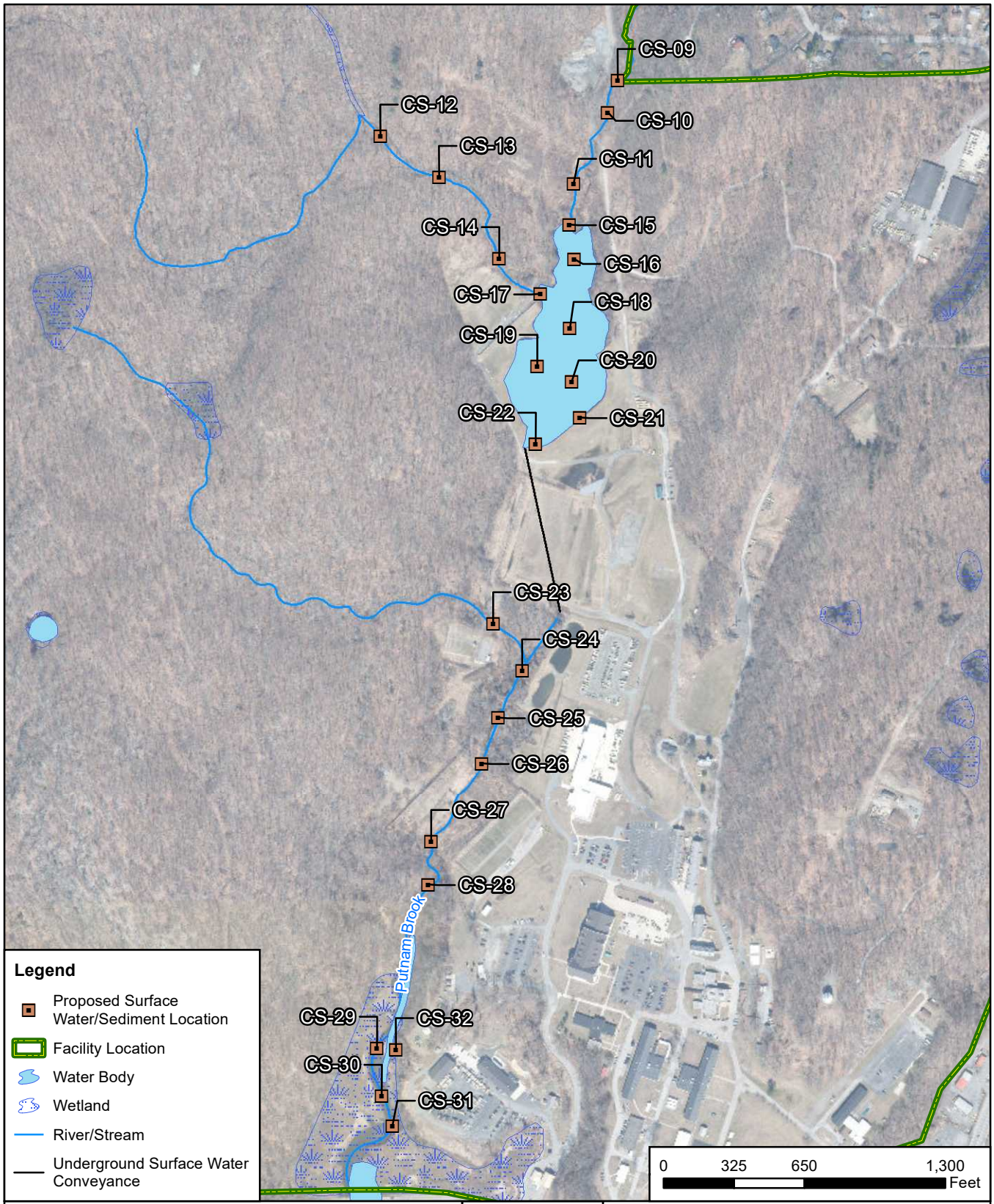
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Camp Smith RI – Proposed Monitoring Well Locations

AECOM
12420 Milestone Center Drive
Germantown, MD 20876

Figure 17-6

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CLIENT	ARNG			
NOTES	Remedial Investigation for PFAS at Camp Smith, NY			
REVISED	4/29/2022	GIS BY	MS	4/29/2022
SCALE	1:7,800	CHK BY	AB	4/29/2022
Base Map: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS,		PM	CM	4/29/2022

Camp Smith RI – Surface Water and Sediment Locations

AECOM
12420 Milestone Center Drive
Germantown, MD 20876

Figure 17-7

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

Laboratory: Pace South Carolina
106 Vantage Point Dr.
West Columbia, SC 29172
803-791-9700
List any required accreditations/certifications: DoD ELAP – PFAS, VOC, pH
NYDOH – PFAS, TOC
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	QSM 5.3 Table B-15 / ME003NI-04	NYDOH – 04/01/2022 DoD-11/18/2024	2 - 250mL wide mouth HDPE (3x for designated MS/MSD sample)	None, ≤6°C	28 days	28 days	48 hours (upon request) 28 days
PFAS	Solid			1 - 4 oz. HDPE	None, ≤6°C	28 days	28 days	48 hours (upon request) 28 days
Volatiles	Aqueous	EPA 8260 / ME0012X	DoD-11/18/2024	Glass with Teflon-lined septum 3x 40 mL Amber vials	Cool, 0-6°C Preserves with HCl to pH ≤ 2	-	14 days (7 days if pH >2)	48 hours (upon request) 28 days
TOC (sub to Pace Green Bay)	Solid	Determination of TOC Using the Multi EA 4000 Instrument / ENV-SOP-GBAY-0051	NYDOH – 04/01/2022	1 - 4 oz. Amber Glass	None, ≤6°C	N/A	14 days	28 days
pH	Solid	9045D/ME0014S	DoD-11/18/2024	Polyethylene, Glass 1 x 2 oz	None	NA	ASAP[1]	28 days

Laboratory: Pace South Carolina
106 Vantage Point Dr.
West Columbia, SC 29172
803-791-9700
List any required accreditations/certifications: DoD ELAP – PFAS, VOC, pH
NYDOH – PFAS, TOC
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
Grain Size (Pace Wyoming)	Solid	ASTM D422/ ENV-SOP-SHRT-0158	N/A	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 South Carolina 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.

°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

Matrix	Analytical Group	Field Samples	Field Duplicates	Matrix Spikes	Matrix Spike Duplicates	Field Reagent Blanks	Equipment Rinsate Blanks[7]	Trip Blanks[8]	Total Samples
Soil, RSC	PFAS (8)[1]	48[2]	5	3	3	0	3	0	62
Soil, SU	PFAS (28)	72	8	4	4	0	5	0	93
	pH, TOC	8[3]	2	1	1	0	0	0	12
	Grain Size	8[3]	0	0	0	0	0	0	8
Soil	PFAS	54	6	3	3	0	3	0	69
	pH, TOC	18[3]	2	1	1	0	0	0	22
	Grain Size	6[3]	0	0	0	0	0	0	6
Groundwater	PFAS (28)	180[4]	18	9	9	1	9	0	226
	VOCs	2[5]	1	1	1	0	1	1	7
Surface Water	PFAS (28)	24	3	2	2	0	0	0	31
Sediment	PFAS (28)	23	3	2	2	0	2	0	32
	pH, TOC[6]	5	1	0	0	0	0	0	6
	Grain Size[6]	5	1	0	0	0	0	0	6
Decontamination Water	PFAS (28)	1	0	0	0	0	0	0	1

Notes:

1.) PFAS RSC surface soil samples will be analyzed for a shortlist of 8 PFAS, as specified in **Worksheet #15**.
2.) The quantity of RSC surface soil samples included in this table includes the 24 proposed RSC locations. An additional 20 step out locations may be warranted based on the results of the RSC results.
3.) The quantity of samples for pH, TOC, and grain size analysis includes soil collected at a rate of two samples per depth interval at both SU01 and SU02 and the six soil samples collected from the monitoring wells.
4.) The quantity of groundwater samples for PFAS (28 target analyte list) analysis included in this table includes 180 planned samples from the existing and proposed nested monitoring wells during four rounds of groundwater sampling to occur at RI Mobilization 1, RI Mobilization 2, and two additional groundwater sampling events.
5.) VOCs will be collected and analyzed at CS-MW006 at AOI 1 Former Fire Pit.
6.) Grain size, pH, and TOC samples will be collected at a rate of 25% from sediment sampling locations.
7.) ERBs apply only if use of non-dedicated sampling equipment is necessary. ERBs for solid matrices are aqueous samples.
8.) Trip blanks will be collected at a rate of one per cooler with VOC samples.

ERB = equipment rinsate blank
PFAS = per- and polyfluoroalkyl substances
RSC = rapid site characterization
SU = sampling unit
TOC = total organic carbon

Measurement Performance Criteria Table — Field Quality Control Samples				
QC Sample	**Analytical Group**	**Frequency**	**Data Quality Indicators**	**MPC**
Matrix: Aqueous (Groundwater/ Surface Water/ Potable Wells)				
Field Duplicate	PFAS, VOCs	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, VOCs	One per 20 field samples[1]	Bias/Accuracy/Precision (lab)	RPD ≤ 30%; Refer to Worksheet #28 for recovery criteria
Equipment Rinsate Blank	PFAS, VOCs	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.
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, VOCs	One per cooler	Representativeness	Temperature must be above freezing and ≤ 6°C
Trip Blank	VOCs	One per cooler	Accuracy/ Bias	No target analytes ≥ ½ LOQ, unless target analytes in field samples are > 10x those in rinsate blank
Matrix: Solid (Soil and Sediment)				
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

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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 facility, exposure to sampling facility 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
VOC = volatile organic compound

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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
3-19	*Headspace Screening for Total VOCs*	AECOM	Y	Modified for programmatic details

Reference Number	Title, Revision Date, and/or Number	Originating Organization	Modified for Project Work?	Comments
3-20	*Operation and Calibration of Photoionization Detector*	AECOM	Y	Modified for programmatic details
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
3-35	*In-Situ Hydraulic Conductivity Testing via Rising or Falling Head Slug Testing*	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

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
TSI Dusttrack II	Calibrate with zero air filter	NA	NA	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)
ME003NI-04	*Determination of Per- and Polyfluoroalkyl Substances (PFAS) by LC/MS/MS (Isotope Dilution) QSM 5.1 Table B-15* 03/30/2021	Definitive	Water/PFAS Solid/PFAS	LC-MS-MS	Pace South Carolina	N
ME0012X-22	*GC/MS Volatiles Analysis,* 09/23/2021, Revision 22	Definitive	Aqueous/Volatiles	GC/MS	Pace South Carolina	N
ENV-SOP-GBAY-0051	*The Determination of Total Organic Carbon Using the Multi EA 4000 Instrument*	Definitive	Solid/TOC	Analytikjena EA4000 with NDIR detector	Pace Green Bay	N
ME0014S-09	*pH by Electrometric Measurement / pH Paper Method SM4500-H B-2011 / 9040C / 150.1 / 9041A / 9045D Effective Date: 01/21/22*	Definitive	Inorganic Non-Metals - Aqueous/Solid	Meter	Pace Analytical Services - South Carolina	N
ENV-SOP-SHRT-0158	*Grain Size Analysis Oct 2020*	Definitive	Solid/Grain Size	Sieve	Pace Wyoming	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 South Carolina performs test remote to field operations.

DIA = data independent acquisition
LC/MS/MS = liquid chromatography tandem mass spectrometry
N = no
NPW = 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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3051 # QAPP Worksheet #24: Analytical Instrument Calibrations

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Instrument/ Equipment	Calibration Procedure	Frequency of Calibration	Acceptance Criteria	Corrective Action	Person(s) Responsible	SOP Reference
LC-MS/MS	Mass Calibration	Instrument must have a valid mass calibration prior to any sample analysis. Mass calibration is verified after each mass calibration, prior to initial calibration (ICAL).	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.	If the mass calibration fails, then recalibrate. If it fails again, consult manufacturer instructions on corrective maintenance.	Analyst, supervisor	ME003NI

Instrument/ Equipment	Calibration Procedure	Frequency of Calibration	Acceptance Criteria	Corrective Action	Person(s) Responsible	SOP Reference
LC-MS/MS	Calibration, Calibration Verification and Spiking Standards	All analytes. Note: Standards containing both branched and linear isomers are to be used during method validation and when reestablishing retention times, to ensure the total response is quantitated for that analyte. Technical grade standards cannot be used for quantitative analysis	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	ME003NI
LC-MS/MS	Mass Spectral Acquisition Rate	Each analyte, extracted internal standard (EIS) analyte	A minimum of 10 spectra scans are acquired across each chromatographic peak.	NA	Analyst, supervisor	ME003NI

Instrument/ Equipment	Calibration Procedure	Frequency of Calibration	Acceptance Criteria	Corrective Action	Person(s) Responsible	SOP Reference
LC-MS/MS	Ion Transitions (Precursor -> Product)	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 NEtFOSAA: 584 —› 419 NMeFOSAA: 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	Analyst, supervisor	ME003NI

Instrument/ Equipment	Calibration Procedure	Frequency of Calibration	Acceptance Criteria	Corrective Action	Person(s) Responsible	SOP Reference
LC-MS/MS	Initial calibration (ICAL); Calibration can be linear (minimum of 5 standards) or quadratic (minimum of 6 standards); weighting is allowed.	At instrument set-up and after ICV or CCV failure, prior to sample analysis.	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 non-linear calibrations must have r2 ≥ 0.99 for each analyte. The isotopically labeled analog of an analyte (Extracted Internal Standard 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 Extracted Internal Standard Analyte with the closest retention time or chemical similarity to the analyte must be used for quantitation. (Internal Standard Quantitation).	Perform maintenance if necessary, repeat calibration if criterion is not met. No samples shall be analyzed until ICAL has passed.	Analyst, supervisor	ME003NI

Instrument/ Equipment	Calibration Procedure	Frequency of Calibration	Acceptance Criteria	Corrective Action	Person(s) Responsible	SOP Reference
LC-MS/MS	Instrument blank (IBLK)	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	ME003NI
LC-MS/MS	Initial calibration verification (ICV)	Once after each ICAL, analysis of a second source standard prior to sample analysis	Analyte concentrations must be within ± 30% of their true value	Correct problem and verify second source standard; rerun second source verification. If that fails, correct problem and repeat ICAL.	Analyst, supervisor	ME003NI
LC-MS/MS	Instrument Sensitivity Check (ISC)	Daily 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	ME003NI
LC-MS/MS	Continuing Calibration Verification (CCV)	Daily prior to sample analysis (ISC); after every 10 field samples; at end of analytical sequence	All analytes must be within ± 30% of their true value	Immediately analyze two additional consecutive CCVs. If both pass, samples may be reported without reanalysis. If either fails, or if two consecutive CCVs cannot be run, perform corrective action(s) and repeat CCV and all associated samples since last successful CCV. Alternately, recalibrate if necessary; then reanalyze all samples since the last acceptable CCV.	Analyst, supervisor	ME003NI

Instrument/ Equipment	Calibration Procedure	Frequency of Calibration	Acceptance Criteria	Corrective Action	Person(s) Responsible	SOP Reference
GC/MS	Tune Check	Prior to ICAL and prior to each 12-hour period of sample analysis	Specific ion abundance criteria of BFB or DFTPP from method.	Retune instrument and verify	Analyst, Supervisor, QA Manager	ME0012X
GC/MS	Initial Calibration (ICAL) minimum five-point linear (or six-point quadratic) initial calibration for all analytes and surrogates	At instrument set-up and after ICV or CCV failure, prior to sample analysis	Each analyte must meet one of the three options: <u>Option 1:</u> RSD for each analyte ≤ 15% <u>Option 2 & 3:</u> linear least squares regression for each analyte or non-linear least squares regression (quadratic): r2≥0.99	Correct problem, then repeat ICAL.	Analyst, Supervisor, QA Manager	ME0012X
GC/MS	Retention Time window position establishment and evaluation	Once per ICAL and at the beginning of the analytical sequence.	Position shall be set using the mid-point of the ICAL curve when ICAL is performed. On days when ICAL is not performed, the initial CCV is used. RRT of each reported analyte within ± 0.06 RRT units.	Correct problem, then rerun ICAL.	Analyst, Supervisor, QA Manager	ME0012X
GC/MS	Initial Calibration Verification (ICV)	Once after each ICAL, analysis of a second source standard prior to sample analysis	All reported analytes within ± 20% of the true value	Correct problem. Rerun ICV. If that fails, repeat ICAL.	Analyst, Supervisor, QA Manager	ME0012X

Instrument/ Equipment	Calibration Procedure	Frequency of Calibration	Acceptance Criteria	Corrective Action	Person(s) Responsible	SOP Reference
GC/MS	Continuing Calibration Verification (CCV)	Daily before sample analysis; after every 12 hours of analysis time; and at the end of the analytical batch run.	All reported analytes and surrogates within ±20% of the true value. All reported analytes and surrogates ≤50% for end of analytical batch CCV.	Immediately analyze two consecutive CCVs. If both pass, samples may be reported without reanalysis. If either fails or if two consecutive CCVs cannot be run, perform corrective action(s) and repeat CCV and all associated samples since last successful CCV. Alternately, recalibrate if necessary; then reanalyze all associated samples since the last acceptable CCV.	Analyst, Supervisor, QA Manager	ME0012X
Analytical Balances	Class “S” weight are completed by an approved ISO 17025	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	ME0014S
Analytikjena EA4000 with NDIR Detector	ICAL	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	ENV-SOP-GBAY-0051
Analytikjena EA4000 with NDIR Detector	ICV	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	ENV-SOP-GBAY-0051
Analytikjena EA4000 with NDIR Detector	CCV	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	ENV-SOP-GBAY-0051

Instrument/ Equipment	Calibration Procedure	Frequency of Calibration	Acceptance Criteria	Corrective Action	Person(s) Responsible	SOP Reference
Analytikjena EA4000 with NDIR Detector	CCB	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	ENV-SOP-GBAY-0051
pH Meter	Calibrate meter	Daily before use	92-102%	Recalibrate meter	Analyst, Supervisor, QA Manager	ME0014S
Grain Size	Sieve – Visual inspection	Every use	No clogging or tears in mesh	Remove from service	Analyst, Supervisor, QA Manager	ENV-SOP-SHRT-0158

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 = micrograms

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

Laboratory: Pace South Carolina

Instrument/ Equipment	Maintenance Activity	Testing Activity	Inspection Activity	Frequency	Acceptance Criteria	Corrective Action	Responsible Person	SOP Reference
LC-MS/MS	Check column pressure and mobile phase levels/expirations daily. Perform the following as needed: prepare aqueous mobile phase, clean/replace injection needle, replace guard cartridge, backflush/replace column, replace injector seat, clean curtain/orifice plate, retune MS	PFAS	Inspect all tubing connections at time of maintenance to assure no leaks present. Monitor instrument performance via calibrations, CCVs, and blanks.	Initially, after major maintenance, CCV not meeting 2X	Same as initial calibration and continuing calibration verification	Same as initial calibration and continuing calibration verification	Analyst/Supervisor	ME003NI
GC/MS	Check for leaks, replace gas line filters, recondition or replace trap, replace column, clean injection port/liner.	Volatiles	Monitor instrument performance via Continuing Calibration Verification	As needed	No maintenance is required as long as instrument QC meets DOD criteria	Replace connections, clean source, replace gas line filters, replace trap, replace GC column, clip column, replace injection port liner, clean injection port, replace Electron Multiplier	Analyst, Supervisor, QA Manager	ME0012X
TOC Analyzer	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-GBAY-0051

Instrument/ Equipment	Maintenance Activity	Testing Activity	Inspection Activity	Frequency	Acceptance Criteria	Corrective Action	Responsible Person	SOP Reference
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	ME0014S
Seives	Cleaning	Grain Size	Visual inspection for clogs or tears	Each use	No instrument error message	Remove from service	Analyst, Department Manager	ENV-SOP-SHRT-0158

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

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

Sampling Organization: AECOM
Laboratory: Pace South Carolina
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 South Carolina	ME002BS-11
Sample custody and storage	Pace South Carolina	ME002BS-11
Sample disposal	Pace South Carolina	ME0012A-09

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 South Carolina SOP Reference: ME003NI
Certification Status: DoD ELAP/NYSDOH

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 and ≤ the mid-level calibration concentration. As Per Worksheet #15 and Table C-44 and 45 of QSM 5.3	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: As Per Worksheet #15 and Table C-44 and 45 of QSM 5.3 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).	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
		Documentation of the primary and confirmation transitions and the ion ratio is required. 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
DoD-ELAP = Department of Defence Environmental Laboratory Accreditation Program
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
NYSDOH = New York State Department of Health
QA = quality assurance
QC = quality control
RPD = relative percent difference
S/N = signal to noise
SOP = standard operating procedure
SPE = solid phase extraction

Matrix: Aqueous
Analytical Group: VOC
Analytical Method: 8260D
Pace South Carolina SOP Reference: ME0012X
Certification Status: DoD ELAP

QC Sample	Frequency/Number	Method/SOP Acceptance Limits	Corrective Action	Person(s) Responsible	Measurement Performance Criteria
Method Blank (MB)	One per preparatory batch of 20 or fewer samples.	No analytes detected > ½ LOQ, or >1/10th the amount measured in any sample, or 1/10th the regulatory limit, whichever is greater. For common laboratory contaminants, no analytes detected > LOQ. Data may not be reported without a valid Method Blank.	Correct problem. If required, reprep and reanalyze MB and all QC samples and field samples processed with the contaminated blank. If reanalysis cannot be performed, data must be qualified and explained in the case narrative.	Analyst, Supervisor, QA Manager	Bias Contamination
Laboratory Control Sample (LCS)	One per preparatory batch of 20 or fewer samples.	See Worksheet #15 for recovery and RPD Limits	Correct problem, then reprep and reanalyze the LCS and all samples in the associated preparatory batch for failed analytes if sufficient sample material is available. If reanalysis cannot be performed, data must be qualified and explained in the case narrative	Analyst, Supervisor, QA Manager	Accuracy/Bias
Matrix Spike (MS) and Matrix Spike Duplicate (MSD)	One per preparatory batch of 20 or fewer samples.	Same as LCS/LCSD	Examine the project specific requirements. Contact the client as to additional measures to be taken.	Analyst, Supervisor, QA Manager	Accuracy/Bias
Internal Standards (IS)	Every field sample, standard, and QC sample	Retention time within ±10 seconds from retention time of the midpoint standard in the ICAL; EICP area within -50% to +100% of ICAL midpoint standard.	Inspect mass spectrometer and GC for malfunctions and correct problem. Reanalysis of sample analyzed while system was malfunctioning is mandatory.	Analyst, Supervisor, QA Manager	Accuracy/Bias
LOD/LOQ Verification	After the ICAL Spike a clean matrix with the analytes of interest	Initially with instrument setup or major maintenance and quarterly, thereafter.	Perform instrument maintenance and repeat failed LOD/LOQ study,	Analyst, Supervisor, QA Manager	Accuracy/Bias

QC Sample	Frequency/Number	Method/SOP Acceptance Limits	Corrective Action	Person(s) Responsible	Measurement Performance Criteria
	at 0.5 to 2 times the LOQ level(s).	LOD meets method quantitative requirements or is at least 3x higher than noise. LOQ is ≤20% or laboratory established limits	passing two consecutive tests, or perform a new DL study.		
Surrogate Spike	All field and QC samples	QC acceptance criteria specified by the project if available; otherwise, use DoD/QSM Appendix C limits or in-house LCS limits if analyte(s) is not listed.	Correct problem, then reprep and reanalyze all failed samples for all surrogates in the associated preparatory batch if sufficient sample material is available. If obvious chromatographic interference is present, reanalysis may not be necessary, but the client must be notified prior to reporting data and the failures must be discussed in the case narrative.	Analyst, Supervisor, QA Manager	Accuracy/Bias

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Matrix: Solid
Analytical Group: TOC
Analytical Method: Lloyd Kahn
Pace Green Bay SOP Reference: ENV-SOP-GBAY-0051
Certification Status: NYSDOH

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.	80% - 120%	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 of 20%	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
LCS = laboratory control spike
LOQ = limit of quantitation
MD = matrix duplicate
MS/MSD = matrix spike/matrix spike duplicate
NYSDOH = New York State Department of Health
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 South Carolina SOP Reference: BTRO-0037
Certification Status: DoD-ELAP

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.	80% - 120%	Re-analyze or re-prepare and re-analyze.	Analyst or Project Chemist	Accuracy/Bias	Same as method

Notes:
% = percent
≤ = less than or equal to
DQI = data quality indicator
DoD-ELAP = Department of Defence Environmental Laboratory Accreditation Program
LCS = laboratory control spike
MD = matrix duplicate
MS = matrix spike
QC = quality control
SOP = standard operating procedure
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
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: Colin Wasteneys

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 Reports. 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 facility. 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 facility conditions.
Step 2 (cont.)	• Discuss the effect of facility 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
Technical Project Planning Meeting Minutes

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Appendix B
SI Analytical Results

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Appendix F Laboratory Data
Decontamination Water and Quality Control Samples
Site Inspection Report, Camp Smith

Area of Interest	DECON SOURCE																FIELD QC											
Sample ID	CS-DECON WATER				CASCADE-DECONWATER 11/21				CS-DECON-040521				CS-DECON-072521				ERB-121019CS				ERB-121119HA				ERB-121119WL			
Sample Date	07/10/2019				11/21/2019				04/05/2021				07/25/2021				12/10/2019				12/11/2019				12/11/2019			
Analyte	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual
Water, PFAS by LCMSMS compliant with QSM 5.3 Table B-15 (ng/l)																												
6:2 FTS	<	3.33	8.33	U	<	3.33	8.33	U	<	2.00	4.00	U	<	3.00	4.00	U	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U
8:2 FTS	<	3.33	8.33	U	<	3.33	8.33	U	<	2.00	4.00	U	<	3.00	4.00	U	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U
NEtFOSAA	<	6.67	8.33	U	<	6.67	8.33	U	<	4.00	8.00	U	<	4.00	8.00	U	<	8.00	10.0	U	<	8.00	10.0	U	<	8.00	10.0	UJ
NMeFOSAA	<	6.67	8.33	U	<	6.67	8.33	U	<	4.00	8.00	U	<	4.00	8.00	U	<	8.00	10.0	U	<	8.00	10.0	U	<	8.00	10.0	UJ
PFBA	2.79	3.33	8.33	J	6.86	3.33	8.33	J	1.67	2.00	4.00	J	2.37	3.50	4.00	J	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U
PFBS	3.07	3.33	8.33	J	<	3.33	8.33	U	2.88	2.00	4.00	J	1.51	2.00	4.00	J	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U
PFDA	<	3.33	8.33	U	<	3.33	8.33	U	<	2.00	4.00	U	<	3.00	4.00	U	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U
PFDoA	<	3.33	8.33	U	<	3.33	8.33	U	<	2.00	4.00	U	<	3.00	4.00	U	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	UJ
PFHpA	2.23	3.33	8.33	J	<	3.33	8.33	U	<	2.00	4.00	U	<	3.00	4.00	U	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U
PFHxA	8.29	3.33	8.33	J	1.65	3.33	8.33	J	1.48	2.00	4.00	J	2.09	2.00	4.00	J	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U
PFHxS	22.9	3.33	8.33		<	3.33	8.33	U	<	2.00	4.00	U	<	3.00	4.00	U	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U
PFNA	<	3.33	8.33	U	<	3.33	8.33	U	<	2.00	4.00	U	<	2.00	4.00	U	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U
PFOA	3.80	3.33	8.33	J	<	3.33	8.33	U	2.09	2.00	4.00	J	1.37	2.00	4.00	J	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U
PFOS	32.0	3.33	8.33		<	1.86	8.33	U	<	2.00	4.00	U	1.63	2.00	4.00	J	4.09	4.00	10.0	J	<	4.00	10.0	U	<	4.00	10.0	U
PFPeA	7.86	3.33	8.33	J	<	3.33	8.33	U	1.03	2.00	4.00	J	2.07	2.00	4.00	J	2.80	4.00	10.0	J	<	4.00	10.0	U	<	4.00	10.0	U
PFTeDA	<	3.33	8.33	U	<	3.33	8.33	U	<	2.00	4.00	U	<	3.00	4.00	U	<	4.00	10.0	UJ	<	4.00	10.0	UJ	<	4.00	10.0	UJ
PFTrDA	<	3.33	8.33	U	<	3.33	8.33	U	<	2.00	4.00	U	<	3.00	4.00	U	<	4.00	10.0	UJ	<	4.00	10.0	UJ	<	4.00	10.0	UJ
PFUnDA	<	3.33	8.33	U	<	3.33	8.33	U	<	2.00	4.00	U	<	3.00	4.00	U	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	UJ

Interpreted Qualifiers

J = Estimated concentration

U = The analyte was not detected at a level greater than or equal to the adjusted detection limit (DL)

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
NMeFOSAA	N-methyl perfluorooctanesulfonamidoacetic acid
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
PFTrDA	perfluorotridecanoic acid
PFUnDA	perfluoro-n-undecanoic acid

Acronyms and Abbreviations

AOI	Area of Interest
ERB	equipment rinsate blank
FRB	field reagent blank
LCMSMS	liquid chromatography with tandem mass spectrometry
LOD	limit of detection
LOQ	limit of quantitation
QC	quality control
QSM	Quality Systems Manual
Qual	interpreted qualifier
ng/l	nanogram per liter
<	analyte not detected above the LOD

Appendix F Laboratory Data
Decontamination Water and Quality Control Samples
Site Inspection Report, Camp Smith

Area of Interest	FIELD QC																							
Sample ID	ERB-121219SS				CS-ERB-01				CS-ERB-02				CS-ERB-03				FRB-121119				CS-FRB-01			
Sample Date	12/12/2019				07/22/2021				07/24/2021				07/25/2021				12/11/2019				07/25/2021			
Analyte	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual
Water, PFAS by LCMSMS compliant with QSM 5.3 Table B-15 (ng/l)																								
6:2 FTS	<	4.00	10.0	U	23.3	3.00	4.00		<	3.00	4.00	U	<	3.00	4.00	U	<	4.00	10.0	U	<	3.00	4.00	U
8:2 FTS	<	4.00	10.0	U	<	3.00	4.00	U	<	3.00	4.00	U	<	3.00	4.00	U	<	4.00	10.0	U	<	3.00	4.00	U
NEtFOSAA	<	8.00	10.0	U	<	4.00	8.00	U	<	4.00	8.00	U	<	4.00	8.00	U	<	8.00	10.0	U	<	4.00	8.00	U
NMeFOSAA	<	8.00	10.0	U	<	4.00	8.00	U	<	4.00	8.00	U	<	4.00	8.00	U	<	8.00	10.0	U	<	4.00	8.00	U
PFBA	<	4.00	10.0	U	<	3.50	4.00	U	<	3.50	4.00	U	<	3.50	4.00	U	<	4.00	10.0	U	<	3.50	4.00	U
PFBS	<	4.00	10.0	U	<	2.00	4.00	U	<	2.00	4.00	U	<	2.00	4.00	U	<	4.00	10.0	U	<	2.00	4.00	U
PFDA	<	4.00	10.0	U	<	3.00	4.00	U	<	3.00	4.00	U	<	3.00	4.00	U	<	4.00	10.0	U	<	3.00	4.00	U
PFDoA	<	4.00	10.0	U	<	3.00	4.00	U	<	3.00	4.00	U	<	3.00	4.00	U	<	4.00	10.0	UJ	<	3.00	4.00	U
PFHpA	<	4.00	10.0	U	<	3.00	4.00	U	<	3.00	4.00	U	<	3.00	4.00	U	<	4.00	10.0	U	<	3.00	4.00	U
PFHxA	<	4.00	10.0	U	<	2.00	4.00	U	<	2.00	4.00	U	<	2.00	4.00	U	<	4.00	10.0	U	<	2.00	4.00	U
PFHxS	<	4.00	10.0	U	<	3.00	4.00	U	<	3.00	4.00	U	<	3.00	4.00	U	<	4.00	10.0	U	<	3.00	4.00	U
PFNA	<	4.00	10.0	U	<	2.00	4.00	U	<	2.00	4.00	U	<	2.00	4.00	U	<	4.00	10.0	U	<	2.00	4.00	U
PFOA	<	4.00	10.0	U	<	2.00	4.00	U	<	2.00	4.00	U	<	2.00	4.00	U	<	4.00	10.0	U	<	2.00	4.00	U
PFOS	2.35	4.00	10.0	J	<	2.00	4.00	U	<	2.00	4.00	U	<	2.00	4.00	U	3.01	4.00	10.0	J	<	2.00	4.00	U
PFPeA	3.31	4.00	10.0	J	<	2.00	4.00	U	<	2.00	4.00	U	<	2.00	4.00	U	2.57	4.00	10.0	J	<	2.00	4.00	U
PFTeDA	<	4.00	10.0	UJ	<	3.00	4.00	U	<	3.00	4.00	U	<	3.00	4.00	U	<	4.00	10.0	UJ	<	3.00	4.00	U
PFTrDA	<	4.00	10.0	UJ	<	3.00	4.00	U	<	3.00	4.00	U	<	3.00	4.00	U	<	4.00	10.0	UJ	<	3.00	4.00	U
PFUnDA	<	4.00	10.0	U	<	3.00	4.00	U	<	3.00	4.00	U	<	3.00	4.00	U	<	4.00	10.0	U	<	3.00	4.00	U

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PFDoA	perfluorododecanoic acid
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PFHxA	perfluorohexanoic acid
PFHxS	perfluorohexanesulfonic acid
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PFOS	perfluorooctanesulfonic acid
PFPeA	perfluoropentanoic acid
PFTeDA	perfluorotetradecanoic acid
PFTrDA	perfluorotridecanoic acid
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LOD	limit of detection
LOQ	limit of quantitation
QC	quality control
QSM	Quality Systems Manual
Qual	interpreted qualifier
ng/l	nanogram per liter
<	analyte not detected above the LOD

Appendix F Laboratory Data
Surface Soil
Site Inspection Report, Camp Smith

Area of Interest		AOI1																								AOI2			
Sample ID		AOI 1-SB1-0.5-1				AOI 1-SB2-0.5-1				AOI 1-SB3-0.5-1				AOI 1-SB3-1-2				CS-MW001S-SB-00-02				CS-MW001S-SB-00-02-D				AOI 2-SB1-0.5-1			
Sample Date		12/11/2019				12/11/2019				12/11/2019				12/11/2019				07/20/2021				07/20/2021				12/10/2019			
Depth		0.5 - 1 ft				0.5 - 1 ft				0.5 - 1 ft				1 - 2 ft				0 - 2 ft				0 - 2 ft				0.5 - 1 ft			
Analyte	OSD Screening Level [a]	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual
Soil, PFAS by LCMSMS compliant with QSM 5.3 Table B-15 (µg/kg)																													
6:2 FTS	-	<	0.431	1.08	U	<	0.502	1.26	U	<	0.416	1.04	U	<	0.495	1.24	U	<	0.244	1.22	U	<	0.236	1.18	U	<	0.427	1.07	U
8:2 FTS	-	<	0.431	1.08	U	<	0.502	1.26	U	<	0.416	1.04	U	<	0.495	1.24	U	<	0.122	1.22	U	<	0.118	1.18	U	<	0.427	1.07	U
NEtFOSAA	-	<	0.431	1.08	U	<	0.502	1.26	U	<	0.416	1.04	U	<	0.495	1.24	U	<	0.122	1.22	U	<	0.118	1.18	U	<	0.427	1.07	U
NMeFOSAA	-	<	0.431	1.08	U	<	0.502	1.26	U	<	0.416	1.04	U	<	0.495	1.24	U	<	0.061	1.22	U	<	0.059	1.18	U	<	0.427	1.07	U
PFBA	-	<	0.431	1.08	U	<	0.502	1.26	U	0.146	0.416	1.04	J	0.325	0.495	1.24	J	0.224	0.122	1.22	J	0.207	0.118	1.18	J	0.143	0.427	1.07	J
PFBS	1900	<	0.431	1.08	U	<	0.502	1.26	U	<	0.416	1.04	U	<	0.495	1.24	U	0.034	0.061	1.22	J	0.034	0.059	1.18	J	<	0.427	1.07	U
PFDA	-	<	0.431	1.08	U	<	0.502	1.26	U	<	0.416	1.04	U	<	0.495	1.24	U	0.093	0.122	1.22	J	0.085	0.118	1.18	J	<	0.427	1.07	U
PFDoA	-	<	0.431	1.08	U	<	0.502	1.26	U	<	0.416	1.04	U	<	0.495	1.24	U	0.032	0.061	1.22	J	0.030	0.059	1.18	J	<	0.427	1.07	U
PFHpA	-	<	0.431	1.08	U	<	0.502	1.26	U	<	0.416	1.04	U	<	0.495	1.24	U	0.134	0.061	1.22	J	0.126	0.059	1.18	J	<	0.427	1.07	U
PFHxA	-	<	0.431	1.08	U	<	0.502	1.26	U	<	0.416	1.04	U	<	0.495	1.24	U	0.123	0.061	1.22	J	0.113	0.059	1.18	J	<	0.427	1.07	U
PFHxS	-	<	0.431	1.08	U	<	0.502	1.26	U	<	0.416	1.04	U	<	0.495	1.24	U	<	0.122	1.22	U	<	0.118	1.18	U	<	0.427	1.07	U
PFNA	-	<	0.431	1.08	U	<	0.502	1.26	U	<	0.416	1.04	U	<	0.495	1.24	U	0.217	0.061	1.22	J	0.197	0.059	1.18	J	<	0.427	1.07	U
PFOA	130	<	0.431	1.08	U	<	0.502	1.26	U	<	0.416	1.04	U	0.919	0.495	1.24	J	0.669	0.244	1.22	J	0.627	0.236	1.18	J	<	0.427	1.07	U
PFOS	130	0.260	0.431	1.08	J	0.345	0.502	1.26	J	<	0.416	1.04	U	0.339	0.495	1.24	J	0.396	0.244	1.22	J	0.334	0.236	1.18	J	0.432	0.427	1.07	J
PFPeA	-	<	0.431	1.08	U	<	0.502	1.26	U	<	0.416	1.04	U	<	0.495	1.24	U	0.129	0.061	1.22	J	0.110	0.059	1.18	J	<	0.427	1.07	U
PFTeDA	-	<	0.431	1.08	U	<	0.502	1.26	UJ	<	0.416	1.04	U	<	0.495	1.24	U	<	0.061	1.22	U	<	0.059	1.18	U	<	0.427	1.07	U
PFTrDA	-	<	0.431	1.08	U	<	0.502	1.26	UJ	<	0.416	1.04	U	<	0.495	1.24	U	<	0.122	1.22	U	<	0.118	1.18	U	<	0.427	1.07	U
PFUnDA	-	<	0.431	1.08	U	<	0.502	1.26	U	<	0.416	1.04	U	<	0.495	1.24	U	0.073	0.061	1.22	J	0.072	0.059	1.18	J	<	0.427	1.07	U

Grey Fill — Detected concentration exceeded OSD Screening Levels

References

a. Assistant Secretary of Defense, 2021. Risk Based Screening Levels Calculated for PFOS and PFOA in Groundwater or Soil using USEPA's Regional Screening Level Calculator. HQ=0.1. 15 September 2021. Soil screening levels based on residential scenario for direct ingestion of contaminated soil.

Interpreted Qualifiers

J = Estimated concentration

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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
NMeFOSAA	N-methyl perfluorooctanesulfonamidoacetic acid
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
PFTrDA	perfluorotridecanoic acid
PFUnDA	perfluoro-n-undecanoic acid

Acronyms and Abbreviations

AOI	Area of Interest
D/FD	duplicate
ft	feet
HQ	hazard quotient
LCMSMS	liquid chromatography with tandem mass spectrometry
LOD	limit of detection
LOQ	limit of quantitation
OSD	Office of the Secretary of Defense
QSM	Quality Systems Manual
Qual	interpreted qualifier
SB	soil boring
USEPA	United States Environmental Protection Agency
µg/kg	micrograms per kilogram
-	not applicable
<	analyte not detected above the LOD

Appendix F Laboratory Data
Surface Soil
Site Inspection Report, Camp Smith

Area of Interest		AOI 2																AOI3											
Sample ID		AOI2-SB2-00-02				AOI2-SB3-00-02				AOI2-SB4-00-02				AOI2-SB5-00-02				AOI 3-SB1-0.5-1				AOI 3-SB1-1-2				AOI 3-SB1-1-2-FD			
Sample Date		07/24/2021				07/24/2021				07/24/2021				07/24/2021				12/10/2019				12/10/2019				12/10/2019			
Depth		0 - 2 ft				0 - 2 ft				0 - 2 ft				0 - 2 ft				0.5 - 1 ft				1 - 2 ft				1 - 2 ft			
Analyte	OSD Screening Level [a]	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual
Soil, PFAS by LCMSMS compliant with QSM 5.3 Table B-15 (µg/kg)																													
6:2 FTS	-	<	0.216	1.08	U	0.460	0.209	1.05	J	<	0.230	1.15	U	<	0.213	1.07	U	<	0.424	1.06	U	<	0.488	1.22	U	<	0.468	1.17	U
8:2 FTS	-	0.077	0.108	1.08	J	7.65	0.105	1.05		0.065	0.115	1.15	J	<	0.107	1.07	U	<	0.424	1.06	U	<	0.488	1.22	U	<	0.468	1.17	U
NEtFOSAA	-	<	0.108	1.08	U	<	0.105	1.05	U	<	0.115	1.15	U	<	0.107	1.07	U	<	0.424	1.06	U	<	0.488	1.22	U	<	0.468	1.17	U
NMeFOSAA	-	<	0.054	1.08	U	<	0.052	1.05	U	<	0.057	1.15	U	<	0.053	1.07	U	<	0.424	1.06	U	<	0.488	1.22	U	<	0.468	1.17	U
PFBA	-	<	0.108	1.08	U	<	0.105	1.05	U	<	0.115	1.15	U	<	0.107	1.07	U	0.270	0.424	1.06	J	0.304	0.488	1.22	J	0.207	0.468	1.17	J
PFBS	1900	<	0.054	1.08	U	<	0.052	1.05	U	<	0.057	1.15	U	<	0.053	1.07	U	<	0.424	1.06	U	<	0.488	1.22	U	<	0.468	1.17	U
PFDA	-	<	0.108	1.08	U	0.111	0.105	1.05	J	<	0.115	1.15	U	<	0.107	1.07	U	<	0.424	1.06	U	<	0.488	1.22	U	<	0.468	1.17	U
PFDoA	-	0.025	0.054	1.08	J	<	0.052	1.05	U	<	0.057	1.15	U	<	0.053	1.07	U	<	0.424	1.06	U	<	0.488	1.22	U	<	0.468	1.17	U
PFHpA	-	<	0.054	1.08	U	0.061	0.052	1.05	J	<	0.057	1.15	U	0.030	0.053	1.07	J	<	0.424	1.06	U	<	0.488	1.22	U	<	0.468	1.17	U
PFHxA	-	<	0.054	1.08	U	0.033	0.052	1.05	J	<	0.057	1.15	U	0.095	0.053	1.07	J	<	0.424	1.06	U	<	0.488	1.22	U	<	0.468	1.17	U
PFHxS	-	0.053	0.108	1.08	J	0.150	0.105	1.05	J	0.067	0.115	1.15	J	<	0.107	1.07	U	<	0.424	1.06	U	<	0.488	1.22	U	<	0.468	1.17	U
PFNA	-	<	0.054	1.08	U	0.071	0.052	1.05	J	<	0.057	1.15	U	0.032	0.053	1.07	J	<	0.424	1.06	U	<	0.488	1.22	U	<	0.468	1.17	U
PFOA	130	<	0.216	1.08	U	0.126	0.209	1.05	J	<	0.230	1.15	U	<	0.213	1.07	U	0.172	0.424	1.06	J	<	0.488	1.22	U	<	0.468	1.17	U
PFOS	130	4.56	0.216	1.08		34.2	0.209	1.05		1.25	0.230	1.15		0.099	0.213	1.07	J	0.194	0.424	1.06	J	<	0.488	1.22	U	<	0.468	1.17	U
PFPeA	-	<	0.054	1.08	U	0.021	0.052	1.05	J	<	0.057	1.15	U	0.095	0.053	1.07	J	<	0.424	1.06	U	<	0.488	1.22	U	<	0.468	1.17	U
PFTeDA	-	<	0.054	1.08	U	<	0.052	1.05	U	<	0.057	1.15	U	<	0.053	1.07	U	<	0.424	1.06	U	<	0.488	1.22	U	<	0.468	1.17	U
PFTrDA	-	<	0.108	1.08	U	<	0.105	1.05	U	<	0.115	1.15	U	<	0.107	1.07	U	<	0.424	1.06	U	<	0.488	1.22	U	<	0.468	1.17	U
PFUnDA	-	0.027	0.054	1.08	J	0.021	0.052	1.05	J	<	0.057	1.15	U	<	0.053	1.07	U	<	0.424	1.06	U	<	0.488	1.22	U	<	0.468	1.17	U

Grey Fill — Detected concentration exceeded OSD Screening Levels

References

a. Assistant Secretary of Defense, 2021. Risk Based Screening Levels Calculated for PFOS and PFOA in Groundwater or Soil using USEPA's Regional Screening Level Calculator. HQ=0.1. 15 September 2021. Soil screening levels based on residential scenario for direct ingestion of contaminated soil.

Interpreted Qualifiers

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U = The analyte was not detected at a level greater than or equal to the adjusted detection limit (DL)

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
NMeFOSAA	N-methyl perfluorooctanesulfonamidoacetic acid
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
PFTrDA	perfluorotridecanoic acid
PFUnDA	perfluoro-n-undecanoic acid

Acronyms and Abbreviations

AOI	Area of Interest
D/FD	duplicate
ft	feet
HQ	hazard quotient
LCMSMS	liquid chromatography with tandem mass spectrometry
LOD	limit of detection
LOQ	limit of quantitation
OSD	Office of the Secretary of Defense
QSM	Quality Systems Manual
Qual	interpreted qualifier
SB	soil boring
USEPA	United States Environmental Protection Agency
µg/kg	micrograms per kilogram
-	not applicable
<	analyte not detected above the LOD

Appendix F Laboratory Data
Surface Soil
Site Inspection Report, Camp Smith

	Area of Interest	AOI3							
	Sample ID	AOI 3-SB2-0.5-1				CS-MW004S-SB-00-02			
	Sample Date	12/10/2019				07/19/2021			
	Depth	0.5 - 1 ft				0 - 2 ft			
Analyte	OSD Screening Level [a]	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual
Soil, PFAS by LCMSMS compliant with QSM 5.3 Table B-15 (µg/kg)									
6:2 FTS	-	<	0.458	1.14	U	<	0.233	1.16	U
8:2 FTS	-	<	0.458	1.14	U	<	0.116	1.16	U
NEtFOSAA	-	<	0.458	1.14	U	<	0.116	1.16	U
NMeFOSAA	-	<	0.458	1.14	U	<	0.058	1.16	U
PFBA	-	0.301	0.458	1.14	J	0.059	0.116	1.16	J
PFBS	1900	<	0.458	1.14	U	<	0.058	1.16	U
PFDA	-	<	0.458	1.14	U	<	0.116	1.16	U
PFDoA	-	<	0.458	1.14	U	<	0.058	1.16	U
PFHpA	-	<	0.458	1.14	U	0.033	0.058	1.16	J
PFHxA	-	<	0.458	1.14	U	0.042	0.058	1.16	J
PFHxS	-	<	0.458	1.14	U	0.048	0.116	1.16	J
PFNA	-	0.130	0.458	1.14	J	<	0.058	1.16	U
PFOA	130	0.173	0.458	1.14	J	0.110	0.233	1.16	J
PFOS	130	1.02	0.458	1.14	J	0.283	0.233	1.16	J
PFPeA	-	<	0.458	1.14	U	0.040	0.058	1.16	J
PFTeDA	-	<	0.458	1.14	U	<	0.058	1.16	U
PFTrDA	-	<	0.458	1.14	U	<	0.116	1.16	U
PFUnDA	-	<	0.458	1.14	U	<	0.058	1.16	U

Grey Fill — Detected concentration exceeded OSD Screening Levels

References

a. Assistant Secretary of Defense, 2021. Risk Based Screening Levels Calculated for PFOS and PFOA in Groundwater or Soil using USEPA's Regional Screening Level Calculator. HQ=0.1. 15 September 2021. Soil screening levels based on residential scenario for direct ingestion of contaminated soil.

Interpreted Qualifiers

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8:2 FTS	8:2 fluorotelomer sulfonate
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NMeFOSAA	N-methyl perfluorooctanesulfonamidoacetic acid
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
PFTrDA	perfluorotridecanoic acid
PFUnDA	perfluoro-n-undecanoic acid

Acronyms and Abbreviations

AOI	Area of Interest
D/FD	duplicate
ft	feet
HQ	hazard quotient
LCMSMS	liquid chromatography with tandem mass spectrometry
LOD	limit of detection
LOQ	limit of quantitation
OSD	Office of the Secretary of Defense
QSM	Quality Systems Manual
Qual	interpreted qualifier
SB	soil boring
USEPA	United States Environmental Protection Agency
µg/kg	micrograms per kilogram
-	not applicable
<	analyte not detected above the LOD

Appendix F Laboratory Data
Shallow Subsurface Soil
Site Inspection Report, Camp Smith

Area of Interest		AOI1												AOI2															
Sample ID		AOI 1-SB1-6-8				AOI 1-SB1-12-14				CS-MW001D-SB-08-10				AOI 2-SB1-11-13				AOI2-SB2-02-04				AOI2-SB3-02-04				AOI2-SB4-02-04			
Sample Date		12/11/2019				12/11/2019				07/20/2021				12/10/2019				07/24/2021				07/24/2021				07/24/2021			
Depth		6 - 8 ft				12 - 14 ft				8 - 10 ft				11 - 13 ft				2 - 4 ft				2 - 4 ft				2 - 4 ft			
Analyte	OSD Screening Level [a]	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual
Soil, PFAS by LCMSMS compliant with QSM 5.3 Table B-15 (µg/kg																													
6:2 FTS	-	<	0.512	1.28	U	<	0.434	1.09	U	<	0.239	1.20	U	<	0.445	1.11	U	<	0.269	1.34	U	3.10	0.239	1.19		<	0.208	1.04	U
8:2 FTS	-	<	0.512	1.28	U	<	0.434	1.09	U	<	0.120	1.20	U	<	0.445	1.11	U	0.670	0.134	1.34	J	30.2	0.119	1.19		2.08	0.104	1.04	
NEtFOSAA	-	<	0.512	1.28	U	<	0.434	1.09	U	<	0.120	1.20	U	<	0.445	1.11	U	<	0.134	1.34	U	<	0.119	1.19	U	<	0.104	1.04	U
NMeFOSAA	-	<	0.512	1.28	U	<	0.434	1.09	U	<	0.060	1.20	U	<	0.445	1.11	U	<	0.067	1.34	U	<	0.060	1.19	U	<	0.052	1.04	U
PFBA	-	0.313	0.512	1.28	J	0.257	0.434	1.09	J	<	0.120	1.20	U	0.299	0.445	1.11	J	<	0.134	1.34	U	0.050	0.119	1.19	J	<	0.104	1.04	U
PFBS	25000	<	0.512	1.28	U	<	0.434	1.09	U	0.025	0.060	1.20	J	<	0.445	1.11	U	<	0.067	1.34	U	<	0.060	1.19	U	<	0.052	1.04	U
PFDA	-	<	0.512	1.28	U	<	0.434	1.09	U	<	0.120	1.20	U	<	0.445	1.11	U	0.066	0.134	1.34	J	0.199	0.119	1.19	J	<	0.104	1.04	U
PFDoA	-	<	0.512	1.28	U	<	0.434	1.09	U	<	0.060	1.20	U	<	0.445	1.11	U	<	0.067	1.34	U	0.025	0.060	1.19	J	<	0.052	1.04	U
PFHpA	-	<	0.512	1.28	U	<	0.434	1.09	U	<	0.060	1.20	U	<	0.445	1.11	U	0.031	0.067	1.34	J	0.195	0.060	1.19	J	0.022	0.052	1.04	J
PFHxA	-	<	0.512	1.28	U	<	0.434	1.09	U	0.034	0.060	1.20	J	<	0.445	1.11	U	0.033	0.067	1.34	J	0.198	0.060	1.19	J	<	0.052	1.04	U
PFHxS	-	<	0.512	1.28	U	<	0.434	1.09	U	<	0.120	1.20	U	<	0.445	1.11	U	0.168	0.134	1.34	J	0.860	0.119	1.19	J	0.079	0.104	1.04	J
PFNA	-	<	0.512	1.28	U	<	0.434	1.09	U	<	0.060	1.20	U	<	0.445	1.11	U	0.046	0.067	1.34	J	0.285	0.060	1.19	J	<	0.052	1.04	U
PFOA	1600	<	0.512	1.28	U	<	0.434	1.09	U	0.129	0.239	1.20	J	<	0.445	1.11	U	<	0.269	1.34	U	0.588	0.239	1.19	J	<	0.208	1.04	U
PFOS	1600	<	0.512	1.28	U	<	0.434	1.09	U	0.117	0.239	1.20	J	<	0.445	1.11	U	24.4	0.269	1.34		191	2.39	11.9		17.6	0.208	1.04	
PFPeA	-	<	0.512	1.28	U	<	0.434	1.09	U	<	0.060	1.20	U	<	0.445	1.11	U	<	0.067	1.34	U	0.121	0.060	1.19	J	0.025	0.052	1.04	J
PFTeDA	-	<	0.512	1.28	UJ	<	0.434	1.09	U	<	0.060	1.20	U	<	0.445	1.11	U	<	0.067	1.34	U	<	0.060	1.19	U	<	0.052	1.04	U
PFTrDA	-	<	0.512	1.28	UJ	<	0.434	1.09	U	<	0.120	1.20	U	<	0.445	1.11	U	<	0.134	1.34	U	<	0.119	1.19	U	<	0.104	1.04	U
PFUnDA	-	<	0.512	1.28	U	<	0.434	1.09	U	<	0.060	1.20	U	<	0.445	1.11	U	0.037	0.067	1.34	J	0.028	0.060	1.19	J	0.022	0.052	1.04	J

Grey Fill — Detected concentration exceeded OSD Screening Levels

References

a. Assistant Secretary of Defense, 2021. Risk Based Screening Levels Calculated for PFOS and PFOA in Groundwater or Soil using USEPA's Regional Screening Level Calculator. HQ=0.1. 15 September 2021. Soil screening levels based on industrial/commercial composite worker scenario for incidental ingestion of contaminated soil.

Interpreted Qualifiers

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J- = Estimated concentration, biased low

U = The analyte was not detected at a level greater than or equal to the adjusted detection limit (DL)

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Chemical Abbreviations

6:2 FTS	6:2 fluorotelomer sulfonate
8:2 FTS	8:2 fluorotelomer sulfonate
NEtFOSAA	N-ethyl perfluorooctane- sulfonamidoacetic acid
NMeFOSAA	N-methyl perfluorooctanesulfonamidoacetic acid
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
PFTrDA	perfluorotridecanoic acid
PFUnDA	perfluoro-n-undecanoic acid

Acronyms and Abbreviations

AOI	Area of Interest
ft	feet
HQ	hazard quotient
LCMSMS	liquid chromatography with tandem mass spectrometry
LOD	limit of detection
LOQ	limit of quantitation
OSD	Office of the Secretary of Defense
QSM	Quality Systems Manual
Qual	interpreted qualifier
SB	soil boring
USEPA	United States Environmental Protection Agency
µg/kg	micrograms per kilogram
-	not applicable
<	analyte not detected above the LOD

Appendix F Laboratory Data
Shallow Subsurface Soil
Site Inspection Report, Camp Smith

Area of Interest		AOI 2				AOI3							
Sample ID		AOI2-SB5-02-04				AOI 3-SB2-7-9				CS-MW004S-SB-07-09			
Sample Date		07/24/2021				12/10/2019				07/19/2021			
Depth		2 - 4 ft				7 - 9 ft				7 - 9 ft			
Analyte	OSD Screening Level [a]	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual
Soil, PFAS by LCMSMS compliant with QSM 5.3 Table B-15 (µg/kg													
6:2 FTS	-	<	0.222	1.11	U	<	0.402	1.00	U	<	0.248	1.24	U
8:2 FTS	-	0.426	0.111	1.11	J	<	0.402	1.00	U	<	0.124	1.24	U
NEtFOSAA	-	<	0.111	1.11	U	<	0.402	1.00	U	<	0.124	1.24	U
NMeFOSAA	-	<	0.056	1.11	U	<	0.402	1.00	U	<	0.062	1.24	U
PFBA	-	<	0.111	1.11	U	0.274	0.402	1.00	J	<	0.124	1.24	U
PFBS	25000	<	0.056	1.11	U	<	0.402	1.00	U	<	0.062	1.24	U
PFDA	-	<	0.111	1.11	U	<	0.402	1.00	U	<	0.124	1.24	U
PFDoA	-	<	0.056	1.11	U	<	0.402	1.00	U	<	0.062	1.24	U
PFHpA	-	<	0.056	1.11	U	<	0.402	1.00	U	<	0.062	1.24	U
PFHxA	-	0.033	0.056	1.11	J	<	0.402	1.00	U	<	0.062	1.24	U
PFHxS	-	0.213	0.111	1.11	J	<	0.402	1.00	U	<	0.124	1.24	U
PFNA	-	<	0.056	1.11	U	<	0.402	1.00	U	<	0.062	1.24	U
PFOA	1600	<	0.222	1.11	U	<	0.402	1.00	U	<	0.248	1.24	U
PFOS	1600	1.42	0.222	1.11	J-	<	0.402	1.00	U	<	0.248	1.24	U
PFPeA	-	<	0.056	1.11	U	<	0.402	1.00	U	<	0.062	1.24	U
PFTeDA	-	<	0.056	1.11	U	<	0.402	1.00	U	<	0.062	1.24	U
PFTrDA	-	<	0.111	1.11	U	<	0.402	1.00	U	<	0.124	1.24	U
PFUnDA	-	<	0.056	1.11	U	<	0.402	1.00	U	<	0.062	1.24	U

Grey Fill — Detected concentration exceeded OSD Screening Levels

References

a. Assistant Secretary of Defense, 2021. Risk Based Screening Levels Calculated for PFOS and PFOA in Groundwater or Soil using USEPA's Regional Screening Level Calculator. HQ=0.1. 15 September 2021. Soil screening levels based on industrial/commercial composite worker scenario for incidental ingestion of contaminated soil.

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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
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Qual	interpreted qualifier
SB	soil boring
USEPA	United States Environmental Protection Agency
µg/kg	micrograms per kilogram
-	not applicable
<	analyte not detected above the LOD

Appendix F Laboratory Data
Deep Subsurface Soil
Site Inspection Report, Camp Smith

Area of Interest	AOI2				AOI 2/3												AOI3			
Sample ID	AOI 2-SB1-21-23				CS-MW002D-SB-39-41				CS-MW003S-SB-40-42				CS-MW003S-SB-40-42-D				AOI 3-SB2-15-17			
Sample Date	12/10/2019				07/23/2021				07/25/2021				07/25/2021				12/10/2019			
Depth	21 - 23 ft				39 - 41 ft				40 - 42 ft				40 - 42 ft				15 - 17 ft			
Analyte	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual
Soil, PFAS by LCMSMS compliant with QSM 5.3 Table B-15 (µg/kg)																				
6:2 FTS	<	0.447	1.12	U	<	0.221	1.11	U	<	0.257	1.28	U	<	0.260	1.30	U	<	0.402	1.00	U
8:2 FTS	<	0.447	1.12	U	<	0.111	1.11	U	<	0.128	1.28	U	<	0.130	1.30	U	<	0.402	1.00	U
NEtFOSAA	<	0.447	1.12	U	<	0.111	1.11	U	<	0.128	1.28	U	<	0.130	1.30	U	<	0.402	1.00	U
NMeFOSAA	<	0.447	1.12	U	<	0.055	1.11	U	<	0.064	1.28	U	<	0.065	1.30	U	<	0.402	1.00	U
PFBA	0.347	0.447	1.12	J	<	0.111	1.11	U	<	0.128	1.28	U	<	0.130	1.30	U	0.234	0.402	1.00	J
PFBS	<	0.447	1.12	U	<	0.055	1.11	U	<	0.064	1.28	U	<	0.065	1.30	U	<	0.402	1.00	U
PFDA	<	0.447	1.12	U	<	0.111	1.11	U	<	0.128	1.28	U	<	0.130	1.30	U	<	0.402	1.00	U
PFDoA	<	0.447	1.12	U	<	0.055	1.11	U	<	0.064	1.28	U	<	0.065	1.30	U	<	0.402	1.00	U
PFHpA	<	0.447	1.12	U	<	0.055	1.11	U	<	0.064	1.28	U	<	0.065	1.30	U	<	0.402	1.00	U
PFHxA	<	0.447	1.12	U	<	0.055	1.11	U	0.026	0.064	1.28	J	<	0.065	1.30	UJ	<	0.402	1.00	U
PFHxS	<	0.447	1.12	U	<	0.111	1.11	U	<	0.128	1.28	U	<	0.130	1.30	U	<	0.402	1.00	U
PFNA	<	0.447	1.12	U	<	0.055	1.11	U	<	0.064	1.28	U	<	0.065	1.30	U	<	0.402	1.00	U
PFOA	<	0.447	1.12	U	<	0.221	1.11	U	<	0.257	1.28	U	<	0.260	1.30	U	<	0.402	1.00	U
PFOS	<	0.447	1.12	U	0.151	0.221	1.11	J	0.131	0.257	1.28	J	0.101	0.260	1.30	J	<	0.402	1.00	U
PFPeA	<	0.447	1.12	U	<	0.055	1.11	U	<	0.064	1.28	U	<	0.065	1.30	U	<	0.402	1.00	U
PFTeDA	<	0.447	1.12	U	<	0.055	1.11	U	<	0.064	1.28	U	<	0.065	1.30	U	<	0.402	1.00	U
PFTrDA	<	0.447	1.12	U	<	0.111	1.11	U	<	0.128	1.28	U	<	0.130	1.30	U	<	0.402	1.00	U
PFUnDA	<	0.447	1.12	U	<	0.055	1.11	U	<	0.064	1.28	U	<	0.065	1.30	U	<	0.402	1.00	U

Interpreted Qualifiers

J = Estimated concentration

U = The analyte was not detected at a level greater than or equal to the adjusted detection limit (DL)

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
NMeFOSAA	N-methyl perfluorooctanesulfonamidoacetic acid
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
PFTrDA	perfluorotridecanoic acid
PFUnDA	perfluoro-n-undecanoic acid

Acronyms and Abbreviations

AOI	Area of Interest
D	duplicate
ft	feet
LCMSMS	liquid chromatography with tandem mass spectrometry
LOD	limit of detection
LOQ	limit of quantitation
QSM	Quality Systems Manual
Qual	interpreted qualifier
SB	soil boring
µg/kg	micrograms per kilogram
<	analyte not detected above the LOD

Appendix F Laboratory Data
Groundwater
Site Inspection Report, Camp Smith

Area of Interest			AOI1																								AOI 2/3			
Sample ID			AOI 1-GW1				AOI 1-GW2				AOI 1-GW3				CS-MW001D-GW				CS-MW001S-GW				CS-MW001S-GW-D				CS-MW002D-GW			
Sample Date			12/11/2019				12/11/2019				12/11/2019				07/24/2021				07/24/2021				07/24/2021				07/28/2021			
Analyte	OSD Screening Level [a]	USEPA HA [b]	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual
Water, PFAS by LCMSMS compliant with QSM 5.3 Table B-15 (ng/l)																														
6:2 FTS	-	-	2.10	4.00	10.0	J	<	4.00	10.0	U	<	4.00	10.0	U	<	3.00	4.00	U	9.15	3.00	4.00		8.61	3.00	4.00		10.1	3.00	4.00	
8:2 FTS	-	-	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U	<	3.00	4.00	U	<	3.00	4.00	U	<	3.00	4.00	U	<	3.00	4.00	U
NEtFOSAA	-	-	<	8.00	10.0	U	<	8.00	10.0	U	<	8.00	10.0	U	<	4.00	8.00	U	<	4.00	8.00	U	<	4.00	8.00	U	<	4.00	8.00	U
NMeFOSAA	-	-	<	8.00	10.0	U	<	8.00	10.0	U	<	8.00	10.0	U	<	4.00	8.00	U	<	4.00	8.00	U	<	4.00	8.00	U	<	4.00	8.00	U
PFBA	-	-	7.28	4.00	10.0	J	4.73	4.00	10.0	J	35.4	4.00	10.0		<	5.12	4.00	U	<	3.50	4.00	U	<	3.50	4.00	U	<	3.50	4.00	U
PFBS	600	-	2.87	4.00	10.0	J	<	4.00	10.0	U	3.39	4.00	10.0	J	<	2.00	4.00	U	<	2.43	4.00	U	<	2.48	4.00	U	<	2.80	4.00	U
PFDA	-	-	1.68	4.00	10.0	J	<	4.00	10.0	U	<	4.00	10.0	U	<	3.00	4.00	U	<	3.00	4.00	U	<	3.00	4.00	U	<	3.00	4.00	U
PFDoA	-	-	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U	<	3.00	4.00	U	<	3.00	4.00	U	<	3.00	4.00	U	<	3.00	4.00	U
PFHpA	-	-	4.77	4.00	10.0	J	3.50	4.00	10.0	J	9.51	4.00	10.0	J	3.00	3.00	4.00	J	1.74	3.00	4.00	J	1.85	3.00	4.00	J	2.75	3.00	4.00	J
PFHxA	-	-	9.81	4.00	10.0	J	3.42	4.00	10.0	J	11.4	4.00	10.0		<	8.21	4.00	U	<	2.37	4.00	U	<	2.45	4.00	U	<	8.52	4.00	U
PFHxS	-	-	14.6	4.00	10.0		3.45	4.00	10.0	J	10.2	4.00	10.0		7.05	3.00	4.00		3.81	3.00	4.00	J	3.80	3.00	4.00	J	17.9	3.00	4.00	
PFNA	-	-	4.18	4.00	10.0	J	4.23	4.00	10.0	J	5.17	4.00	10.0	J	<	2.00	4.00	U	<	2.00	4.00	U	<	2.00	4.00	U	<	2.00	4.00	U
PFOA	40	70	29.0	4.00	10.0		24.0	4.00	10.0	J-	58.4	4.00	10.0		16.1	2.00	4.00		14.3	2.00	4.00		14.5	2.00	4.00		<	4.80	4.00	U
PFOS	40	70	37.8	4.00	10.0		13.2	4.00	10.0	J+	12.5	4.00	10.0		10.8	2.00	4.00		<	5.75	4.00	U	<	5.81	4.00	U	37.7	2.00	4.00	
PFPeA	-	-	<	10.0	10.0	U	<	10.0	10.0	U	<	10	10.0	U	<	7.28	4.00	U	<	2.00	4.00	U	<	2.00	4.00	U	<	8.02	4.00	U
PFTeDA	-	-	<	4.00	10.0	UJ	<	4.00	10.0	UJ	<	4.00	10.0	UJ	<	3.00	4.00	U	<	3.00	4.00	U	<	3.00	4.00	U	<	3.00	4.00	U
PFTrDA	-	-	<	4.00	10.0	UJ	<	4.00	10.0	UJ	<	4.00	10.0	UJ	<	3.00	4.00	U	<	3.00	4.00	U	<	3.00	4.00	U	<	3.00	4.00	U
PFUnDA	-	-	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U	<	3.00	4.00	U	<	3.00	4.00	U	<	3.00	4.00	U	<	3.00	4.00	U
Total PFOA+PFOS	-	70	66.8	4			37.2	4			70.9	4			26.9	2			14.3	5.75			14.5	5.81			37.7	4.8		

Grey Fill	Detected concentration exceeded OSD Screening Levels
Bold Font	Detected concentration exceeded USEPA HA Screening Levels

References

a. Assistant Secretary of Defense, 2021. Risk Based Screening Levels Calculated for PFOS and PFOA in Groundwater or Soil using USEPA's Regional Screening Level Calculator. HQ=0.1. 15 September 2021. Groundwater screening levels based on residential scenario for direct ingestion of groundwater.

b. USEPA, 2016. Drinking Water Health Advisory for 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 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

J- = Estimated concentration, biased low

J+ = Estimated concentration, biased high

U = The analyte was not detected at a level greater than or equal to the adjusted detection limit (DL)

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
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NMeFOSAA	N-methyl perfluorooctanesulfonamidoacetic acid
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
PFTrDA	perfluorotridecanoic acid
PFUnDA	perfluoro-n-undecanoic acid

Acronyms and Abbreviations

AOI	Area of Interest
D/FD	duplicate
GW	groundwater
HA	Health Advisory
HQ	hazard quotient
LCMSMS	liquid chromatography with tandem mass spectrometry
LOD	limit of detection
LOQ	limit of quantitation
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
<	analyte not detected above the LOD

Appendix F Laboratory Data
Groundwater
Site Inspection Report, Camp Smith

Area of Interest			AOI 2/3				AOI3															
Sample ID			CS-MW003S-GW				AOI 3-GW1				AOI 3-GW1-FD				AOI 3-GW2				CS-MW004S-GW			
Sample Date			07/27/2021				12/10/2019				12/10/2019				12/10/2019				07/22/2021			
Analyte	**OSD Screening Level [a]**	**USEPA HA [b]**	**Result**	**LOD**	**LOQ**	**Qual**	**Result**	**LOD**	**LOQ**	**Qual**	**Result**	**LOD**	**LOQ**	**Qual**	**Result**	**LOD**	**LOQ**	**Qual**	**Result**	**LOD**	**LOQ**	**Qual**
Water, PFAS by LCMSMS compliant with QSM 5.3 Table B-15 (ng/l)																						
6:2 FTS	-	-	12.6	3.00	4.00		<	4.00	10.0	U	<	4.00	10.0	U	2.60	4.00	10.0	J	224	3.00	4.00	J-
8:2 FTS	-	-	<	3.00	4.00	U	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U	<	3.00	4.00	U
NEtFOSAA	-	-	<	4.00	8.00	U	<	8.00	10.0	U	<	8.00	10.0	U	<	8.00	10.0	U	<	4.00	8.00	U
NMeFOSAA	-	-	<	4.00	8.00	U	<	8.00	10.0	U	<	8.00	10.0	U	<	8.00	10.0	U	<	4.00	8.00	U
PFBA	-	-	14.3	3.50	4.00		12.9	4.00	10.0		12.5	4.00	10.0		4.50	4.00	10.0	J	<	4.57	4.00	U
PFBS	600	-	<	3.52	4.00	U	3.77	4.00	10.0	J	3.69	4.00	10.0	J	2.66	4.00	10.0	J	<	2.00	4.00	U
PFDA	-	-	<	3.00	4.00	U	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U	<	3.00	4.00	U
PFDoA	-	-	<	3.00	4.00	U	<	4.00	10.0	U	<	4.00	10.0	UJ	<	4.00	10.0	U	<	3.00	4.00	U
PFHpA	-	-	27.0	3.00	4.00		8.83	4.00	10.0	J	8.09	4.00	10.0	J	<	4.00	10.0	U	<	3.00	4.00	U
PFHxA	-	-	43.2	2.00	4.00		22.0	4.00	10.0		21.3	4.00	10.0		4.49	4.00	10.0	J	<	2.20	4.00	U
PFHxS	-	-	64.1	3.00	4.00		6.19	4.00	10.0	J	5.93	4.00	10.0	J	<	4.00	10.0	U	<	3.00	4.00	U
PFNA	-	-	1.70	2.00	4.00	J	3.57	4.00	10.0	J	4.25	4.00	10.0	J	<	4.00	10.0	U	<	2.00	4.00	U
PFOA	40	70	21.2	2.00	4.00		35.5	4.00	10.0		39.9	4.00	10.0		10.3	4.00	10.0		<	2.00	4.00	U
PFOS	40	70	**147**	2.00	4.00		15.3	4.00	10.0		14.8	4.00	10.0		19.7	4.00	10.0		<	2.00	4.00	U
PFPeA	-	-	48.5	2.00	4.00		21.9	4.00	10.0		22.2	4.00	10.0		<	7.15	10.0	U	<	2.00	4.00	U
PFTeDA	-	-	<	3.00	4.00	U	<	4.00	10.0	UJ	<	4.00	10.0	UJ	<	4.00	10.0	UJ	<	3.00	4.00	U
PFTrDA	-	-	<	3.00	4.00	U	<	4.00	10.0	UJ	<	4.00	10.0	UJ	<	4.00	10.0	UJ	<	3.00	4.00	U
PFUnDA	-	-	<	3.00	4.00	U	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U	<	3.00	4.00	U
Total PFOA+PFOS	-	70	168	2			50.8	4			54.7	4			30.0	4			<	2		U

Grey Fill	Detected concentration exceeded OSD Screening Levels
Bold Font	Detected concentration exceeded USEPA HA Screening Levels

References

a. Assistant Secretary of Defense, 2021. Risk Based Screening Levels Calculated for PFOS and PFOA in Groundwater or Soil using USEPA's Regional Screening Level Calculator. HQ=0.1. 15 September 2021. Groundwater screening levels based on residential scenario for direct ingestion of groundwater.

b. USEPA, 2016. Drinking Water Health Advisory for 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 PFOS. Office of Water (4304T). Health and Ecological Criteria Division, Washington, DC 20460. EPA Document Number: 822-R-16-004. May 2016.

Interpreted Qualifiers

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J- = Estimated concentration, biased low

J+ = Estimated concentration, biased high

U = The analyte was not detected at a level greater than or equal to the adjusted detection limit (DL)

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

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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
PFTrDA	perfluorotridecanoic acid
PFUnDA	perfluoro-n-undecanoic acid

Acronyms and Abbreviations

AOI	Area of Interest
D/FD	duplicate
GW	groundwater
HA	Health Advisory
HQ	hazard quotient
LCMSMS	liquid chromatography with tandem mass spectrometry
LOD	limit of detection
LOQ	limit of quantitation
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
<	analyte not detected above the LOD

Appendix F Laboratory Data
Sediment
Site Inspection Report, Camp Smith

Area of Interest	Camp Smith																													
Sample ID	CS-SD01-0-1				CS-SD02-0-1				CS-SD03-0-1				CS-SD04-0-1				CS-SD05-0-1				CS-SD06-0-1				CS-SD07-0-1				CS-SD08-0-1			
Sample Date	12/12/2019				12/12/2019				12/12/2019				12/12/2019				12/11/2019				12/12/2019				12/12/2019				12/12/2019			
Depth	0 - 1 ft				0 - 1 ft				0 - 1 ft				0 - 1 ft				0 - 1 ft				0 - 1 ft				0 - 1 ft				0 - 1 ft			
Analyte	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual
Sediment, PFAS by LCMSMS compliant with QSM 5.3 Table B-15 (µg/kg)†																																
6:2 FTS	<	2.30	5.76	U	<	0.810	2.02	U	<	7.66	19.1	U	<	0.552	1.38	U	<	0.743	1.86	U	<	0.447	1.12	U	<	1.08	2.71	U	<	1.34	3.34	U
8:2 FTS	<	2.30	5.76	UJ	<	0.810	2.02	U	<	7.66	19.1	U	<	0.552	1.38	U	<	0.743	1.86	U	<	0.447	1.12	U	<	1.08	2.71	U	<	1.34	3.34	UJ
NEtFOSAA	<	2.30	5.76	UJ	<	0.810	2.02	U	<	7.66	19.1	U	<	0.552	1.38	U	<	0.743	1.86	U	<	0.447	1.12	U	<	1.08	2.71	UJ	<	1.34	3.34	U
NMeFOSAA	<	2.30	5.76	UJ	<	0.810	2.02	U	<	7.66	19.1	U	<	0.552	1.38	U	<	0.743	1.86	U	<	0.447	1.12	U	<	1.08	2.71	U	<	1.34	3.34	U
PFBA	<	2.30	5.76	U	0.402	0.810	2.02	J	<	7.66	19.1	U	<	0.552	1.38	U	<	0.743	1.86	U	<	1.12	1.12	U	<	1.08	2.71	U	<	1.34	3.34	U
PFBS	<	2.30	5.76	U	<	0.810	2.02	U	<	7.66	19.1	U	<	0.552	1.38	U	<	0.743	1.86	U	<	0.447	1.12	U	<	1.08	2.71	U	<	1.34	3.34	U
PFDA	<	2.30	5.76	UJ	<	0.810	2.02	U	<	7.66	19.1	U	<	0.552	1.38	U	<	0.743	1.86	U	<	0.447	1.12	U	<	1.08	2.71	U	<	1.34	3.34	UJ
PFDoA	<	2.30	5.76	UJ	<	0.810	2.02	UJ	<	7.66	19.1	U	<	0.552	1.38	U	<	0.743	1.86	U	<	0.447	1.12	U	<	1.08	2.71	UJ	<	1.34	3.34	UJ
PFHpA	<	2.30	5.76	U	<	0.810	2.02	U	<	7.66	19.1	U	<	0.552	1.38	U	<	0.743	1.86	U	<	0.447	1.12	U	<	1.08	2.71	U	<	1.34	3.34	U
PFHxA	<	2.30	5.76	U	0.353	0.810	2.02	J	<	7.66	19.1	U	<	0.552	1.38	U	<	0.743	1.86	U	<	0.447	1.12	U	<	1.08	2.71	U	<	1.34	3.34	U
PFHxS	<	2.30	5.76	U	<	0.810	2.02	U	<	7.66	19.1	U	<	0.552	1.38	U	<	0.743	1.86	U	0.199	0.447	1.12	J	<	1.08	2.71	U	<	1.34	3.34	U
PFNA	<	2.30	5.76	UJ	0.192	0.810	2.02	J	<	7.66	19.1	U	<	0.552	1.38	U	<	0.743	1.86	U	<	0.447	1.12	U	<	1.08	2.71	U	<	1.34	3.34	U
PFOA	<	2.30	5.76	U	1.07	0.810	2.02	J	<	7.66	19.1	U	<	0.552	1.38	U	0.283	0.743	1.86	J	<	0.447	1.12	U	<	1.08	2.71	U	<	1.34	3.34	U
PFOS	2.14	2.30	5.76	J+	3.24	0.810	2.02		<	7.66	19.1	U	<	1.02	1.38	U	1.14	0.743	1.86	J	3.77	0.447	1.12		<	0.947	2.71	U	2.13	1.34	3.34	J
PFPeA	<	2.30	5.76	U	<	0.810	2.02	U	<	7.66	19.1	U	<	0.552	1.38	U	<	0.743	1.86	U	<	0.447	1.12	U	<	1.08	2.71	U	<	1.34	3.34	U
PFTeDA	<	2.30	5.76	UJ	<	0.810	2.02	UJ	<	7.66	19.1	UJ	<	0.552	1.38	UJ	<	0.743	1.86	UJ	<	0.447	1.12	U	<	1.08	2.71	UJ	<	1.34	3.34	UJ
PFTrDA	<	2.30	5.76	UJ	<	0.810	2.02	UJ	<	7.66	19.1	UJ	<	0.552	1.38	UJ	<	0.743	1.86	UJ	<	0.447	1.12	U	<	1.08	2.71	UJ	<	1.34	3.34	UJ
PFUnDA	<	2.30	5.76	UJ	0.299	0.810	2.02	J	<	7.66	19.1	UJ	<	0.552	1.38	U	<	0.743	1.86	U	<	0.447	1.12	U	<	1.08	2.71	U	<	1.34	3.34	UJ

†Samples collected during Mobilization 1 were analyzed by QSM 5.1 (which was the most current version at the time of the event)

Interpreted Qualifiers

J = Estimated concentration

J+ = Estimated concentration, biased high

U = The analyte was not detected at a level greater than or equal to the adjusted detection limit (DL)

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
NMeFOSAA	N-methyl perfluorooctanesulfonamidoacetic acid
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
PFTrDA	perfluorotridecanoic acid
PFUnDA	perfluoro-n-undecanoic acid

Acronyms and Abbreviations

ft	feet
LCMSMS	liquid chromatography with tandem mass spectrometry
LOD	limit of detection
LOQ	limit of quantitation
QSM	Quality Systems Manual
Qual	interpreted qualifier
SD	sediment
µg/kg	micrograms per kilogram
<	analyte not detected above the LOD

Appendix F Laboratory Data
Surface Water
Site Inspection Report, Camp Smith

Area of Interest	Camp Smith																			
Sample ID	CS-SW01				CS-SW02				CS-SW03				CS-SW04				CS-SW05			
Sample Date	12/12/2019				12/12/2019				12/12/2019				12/12/2019				12/11/2019			
Analyte	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual
Water, PFAS by LCMSMS compliant with QSM 5.3 Table B-15 (ng/l)																				
6:2 FTS	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U
8:2 FTS	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U
NEtFOSAA	<	8.00	10.0	U	<	8.00	10.0	U	<	8.00	10.0	U	<	8.00	10.0	UJ	<	8.00	10.0	UJ
NMeFOSAA	<	8.00	10.0	U	<	8.00	10.0	U	<	8.00	10.0	U	<	8.00	10.0	U	<	8.00	10.0	UJ
PFBA	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U
PFBS	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U
PFDA	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	UJ
PFDoA	<	4.00	10.0	UJ	<	4.00	10.0	UJ	<	4.00	10.0	UJ	<	4.00	10.0	UJ	2.64	4.00	10.0	J-
PFHpA	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U
PFHxA	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U
PFHxS	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U
PFNA	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U
PFOA	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U	<	4.00	10.0	U
PFOS	<	2.86	10.0	U	<	4.00	10.0	U	<	6.63	10.0	U	<	3.30	10.0	U	<	8.16	10.0	U
PFPeA	<	4.00	10.0	U	<	4.00	10.0	U	<	2.90	10.0	U	<	4.00	10.0	U	<	3.08	10.0	U
PFTeDA	<	4.00	10.0	UJ	<	4.00	10.0	UJ	<	4.00	10.0	UJ	<	4.00	10.0	UJ	<	4.00	10.0	UJ
PFTrDA	<	4.00	10.0	UJ	<	4.00	10.0	UJ	<	4.00	10.0	UJ	<	4.00	10.0	UJ	<	4.00	10.0	UJ
PFUnDA	<	4.00	10.0	UJ	<	4.00	10.0	UJ	<	4.00	10.0	U	<	4.00	10.0	UJ	<	4.00	10.0	UJ

Interpreted Qualifiers

J- = Estimated concentration, biased low

U = The analyte was not detected at a level greater than or equal to the adjusted detection limit (DL)

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
NMeFOSAA	N-methyl perfluorooctanesulfonamidoacetic acid
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
PFTrDA	perfluorotridecanoic acid
PFUnDA	perfluoro-n-undecanoic acid

Acronyms and Abbreviations

LCMSMS	liquid chromatography with tandem mass spectrometry
LOD	limit of detection
LOQ	limit of quantitation
QSM	Quality Systems Manual
Qual	interpreted qualifier
ng/l	nanogram per liter
SW	surface water
<	analyte not detected above the LOD

Appendix F Laboratory Data
TOC and pH
Site Inspection Report, Camp Smith

Area of Interest	AOI1																											
Sample ID	AOI 1-SB1-0.5-1				AOI 1-SB1-6-8				AOI 1-SB1-12-14				AOI 1-SB2-0.5-1				AOI 1-SB3-0.5-1				AOI 1-SB3-1-2				CS-MW001S-SB-00-02			
Sample Date	12/11/2019				12/11/2019				12/11/2019				12/11/2019				12/11/2019				12/11/2019				07/20/2021			
Depth	0.5 - 1 ft				6 - 8 ft				12 - 14 ft				0.5 - 1 ft				0.5 - 1 ft				1 - 2 ft				0 - 2 ft			
Analyte	**Result**	**LOD**	**LOQ**	**Qual**	**Result**	**LOD**	**LOQ**	**Qual**	**Result**	**LOD**	**LOQ**	**Qual**	**Result**	**LOD**	**LOQ**	**Qual**	**Result**	**LOD**	**LOQ**	**Qual**	**Result**	**LOD**	**LOQ**	**Qual**	**Result**	**LOD**	**LOQ**	**Qual**
pH	7.89	1.00	1.00	J	5.84	1.00	1.00	J	7.46	1.00	1.00	J	7.80	1.00	1.00	J	9.25	1.00	1.00	J	7.52	1.00	1.00	J	7.26	1.00	1.00	J
Total Organic Carbon (mg/kg)	10500	200	250		868	200	250		586	200	250		4230	200	250		68800	200	250		10300	200	250		14400	200	250	

Acronyms and Abbreviations

AOI	Area of Interest
D	duplicate
ft	ft
LOD	limit of detection
LOQ	limit of quantitation
Qual	interpreted qualifier
mg/kg	milligram per kilogram
SB	soil boring
<	analyte not detected above the LOD

Interpreted Qualifiers

J = Estimated concentration

Appendix F Laboratory Data
TOC and pH
Site Inspection Report, Camp Smith

Area of Interest	AOI 1				AOI 2				AOI 2/3			
Sample ID	CS-MW001S-SB-00-02-D				AOI2-SB4-00-02				CS-MW003S-SB-40-42			
Sample Date	07/20/2021				07/24/2021				07/25/2021			
Depth	0 - 2 ft				0 - 2 ft				40 - 42 ft			
Analyte	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual	Result	LOD	LOQ	Qual
pH	7.22	1.00	1.00	J	7.86	1.00	1.00	J	8.31	1.00	1.00	J
Total Organic Carbon (mg/kg)	15000	200	250		938	200	250		529	200	250	J

Acronyms and Abbreviations

AOI	Area of Interest
D	duplicate
ft	ft
LOD	limit of detection
LOQ	limit of quantitation
Qual	interpreted qualifier
mg/kg	milligram per kilogram
SB	soil boring
<	analyte not detected above the LOD

Interpreted Qualifiers

J = Estimated concentration

Appendix F Laboratory Data
Grain Size
Site Inspection Report, Camp Smith

Area of Interest	AOI 2/3
Sample ID	CS-MW002D-SB-62-63
Sample Date	7/23/2021
Depth	62 - 63 ft
	%
Grain Size by ASTM D422 [1]	
Clay (<0.002 mm)	33.89
Silt (>0.002 - 0.075 mm)	63.24
Fine Sand (>0.075 - 0.42 mm)	2.53
Medium Sand (>0.42 - 2.0 mm)	0.34
Coarse Sand (>2.0 - 4.75 mm)	0
Gravel (>4.75 - 75 mm)	0

Notes

1.) Grain size fraction based on USCS soil classifications

Acronyms and Abbreviations

%	percent
AOI	Area of Interest
ASTM	American Society for Testing and Materials
CS	Camp Smith
ft	feet
mm	millimeter
MW	monitoring well
SB	soil boring
USCS	Unified Soil Classification System

Sample ID	CS-ST-04S-072621			
Sample Date	07/26/2021			
Analyte	Result	LOD	LOQ	Qual
Soil, PFAS by LCMSMS compliant with QSM 5.3 Table B-15 (µg/k				
6:2 FTS	<	0.316	1.58	U
8:2 FTS	<	0.158	1.58	U
NEtFOSAA	<	0.158	1.58	U
NMeFOSAA	<	0.079	1.58	U
PFBA	0.090	0.158	1.58	J
PFBS	<	0.079	1.58	U
PFDA	<	0.158	1.58	U
PFDoA	<	0.079	1.58	U
PFHpA	<	0.079	1.58	U
PFHxA	0.032	0.079	1.58	J
PFHxS	<	0.158	1.58	U
PFNA	<	0.079	1.58	U
PFOA	<	0.316	1.58	U
PFOS	<	0.316	1.58	U
PFPeA	<	0.079	1.58	U
PFTeDA	<	0.079	1.58	U
PFTrDA	<	0.158	1.58	U
PFUnDA	<	0.079	1.58	U

Interpreted Qualifiers

J = Estimated concentration

U = The analyte was not detected at a level greater than or equal to the adjusted detection limit

Chemical Abbreviations

6:2 FTS	6:2 fluorotelomer sulfonate
8:2 FTS	8:2 fluorotelomer sulfonate
NEtFOSAA	N-ethyl perfluorooctane- sulfonamidoacetic acid
NMeFOSAA	N-methyl perfluorooctanesulfonamidoacetic acid
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
PFTrDA	perfluorotridecanoic acid
PFUnDA	perfluoro-n-undecanoic acid

Acronyms and Abbreviations

CS	Camp Smith
LCMSMS	liquid chromatography with tandem mass spectrometry
LOD	limit of detection
LOQ	limit of quantitation
QSM	Quality Systems Manual
Qual	interpreted qualifier
µg/kg	micrograms per kilogram
<	analyte not detected above the LOD

Appendix C
Analytical Laboratory Documentation

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CERTIFICATE OF ACCREDITATION

The ANSI National Accreditation Board

Hereby attests that

Pace Analytical – South Carolina

106 Vantage Point Drive
West Columbia, SC 29172

Fulfills the requirements of

ISO/IEC 17025:2017

and the

U.S. Department of Defense (DoD) Quality Systems Manual for Environmental Laboratories (DoD QSM V5.3)

In the field of

TESTING

This certificate is valid only when accompanied by a current scope of accreditation document.
The current scope of accreditation can be verified at www.anab.org.

R. Douglas Leonard Jr., VP, PILR SBU

Expiry Date: 18 November 2024
Certificate Number: L2224.01

This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2017. This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (refer to joint ISO-ILAC-IAF Communiqué dated April 2017).

SCOPE OF ACCREDITATION TO ISO/IEC 17025:2017 AND U.S. DEPARTMENT OF DEFENSE (DOD) QUALITY SYSTEMS MANUAL FOR ENVIRONMENTAL LABORATORIES (DOD QSM V5.3)

Pace Analytical – South Carolina

106 Vantage Point Drive
West Columbia, SC 29172
Kelly Nance
803-227-2702

TESTING

Valid to: **November 18, 2024** Certificate Number: **L2224**

Environmental

Non-Potable Water		
Technology	**Method**	**Analyte**
GC	EPA 8151A	2,4,5-T
GC	EPA 8151A	2,4D
GC	EPA 8151A	2,4DB
GC	EPA 8151A	Dalapon
GC	EPA 8151A	Dicamba
GC	EPA 8151A	Dichloroprop
GC	EPA 8151A	Dinoseb
GC	EPA 8151A	MCPA
GC	EPA 8151A	MCPP
GC	EPA 8151A	Silvex(2,4,5 TP)
GC/MS	EPA 8270E	0,0,0-Triethylphosphorothioate
GC/MS	EPA 8270E	1,2,4,5-Tetrachlorobenzene
GC/MS	EPA 8270E	1,2,4-Trichlorobenzene
GC/MS	EPA 8270E	1,2-Dichlorobenzene
GC/MS	EPA 8270E	1,3-Dichlorobenzene
GC/MS	EPA 8270E	1,3,5-Trinitrobenzene
GC/MS	EPA 8270E	1,4-Benzoquinone
GC/MS	EPA 8270E	1,4-Dichlorobenzene
GC/MS	EPA 8270E	1,4-Dinitrobenzene
GC/MS	EPA 8270E	1,4-Naphthoquinone

Non-Potable Water		
Technology	**Method**	**Analyte**
GC/MS	EPA 8270E	1-Chloronaphthalene
GC/MS	EPA 8270E	1-Methylnaphthalene
GC/MS	EPA 8270E	1-Naphthylamine
GC/MS	EPA 8270E	2,3,4,6-Tetrachlorophenol
GC/MS	EPA 8270E	2,3,5,6-Tetrachlorophenol
GC/MS	EPA 8270E	2,4,5-Trichlorophenol
GC/MS	EPA 8270E	2,4,6-Trichlorophenol
GC/MS	EPA 8270E	2,4-Dichlorophenol
GC/MS	EPA 8270E	2,4-Dimethylphenol
GC/MS	EPA 8270E	2,4-Dinitrophenol
GC/MS	EPA 8270E	2,4-Dinitrotoluene
GC/MS	EPA 8270E	2,6-Dichlorophenol
GC/MS	EPA 8270E	2,6-Dinitrotoluene
GC/MS	EPA 8270E	2-Acetylaminofluorene
GC/MS	EPA 8270E	2-Chloronaphthalene
GC/MS	EPA 8270E	2-Chlorophenol
GC/MS	EPA 8270E	2-Methylnaphthalene
GC/MS	EPA 8270E	2-Methylphenol
GC/MS	EPA 8270E	2-Naphthylamine
GC/MS	EPA 8270E	2-Nitroaniline
GC/MS	EPA 8270E	2-Nitrophenol
GC/MS	EPA 8270E	2-Picoline
GC/MS	EPA 8270E	3,3'-Dichlorobenzidine
GC/MS	EPA 8270E	3,3'-Dimethylbenzidine
GC/MS	EPA 8270E	3-Methylcholanthrene
GC/MS	EPA 8270E	3-Nitroaniline
GC/MS	EPA 8270E	4,4'-Methylene-bis-chloroaniline
GC/MS	EPA 8270E	4,6-Dinitro-2-methylphenol
GC/MS	EPA 8270E	4-Aminobiphenyl
GC/MS	EPA 8270E	4-Bromophenylphenylether
GC/MS	EPA 8270E	4-Chloro-3-methylphenol
GC/MS	EPA 8270E	4-Chloroaniline
GC/MS	EPA 8270E	4-Chlorophenylphenylether
GC/MS	EPA 8270E	4-Nitroaniline
GC/MS	EPA 8270E	4-Nitrophenol
GC/MS	EPA 8270E	5-Nitro-o-toluidine

Non-Potable Water		
Technology	**Method**	**Analyte**
GC/MS	EPA 8270E	7,12-Dimethylbenzo(a)anthracene
GC/MS	EPA 8270E	Acenaphthene
GC/MS	EPA 8270E	Acenaphthylene
GC/MS	EPA 8270E	Acetophenone
GC/MS	EPA 8270E	Aniline
GC/MS	EPA 8270E	Anthracene
GC/MS	EPA 8270E	Aramite
GC/MS	EPA 8270E	Atrazine
GC/MS	EPA 8270E	Azobenzene
GC/MS	EPA 8270E	Benzaldhyde
GC/MS	EPA 8270E	Benzidine
GC/MS	EPA 8270E	Benzo(a)Anthracene
GC/MS	EPA 8270E	Benzo(a)pyrene
GC/MS	EPA 8270E	Benzo(b)fluoranthene
GC/MS	EPA 8270E	Benzo(g,h,i)perylene
GC/MS	EPA 8270E	Benzo(k)fluoranthene
GC/MS	EPA 8270E	Benzoic acid
GC/MS	EPA 8270E	Benzyl alcohol
GC/MS	EPA 8270E	Biphenyl
GC/MS	EPA 8270E	bis(2-Chloroethoxy)methane
GC/MS	EPA 8270E	bis(2-Chloroethyl)ether
GCMS	EPA 8270E	Bis (2-Chloro-1-methylethyl) ether
GC/MS	EPA 8270E	bis(2-Ethylhexyl)phthalate
GC/MS	EPA 8270E	Butylbenzylphthalate
GC/MS	EPA 8270E	Caprolactam
GC/MS	EPA 8270E	Carbazole
GC/MS	EPA 8270E	Chrysene
GC/MS	EPA 8270E	Chlorobenzilate
GC/MS	EPA 8270E	DEET
GC/MS	EPA 8270E	Diallate
GC/MS	EPA 8270E	Dibenzo(a,h)acridine
GC/MS	EPA 8270E	Dibenzo(a,h)anthracene
GC/MS	EPA 8270E	Dibenzo(a,e)pyrene
GC/MS	EPA 8270E	Dibenzofuran
GC/MS	EPA 8270E	Diethylphthalate
GC/MS	EPA 8270E	Dimethoate

Non-Potable Water		
Technology	**Method**	**Analyte**
GC/MS	EPA 8270E	Dimethylphthalate
GC/MS	EPA 8270E	Di-n-butylphthalate
GC/MS	EPA 8270E	Di-n-octylphthalate
GC/MS	EPA 8270E	Dinoseb
GC/MS	EPA 8270E	Disulfoton
GC/MS	EPA 8270E	Ethyl methacrylate
GC/MS	EPA 8270E	Ethyl methanesulfonate
GC/MS	EPA 8270E	Famphur
GC/MS	EPA 8270E	Fluoranthene
GC/MS	EPA 8270E	Fluorene
GC/MS	EPA 8270E	Hexachlorobenzene
GC/MS	EPA 8270E	Hexachlorobutadiene
GC/MS	EPA 8270E	Hexachlorocyclopentadiene
GC/MS	EPA 8270E	Hexachloroethane
GC/MS	EPA 8270E	Hexachloropropene
GC/MS	EPA 8270E	Indene
GC/MS	EPA 8270E	Indeno(1,2,3-c,d)pyrene
GC/MS	EPA 8270E	Isodrin
GC/MS	EPA 8270E	Isophorone
GC/MS	EPA 8270E	Isosafrole
GC/MS	EPA 8270E	Kepone
GC/MS	EPA 8270E	m+p-Cresol
GC/MS	EPA 8270E	m-Dinitrobenzene
GC/MS	EPA 8270E	Methyl methacrylate
GC/MS	EPA 8270E	Methyl methanesulfonate
GC/MS	EPA 8270E	Methyl parathion
GC/MS	EPA 8270E	Mirex
GC/MS	EPA 8270E	Naphthalene
GC/MS	EPA 8270E	Nitrobenzene
GC/MS	EPA 8270E	N-Nitrosodiethylamine
GC/MS	EPA 8270E	N-Nitrosodimethylamine
GC/MS	EPA 8270E	N-Nitrosodi-n-butylamine
GC/MS	EPA 8270E	n-Nitroso-di-n-propylamine
GC/MS	EPA 8270E	n-Nitrosodiphenylamine
GC/MS	EPA 8270E	N-Nitrosomethylethylamine
GC/MS	EPA 8270E	N-Nitrosomorpholine

Non-Potable Water		
Technology	**Method**	**Analyte**
GC/MS	EPA 8270E	N-Nitrosopiperidine
GC/MS	EPA 8270E	N-Nitrosopyrrolidine
GC/MS	EPA 8270E	o-Cresol
GC/MS	EPA 8270E	o-Toluidine
GC/MS	EPA 8270E	p-(Dimethylamino)azobenzene
GC/MS	EPA 8270E	Parathion
GC/MS	EPA 8270E	Pentachlorobenzene
GC/MS	EPA 8270E	Pentachloroethane
GC/MS	EPA 8270E	Pentachloronitrobenzene
GC/MS	EPA 8270E	Pentachlorophenol
GC/MS	EPA 8270E	Phenacetin
GC/MS	EPA 8270E	Phenanthrene
GC/MS	EPA 8270E	Phenol
GC/MS	EPA 8270E	Phorate
GC/MS	EPA 8270E	Pronamide
GC/MS	EPA 8270E	Pyrene
GC/MS	EPA 8270E	Pyridine
GC/MS	EPA 8270E	Quinoline
GC/MS	EPA 8270E	Safrole
GC/MS	EPA 8270E	Tetraethyl dithiopyrophosphate
GC/MS	EPA 8270E	Thionazine
GC/MS	EPA 8270E	Tributyl phosphate
GC/MS	EPA 8270E	p-Phenylenediamine
GC/MS	EPA 8270E SIM	Acenaphthene
GC/MS	EPA 8270E SIM	Acenaphthylene
GC/MS	EPA 8270E SIM	Anthracene
GC/MS	EPA 8270E SIM	Benzo(a)anthracene
GC/MS	EPA 8270E SIM	Benzo(a)pyrene
GC/MS	EPA 8270E SIM	Benzo(b)fluoranthene
GC/MS	EPA 8270E SIM	Benzo(g,h,i)perylene
GC/MS	EPA 8270E SIM	Benzo(k)fluoranthene
GC/MS	EPA 8270E SIM	Chrysene
GC/MS	EPA 8270E SIM	Dibenz(a,h)anthracene
GC/MS	EPA 8270E SIM	1,4-Dioxane
GC/MS	EPA 8270E SIM	Fluoranthene
GC/MS	EPA 8270E SIM	Fluorene

Non-Potable Water		
Technology	**Method**	**Analyte**
GC/MS	EPA 8270E SIM	Indeno(1,2,3-cd)pyrene
GC/MS	EPA 8270E SIM	1-Methylphenol
GC/MS	EPA 8270E SIM	2-Methylphenol
GC/MS	EPA 8270E SIM	Naphthalene
GC/MS	EPA 8270E SIM	Pentachlorophenol
GC/MS	EPA 8270E SIM	Phenanthrene
GC/MS	EPA 8270E SIM	Pyrene
GC/MS	EPA 625.1	Acenaphthene
GC/MS	EPA 625.1	Acenaphthylene
GC/MS	EPA 625.1	Aniline
GC/MS	EPA 625.1	Anthracene
GC/MS	EPA 625.1	Benzidine
GC/MS	EPA 625.1	Benzo(a)anthracene
GC/MS	EPA 625.1	Benzo(a)pyrene
GC/MS	EPA 625.1	Benzo(b)fluoranthene
GC/MS	EPA 625.1	Benzo(g,h,i)perylene
GC/MS	EPA 625.1	Benzo(k)fluoranthene
GC/MS	EPA 625.1	Benzoic acid
GC/MS	EPA 625.1	Benzyl alcohol
GC/MS	EPA 625.1	4-Bromophenyl phenyl ether
GC/MS	EPA 625.1	Butyl benzyl phthalate
GC/MS	EPA 625.1	Carbazole
GC/MS	EPA 625.1	bis (2-Chloro-1-methylethyl) ether
GC/MS	EPA 625.1	4-Chloro-3-methyl phenol
GC/MS	EPA 625.1	4-Chloroaniline
GC/MS	EPA 625.1	bis(2-Chloroethoxy)methane
GC/MS	EPA 625.1	bis(2-Chloroethyl)ether
GC/MS	EPA 625.1	2-Chloronaphthalene
GC/MS	EPA 625.1	2-Chlorophenol
GC/MS	EPA 625.1	4-Chlorophenyl phenyl ether
GC/MS	EPA 625.1	Chrysene
GC/MS	EPA 625.1	n-Decane
GC/MS	EPA 625.1	Dibenzo(a,h)anthracene
GC/MS	EPA 625.1	Dibenzofuran
GC/MS	EPA 625.1	2,3-Dichloroaniline
GC/MS	EPA 625.1	1,2-Dichlorobenzene

Non-Potable Water		
Technology	**Method**	**Analyte**
GC/MS	EPA 625.1	1,3-Dichlorobenzene
GC/MS	EPA 625.1	1,4-Dichlorobenzene
GC/MS	EPA 625.1	3,3'-Dichlorobenzidine
GC/MS	EPA 625.1	2,4-Dichlorophenol
GC/MS	EPA 625.1	2,6-Dichlorophenol
GC/MS	EPA 625.1	Diethylphthalate
GC/MS	EPA 625.1	Dimethyl phthalate
GC/MS	EPA 625.1	3,3'-Dimethylbenzidine
GC/MS	EPA 625.1	2,4-Dimethylphenol
GC/MS	EPA 625.1	Di-n-butyl phthalate
GC/MS	EPA 625.1	4,6-Dinitro-2-methylphenol
GC/MS	EPA 625.1	2,4-Dinitrophenol
GC/MS	EPA 625.1	2,4-Dinitrotoluene
GC/MS	EPA 625.1	2,6-Dinitrotoluene
GC/MS	EPA 625.1	Di-n-octylphthalate
GC/MS	EPA 625.1	1,2-Diphenylhydrazine(as azobenzene)
GC/MS	EPA 625.1	bis(2-Ethylhexyl)phthalate
GC/MS	EPA 625.1	Fluoranthene
GC/MS	EPA 625.1	Fluorene
GC/MS	EPA 625.1	Hexachlorobenzene
GC/MS	EPA 625.1	Hexachlorobutadiene
GC/MS	EPA 625.1	Hexachlorocyclopentadiene
GC/MS	EPA 625.1	Hexachloroethane
GC/MS	EPA 625.1	Indeno(1,2,3-c,d)pyrene
GC/MS	EPA 625.1	Isophorone
GC/MS	EPA 625.1	1-Methylnaphthalene
GC/MS	EPA 625.1	2-Methylnaphthalene
GC/MS	EPA 625.1	2-Methylphenol
GC/MS	EPA 625.1	3+4-Methylphenol
GC/MS	EPA 625.1	N,N-Diethyl-m-toluamide (DEET)
GC/MS	EPA 625.1	Naphthalene
GC/MS	EPA 625.1	Nitrobenzene
GC/MS	EPA 625.1	2-Nitrophenol
GC/MS	EPA 625.1	4-Nitrophenol
GC/MS	EPA 625.1	N-Nitrosodimethylamine
GC/MS	EPA 625.1	N-Nitrosodi-n-propylamine

Non-Potable Water		
Technology	**Method**	**Analyte**
GC/MS	EPA 625.1	N-Nitrosodiphenylamine (Diphenylamine)
GC/MS	EPA 625.1	n-Octadecane
GC/MS	EPA 625.1	Pentachlorophenol
GC/MS	EPA 625.1	Phenanthrene
GC/MS	EPA 625.1	Phenol
GC/MS	EPA 625.1	Piperonyl butoxide (PIP)
GC/MS	EPA 625.1	Pyrene
GC/MS	EPA 625.1	alpha-Terpineol
GC/MS	EPA 625.1	1,2,4-Trichlorobenzene
GC/MS	EPA 625.1	2,4,6-Trichlorophenol
GC/MS	EPA 8260D	1,1,1,2-Tetrachloroethane
GC/MS	EPA 8260D	1,1,1-Trichloroethane
GC/MS	EPA 8260D	1,1,2,2-Tetrachloroethene
GC/MS	EPA 8260D	1,1,2-Trichloroethane
GC/MS	EPA 8260D	1,1-Dichloroethane
GC/MS	EPA 8260D	1,1-Dichloroethene
GC/MS	EPA 8260D	1,1-Dichloropropene
GC/MS	EPA 8260D	1,2,3-Trichlorobenzene
GC/MS	EPA 8260D	1,2,3-Trichloropropane
GC/MS	EPA 8260D	1,2,4-Trichlorobenzene
GC/MS	EPA 8260D	1,2,4-Trimethylbenzene
GC/MS	EPA 8260D	1,2-Dibromo-3-chloropropane
GC/MS	EPA 8260D	1,2-Dibromoethane (EDB)
GC/MS	EPA 8260D	1,2-Dichlorobenzene
GC/MS	EPA 8260D	1,2-Dichloroethane
GC/MS	EPA 8260D	1,2-Dichloropropane
GC/MS	EPA 8260D	1,3,5-Trimethylbenzene
GC/MS	EPA 8260D	1,3-Dichlorobenzene
GC/MS	EPA 8260D	1,3-Dichloropropane
GC/MS	EPA 8260D	1,4-Dichlorobenzene
GC/MS	EPA 8260D	1,4-Dioxane
GC/MS	EPA 8260D	2,2-Dichloropropane
GC/MS	EPA 8260D	2-Butanone (MEK)
GC/MS	EPA 8260D	2-Chloroethylvinyl ether
GC/MS	EPA 8260D	2-Chlorotoluene
GC/MS	EPA 8260D	2-Hexanone

Non-Potable Water		
Technology	**Method**	**Analyte**
GC/MS	EPA 8260D	3,3-Dimethyl-1-butanol
GC/MS	EPA 8260D	4-Chlorotoluene
GC/MS	EPA 8260D	4-Methyl-2-pentanone
GC/MS	EPA 8260D	Acetone
GC/MS	EPA 8260D	Acetonitrile
GC/MS	EPA 8260D	Acrolein
GC/MS	EPA 8260D	Acrylonitrile
GC/MS	EPA 8260D	Allyl chloride
GC/MS	EPA 8260D	Benzene
GC/MS	EPA 8260D	Benzyl chloride
GC/MS	EPA 8260D	Bromobenzene
GC/MS	EPA 8260D	Bromochloromethane
GC/MS	EPA 8260D	Bromodichloromethane
GC/MS	EPA 8260D	Bromoform
GC/MS	EPA 8260D	Bromomethane
GC/MS	EPA 8260D	Carbon disulfide
GC/MS	EPA 8260D	Carbon tetrachloride
GC/MS	EPA 8260D	Chlorobenzene
GC/MS	EPA 8260D	Chloroethane
GC/MS	EPA 8260D	Chloroform
GC/MS	EPA 8260D	Chloromethane
GC/MS	EPA 8260D	Chloroprene
GC/MS	EPA 8260D	cis-1,2-Dichloroethene
GC/MS	EPA 8260D	cis-1,3-Dichloropropene
GC/MS	EPA 8260D	Cyclohexane
GC/MS	EPA 8260D	Cyclohexanone
GC/MS	EPA 8260D	Dibromochloromethane
GC/MS	EPA 8260D	Dibromomethane
GC/MS	EPA 8260D	Dichlorodifluoromethane
GC/MS	EPA 8260D	Diisopropyl ether (IPE)
GC/MS	EPA 8260D	Ethanol
GC/MS	EPA 8260D	Ethyl ether
GC/MS	EPA 8260D	Ethyl methacrylate
GC/MS	EPA 8260D	Ethylbenzene
GC/MS	EPA 8260D	Ethyl-Tert-Butyl Ether
GC/MS	EPA 8260D	Freon 113

Non-Potable Water		
Technology	**Method**	**Analyte**
GC/MS	EPA 8260D	Hexachlorobutadiene
GC/MS	EPA 8260D	Isobutyl alcohol
GC/MS	EPA 8260D	Isopropylbenzene
GC/MS	EPA 8260D	m+p-Xylenes
GC/MS	EPA 8260D	Methacrylonitrile
GC/MS	EPA 8260D	Methyl Acetate
GC/MS	EPA 8260D	Methyl iodide
GC/MS	EPA 8260D	Methyl methacrylate
GC/MS	EPA 8260D	Methyl tertiary butyl ether (MTBE)
GC/MS	EPA 8260D	Methylcyclohexane
GC/MS	EPA 8260D	Methylene chloride
GC/MS	EPA 8260D	Naphthalene
GC/MS	EPA 8260D	n-Butylbenzene
GC/MS	EPA 8260D	n-Propylbenzene
GC/MS	EPA 8260D	o-Xylene
GC/MS	EPA 8260D	Pentachloroethane
GC/MS	EPA 8260D	p-Isopropyltoluene
GC/MS	EPA 8260D	Propionitrile
GC/MS	EPA 8260D	sec-Butylbenzene
GC/MS	EPA 8260D	Styrene
GC/MS	EPA 8260D	Tert-Amyl Alcohol (TAA)
GC/MS	EPA 8260D	Tert-Amyl Methyl Ether (TAME)
GC/MS	EPA 8260D	Tert-Butyl Alcohol (TBA)
GC/MS	EPA 8260D	Tert-Butyl Formate (TBF)
GC/MS	EPA 8260D	tert-Butylbenzene
GC/MS	EPA 8260D	Tetrachloroethene
GC/MS	EPA 8260D	Tetrahydrofuran
GC/MS	EPA 8260D	Toluene
GC/MS	EPA 8260D	Total Xylenes
GC/MS	EPA 8260D	trans-1,2-Dichloroethene
GC/MS	EPA 8260D	trans-1,3-Dichloropropene
GC/MS	EPA 8260D	trans-1,4-Dichloro-2-butene
GC/MS	EPA 8260D	Trichloroethene
GC/MS	EPA 8260D	Trichlorofluoromethane
GC/MS	EPA 8260D	Vinyl acetate
GC/MS	EPA 8260D	Vinyl chloride

Non-Potable Water		
Technology	**Method**	**Analyte**
GC/MS	EPA 8260D SIM	1,4-Dioxane
GC/MS	EPA 624.1	Acetone
GC/MS	EPA 624.1	Acetonitrile
GC/MS	EPA 624.1	Acrolein
GC/MS	EPA 624.1	Acrylonitrile
GC/MS	EPA 624.1	Benzene
GC/MS	EPA 624.1	Bromochloromethane
GC/MS	EPA 624.1	Bromodichloromethane
GC/MS	EPA 624.1	Bromoform
GC/MS	EPA 624.1	Bromomethane (Methyl bromide)
GC/MS	EPA 624.1	2-Butanone (MEK)
GC/MS	EPA 624.1	Carbon disulfide
GC/MS	EPA 624.1	Carbon tetrachloride
GC/MS	EPA 624.1	Chlorobenzene
GC/MS	EPA 624.1	Chloroethane
GC/MS	EPA 624.1	2-Chloroethylvinylether
GC/MS	EPA 624.1	Chloroform
GC/MS	EPA 624.1	Chloromethane (Methyl chloride)
GC/MS	EPA 624.1	Dibromochloromethane
GC/MS	EPA 624.1	1,2-Dibromoethane (EDB)
GC/MS	EPA 624.1	1,2-Dichlorobenzene
GC/MS	EPA 624.1	1,3-Dichlorobenzene
GC/MS	EPA 624.1	1,4-Dichlorobenzene
GC/MS	EPA 624.1	Dichlorodifluoromethane
GC/MS	EPA 624.1	1,1-Dichloroethane
GC/MS	EPA 624.1	1,2-Dichloroethane
GC/MS	EPA 624.1	1,1-Dichloroethene
GC/MS	EPA 624.1	cis-1,2-Dichloroethene
GC/MS	EPA 624.1	trans-1,2-Dichloroethene
GC/MS	EPA 624.1	1,2-Dichloropropane
GC/MS	EPA 624.1	cis-1,3-Dichloropropene
GC/MS	EPA 624.1	trans-1,3-Dichloropropene
GC/MS	EPA 624.1	Diisopropyl ether (IPE)
GC/MS	EPA 624.1	1,4-Dioxane
GC/MS	EPA 624.1	Ethylbenzene
GC/MS	EPA 624.1	Methyl methacrylate

Non-Potable Water		
Technology	**Method**	**Analyte**
GC/MS	EPA 624.1	Methyl tertiary butyl ether (MTBE)
GC/MS	EPA 624.1	Methylene chloride
GC/MS	EPA 624.1	Naphthalene
GC/MS	EPA 624.1	Styrene
GC/MS	EPA 624.1	1,1,2,2-Tetrachloroethane
GC/MS	EPA 624.1	Tetrachloroethene
GC/MS	EPA 624.1	Toluene
GC/MS	EPA 624.1	1,2,4-Trichlorobenzene
GC/MS	EPA 624.1	1,1,1-Trichloroethane
GC/MS	EPA 624.1	1,1,2-Trichloroethane
GC/MS	EPA 624.1	Trichloroethene
GC/MS	EPA 624.1	Trichlorofluoromethane
GC/MS	EPA 624.1	1,2,4-Trimethylbenzene
GC/MS	EPA 624.1	1,3,5-Trimethylbenzene
GC/MS	EPA 624.1	Vinyl acetate
GC/MS	EPA 624.1	Vinyl chloride
GC/MS	EPA 624.1	Xylenes (total)
GC/MS	SM 6200B-2011	Benzene
GC/MS	SM 6200B-2011	Bromobenzene
GC/MS	SM 6200B-2011	Bromochloromethane
GC/MS	SM 6200B-2011	Bromodichloromethane
GC/MS	SM 6200B-2011	Bromoform
GC/MS	SM 6200B-2011	Bromomethane (Methyl bromide)
GC/MS	SM 6200B-2011	n-Butylbenzene
GC/MS	SM 6200B-2011	sec-Butylbenzene
GC/MS	SM 6200B-2011	tert-Butylbenzene
GC/MS	SM 6200B-2011	Carbon tetrachloride
GC/MS	SM 6200B-2011	Chlorobenzene
GC/MS	SM 6200B-2011	Chloroethane
GC/MS	SM 6200B-2011	Chloroform
GC/MS	SM 6200B-2011	Chloromethane (Methyl chloride)
GC/MS	SM 6200B-2011	2-Chlorotoluene
GC/MS	SM 6200B-2011	4-Chlorotoluene
GC/MS	SM 6200B-2011	Dibromochloromethane
GC/MS	SM 6200B-2011	1,2-Dibromoethane (EDB)
GC/MS	SM 6200B-2011	Dibromomethane (Methylene bromide)

Non-Potable Water		
Technology	**Method**	**Analyte**
GC/MS	SM 6200B-2011	1,2-Dichlorobenzene
GC/MS	SM 6200B-2011	1,3-Dichlorobenzene
GC/MS	SM 6200B-2011	1,4-Dichlorobenzene
GC/MS	SM 6200B-2011	Dichlorodifluoromethane
GC/MS	SM 6200B-2011	1,1-Dichloroethane
GC/MS	SM 6200B-2011	1,2-Dichloroethane
GC/MS	SM 6200B-2011	1,1-Dichloroethene
GC/MS	SM 6200B-2011	cis-1,2-Dichloroethene
GC/MS	SM 6200B-2011	trans-1,2-Dichloroethene
GC/MS	SM 6200B-2011	1,2-Dichloropropane
GC/MS	SM 6200B-2011	1,3-Dichloropropane
GC/MS	SM 6200B-2011	2,2-Dichloropropane
GC/MS	SM 6200B-2011	1,1-Dichloropropene
GC/MS	SM 6200B-2011	cis-1,3-Dichloropropene
GC/MS	SM 6200B-2011	trans-1,3-Dichloropropene
GC/MS	SM 6200B-2011	Diisopropyl ether (IPE)
GC/MS	SM 6200B-2011	Ethylbenzene
GC/MS	SM 6200B-2011	Hexachlorobutadiene
GC/MS	SM 6200B-2011	Isopropylbenzene (Cumene)
GC/MS	SM 6200B-2011	p-Isopropyltoluene (p-Cymene)
GC/MS	SM 6200B-2011	Methyl tertiary butyl ether (MTBE)
GC/MS	SM 6200B-2011	4-Methyl-2-pentanone
GC/MS	SM 6200B-2011	Methylene chloride
GC/MS	SM 6200B-2011	Naphthalene
GC/MS	SM 6200B-2011	n-Propylbenzene
GC/MS	SM 6200B-2011	Styrene
GC/MS	SM 6200B-2011	1,1,1,2-Tetrachloroethane
GC/MS	SM 6200B-2011	1,1,2,2-Tetrachloroethane
GC/MS	SM 6200B-2011	Tetrachloroethene
GC/MS	SM 6200B-2011	Toluene
GC/MS	SM 6200B-2011	1,1,2-Trichloro-1,2,2-Trifluoroethane
GC/MS	SM 6200B-2011	1,2,3-Trichlorobenzene
GC/MS	SM 6200B-2011	1,2,4-Trichlorobenzene
GC/MS	SM 6200B-2011	1,1,1-Trichloroethane
GC/MS	SM 6200B-2011	1,1,2-Trichloroethane
GC/MS	SM 6200B-2011	Trichloroethene

Non-Potable Water		
Technology	**Method**	**Analyte**
GC/MS	SM 6200B-2011	Trichlorofluoromethane
GC/MS	SM 6200B-2011	1,2,3-Trichloropropane
GC/MS	SM 6200B-2011	1,3,5-Trimethylbenzene (Mesitylene)
GC/MS	SM 6200B-2011	1,2,4-Trimethylbenzene
GC/MS	SM 6200B-2011	Vinyl chloride
GC/MS	SM 6200B-2011	m+p - Xylenes
GC/MS	SM 6200B-2011	o-Xylene
GC	EPA 8081B	4,4'-DDD
GC	EPA 8081B	4,4'-DDE
GC	EPA 8081B	4,4'-DDT
GC	EPA 8081B	Aldrin
GC	EPA 8081B	alpha-BHC
GC	EPA 8081B	alpha-Chlordane
GC	EPA 8081B	beta-BHC
GC	EPA 8081B	Chlordane
GC	EPA 8081B	delta-BHC
GC	EPA 8081B	Dieldrin
GC	EPA 8081B	Endosulfan I
GC	EPA 8081B	Endosulfan II
GC	EPA 8081B	Endosulfan sulfate
GC	EPA 8081B	Endrin
GC	EPA 8081B	Endrin Aldehyde
GC	EPA 8081B	Endrin Ketone
GC	EPA 8081B	gamma-BHC (Lindane)
GC	EPA 8081B	gamma-Chlordane
GC	EPA 8081B	Heptachlor
GC	EPA 8081B	Heptachlor Epoxide
GC	EPA 8081B	Methoxychlor
GC	EPA 8081B	Mirex
GC	EPA 8081B	Toxaphene
GC	EPA 8082A	Aroclor 1016
GC	EPA 8082A	Aroclor 1221
GC	EPA 8082A	Aroclor 1232
GC	EPA 8082A	Aroclor 1242
GC	EPA 8082A	Aroclor 1248
GC	EPA 8082A	Aroclor 1254
GC	EPA 8082A	Aroclor 1260

Non-Potable Water		
Technology	**Method**	**Analyte**
GC	EPA 8082A	Aroclor 1262
GC	EPA 8082A	Aroclor 1268
GC	EPA 608.3	Aldrin
GC	EPA 608.3	gamma-BHC (Lindane)
GC	EPA 608.3	alpha-BHC
GC	EPA 608.3	beta-BHC
GC	EPA 608.3	delta-BHC
GC	EPA 608.3	Chlordane
GC	EPA 608.3	cis-Chlordane
GC	EPA 608.3	trans-Chlordane
GC	EPA 608.3	4,4'-DDD
GC	EPA 608.3	4,4'-DDE
GC	EPA 608.3	4,4'-DDT
GC	EPA 608.3	Dieldrin
GC	EPA 608.3	Endosulfan I
GC	EPA 608.3	Endosulfan II
GC	EPA 608.3	Endosulfan sulfate
GC	EPA 608.3	Endrin
GC	EPA 608.3	Endrin aldehyde
GC	EPA 608.3	Endrin ketone
GC	EPA 608.3	Heptachlor
GC	EPA 608.3	Heptachlor epoxide
GC	EPA 608.3	Methoxychlor
GC	EPA 608.3	Toxaphene
GC	EPA 608.3	Aroclor 1016
GC	EPA 608.3	Aroclor 1221
GC	EPA 608.3	Aroclor 1232
GC	EPA 608.3	Aroclor 1242
GC	EPA 608.3	Aroclor 1248
GC	EPA 608.3	Aroclor 1254
GC	EPA 608.3	Aroclor 1260
HPLC	EPA 8330A	2-Amino-4,6-dinitrotoluene
HPLC	EPA 8330A	4-Amino-2,6-dinitrotoluene
HPLC	EPA 8330A	1,3-Dinitrobenzene
HPLC	EPA 8330A	2,4-Dinitrotoluene
HPLC	EPA 8330A	2,6-Dinitrotoluene

Non-Potable Water		
Technology	**Method**	**Analyte**
HPLC	EPA 8330A	HMX
HPLC	EPA 8330A	Nitrobenzene
HPLC	EPA 8330B	Nitrocellulose
HPLC	EPA 8330B	Nitroguanidine
HPLC	EPA 8330B	Guanidine nitrate
HPLC	EPA 8330A	2-Nitrotoluene
HPLC	EPA 8330A	3-Nitrotoluene
HPLC	EPA 8330A	4-Nitrotoluene
HPLC	EPA 8330A	RDX
HPLC	EPA 8330A	Tetryl
HPLC	EPA 8330A	1,3,5-Trinitrobenzene
HPLC	EPA 8330A	2,4,6-Trinitrotoluene
HPLC	EPA 8330B	2-Amino-4,6-dinitrotoluene
HPLC	EPA 8330B	4-Amino-2,6-dinitrotoluene
HPLC	EPA 8330B	1,3-Dinitrobenzene
HPLC	EPA 8330B	2,4-Dinitrotoluene
HPLC	EPA 8330B	2,6-Dinitrotoluene
HPLC	EPA 8330B	HMX
HPLC	EPA 8330B	Nitrobenzene
HPLC	EPA 8330B	Nitroglycerin (NG)
HPLC	EPA 8330B	2-Nitrotoluene
HPLC	EPA 8330B	3-Nitrotoluene
HPLC	EPA 8330B	4-Nitrotoluene
HPLC	EPA 8330B	RDX
HPLC	EPA 8330B	Tetryl
HPLC	EPA 8330B	1,3,5-Trinitrobenzene
HPLC	EPA 8330B	2,4,6-Trinitrotoluene
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	N-ethylperfluoro-1-octanesulfonamidoacetic acid (EtFOSAA)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Fluorotelomer sulfonate 8:2 [1H,1H,2H,2H-perfluorodecane sulfonate] (8:2 FTS)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Fluorotelomer sulfonate 4:2 [1H,1H,2H,2H-perfluorohexane sulfonate] (4:2 FTS)

Non-Potable Water		
Technology	**Method**	**Analyte**
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Fluorotelomer sulfonate 6:2 [1H,1H,2H,2H-perfluorooctane sulfonate] (6:2 FTS
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	GenX (HFPO-DA)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	N-methylperfluoro-1-octanesulfonamidoacetic acid (MeFOSAA)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluoro-1-butanesulfonate (PFBS)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluoro-n-butanoic acid (PFBA)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluoro-1-decanesulfonate (PFDS)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluoro-n-decanoic acid (PFDA)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluoro-n-dodecanoic acid (PFDoA)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluoro-1-heptanesulfonate (PFHpS)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluoro-n-heptanoic acid (PFHpA)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluoro-1-hexanesulfonate (PFHxS)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluoro-n-hexanoic acid (PFHxA)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluoro-1-nonanesulfonate (PFNS)

Non-Potable Water		
Technology	**Method**	**Analyte**
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluoro-n-nonanoic acid (PFNA)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluorooctanesulfonate (PFOS)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluoro-1-octanesulfonamide (PFOSA)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluoro-n-octanoic acid (PFOA)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluoro-n-pentanoic acid (PFPeA)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluoro-1-pentansulfonate (PFPeS)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluoro-n-tetradecanoic acid (PFTeDA)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluoro-n-tridecanoic acid (PFTrDA)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluoro-n-undecanoic acid (PFUDA)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	N-methylperfluoro-1-octanesulfonamide (MeFOSA)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	N-ethylperfluoro-1-octanesulfonamide (EtFOSA)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	1H,1H,2H,2H-perfluorododecane sulfonate (10:2FTS)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	N-Ethyl Perfluorooctane sulfonamido ethanol (EtFOSE)

Non-Potable Water		
Technology	**Method**	**Analyte**
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	N-Methyl Perfluorooctane sulfonamido ethanol (MeFOSE)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Sodium dodecafluoro-3H-4, 8-dioxanonanoate (NaDONA)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	9Cl-PF3ONS
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	11Cl-PF3OUDS
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluorododecanesulfonic acid (PFDOS)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluorohexadecanoic acid (PFHxDA)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluorooctadecanoic acid (PFODA)
GC	EPA 8015C	Diesel Range Organics
GC	EPA 8015C	WI-Diesel Range Organics
GC	EPA 8015C	Gasoline Range Organics
GC	EPA 8015C	WI-Gasoline Range Organics
GC	RSK - 175	Methane, Ethane, Ethene
GC	EPA 8011	1,2-Dibromoethane (EDB)
GC	EPA 8011	1,2-Dibromo-3-chloropropane (DBCP)
GC	FL-PRO	FL-PRO
ICP	EPA 6010D	Aluminum
ICP	EPA 6010D	Antimony
ICP	EPA 6010D	Arsenic
ICP	EPA 6010D	Barium
ICP	EPA 6010D	Beryllium
ICP	EPA 6010D	Cadmium
ICP	EPA 6010D	Calcium
ICP	EPA 6010D	Chromium
ICP	EPA 6010D	Cobalt
ICP	EPA 6010D	Copper

Non-Potable Water		
Technology	**Method**	**Analyte**
ICP	EPA 6010D	Iron
ICP	EPA 6010D	Lead
ICP	EPA 6010D	Magnesium
ICP	EPA 6010D	Manganese
ICP	EPA 6010D	Molybdenum
ICP	EPA 6010D	Nickel
ICP	EPA 6010D	Potassium
ICP	EPA 6010D	Selenium
ICP	EPA 6010D	Silver
ICP	EPA 6010D	Sodium
ICP	EPA 6010D	Thallium
ICP	EPA 6010D	Tin
ICP	EPA 6010D	Vanadium
ICP	EPA 6010D	Zinc
ICP/MS	EPA 200.8	Aluminum
ICP/MS	EPA 200.8	Antimony
ICP/MS	EPA 200.8	Arsenic
ICP/MS	EPA 200.8	Barium
ICP/MS	EPA 200.8	Beryllium
ICP/MS	EPA 200.8	Boron
ICP/MS	EPA 200.8	Cadmium
ICP/MS	EPA 200.8	Calcium
ICP/MS	EPA 200.8	Chromium
ICP/MS	EPA 200.8	Cobalt
ICP/MS	EPA 200.8	Copper
ICP/MS	EPA 200.8	Iron
ICP/MS	EPA 200.8	Lead
ICP/MS	EPA 200.8	Magnesium
ICP/MS	EPA 200.8	Manganese
ICP/MS	EPA 200.8	Molybdenum
ICP/MS	EPA 200.8	Nickel
ICP/MS	EPA 200.8	Potassium
ICP/MS	EPA 200.8	Selenium
ICP/MS	EPA 200.8	Silicon
ICP/MS	EPA 200.8	Silver
ICP/MS	EPA 200.8	Sodium

Non-Potable Water		
Technology	**Method**	**Analyte**
ICP/MS	EPA 200.8	Thallium
ICP/MS	EPA 200.8	Tin
ICP/MS	EPA 200.8	Titanium
ICP/MS	EPA 200.8	Vanadium
ICP/MS	EPA 200.8	Zinc
ICP/MS	EPA 6020B	Aluminum
ICP/MS	EPA 6020B	Antimony
ICP/MS	EPA 6020B	Arsenic
ICP/MS	EPA 6020B	Barium
ICP/MS	EPA 6020B	Beryllium
ICP/MS	EPA 6020B	Cadmium
ICP/MS	EPA 6020B	Calcium
ICP/MS	EPA 6020B	Chromium
ICP/MS	EPA 6020B	Cobalt
ICP/MS	EPA 6020B	Copper
ICP/MS	EPA 6020B	Iron
ICP/MS	EPA 6020B	Lead
ICP/MS	EPA 6020B	Magnesium
ICP/MS	EPA 6020B	Manganese
ICP/MS	EPA 6020B	Nickel
ICP/MS	EPA 6020B	Potassium
ICP/MS	EPA 6020B	Selenium
ICP/MS	EPA 6020B	Silver
ICP/MS	EPA 6020B	Sodium
ICP/MS	EPA 6020B	Thallium
ICP/MS	EPA 6020B	Tin
ICP/MS	EPA 6020B	Vanadium
ICP/MS	EPA 6020B	Zinc
CVAA	EPA 1631E	Low Level Mercury
CVAA	EPA 7470A / EPA 245.1	Mercury
Gravimetric	EPA 1664B	Oil & Grease
Titration	SM 2320B-2011	Alkalinity
Calculation	SM 2320B-2011	Bicarbonate Alkalinity
Calculation	SM 2320B-2011	Carbonate Alkalinity
Calculation	SM 2320B-2011	Hydroxide Alkalinity
Calculation	SM 4500-CO2 D	Carbon Dioxide (CO2)

Non-Potable Water		
Technology	**Method**	**Analyte**
Photometric	SM 2120F-2011	Color
Photometric	SM 2120B-2011	Platinum Cobalt Color
UV/VIS	SM 3500-Fe B-2011	Ferrous Iron
Titration	SM 4500-S2 F-2011	Sulfide
Wet Oxidation	EPA 9060A	TOC
Wet Oxidation	SM 5310C-2011	TOC
Titration	SM 2340C-2011	Total Hardness
Filtration	SM 2540C-2011	Total Dissolved Solids (TDS)
Filtration	SM 2540D-2011	Total Suspended Solids (TSS)
UV/VIS	Kelada-01	Total Cyanide
UV/VIS	SM 4500-CN E-2011	Total Cyanide
UV/VIS	EPA 9012B	Total Cyanide
UV/VIS	EPA 9065	Phenolics
UV/VIS	EPA 9066	Phenolics
IC	EPA 9056A	Fluoride
IC	EPA 9056A	Chloride
IC	EPA 9056A	Sulfate
IC	EPA 9056A	Bromide
IC	EPA 9056A	Nitrate
IC	EPA 9056A	Nitrite
IC	EPA 300.0	Fluoride
IC	EPA 300.0	Chloride
IC	EPA 300.0	Sulfate
IC	EPA 300.0	Bromide
IC	EPA 300.0	Nitrate
IC	EPA 300.0	Nitrite
IC	EPA 218.6	Hexavalent chromium
IC	EPA 7199	Hexavalent chromium
UV/VIS	EPA 7196A	Hexavalent chromium
Discrete Analyzer	SM 3500-Cr B-2011	Hexavalent chromium
Pensky-Martens	EPA 1010A	Ignitability
Electrode	EPA 9040C	Corrosivity
Electrode	SM 4500-H B-2011	Corrosivity

Non-Potable Water		
Technology	**Method**	**Analyte**
Electrode	EPA 120.1	Specific Conductance
Electrode	EPA 180.1	Turbidity
Photometric	Sec. 7.3.3 SW-846	Reactive Cyanide
Titration	Sec. 7.3.4 SW-846	Reactive Sulfide
UV/VIS	EPA 353.2	Nitrate
UV/VIS	EPA 353.2	Nitrite
UV/VIS	EPA 353.2	Nitrate-Nitrite
UV/VIS	EPA 365.1	Phosphorus/ Orthophosphate
Gas Diffusion / UV/VIS	EPA 350.1	Ammonia - N
UV/VIS	EPA 351.2	TKN
UV/VIS	SM 5220D-2011	COD
GC	MADEP-EPH-MOD	Extractable Petroleum Hydrocarbons (EPH) Modified
GC	MADEP-VPH-MOD	Volatile Petroleum Hydrocarbons (VPH) Modified
Preparation	**Method**	**Type**
Organic Preparation	EPA 3520C	Organic Prep. of Water by Continuous Liquid-Liquid
Organic Preparation	EPA 3535A	Solid-Phase Extraction (SPE)
Organic Cleanup	EPA 3620B	Florisil Cleanup Procedure
Organic Cleanup	EPA 3660B	Sulfur Cleanup Procedure
Organic Cleanup	EPA 3665A	Sulfuric Acid Cleanup Procedure
Waste Dilution	EPA 3580A	Waste Dilution
Volatile Organic Preparation	EPA 5030B	Purge-and-Trap for Aqueous Samples
Volatile Organic Preparation	EPA 5035	Closed-System Purge-and-Trap and extraction for Volatile Organics in Soil and Waste Samples
Volatile Organic Preparation	EPA 3585	Waste Dilution for Volatile Organics
Inorganic Preparation	EPA 3005A	Preparation of Waters by Hotblock
Inorganic Preparation	EPA 1311	Toxicity Characteristic Leaching Procedure (TCLP)
Inorganic Metals Preparation	EPA 3010A	Acid Digestion of Aqueous Samples and TCLP/SPLP Extracts for ICP analysis
Inorganic Metals Preparation	EPA 3030C	Acid Digestion of Aqueous Samples for ICP Spectroscopy
Organic Cleanup	EPA 3640	GPC Cleanup Procedure

Solid and Chemical Materials		
Technology	**Method**	**Analyte**
GC	EPA 8151A	Dalapon
GC	EPA 8151A	Dicamba
GC	EPA 8151A	Dichloroprop
GC	EPA 8151A	MCPP
GC	EPA 8151A	MCPA
GC	EPA 8151A	2,4D
GC	EPA 8151A	Silvex(2,4,5 TP)
GC	EPA 8151A	2,4,5-T
GC	EPA 8151A	2,4DB
GC	EPA 8151A	Dinoseb
GC/MS	EPA 8270E	1,2,4,5-Tetrachlorobenzene
GC/MS	EPA 8270E	1,2,4-Trichlorobenzene
GC/MS	EPA 8270E	1,2-Dichlorobenzene
GC/MS	EPA 8270E	1,3-Dichlorobenzene
GC/MS	EPA 8270E	1,4-Dichlorobenzene
GC/MS	EPA 8270E	1-Methylnaphthalene
GC/MS	EPA 8270E	2,3,4,6-Tetrachlorophenol
GC/MS	EPA 8270E	2,4,5-Trichlorophenol
GC/MS	EPA 8270E	2,4,6-Trichlorophenol
GC/MS	EPA 8270E	2,4-Dichlorophenol
GC/MS	EPA 8270E	2,4-Dimethylphenol
GC/MS	EPA 8270E	2,4-Dinitrophenol
GC/MS	EPA 8270E	2,4-Dinitrotoluene
GC/MS	EPA 8270E	2,6-Dichlorophenol
GC/MS	EPA 8270E	2,6-Dinitrotoluene
GC/MS	EPA 8270E	2-Chloronaphthalene
GC/MS	EPA 8270E	2-Chlorophenol
GC/MS	EPA 8270E	2-Methylnaphthalene
GC/MS	EPA 8270E	2-Methylphenol
GC/MS	EPA 8270E	2-Nitroaniline
GC/MS	EPA 8270E	2-Nitrophenol
GC/MS	EPA 8270E	3,3'-Dichlorobenzidine
GC/MS	EPA 8270E	3,3'-Dimethylbenzidine
GC/MS	EPA 8270E	3-Nitroaniline
GC/MS	EPA 8270E	4,6-Dinitro-2-methylphenol
GC/MS	EPA 8270E	4-Bromophenylphenylether

Solid and Chemical Materials		
Technology	**Method**	**Analyte**
GC/MS	EPA 8270E	4-Chloro-3-methylphenol
GC/MS	EPA 8270E	4-Chloroaniline
GC/MS	EPA 8270E	4-Chlorophenylphenylether
GC/MS	EPA 8270E	4-Nitroaniline
GC/MS	EPA 8270E	4-Nitrophenol
GC/MS	EPA 8270E	Acenaphthene
GC/MS	EPA 8270E	Acenaphthylene
GC/MS	EPA 8270E	Acetophenone
GC/MS	EPA 8270E	Anthracene
GC/MS	EPA 8270E	Atrazine
GC/MS	EPA 8270E	Azobenzene
GC/MS	EPA 8270E	Benzaldhyde
GC/MS	EPA 8270E	Benzidine
GC/MS	EPA 8270E	Benzo(a)Anthracene
GC/MS	EPA 8270E	Benzo(a)pyrene
GC/MS	EPA 8270E	Benzo(b)fluoranthene
GC/MS	EPA 8270E	Benzo(g,h,i)perylene
GC/MS	EPA 8270E	Benzo(k)fluoranthene
GC/MS	EPA 8270E	Benzoic acid
GC/MS	EPA 8270E	Benzyl alcohol
GC/MS	EPA 8270E	Biphenyl
GC/MS	EPA 8270E	bis(2-Chloroethoxy)methane
GC/MS	EPA 8270E	bis(2-Chloroethyl)ether
GCMS	EPA 8270E	Bis (2-Chloro-1-methylethyl) ether
GC/MS	EPA 8270E	bis(2-Ethylhexyl)phthalate
GC/MS	EPA 8270E	Butylbenzylphthalate
GC/MS	EPA 8270E	Caprolactam
GC/MS	EPA 8270E	Carbazole
GC/MS	EPA 8270E	Chrysene
GC/MS	EPA 8270E	DEET
GC/MS	EPA 8270E	Dibenzo(a,h)anthracene
GC/MS	EPA 8270E	Dibenzofuran
GC/MS	EPA 8270E	Diethylphthalate
GC/MS	EPA 8270E	Dimethylphthalate
GC/MS	EPA 8270E	Di-n-butylphthalate
GC/MS	EPA 8270E	Di-n-octylphthalate

Solid and Chemical Materials		
Technology	**Method**	**Analyte**
GC/MS	EPA 8270E	Fluoranthene
GC/MS	EPA 8270E	Fluorene
GC/MS	EPA 8270E	Hexachlorobenzene
GC/MS	EPA 8270E	Hexachlorobutadiene
GC/MS	EPA 8270E	Hexachlorocyclopentadiene
GC/MS	EPA 8270E	Hexachloroethane
GC/MS	EPA 8270E	Indeno(1,2,3-c,d)pyrene
GC/MS	EPA 8270E	Isophorone
GC/MS	EPA 8270E	m+p-Cresol
GC/MS	EPA 8270E	Naphthalene
GC/MS	EPA 8270E	Nitrobenzene
GC/MS	EPA 8270E	N-Nitrosodimethylamine
GC/MS	EPA 8270E	n-Nitroso-di-n-propylamine
GC/MS	EPA 8270E	n-Nitrosodiphenylamine
GC/MS	EPA 8270E	N-Nitrosopyrrolidine
GC/MS	EPA 8270E	o-Cresol
GC/MS	EPA 8270E	Pentachlorophenol
GC/MS	EPA 8270E	Phenanthrene
GC/MS	EPA 8270E	Phenol
GC/MS	EPA 8270E	Pyrene
GC/MS	EPA 8270E	Pyridine
GC/MS	EPA 8270E	n-Nitrosopiperidine
GC/MS	EPA 8270E	n-Nitrosomethylethylamine
GC/MS	EPA 8270E	p-Phenylenediamine
GC/MS	EPA 8270E	2-Picoline
GC/MS	EPA 8270E	1-Naphthylamine
GC/MS	EPA 8270E	n-Nitrosodiethylamine
GC/MS	EPA 8270E	n-Nitrosomorpholine
GC/MS	EPA 8270E	p-(Dimethylamino)azobenzene
GC/MS	EPA 8270E	Phenacetin
GC/MS	EPA 8270E	Pentachloronitrobenzene (Quintozene)
GC/MS	EPA 8270E	2-Naphthylamine
GC/MS	EPA 8270E	n-Nitroso-di-n-butylamine
GC/MS	EPA 8270E	4-Aminobiphenyl
GC/MS	EPA 8270E	o-Toluidine
GC/MS	EPA 8270E	5-Nitro-o-toluidine

Solid and Chemical Materials		
Technology	**Method**	**Analyte**
GC/MS	EPA 8270E SIM	Acenaphthene
GC/MS	EPA 8270E SIM	Acenaphthylene
GC/MS	EPA 8270E SIM	Anthracene
GC/MS	EPA 8270E SIM	Benzo(a)anthracene
GC/MS	EPA 8270E SIM	Benzo(a)pyrene
GC/MS	EPA 8270E SIM	Benzo(b)fluoranthene
GC/MS	EPA 8270E SIM	Benzo(g,h,i)perylene
GC/MS	EPA 8270E SIM	Benzo(k)fluoranthene
GC/MS	EPA 8270E SIM	Chrysene
GC/MS	EPA 8270E SIM	Dibenz(a,h)anthracene
GC/MS	EPA 8270E SIM	1,4-Dioxane
GC/MS	EPA 8270E SIM	Fluoranthene
GC/MS	EPA 8270E SIM	Fluorene
GC/MS	EPA 8270E SIM	Indeno(1,2,3-cd)pyrene
GC/MS	EPA 8270E SIM	1-Methylphenol
GC/MS	EPA 8270E SIM	2-Methylphenol
GC/MS	EPA 8270E SIM	Naphthalene
GC/MS	EPA 8270E SIM	Pentachlorophenol
GC/MS	EPA 8270E SIM	Phenanthrene
GC/MS	EPA 8270E SIM	Pyrene
GC/MS	EPA 8260D	1,1,1,2-Tetrachloroethane
GC/MS	EPA 8260D	1,1,1-Trichloroethane
GC/MS	EPA 8260D	1,1,2,2-Tetrachloroethene
GC/MS	EPA 8260D	1,1,2-Trichloroethane
GC/MS	EPA 8260D	1,1-Dichloroethane
GC/MS	EPA 8260D	1,1-Dichloroethene
GC/MS	EPA 8260D	1,1-Dichloropropene
GC/MS	EPA 8260D	1,2,3-Trichlorobenzene
GC/MS	EPA 8260D	1,2,3-Trichloropropane
GC/MS	EPA 8260D	1,2,4-Trichlorobenzene
GC/MS	EPA 8260D	1,2,4-Trimethylbenzene
GC/MS	EPA 8260D	1,2-Dibromo-3-chloropropane
GC/MS	EPA 8260D	1,2-Dibromoethane (EDB)
GC/MS	EPA 8260D	1,2-Dichlorobenzene
GC/MS	EPA 8260D	1,2-Dichloroethane
GC/MS	EPA 8260D	1,2-Dichloropropane

Solid and Chemical Materials		
Technology	**Method**	**Analyte**
GC/MS	EPA 8260D	1,3,5-Trimethylbenzene
GC/MS	EPA 8260D	1,3-Dichlorobenzene
GC/MS	EPA 8260D	1,3-Dichloropropane
GC/MS	EPA 8260D	1,4-Dichlorobenzene
GC/MS	EPA 8260D	1,4-Dioxane
GC/MS	EPA 8260D	2,2-Dichloropropane
GC/MS	EPA 8260D	2-Butanone (MEK)
GC/MS	EPA 8260D	2-Chloroethylvinyl ether
GC/MS	EPA 8260D	2-Chlorotoluene
GC/MS	EPA 8260D	2-Hexanone
GC/MS	EPA 8260D	4-Chlorotoluene
GC/MS	EPA 8260D	4-Methyl-2-pentanone
GC/MS	EPA 8260D	Acetone
GC/MS	EPA 8260D	Acetonitrile
GC/MS	EPA 8260D	Acrolein
GC/MS	EPA 8260D	Acrylonitrile
GC/MS	EPA 8260D	Allyl chloride
GC/MS	EPA 8260D	Benzene
GC/MS	EPA 8260D	Benzyl chloride
GC/MS	EPA 8260D	Bromobenzene
GC/MS	EPA 8260D	Bromochloromethane
GC/MS	EPA 8260D	Bromodichloromethane
GC/MS	EPA 8260D	Bromoform
GC/MS	EPA 8260D	Bromomethane
GC/MS	EPA 8260D	Carbon disulfide
GC/MS	EPA 8260D	Carbon tetrachloride
GC/MS	EPA 8260D	Chlorobenzene
GC/MS	EPA 8260D	Chloroethane
GC/MS	EPA 8260D	Chloroform
GC/MS	EPA 8260D	Chloromethane
GC/MS	EPA 8260D	Chloroprene
GC/MS	EPA 8260D	cis-1,2-Dichloroethene
GC/MS	EPA 8260D	cis-1,3-Dichloropropene
GC/MS	EPA 8260D	Cyclohexane
GC/MS	EPA 8260D	Cyclohexanone
GC/MS	EPA 8260D	Dibromochloromethane

Solid and Chemical Materials		
Technology	**Method**	**Analyte**
GC/MS	EPA 8260D	Dibromomethane
GC/MS	EPA 8260D	Dichlorodifluoromethane
GC/MS	EPA 8260D	Diisopropyl ether (IPE)
GC/MS	EPA 8260D	Ethyl ether
GC/MS	EPA 8260D	Ethyl methacrylate
GC/MS	EPA 8260D	Ethylbenzene
GC/MS	EPA 8260D	Freon 113
GC/MS	EPA 8260D	Hexachlorobutadiene
GC/MS	EPA 8260D	Isobutyl alcohol
GC/MS	EPA 8260D	Isopropylbenzene
GC/MS	EPA 8260D	m+p-Xylenes
GC/MS	EPA 8260D	Methacrylonitrile
GC/MS	EPA 8260D	Methyl Acetate
GC/MS	EPA 8260D	Methyl iodide
GC/MS	EPA 8260D	Methyl methacrylate
GC/MS	EPA 8260D	Methyl tertiary butyl ether (MTBE)
GC/MS	EPA 8260D	Methylcyclohexane
GC/MS	EPA 8260D	Methylene chloride
GC/MS	EPA 8260D	Naphthalene
GC/MS	EPA 8260D	n-Butylbenzene
GC/MS	EPA 8260D	n-Propylbenzene
GC/MS	EPA 8260D	o-Xylene
GC/MS	EPA 8260D	Pentachloroethane
GC/MS	EPA 8260D	p-Isopropyltoluene
GC/MS	EPA 8260D	Propionitrile
GC/MS	EPA 8260D	sec-Butylbenzene
GC/MS	EPA 8260D	Styrene
GC/MS	EPA 8260D	tert-Butylbenzene
GC/MS	EPA 8260D	Tetrachloroethene
GC/MS	EPA 8260D	Tetrahydrofuran
GC/MS	EPA 8260D	Toluene
GC/MS	EPA 8260D	Total Xylenes
GC/MS	EPA 8260D	trans-1,2-Dichloroethene
GC/MS	EPA 8260D	trans-1,3-Dichloropropene
GC/MS	EPA 8260D	trans-1,4-Dichloro-2-butene
GC/MS	EPA 8260D	Trichloroethene

Solid and Chemical Materials		
Technology	**Method**	**Analyte**
GC/MS	EPA 8260D	Trichlorofluoromethane
GC/MS	EPA 8260D	Vinyl acetate
GC/MS	EPA 8260D	Vinyl chloride
GC/MS	EPA 8260C SIM	1,4-Dioxane
GC	EPA 8081B	4,4'-DDD
GC	EPA 8081B	4,4'-DDE
GC	EPA 8081B	4,4'-DDT
GC	EPA 8081B	Aldrin
GC	EPA 8081B	alpha-BHC
GC	EPA 8081B	alpha-Chlordane
GC	EPA 8081B	beta-BHC
GC	EPA 8081B	Chlordane
GC	EPA 8081B	delta-BHC
GC	EPA 8081B	Dieldrin
GC	EPA 8081B	Endosulfan I
GC	EPA 8081B	Endosulfan II
GC	EPA 8081B	Endosulfan sulfate
GC	EPA 8081B	Endrin
GC	EPA 8081B	Endrin Aldehyde
GC	EPA 8081B	Endrin Ketone
GC	EPA 8081B	gamma-BHC (Lindane)
GC	EPA 8081B	gamma-Chlordane
GC	EPA 8081B	Heptachlor
GC	EPA 8081B	Heptachlor Epoxide
GC	EPA 8081B	Methoxychlor
GC	EPA 8081B	Mirex
GC	EPA 8081B	Toxaphene
GC	EPA 8082A	Aroclor 1016
GC	EPA 8082A	Aroclor 1221
GC	EPA 8082A	Aroclor 1232
GC	EPA 8082A	Aroclor 1242
GC	EPA 8082A	Aroclor 1248
GC	EPA 8082A	Aroclor 1254
GC	EPA 8082A	Aroclor 1260
GC	EPA 8082A	Aroclor 1262
GC	EPA 8082A	Aroclor 1268

Solid and Chemical Materials		
Technology	**Method**	**Analyte**
HPLC	EPA 8330A	2-Amino-4,6-dinitrotoluene
HPLC	EPA 8330A	4-Amino-2,6-dinitrotoluene
HPLC	EPA 8330A	1,3-Dinitrobenzene
HPLC	EPA 8330A	2,4-Dinitrotoluene
HPLC	EPA 8330A	2,6-Dinitrotoluene
HPLC	EPA 8330A	HMX
HPLC	EPA 8330A	Nitrobenzene
HPLC	EPA 8330A	2-Nitrotoluene
HPLC	EPA 8330A	3-Nitrotoluene
HPLC	EPA 8330A	4-Nitrotoluene
HPLC	EPA 8330A	RDX
HPLC	EPA 8330A	Tetryl
HPLC	EPA 8330A	1,3,5-Trinitrobenzene
HPLC	EPA 8330A	2,4,6-Trinitrotoluene
GC	EPA 8015C	Diesel Range Organics
GC	EPA 8015C	WI-Diesel Range Organics
GC	EPA 8015C	Gasoline Range Organics
GC	EPA 8015C	WI-Gasoline Range Organics
GC	FL-PRO	FL-PRO
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	N-ethylperfluoro-1-octanesulfonamidoacetic acid (EtFOSAA)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Fluorotelomer sulfonate 8:2 [1H,1H,2H,2H-perfluorodecane sulfonate] (8:2 FTS)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Fluorotelomer sulfonate 4:2 [1H,1H,2H,2H-perfluorohexane sulfonate] (4:2 FTS)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Fluorotelomer sulfonate 6:2 [1H,1H,2H,2H-perfluorooctane sulfonate] (6:2 FTS)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	GenX (HFPO-DA)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	N-methylperfluoro-1-octanesulfonamidoacetic acid (MeFOSAA)

Solid and Chemical Materials		
Technology	**Method**	**Analyte**
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluoro-1-butanesulfonate (PFBS)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluoro-n-butanoic acid (PFBA)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluoro-1-decanesulfonate (PFDS)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluoro-n-decanoic acid (PFDA)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluoro-n-dodecanoic acid (PFDoA)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluoro-1-heptanesulfonate (PFHpS)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluoro-n-heptanoic acid (PFHpA)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluoro-1-hexanesulfonate (PFHxS)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluoro-n-hexanoic acid (PFHxA)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluoro-1-nonanesulfonate (PFNS)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluoro-n-nonanoic acid (PFNA)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluorooctanesulfonate (PFOS)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluoro-1-octanesulfonamide (PFOSA)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluoro-n-octanoic acid (PFOA)

Solid and Chemical Materials		
Technology	**Method**	**Analyte**
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluoro-n-pentanoic acid (PFPeA)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluoro-1-pentansulfonate (PFPeS)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluoro-n-tetradecanoic acid (PFTeDA)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluoro-n-tridecanoic acid (PFTrDA)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluoro-n-undecanoic acid (PFUDA)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	N-methylperfluoro-1-octanesulfonamide (MeFOSA)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	N-ethylperfluoro-1-octanesulfonamide (EtFOSA)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	1H,1H,2H,2H-perfluorododecane sulfonate (10:2FTS)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	N-Ethyl Perfluorooctane sulfonamido ethanol (EtFOSE)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	N-Methyl Perfluorooctane sulfonamido ethanol (MeFOSE)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Sodium dodecafluoro-3H-4, 8-dioxanonanoate (NaDONA)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	9Cl-PF3ONS
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	11Cl-PF3OUDS
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluorododecanesulfonic acid (PFDOS)

Solid and Chemical Materials		
Technology	**Method**	**Analyte**
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluorohexadecanoic acid (PFHxDA)
LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15	Perfluorooctadecanoic acid (PFODA)
HPLC	EPA 8330B MOD	2-Amino-4,6-dinitrotoluene
HPLC	EPA 8330B MOD	4-Amino-2,6-dinitrotoluene
HPLC	EPA 8330B MOD	1,3-Dinitrobenzene
HPLC	EPA 8330B MOD	2,4-Dinitrotoluene
HPLC	EPA 8330B MOD	2,6-Dinitrotoluene
HPLC	EPA 8330B MOD	HMX
HPLC	EPA 8330B MOD	Nitrobenzene
HPLC	EPA 8330B MOD	Nitrocellulose
HPLC	EPA 8330B MOD	Nitroguanidine
HPLC	EPA 8330B MOD	Guanidine nitrate
HPLC	EPA 8330B MOD	Nitroglycerin (NG)
HPLC	EPA 8330B MOD	2-Nitrotoluene
HPLC	EPA 8330B MOD	3-Nitrotoluene
HPLC	EPA 8330B MOD	4-Nitrotoluene
HPLC	EPA 8330B MOD	RDX
HPLC	EPA 8330B MOD	Tetryl
HPLC	EPA 8330B MOD	1,3,5-Trinitrobenzene
HPLC	EPA 8330B MOD	2,4,6-Trinitrotoluene
ICP	EPA 6010D	Aluminum
ICP	EPA 6010D	Antimony
ICP	EPA 6010D	Arsenic
ICP	EPA 6010D	Barium
ICP	EPA 6010D	Beryllium
ICP	EPA 6010D	Cadmium
ICP	EPA 6010D	Calcium
ICP	EPA 6010D	Chromium
ICP	EPA 6010D	Cobalt
ICP	EPA 6010D	Copper
ICP	EPA 6010D	Iron
ICP	EPA 6010D	Lead
ICP	EPA 6010D	Magnesium

Solid and Chemical Materials		
Technology	**Method**	**Analyte**
ICP	EPA 6010D	Manganese
ICP	EPA 6010D	Molybdenum
ICP	EPA 6010D	Nickel
ICP	EPA 6010D	Potassium
ICP	EPA 6010D	Selenium
ICP	EPA 6010D	Silver
ICP	EPA 6010D	Sodium
ICP	EPA 6010D	Thallium
ICP	EPA 6010D	Tin
ICP	EPA 6010D	Vanadium
ICP	EPA 6010D	Zinc
ICP/MS	EPA 6020B	Aluminum
ICP/MS	EPA 6020B	Antimony
ICP/MS	EPA 6020B	Arsenic
ICP/MS	EPA 6020B	Barium
ICP/MS	EPA 6020B	Beryllium
ICP/MS	EPA 6020B	Cadmium
ICP/MS	EPA 6020B	Calcium
ICP/MS	EPA 6020B	Chromium
ICP/MS	EPA 6020B	Cobalt
ICP/MS	EPA 6020B	Copper
ICP/MS	EPA 6020B	Iron
ICP/MS	EPA 6020B	Lead
ICP/MS	EPA 6020B	Magnesium
ICP/MS	EPA 6020B	Manganese
ICP/MS	EPA 6020B	Nickel
ICP/MS	EPA 6020B	Potassium
ICP/MS	EPA 6020B	Selenium
ICP/MS	EPA 6020B	Silver
ICP/MS	EPA 6020B	Sodium
ICP/MS	EPA 6020B	Thallium
ICP/MS	EPA 6020B	Vanadium
ICP/MS	EPA 6020B	Zinc
CVAA	EPA 7471B	Mercury
Titration	Walkley-Black	TOC
UV/VIS	EPA 9012B	Total Cyanide

Solid and Chemical Materials		
Technology	**Method**	**Analyte**
UV/VIS	EPA 9065	Phenolics
UV/VIS	EPA 9066	Phenolics
IC	EPA 9056A	Bromide
IC	EPA 9056A	Chloride
IC	EPA 9056A	Fluoride
IC	EPA 9056A	Sulfate
IC	EPA 9056A	Nitrate
IC	EPA 9056A	Nitrite
IC	EPA 300.0	Fluoride
IC	EPA 300.0	Chloride
IC	EPA 300.0	Sulfate
IC	EPA 300.0	Bromide
IC	EPA 300.0	Nitrate
IC	EPA 300.0	Nitrite
IC	EPA 7199 / EPA 3060A	Hexavalent chromium
UV/VIS	EPA 7196A EPA 3060A	Hexavalent chromium
Pensky-Martens	EPA 1010A	Ignitability
Electrode	EPA 9045D	Corrosivity
Photometric	Sec. 7.3.3 SW-846	Reactive Cyanide
Titration	Sec. 7.3.4 SW-846	Reactive Sulfide
Filtration	EPA 9095B	Paint Filter Test
UV/VIS	EPA 365.1 MOD	Phosphorus
UV/VIS	EPA 353.2 MOD	Nitrate
UV/VIS	EPA 353.2 MOD	Nitrite
UV/VIS	EPA 353.2 MOD	Nitrate-Nitrite
UV/VIS	EPA 350.1	Ammonia
Gas Diffusion / UV/VIS	EPA 350.1	Ammonia - N
UV/VIS	EPA 351.2 MOD	TKN
GC	MADEP-EPH MOD	Extractable Petroleum Hydrocarbons (EPH) Modified
GC	MADEP-VPH-MOD	Volatile Petroleum Hydrocarbons (VPH) Modified
Preparation	**Method**	**Type**
Organic Preparation	EPA 3550C	Preparation of Soil by Sonication
Organic Preparation	EPA 3546	Microwave Extraction
Organic Cleanup	EPA 3620B	Florisil Cleanup Procedure
Organic Cleanup	EPA 3660B	Sulfur Cleanup Procedure

Solid and Chemical Materials		
Technology	**Method**	**Analyte**
Organic Cleanup	EPA 3665A	Sulfuric Acid Cleanup Procedure
Organic Cleanup	EPA 3640C	GPC Cleanup Procedure
Volatile Organic Preparation	EPA 5035	Closed-System Purge-and-Trap and extraction for Volatile Organics in Soil and Waste Samples
Volatile Organic Preparation	EPA 3585	Waste Dilution for Volatile Organics
Waste Dilution	EPA 3580A	Waste Dilution
Inorganic Preparation	EPA 3050B	Preparation of Soils by Hotblock
Inorganic Preparation	EPA 1311	Toxicity Characteristic Leaching Procedure (TCLP)
Inorganic Preparation	EPA 1312	Synthetic Precipitation Leaching Procedure (SPLP)
Inorganic Metals Preparation	EPA 3010A	Acid Digestion of Aqueous Samples and TCLP/SPLP Extracts

Biological Tissue		
Technology	**Method**	**Analyte**
GC	EPA 8081B	4,4'-DDE
GC	EPA 8081B	4,4'-DDT
GC	EPA 8081B	Aldrin
GC	EPA 8081B	alpha-BHC
GC	EPA 8081B	alpha-Chlordane
GC	EPA 8081B	beta-BHC
GC	EPA 8081B	Chlordane
GC	EPA 8081B	delta-BHC
GC	EPA 8081B	Dieldrin
GC	EPA 8081B	Endosulfan I
GC	EPA 8081B	Endosulfan II
GC	EPA 8081B	Endosulfan sulfate
GC	EPA 8081B	Endrin
GC	EPA 8081B	Endrin Aldehyde
GC	EPA 8081B	Endrin Ketone
GC	EPA 8081B	gamma-BHC (Lindane)
GC	EPA 8081B	gamma-Chlordane
GC	EPA 8081B	Heptachlor
GC	EPA 8081B	Heptachlor Epoxide
GC	EPA 8081B	Methoxychlor
GC	EPA 8081B	Toxaphene
GC	EPA 8082A	Aroclor 1016
GC	EPA 8082A	Aroclor 1221

Biological Tissue		
Technology	**Method**	**Analyte**
GC	EPA 8082A	Aroclor 1232
GC	EPA 8082A	Aroclor 1242
GC	EPA 8082A	Aroclor 1248
GC	EPA 8082A	Aroclor 1254
GC	EPA 8082A	Aroclor 1260
GC	EPA 8082A	Aroclor 1262
GC	EPA 8082A	Aroclor 1268
GC/MS	EPA 8270E	1,1'-Biphenyl
GC/MS	EPA 8270E	1-Methylnaphthalene
GC/MS	EPA 8270E	2-Methylnaphthalene
GC/MS	EPA 8270E	Acenaphthene
GC/MS	EPA 8270E	Acenaphthylene
GC/MS	EPA 8270E	Anthracene
GC/MS	EPA 8270E	Atrazine
GC/MS	EPA 8270E	Benzo(a)anthracene
GC/MS	EPA 8270E	Benzo(b)fluoranthene
GC/MS	EPA 8270E	Benzo(g,h,i)perylene
GC/MS	EPA 8270E	Benzo(k)fluoranthene
GC/MS	EPA 8270E	Chrysene
GC/MS	EPA 8270E	Dibenzo(a,h)anthracene
GC/MS	EPA 8270E	Dibenzofuran
GC/MS	EPA 8270E	Dimethoate
GC/MS	EPA 8270E	Disulfoton
GC/MS	EPA 8270E	Fluoranthene
GC/MS	EPA 8270E	Fluorene
GC/MS	EPA 8270E	Hexachlorobenzene
GC/MS	EPA 8270E	Indeno(1,2,3-c,d)pyrene
GC/MS	EPA 8270E	Methyl parathion
GC/MS	EPA 8270E	Naphthalene
GC/MS	EPA 8270E	Phenanthrene
GC/MS	EPA 8270E	Phorate
GC/MS	EPA 8270E	Pronamide
GC/MS	EPA 8270E	Pyrene
Preparation	**Method**	**Type**
Organic Preparation	EPA 3540C	Soxhlet Extraction

Drinking water		
Technology	**Method**	**Analyte**
GC/MS	EPA 524.2	1,1,1,2-Tetrachloroethane
GC/MS	EPA 524.2	1,1,1-Trichloroethane
GC/MS	EPA 524.2	1,1,2,2-Tetrachloroethane
GC/MS	EPA 524.2	1,1,2-Trichloroethane
GC/MS	EPA 524.2	1,1-Dichloroethane
GC/MS	EPA 524.2	1,1-Dichloroethene
GC/MS	EPA 524.2	1,1-Dichloropropene
GC/MS	EPA 524.2	1,2,3-Trichlorobenzene
GC/MS	EPA 524.2	1,2,3-Trichloropropane
GC/MS	EPA 524.2	1,2,4-Trichlorobenzene
GC/MS	EPA 524.2	1,2,4-Trimethylbenzene
GC/MS	EPA 524.2	1,2-Dibromo-3-chloropropane (DBCP)
GC/MS	EPA 524.2	1,2-Dibromoethane (EDB)
GC/MS	EPA 524.2	1,2-Dichlorobenzene
GC/MS	EPA 524.2	1,2-Dichloroethane
GC/MS	EPA 524.2	1,2-Dichloropropane
GC/MS	EPA 524.2	1,3,5-Trimethylbenzene
GC/MS	EPA 524.2	1,3-Dichlorobenzene
GC/MS	EPA 524.2	1,3-Dichloropropane
GC/MS	EPA 524.2	1,4-Dichlorobenzene
GC/MS	EPA 524.2	2,2-Dichloropropane
GC/MS	EPA 524.2	2-Butanone (MEK)
GC/MS	EPA 524.2	2-Chlorotoluene
GC/MS	EPA 524.2	2-Hexanone
GC/MS	EPA 524.2	2-Nitropropane
GC/MS	EPA 524.2	3-Chloropropene (Allyl chloride)
GC/MS	EPA 524.2	4-Chlorotoluene
GC/MS	EPA 524.2	4-Methyl-2-pentanone
GC/MS	EPA 524.2	Acetone
GC/MS	EPA 524.2	Acrylonitrile
GC/MS	EPA 524.2	Benzene
GC/MS	EPA 524.2	Bromobenzene
GC/MS	EPA 524.2	Bromochloromethane
GC/MS	EPA 524.2	Bromodichloromethane
GC/MS	EPA 524.2	Bromoform
GC/MS	EPA 524.2	Bromomethane (Methyl bromide)
GC/MS	EPA 524.2	Carbon disulfide
GC/MS	EPA 524.2	Carbon tetrachloride

Drinking water		
Technology	**Method**	**Analyte**
GC/MS	EPA 524.2	Chlorobenzene
GC/MS	EPA 524.2	Chloroethane
GC/MS	EPA 524.2	Chloroform
GC/MS	EPA 524.2	Chloromethane (Methyl chloride)
GC/MS	EPA 524.2	cis-1,2-Dichloroethene
GC/MS	EPA 524.2	cis-1,3-Dichloropropene
GC/MS	EPA 524.2	Cyclohexane
GC/MS	EPA 524.2	Dibromochloromethane
GC/MS	EPA 524.2	Dibromomethane (Methylene bromide)
GC/MS	EPA 524.2	Dichlorodifluoromethane
GC/MS	EPA 524.2	Ethyl ether
GC/MS	EPA 524.2	Ethyl methacrylate
GC/MS	EPA 524.2	Ethylbenzene
GC/MS	EPA 524.2	Hexachlorobutadiene
GC/MS	EPA 524.2	Isopropylbenzene
GC/MS	EPA 524.2	m+p - Xylenes
GC/MS	EPA 524.2	Methacrylonitrile
GC/MS	EPA 524.2	Methyl iodide (Iodomethane)
GC/MS	EPA 524.2	Methyl methacrylate
GC/MS	EPA 524.2	Methyl tertiary butyl ether (MTBE)
GC/MS	EPA 524.2	Methylene chloride
GC/MS	EPA 524.2	Naphthalene
GC/MS	EPA 524.2	n-Butylbenzene
GC/MS	EPA 524.2	n-Propylbenzene
GC/MS	EPA 524.2	o - Xylenes
GC/MS	EPA 524.2	Pentachloroethane
GC/MS	EPA 524.2	p-Isopropyltoluene
GC/MS	EPA 524.2	Propionitrile (Ethyl cyanide)
GC/MS	EPA 524.2	sec-Butylbenzene
GC/MS	EPA 524.2	Styrene
GC/MS	EPA 524.2	tert-Butylbenzene
GC/MS	EPA 524.2	Tetrachloroethene
GC/MS	EPA 524.2	Toluene
GC/MS	EPA 524.2	trans-1,2-Dichloroethene
GC/MS	EPA 524.2	trans-1,3-Dichloropropene
GC/MS	EPA 524.2	trans-1,4-Dichloro-2-butene

Drinking water		
Technology	**Method**	**Analyte**
GC/MS	EPA 524.2	Trichloroethene
GC/MS	EPA 524.2	Trichlorofluoromethane
GC/MS	EPA 524.2	Vinyl chloride
GC/MS	EPA 524.2	Xylenes (total)
LC/MS/MS	EPA 537.1	N-ethylperfluoro-1-octanesulfonamidoacetic acid (EtFOSAA)
LC/MS/MS	EPA 537.1	N-methylperfluoro-1-octanesulfonamidoacetic acid (MeFOSAA)
LC/MS/MS	EPA 537.1	Perfluoro-1-butanesulfonate (PFBS)
LC/MS/MS	EPA 537.1	Perfluoro-n-decanoic acid (PFDA)
LC/MS/MS	EPA 537.1	Perfluoro-n-dodecanoic acid (PFDoA)
LC/MS/MS	EPA 537.1	Perfluoro-n-heptanoic acid (PFHpA)
LC/MS/MS	EPA 537.1	Perfluoro-1-hexanesulfonate (PFHxS)
LC/MS/MS	EPA 537.1	Perfluoro-n-hexanoic acid (PFHxA)
LC/MS/MS	EPA 537.1	Perfluoro-n-nonanoic acid (PFNA)
LC/MS/MS	EPA 537.1	Perfluorooctanesulfonate (PFOS)
LC/MS/MS	EPA 537.1	Perfluoro-n-octanoic acid (PFOA)
LC/MS/MS	EPA 537.1	Perfluoro-n-tetradecanoic acid (PFTeDA)
LC/MS/MS	EPA 537.1	Perfluoro-n-tridecanoic acid (PFTrDA)
LC/MS/MS	EPA 537.1	Perfluoro-n-undecanoic acid (PFUDA)
LC/MS/MS	EPA 537.1	NaDONA
LC/MS/MS	EPA 537.1	GenX
LC/MS/MS	EPA 537.1	9CL-PF3ONS
LC/MS/MS	EPA 537.1	11CL-PF3OUDS
LC/MS/MS	EPA 533	9-chlorohexadecafluoro-3-oxanone-1-sulfonic acid (9Cl-PF3ONS)
LC/MS/MS	EPA 533	11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (11Cl-PF3OUdS)
LC/MS/MS	EPA 533	1H, 1H, 2H, 2H-perfluorodecane sulfonic acid (8:2 FTS)
LC/MS/MS	EPA 533	1H, 1H, 2H, 2H-perfluorooctane sulfonic acid (6:2 FTS)
LC/MS/MS	EPA 533	1H, 1H, 2H, 2H-perfluorohexane sulfonic acid (4:2 FTS)
LC/MS/MS	EPA 533	Hexafluoropropylene oxide dimer acid (GenX)
LC/MS/MS	EPA 533	4,8-dioxa-3H-perfluorononanoic acid (ADONA)
LC/MS/MS	EPA 533	Nonafluoro-3,6-dioxaheptanoic acid (NFDHA)
LC/MS/MS	EPA 533	Perfluoro(2-ehtoxyethane)sulfonic acid (PFEESA)
LC/MS/MS	EPA 533	Perfluorobutanesulfonic acid (PFBS)
LC/MS/MS	EPA 533	Perfluoroheptanesulfonic acid (PFHpS)

Drinking water		
Technology	**Method**	**Analyte**
LC/MS/MS	EPA 533	Perfluoropentanesulfonic acid (PFPeS)
LC/MS/MS	EPA 533	Perfluoro-3-methoxypropanoic acid (PFMPA)
LC/MS/MS	EPA 533	Perfluoro-4-methoxybutanoic acid (PFMBA)
LC/MS/MS	EPA 533	Perfluorohexanesulfonic acid (PFHxS)
LC/MS/MS	EPA 533	Perfluorobutanoic acid (PFBA)
LC/MS/MS	EPA 533	Perfluorodecanoic acid (PFDA)
LC/MS/MS	EPA 533	Perfluorododecanoic acid (PFDoA)
LC/MS/MS	EPA 533	Perfluoroheptanoic acid (PFHpA)
LC/MS/MS	EPA 533	Perfluorohexanoic acid (PFHxA)
LC/MS/MS	EPA 533	Perfluorononanoic acid (PFNA)
LC/MS/MS	EPA 533	Perfluorooctanoic acid (PFOA)
LC/MS/MS	EPA 533	Perfluoropentanoic acid (PFPeA)
LC/MS/MS	EPA 533	Perfluoroundecanoic acid (PFUdA)
LC/MS/MS	EPA 533	Perfluorooctanesulfonic acid (PFOS)

Note:

1. This scope is formatted as part of a single document including Certificate of Accreditation No. L2224.

R. Douglas Leonard Jr., VP, PILR SBU

Schnabel ENGINEERING

Standard Operating Procedure

Grain Size Determined by Sedimentation Analysis (Hydrometer)

SCOPE AND APPLICATION

This method determines the particle size distribution in soil. Particles greater than 75-um (gravels to fine sands) are determined by sieving and particles less than 75-um (silts and clays) are determined by sedimentation using a hydrometer. This preparation is used for samples containing gravel, sand, silt, and clay.

References used: ASTM Standards D6913 and/or D7928

ASTM D6913 test method is typically used for determining the gradation of soil between the 3-in. (75-mm) and No. 200 (75-µm) sieves.

ASTM D7928 test method covers the quantitative determination of the distribution of particle sizes of the fine-grained portion of soils. The sedimentation or hydrometer method is used to determine the particle-size distribution (gradation) of the material that is finer than the No. 200 (75-µm) sieve and larger than about 0.2-µm. The test is performed on material passing the No. 10 (2.0-mm) or finer sieve.

EQUIPMENT AND SUPPLIES

Balance sensitive to 0.01 grams
Mixer and dispersion cup
1000 ml sedimentation cylinder
Sodium Hexametaphosphate (dispersion reagent)
Soil test hydrometer
Mortar and rubber tipped pestle for breaking up soil aggregates
Oven with temperature range of 60°C to 110°C
Thermometer accurate to 0.5°C
Timer
Mixing utensils, metal and bristle brushes for sample recovery
Rototap machine, if necessary.

Typical sieves sizes used, where appropriate:
Note: sieve sizes used may vary depending on sample material and project specification

Sieve Size (in.)(mm)		
3.0 in. (75.00mm)	1/2 in. (12.50mm)	No. 40 (425um)
2.0 in. (50.00mm)	3/8 in. (9.50mm)	No. 60 (250.0um)
1.5 in. (37.50mm)	No. 4 (475mm)	No. 100 (150.0um)
1.0 in. (25.00mm)	No. 10 (2.00mm)	No. 200 (75.0um)
3/4 in. (19.00mm)	No. 20 (850.0um)	

SAMPLE COLLECTION, PRESERVATION, SHIPMENT AND STORAGE

Minimum quantity of sample depends on subsequent analyses to be performed. Typical sample of 150 to 350 grams is used for analysis. Larger amounts (from 500 to 5000 grams) are specified for particle size analysis of soils with appreciable gravel component. The sample container must remained sealed to maintain natural water content.

There are no holding time requirements.

QUALITY CONTROL

Check balance daily with Class S weight, yearly manufacturer calibration.
Oven temperature is checked daily prior to start of work.
Thermometer is checked against similar or more accurate temperature device.

CALIBRATION AND STANDARDIZATION

Sieves calibrated twice a year using the National Bureau of Standard, Certificate of Calibration, standard reference materials 1017a, 1018a and 1019a calibrated glass beads.

Hydrometers are calibrated twice a year, and checked prior to each use.

Thermometer calibrated against NIST certified thermometer.

PROCEDURE

An air-dried representative sample is weighed. This weight is recorded as the dry weight of the sample.

Sample is processed through a series of sieve sizes greater than and equal to the No. 10 sieve size. This separates the soil sample from the material greater than the No. 10 sieve and what material is finer than the No. 10 sieve.

Weigh and record the contents of each sieve greater than No. 10. Also, weigh and record the contents retained on the No. 10 sieve.

Hydrometer Test: The soil passing the No. 10 sieve is used in the following steps.

Hydroscopic Moisture: Take a representative sample and place in a small tin (record weight of tin). Record weight of sample and tin. Place in oven for at least 16hrs. Place the tin in the oven at 110°C for at least 16 hours. Remove the tin and record the weight after drying period.

Weigh and record an appropriate amount of soil depending on the soil type. Typically, sample size for fine grained soils (clay/silt) is approximately 50 grams, and coarse grained soils (sand) approximately 100 grams, when feasible.

Add 100 ml of dispersing agent to soil sample and enough distilled water to be sufficient enough to facilitate the process of breaking apart the soil aggregations. Sample is then placed in the dispersion cup and agitated/blended for one minute. Upon completion of the blending, the dispersed slurry is then transferred into the sedimentation cylinder making sure all the slurry is transferred to the cylinder. Use a rinse bottle if necessary. Distilled water is used to fill the cylinder to the 1000 ml +/- mark. Then using the tipping method, tip the cylinder upside down and back for a period of one minute to complete the agitation of the slurry. If soils are highly plastic, the use of an agitator may be used. Cover cylinder to prevent evaporation and allow the cylinder to sit overnight.

The next day, the mixture in the cylinder needs to be remixed by the tipping method. Upon completion of the last inversion, start taking hydrometer readings using the prescribed times. A reading consists of inserting the hydrometer gently into the cylinder, (after the cylinder has been shaken for 1 minute), about 20 seconds before the actual reading. Read the hydrometer at the top of the meniscus and the reading where the plane of the water surface intersects the stem. The difference of the two readings is the meniscus correction. Record this value. Remove the hydrometer and insert a temperature sensor into the cylinder to the depth to which the hydrometer reached. Read the temperature meter to the nearest 0.1°C and remove the temperature sensor. The hydrometers and temperature sensor are rinsed in a distilled water bath between each reading.

The hydrometer reading, temperature, and time (from table) is entered on the hydrometer data sheet at the corresponding cylinder (test) number and time portion on the data sheet; deviations from the table schedule are noted on the sheet. The readings are taken at 0.5, 1, 2, 4, 15, 30, 60, 120, 240 and 1440 minute intervals. Temperature is recorded at the beginning of the sedimentation test and then every 30 minute intervals.

Upon completion of the 1440 minute reading, the sediment is washed over a No. 200 sieve. The soil retained on the No. 200 sieve is placed in an oven and dried overnight. The next day, the sample is removed from the oven. Record the weight.

Information obtained during the set up and testing process is entered in our gINT program to generate the necessary information to generate a sieve curve and gravel, sand, silt and clay particle information.

Note: when a full sieve is required, the sample removed from the oven after the No. 200 wash would be placed in the appropriate sieve stack on a Rototap sieve shaking machine. Upon completion of shaking, the sieves would be weighed and recorded.



Document Information

Document Number: ME003NI **Revision: -04**

Document Title: Determination of Per- and Polyfluoroalkyl Substances (PFAS) by LC/MS/MS (Isotope Dilution)

Department(s): |LC/MS/MS|

Date Information

Effective Date: Tuesday, March 30, 2021

Notes

Document Notes:

All Dates and Times are in Eastern Standard Time Zone.

Signature Manifest

Document Number: ME003NI **Revision:** -04

Title: Determination of Per- and Polyfluoroalkyl Substances (PFAS) by LC/MS/MS (Isotope Dilution)

All dates and times are in Eastern Standard Time Zone.

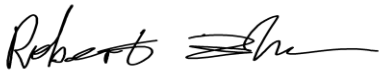
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General Manager 1



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Quality Manager



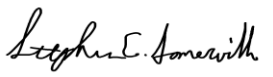
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3/30/2021 11:12:33 AM
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Supervisor

TEST METHOD STANDARD OPERATING PROCEDURE
TITLE: Determination of Per- and Polyfluoroalkyl Substances (PFAS) by LC/MS/MS (Isotope Dilution)
METHOD: QSM 5.3 Table B-15 [All but New Jersey]
ISSUER: Pace ENV - Local Quality - WCOL

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1.0 Scope And Application

This standard operating procedure (SOP) describes the laboratory procedure for the determination of Per- and Polyfluoroalkyl Substances (PFAS) by Liquid Chromatography Tandem Mass Spectrometry (LC/MS/MS) with Isotope Dilution Quantification in aqueous and solid matrices.

The requirements outlined in this SOP conform to those presented in Table B-15 of the Department of Defense (DoD)/Department of Energy (DOE) Consolidated Quality Systems Manual (QSM) for Environmental Laboratories. Table B-15 requirements are included in Appendix DoD for reference. Additional appendices are included for state and/or program specific method criteria, which supersede and/or supplement the method criteria prescribed in this SOP

1.1 Target Analyte List and Limits of Quantitation (LOQ)

The target analytes and the normal LOQ that can be achieved with this procedure are provided in Table 2.

LOQ are established in accordance with Pace policy and SOPs for method validation and for the determination of detection limits (DL) and quantitation limits (LOQ). DL and LOQ are routinely verified and updated when needed. The current LOQ for each target analyte that can be determined by this SOP as of the effective date of this SOP is provided in Table 1, Appendix A.

The reporting limit (RL) is the value to which analytes are reported as detected or not detected in the final report. When the RL is less than the lower limit of quantitation (LLOQ), all detects and non-detects at the RL are qualitative. The LLOQ is the lowest point of the calibration curve used for each target analyte.

DL, LOQ, and RL are always adjusted to account for actual amounts used and for dilution.

2.0 Summary of Method

NOTE: Refer to appendices for state and/or program specific method criteria, which supersede and/or supplement the method criteria prescribed in this SOP.

2.1 **PFAS Isotope Dilution method (aqueous; ID-AQ)** - A 250-mL water sample is fortified with surrogates (SUR; also referred to as extracted internal standards [EIS] or isotope dilution standards [IDS]) and passed through a solid phase extraction (SPE) cartridge (Phenomenex Strata-XL-AW or equivalent) to extract the method analytes and SUR. The compounds are eluted from the SPE cartridge with 4-mL of methanol and 4-mL of ammonia-methanol (0.6%). Samples are then filtered by SPE (Strata-GCB, Strata PFAS(WAX/GCB), or equivalent), with a tube rinse of 2-mL of clean MeOH. With the filtration tube rinse, the final extract volume is approximately 10 mL. An aliquot of the extract is fortified with instrument standards (IS). 10-µL of the fortified aliquot is injected on an LC equipped with a C18 column that is coupled to an MS/MS detector. The analytes are separated and identified by comparing the acquired mass spectra and retention times to the reference spectra and retention times for calibration standards acquired under identical LC/MS/MS conditions. The concentration of each analyte is determined by using the internal standard isotope dilution technique.

2.2 **PFAS Isotope Dilution method (solid; ID-Solid)** - Approximately 1g of solid sample is spiked with SUR/EIS/IDS and mixed with 4mL of methanol and 4mL of ammonia-methanol (0.6%). The spiked sample with extraction solvent is then shaken on an orbital shaker, followed by sonication and centrifugation. The extract is filtered by SPE (Strata-GCB, Strata PFAS(WAX/GCB), or equivalent), with

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a tube rinse of 2-mL of clean MeOH. The final extract volume following the filtration step is approximately 10 mL. An aliquot of the extract is fortified with instrument standards (IS). 10-µL of the fortified aliquot is injected on an LC equipped with a C18 column that is linked to an MS/MS detector. The analytes are separated and identified by comparing the acquired mass spectra and retention times to the reference spectra and retention times for calibration standards acquired under identical LC/MS/MS conditions. The concentration of each analyte is determined by using the internal standard isotope dilution technique. See Appendix B for specific procedures for preparing and analyzing solid samples by ID-Solid.

2.3 **PFAS Isotope Dilution method (Aqueous Serial Dilution; ID-SD)** - Samples of known high PFAS concentrations, such as AFFF pure product formulations, can be prepared by serial dilution instead of SPE, with documented project approval. The sample serial dilutions will be prepared in 96% MeOH: 4% water. IS and SUR will be spiked into the diluted sample (not the original sample collected) in the preparation vial. Any target analytes found to be ND in any samples shall be spiked at the LOQ level (post-spike) in those samples at the dilution reported and analyzed again. Recovery for the post-spiked analytes must fall within 70-130% of the expected value; if these criteria are not met, the post-spike analysis will be repeated at successively higher dilutions until recovery is acceptable. The spiking concentration will be used to calculate the project specific LOQ for each analyte. 10-µL of the prepared dilution aliquot is injected on an LC equipped with a C18 column that is coupled to an MS/MS detector. The analytes are separated and identified by comparing the acquired mass spectra and retention times to the reference spectra and retention times for calibration standards acquired under identical LC/MS/MS conditions. The concentration of each analyte is determined by using the internal standard isotope dilution technique. See Appendix C for specific procedures for preparing and analyzing serial dilution samples by ID-SD.

3.0 Interferences

3.1 Non-volumetric glassware can be solvent rinsed or heated in a muffle furnace at 400°C for 2-hours. Volumetric glassware should be solvent rinsed and can be heated in an oven at a temperature below 120°C. Store clean glassware inverted or capped. Do not cover with aluminum foil since PFAS may potentially be transferred from the aluminum foil to the glassware.

NOTE: PFAS standards, extracts and samples should not come into contact with any glass containers or pipettes as these analytes can potentially adsorb to glass surfaces. PFAS analyte, internal standards (IS) and surrogate standards (SUR) commercially purchased in glass ampoules are acceptable; however, all subsequent transfers or dilutions performed by the analyst must be prepared and stored in HDPE or polypropylene containers.

3.2 Method interferences may be caused by contaminants in solvents, reagents (including reagent water), sample containers and caps, and other sample processing equipment that lead to discrete artifacts and/or elevated baselines in the chromatograms. Method analytes may also be found in many common laboratory supplies and equipment, such as PTFE (polytetrafluoroethylene) products, LC solvent lines, methanol, aluminum foil, SPE sample transfer lines, etc. Supplies and equipment are demonstrated to be free from interference (no analyte detected > ½ LoQ) by evaluation of routine method blanks (MB). Subtracting blank values from sample results is not permitted.

3.3 Matrix interferences may be caused by contaminants that are co-extracted from the sample. The extent of matrix interferences will vary considerably from source to source, depending upon the nature of the water. Humic and/or fulvic material can be co-extracted during SPE and high levels can cause

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enhancement and/or suppression in the electrospray ionization source or low recoveries on the SPE sorbent.

3.4 SPE cartridges/tubes can be a source of interferences. The analysis of field and laboratory reagent blanks can provide important information regarding the presence or absence of such interferences. Brands and sorbent lots of SPE devices should be tested to ensure that contamination does not prevent analyte identification and quantitation.

4.0 Definitions

Refer to the Laboratory Quality Manual [QAMP ME0012K] for a glossary of common lab terms and definitions.

4.1 **Collisionally Activated Dissociation (CAD)** – The process of converting the precursor ion's translational energy into internal energy by collisions with neutral gas molecules to bring about dissociation into product ions.

4.2 **Surrogate/Extracted Internal Standard/Isotope Dilution Standard (SUR/EIS/IDS)** – A pure chemical which chemically resembles method analytes and is extremely unlikely to be found in any sample. This chemical is added to a sample aliquot (field and QC) in known amount(s) before the extraction and analysis processes. The purpose of the SUR is to monitor method performance from extraction to final chromatographic measurement. For the ID methods, the SUR is used as an isotope dilution standard for measuring the relative response and quantification of other method analytes.

4.3 **Field Duplicates (FD1 and FD2)** – Two separate samples collected at the same time and place under identical circumstances and treated exactly the same throughout field and laboratory procedures. Analyses of FD1 and FD2 give a measure of the precision associated with sample collection, preservation, and storage, as well as laboratory procedures.

4.4 **Precursor Ion** – The precursor ion is typically the deprotonated molecule ([M-H]-) of the method analyte. In MS/MS, the precursor ion is the mass selected and fragmented by collisionally activated dissociation to produce distinctive product ions of smaller m/z.

4.5 **Product Ion** – A product ion is one of the fragment ions produced in MS/MS by collisionally activated dissociation of the precursor ion.

4.6 **Non-conformance Memo (NCM)** - A form used to document a non-conforming event. An analyst must document a non-conformance memo when a non-conforming event occurs. A non-conforming event may include the reporting of analytical data outside of method or SOP criteria, or when there is a deviation from a written policy or procedure. Information in an NCM may be used by project managers to flag data in the report narrative, or by the quality department to track trends and initiate corrective actions, where applicable. Additional information on the NCM policy and procedure is located in the Nonconformance and Corrective Action SOP [QA SOP ME0012BO].

4.7 **Minimum Reporting Level (MRL) [WI DNR Compliance]** - The minimum concentration that can be reported as a quantitated value for a method analyte in a sample following analysis. This defined concentration can be no lower than the concentration of the lowest calibration standard for that analyte and can only be used if acceptable QC criteria for this standard are met. Synonymous with Limit of Quantitation (LOQ).

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5.0 Health and safety

The toxicity or carcinogenicity of each chemical material used in the laboratory has not been fully established. Each chemical should be regarded as a potential health hazard and exposure to these compounds should be as low as reasonably achievable.

The laboratory maintains documentation of hazard assessments and OSHA regulations regarding the safe handling of the chemicals specified in each method. Safety data sheets for all hazardous chemicals are available to all personnel. Employees must abide by the health, safety and environmental (HSE) policies and procedures specified in this SOP and in the Pace Chemical Hygiene / Safety Manual.

Personal protective equipment (PPE) such as safety glasses, gloves, and a laboratory coat must be worn in designated areas and while handling samples and chemical materials to protect against physical contact with samples that contain potentially hazardous chemicals and exposure to chemical materials used in the procedure.

Concentrated corrosives present additional hazards and are damaging to skin and mucus membranes. Use these acids in a fume hood whenever possible with additional PPE designed for handing these materials. If eye or skin contact occurs, flush with large volumes of water. When working with acids, always add acid to water to prevent violent reactions. Any processes that emit large volumes of solvents (evaporation/concentration processes) must be in a hood or apparatus that prevents employee exposure.

Contact your supervisor or local HSE coordinator with questions or concerns regarding safety protocol or safe handling procedures for this procedure.

6.0 Sample Collection, Preservation, Holding Time, And Storage

Samples should be collected in accordance with a sampling plan and procedures appropriate to achieve the regulatory, scientific, and data quality objectives for the project.

The laboratory performs samples collection for samples to be analyzed by this SOP in accordance with the *Field Services* SOP [FS SOP ME001BS]. Refer to this SOP for these instructions.

The laboratory will provide containers for the collection of samples upon client request for analytical services. Bottle kits are prepared in accordance with the *Sample Container Shipping* SOP [AD SOP ME001DS].

Requirements for container type, preservation, and field quality control (QC) for the common list of test methods offered by Pace are listed in the *Pace-WCOL Analytical Methods List* [ME002BS].

General Requirements

Matrix	Routine Container	Min. Sample Amount[1]	Preservation	Holding Time
Aqueous	250 mL HDPE bottle fitted with polyethylene screw-cap lid	250 mL	**Thermal:** ≤ 10°C[2] **Chemical:** None	**Collection to Prep:** 28 days **Prep to Analysis:** 28 days
Solid	4 oz. HDPE bottle fitted with polyethylene screw-cap lid	10 g	**Thermal:** ≤ 10°C **Chemical:** None	**Collection to Prep:** 28 days **Prep to Analysis:** 28 days

[1]*Minimum amount needed for each discrete analysis.*
[2]*For Wisconsin compliance, samples must be received at above their freezing point to 6°C*

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Field / Matrix QC

Trip Blank	MS/MSD	Field Duplicate
Analysis of TB required only if sample contains analyte concentrations at or above the LoQ.[1]	Analysis of an MS is required in each extraction batch. Assessment of method precision can be accomplished by analysis of a FD; however, infrequent occurrence of method analytes might hinder this assessment. If the occurrence of method analytes in the samples is infrequent, or if historical trends are unavailable, an MSD must be analyzed. Extraction batches that contain MSD will not require the extraction of an FD.	Within each extraction batch a minimum of one FD or MSD must be analyzed. If method analytes are not routinely observed in field samples, an MSD should be analyzed rather than an FD.

[1] Lab analyzes all TB, regardless of sample concentration.

Thermal preservation is checked and recorded on receipt in the laboratory in accordance with the *Sample Receiving* SOP [AD SOP ME0013H]. Chemical preservation is checked and recorded at time of receipt or prior to sample preparation.

After receipt, samples are stored at 4±2°C until sample preparation. Prepared samples (extracts, digestates, distillates, other) are stored at room temperature until sample analysis.

NOTE: Wisconsin compliance sample extracts will be stored at 0-6°C until sample analysis.

After analysis, unless otherwise specified in the analytical services contract, samples are retained for 30 days from date of final report and then disposed of in accordance with Federal, State, and Local regulations.

7.0 Equipment And Supplies

7.1 Equipment

NOTE: Refer to the Major Operational Equipment List [QA Control Log ME001PM] for specific details regarding the equipment and data processing software utilized during this procedure.

NOTE: Due to the possibility of adsorption of analytes onto glass, HDPE containers are used for all standard, sample and extraction preparations. Any time a new lot of SPE cartridges/tubes, solvents, cryovials, or autosampler vials are used, it must be demonstrated that a MB is reasonably free of contamination and that the criteria in Section 11.4.1 are met.

7.1.1 Analytical Balance – Capable of weighing to the nearest 0.0001 g

7.1.2 Solid Phase Extraction (SPE) Apparatus

7.1.2.1 SPE Cartridges Strata-XL-AW 100um Polymeric Weak Anion (0.5 g, 6mL) (Phenomenex Part # 8B-S051-HCH) or equivalent

7.1.2.2 Strata-GCB filtration tubes, 250mg/6mL, Phenomenex part# 8B-S528-FCH, or equivalent.

7.1.2.3 Stacked SPE/filtration cartridges: Strata PFAS(WAX/GCB), 200mg/50mg/6mL, Phenomenex part# CS0-9207, or equivalent

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7.1.2.4 Vacuum Extraction Manifold – 24-port SPE manifold, Phenomenex part# AH0-6024, or equivalent. Care must be taken with automated SPE systems to ensure the PTFE commonly used in these systems does not contribute to unacceptable analyte concentrations in the MB.

7.1.2.5 SPE reservoirs – 60mL polypropylene, Phenomenex part# AH0-7189, or equivalent.

7.1.2.6 SPE adapter caps – Phenomenex Part# AH0-7191 (Adapter cap for 1, 3, 6mL SPE tubes)

7.1.2.7 Vacuum tubing – 1/4" ID, 5/8" OD, 3/16" wall; Fisher Scientific part# 14-176-6B or equivalent

7.1.3 **Vacuum Pump** – Sufficient capacity to maintain a vacuum of approximately 10 to 15 inches of mercury for extraction cartridges. Millipore model# WP6111560, 115V, 60Hz, 3.5A.

7.1.4 Liquid Chromatography (LC)/Tandem Mass Spectrometer (MS/MS) with Data System

7.1.4.1 LC System – Agilent Model 1260, with Degasser (G4225A), Binary Pump (G1312B), Autosampler (G1329B), Thermostat (G1330B), Column Compartment (G1316A).

7.1.4.2 NOTE: PFAS can build up in the PTFE solvent transfer lines and PTFE solvent frits. To prevent long delays in purging high levels of PFAS from the LC solvent lines, PEEK tubing and stainless-steel frits are used.

7.1.4.3 Tandem Mass Spectrometer (MS/MS) – Sciex 4500 or 5500 MS/MS, in negative ion electrospray ionization (ESI) mode. A minimum of 10 scans across the chromatographic peak is required to ensure adequate precision.

7.1.4.4 Analytical Column – Phenomenex Gemini® 3µm C18 110Å LC column 50 x3mm, (part# 00B-4439-Y0). Any column that provides adequate resolution, peak shape, capacity, accuracy, and precision may be used.

7.1.4.5 Mixing/Delay Column – Phenomenex Luna 5µm C18 100Å LC column 30 x 3mm (part# 00A-4252-Y0) or equivalent.

7.1.4.6 Guard cartridge – SecurityGuard Cartridges: Gemini C18, 2-3mm ID, 10/pk; Part# AJ0-7596/AJ0-7597; Phenomenex Part# KJ0-4282 (SecurityGuard Guard Cartridge Kit)

7.1.5 **Vortex Mixer** - Bibby Scientific/Stuart Vortex Mixer, Model SA8, or equivalent.

7.1.6 **Orbital shaker table** - VWR Model 3500 Standard Shaker, 120V, or equivalent

7.1.7 **Centrifuge** - VWR Clinical 200, Hettich Rotanta 460, or equivalent

7.1.8 **Sonicator** - VWR Model 97043-976, or equivalent

7.2 Supplies

7.2.1 **Extract/Standard storage containers** – 15-mL, 8-mL, or 4-mL narrow-mouth HDPE container - Thermo Scientific item# 2002-9050, 2002-9025, 2002-9125; 2.0-mL screw-top polypropylene

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cryogenic vials – Grainger item# 6EMV1;1.5-mL snap-cap polypropylene microcentrifuge tubes - Fisher item# 05-408-129; or equivalent.

7.2.2 **Centrifuge Tubes** – 15-mL conical polypropylene tubes with or without (MoldPro) polypropylene screw caps for preparing and storing extract solutions and for collection of eluents (VWR catalogue# 10026-076 or equivalent; MoldPro, Inc. item# MP-100, 17x100mm sample tubes or equivalent, alternate extract collection tubes). 500-mL conical polypropylene bottles with polypropylene screw caps for centrifuging aqueous samples containing high solids content (Fisher catalogue# 07-200-621 or equivalent).

7.2.3 **Autosampler Vials** – Polypropylene vials (Agilent part# 5188-2788) with polypropylene caps (Agilent part# 5182-0542), or equivalent.

NOTE: Polypropylene vials and caps are necessary to prevent contamination of the sample from PTFE coated septa. However, polypropylene caps do not reseal, so evaporation occurs after injection. Thus, multiple injections from the same vial are not advisable.

7.2.4 **Polypropylene Graduated Cylinders** – Suggested sizes include 25, 50, 100 and 1000-mL cylinders

7.2.5 **Micropipettes** – Range of volumes (see section 8 for volumes needed)

7.2.6 **Plastic Pipettes** – Polypropylene or polyethylene disposable pipettes, Fisher Cat# 13-711-7M or equivalent.

7.2.7 **Ottawa Sand** - for solid QC preparation (VWR catalog #: EM-SX0075-3 or equivalent)

8.0 Reagents And Standards

NOTE: Reagent grade or better chemicals should be used. Unless otherwise indicated, it is intended that ACS reagents be used, where such specifications are available. Other grades may be used, provided it is first determined that the reagent is of sufficiently high purity to permit its use without lessening the quality of the analysis.

8.1 Reagents

8.1.1 **Reagent Water** – Optima LC/MS water, Fisher part# W6-4 or equivalent.

8.1.1.1 The reagent water should not contain any measurable quantities of any method analytes or interfering compounds greater than 1/2 the LOQ for each analyte of interest.

8.1.2 **Methanol (MeOH, CH3OH, CAS#: 67-56-1)** – HPLC grade, demonstrated to be free of analytes and interferences (Fisher part# A452-4 or equivalent).

8.1.3 **Ammonium Acetate (NH4C2H3O2, CAS#: 631-61-8)** – LC/MS grade (Fisher part# A114-50 or equivalent).

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8.1.4 **20 mM Ammonium Acetate** – To prepare 1 L, add 1.54 g ammonium acetate to 1L of reagent water (0.77g into 0.5L reagent water). This solution is prone to volatility losses and should be replaced at least every 48 hours.

8.1.5 **Ammonium Hydroxide (NH4OH, CAS#: 1336-21-6)** – ACS Plus grade (Fisher part# A669C-212 or equivalent)

8.1.6 **Ammonia-Methanol (Amm-MeOH, 0.6%)** – In a 1000 mL graduated cylinder, add 20 mL NH4OH (Ammonium Hydroxide) and fill to volume with methanol (980 mL reagent MeOH). Invert to mix.

8.1.7 **Ammonium Acetate/Acetic Acid buffer (25mM, pH 4)** – In a 2000 mL volumetric flask, add 2.32 mL acetic acid and 0.80 g ammonium acetate then fill to volume with reagent water (1997.68 mL reagent water). Invert to mix.

8.1.8 **Nitrogen** – Nitrogen aids in aerosol generation of the ESI liquid spray and is used as collision gas in some MS/MS instruments. The nitrogen used should meet or exceed instrument manufacturer's specifications.

8.2 Standards

NOTE: When a compound purity is assayed to be 96% or greater (standards purchased from Wellington are >98%), the weight can be used without correction to calculate the concentration of the stock standard. PFAS analyte, IS, and SUR standards commercially purchased in glass ampoules are acceptable; however, all subsequent transfers or dilutions performed by the analyst must be prepared and stored in HDPE containers. Solution concentrations listed in this section were used to develop this method and are included as an example. Alternate concentrations may be used as necessary depending on instrument sensitivity and the calibration range used. Standards for sample fortification generally should be prepared in the smallest volume that can be accurately measured to minimize the addition of excess organic solvent to aqueous samples.

NOTE: The final compositions for all standards in section 8.2 contain 96:4% (v/v) methanol/water. The solutions are stored at 2-6°C in HDPE containers.

8.2.1 **Instrument Standards (IS) Stock Standards –** The stocks are obtained from Wellington Labs (catalog # MPFHxA and catalog # MPFAC-C-IS). IS stock standard solutions are stable for at least 12 months when stored at 2-6°C. The IS used for ID-AQ are comprised of the following compounds:

- Perfluoro-n-[1,2-13C2]hexanoic acid (13C2-PFHxA)
- Perfluoro-n-[1,2-13C2] octanoic acid (13C2-PFOA)
- Sodium perfluoro-1-[1,2,3,4-13C4] octanesulfonic acid (13C4-PFOS)
- Perfluoro-n-[2,3,4-13C3] butanoic acid (13C3-PFBA)
- Perfluoro-n-[1,2-13C2] decanoic acid (13C2-PFDA)

8.2.2 **Instrument Standard (IS) 50X Mix -** Dilute the stock standard with methanol/water in accordance with the table below:

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IS 50X Mix Preparation (Aqueous)				
Standard Name	**Conc. of Stock Std. (µg/mL)**	**Aliquoted Volume (µL)**	**Dilution Volume (mL)**	**Final Conc. (µg/mL)**
Perfluoro-n-[1,2-$^{13}C_2$]hexanoic acid (13C2-PFHxA)	50	200	10	1.0

8.2.3 **Instrument Standard (IS) 20 ppb Mix -** Combine the IS 50X Mix and Wellington Labs stock standard part# MPFAC-C-IS and dilute with methanol/water in accordance with the table below:

20 ppb IS Mix Preparation (Aqueous)				
Standard Name	**Conc. of Stock Std. (µg/mL)**	**Aliquoted Volume (µL)**	**Dilution Volume (mL)**	**Final Conc. (µg/mL)**
IS 50X Mix	1	300	15	0.02
MPFAC-C-IS Stock	2	150	15	0.02

NOTE: The complete list of compounds included in the ID (Aqueous and Solid) 20 ppb IS Mix are found in Table 5.

8.2.4 **Surrogate (SUR) Stock Standard Solutions –** The SUR standard stocks are obtained from Wellington Labs (catalog #s: M2PFHxDA, M2-4:2FTS, M2-6:2FTS, M2-8:2FTS, M8FOSA-I, d-N-EtFOSA-M, d-N-MeFOSA-M, d5-N-EtFOSAA-M, d3-N-MeFOSAA-M and MPFAC-C-ES). SUR stock standard solutions are stable for at least 12 months when stored at 2-6°C.

8.2.5 **SUR 50X Mix** - Dilute the stock standards with methanol/water in accordance with the table below:

SUR 50X Mix Preparation (Aqueous)				
Standard Name	**Conc. of Stock Std. (µg/mL)**	**Aliquoted Volume (µL)**	**Dilution Volume (mL)**	**Final Conc. (µg/mL)**
Sodium 1H, 1H, 2H, 2H-perfluoro-[1,2-$^{13}C_2$] hexane sulfonate (13C2-4:2FTS)	50	1000	10	5.0
Sodium 1H, 1H, 2H, 2H-perfluoro-[1,2-$^{13}C_2$] octane sulfonate (13C2-6:2FTS)	50	1000	10	5.0
Sodium 1H, 1H, 2H, 2H-perfluoro-[1,2-$^{13}C_2$] decane sulfonate (13C2-8:2FTS)	50	1000	10	5.0

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SUR 50X Mix Preparation (Aqueous) Cont'd				
Standard Name	**Conc. of Stock Std. (µg/mL)**	**Aliquoted Volume (µL)**	**Dilution Volume (mL)**	**Final Conc. (µg/mL)**
Perfluoro-1-[$^{13}C_8$] octanesulfonamide (13C8-PFOSA)	50	200	10	1.0
N-ethyl-d5-perfluoro-1-octanesulfonamide (d5-EtFOSA)	50	200	10	1.0
N-methyl-d3-perfluoro-1-octanesulfonamide (d3-MeFOSA)	50	200	10	1.0
N-ethyl-d5-perfluoro-1-octanesulfonamidoacetic acid (d5-EtFOSAA)	50	1000	10	5.0
N-methyl-d3-perfluoro-1-octanesulfonamidoacetic acid (d3-MeFOSAA)	50	1000	10	5.0
2,3,3,3-Tetrafluoro-2-(1,1,2,2,3,3,3-heptafluoropropoxy)-$^{13}C_3$-propanoic acid (13C3-GenX)	50	1000	10	5.0
2-(N-methyl-d3-perfluoro-1-octanesulfonamido) ethan-4-ol (d7-MeFOSE)	50	200	10	1.0
2-(N-ethyl-d5-perfluoro-1-octanesulfonamido) ethan-4-ol (d9-EtFOSE)	50	200	10	1.0
Perfluoro-n-[1,2-$^{13}C_2$] hexadecanoic acid (13C2-PFHxDA)	50	200	10	1.0

8.2.6 **20 ppb SUR Mix** - combine the SUR 50X mix and Wellington Labs standard part# MPFAC-C-ES and dilute with methanol/water in accordance with the table below:

20 ppb SUR Mix Preparation (Aqueous)				
Standard Name	**Conc. of Stock Std. (µg/mL)**	**Aliquoted Volume (µL)**	**Dilution Volume (mL)**	**Final Conc. (µg/mL)**
SUR 50X Mix	1	300	15	0.02
MPFAC-C-ES Stock	2	150	15	0.02

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8.2.7 **100 ppb SUR Mix** - Combine the SUR 50X mix and Wellington Labs standard part# MPFAC-C-ES and dilute with methanol/water in accordance with the table below:

100 ppb SUR Mix Preparation (Aqueous)				
Standard Name	**Conc. of Stock Std. (µg/mL)**	**Aliquoted Volume (µL)**	**Dilution Volume (mL)**	**Final Conc. (µg/mL)**
SUR 50X Mix	1	2200	22	0.10
MPFAC-C-ES Stock	2	1100	22	0.10

NOTE: The complete list of compounds included in the ID (Aqueous and Solid) 100 ppb and 20 ppb SUR Mixes are found under Table 5.

8.2.8 **Analyte Primary Dilution Standards (PDS)** – Analyte standards are purchased from Wellington Labs as ampoulized solutions. The PDS standards are stable for at least 12 months when stored at 2-6°C.

8.2.8.1 PFHxS, PFOS and other sulfonic acids are not available as the acid form, but rather as their corresponding salts, such as Na+ and K+. These salts are acceptable for use as stock standards as long as the weight is corrected for the salt content according to the equation below.

$$Mass_{acid} = Measured\ Mass_{salt} \times \frac{MW_{acid}}{MW_{salt}}$$

Where:
MW_{acid} = the molecular weight of PFAA
MW_{salt} = the molecular weight of purchased salt

8.2.9 **10X Stock Analyte PDS** – Contains all target analytes at 0.2 ug/mL, except GenX which is present at 0.4 ug/mL (GenX is present in PFAC-30PAR; additional spike of individual stock standard is added to give double concentration). Prepare as outlined below:

8.2.9.1 2 mL of the primary lot of PFAC-30PAR standard mix, 40 uL of MeFOSA, EtFOSA, 10:2 FTS, MeFOSE, EtFOSE, GenX, PFDOS, PFHxDA, and PFODA primary standards, are diluted to 10 mL with methanol and reagent water, for a final composition of 96%MeOH.

8.2.10 **100X Analyte PDS** - Contains all target analytes at 20 ng/mL, except GenX which is present at 40 ng/mL. Prepare as outlined below:

8.2.10.1 1 mL of Stock (10X) Analyte PDS is diluted to 10 mL with 9 mL of 96% MeOH

8.2.11 **1000X Analyte PDS** - Contains all target analytes at 2.0 ng/mL, except GenX which is present at at 4.0 ng/mL. Prepare as outlined below:

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8.2.11.1 1 mL of 100X Analyte PDS is diluted to 10 mL with 9 mL of 96% MeOH

8.2.12 **Initial Calibration Standards (ICAL)** – According to the table below, prepare calibration standards at the following nominal concentrations in pg/mL (ng/L): 50, 100, 200, 500, 1000, 2000, 5000, 10000, 15000 and 20000, except for GenX which will be at double these concentrations. The ICAL standards are stable for at least three months when stored at room temperature, or 12 months when stored at 2-6°C. The final composition of the above solutions contains 96:4% (vol/vol) methanol: water. See Table 5 for a list of analytes and exact concentrations.

ICAL Preparation (Aqueous)									
ICAL Level	**PFAS Conc. (pg/mL)**	**SUR Conc. (pg/mL)**	**IS Conc. (pg/mL)**	**PFAS PDS 10X (mL)**	**PFAS PDS 100X (mL)**	**PFAS PDS 1000X (mL)**	**20 ppb SUR (mL)**	**20 ppb IS (mL)**	**Final Volume (mL)**
1	50	1000	1000	-	-	0.125	0.25	0.25	5
2	100	1000	1000	-	-	0.250	0.25	0.25	5
3	200	1000	1000	-	-	0.500	0.25	0.25	5
4	500	1000	1000	-	0.125	-	0.25	0.25	5
5	1000	1000	1000	-	0.250	-	0.25	0.25	5
6	2000	1000	1000	-	0.500	-	0.25	0.25	5
7	5000	1000	1000	0.125	-	-	0.25	0.25	5
8	10000	1000	1000	0.25	-	-	0.25	0.25	5
9	15000	1000	1000	0.375	-	-	0.25	0.25	5
10	20000	1000	1000	0.50	-	-	0.25	0.25	5

NOTE: ICAL preparation procedures are subject to change without notice

8.2.13 **10X ICV PDS mix** – Second source standard containing required target analytes at 0.2 ug/mL or 200ppb, except those compounds not contained in the PFAC-24PAR stock mix, which are present at a nominal concentration of 1.0 ug/mL or 1000ppb. Prepare as outlined below:

8.2.14.1 Dilute PFAC-24PAR standard mix (secondary source/preparation) and 40uL each of GenX, ADONA, 9Cl-PF3ONS, 11Cl-PF3OUDS, and 10:2 FTS secondary standards are diluted to 2mL with methanol and water, for a final solvent composition of 96:4% MeOH:water. The PFAC-24PAR standard includes all analytes listed in Table 5 except the following: GenX, ADONA, 9Cl-PF3ONS, 11Cl-PF3OUDS, 10:2 FTS, MeFOSA, EtFOSA, MeFOSE, EtFOSE, PFDOS, PFHxDA, and PFODA.

8.2.14 **100X ICV Mix** - Second source standard containing required target analytes at 0.02 ug/mL or 20ppb. Prepare as outlined below:

8.2.14.1 Dilute 0.5 mL of the 10X ICV PDS mix to 5mL using 96:4% MeOH:water.

8.2.15 **ICV Sample Solution (500ppt)** – Prepare according to the table below. The final solvent composition of this solution should be 96:4% MeOH: water. Note: secondary standards for the following compounds are not included in the ICV sample: MeFOSA, EtFOSA, MeFOSE, EtFOSE, PFDOS, PFHxDA, PFODA

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ICV Preparation (Aqueous)				
Standard Name	**Conc. of Stock Std. (pg/mL)**	**Aliquoted Volume (µL)**	**Dilution Volume (mL)**	**Final Conc. (pg/mL)**
PFAS ICV 100X Mix	20000	25	1.0	500
Full List SUR mix, 20ppb	20000	50	1.0	1000
Full List IS mix, 20ppb	20000	50	1.0	1000

8.2.16 **Isomer check** – For target compounds which have multiple chromatographic peaks due to branched and linear isomers, but for which quantitative standards are not available, a qualitative check is analyzed with each calibration event to demonstrate the peak shape and retention time of the branched isomers. See sections 10.6, 10.7 for integration information.

8.2.16.1 **Isomer Check 50X Mix** – 20 µL each of TPFOA, br-MeFOSAA, and br-EtFOSAA standards (Wellington Laboratories item #s T-PFOA, br-MeFOSAA, and br-EtFOSAA) are diluted to 1 mL with 900 µL of MeOH and 40 µL of reagent water. Final solvent composition is 96:4% MeOH:water. This solution is used to create the actual isomer check standard to be analyzed with each ICAL. Note: branched/linear isomer mixes of MeFOSAA and EtFOSAA are now present in the analyte PDS solutions, so these compounds will be calibrated with branched and linear isomers summed, but will also continue to be present in the Isomer Check mix.

8.2.16.2 **Isomer Check Standard** - 10 µL of the Isomer Check 50X Mix plus 50 µL each of the 20 ppb IS and 20 ppb SUR are diluted to 1 mL with 890 µL of 96% MeOH. The concentrations of the isomer components should be approximately 10000 ppt. Final solvent composition is 96:4% MeOH:water. This sample will be analyzed with each calibration event to demonstrate peak shape and retention time of the additional branched isomers of the included compounds.

8.2.16.3 As more qualitative standards containing mixes of branched and linear isomers become commercially available, the lab will add those newly available compounds/standards to the isomer check mix and analyze them in the manner described in Sec. 8.2.16.

8.3 Instrument Blank (IBLK) – The instrument blank is prepared by spiking 180 µL 96% MeOH with 10 µL of 20 ppb IS Mix and 10 µL of 20 ppb SUR Mix in an autosampler vial. Cap and vortex to mix. Alternatively, spike 864 µL of MeOH and 36 µL of Water with 50 µL of IS 20ppb mix and 50 µL of SUR 20ppb; cap and vortex to mix, then aliquot into auto-sampler vial.

8.4 Method Blank (MB) – Spike 250 mL reagent water with 110 µL of the 100ppb SUR Mix. Mix well, extract as normal alongside client samples.

9.0 Procedure

9.1. Equipment Preparation

9.1.1 Support Equipment

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9.1.1.1 Refrigerator units are maintained and verified as required by the Quality Assurance Management Plan [QAMP ME0012K].

9.1.1.2 The balance is verified at the beginning of each analytical day using a certified weight set. Refer to the Equipment and Instrumentation SOP [QA SOP ME002JT] for balance verification procedures and acceptance criteria.

9.1.1.3 Bottletop dispensers, pipettes, and thermometers are maintained and verified as required by the Equipment and Instrumentation SOP [QA SOP ME002JT].

9.1.2 Instrument

9.1.2.1 Chromatographic Conditions

Step	Total Time (min)	Flow Rate (uL/min)	A: 20mM Ammonium Acetate (%)	B: Methanol (%)
0	0.00	1200	95.0	5.0
1	0.10	1200	45.0	55.0
2	4.50	1200	1.0	99.0
3	6.00	1200	1.0	99.0
4	6.10	1200	95.0	5.0
5	8.10	1200	95.0	5.0

9.1.2.2 Mass Spectrometric Conditions

Parameter	Setting or Value
Syringe Size	100 µL
Injection Volume	10 µL
Draw Speed	50.0 µL/min
Eject Speed	50.0 µL/min
Needle Level	3.0 mm
Column Oven Temperature	40°C
MRM Scan Window	60 sec
Curtain Gas (CUR)	30.0
Collision Gas (CAD)	9
Ion Spray Voltage (IS)	-4500.0 V
Temperature (TEM)	450.0°C
Ion Source Gas 1 (GS1)	40.0
Ion Source Gas 2 (GS2)	60.0

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9.2. Initial Calibration

9.2.1 Mass Calibration – calibrate the mass scale of the MS with the calibration compounds and procedures prescribed by the manufacturer. Mass calibration/mass tune will be performed any time major maintenance is performed on the MS, or following any catastrophic instrument failure (power loss, etc.)

9.2.2 Mass Calibration verification – a mass calibration verification will be analyzed following mass calibration/mass tune, prior to each ICAL. A prepared standard containing PFAS targets will be injected using the normal LC parameters for analysis but set up to perform a product ion (MS2) scan for the quantitation product ions of PFOA (m/z 369) and PFOS (m/z 80). If these target product ions are detected at the expected RT, the mass calibration has been verified. A chromatogram image will be included in each data package as documented verification of appropriate mass calibration.

9.2.3 Prepare a set of at least five ICAL standards (six ICAL standards for quadratic regressions) as described in Section 8. The lowest concentration ICAL standard must be at or below the LOQ, which may depend on system sensitivity. It is recommended that at least four of the ICAL standards are at a concentration greater than or equal to the LOQ.

9.2.4 The LC/MS/MS system is calibrated using the IS technique. A calibration curve for each of the analytes is generated by average response factor (AVG RF), linear regression, or quadratic regression. Linear regression curves may be concentration weighted, if necessary. Linear or quadratic calibration regressions are not expected to be set through zero.

9.2.4.1 The linear regression curve is expressed as below:

$y = ax + b$

Where a is the slope and b is the y-intercept. When forced through 0, b=0.

$y = AS/ASUR$ $x = CS/CSUR$

AS is peak response of target analyte in calibration standards
ASUR is peak response of surrogate standard (SUR) in calibration standards
CS is concentration of target analyte in calibration standards
CSUR is concentration of surrogate standard (SUR) in calibration standards

9.2.5 Calibration Sequence

9.2.5.1 Calibration standards must be analyzed in sequence from lowest to highest concentration to minimize the chance that carryover from a higher concentration standard will boost the area of a lower concentration standard.

9.2.6 ICAL Evaluation

9.2.6.1 Acceptance Criteria – When quantitated using the ICAL curve, each calibration level for each analyte must calculate to be within 70-130% of its true value (±30% RE). For calibration curves produced using average response factors, the percent relative standard deviation

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(%RSD) of the RFs for all analytes must be <20%. Linear or non-linear regressions must have r2 ≥0.99 (r ≥ 0.995) for each analyte. Weighting (typically 1/x or 1/x2) is allowed for linear and non-linear regressions. If these criteria cannot be met, the analyst will have difficulty meeting ongoing QC criteria. It is recommended that corrective action is taken to reanalyze the ICAL standards, restrict the range of calibration, or select an alternate method of calibration.

9.2.6.1.1 Calibration Point Dropping – If more than the minimum number of standards are analyzed and levels are excluded from the calibration, only the lowest or highest standards may be excluded, except as noted here. The removal of calibration levels from the interior of the curve is allowed only when there is sound technical reason for doing so and when the level is removed for all analytes; for example, when it can be proven that the wrong standard was analyzed for the calibration level or there is obvious evidence that the instrument malfunctioned during injection of the standard. **The removal of any calibration level from the interior of the curve must be approved by the department supervisor/manager. Management approval and the rationale for the level removal must be documented and kept with the technical record.**

9.2.6.1.2 Calibration Point Replacement – replacing a calibration standard may sometimes be needed to correct for a technical problem that occurred during analysis such as power failure, incomplete injection of the standard or similar situation. Replacement of one standard, when analyzed within 24 hours of original analysis time and replacing all analytes in the original standard, is permitted. **The replacement of the standard must be approved by the department supervisor/manager; approval and the reason for replacement must be documented and kept with the technical record.**

9.2.6.1.3 For Wisconsin compliance analysis, requantitated concentrations for all target compounds at all concentration levels must be within the range 70-130% of their actual concentrations, except for the lowest calibration concentration level, which must be within the range of 50-150% of actual concentrations.

9.2.6.1.4 Calibration results for labeled Surrogate and Internal Standard compounds will be evaluated by comparing the area response of each level to the ICAL midpoint level (L5 – 1000ppt). Any ICAL points for which SUR or IS responses fall outside of 50-200% of the midpoint ICAL shall be removed. If any more than two ICAL points fail these criteria, the system should be inspected, and maintenance should be performed if needed. A new ICAL will then be analyzed following any maintenance.

NOTE: When acquiring MS/MS data, LC operating conditions must be carefully reproduced for each analysis to provide reproducible retention times. If this is not done, the correct ions will not be monitored at the appropriate times. As a precautionary measure, the chromatographic peaks in each window must not elute too close to the edge of the segment time window.

9.2.7 Calibration Locking – After all ICAL and ICV acceptance criteria are met, the calibration is considered “locked” and no further changes may be made until the next calibration event. In the AIM2 data processing software, the primary review (L1) analyst will set the “Sample State” for all files of the calibration event to “Locked” state. When files are in “Locked” state, no permanent changes can be made to the samples. The calibration design or fit must never be changed during

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routine data processing of any analytical sequence associated with the calibration; the only exception is when a problem with the original calibration curve is found. In that case, the problem must be handled as a quality incident. If the investigation of the incident indicates that the calibration is invalid, then all data associated with the calibration must be reprocessed under the corrected calibration.

9.2.8 Relative Error

9.2.8.1 Each calibration level for each analyte must calculate to be within 70-130% of its true value (±30% RE)

9.2.9 Initial Calibration Verification (ICV)

9.2.9.1 As part of the IDOC, each time a new Analyte PDS is prepared, and once after each ICAL, analyze an ICV sample from a second source (different from the source of the ICAL standards). If a second vendor is not available, then a different lot of the standard should be used. The ICV should be prepared and analyzed just like a CCV. Acceptance criteria for the ICV are identical to the CCVs; the calculated amount for each analyte must be ± 30% of the expected value. If measured analyte concentrations are not of acceptable accuracy, correct the problem and rerun the ICV. If the problem persists, repeat the ICAL. Samples are not to be analyzed until the ICAL has been verified by acceptable ICV accuracy. The lab will add additional target analytes to the ICV mix as second source standards become commercially available.

9.2.10 Continuing Calibration Verification/Instrument Sensitivity Check (CCV/ISC)

9.2.10.1 CCV Standards are analyzed at the beginning of each analysis batch, after every 10 samples, and at the end of the analysis batch. In this context, a “sample” is considered to be a field sample. MBs, CCVs, LCSs, MSs, FDs, TBs and MSDs are not counted as samples. In the event that 10 field samples and various non-field sample QC (BLKs, MBs, CCVs, LCSs, MSs, FDs, TBs and MSDs) are injected between a set of CCVs, the maximum injections between CCVs is limited to 20. Inject an aliquot of the appropriate concentration ICAL standard and analyze with the same conditions used during the initial calibration.

9.2.10.1.1 The daily Instrument Sensitivity Check (ISC; DOD required) will be used as the daily opening CCV and will be analyzed at a concentration at or below the LoQ using prepared ICAL standards.

9.2.10.1.2 The prepared mid-level ICAL solution will be analyzed for subsequent bracketing and closing CCVs.

9.2.10.1.3 Calculate the concentration of each analyte and surrogate in the CCV. The calculated amount for each analyte must be within ± 30% of the true value. The area response for each surrogate compound must be within ±50% of the area of the corresponding compound in the ICAL midpoint, or the ISC on days in which an ICAL is not analyzed. If these conditions do not exist, then all data for the problem analyte must be considered invalid, and remedial action should be taken which may require recalibration. Any field or QC samples that have been analyzed since the last acceptable calibration verification should be reanalyzed after adequate calibration has been restored, with the following

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exception: if the CCV fails because the calculated concentration is greater than 130% for a particular method analyte, and the associated field sample extracts show no detection for that method analyte, non-detects may be reported without re-analysis.

9.2.10.1.3.1 For Wisconsin and other non-DoD compliance samples, the calculated amount for each analyte must be within ± 30% of the true value except for the ISC, for which the calculated amount for each analyte must be within ± 50% of the true value.

9.2.10.1.4 Remedial Action – Failure to meet CCV QC performance criteria may require remedial action. Major maintenance, such as cleaning the electrospray probe, cleaning the mass analyzer, replacing the LC column, etc., requires recalibration and verification of sensitivity by analyzing a CCV at or below the LOQ.

9.2.10.1.4.1 Remedial Actions taken to correct for ICAL, ICV, and CCV acceptance criteria exceptions must be documented and must be traceable to the ICAL/ICV/CCV for which the corrective action was performed. The instrument maintenance log entry for the remedial action must include some reference to the failing result (batch, ID, file number, etc) for which the remedial action is being taken.

9.2.10.1.5 If reanalysis cannot be performed, the data must be qualified. An NCM must be generated which describes the reason that reanalysis is not being performed.

9.3. Sample Preparation (Aqueous)

Some of the PFAS adsorb to surfaces, including polypropylene and HDPE. Therefore, aqueous sample containers must be rinsed with the elution solvent. The container rinse is passed through the cartridge to elute the method analytes and is then collected.

NOTE: The SPE cartridges, reservoirs, and sample containers described in this section are designed as single use items and should be discarded after use. They may not be refurbished for reuse in subsequent analyses.

9.3.1 Weigh the full sample container. Initial volume for samples requiring centrifugation (see below) should be recorded after the centrifugation procedure has been completed.

9.3.2 Inspect samples; determine if sample centrifugation is warranted for each sample. Samples containing settled or suspended solids may require centrifugation in order to be fully loaded through the SPE sorbent; see Appendix D for more guidance in the Aqueous Sample Centrifugation Protocol. If centrifugation is warranted, follow the PFAS centrifuge procedure in Appendix D of this SOP.

9.3.2.1 Leachate samples and most samples from landfill-impacted sites will be prepared at an up-front (pre-extraction) dilution of 10X (25mL aliquot of sample into final volume of 250mL, using verified pipette).

9.3.3 Spike the sample containers with 110 µL of the 100 ppb SUR Mix. Invert the sample to mix.

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9.3.4 Spike the LCS/LCSD, MS, and either FD or MSD appropriately according to the corresponding section under Reagents and Standards

9.3.5 Clean SPE adapter caps by thoroughly rinsing with MeOH and allow to dry before using them to connect the cartridges/reservoirs.

9.3.6 Attach the SPE extraction cartridges (Strata-XL-AW) to the converter caps and the reservoirs. Place the cartridge setups in the active SPE manifold ports.

9.3.7 Wet the rim of the manifold body with DI water to form a proper seal with the manifold top.

9.3.8 Place the top on the SPE manifold, start the vacuum pump, and ensure the vacuum is approximately 5-10in. Hg.

9.3.9 Condition each SPE cartridge in individual steps with the following solvents. Solvent volumes used for conditioning step 1 should be used to rinse down the inside of the SPE reservoirs, to remove any potential contamination from the inside of the reservoirs. After adding the conditioning solvent to the reservoir/cartridge setup for each conditioning step, the analyst should allow the conditioning solvent to soak the SPE sorbent for 2 minutes before passing the solvent through the SPE sorbent in a dropwise fashion **(do not allow to go dry during conditioning).**

9.3.9.1 Conditioning step 1 - 4mL Ammonia-MeOH (0.6%) + 4mL MeOH

9.3.9.2 Conditioning step 2 - 4mL Ammonium acetate/acetic acid buffer

If the SPE cartridge goes dry during any step of the conditioning process, restart conditioning with first step (Amm-MeOH+MeOH).

9.3.10 Add the entire water sample to the SPE tube/reservoir **(do not allow to go dry during sample loading).**

9.3.10.1 Samples containing settled or suspended solids may require centrifugation in order to be fully loaded through the SPE sorbent; see Appendix D for the Aqueous Sample Centrifugation Protocol.

9.3.11 Adjust the pressure/SPE stopcocks to load the sample at ~10-15mL/min; this rate equates to loading time of 17-25 mins for a 250mL sample

9.3.12 Once the entire sample has passed through the SPE cartridge, wash the cartridge by passing 4 mL of the Ammonium Acetate/Acetic Acid buffer through the sorbent at a rate similar to the sample loading rate in 11.2.10

9.3.13 Use the vacuum to dry cartridges under high vacuum (≤20in. Hg) for ~5mins.

9.3.14 Release the vacuum, remove the top from the SPE manifold and wet the rim of the manifold. Place the rack with the eluent collection tubes in the manifold and replace the top, ensuring that the active SPE ports are set in the corresponding collection tubes and a proper seal is formed. Turn the pump back on and ensure the pressure is approximately 5-10in. Hg.

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9.3.15 Add 4mL MeOH to each empty sample container, then cap and shake each bottle to ensure all interior surfaces get rinsed. Transfer rinsate to the SPE, using a pipette to swirl MeOH along the insides of the reservoir to rinse.

9.3.16 Rinse each empty sample container a second time with 4mL Ammonia-MeOH (0.6 %). Transfer to the SPE, using a pipette to swirl the Ammonia-MeOH solution along the inside of the reservoir to rinse.

9.3.17 Allow the eluent to soak the sorbent bed for 2 minutes before elution, as in section 9.3.9. Collect the total eluent in the previously positioned collection tubes. Adjust the pressure/SPE stopcock to elute in a ***slow*** dropwise fashion.

9.3.18 Release the vacuum and remove the collection tube rack.

9.3.19 Replace the extraction cartridge setups (Strata-XL-AW and reservoirs) with stacked PFAS(WAX/GCB) tubes; place the manifold top on the manifold body and resume the vacuum, ensuring a proper seal and pressure.

9.3.20 Condition the WAX/GCB tubes with 3 mL MeOH, but do not dry the tubes fully. Allow the rinse solvent to soak the sorbent bed for 2 mins before passing the solvent, as in section 9.3.9. **If the SPE cartridge goes dry during the conditioning process, restart conditioning.**

9.3.21 Release the vacuum, remove the top, and place the collection rack with clean, empty collection tubes in the manifold body, ensuring the proper alignment of the SPE ports with collection tubes. Resume the vacuum, ensuring a proper seal and pressure. Filter the extract through the WAX/GCB tubes under vacuum and collect the filtrate.

9.3.22 Rinse the WAX/GCB tubes with 2mL of fresh MeOH, allowing the sorbent to soak in the elution solvent for 2 mins as in section 9.3.9, and collect the rinsate in a slow dropwise fashion.

9.3.23 Weigh the empty container and document the weight.

9.3.24 The difference between the weights from sections 9.3.1 and 9.3.23 is the sample volume (assuming 1g/mL density). Sample volumes will be rounded to the nearest 1.0 mL for use in calculations.

9.3.25 In a polypropylene autosampler vial, combine 8 µL water, 10 µL (20ppb) IS mix, and 182 µL of sample extract. Cap and vortex thoroughly to mix. This aliquot is ready for analysis.

9.3.26 Transfer the remaining extracts to 8 mL HDPE containers for storage at room temperature.

NOTE: For Wisconsin compliance samples, sample extracts must be stored at 0-6°C

9.3.27 Manifold cleanup – use the methanol squirt bottle to thoroughly rinse all stopcocks on the vacuum manifold top. The stopcocks should be rotated while methanol is squirted into/through the stopcocks so that the entire body of the stopcock housing and rotor are cleaned well. The rotor should be rotated **several times in both directions** to ensure the stopcock is thoroughly decontaminated. If samples with high levels of contamination are processed, or if there is a concern that carryover contamination could impact samples yet to be prepared, Isopropyl Alcohol may be used to clean the manifold and stopcocks before cleaning twice with MeOH.

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9.3.28 For samples that show analyte detections above the range of the ICAL, sample dilutions will need to be prepared. See Appendix E for dilution preparation scheme.

9.3.28.1 Samples requiring diluted analyses post-extraction will be refortified with EIS to enable proper quantitation. Samples diluted in this manner are no longer technically quantitated using isotope dilution quantitation

9.4. Analysis

9.4.1 Column Flush – Each day of analysis, the column must be thoroughly flushed with 100% MeOH for at least 60 minutes to clear any accumulated impurities and interferents from the sample pathway and equilibrate the system. It is also good practice to open the purge valve on the pumps for the first ~1min of flush time. The column should then be equilibrated to the analysis starting conditions by flushing for 30 mins with 50:50 Ammonium Acetate: MeOH and finally 30 mins with 95:5 Ammonium acetate: MeOH. Ensure that pressure is stable.

9.4.2 Analytical Sequence – Following the daily column flush, three (3) high ICAL standard (L9 or L10) injections and one blank injection will be made in order to prime the system before analyzing opening QC and client samples. Following these opening injections, Instrument Sensitivity Check (ISC) samples will be analyzed as the opening CCV (section 9.2.10). When a passing ISC sample has been evaluated, an instrument blank will be analyzed to demonstrate the absence of system contamination. After system contamination is determined to be acceptable (no target analyte concentrations >1/2 LOQ), samples may be analyzed. After every tenth field sample analyzed in a sequence, a CCV will be analyzed (section 9.2.10), as well as at the end of the sequence. Each bracketing CCV should be followed by a CCB/IBLK sample injection. If system contamination is detected (any target analyte concentration >1/2 LOQ) in a CCB/IBLK following a bracketing CCV, and a Wisconsin compliance sample in the associated analysis window (prior to next CCV) shows a concurrent target analyte detection, that sample will be reanalyzed with an acceptable CCB. If the sample cannot be reanalyzed for some reason, the data for the CCB-detected compound(s) in the affected sample will be qualified with an NCM.

10.0 Data Analysis And Calculations

10.1 Qualitative Identification

10.1.1 Manual Integration

10.1.2.1 Manual changes to automated integration is called manual integration. Manual integration is sometimes necessary to correct inaccurate automated integrations but must never be used to meet QC criteria or to substitute for proper instrument maintenance and/or method set-up. To assure that all manual integrations are performed consistently and are ethically justified, all manual integrations must be performed, reviewed, and recorded in accordance with corporate SOP ENV-SOP-CORQ-0006, Manual Integration.

10.2 Calculations

See the Laboratory Quality Assurance Manual [QAMP ME0012K] for equations for common calculations.

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NOTE: The surrogate standard/Extracted Internal Standard (SUR/EIS) is used for quantitation in the PFAS ID methods.

10.3.1 Complete chromatographic resolution is not necessary for accurate and precise measurements of analyte concentrations using MS/MS. Concentrations are calculated by measuring the product ions (Q3 Mass) listed in Table 4. Other ions may be selected at the discretion of the analyst.

10.3.2 Calculate analyte and surrogate concentrations using the multipoint calibration established in Section 9.2. Do not use daily calibration verification data to quantitate analytes in samples. Final analyte concentrations are adjusted to reflect the actual sample volume determined in Section 9.

Sample concentration for aqueous samples:

$$\text{Concentration (ng/L)} = (\text{Cs})(\text{DF})$$

Where:

DF = dilution factor

Cs – see below

From the equation in section 10.3.2, Cs is calculated as follows:

$$\text{Cs} = \left(\frac{As}{Asur} - b\right) \cdot \left(\frac{Csur}{a}\right)$$

Where:

As is peak response of target analyte in the sample

Asur is peak response of internal standard in the sample (SUR for isotope dilution methods)

Cs is concentration of target analyte in the sample

Csur is concentration of internal standard in the sample (SUR for isotope dilution methods)

a is the slope from the ICAL linear regression

b is the y-intercept from the ICAL linear regression

10.3.3 Results for target analytes must be quantified from the most recent ICAL analyzed on the same instrument. During both primary (L1) and secondary (L2) review, analysts must review the ICAL Form 6 RF report (ICAL summary) to ensure that the most recent ICAL analyzed on the same instrument was utilized for the quantitation of all samples.

10.3 Prior to reporting the data, the chromatogram must be reviewed by a trained analyst for any incorrect peak identification or poor integration.

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10.4 Dilution - When the concentrations of target analytes on-column exceed the highest concentration of initial calibration standard, dilution analyses are required. An appropriate dilution should be in the upper half of the calibration range, or close to the CCV. The diluted extract must maintain the same methanol/water ratio as the original extract. If a dilution of the extract is required, fortification of the SUR/EIS in the diluted extract is necessary. Samples requiring diluted analyses post-extraction will be refortified with SUR/EIS to enable proper quantitation. Samples diluted in this manner are no longer technically quantitated using isotope dilution quantitation. Refer to Appendix E for dilution preparation information.

10.5 PFHxS, PFOS, MeFOSAA and EtFOSAA have multiple chromatographic peaks using the LC conditions in Table 4 due to the linear and branched isomers of these compounds. The areas of all the linear and branched isomer peaks observed in the ICAL standards for each of these analytes must be integrated together and summed. The concentrations are reported as a total for each of these analytes. Purchased standards contain both linear and branched isomers; therefore, individual ICALs for the linear and branched isomers will not be possible. PFOA also has multiple chromatographic peaks using the LC conditions in Table 4 due to linear and branched isomers of this compound. However, a quantitative standard containing both linear and branched isomers is not currently available, so ICAL standards will not show multiple peaks for PFOA. A technical (qualitative) standard is analyzed with each calibration event to identify where the branched isomer peak elutes, relative to the linear isomer peak. In client samples, the areas of the linear and branched isomer peaks observed must be integrated together and summed. The concentration of PFOA in client samples will be reported as a sum total of branched and linear isomers. As more standards (quantitative or qualitative) containing both branched and linear isomers for other target analytes become available, these will be used in the same way as for PFHxS/PFOS/MeFOSAA/EtFOSAA or PFOA. Following the same procedure, any target analyte for which a standard has been purchased and analyzed will be integrated and reported as a sum total of branched and linear isomers.

10.6.1 MeFOSAA and EtFOSAA standards containing branched and linear isomers are also present in the Isomer Check solutions.

10.6 Integration - Sample integration is performed automatically by quantitation software and reviewed by the analyst for any incorrect analyte identification or poor integration. A peak is considered a positive detection if the primary (quantitation) ion transition peak shows a signal-to-noise ratio (S/N) of at least 10.0:1 and is defined by at least 10 MS scans (data points) across the baseline of the peak. For analytes with a secondary (confirmation) ion transition, the primary and secondary ion transitions must elute at nominally the same retention time (±2 seconds). Further, the secondary transition must show S/N of at least 3.0:1.

10.7.1 For Wisconsin compliance analysis, quantitation ion transition peaks are considered positive detections if the S/N is at least 3.0:1

10.7.2 Retention Time (RT) acceptance – RT of each analyte, SUR, and IS must fall within 0.4 minutes (±0.2 mins) of the corresponding RTs from the ICAL midpoint, or the daily ISC on days when ICAL is not performed. Analytes with matched (labeled analogue) SUR compounds must elute within 0.1 mins of the associated SUR.

10.7 Calculations must utilize all available digits of precision, but final reported concentrations should be rounded to an appropriate number of significant figures (one digit of uncertainty), typically two, and not more than three significant figures.

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10.8 Calculate the % recovery for the LCS using the following equation:

$$\%\ \text{Recovery} = \frac{\text{Concentration (or amount)found}}{\text{Concentration (or amount) spiked}} \times 100$$

10.9 Calculate the MS % recovery for each analyte using the equation:

$$\%\ \text{Recovery} = \frac{\text{Xs} - \text{X}}{\text{t}} \times 100$$

Where:
Xs = measured concentration in the spiked sample
X = measured concentration in the unspiked sample
t = spike concentration

10.10 Calculate the relative percent difference (RPD) for duplicate measurements (FD1 and FD2 or MS and MSD) using the equation:

$$\text{RPD} = \frac{|\text{X2} - \text{X1}|}{\frac{\text{X2} + \text{X1}}{2}} \times 100$$

Where:
X1 = FD1 or MS result
X2 = FD2 or MSD result

10.11 Calculate the percent relative standard deviation (%RSD) for calibration curves produced using average response factor using the equation:

$$\%\ \text{RSD} = \frac{\text{SD}}{\text{AVG}} \times 100$$

Where:
SD = the standard deviation of the curve
AVG = the average response factor for the curve (y = AVG*x)

11.0 Quality Control and Method Performance

11.1 Quality Control

The following QC samples are prepared and analyzed with each batch of samples. Refer to Appendix B for acceptance criteria and required corrective action.

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QC Item	Frequency
Method Blank (MB)	1 per batch
Laboratory Control Sample (LCS)	1 per batch
Laboratory Control Sample Duplicate (LCSD)	As needed
Matrix Spike (MS)	1 per batch
Matrix Spike Duplicate (MSD)	1 per batch or as needed
Sample Duplicate	1 per batch or as needed

11.2 Instrument QC

The following Instrument QC checks are performed.

QC Item	Frequency
Initial Calibration (ICAL)	Following major instrument maintenance, when new ICAL standards are prepared, and as needed to account for instrumental drift
Instrument Blank (IBLK)	After calibration, daily prior to sample analysis, after each CCV
Initial Calibration Verification (ICV)	After calibration.
Continuing Calibration Verification (CCV)	At the beginning of each batch, after every 10 samples, and at end of each batch
Instrument Sensitivity Check (ISC)	Daily opening CCV(s)

11.3 Instrument Blank (IBLK) – One instrument blank (IBLK) is analyzed immediately following the highest ICAL standard analyzed, on a daily basis prior to sample analysis, and following each bracketing CCV in a sequence, to check for carryover and instrument contamination. The concentration of each analyte must be ≤ 1/2 the LOQ. If the instrument blank does not pass this requirement after the highest ICAL standard, the calibration must be performed using a lower concentration for the highest standard until the acceptance criteria is met.

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11.3.1 If any target analyte is detected in both a Wisconsin compliance sample and the IBLK/CCB immediately preceding (following bracketing CCV), an NCM will be generated to document the potential bias.

11.4 Method Blank (MB) – One method blank (MB) must be processed with each extraction batch. If more than 20 samples are included in a batch, analyze an MB for every 20 samples. The MB is to contain all reagents specific to the method that is carried through the entire analytical procedure, including preparation and analysis.

11.4.1 The MB must not contain any analyte of interest at or above 1/2 of the LOQ or project specific-requirements. (Note: see appendices for state or program specific requirements). If the MB contains an analyte of interest at or above 1/2 of the LOQ, then the MB and associated samples must be reanalyzed. If the MB contamination is confirmed, the entire batch must be re-prepared and reanalyzed. Reanalysis or re-extraction is not required if the samples are not impacted. Samples are not impacted when:

11.4.1.1 The MB detection is not present in the sample.

11.4.1.2 The sample concentration is ≥10x the concentration of the detection in the MB.

11.4.2 The MB must have acceptable surrogate recoveries. If surrogate recoveries are not acceptable, sample analysis should stop immediately. Corrective action should be taken. The MB should be reanalyzed if the analyst feels that the failure could be attributed to instrument problems. If the analyst feels that the failure is due to a poor extraction, the entire batch associated with the MB must be re-extracted.

11.5 Laboratory Control Sample (LCS) – An LCS is required with each extraction batch. The spiked concentration of the LCS will be at a low concentration of the calibration curve. See DoD acceptance criteria for LCS targets in Table 6. If the LCS results do not meet the criteria listed in Table 6 for method analytes, then all data for the problem analyte(s) must be considered invalid for all samples in the extraction batch. For target analytes not included in the DoD Limits for batch control table (Appendix C of QSM 5.3), in-house limits of 70-150% recovery will be used as acceptance criteria.

11.5.1 The LCS for ID-AQ is prepared by spiking 250 mL of reagent water with 200 µL of the 100X PDS mix (20 ppb) for a concentration of 16 ppt (GenX at 32 ppt). The LCS is also spiked with 110 µL of Full List 100 ppb SUR mix and extracted as normal alongside client samples.

11.5.2 For Wisconsin compliance and other non-DoD compliance samples, acceptance limits will be 50-150% recovery for all target compounds.

11.6 Instrument Standards (IS) – The analyst will monitor the peak areas of the IS in all injections during each analysis day. The IS responses (peak areas) in any chromatographic run should not deviate by more than 50% from the area measured during initial analyte calibration or the daily CCV. If the IS areas in a chromatographic run do not meet these criteria, consider injecting a second preparation of that extract prepared in a new capped autosampler vial. Loss due to evaporation has been observed when using polypropylene caps which can cause high IS response. Deviations in IS responses may alternately indicate instrumental issues (i.e. poor injection, occluded needle, etc.). Deviations of IS response from acceptance criteria will not necessarily be cause to reject sample data.

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11.6.1 If the reinjected aliquot produces an acceptable IS response, report the results for that aliquot.

11.6.2 If the reinjected extract fails again, the analyst should check the calibration by reanalyzing the most recently acceptable ICAL standard. If the ICAL standard fails the criteria of Section 9.2.6, maintenance and/or recalibration is needed.

11.7 Surrogates (SUR/EIS/IDS) – The surrogate standard (SUR, also referred to as extracted internal standard [EIS] or isotope dilution standard [IDS]) is fortified into all samples, MBs, LCSs, MSs, MSDs prior to extraction. It is also included in the ICAL standards.

11.7.1 The analyst must monitor the peak areas of the SUR in all injections during each analysis day. The SUR responses (peak areas) in any chromatographic run must not deviate by more than 50% from the area measured in the ICAL midpoint (L5) standard during initial calibration or in the daily opening CCV. When the SUR/EIS/IDS recovery from a sample, blank, or CCV is not within this range check the following: calculations to locate possible errors, standard solutions for degradation or contamination, and instrument performance. Correct the problem and inject a second preparation of that sample extract (or blank or CCV) prepared in a new capped autosampler vial. Loss due to evaporation has been observed when using polypropylene caps which can cause high SUR response.

11.7.2 For Wisconsin and other non-DoD compliance analysis, all SUR/EIS/IDS compounds must recover within the range 25-150% in extracted samples, except 13C8-PFOSA, d3-MeFOSA, d5-EtFOSA, d7-MeFOSE, and d9-EtFOSE, which must recover within the range 10-150% in extracted samples. Recovery will be based on area counts as described above. For all instrument QC (CCV, ICV, ICB, CCB, IBLK) used for Wisconsin compliance, SUR/EIS/IDS compounds must recover within the range 50-150% in each injection.

11.7.3 If extract reanalysis meets the surrogate recovery acceptance criteria, report only the data for the reanalyzed extract.

11.7.4 If the extract reanalysis fails the 50-150% acceptance criteria (or 10/25-150% for non-DoD compliance), the analyst should check the calibration by injecting the last ICAL standard that passed. If the ICAL standard fails the criteria of Section 9.2.6, maintenance and/or recalibration is in order. If the ICAL standard is acceptable, extraction of the sample should be repeated provided the sample is still within the holding time. If the re-extracted sample also fails the recovery acceptance criteria, an NCM will be generated describing that the results are suspect due to surrogate recovery. Alternatively, a new sample can be collected and re-analyzed.

11.8 Ion Ratios – In analytes for which two ion transitions (quantitation and confirmation) are analyzed, the area ratio between the confirmation and quantitation transitions shall be monitored and documented. The ion ratio for all analytes in each injection should be within 50-150% of the average ion ratio for the same analyte in the ICAL. On days ICAL is not performed, the ion ratio should be within 50-150% of the initial CCV standard. Targets detected and identified with ion ratios that fail these acceptance criteria will be flagged in the ion ratio report, but not disqualified.

11.9 Matrix Spike (MS) – Analysis of an MS is required in each extraction batch. Assessment of method precision can be accomplished by analysis of a duplicate collected in the field; however, infrequent occurrence of method analytes might hinder this assessment. If the occurrence of method analytes in the samples is infrequent, or if historical trends are unavailable, a matrix spike duplicate (MSD) must be

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prepared, extracted, and analyzed. Extraction batches that contain MSD will not require the extraction of an FD.

11.9.1 Within each extraction batch, a minimum of one sample is spiked as an MS for every 20 samples analyzed. Client samples are spiked in the same manner as the LCS. 250mL of sample is spiked with 200 µL of 100X PDS mix (20 ppb) plus 110 µL of Full List 100 ppb SUR mix and extracted as normal alongside other client samples.

11.9.1.1 Analyte recoveries may exhibit matrix effect. For matrix spike samples, recoveries should range between 70-150%. If the % recovery falls outside of the acceptable range, corrective action must occur. The initial corrective action will be to check all calculations. If the calculations are correct, check the recovery of that analyte in the LCS. If the recovery of the analyte in the LCS is within limits, then matrix interference has been demonstrated and the laboratory operation may proceed. Analytical reports will show qualifier flags in such cases.

11.9.1.2 If the recovery for any analyte is outside the acceptance criteria for the matrix spike and the LCS, the laboratory is out of control and corrective action will be taken. Corrective action may include re-preparation and reanalysis of the batch. An NCM will be generated to document the corrective action taken.

11.10 Field Duplicate (FD) or Matrix Spike Duplicate (MSD) – Within each extraction batch (not to exceed 20 Field Samples), a minimum of one FD or MSD must be analyzed. If method analytes are not routinely observed in field samples, an MSD should be analyzed rather than an FD.

11.10.1 Relative Percent Differences (RPDs) – FDs should have RPDs that are ≤30% between the original sample and the FD. If the RPD of any analyte falls outside the acceptance criteria, and the laboratory performance for that analyte is shown to be in control in the LCS, the recovery is judged to be matrix biased. An NCM is written describing that the result for that analyte in the unspiked sample is suspect due to matrix effects.

11.10.2 RPDs for MS/MSDs should be ≤30%. If the RPD falls outside of the acceptable range, corrective action must occur. The initial corrective action will be to check all calculations. If the calculations are correct, check the recovery of that analyte in the LCS. If the recovery of the analyte in the LCS is within limits, then matrix interference has been demonstrated and the laboratory operation may proceed. Analytical reports will show qualifier flags in such cases.

11.10.3 Every effort is made to ensure that an MS/MSD or an FD is included in every batch. In the event that there is insufficient sample to analyze an MS/MSD pair or if no FD is available, a duplicate LCS (laboratory control sample duplicate (LCSD)) is included in the batch. The MS/MSD must be analyzed at the same dilution as the most concentrated reportable analysis of the parent sample (the un-spiked sample).

11.11 Trip Blank (TB) – The purpose of the TB is to ensure that PFAS measured in the samples were not inadvertently introduced into the sample during sample collection/handling. Analysis of the TB is required only if a sample contains a method analyte or analytes at or above the LOQ. The TB is processed, extracted and analyzed in exactly the same manner as the samples. If an analyte found in the sample is present in the TB at a concentration greater than 1/2 the LOQ, then all samples collected with that TB are invalid and must be recollected and reanalyzed.

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11.12 Reagent Water Contamination Testing – reagent water purchased from an approved vendor, confirmed to be reasonably free of PFAS compounds, will be used for QC samples (MB/LCS/LCSD) in extraction batches and also sent to clients for use as trip blanks (TB), field blanks (FB), and equipment blanks (EB). Tested reagent water may also be sent to client sampling sites for other uses. Reagent water used for these purposes will be tested by the lab to confirm the absence of PFAS compounds prior to shipping to clients or being used for QC samples. When new lots of reagent water are received, one sample from one of the bottles of the new lot will be prepared and tested as a sample using the ID-AQ method. These test samples will be treated exactly the same as all other client samples, taken through the entire extraction and analysis process. Should any PFAS contamination be detected in the reagent water lot, the water in that lot will not be used further for PFAS QC or field use. The lot may be tested again to confirm the presence of contamination.

11.13 Method Performance

11.3.1 Method Validation

11.3.1.1 Detection Limits

Detection limits (DL) and limits of quantitation (LOQ) are established at initial method setup and verified on an on-going basis thereafter. Refer to Pace ENV corporate SOP ENV-SOP-CORQ-0011 Method Validation and Instrument Verification and to the *Method Validation* SOP [QA Policy ME003BF] for these procedures.

11.3.1.2 The MDL is prepared by spiking 250 mL of reagent water with 25 µL of 100X PDS mix (20ppb), for a concentration of 2 ppt (50 ppt on column), plus 110 µL of Full List 100ppb SUR mix and extracted as normal. An equal number of MB (see section 11.4) will be extracted and analyzed with MDL samples.

11.3.1.3 MRL samples for Wisconsin compliance analysis will be spiked at twice the target analyte concentration of the MDL spiked samples.

11.3.1.4 For non-standard, non-regulatory analytes, an MDL study should be performed and calibration curve generated before analyzing any samples, unless lesser requirements are previously agreed to with the client.

11.14 Analyst Qualifications and Training

Employees that perform any step of this procedure must have a completed Read and Acknowledgment Statement for this version of the SOP in their training record. In addition, prior to unsupervised (independent) work on any client sample, analysts that prepare or analyze samples must have successful initial demonstration of capability (IDOC) and must successfully demonstrate on-going proficiency on an annual basis. Successful means the initial and on-going DOC met criteria, documentation of the DOC is complete, and the DOC record is in the employee's training file. Refer to the *Demonstration of Capability* SOP [QA SOP ME001F2] for more information.

12.0 Data Review And Corrective Action

12.1 Data Review

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Pace's data review process includes a series of checks performed at different stages of the analytical process by different people to ensure that SOPs were followed, the analytical record is complete and properly documented, proper corrective actions were taken for QC failure and other nonconformance(s), and that test results are reported with proper qualification.

The review steps and checks that occur as employee's complete tasks and review their own work is called primary review.

All data and results are also reviewed by an experienced peer or supervisor. Secondary review is performed to verify SOPs were followed, that calibration, instrument performance, and QC criteria were met and/or proper corrective actions were taken, qualitative ID and quantitative measurement is accurate, all manual integrations are justified and documented in accordance with the Pace ENV's SOP for manual integration, calculations are correct, the analytical record is complete and traceable, and that results are properly qualified.

A third-level review, called a completeness check, is performed by reporting or project management staff to verify the data report is not missing information and project specifications were met.

Refer to the *Data Review* SOP [QA SOP ME003LP] for specific instructions and requirements for each step of the data review process.

12.2 Corrective Action

Corrective action is expected any time QC or sample results are not within acceptance criteria. If corrective action is not taken or was not successful, the decision/outcome must be documented in the analytical record. The primary analyst has primary responsibility for taking corrective action when QA/QC criteria are not met. Secondary data reviewers must verify that appropriate action was taken and/or that results reported with QC failure are properly qualified.

Corrective action is also required when carryover is suspected and when results are over range.

Samples analyzed after a high concentration sample must be checked for carryover and reanalyzed if carryover is suspected. Carryover is usually indicated by low concentration detects of the analyte in successive samples analyzed after the high concentration sample.

Sample results at concentrations above the upper limit of quantitation must be diluted and reanalyzed. The result in the diluted samples should be within the upper half of the calibration range. Results less than the mid-range of the calibration indicate the sample was over diluted and analysis should be repeated with a lower level of dilution. If dilution is not performed, any result reported above the upper range is considered a qualitative measurement and must be qualified as an estimated value.

Refer to Appendix B for a complete summary of QC, acceptance criteria, and recommended corrective actions for QC associated with this test method.

13.0 Pollution Prevention And Waste Management

Pace proactively seeks ways to minimize waste generated during our work processes. Some examples of pollution prevention include but are not limited to: reduced solvent extraction, solvent capture, use of reusable cycletainers for solvent management, and real-time purchasing.

The EPA requires that laboratory waste management practice to be conducted consistent with all applicable federal and state laws and regulations. Excess reagents, samples and method process wastes must be

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characterized and disposed of in an acceptable manner in accordance with Pace's Chemical Hygiene Plan / Safety Manual.

14.0 Modifications

14.1 A modification is a change to a reference test method made by the laboratory. For example, changes in stoichiometry, technology, quantitation ions, reagent or solvent volumes, reducing digestion or extraction times, instrument runtimes, etc. are all examples of modifications. Refer to Pace ENV corporate SOP ENV-SOP-CORQ-0011 *Method Validation and Instrument Verification* for the conditions under which the procedures in test method SOPs may be modified and for the procedure and document requirements.

14.1.1 The analyst is permitted to modify LC columns, LC conditions, internal standards or surrogate standards, and MS and MS/MS conditions. Each time such method modifications are made, the analyst must repeat the procedures of the IDOC. **Modifications to LC conditions should still produce conditions such that co-elution of the method analytes is minimized to reduce the probability of suppression/enhancement effects.**

15.0 Responsibilities

Pace ENV employees that perform any part this procedure in their work activities must have a signed Read and Acknowledgement Statement in their training file for this version of the SOP. The employee is responsible for following the procedures in this SOP and handling temporary departures from this SOP in accordance with Pace's policy for temporary departure.

Pace supervisors/managers are responsible for training employees on the procedures in this SOP and monitoring the implementation of this SOP in their work area.

16.0 Attachments

16.1 Appendix A: Tables

16.1.1 Table 1 – Target Analyte List

16.1.2 Table 2 – Reporting Limits (LOQ)

16.1.3 Table 3 – Labeled Standard Associations

16.1.4 Table 4 – Instrument Conditions

16.1.5 Table 5 – Calibration Levels

16.1.6 Table 6 – DoD Batch Control Limits

16.2 Appendix B – PFAS ID – Solid Matrix

16.3 Appendix C – Aqueous Serial Dilution

16.4 Appendix D – Aqueous Sample Centrifugation Protocol

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16.5 Appendix E – Extract Dilution Preparations

16.6 Appendix F – Chemical Derivation of Ion Transitions

16.7 Appendix G – DoD/DOE QSM Requirements

17.0 References

NOTE: Where references exclude a date or edition, the latest edition of the referenced document adopted/recognized by the laboratory's accreditation bodies applies. Refer to the Quality Assurance Management Plan [QAMP ME0012K] for details.

17.1 *Determination of Selected Per- and Polyfluorinated Alkyl Substances in Drinking Water by Solid Phase Extraction and Liquid Chromatography* / Tandem Mass Spectrometry (LC/MS/MS), USEPA, Method 537.1, Version 1.0, November 2018.

17.2 *Department of Defense Department of Energy Consolidated Quality Systems Manual (QSM)* for Environmental Laboratories

17.3 Water Quality – Determination of Perfluorooctanesulfonate (PFOS) and Perfluorooctanoate (PFOA) – Method for Unfiltered Samples Using Solid Phase Extraction and Liquid Chromatography/Mass Spectrometry, ISO 25101:2009 €.

17.4 Solvent-Extractable Nonvolatile Compounds by High-Performance Liquid Chromatography/Thermospray/Mass Spectrometry (HPLC/TS/MS) or Ultraviolet (UV) detection, USEPA, SW846, Method 9321B, Revision 2, February 2007.

17.5 Knepper, T.P. (2003) Analysis and Fate of Surfactants in the Aquatic Environment. Amsterdam, The Netherlands; Elsevier Science B.V.

17.6 Knepper, T.P. (2012) Polyfluorinated Chemicals and Transformation Products. Berlin, Germany: Springer-Verlag Berlin Heidelberg.

17.7 Rapid Commun Mass Spectrom 2007;21 (23): 3803-14.

17.8 *Wisconsin Department of Natural Resources Notice of Final Guidance and Certification, Wisonsin PFAS Aqueous (Non-Potable Water) and Non-Aqueous Matrices Method Expectations*. Wisconsin DNR. Version 12.16.2019.

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18.0 Revision History

Revision #	Revision Date	Section Modified	Modification	Reason for Modification
-04	**03/30/2021**	All	Re-format and re-write entire document	Compliance with PAS policy
		8.2.1 and 8.2.2	Internal changed to Instrument	Clarification
		8.2.12	Updated ICAL table	Clarification
		6.0 and 9.3.26	Added note that WI extracts will be stored 0-6C	WI audit observation #1b
		9.2.4	Added that linear or quadratic calibration regressions are not expected to be set through zero	WI audit observation #4d
		9.2.6.1	Added Calibration Point Dropping, Calibration Point Replacement, and Calibration Locking sections	PAS calibration policy
		9.2.6.1.3	Added recovery limits for WI samples	WI audit observation #3b
		9.2.6 and 9.3	Removed correction factors	Built into AIM software
		9.2.10.1.4	Added remedial actions	Procedure update
		9.3.2.1	Include dilutions for leachate and landfill-impacted samples	Procedure update
		9.4.2	Analytical sequence updated to include CCB/IBLK following each CCV.	WI audit observation #3a
		10.3.3	Added results must be quantified from the most recent ICAL analyzed on the same instrument	PAS calibration policy
		11.3	Added CCB/IBLK will be analyzed after each CCV & corrective action for WI samples	WI audit observation #3a

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APPENDIX A: TABLES

TABLE 1 – TARGET ANALYTE LIST

Analyte Name	Analyte Acronym	CAS Number	Method 537.1	ID (Aqueous)	DAI	ID (Solid)
Fluorotelomer sulfonate 4:2 [1H,1H,2H,2H-perfluorohexane sulfonate]	4:2 FTS	757124-72-4*	No	Yes	No	Yes
Fluorotelomer sulfonate 6:2 [1H,1H,2H,2H-perfluorooctane sulfonate]	6:2 FTS	27619-97-2	No	Yes	No	Yes
Fluorotelomer sulfonate 8:2 [1H,1H,2H,2H-perfluorodecane sulfonate]	8:2 FTS	39108-34-4	No	Yes	No	Yes
1H,1H,2H,2H-perfluorododecane sulfonic acid	10:2FTS	120226-60-0*	No	Yes	No	Yes
N-ethylperfluoro-1-octanesulfonamidoacetic acid	EtFOSAA	2991-50-6	Yes	Yes	No	Yes
N-methylperfluoro-1-octanesulfonamidoacetic acid	MeFOSAA	2355-31-9	Yes	Yes	No	Yes
Perfluoro-1-butanesulfonic acid	PFBS	375-73-5*	Yes	Yes	Yes	Yes
Perfluoro-n-butanoic acid	PFBA	375-22-4	No	Yes	Yes	Yes
Perfluoro-1-decanesulfonic acid	PFDS	335-77-3*	No	Yes	No	Yes
Perfluoro-n-decanoic acid	PFDA	335-76-2	Yes	Yes	Yes	Yes
Perfluoro-n-dodecanoic acid	PFDoA	307-55-1	Yes	Yes	No	Yes
Perfluoro-1-heptanesulfonic acid	PFHpS	375-92-8*	Yes	Yes	No	Yes
Perfluoro-n-heptanoic acid	PFHpA	375-85-9	Yes	Yes	Yes	Yes
Perfluoro-1-hexanesulfonic acid	PFHxS	355-46-4*	Yes	Yes	Yes	Yes
Perfluoro-n-hexanoic acid	PFHxA	307-24-4	Yes	Yes	Yes	Yes
Perfluoro-1-nonanesulfonic acid	PFNS	68259-12-1*	Yes	Yes	No	Yes
Perfluoro-n-nonanoic acid	PFNA	375-95-1	Yes	Yes	Yes	Yes
Perfluorooctanesulfonic acid	PFOS	1763-23-1*	Yes	Yes	Yes	Yes
Perfluoro-1-octanesulfonamide	PFOSA	754-91-6	No	Yes	No	Yes
Perfluoro-n-octanoic acid	PFOA	335-67-1	No	Yes	Yes	Yes
Perfluoro-n-pentanoic acid	PFPeA	2706-90-3	Yes	Yes	Yes	Yes
Perfluoro-1-pentansulfonic acid	PFPeS	2706-91-4*	Yes	Yes	No	Yes
Perfluoro-n-tetradecanoic acid	PFTeDA	376-06-7	Yes	Yes	No	Yes

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TABLE 1 – TARGET ANALYTE LIST (CONT'D)

Analyte Name	Analyte Acronym	CAS Number	Method 537.1	ID (Aqueous)	DAI	ID (Solid)
Perfluoro-n-tridecanoic acid	PFTrDA	72629-94-8	Yes	Yes	No	Yes
Perfluoro-n-undecanoic acid	PFUdA	2058-94-8	Yes	Yes	No	Yes
N-methylperfluoro-1-octanesulfonamide	MeFOSA	31506-32-8	No	Yes	No	Yes
N-methylperfluoro-1-octanesulfonamide	EtFOSA	4151-50-2	No	Yes	No	Yes
Hexafluoropropylene oxide dimer acid	GenX	13252-13-6	Yes	Yes	No	Yes
4,8-dioxa-3H-perfluorononanoic acid	ADONA	919005-14-4	Yes	Yes	No	Yes
9-chlorohexadecafluoro-3-oxanone-1-sulfonic acid	9Cl-PF3ONS	756426-58-1*	Yes	Yes	No	Yes
11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid	11Cl-PF3OUDS	763051-92-9*	Yes	Yes	No	Yes
2-(N-methylperfluoro-1-octanesulfonamido)-ethanol	MeFOSE	24448-09-7	No	Yes	No	Yes
2-(N-ethylperfluoro-1-octanesulfonamido)-ethanol	EtFOSE	1691-99-2	No	Yes	No	Yes
Perfluoro-1-dodecanesulfonic acid	PFDOS	79780-39-5*	No	Yes^	No	Yes^
Perfluoro-n-hexadecanoic acid	PFHxDA	67905-19-5	No	Yes^	No	Yes^
Perfluoro-n-octadecanoic acid	PFODA	16517-11-6	No	Yes^	No	Yes^

* CAS Numbers are for the acid and not the salt.
^ Compounds for Wisconsin compliance analysis
NOTE: Methods 537.1 and DAI are addressed in SOPs ME002I6 and ME002I7 respectively.

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TABLE 2A – REPORTING LIMITS (LOQ) – PFAS ISOTOPE DILUTION – AQUEOUS MATRIX
NOTE: Reporting Limits are subject to change. Current limits are available in LIMs

Analyte Acronym	Analyte Name	CAS Number	Spiked Conc[1] (ng/L)	DL (ng/L)	LOD (ng/L)	LOQ (ng/L)
EtFOSAA	N-ethylperfluoro-1-octanesulfonamidoacetic acid	2991-50-6	2.0	2	4	8
8:2 FTS	Fluorotelomer sulfonate 8:2 [1H,1H,2H,2H-perfluorodecane sulfonate]	39108-34-4	1.916	2	4	8
4:2 FTS	Fluorotelomer sulfonate 4:2 [1H,1H,2H,2H-perfluorohexane sulfonate]	757124-72-4[2]	1.868	2	4	8
6:2 FTS	Fluorotelomer sulfonate 6:2 [1H,1H,2H,2H-perfluorooctane sulfonate]	27619-97-2	1.896	2	4	8
MeFOSAA	N-methylperfluoro-1-octanesulfonamidoacetic acid	2355-31-9	2.0	2	4	8
PFBS	Perfluoro-1-butanesulfonic acid	375-73-5[2]	1.768	1	2	4
PFBA	Perfluoro-n-butanoic acid	375-22-4	2.0	1	2	4
PFDS	Perfluoro-1-decanesulfonic acid	335-77-3[2]	1.928	1	2	4
PFDA	Perfluoro-n-decanoic acid	335-76-2	2.0	1	2	4
PFDoA	Perfluoro-n-dodecanoic acid	307-55-1	2.0	1	2	4
PFHpS	Perfluoro-1-heptanesulfonic acid	375-92-8[2]	1.904	1	2	4
PFHpA	Perfluoro-n-heptanoic acid	375-85-9	2.0	1	2	4
PFHxS	Perfluoro-1-hexanesulfonic acid	355-46-4[2]	1.82	1	2	4
PFHxA	Perfluoro-n-hexanoic acid	307-24-4	2.0	1	2	4
PFNS	Perfluoro-1-nonanesulfonic acid	68259-12-1[2]	1.92	1	2	4
PFNA	Perfluoro-n-nonanoic acid	375-95-1	2.0	1	2	4
PFOS	Perfluorooctanesulfonic acid	1763-23-1[2]	1.856	1	2	4
PFOSA	Perfluoro-1-octanesulfonamide	754-91-6	2.0	1	2	4

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TABLE 2A – REPORTING LIMITS (LOQ) – PFAS ISOTOPE DILUTION – AQUEOUS MATRIX CONT'D
NOTE: Reporting Limits are subject to change. Current limits are available in LIMs

Analyte Acronym	Analyte Name	CAS Number	Spiked Conc[1] (ng/L)	DL (ng/L)	LOD (ng/L)	LOQ (ng/L)
PFOA	Perfluoro-n-octanoic acid	335-67-1	2.0	1	2	4
PFPeA	Perfluoro-n-pentanoic acid	2706-90-3	2.0	1	2	4
PFPeS	Perfluoro-1-pentansulfonic acid	2706-91-4[2]	1.876	1	2	4
PFTeDA	Perfluoro-n-tetradecanoic acid	376-06-7	2.0	1	2	4
PFTrDA	Perfluoro-n-tridecanoic acid	72629-94-8	2.0	1	2	4
PFUdA	Perfluoro-n-undecanoic acid	2058-94-8	2.0	1	2	4
MeFOSA	N-methylperfluoro-1-octanesulfonamide	31506-32-8	2.0	4	8	16
EtFOSA	N-methylperfluoro-1-octanesulfonamide	4151-50-2	2.0	2	4	8
10:2FTS	1H,1H,2H,2H-perfluorododecane sulfonate	120226-60-0[2]	1.928	2	4	8
GenX	Tetrafluoro-2-(heptafluoropropoxy) propanoic acid	13252-13-6	4.0	2	4	8
ADONA	4,8-dioxa-3H-perfluorononanoic acid	919005-14-4	1.884	2	4	8
9Cl-PF3ONS	9-chlorohexadecafluoro-3-oxanone-1-sulfonic acid	756426-58-1[2]	1.864	2	4	8
11Cl-PF3OUDS	11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid	763051-92-9[2]	1.884	2	4	8
MeFOSE	2-(N-methylperfluoro-1-octanesulfonamido)-ethanol	24448-09-7	2.0	2	4	8
EtFOSE	2-(N-ethylperfluoro-1-octanesulfonamido)-ethanol	1691-99-2	2.0	2	4	8
PFDOS	Perfluoro-1-dodecanesulfonic acid	79780-39-5[2]	1.936	2	4	8
PFHxDA	Perfluoro-n-hexadecanoic acid	67905-19-5	2.0	2	4	8
PFODA	Perfluoro-n-octadecanoic acid	16517-11-6	2.0	2	4	8

[1]Spiking concentration used to determine DL.
[2]CAS Numbers are for the acid and not the salt.

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TABLE 2B – REPORTING LIMITS (LOQ) – PFAS ISOTOPE DILUTION – SOLID MATRIX
NOTE: Reporting Limits are subject to change. Current limits are available in LIMs

Analyte Acronym	Analyte Name	CAS Number	Spiked Conc[1] (µg/kg)	DL (µg/kg)	LOD (µg/kg)	LOQ (µg/kg)
EtFOSAA	N-ethylperfluoro-1-octanesulfonamidoacetic acid	2991-50-6	0.5	0.5	1	2
8:2 FTS	Fluorotelomer sulfonate 8:2 [1H,1H,2H,2H-perfluorodecane sulfonate]	39108-34-4	0.479	0.5	1	2
4:2 FTS	Fluorotelomer sulfonate 4:2 [1H,1H,2H,2H-perfluorohexane sulfonate]	757124-72-4[2]	0.467	0.5	1	2
6:2 FTS	Fluorotelomer sulfonate 6:2 [1H,1H,2H,2H-perfluorooctane sulfonate]	27619-97-2	0.474	0.5	1	2
MeFOSAA	N-methylperfluoro-1-octanesulfonamidoacetic acid	2355-31-9	0.5	0.5	1	2
PFBS	Perfluoro-1-butanesulfonic acid	375-73-5	0.442	0.2	0.5	1
PFBA	Perfluoro-n-butanoic acid	375-22-4	0.5	0.2	0.5	1
PFDS	Perfluoro-1-decanesulfonic acid	335-77-3	0.482	0.2	0.5	1
PFDA	Perfluoro-n-decanoic acid	335-76-2	0.5	0.2	0.5	1
PFDoA	Perfluoro-n-dodecanoic acid	307-55-1	0.5	0.2	0.5	1
PFHpS	Perfluoro-1-heptanesulfonic acid	375-92-8	0.476	0.2	0.5	1
PFHpA	Perfluoro-n-heptanoic acid	375-85-9	0.5	0.2	0.5	1
PFHxS	Perfluoro-1-hexanesulfonic acid	355-46-4	0.455	0.2	0.5	1
PFHxA	Perfluoro-n-hexanoic acid	307-24-4	0.5	0.2	0.5	1
PFNS	Perfluoro-1-nonanesulfonic acid	68259-12-1	0.48	0.2	0.5	1
PFNA	Perfluoro-n-nonanoic acid	375-95-1	0.5	0.2	0.5	1
PFOS	Perfluorooctanesulfonic acid	1763-23-1	0.464	0.2	0.5	1
PFOSA	Perfluoro-1-octanesulfonamide	754-91-6	0.5	0.2	0.5	1

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TABLE 2B – REPORTING LIMITS (LOQ) – PFAS ISOTOPE DILUTION – SOLID MATRIX CONT'D
NOTE: Reporting Limits are subject to change. Current limits are available in LIMs

Analyte Acronym	Analyte Name	CAS Number	Spiked Conc[1] (µg/kg)	DL (µg/kg)	LOD (µg/kg)	LOQ (µg/kg)
PFOA	Perfluoro-n-octanoic acid	335-67-1	0.5	0.2	0.5	1
PFPeA	Perfluoro-n-pentanoic acid	2706-90-3	0.5	0.2	0.5	1
PFPeS	Perfluoro-1-pentanesulfonic acid	2706-91-4	0.469	0.2	0.5	1
PFTeDA	Perfluoro-n-tetradecanoic acid	376-06-7	0.5	0.2	0.5	1
PFTrDA	Perfluoro-n-tridecanoic acid	72629-94-8	0.5	0.2	0.5	1
PFUdA	Perfluoro-n-undecanoic acid	2058-94-8	0.5	0.2	0.5	1
MeFOSA	N-methylperfluoro-1-octanesulfonamide	31506-32-8	0.5	0.5	1	2
EtFOSA	N-ethylperfluoro-1-octanesulfonamide	4151-50-2	0.5	0.5	1	2
10:2FTS	1H,1H,2H,2H-perfluorododecane sulfonate	120226-60-0[2]	0.482	0.5	1	2
GenX	Tetrafluoro-2-(heptafluoropropoxy) propanoic acid	13252-13-6	1.0	1	2	4
ADONA	4,8-dioxa-3H-perfluorononanoic acid	919005-14-4	0.471	0.5	1	2
9Cl-PF3ONS	9-chlorohexadecafluoro-3-oxanone-1-sulfonic acid	756426-58-1	0.466	0.5	1	2
11Cl-PF3OUDS	11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid	763051-92-9	0.471	0.5	1	2
MeFOSE	2-(N-methylperfluoro-1-octanesulfonamido)-ethanol	24448-09-7	0.5	0.5	1	2
EtFOSE	2-(N-ethylperfluoro-1-octanesulfonamido)-ethanol	1691-99-2	0.5	0.5	1	2
PFDOS	Perfluoro-1-dodecanesulfonic acid	79780-39-5[2]	0.484	0.2	0.5	1
PFHxDA	Perfluoro-n-hexadecanoic acid	67905-19-5	0.5	0.5	1	2
PFODA	Perfluoro-n-octadecanoic acid	16517-11-6	0.5	0.2	0.5	1

[1]Spiking concentration used to determine DL.
[2]CAS Numbers are for the acid and not the salt.

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TABLE 3 – LABELED STANDARD ASSOCIATIONS – PFAS ISOTOPE DILUTION – AQUEOUS AND SOLID MATRIX

Target Analyte	Associated Labeled Standard
4:2 FTS	13C2_4:2FTS_2
6:2 FTS	13C2_6:2FTS_2
8:2 FTS	13C2_8:2FTS_2
10:2FTS	13C2_8:2 FTS_2
EtFOSAA	d5-EtFOSAA
MeFOSAA	d3-MeFoSAA
PFBS	13C3_PFBS
PFBA	13C4_PFBA
PFDS	13C8_PFOS
PFDA	13C6_PFDA
PFDoA	13C2_PFDoA
PFHpS	13C3_PFHxS
PFHpA	13C4_PFHpA
PFHxS	13C3_PFHxS
PFHxA	13C5_PFHxA
PFNS	13C8_PFOS
PFNA	13C9_PFNA
PFOS	13C8_PFOS
PFOSA	13C8_PFOSA
PFOA	13C8_PFOA
PFPeA	13C5_PFPeA
PFPeS	13C3_PFBS
PFTeDA	13C2_PFTeDA
PFTrDA	13C2_PFDoA
PFUdA	13C7_PFUdA
MeFOSA	d3-MeFOSA
EtFOSA	d5-EtFOSA
GenX	13C3-GenX
ADONA	13C3_PFHxS
9Cl-PF3ONS	13C8_PFOS
11Cl-PF3OUDS	13C8_PFOS
MeFOSE	d7-MeFOSE
EtFOSE	d9-EtFOSE
PFDOS	13C8_PFOS
PFHxDA	13C2-PFHxDA
PFODA	13C2-PFHxDA

NOTE: For method ID-AQ and ID-Solid, the labeled quantitation standards are contained in the SUR solution.

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TABLE 4: ID INSTRUMENT CONDITIONS – AQUEOUS AND SOLID MATRIX

LC Program

Step	Total Time (min)	Flow Rate (uL/min)	A: 20mM Ammonium Acetate (%)	B: Methanol (%)
0	0.00	1200	95.0	5.0
1	0.10	1200	45.0	55.0
2	4.50	1000	1.0	99.0
3	6.00	1000	1.0	99.0
4	6.10	1000	95.0	5.0
5	8.10	1000	95.0	5.0

Built-in Diverter Valve Program

Step	Total Time (min)	Position
1	0.0	Waste
2	1.0	MS
3	5.8	Waste

Instrument Parameters

Parameter	Setting or Value
Syringe Size	100 µL
Injection Volume	10 µL
Draw Speed	50.0 µL/min
Eject Speed	50.0 µL/min
Needle Level	3.0 mm
Column Oven Temperature	40°C
MRM Scan Window	30 sec
Curtain Gas (CUR)	30.0
Collision Gas (CAD)	9
Ion Spray Voltage (IS)	-4500.0 V
Temperature (TEM)	450.0°C
Ion Source Gas 1 (GS1)	40.0
Ion Source Gas 2 (GS2)	60.0

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MS/MS Conditions*

ID	Q1 Mass (Da)	Q3 Mass (Da)	Time (min)	DP (volts)	EP (volts)	CE (volts)	CXP (volts)
4:2 FTS	327	307	2.42	-20	-4	-28	-8
4:2 FTS_2	327	81	2.42	-20	-4	-50	-8
6:2 FTS	427	407	3.23	-20	-4	-32	-8
6:2 FTS_2	427	81	3.23	-20	-4	-72	-8
8:2 FTS	527	507	4.02	-20	-4	-40	-8
8:2 FTS_2	527	81	4.02	-20	-4	-82	-8
9Cl-PF3ONS	531	351	3.88	-75	-10	-38	-10
10:2 FTS	627	607	4.66	-20	-8	-45	-8
10:2 FTS_2	627	80	4.66	-20	-8	-92	-8
11Cl-PF3OUDS	631	451	4.52	-90	-10	-41	-13
ADONA	377	251	2.95	-47	-8	-18	-8
ADONA_2	377	85	2.95	-47	-8	-68	-8
EtFOSA	526	169	4.71	-50	-10	-37	-8
EtFOSA_2	526	219	4.71	-50	-10	-37	-8
EtFOSE	630	59	4.65	-39	-4	-58	-8
GenX	285	119	2.58	-51	-10	-38	-8
GenX_2	285	185	2.58	-51	-10	-28	-8
MeFOSA	512	169	4.52	-50	-10	-37	-8
MeFOSA_2	512	219	4.52	-50	-10	-37	-8
MeFOSE	616	59	4.49	-50	-10	-58	-8
N-EtFOSAA	584	419	4.36	-50	-10	-28	-8
N-EtFOSAA_2	584	526	4.36	-50	-10	-28	-8
N-MeFOSAA	570	419	4.20	-50	-10	-28	-8
N-MeFOSAA_2	570	483	4.20	-50	-10	-22	-8
PFBA	212.9	168.9	1.71	-10	-8	-12	-8
PFBS	298.9	80	2.15	-20	-4	-56	-5.5
PFBS_2	298.9	99	2.15	-20	-4	-46	-9
PFDA	513	469	4.03	-10	-8	-17	-8
PFDA_2	513	169	4.03	-10	-8	-27	-8
PFDoA	613	569	4.66	-10	-8	-18	-8
PFDoA_2	613	169	4.66	-10	-8	-30	-8
PFDOS	699	80	4.65	-150	-10	-125	-7
PFDOS_2	699	99	4.65	-150	-10	-120	-10
PFDS	599	80	4.34	-20	-7	-118	-5.5
PFDS_2	599	99	4.34	-20	-7	-95	-9
PFHpA	363	319	2.85	-10	-8	-14	-8
PFHpA_2	363	169	2.85	-10	-8	-25	-8
PFHpS	449	80	3.27	-20	-4	-80	-5.5
PFHpS_2	449	99	3.27	-20	-4	-70	-9
PFHxA	313	269	2.46	-10	-8	-14	-8
PFHxA_2	313	119	2.46	-10	-8	-25	-8
PFHxDA	813	769	5.31	-123	-13	-22	-19

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MS/MS Conditions* Continued

ID	Q1 Mass (Da)	Q3 Mass (Da)	Time (min)	DP (volts)	EP (volts)	CE (volts)	CXP (volts)
PFHxDA_2	813	269	5.31	-123	-6.5	-37	-22
PFHxS	399	80	2.87	-20	-4	-74	-5.5
PFHxS_2	399	99	2.87	-20	-4	-60	-9
PFNA	463	419	3.66	-10	-8	-16	-8
PFNA_2	463	169	3.66	-10	-8	-26	-8
PFNS	549	80	4.02	-20	-5.5	-115	-5.5
PFNS_2	549	99	4.02	-20	-5.5	-92	-5.5
PFOA	413	369	3.26	-10	-8	-14	-8
PFOA_2	413	169	3.26	-10	-8	-26	-8
PFODA	913	869	5.70	-120	-9	-25	-15
PFODA_2	913	319	5.70	-120	-9	-42	-15
PFOS	499	80	3.66	-20	-4	-95	-5.5
PFOS_2	499	99	3.66	-20	-4	-87	-9
PFOSA	498	78	4.02	-20	-4	-85	-8
PFPeA	262.9	218.9	2.09	-10	-8	-13	-8
PFPeS	349	80	2.50	-20	-4	-70	-5.5
PFPeS_2	349	99	2.50	-20	-4	-60	-9
PFTeDA	713	669	5.15	-10	-4	-22	-8
PFTeDA_2	713	169	5.15	-10	-4	-38	-8
PFTrDA	663	619	4.92	-10	-4	-20	-8
PFTrDA_2	663	169	4.92	-10	-4	-36	-8
PFUdA	563	519	4.36	-10	-8	-18	-8
PFUdA_2	563	169	4.36	-10	-8	-28	-8
13C2-PFDA	515	470	4.03	-10	-8	-17	-8
13C2-PFDoA	615	570	4.66	-10	-4	-18	-8
13C2-PFHxA	315	270	2.46	-10	-8	-14	-8
13C2-PFHxDA	815	770	5.31	-107	-10	-24	-16
13C2-PFOA	415	370	3.26	-10	-8	-14	-8
13C2-PFTeDA	715	670	5.15	-10	-4	-22	-8
13C3-GenX	287	185	2.58	-55	-10	-24	-10
13C3-PFBA	216	172	1.71	-10	-8	-12	-8
13C3_PFBS	302	80	2.15	-20	-4	-56	-5.5
13C3_PFHxS	402	80	2.87	-20	-4	-74	-5.5
13C4_PFBA	217	172	1.71	-10	-8	-12	-8
13C4_PFHpA	367	322	2.85	-10	-8	-14	-8
13C4_PFOS	503	80	3.66	-20	-4	-95	-5.5
13C5_PFHxA	318	273	2.46	-10	-8	-14	-8
13C5_PFPeA	267.9	223	2.09	-10	-8	-13	-8
13C6_PFDA	519	474	4.03	-10	-8	-16	-8
13C7_PFUdA	570	525	4.36	-10	-8	-18	-8

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MS/MS Conditions* Continued

ID	Q1 Mass (Da)	Q3 Mass (Da)	Time (min)	DP (volts)	EP (volts)	CE (volts)	CXP (volts)
13C8_PFOA	421	376	3.26	-10	-8	-14	-8
13C8_PFOS	507	80	3.66	-20	-4	-95	-5.5
13C8_PFOSA	506	78	4.02	-20	-4	-85	-8
13C9_PFNA	472	427	3.66	-10	-8	-16	-8
d3-MeFOSA	515	169	4.52	-50	-10	-37	-8
d3-MeFOSAA	573	419	4.20	-50	-10	-28	-8
d5-EtFOSA	531	169	4.71	-50	-10	-37	-8
d5-EtFOSAA	589	419	4.36	-50	-10	-28	-8
d7-MeFOSE	623	59	4.49	-50	-5.5	-58	-5.5
d9-EtFOSE	639	59	4.65	-60	-4	-60	-8
M2-4:2 FTS	329	309	2.42	-20	-4	-28	-8
13C2-4:2 FTS_2	329	81	2.42	-20	-4	-28	-8
M2-6:2FTS	429	409	3.23	-20	-4	-32	-8
13C2-6:2FTS_2	429	81	3.23	-20	-4	-32	-8
M2-8:2FTS	529	509	4.02	-20	-4	-40	-8
13C2-8:2FTS_2	529	81	4.02	-20	-4	-82	-8

*Some MS/MS conditions may need to be re-optimized for individual instruments
NOTE: See Appendix E for the chemical derivation of the ion transitions.

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TABLE 5: CALIBRATION LEVELS (ng/L) – ID ICAL – AQUEOUS AND SOLID MATRIX

Analyte	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8	Level 9	Level 10
	PFAS Full List Native PDS Mix, 1000X			PFAS Full List Native PDS Mix, 100X				PFAS Full List Native PDS Mix, 10X		
PFBA	50	100	200	500	1000	2000	5000	10000	15000	20000
PFPeA	50	100	200	500	1000	2000	5000	10000	15000	20000
PFBS	44	88	177	442	884	1768	4420	8840	13260	17680
PFHxA	50	100	200	500	1000	2000	5000	10000	15000	20000
PFPeS	47	94	188	469	938	1876	4690	9380	14070	18760
PFHpA	50	100	200	500	1000	2000	5000	10000	15000	20000
PFHxS	46	91	182	455	910	1820	4550	9100	13650	18200
PFOA	50	100	200	500	1000	2000	5000	10000	15000	20000
PFHpS	48	95	190	476	952	1904	4760	9520	14280	19040
PFNA	50	100	200	500	1000	2000	5000	10000	15000	20000
PFOS	46	93	186	464	928	1856	4640	9280	13920	18560
PFDA	50	100	200	500	1000	2000	5000	10000	15000	20000
PFNS	48	96	192	480	960	1920	4800	9600	14400	19200
4:2FTS	47	93	187	467	934	1868	4670	9340	14010	18680
6:2FTS	47	95	190	474	948	1896	4740	9480	14220	18960
8:2 FTS	48	96	192	479	958	1916	4790	9580	14370	19160
PFOSA	50	100	200	500	1000	2000	5000	10000	15000	20000

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TABLE 5: CALIBRATION LEVELS (ng/L) – ID ICAL – AQUEOUS AND SOLID MATRIX CONT'D										
Analyte	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5**	**Level 6**	**Level 7**	**Level 8**	**Level 9**	**Level 10**
	PFAS Full List Native PDS Mix, 1000X			**PFAS Full List Native PDS Mix, 100X**				**PFAS Full List Native PDS Mix, 10X**		
MeFOSA	50	100	200	500	1000	2000	5000	10000	15000	20000
EtFOSA	50	100	200	500	1000	2000	5000	10000	15000	20000
PFUDA	50	100	200	500	1000	2000	5000	10000	15000	20000
MeFOSAA	50	100	200	500	1000	2000	5000	10000	15000	20000
EtFOSAA	50	100	200	500	1000	2000	5000	10000	15000	20000
PFDS	48	96	193	482	964	1928	4820	9640	14460	19280
PFDoA	50	100	200	500	1000	2000	5000	10000	15000	20000
10:2FTS	48	96	193	482	964	1928	4820	9640	14460	19280
PFTrDA	50	100	200	500	1000	2000	5000	10000	15000	20000
PFTeDA	50	100	200	500	1000	2000	5000	10000	15000	20000
GenX	100	200	400	1000	2000	4000	10000	20000	30000	40000
ADONA	47	94	188	471	942	1884	4710	9420	14130	18840
9Cl-PF3ONS	47	93	186	466	932	1864	4660	9320	13980	18640
11Cl-PF3OUDS	47	94	188	471	942	1884	4710	9420	14130	18840
MeFOSE	50	100	200	500	1000	2000	5000	10000	15000	20000
EtFOSE	50	100	200	500	1000	2000	5000	10000	15000	20000
PFDOS	48	97	194	484	968	1936	4840	9680	14520	19360
PFHxDA	50	100	200	500	1000	2000	5000	10000	15000	20000
PFODA	50	100	200	500	1000	2000	5000	10000	15000	20000
Surrogates (SUR)	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Internal Standards (IS)	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000

NOTE: See Table 1 for method specific target analytes.

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NOTE: *The ID (Aqueous and Solid) SUR includes the following compounds:*

- Sodium 1H, 1H, 2H, 2H-perfluoro-[1,2-13C2] hexane sulfonate (M2-4:2FTS or 13C2-4:2FTS)
- Sodium 1H, 1H, 2H, 2H-perfluoro-[1,2-13C2] octane sulfonate (M2-6:2FTS or 13C2-6:2FTS)
- Sodium 1H, 1H, 2H, 2H-perfluoro-[1,2-13C2] decane sulfonate (M2-8:2FTS or 13C2-8:2FTS)
- Perfluoro-1-[13C8] octanesulfonamide (M8FOSA-I or 13C8FOSA)
- N-ethyl-d5-perfluoro-1-octanesulfonamide (d-N-EtFOSA-M)
- N-methyl-d3-perfluoro-1-octanesulfonamide (d-N-MeFOSA-M)
- N-ethyl-d5-perfluoro-1-octanesulfonamidoacetic acid (d5-N-EtFOSAA)
- N-methyl-d3-perfluoro-1-octanesulfonamidoacetic acid (d3-N-MeFOSAA)
- Perfluoro-n-[13C4]butanoic acid (MPFBA or 13C4PFBA)
- Perfluoro-n-[13C5]pentanoic acid (M5PFPeA or 13C5PFPeA)
- Perfluoro-n-[1,2,3,4,6-13C5]hexanoic acid (M5PFHxA or 13C5PFHxA)
- Perfluoro-n-[1,2,3,4-13C4]heptanoic acid (M4PFHpA or 13C4PFHpA)
- Perfluoro-n-[13C8]octanoic acid (M8PFOA or 13C8PFOA)
- Perfluoro-n-[13C9]nonanoic acid (M9PFNA or 13C9PFNA)
- Perfluoro-n-[1,2,3,4,5,6-13C5]decanoicanoic acid (M6PFDA or 13C6PFDA)
- Sodium perfluoro-1-[2,3,4-13C3]butanesulfonate (M3PFBS or 13C3PFBS)
- Sodium perfluoro-1-[1,2,3-13C3]hexanesulfonate (M3PFHxS or 13C3PFHxS)
- Sodium perfluoro-1-[13C8]octanesulfonate (M8PFOS or 13C8PFOS)
- Perfluoro-n-[1,2,3,4,5,6,7-13C7]undecanoic acid (M7PFUdA or 13C7PFUdA)
- Perfluoro-n-[1,2-13C2]dodecanoic acid (MPFDoA or 13C2PFDoA)
- Perfluoro-n-[1,2-13C2]tetradecanoic acid (M2PFTeDA or 13C2PFTeDA)
- Tetrafluoro-2-(heptafluoropropoxy)-13C3 propanoic acid (13C3-GenX)
- 2-(N-methyl-d3-perfluoro-1-octanesulfonamido) ethan-4-ol (d7-MeFOSE)
- 2-(N-ethyl-d5-perfluoro-1-octanesulfonamido) ethan-4-ol (d9-EtFOSE)
- Perfluoro-n-[1,2-$^{13}C_2$] hexadecanoic acid (13C2-PFHxDA)

NOTE: *The ID (Aqueous and Solid) IS includes the following compounds:*

- Perfluoro-n-[1,2-13C2]hexanoic acid (M2PFHxA or 13C2PFHxA)
- Perfluoro-n-[2,3,4-13C3]butanoic acid (M3PFBA or 13C3PFBA)
- Perfluoro-n-[1,2-13C2]octanoic acid (M2PFOA or 13C2PFOA)
- Perfluoro-n-[1,2-13C2]decanoic acid (MPFDA or 13C2PFDA)
- Sodium perfluoro-1-[1,2,3,4-13C4]octanesulfonate (MPFOS or 13C4PFOS)

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TABLE 6A: DOD BATCH CONTROL LIMITS – AQUEOUS MATRIX*

The limits outlined in this table shall be used when reporting data for DoD/DOE projects

CAS	Analyte Acronym	Lower Control Limit (%REC)	Upper Control Limit (%REC)
2991-50-6	EtFOSAA	61	135
39108-34-4	8:2 FTS	67	138
757124-72-4	4:2 FTS	63	143
27619-97-2	6:2 FTS	64	140
2355-31-9	MeFOSAA	65	136
375-73-5	PFBS	72	130
375-22-4	PFBA	73	129
335-77-3	PFDS	53	142
335-76-2	PFDA	71	129
307-55-1	PFDoA	72	134
375-92-8	PFHpS	69	134
375-85-9	PFHpA	72	130
355-46-4	PFHxS	68	131
307-24-4	PFHxA	72	129
68259-12-1	PFNS	69	127
375-95-1	PFNA	69	130
1763-23-1	PFOS	65	140
754-91-6	PFOSA	67	137
335-67-1	PFOA	71	133
2706-90-3	PFPeA	72	129
2706-91-4	PFPeS	71	127
376-06-7	PFTeDA	71	132
72629-94-8	PFTrDA	65	144
2058-94-8	PFUdA	69	133
31506-32-8	MeFOSA	68	141
4151-50-2	EtFOSA	70	150
120226-60-0	10:2FTS	70	150
13252-13-6	GenX	70	150
919005-14-4	ADONA	70	150
756426-58-1	9Cl-PF3ONS	70	150
763051-92-9	11Cl-PF3OUDS	70	150
24448-09-7	MeFOSE	70	150
1691-99-2	EtFOSE	70	150

***For Wisconsin compliance analysis, LCS recovery limits for all compounds are 60-135% when spiked at mid-range or high-range concentrations; 50-150% when spiked at low-range concentration.**

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TABLE 6B: DOD BATCH CONTROL LIMITS – SOLID MATRIX*

The limits outlined in this table shall be used when reporting data for DoD/DOE projects

CAS	Analyte Acronym	Lower Control Limit (%REC)	Upper Control Limit (%REC)
2991-50-6	EtFOSAA	61	139
39108-34-4	8:2 FTS	65	137
757124-72-4	4:2 FTS	62	145
27619-97-2	6:2 FTS	64	140
2355-31-9	MeFOSAA	63	144
375-73-5	PFBS	72	128
375-22-4	PFBA	71	135
335-77-3	PFDS	59	134
335-76-2	PFDA	69	133
307-55-1	PFDoA	69	135
375-92-8	PFHpS	70	132
375-85-9	PFHpA	71	131
355-46-4	PFHxS	67	130
307-24-4	PFHxA	70	132
68259-12-1	PFNS	69	125
375-95-1	PFNA	72	129
1763-23-1	PFOS	68	136
754-91-6	PFOSA	67	137
335-67-1	PFOA	69	133
2706-90-3	PFPeA	69	132
2706-91-4	PFPeS	73	123
376-06-7	PFTeDA	69	133
72629-94-8	PFTrDA	66	139
2058-94-8	PFUdA	64	136
31506-32-8	MeFOSA	70	150
4151-50-2	EtFOSA	70	150
120226-60-0	10:2FTS	70	150
13252-13-6	GenX	70	150
919005-14-4	ADONA	70	150
756426-58-1	9Cl-PF3ONS	70	150
763051-92-9	11Cl-PF3OUDS	70	150
24448-09-7	MeFOSE	70	150
1691-99-2	EtFOSE	70	150

***For Wisconsin compliance analysis, LCS recovery limits for all compounds are 60-135% when spiked at mid-range or high-range concentrations; 50-150% when spiked at low-range concentration.**

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APPENDIX B. PFAS ID – SOLID MATRIX

1. Standard Preparation

1.1 Internal standards for ID-Solid are the following five compounds: Perfluoro-n-[1,2-$^{13}C_2$]hexanoic acid ($^{13}C_2$-PFHxA), Perfluoro-n-[1,2-$^{13}C_2$] octanoic acid ($^{13}C_2$-PFOA) and Sodium perfluoro-1-[1,2,3,4-$^{13}C_4$]octanesulfonate ($^{13}C_4$-PFOS), Perfluoro-n-[2,3,4-$^{13}C_3$] butanoic acid ($^{13}C_3$-PFBA) and Perfluoro-n-[1,2-$^{13}C_2$] decanoic acid ($^{13}C_2$-PFDA).

1.2 Internal Standard (IS) 50X Mix: dilute the stock standard with methanol/water in accordance to section 1.10 and the table below:

ID (Solid) IS 50X Mix

Standard Name	Conc. of Stock Std.	Aliquoted Volume	Dilution Volume	Final Conc.
	µg/mL	µL	mL	µg/mL
Perfluoro-n-[1,2-$^{13}C_2$]hexanoic acid (13C2-PFHxA)	50	200.0	10.0	1.0

1.3 20 ppb IS Mix: combine the IS 50X mix in section 1.2 and Wellington Labs standard part# MPFAC-C-IS and dilute with methanol/water in accordance to section 1.10 and the table below:

ID (Solid) 20 ppb IS Mix

Standard Name	Conc. of Stock Std.	Aliquoted Volume	Dilution Volume	Final Conc.
	µg/mL	µL	mL	µg/mL
MOD-ID IS 50X Mix	1	300.0	15.0	0.020
MPFAC-C-IS stock	2	150.0	15.0	0.020

1.4 SUR 50X Mix: Dilute the stock standards with methanol/water in accordance to section 1.10 and the table below:

ID (Solid) SUR 50X Mix

Standard Name	Conc. of Stock Std.	Aliquoted Volume	Dilution Volume	Final Conc.
	µg/mL	µL	mL	µg/mL
Sodium 1H, 1H, 2H, 2H-perfluoro-[1,2-$^{13}C_2$] hexane sulfonate (13C2-4:2FTS)	50	1000	10.0	5.0
Sodium 1H, 1H, 2H, 2H-perfluoro-[1,2-$^{13}C_2$] octane sulfonate (13C2-6:2FTS)	50	1000	10.0	5.0
Sodium 1H, 1H, 2H, 2H-perfluoro-[1,2-$^{13}C_2$] decane sulfonate (13C2-8:2FTS)	50	1000	10.0	5.0
Perfluoro-1-[$^{13}C_8$] octanesulfonamide (13C8-PFOSA)	50	200	10.0	1.0

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N-ethyl-d5-perfluoro-1-octanesulfonamide (d5-EtFOSA)	50	200	10.0	1.0
N-methyl-d3-perfluoro-1-octanesulfonamide (d3-MeFOSA)	50	200	10.0	1.0
N-ethyl-d5-perfluoro-1-octanesulfonamidoacetic acid (d5-EtFOSAA)	50	1000	10.0	5.0
N-methyl-d3-perfluoro-1-octanesulfonamidoacetic acid (d3-MeFOSAA)	50	1000	10.0	5.0
2,3,3,3-Tetrafluoro-2-(1,1,2,2,3,3,3-heptafluoropropoxy)-$^{13}C_3$-propanoic acid (13C3-GenX)	50	1000	10.0	5.0
2-(N-methyl-d3-perfluoro-1-octanesulfonamido) ethan-4-ol (d7-MeFOSE)	50	200	10.0	1.0
2-(N-ethyl-d5-perfluoro-1-octanesulfonamido) ethan-4-ol (d9-EtFOSE)	50	200	10.0	1.0
Perfluoro-n-[1,2-$^{13}C_2$] hexadecanoic acid (13C2-PFHxDA)	50	200	10	1.0

1.5 20 ppb SUR mix: combine the SUR 50X mix in section 1.4 and Wellington Labs standard part# MPFAC-C-ES and dilute with methanol/water in accordance to section 1.10 and the table below:

ID (Solid) 20 ppb SUR Mix

Standard Name	Conc. of Stock Std.	Aliquoted Volume	Dilution Volume	Final Conc.
	µg/mL	**µL**	**mL**	**µg/mL**
ID SUR 50X mix	1	300.0	15.0	0.020
MPFAC-C-ES stock	2	150.0	15.0	0.020

1.6 100 ppb SUR mix: combine the SUR 50X mix in section 1.4 and Wellington Labs standard part# MPFAC-C-ES and dilute with methanol/water in accordance with section 1.10 and the table below:

ID (Solid) 100 ppb SUR Mix

Standard Name	Conc. of Stock Std.	Aliquoted Volume	Dilution Volume	Final Conc.
	µg/mL	**µL**	**mL**	**µg/mL**
ID SUR 50X mix	1	1500	15.0	0.10
MPFAC-C-ES stock	2	750	15.0	0.10

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NOTE: The compounds included in the ID (Aqueous and Solid) SUR Mix are listed under Table 5.

1.7 Solid Spiking Standard (SSS) – For ID-Solid, a separate solution of target analytes will be prepared and used to spike all QC samples (LCS, MS/MSD) prior to extraction. The concentration of all target analytes will be 500 ng/mL, except GenX which will be 1000 ng/mL. The SSS is stable for 12 months when stored at 2-6°C. Prepare according to section 1.10 and the table below:

ID Solid Spiking Standard (SSS)

Component	Conc. of Stock Std.	Aliquot volume	Dilution Volume	Final Conc.
	ng/mL	µL	mL	ng/mL
PFAC-30PAR	1000	2000	4	500
MeFOSA	50000	40	4	500
EtFOSA	50000	40	4	500
10:2 FTS	48200	40	4	482
GenX	50000	40	4	500
MeFOSE	50000	40	4	500
EtFOSE	50000	40	4	500
PFDOS	50000	40	4	484
PFHxDA	50000	40	4	500
PFODA	50000	40	4	500

1.8 Analyte Primary Dilution Standard (PDS) Solutions – For ID-Solid, a list of these solutions is provided below. The PDS standards are stable for two weeks when stored at room temperature, or 12 months when stored at 2-6°C. Wellington Laboratories item #s for the standards used to prepare the PDS solutions are as follows: PFAC-30PAR (30 compound mix of native PFAS); N-MeFOSA-M; N-EtFOSA-M; 10:2FTS; HFPO-DA (GenX); N-MeFOSE-M; N-EtFOSE-M; PFDOS; PFHxDA; PFODA

1.8.1 Stock (10X) Analyte PDS (containing all target analytes at 0.2 ug/mL, except GenX which is present at 0.4 ug/mL) - 2 mL of the primary lot of PFAC-30PAR standard mix, 40 uL of MeFOSA, EtFOSA, 10:2 FTS, MeFOSE, EtFOSE, GenX, PFDOS, PFHxDA, and PFODA are diluted to 10 mL with Methanol and reagent water.

1.8.2 100X Analyte PDS (containing all target analytes at 20 ng/mL; GenX at 40 ng/mL) – 1 mL of Stock (10X) Analyte PDS is diluted to 10 mL with 9 mL of 96% MeOH

1.8.3 1000X Analyte PDS (containing all target analytes at 2.0 ng/mL; GenX at 4.0 ng/mL) – 1 mL of 100X Analyte PDS is diluted to 10 mL with 9 mL of 96% MeOH

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1.9 Initial Calibration Standards (ICAL) – Using the standards in sections 1.3, 1.5, and 1.8 and according to the table below prepare calibration standards at the following concentrations in pg/mL (ng/L): 50, 100, 200, 500, 1000, 2000, 5000, 10000, and 20000, except GenX which will be at double these concentrations. The ICAL standards are stable for three months when stored at room temperature, or 12 months when stored at 2-6°C. The final compositions of the above solutions contain 96:4% (vol/vol) methanol: water. See Table 5 for a list of analytes and exact concentrations.

ID-Solid ICAL Preparation

PFAS Conc. (pg/mL)	SUR Conc. (pg/mL)	IS Conc. (pg/mL)	PFAS FL PDS 10X	PFAS FL PDS 100X	PFAS FL PDS 1000X	20 ppb SUR	20 ppb IS	Final Volume
			mL	mL	mL	mL	mL	mL
50	1000	1000	-	-	0.125	0.25	0.25	5.00
100	1000	1000	-	-	0.250	0.25	0.25	5.00
200	1000	1000	-	-	0.500	0.25	0.25	5.00
500	1000	1000	-	0.125	-	0.25	0.25	5.00
1000	1000	1000	-	0.250	-	0.25	0.25	5.00
2000	1000	1000	-	0.500	-	0.25	0.25	5.00
5000	1000	1000	0.125	-	-	0.25	0.25	5.00
10000	1000	1000	0.25	-	-	0.25	0.25	5.00
15000	1000	1000	0.375	-	-	0.25	0.25	5.00
20000	1000	1000	0.50	-	-	0.25	0.25	5.00

1.10 The final composition for all the standards in sections 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8 and 1.9 contains 96:4% (v/v) methanol/water.

1.11 ***10X ICV PDS mix*** – Second source standard containing required target analytes at 0.2 ug/mL or 200ppb, except those compounds not contained in the PFAC-24PAR stock mix, which are present at a nominal concentration of 1.0 ug/mL or 1000ppb. Prepare as outlined below:

1.11.1 Dilute PFAC-24PAR standard mix (secondary source/preparation) and 40uL each of GenX, ADONA, 9Cl-PF3ONS, 11Cl-PF3OUDS, and 10:2 FTS secondary standards are diluted to 2mL with methanol and water, for a final solvent composition of 96:4% MeOH:water. The PFAC-24PAR standard includes all analytes listed in Table 5 except the following: GenX, ADONA, 9Cl-PF3ONS, 11Cl-PF3OUDS, 10:2 FTS, MeFOSA, EtFOSA, MeFOSE, EtFOSE, PFDOS, PFHxDA, and PFODA.

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1.12 ***100X ICV Mix*** - Second source standard containing required target analytes at 0.02 ug/mL or 20ppb. Prepare as outlined below:

1.12.1 Dilute 0.5 mL of the 10X ICV PDS mix to 5mL using 96:4% MeOH:water.

1.13 ***ICV Sample Solution (500ppt)*** – Prepare according to the table below. The final solvent composition of this solution should be 96:4% MeOH: water. Note: secondary standards for the following compounds are not included in the ICV sample: MeFOSA, EtFOSA, MeFOSE, EtFOSE, PFDOS, PFHxDA, PFODA

ICV Preparation (Aqueous)				
Standard Name	**Conc. of Stock Std. (pg/mL)**	**Aliquoted Volume (µL)**	**Dilution Volume (mL)**	**Final Conc. (pg/mL)**
PFAS ICV 100X Mix	20000	25	1.0	500
Full List SUR mix, 20ppb	20000	50	1.0	1000
Full List IS mix, 20ppb	20000	50	1.0	1000

1.14 ***Isomer check*** – For target compounds which have multiple chromatographic peaks due to branched and linear isomers, but for which quantitative standards are not available, a qualitative check is analyzed with each calibration event to demonstrate the peak shape and retention time of the branched isomers. See sections 10.6, 10.7 for integration information.

1.14.1 ***Isomer Check 50X Mix*** – 20 µL each of TPFOA, br-MeFOSAA, and br-EtFOSAA standards (Wellington Laboratories item #s T-PFOA, br-MeFOSAA, and br-EtFOSAA) are diluted to 1 mL with 900 µL of MeOH and 40 µL of reagent water. Final solvent composition is 96:4% MeOH:water. This solution is used to create the actual isomer check standard to be analyzed with each ICAL. Note: branched/linear isomer mixes of MeFOSAA and EtFOSAA are now present in the analyte PDS solutions, so these compounds will be calibrated with branched and linear isomers summed, but will also continue to be present in the Isomer Check mix.

1.14.2 ***Isomer Check Standard*** - 10 µL of the Isomer Check 50X Mix plus 50 µL each of the 20 ppb IS and 20 ppb SUR are diluted to 1 mL with 890 µL of 96% MeOH. The concentrations of the isomer components should be approximately 10000 ppt. Final solvent composition is 96:4% MeOH:water. This sample will be analyzed with each calibration event to demonstrate peak shape and retention time of the additional branched isomers of the included compounds.

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As more qualitative standards containing mixes of branched and linear isomers become commercially available, the lab will add those newly available compounds/standards to the isomer check mix and analyze them in the manner described in Sec. 1.14.

1.15 Instrument Blank (IBLK) – The instrument blank is prepared by spiking 180 µL 96% MeOH with 10 µL of 20 ppb IS Mix and 10 µL of 20 ppb SUR Mix in an autosampler vial. Cap and vortex to mix. Alternatively, spike 864 µL of MeOH and 36 µL of water with 50 µL of IS 20ppb mix and 50 µL of SUR 20ppb; cap and vortex to mix, then aliquot into auto-sampler vial.

1.16 Method Blank (MB) – Weigh 1.0g of Ottawa sand into a pre-tared 15mL Falcon tube and spike with 110µL of 100ppb SUR mix. Extract as normal alongside client samples.

1.17 Continuing Calibration Verification/Instrument Sensitivity Check (CCV/ISC) - The CCV and the ISC are prepared in the same manner. The daily Instrument Sensitivity Check (ISC; DOD required) will be used as the daily opening CCV, and will be analyzed at both the 100ppt and 200ppt levels using prepared ICAL standards. The prepared ICAL standard at the 1000ppt level will be used as the CCV to be analyzed every ten samples and at the conclusion of the analytical run, as closing CCV. Analyte concentrations must be within +/-30% of their true values.

1.18 Laboratory Control Sample (LCS) – The LCS is prepared by spiking approximately 1g of Ottawa sand with 100 µL of 100X PDS (20 ng/mL) for a concentration of 2 µg/kg (2000 pg/g; 2000 ng/kg; 2 ng/g). The LCS is also spiked with 110 µL of Full List SUR mix (100 ppb) and extracted as normal alongside client samples.

1.19 Matrix Spike/Matrix Spike Duplicate (MS/MSD) – Client samples are spiked in the same manner as an LCS. 1g of sample is spiked with 100 µL of 100X PDS (20 ng/mL) for a concentration of 2 µg/kg, plus 110µL of Full List SUR mix (100ppb) and extracted as normal alongside other client samples.

1.20 Method Detection Limit (MDL) – MDL sample preparation and analysis will be performed over three separate days. Each MDL sample will be extracted with an equal number of MB samples. The MDL is prepared by spiking approximately 1g of Ottawa sand with 25 µL of 100X PDS mix for a concentration of 500 pg/g (500 ng/kg; 0.5 µg/kg), plus 110µL of Full List SUR mix (100ppb) and extracted as normal. An equal number of MB (see section 1.16 above) will be extracted and analyzed with MDL samples.

1.21 Initial (and Continuing) Demonstration of Capability (IDOC/CDOC) – The IDOC/CDOC is prepared by spiking approximately 1g of Ottawa sand with 100 µL 100X PDS plus 110µL of Full List SUR mix (100ppb) and extracted as normal. IDOC/CDOC sample final concentration equals 2µg/kg. Four replicates should be prepared and analyzed.

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1.22 Ammonia-Methanol (Amm-MeOH, 0.6%) – In a 1000 mL graduated cylinder, add 20 mL NH4OH (Ammonium Hydroxide) and fill to volume with methanol (980 mL reagent MeOH). Invert to mix.

2. Sample Preparation

2.1 Allow samples time to come to room temperature.

2.2 Homogenize sample with a tongue depressor and/or vigorously shake sample container to ensure sample homogeneity.

2.3 Weigh approximately 1.0 g of sample into a pre-tared 15 mL Falcon tube, record sample weight.

2.4 Spike sample aliquot with 110 µL 100ppb SUR mix; spike QC samples appropriately (LCS, MS/MSD spiked with 100 µL of 100X PDS)

2.5 Add 4 mL MeOH and 4 mL 0.6% Amm-MeOH to sample tube and cap tightly.

2.6 Place sample tubes on orbital shaker table for 30-35mins, on level 9.

2.7 Place samples in a tray and place the tray in a sonic bath at room temperature, sonicate for 30-35mins.

2.8 Remove rack from sonic bath and dry individual sample tubes before placing in a centrifuge and centrifuge at 3000RPM for 5 mins.

2.9 If centrifugation of sample does not fully separate solids from the extraction fluids, the resultant supernatant can be decanted from original sample tube into a clean centrifuge tube by pouring or using a plastic pipette. Decanting the supernatant from poorly separated extracts may help speed up the filtration process.

2.10 Place PFAS (WAX/GCB) SPE tubes, labelled for each sample, into individual active luer ports in the vacuum manifold top.

2.11 Wet rim of manifold body and place manifold top on manifold body. Start the vacuum pump and ensure that a proper seal is formed between the manifold top and body, and vacuum is at a proper level (approximately 5in. Hg).

2.12 Condition the WAX/GCB tubes by passing 3mL MeOH in a slow drop-wise fashion through the tube, allowing the conditioning solvent to fully soak the sorbent for 2 mins before passing through the cartridge; discard eluent. Do not dry WAX/GCB tubes; if a tube goes dry, restart the conditioning.

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2.13 Release vacuum and remove manifold top. Place a rack containing clean, labelled 15mL Falcon tubes in the manifold body and replace the top. Ensure that the correct luer is inserted into the corresponding falcon tube in the manifold body.

2.14 Start vacuum and ensure proper seal and vacuum are achieved.

2.15 Load decanted extracts into corresponding labelled WAX/GCB filtration tubes and begin passing the extracts through the tube in a drop-wise fashion; collect in the previously positioned clean, labelled 15mL Falcon tubes. Not all of the extract will fit at once in the tube, so be ready to load the remainder.

2.16 When the entire extract has eluted through the tube, close the stopcock to keep the tube from drying before/during the following step.

2.17 Rinse each tube with 2mL of clean MeOH, allowing the rinse solvent to fully soak the sorbent for 2 mins before passing through the cartridge (as in Sec. 2.12 above), and collect the rinsate in a slow drop-wise fashion.

2.18 Release vacuum, remove manifold top from body, and remove collection tubes. Cap tubes and invert to mix. Re-centrifuge and store at room temperature until ready to prepare autosampler vials for injection.

2.19 Add 8µL of reagent water, 10µL of IS mix, and 182µL of extract to a clean, labelled polypropylene autosampler vial. Cap and vortex thoroughly to mix. Ensure there is not an air bubble trapped at the bottom of the insert. This vial is ready for analysis.

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APPENDIX C. AQUEOUS SERIAL DILUTION

1 Standard Preparation

1.1 IS, SUR, and ICV standard solutions prepared for ID-AQ are used for samples analyzed by serial dilution instead of SPE. See Section 8 in the main body of the SOP for more information on preparation and contents of these solutions.

1.2 Dilutions of individual analyte stock standards are used for fortifying post-spike samples. Typically, these diluted stocks are prepared by a two-step serial dilution for a nominal concentration of 5ppb (some analytes have different concentrations due to differing stock concentrations). These diluted stocks are prepared by diluting 10uL of stock solution with 950uL of MeOH and 40uL of reagent water (FV=1mL), then further diluting 10uL of this initial 100X solution with 990uL of 96% MeOH, for a final dilution of 10,000X. The 10,000X DIL stock solution will typically be used for fortifying post-spike samples.

1.3 ICALs, ICAL standards, and instrument QC (CCVs, IBLKs) are the same as for ID-AQ and all acceptance criteria used for ID-AQ applies.

1.4 Samples analyzed by serial dilution do not require an LCS or MB to be prepared alongside the samples, as no extraction is performed. Daily IBLKs take the place of MBs.

2 Sample Preparation – Samples of known high PFAS concentrations can be prepared by serial dilution instead of SPE, with documented project approval.

2.1 All solutions prepared for instrumental analysis in this section and Section 3 shall have a solvent composition of 96:4% MeOH:water.

2.2 An initial dilution of the sample is made up with no IS or SUR added, to be used as the base dilution for successive serial dilutions. This initial dilution is typically prepared at 100X.

2.3 Using the initial sample dilution, prepare a high dilution (e.g. 50,000X) and analyze it to determine the approximate concentration of target analytes in the samples. Use the information obtained from this analysis to determine the next serial dilution to be prepared. Be sure to include IS and SUR standards at the appropriate concentration in each analyzed serial dilution. IS/SUR compounds should typically be present at a concentration of 1000pg/mL (1ppb).

2.4 Prepare successively lower dilutions of each serial dilution sample until all target analytes fail for over-range detection, IS response being out of acceptance, and/or SUR recovery being out of acceptance. Use the Non-Extracted Method PFAS Serial Dilution Prep Log and Post-spike Log (ME002DR) to record dilution and post-spike preparations. Be sure to include IS and SUR standards at the appropriate concentration in each analyzed serial dilution. No serial dilution samples will be analyzed at a dilution below 25X, in order to maintain proper solvent composition in the analyzed sample.

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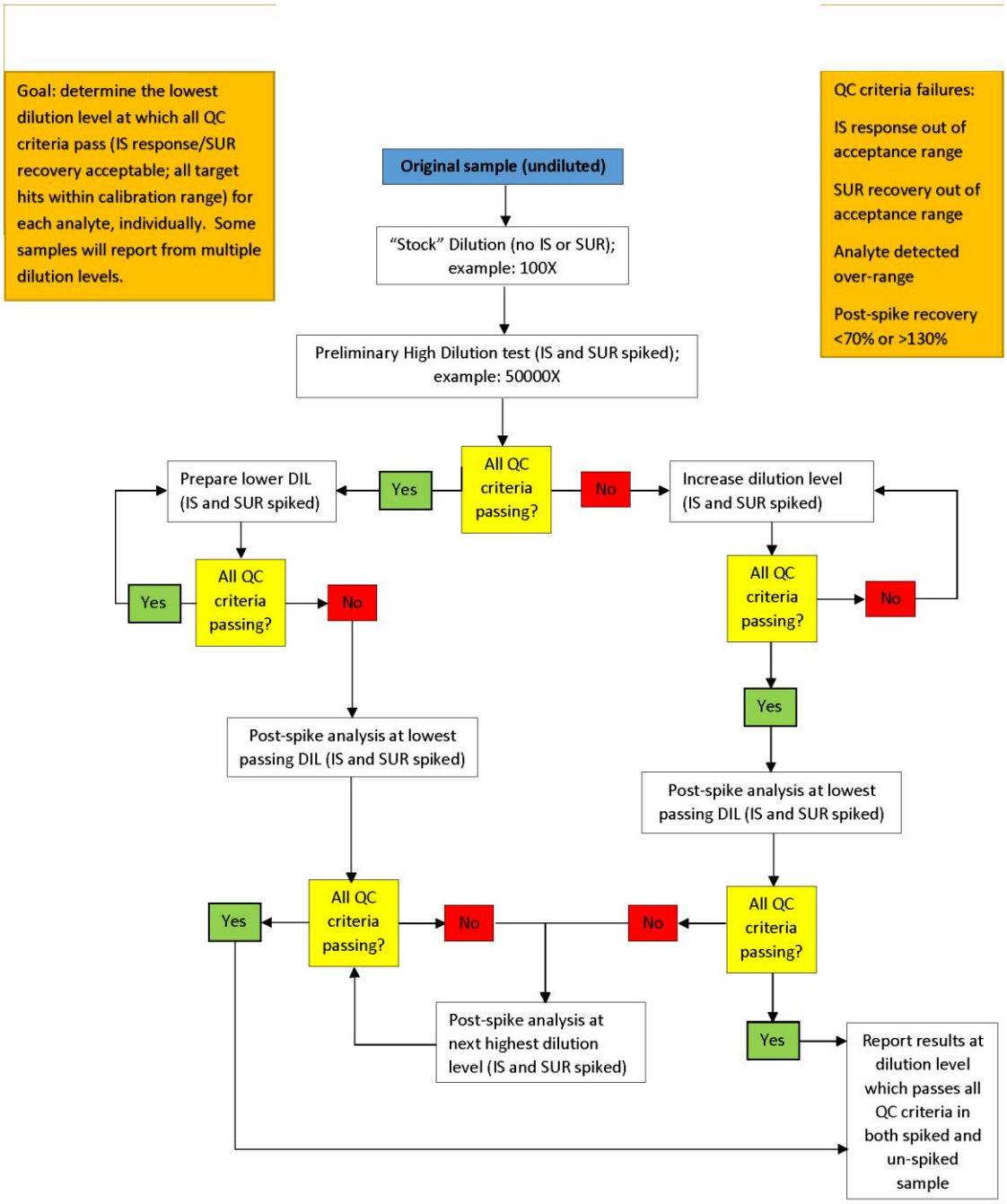
NOTE: Each target analyte should be evaluated individually in each serial dilution preparation. Associated IS/SUR compounds must pass acceptance criteria for an individual analyte to be reported. If the associated SUR and/or IS for one compound fails in a dilution sample, but *any* others pass, further dilution analysis will be necessary. Once a dilution level is reached in which all targets fail for one of the above-stated reasons, analysis will begin on the post-spiked samples.

2.5 For each target analyte, determine the dilution level at which the sample fails for one of the reasons stated in Section 2.4. The corresponding post-spike sample should be prepared at the next highest dilution level; in other words, determine the lowest dilution level at which a target analyte and its corresponding IS/SUR pass and prepare post-spike samples beginning at that dilution level.

TEST METHOD STANDARD OPERATING PROCEDURE
TITLE: Determination of Per- and Polyfluoroalkyl Substances (PFAS) by LC/MS/MS (Isotope Dilution)
METHOD: QSM 5.3 Table B-15 [All but New Jersey]
ISSUER: Pace ENV - Local Quality - WCOL

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Serial Dilution Decision Tree



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3 Post-spike sample preparation – Post-spike samples must be prepared for all serial dilution samples which are ND for any target analyte at the reported dilution level. Non-detected target analytes will be individually spiked into post-spike dilution preparations at an expected on-column concentration equal to the stated LOQ in order to validate the stated LOQ in the sample matrix. If an analyte is detected in a reportable dilution, no post-spiking of that analyte is required; the LOQ will equal the stated LOQ times the dilution factor of the reported analysis.

3.1 Post-spike samples must be prepared at the same dilution level as the reported sample results, and spiked at a concentration equivalent to the LOQ in the diluted sample. Post-spike analysis shall be prepared and evaluated for EACH non-detected analyte in EACH sample.

3.2 Calculate the appropriate amount of 10000X DIL stock solution necessary for the post-spike preparation by using the following equation:

$$\text{Spike Volume (mL)} = \frac{\text{LOQ(pg/mL)} * \text{final volume(mL)}}{\text{DIL stock(pg/mL)}}$$

3.3 Calculate the appropriate amount of 20ppb SUR and 20ppb IS necessary for the post-spike preparation by using the following equation:

$$\text{Spike Volume (mL)} = \frac{\text{1000(pg/mL)} * \text{final volume(mL)}}{\text{20000(pg/mL)}}$$

3.4 Prepare post-spikes at the reported dilution level for all ND analytes and record all post-spike preparation information using ME002DR. Use this logbook to ensure final volumes are correct and that all post-spike samples have solvent concentrations of 96% MeOH.

3.4.1 The analyte post-spiked into the dilution preparation must recover within 70-130% in order to be acceptable/reportable. All other QC criteria must be met as well (IS, SUR passing; opening/closing CCVs passing; acceptable IBLK).

3.4.2 Only the target analyte(s) being spiked and its corresponding IS/SUR must pass for each individual post-spike sample to be acceptable.

3.4.3 If a spiked analyte does not meet the 70-130% recovery limit, re-prepare the post-spike sample at successively higher dilutions using the steps above until recovery is within acceptance limits and corresponding IS/SUR compounds pass.

3.5 When a post-spike sample passes recovery and other QC criteria for the specific analyte(s) spiked, post-spiking analysis is complete for that sample/analyte combination.

3.6 The dilution reported for any individual analyte shall be the same dilution at which the post-spike sample passes for that analyte. If the initial post-spike sample fails when prepared at the expected reportable sample dilution, the LOQ has not been validated for this dilution level. Therefore, the reported dilution for that analyte/sample will be elevated to match the lowest passing dilution level of the post-spike analysis.

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Report analyte results from the lowest dilution level which passes for all sample and post-spike QC criteria. The LOQ for ND analytes will equal the stated LOQ times the reported dilution factor.

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APPENDIX D: Aqueous Sample Centrifugation Protocol

1. Preliminary considerations – The DoD QSM5.3, Table B-15, states that "[aqueous] samples with >1% solids may require centrifugation prior to SPE extraction." Additionally, the Wisconsin Department of Natural Resources (WDNR) guidance document, titled "Wisconsin PFAS Aqueous (Non-Potable Water) and Non-Aqueous Matrices Method Expectations," states "add the EIS [Extracted Internal Standard] before any extraction, centrifuging, filtering or phase separation takes place…Samples should only be centrifuged when the suspended solids content appears visually high enough, by chemist inspection, that it would cause the SPE cartridge to clog…It is expected that the solid phase remains in the container when rinsing the container walls with the polar elution solvent. Rinsing the container walls would therefore also include rinsing of the solids. If removing the solvent disrupts the solid phase significantly, the container can be centrifuged again before removing the solvent for use during the elution step of the SPE procedure…When the sample has significant solids, the laboratory should account for the weight or volume displaced by the solids in the initial sample volume determination…One or more rinses of polar solvent can be used for quantitative transfers. Rinse the sample bottle and cap with elution solvent, pour the solvent from each rinse through the SPE cartridge during the elution step, and collect the filtrate for analysis. Bring to a quantitative final volume with the final injection solvent and vortex well." Whether or not an individual sample will require centrifugation for proper preparation will be determined and documented by the preparation analyst.

2. Procedure:

   2.1 Inspect the sample and consider the necessity of centrifuging. Consider any visible indications of particulate matter including settled solids collected on the bottom of the container, cloudiness and/or dark color of the sample, suspended solids within the sample, increased viscosity, etc. If uncertain, seek a second opinion from another analyst, supervisor, or operations director.

   2.2 If, in the judgement of the preparation analyst, a sample requires centrifugation the analyst will contemporaneously make a note on the prep batch log indicating this fact.

   2.3 Spike samples requiring centrifugation in the same manner and with the same standard volume as samples which will not be centrifuged.

   2.4 Label a 500mL conical centrifuge bottle with the sample ID for each sample that will be centrifuged. Set them in an appropriate rack with the caps removed.

   2.5 Vigorously shake the spiked sample and then quickly pour into the labeled centrifuge bottle. Try to ensure that the original sample bottle is devoid of any solid material. Be careful to avoid spilling sample during the transfer process. Tightly cap each centrifuge bottle after transfers are complete.

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2.6 Transfer capped centrifuge bottles to centrifuge, ensuring that the centrifuge carousel is symmetrically balanced. Close top and centrifuge at 3000 RPM for 6 minutes.

2.7 Remove centrifuge bottles and decant the centrifuged liquid off of the condensed solids, back into the original sample bottle. Try to avoid transferring any of the condensed solids from the centrifuge bottle back to the original sample bottle, while maximizing the amount of liquid decanted off of the solid portion.

2.8 Extract the decanted sample as normal alongside un-centrifuged samples, up to the bottle rinse and elution steps.

2.9 When the SPE cartridges have been dried, rinse the original sample bottle as normal. Additionally, add 4mL of Methanol (MeOH) to each centrifuge bottle to rinse the inside of the centrifuge bottles as well as the cap. If the condensed solids become re-suspended while rinsing the centrifuge bottles, re-centrifugation may be required. Using a transfer pipet or mechanical pipet, transfer the MeOH rinse from the centrifuge bottle into the SPE cartridge and elute with the original sample bottle rinse into a 15mL conical centrifuge tube.

Note: If any samples in a prep batch have been centrifuged, all sample extracts in the batch should be eluted into 15mL conical centrifuge tubes, as the standard centrifuge tubes typically used to collect the eluent are shorter than the 15mL conical tubes. This may cause loss of extract during elution due to the tips of the male luers on the underside of the manifold not actually being located within the top of the shorter (standard) centrifuge tubes during elution.

2.10 Add an additional volume of MeOH to the elution of all batch QC samples (MB/LCS/LCSD) to match the volume used for elution for any centrifuged sample in the prep batch. Typically, this will mean that 4mL of clean MeOH will be added directly to the SPE reservoir and eluted with the normal bottle rinses.

Batch QC and client samples with additional container rinse volume should be filtered as normal through GCB cleanup cartridges.

2.11 Following filtration, all samples (client and QC) with extract final volumes in excess of the standard 10mL shall be concentrated to an approximate volume of 9.5mL using the TuborVap LV. Water bath temperature should be 60-65°C; nitrogen gas flow should be set to an appropriate rate to avoid losing liquid extract out of the top of the elution tube due to splash out from excessive gas flow, while still creating a vortex within the extract. Suggested evaporation gas flow rate setting is 1.0L/min for extracts with 14mL final volume (FV), but evaporation gas flow rate can be adjusted per analyst discretion, as long as extract loss/splash-out is avoided.

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2.12 Once the sample has been concentrated to approximately 9.5mL, remove elution tube from the TurboVap and allow to cool to room temperature.

2.13 Once cooled, bring the sample extract to a final volume of 10mL with MeOH, using a disposable transfer pipet. Use a reference 15mL conical centrifuge tube containing a pre-measured 10mL volume of MeOH to verify the final extract reconstitution volume. Record data regarding the extract concentration steps on the prep batch sheet, including evaporator ID, water bath temperature, evaporation gas flow rate, lot of MeOH and pipets used for reconstitution

2.14 After reconstituting to 10mL FV, cap and invert elution tubes. Transfer to extract storage bottles (8mL HDPE Nalgene bottles). Analyze as normal alongside un-centrifuged samples.

2.15 Generate a Non-Conformance Memo (NCM) noting which samples in the prep batch included centrifugation in the extraction process and any additional observations and/or deficiencies that were noted during the centrifugation process.

TEST METHOD STANDARD OPERATING PROCEDURE
TITLE: Determination of Per- and Polyfluoroalkyl Substances (PFAS) by LC/MS/MS (Isotope Dilution)
METHOD: QSM 5.3 Table B-15 [All but New Jersey]
ISSUER: Pace ENV - Local Quality - WCOL

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APPENDIX E. EXTRACT DILUTION PREPARATIONS

	Document Name: Extraction Dilution Preparations	Document Revised: 3/19/2021 Page 1 of 1
	Document No.: ME003.IZ-02	Issuing Authority: Pace ENV – Local Quality - WCOL

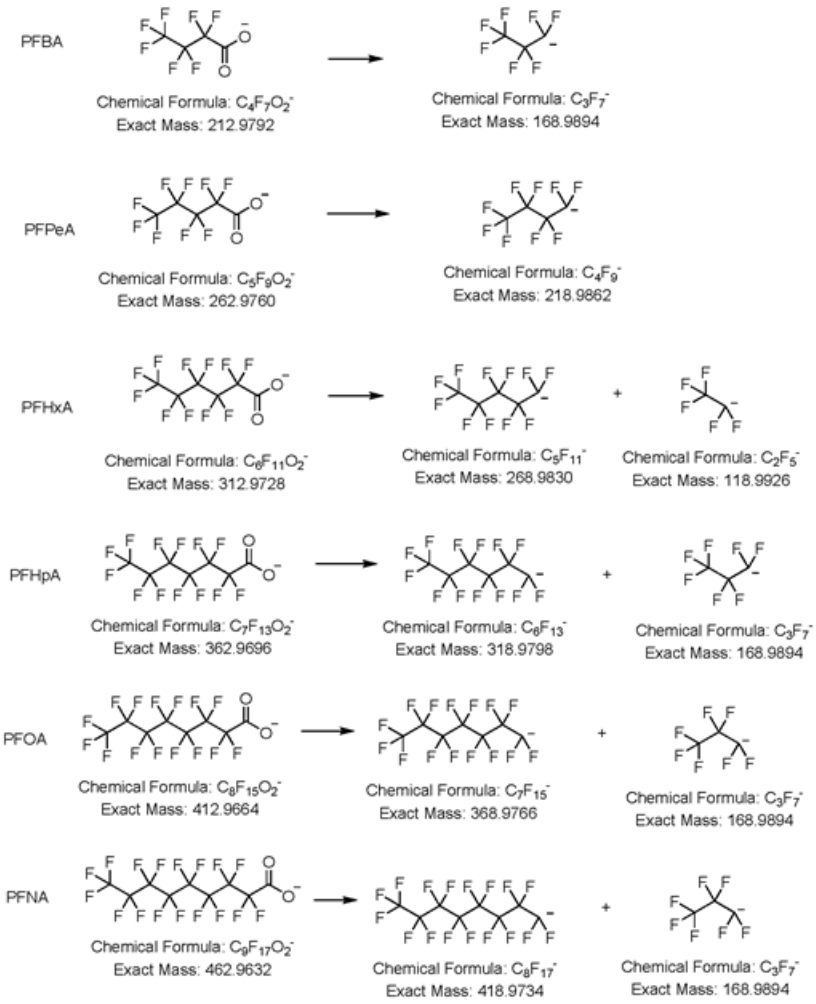
Extract Dilution Preparations

537	1X	5X	10X	20X	50X	100X	200X
EXTRACT (µL)	950	200	100	50	20	10	5
IS (µL)	50	40	45	47.5	49	49.5	49.75
96% MeOH (µL)	-	760	855	902.5	931	940.5	945.25
TOTAL (µL)	1000	1000	1000	1000	1000	1000	1000
ID Aq/ID-S	1X	5X	10X	20X	50X	100X	200X
EXTRACT (µL)	182	200	100	50	20	10	5
IS (µL)	10	50	50	50	50	50	50
ES (µL)	0	40	45	47.5	49	49.5	49.75
MeOH (µL)	0	674	769	816.5	845	854.5	859.25
WATER (µL)	8	36	36	36	36	36	36
TOTAL (µL)	200	1000	1000	1000	1000	1000	1000
In-vial 50X ID Screen **(Not for reporting purposes)**		186 (µL) 96%MeOH	+	10(µL) SUR	+	4(µL) sample extract	
DAI	1X	5X	10X	20X	50X	100X	
SAMPLE (µL)	700	140	70	35	14	7	
ES (µL)	25	25	25	25	25	25	
MeOH (µL)	275	275	275	275	275	275	
Water (µL)	0	560	630	665	686	693	
TOTAL (µL)	1000	1000	1000	1000	1000	1000	
533	1X	5X	10X	20X	50X	100X	200X
EXTRACT (µL)	950	200	100	50	20	10	5
IS (µL)	50	40	45	47.5	49	49.5	49.75
ES (µL)	0	40	45	47.5	49	49.5	49.75
80% MeOH (µL)	0	720	810	855	882	891	895.5
TOTAL (µL)	1000	1000	1000	1000	1000	1000	1000

NOTE: Serial dilution will be performed for dilutions higher than 200X.

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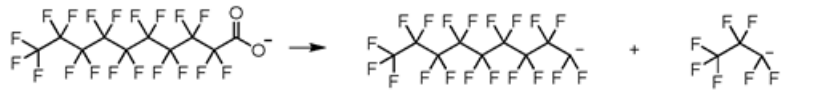
APPENDIX F. CHEMICAL DERIVATION OF ION TRANSITIONS



TEST METHOD STANDARD OPERATING PROCEDURE
TITLE: Determination of Per- and Polyfluoroalkyl Substances (PFAS) by LC/MS/MS (Isotope Dilution)
METHOD: QSM 5.3 Table B-15 [All but New Jersey]
ISSUER: Pace ENV - Local Quality - WCOL

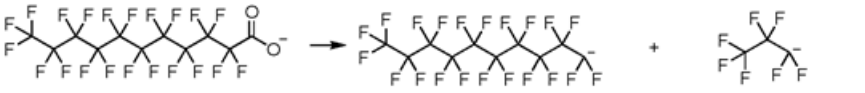
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PFDA



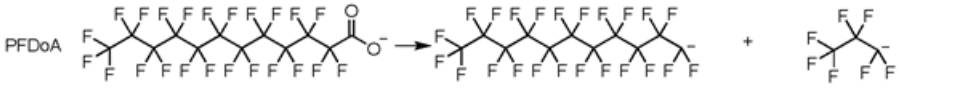
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PFUnA



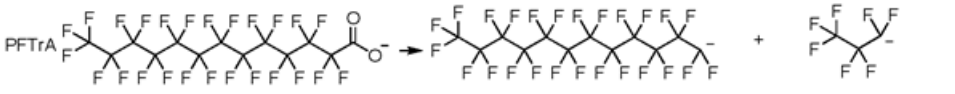
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PFDoA



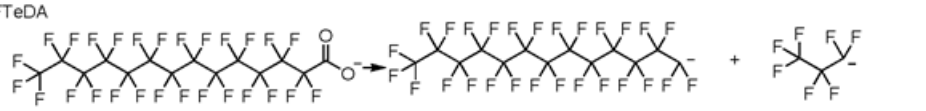
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PFTrA



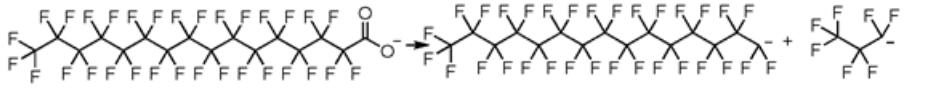
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PFTeDA



Chemical Formula: $C_{14}F_{27}O_2^-$ Exact Mass: 712.9473 | Chemical Formula: $C_{13}F_{27}^-$ Exact Mass: 668.9574 | Chemical Formula: $C_3F_7^-$ Exact Mass: 168.9894

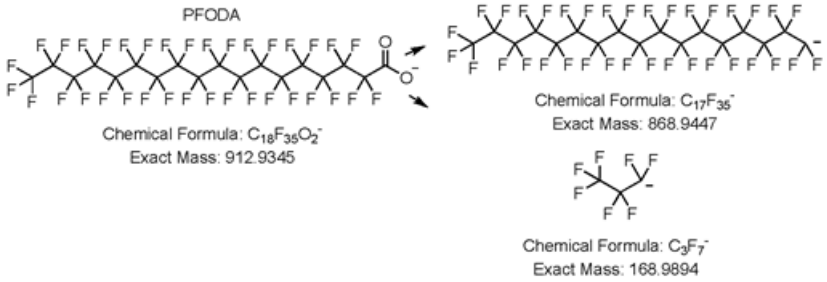
PFHxDA



Chemical Formula: $C_{16}F_{31}O_2^-$ Exact Mass: 812.9409 | Chemical Formula: $C_{15}F_{31}^-$ Exact Mass: 768.9510 | Chemical Formula: $C_3F_7^-$ Exact Mass: 168.9894

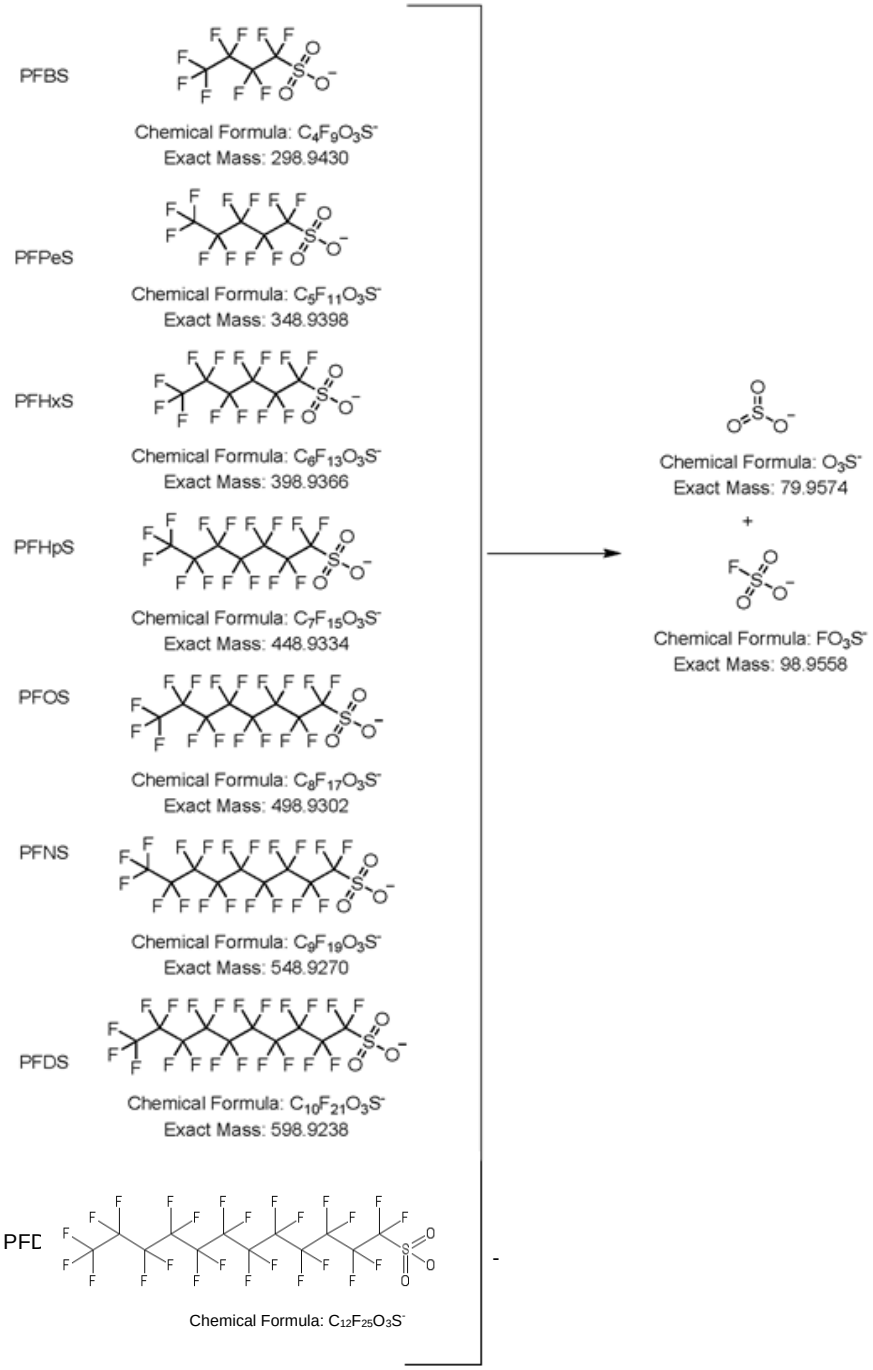
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TITLE: Determination of Per- and Polyfluoroalkyl Substances (PFAS) by LC/MS/MS (Isotope Dilution)
METHOD: QSM 5.3 Table B-15 [All but New Jersey]
ISSUER: Pace ENV - Local Quality - WCOL

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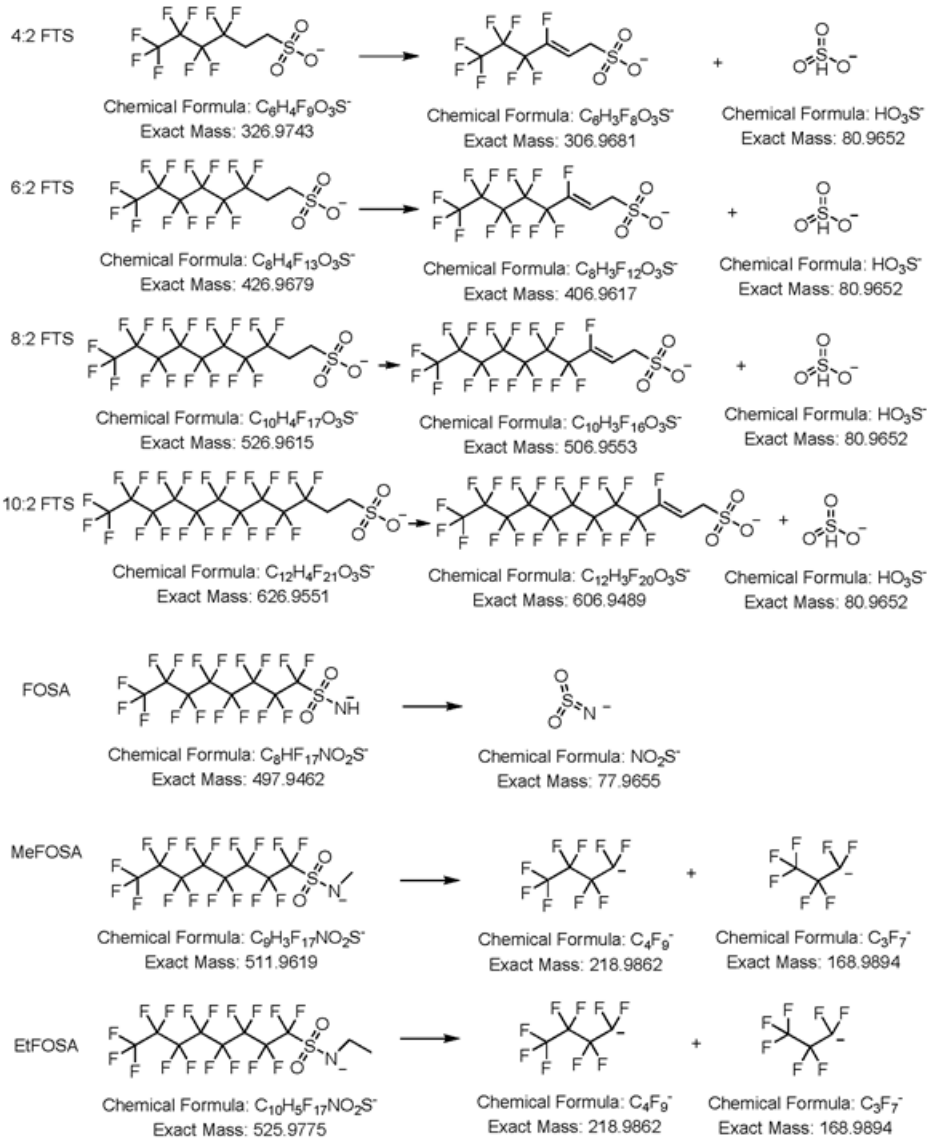
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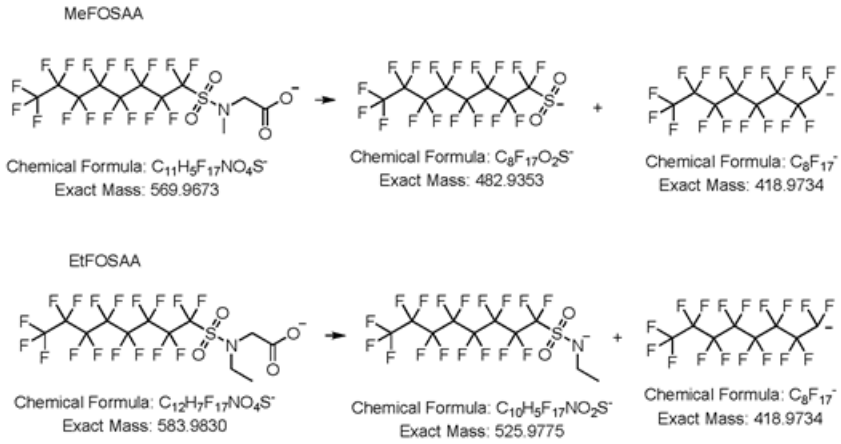
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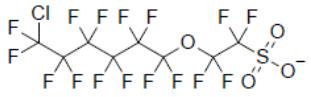
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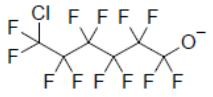


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9Cl-PF3ONS

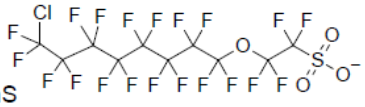


Molecular Formula: $C_8ClF_{16}O_4S^-$
Monoisotopic Mass: 530.895581 Da

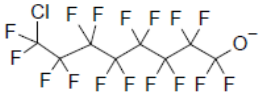


Molecular Formula: $C_6ClF_{12}O^-$
Monoisotopic Mass: 350.945154 Da

11Cl-PF3OUnS

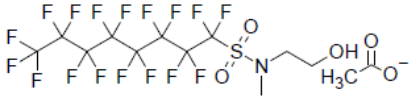


Molecular Formula: $C_{10}ClF_{20}O_4S^-$
Monoisotopic Mass: 630.889194 Da



Molecular Formula: $C_8ClF_{16}O^-$
Monoisotopic Mass: 450.938767 Da

MeFOSE
Acetate Adduct

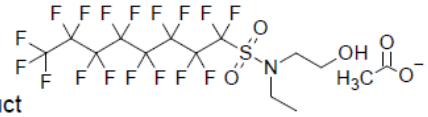


Molecular Formula: $C_{13}H_{11}F_{17}NO_5S^-$
Monoisotopic Mass: 616.009195 Da



Molecular Formula: $C_2H_3O_2^-$
Monoisotopic Mass: 59.013853 Da

EtFOSE
Acetate Adduct

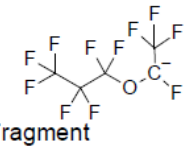


Molecular Formula: $C_{14}H_{13}F_{17}NO_5S^-$
Monoisotopic Mass: 630.024846 Da

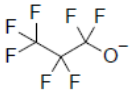


Molecular Formula: $C_2H_3O_2^-$
Monoisotopic Mass: 59.013853 Da

GenX HFPO-DA
-CO2 In-Source Fragment



Molecular Formula: $C_5F_{11}O^-$
Monoisotopic Mass: 284.977898 Da



Molecular Formula: $C_3F_7O^-$
Monoisotopic Mass: 184.984286 Da

+



Molecular Formula: $C_2F_5^-$
Monoisotopic Mass: 118.992565 Da

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APPENDIX G: DOD/DOE QSM REQUIREMENTS

Sections found in this appendix replace and/or supplement the existing sections of the SOP. These requirements must be met when analyzing samples for the Department of Defense, as stipulated in the DOD Quality System Manual.

Table B-15. Per- and Polyfluoroalkyl Substances (PFAS) Using Liquid Chromatography Tandem Mass Spectrometry (LC/MS/MS) With Isotope Dilution or Internal Standard Quantification in Matrices Other Than Drinking Water

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Aqueous Sample Preparation	Each sample and associated batch QC samples.	Solid Phase Extraction (SPE) must be used unless samples are known to contain high PFAS concentrations (e.g., Aqueous Film Forming Foam (AFFF) formulations). 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.	NA.	Samples with > 1% solids may require centrifugation prior to SPE extraction. Pre-screening of separate aliquots of aqueous samples is recommended.
Solid Sample Preparation	Each sample and associated batch QC samples.	Entire sample received by the laboratory must be homogenized prior to subsampling.	NA.	NA.	NA.
Biota Sample Preparation	Each sample and associated batch QC samples.	Sample prepared as defined by the project (e.g., whole fish versus filleted fish).	NA.	NA.	NA.

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Table B-15. Per- and Polyfluoroalkyl Substances (PFAS) Using Liquid Chromatography Tandem Mass Spectrometry (LC/MS/MS) With Isotope Dilution or Internal Standard Quantification in Matrices Other Than Drinking Water

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
AFFF and AFFF Mixture Samples Preparation	Each sample and associated batch QC samples.	Each field sample must be prepared in duplicate (equivalent to matrix duplicate). Serial dilutions must be performed to achieve the lowest LOQ possible for each analyte.	NA.	NA.	Adsorption onto bottle is negligible compared to sample concentration so subsampling is allowed. Multiple dilutions will most likely have to be reported in order to achieve the lowest LOQ possible for each analyte.
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.	Flagging is not appropriate.	Cleanup should reduce bias from matrix interferences.
Mass Calibration	Instrument must have a valid mass calibration prior to any sample analysis. Mass calibration is verified after each mass calibration, prior to initial calibration (ICAL).	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.	If the mass calibration fails, then recalibrate. If it fails again, consult manufacturer instructions on corrective maintenance.	Flagging is not appropriate.	Problem must be corrected. No samples may be analyzed under a failing mass calibration. The mass calibration is updated on an as-needed basis (e.g., QC failures, ion masses fall outside of the ±0.5 amu of the true value, major instrument maintenance is performed, or the instrument is moved).

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Table B-15. Per- and Polyfluoroalkyl Substances (PFAS) Using Liquid Chromatography Tandem Mass Spectrometry (LC/MS/MS) With Isotope Dilution or Internal Standard Quantification in Matrices Other Than Drinking Water

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Mass Spectral Acquisition Rate	Each analyte, Extracted Internal Standard (EIS) Analyte.	A minimum of 10 spectra scans are acquired across each chromatographic peak.	NA.	Flagging is not appropriate.	NA.
Calibration, Calibration Verification, and Spiking Standards	All analytes.	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.	Flagging is not appropriate.	Standards containing both branched and linear isomers are to be used during method validation and when reestablishing retention times, to ensure the total response is quantitated for that analyte. Technical grade standards cannot be used for quantitative analysis.

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Table B-15. Per- and Polyfluoroalkyl Substances (PFAS) Using Liquid Chromatography Tandem Mass Spectrometry (LC/MS/MS) With Isotope Dilution or Internal Standard Quantification in Matrices Other Than Drinking Water

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
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. In-house acceptance criteria for evaluation of ion ratios must be used and must not exceed 50-150%. Signal to Noise Ratio (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).	NA.	PFAS identified with Ion ratios that fail acceptance criteria must be flagged. Any quantitation ion peak that does not meet the maximization criteria shall be included in the summed integration and the resulting data flagged as "estimated, biased high".	For example: Ion Ratio = (quant ion abundance/ confirm ion abundance) Calculate the average ratio (A) and standard deviation (SD) using the ICAL standards. An acceptance range of ratio could be within A ±3SD for confirmation of detection.

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Table B-15. Per- and Polyfluoroalkyl Substances (PFAS) Using Liquid Chromatography Tandem Mass Spectrometry (LC/MS/MS) With Isotope Dilution or Internal Standard Quantification in Matrices Other Than Drinking Water

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Ion Transitions (Precursor-> Product)	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 NEtFOSAA: 584 → 419 NMeFOSAA: 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.	Flagging is not appropriate	NA.

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Table B-15. Per- and Polyfluoroalkyl Substances (PFAS) Using Liquid Chromatography Tandem Mass Spectrometry (LC/MS/MS) With Isotope Dilution or Internal Standard Quantification in Matrices Other Than Drinking Water

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Initial Calibration (ICAL)	At instrument set-up and after ICV or CCV failure, prior to sample analysis.	The isotopically labeled analog of an analyte (Extracted Internal Standard 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 Extracted Internal Standard 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. *(continued next page)*	Correct problem, then repeat ICAL.	Flagging is not appropriate.	No samples shall be analyzed until ICAL has passed. External Calibration is not allowed for any analyte. Calibration can be linear (minimum of 5 standards) or quadratic (minimum of 6 standards); weighting is allowed.

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Table B-15. Per- and Polyfluoroalkyl Substances (PFAS) Using Liquid Chromatography Tandem Mass Spectrometry (LC/MS/MS) With Isotope Dilution or Internal Standard Quantification in Matrices Other Than Drinking Water

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Initial Calibration (ICAL) *(Continued)*		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 non-linear calibrations must have $r^2 \geq 0.99$ for each analyte.			
Retention Time window position establishment	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.	NA.	Calculated for each analyte and EIS.
Retention Time (RT) window width	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.	NA.	Calculated for each analyte and EIS.

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Table B-15. Per- and Polyfluoroalkyl Substances (PFAS) Using Liquid Chromatography Tandem Mass Spectrometry (LC/MS/MS) With Isotope Dilution or Internal Standard Quantification in Matrices Other Than Drinking Water

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Instrument Sensitivity Check (ISC)	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.	Flagging is not appropriate.	No samples shall be analyzed until ISC has met acceptance criteria. ISC can serve as the initial daily CCV.
Initial Calibration Verification (ICV)	Once after each ICAL, analysis of a second source standard prior to sample analysis.	Analyte concentrations must be within ±30% of their true value.	Correct problem, rerun ICV. If problem persists, repeat ICAL.	Flagging is not appropriate.	No samples shall be analyzed until calibration has been verified.
Continuing Calibration Verification (CCV)	Prior to sample analysis, after every 10 field samples, and at the end of the analytical sequence.	Concentration of analytes must range from the LOQ to the mid-level calibration concentration. Analyte concentrations must be within ±30% of their true value.	Immediately analyze two additional consecutive CCVs. If both pass, samples may be reported without reanalysis. If either fails, or if two consecutive CCVs cannot be run, perform corrective action(s) and repeat CCV and all associated samples since last successful CCV. Alternately, recalibrate if necessary; then reanalyze all associated samples since the last acceptable CCV.	If reanalysis cannot be performed, data must be qualified and explained in the Case Narrative. Apply Q-flag to all results for the specific analyte(s) in all samples since the last acceptable calibration verification.	Results may not be reported without valid CCVs. Instrument Sensitivity Check (ISC) can serve as a bracketing CCV.

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Table B-15. Per- and Polyfluoroalkyl Substances (PFAS) Using Liquid Chromatography Tandem Mass Spectrometry (LC/MS/MS) With Isotope Dilution or Internal Standard Quantification in Matrices Other Than Drinking Water

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Instrument Blanks	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.	Flagging is only appropriate in cases when the sample cannot be reanalyzed and when there is no more sample left.	No samples shall be analyzed until instrument blank has met acceptance criteria. Note: Successful analysis following the highest standard analyzed determines the highest concentration that carryover does not occur. When the highest standard analyzed is not part of the calibration curve, it cannot be used to extend out the calibration range, it is used only to document a higher concentration at which carryover still does not occur.

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Table B-15. Per- and Polyfluoroalkyl Substances (PFAS) Using Liquid Chromatography Tandem Mass Spectrometry (LC/MS/MS) With Isotope Dilution or Internal Standard Quantification in Matrices Other Than Drinking Water

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Extracted Internal Standard (EIS) Analytes	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. Extracted Internal Standard 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.	Correct problem. If required, re-extract and reanalyze associated field and QC samples. If recoveries are acceptable for QC samples, but not field samples, the field samples must be re-extracted and analyzed (greater dilution may be needed). Samples may be re-extracted and analyzed outside of hold times, as necessary for corrective action associated with QC failure.	Apply Q-flag and discuss in the Case Narrative only if reanalysis confirms failures in exactly the same manner.	Failing analytes shall be thoroughly documented in the Case Narrative. EIS should be 96% (or greater) purity. When the impurity consists of the unlabeled analyte, the EIS can result in a background artifact in every sample, standard and blank, if the EIS is fortified at excessive concentrations.
Method Blank (MB)	One per preparatory batch.	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 re-extracted and analyzed outside of hold times, as necessary for corrective action associated with QC failure. Examine the project-specific requirements. Contact the client as to additional measures to be taken.	If reanalysis cannot be performed, data must be qualified and explained in the Case Narrative. Apply B-flag to all results for the specific analyte(s) in all samples in the associated preparatory batch.	Results may not be reported without a valid MB. Flagging is only appropriate in cases where the samples cannot be reanalyzed.

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Table B-15. Per- and Polyfluoroalkyl Substances (PFAS) Using Liquid Chromatography Tandem Mass Spectrometry (LC/MS/MS) With Isotope Dilution or Internal Standard Quantification in Matrices Other Than Drinking Water

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Laboratory Control Sample (LCS)	One per preparatory batch.	Blank spiked with all analytes at a concentration ≥ LOQ and ≤ the mid-level calibration concentration. A laboratory must use the DoD/DOE QSM Appendix C Limits for batch control if project limits are not specified. If the analyte(s) are not listed, use in-house LCS limits if project limits are not specified.	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 re-extracted and analyzed outside of hold times, as necessary for corrective action associated with QC failure. Examine the project-specific requirements. Contact the client as to additional measures to be taken.	If reanalysis cannot be performed, data must be qualified and explained in the Case Narrative. Apply Q-flag to specific analyte(s) in all samples in the associated preparatory batch.	Results may not be reported without a valid LCS. Flagging is only appropriate in cases where the samples cannot be reanalyzed.
Matrix Spike (MS)	One per preparatory batch. Not required for aqueous samples prepared by serial dilution instead of SPE.	Sample spiked with all analytes at a concentration ≥ LOQ and ≤ the mid-level calibration concentration. A laboratory must use the DoD/DOE QSM Appendix C Limits for batch control if project limits are not specified. If the analyte(s) are not listed, use in-house LCS limits if project limits are not specified.	Examine the project-specific requirements. Contact the client as to additional measures to be taken.	For the specific analyte(s) in the parent sample, apply J-flag if acceptance criteria are not met and explain in the Case Narrative.	For matrix evaluation only. If MS results are outside the limits, the data shall be evaluated to determine the source(s) of difference (i.e., matrix effect or analytical error).

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Table B-15. Per- and Polyfluoroalkyl Substances (PFAS) Using Liquid Chromatography Tandem Mass Spectrometry (LC/MS/MS) With Isotope Dilution or Internal Standard Quantification in Matrices Other Than Drinking Water

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Matrix Spike Duplicate (MSD) or Matrix Duplicate (MD)	For MSD: One per preparatory batch. For MD: Each aqueous sample prepared by serial dilution instead of SPE.	For MSD: Sample spiked with all analytes at a concentration ≥ LOQ and ≤ the mid-level calibration concentration. A laboratory must use the DoD/DOE QSM Appendix C Limits for batch control if project limits are not specified. If the analyte(s) are not listed, use in-house LCS limits if project limits are not specified. RPD ≤ 30% (between MS and MSD or sample and MD).	Examine the project-specific requirements. Contact the client as to additional measures to be taken.	For the specific analyte(s) in the parent sample, apply J-flag if acceptance criteria are not met and explain in the Case Narrative.	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 ≥ LOQ. The MD is a second aliquot of the field sample that has been prepared by serial dilution.
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 all analytes reported as < LOQ into the dilution that the result for that analyte is reported from. The spike must be at the LOQ concentration to be reported for this sample as < LOQ. When analyte concentrations are calculated as < LOQ, the post spike for that analyte must recover within 70-130% of its true value.	When analyte concentrations are calculated as < LOQ, and the spike recovery does not meet the acceptance criteria, the sample, sample duplicate, and post spike sample must be reanalyzed at consecutively higher dilutions until the criteria is met.	Flagging is not appropriate.	When analyte concentrations are calculated as < LOQ, results may not be reported without acceptable post spike recoveries.

Document Information

Document Number: ME0012X **Revision: -22**

Document Title: GC/MS Volatiles Analysis

Department(s): |Volatiles|

Date Information

Effective Date: Thursday, September 23, 2021

Notes

Document Notes:

All Dates and Times are in Eastern Standard Time Zone.

Signature Manifest

Document Number: ME0012X **Revision:** -22

Title: GC/MS Volatiles Analysis

All dates and times are in Eastern Standard Time Zone.

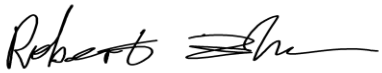
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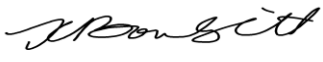
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1.0 Scope and Application

This standard operating procedure (SOP) describes the laboratory procedure for the determination of volatile organic compounds by Gas Chromatography/Mass Spectrometry.

This method is based upon SW-846 8260B. In addition, this method meets the requirements outlined in SW-846 8260C, SW-846 8260D, Standard Methods 6200 B-2011 and for analysis of wastewater following EPA Method 624.1. Refer to the appendices at the end of the SOP for 624.1, SM6200 B-2011,8260C and 8260D requirements. Refer to Table A-I for the list of compounds applicable for this method. Additional compounds may be amenable to this method. If non-standard analytes are required, they must be validated by the procedures described in Section 11.4.1.2 before sample analysis.

M-xylene cannot be separated from p-xylene by the conditions specified in this method.

Note: Numerous reference methods are covered under this SOP, the current practice will be in most cases to follow the most stringent criteria.

1.1 Target Analyte List and Limits of Quantitation (LOQ)

The limit of quantitation (LOQ) for determining an individual compound is approximately 5.0 µg/Kg (wet weight) for low level soil/sediment samples, 250 µg/kg for high level soil/sediment, 2500 µg/kg for wastes (dependent of matrix), and 5.0 µg/L for aqueous samples. Some compounds have higher reporting limits. For projects requiring lower LOQs, Shealy can supply a lower calibration that will reach as low as 0.5 µg/L for most compounds. The target analytes and the standarde LOQ that can be achieved with this procedure are provided in Table A-I, Appendix A.

LOQ are established in accordance with Pace policy and SOPs for method validation and for the determination of detection limits (DL) and quantitation limits (LOQ). DL and LOQ are routinely verified and updated when needed. The current LOQ for each target analyte that can be determined by this SOP as of the effective date of this SOP is provided in Table 1, Appendix A.

The reporting limit (RL) is the value to which analytes are reported as detected or not detected in the final report. When the RL is less than the lower limit of quantitation (LLOQ), all detects and non-detects at the RL are qualitative. The LLOQ is the lowest point of the calibration curve used for each target analyte.

DL, LOQ, and RL are always adjusted to account for actual amounts used and for dilution.

1.2 Applicable Matrices

This method is applicable to the determination of the concentration of volatile organic compounds in solid, non-aqueous, and aqueous matrices

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2.0 Summary of Method

Volatile compounds are purged by helium gas from aqueous and soil/sediment samples and concentrated onto a trap. The trap is then heated rapidly, and all the volatile compounds are transferred into GC inlet and analyzed by GC/MS. Qualitative identification of the target compounds is performed using the retention time and the relative abundance of characteristic ions. Quantitative analysis is performed using the internal standard technique with a single characteristic ion.

3.0 Interferences

3.1 Method interferences may be caused by contaminants in solvents, reagents, glassware, and other processing apparatus that lead to discrete artifacts. All of these materials must be routinely demonstrated to be free from interferences under conditions of the analysis by running laboratory method blanks as described in the Quality Control section. Raw GC/MS data from all blanks, samples, and spikes must be evaluated for interferences. If interference is detected, it is necessary to determine if the source of interference is in the preparation and/or cleanup of the samples; then take corrective action to eliminate the problem.

3.2 Volatile preparation and analysis should be physically separated from the laboratory area where target solvents are used. Air supply for the volatiles should provide positive pressure relative to other laboratory areas.

3.3 Samples can be contaminated by diffusion of volatile organics (particularly fluorocarbons and methylene chloride) through the septum seal into the sample during shipment and storage. Protect samples from sources of volatiles during collection, shipment, and storage. A reagent water field blank carried through sampling and analysis can serve as a check on such contamination.

3.4 The use of high purity reagents, solvents, and gases helps to minimize interference problems.

3.5 Matrix interferences may be caused by contaminants that are co-extracted from the sample. The extent of matrix interferences will vary considerably from source to source, depending upon the nature of the sample.

3.6 Contamination by carryover can occur whenever high-level and low-level samples are sequentially analyzed. To reduce carryover, the sampling system and the concentrator must be cleaned thoroughly between samples. Whenever an unusually concentrated sample is encountered, it should be followed, if possible, by the analysis of a blank to check for cross contamination. The sample immediately following the unusually concentrated sample may also be used to check for cross-contamination.

3.7 Acetone and methylene chloride contamination is commonly observed in this analysis and its occurrence must be carefully evaluated as an indicator of a contamination problem in the sample preparation step of the analysis.

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4.0 Definitions

Refer to the *Laboratory Quality Manual* [QAMP ME0012K] for a glossary of common lab terms and definitions.

4.1 Non-conformance Memo (NCM) - A form used to document a non-conforming event. An analyst must document a non-conformance memo when a non-conforming event occurs. A non-conforming event may include the reporting of analytical data outside of method or SOP criteria, or when there is a deviation from a written policy or procedure. Information in an NCM may be used by project managers to flag data in the report narrative, or by the quality department to track trends and initiate corrective actions, where applicable. Additional information on the NCM policy and procedure is located in the *Complaints and Nonconformances* SOP [QA SOP ME001BO].

4.2 Calibration Check Compounds (CCC) – A subset of target compounds used to evaluate the calibration stability of the GC/MS system. A maximum percent deviation of the CCC's is specified for calibration acceptance.

4.3 System Performance Check Compounds (SPCC) – Target compounds designated to monitor chromatographic performance, sensitivity, and compound instability or degradation on active sites. Minimum response factors are specified for acceptable performance.

4.4 Marginal Exceedance (ME) – A marginal exceedance is defined as being beyond the LCS control limit (method defined or three standard deviations), but within the ME limits. ME limits are between three and four standards deviations around the mean.

5.0 Health and Safety

The toxicity or carcinogenicity of each chemical material used in the laboratory has not been fully established. Each chemical should be regarded as a potential health hazard and exposure to these compounds should be as low as reasonably achievable.

The laboratory maintains documentation of hazard assessments and OSHA regulations regarding the safe handling of the chemicals specified in each method. Safety data sheets for all hazardous chemicals are available to all personnel. Employees must abide by the health, safety and environmental (HSE) policies and procedures specified in this SOP and in the Pace Chemical Hygiene / Safety Manual.

Personal protective equipment (PPE) such as safety glasses, gloves, and a laboratory coat must be worn in designated areas and while handling samples and chemical materials to protect against physical contact with samples that contain potentially hazardous chemicals and exposure to chemical materials used in the procedure.

Concentrated corrosives present additional hazards and are damaging to skin and mucus membranes. Use these acids in a fume hood whenever possible with additional PPE designed for handing these materials. If eye or skin contact occurs, flush with large volumes of water. When working with acids, always add acid to water to prevent violent reactions. Any processes that emit large volumes of

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solvents (evaporation/concentration processes) must be in a hood or apparatus that prevents employee exposure.

Contact your supervisor or local HSE coordinator with questions or concerns regarding safety protocol or safe handling procedures for this procedure.

6.0 Sample Collection, Preservation, Holding Time, and Storage

Samples should be collected in accordance with a sampling plan and procedures appropriate to achieve the regulatory, scientific, and data quality objectives for the project.

The laboratory performs samples collection for samples to be analyzed by this SOP in accordance with the *Field Services* SOP [FS SOP ME001BS]. Refer to this SOP for these instructions.

The laboratory will provide containers for the collection of samples upon client request for analytical services. Bottle kits are prepared in accordance with the *Sample Container Shipping* SOP [AD SOP ME001DS].

Requirements for container type, preservation, and field quality control (QC) for the common list of test methods offered by Pace are listed in the *Pace-WCOL Analytical Methods List* [ME002BS].

General Requirements

Aqueous Sample Collection and Preservation

Aqueous samples are collected in three 40-mL volatile sample vials preserved with hydrochloric acid ($Na_2S_2O_3$ if chlorinated) and stored at 4 ± 2°C.

If 2-Chloroethyl vinyl ether is an analyte of interest, another set of three 40-mL volatile vials must be collected without preservative and stored at 4 ± 2°C. The compound 2-Chloroethyl vinyl ether breaks down in the presence of acid, and therefore, cannot be reported from a preserved sample.

If acrolein and acrylonitrile are analytes of interest, samples must be analyzed from an unpreserved via and stored at 4 ± 2°C.

Samples must be checked for presence of air bubbles. The size of any bubble caused by degassing upon cooling the sample must not exceed 5 – 6 mm. When a bubble is present, observe the cap and septum to ensure that a proper seal was made at the time of sampling. Document presence of air bubbles (> 5-6 mm) using an NCM.

Samples requiring 1,4-Dioxane by method 624.1 must be submitted unpreserved.

Solid Sample Collection and Preservation

Solid samples collected using Terra Core® **or equivalent soil kit:**

Use the Terra Core® or equivalent sampling kit in to collect approximately 5 grams of soil sample into 2 pre-weighed 40-mL vials each containing reagent water and a stir bar, 1 pre-weighed 40-mL vial containing 5 mL of methanol preservative, and 1 empty (un-preserved) pre-weighed 40-mL vial. Tightly

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cap all the vials. In addition, solid samples are collected in a 2 oz glass container for dry weight determination. The 40-mL vials containing solid samples and reagent water must be stored in a freezer in which temperature is less than -10°C within 48 hours of collection for preservation. To avoid potential vial breakage, store the vials horizontally in freezer until frozen, at which time vials may be placed upright in boxes. After samples are frozen, boxes may be stacked on top of each other to conserve space in the freezer. The solid samples preserved in methanol, in unpreserved vials, and those in the 2 oz containers must be stored under 4 ± 2°C.

Solid Samples Collected in En Core® Sampler:

Two En Core® samplers should be collected for low level analysis. An additional sample is collected for potential high-level analysis. The samplers must be sealed immediately after collection. The samples must be preserved in the laboratory as follows within 48 hours of collection.

Weigh two 40-mL VOC vials each containing 5.0 mL of reagent water and a magnetic stir bar to the nearest 0.01 gram. Open the sampler and carefully transfer the solid sample into the vial. Cap the vial. Re-weigh the vial. Record the weight to the nearest 0.01 g. The difference between the second and first weight is the sample weight. Record the weight in a logbook. The samples must be analyzed within 48 hours of preservation or the vials must be stored horizontally in a freezer within 48 hours of collection. Note: Care must be taken to keep vial threads clean in order to achieve a hermetic seal. Internal standard recoveries of less than 50% are typical when vial is not properly sealed.

An additional sample is collected for potential high-level analysis in a 2 oz glass container or a third En Core® sampler. Within 48 hours of collection, approximately 5 grams of the solid sample from the 2 oz jar or the contents of the sampler must be preserved in 5.0 mLs of methanol.

Compositing Low Level 5035 VOA vials (soils):

Samples must be collected in En Core® samplers. At least 3 total En Core® samplers (5 En Core® samplers if MS/MSD is required) must be collected to ensure that the laboratory has adequate mass for homogenization (e.g. if 3 discrete samples collect 1 En Core® sampler each – if 2 discrete samples collect 2 En Core®samplers each).

The laboratory will extrude the En Core® samplers into a clean beaker that is cooled on ice and quickly (30-60 seconds) mix the soil together to reduce any potential loss of volatiles.

Once mixed a TerraCore sampler will be used to collect 2 aliquots (4 aliquots if MS/MSD is required) of the homogenized soil into pre-weighed 40-mL volatile vials with water and stir bar.

Aqueous & Solid Sample Holding Times

The maximum holding time for all samples is 14 days from collection, unless otherwise stated below.

If 2-chloroethyl vinyl ether is an analyte of interest, the holding time is 7 days in an unpreserved vial. The compound 2-Chloroethyl vinyl ether breaks down in the presence of acid and therefore, cannot be reported from a preserved sample.

EPA SW-846 Method 8260 - If acrolein and/or acrylonitrile is an analyte of interest, the maximum holding time is 7 days. Samples must be preserved to a pH of 4-5 SU and stored at –4 ± 2°C.

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EPA Method 624.1 - If acrolein and/or acrylonitrile is an analyte of interest, the holding time is 3 days and must be analyzed from an unpreserved vial. The holding time may be extended to 14 days if sample pH is adjusted to 4-5 SU.

Field / Matrix QC

Trip blanks require two 40-mL volatile vials with the applicable preservative. If required, equipment blanks and field duplicates require an additional set of 40-mL volatile vials with the applicable preservative. If requested, MS/MSD require two additional sets of 40-mL volatile vials with the applicable preservative.

Thermal preservation is checked and recorded on receipt in the laboratory in accordance with the *Sample Receiving* SOP [AD SOP ME0013H]. Chemical preservation is checked and recorded by the laboratory after sample analysis.

After receipt, samples are stored at 4 ± 2°C until sample preparation. Prepared samples (extracts, digestates, distillates, other) are stored at 4 ± 2°C until sample analysis.

After analysis, unless otherwise specified in the analytical services contract, samples are retained for 28 days from date of final report and then disposed of in accordance with Federal, State, and Local regulations.

7.0 Equipment and Supplies

NOTE: Refer to the *Major Operational Equipment List* [QA Control Log ME001PM] for specific details regarding the equipment utilized during this procedure.

7.1 Equipment

7.1.1 Gas Chromatograph/Mass Spectrometer System (GC/MS) – An analytical system complete with a temperature-programmable gas chromatograph suitable for split/splitless injection and all required accessories, including syringes, analytical columns, and gases. The capillary column should be directly coupled to the source.

7.1.2 Column – Silicon-coated fused-silica capillary columns. DB-624 30m x 0.25mm x 1.4 µm, DB-624 20m x 0.18mm x 1.0 µm, Rxi-624Sil MS 30m x 0.25mmIDx 1.4umdf or equivalent.

7.1.3 Mass Spectrometer – Capable of scanning from mass/charge (m/z) 35 to 300 every two seconds or less, using 70 volts (nominal) electron energy in the electron impact ionization mode. The mass spectrometer must be capable of producing a mass spectrum for 4-bromofluorobenzene (BFB) which meets all of the criteria in Table A-IV when 50 ng of the GC/MS tuning standard are injected through the GC.

7.1.4 GC/MS Interface – Any GC-to-MS interface that gives acceptable calibration points and achieves acceptable tuning performance criteria may be used.

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7.1.5 Data System – A computer system must be interfaced to the mass spectrometer. The system must allow the continuous acquisition and storage on machine-readable media of all mass spectra obtained throughout the duration of the chromatographic program. The computer must have software that can search any GC/MS data file for ions of a specific mass and that can plot such ion abundances versus time or scan number. This type of plot is defined as the Extracted Ion Current Profile (EICP). Software must also be available that allows integrating the abundances in any EICP between specified time or scan-number limits. The most recent version of the EPA/NIH Mass Spectral Library is recommended.

7.1.6 Purge and Trap – Eclipse model 4660 purge and trap coupled to an OI 4551-A or OI model 4100 autosampler.

7.1.7 Trap – OI Trap #10 or equivalent

7.1.8 Syringes –Hamilton Laboratory grade syringes or equivalent.

7.1.9 Laboratory glassware - Class A Volumetric flasks, and other laboratory glassware required for adequate preparation and storage of any standards and reagents.

7.1.10 Analytical balance - capable of accurately weighing to the nearest 0.01g.

7.2 Supplies

7.2.1 Soil sample collection kit (Terra Core® or equivalent) – Two 40-ml VOC vials each with a magnetic stir bar and 5.0 mL of reagent water weighed to nearest 0.01 gram. One 40-mLVOC vial containing 5.0 mL methanol preservative, weighed to the nearest 0.01 gram. One unpreserved 40-mL VOC vial weighed to the nearest 0.01 gram. One 2 oz glass container, at client request for percent solid analysis. One 5.0g plastic disposable Terra Core® Sampler or equivalent (En Novative Technologies, Inc., 1795 Industrial Drive, Green Bay, WI 54302, www.ennovativetech.com) The plastic sampler or T-handle has a barrel smaller than the neck of the soil vial and is not an approved storage device. One sampler is needed for each sample to be collected.

7.2.2 En Core® sampler – (En Novative Technologies, Inc., 1795 Industrial Drive, Green Bay, WI 54302, www.ennovativetech.com), or equivalent. Soil sample can be stored in the inert composite polymer En Core® sampler for up to 48 hours without preservative. 5-gram samplers are used for each sample.

7.2.3 Ottawa sand – for matrix match.

7.2.4 pH test strips, wide range, Fisher Scientific 13640516, or equivalent

7.2.5 pH test strips, 0-3 SU, Fisher Scientific 13-640-511, or equivalent

7.2.6 chlorine test strips, Hach Aquachek TRC test strips 2745050, or equivalent

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8.0 Reagents and Standards

NOTE: Other volumes of standards and reagents may be prepared to account for expected usage. As long as all ratios are kept constant, this is not considered a deviation from the approved procedure.

NOTE: All stored reagents and standards must be labeled as required by the Preparation and *Documentation of Laboratory Standards and Reagents* SOP [QA SOP ME001HG], the *Contingency and Emergency Preparedness Plan* [HS SOP ME0012D], the *Safety Manual* [Corp Manual COR-MAN-HSE], and the *Laboratory Quality Manual* [QAMP ME0012K].

8.1 Reagents

8.1.1 Methanol (CH3OH) – Purge-and-trap grade or equivalent, demonstrated to be free from interferences for the compounds of interest at their lower limit of quantitation (LLOQ). This solvent must be stored apart from other solvents to avoid contamination. Commercially available from an approved vendor; follow manufacture expiration date.

8.1.2 Reagent water – A series of in-house deionized (DI) tanks is employed to purify the incoming water. Reagent water must be free of the analytes of interest as demonstrated through the analysis of method blanks. See the *Deionized Water System* SOP [QA SOP ME0012S] for further information.

8.1.3 Carrier gas – Ultra high purity helium.

8.1.4 Antifoaming agent - Antifoam B Silicone, part number JTB531-5, or equivalent.

8.1.5 Sodium Thiosulfate.

8.2 Standards

8.2.1 Primary standards - All standards used directly out of the flame-sealed ampules are considered to be primary standards. All primary standards expire six months after the open date (or manufacturer's expiration date, whichever has the stricter criteria). After the ampule is opened, the remaining standard is stored in a an amber 1mL autosampler vial. The standard must be refrigerated at ≤ -10 °C when not in use.

8.2.2 Working standards - All standards that are diluted from the manufacturer's ampule before analysis are considered working standards. The recipe for prepping the working standards can be found in Appendix F. All working standards expire one month after their prep date (or manufacturer's expiration date, whichever has the stricter criteria). Gas standards expire after one week. The standard must be refrigerated at ≤ -10 °C when not in use.

8.2.2.1 Daily working standards expire 12 hours after prep when not refrigerated and 24 hours after prep if refrigerated at 4 ± 2°C.

8.2.2.2 The gas working standards expire one week after the open date. The standard must be refrigerated at ≤-10° C when not in use.

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8.2.2.3 Standards for the permanent gases must be monitored frequently by comparison to the initial calibration curve. A fresh ampule or fresh standard must be prepared if the gas compounds fail CCV criteria on more than one instrument.

8.2.2.4 Standards for the non-gases must be monitored frequently by comparison to the initial calibration. Fresh standards must be prepared is a noticeable drift is observed.

8.2.3 Calibration standards - A minimum five-point calibration curve is prepared. The low point must be at or below the reporting limit. Refer to Table A-X for typical calibration levels for all analytes. Other calibration levels may be used, depending on instrument capability, but the low standard must support the reporting limit and the high standard defines the upper range of the calibration.

8.2.4 Initial Calibration Verification (ICV) standard - An ICV is prepared from a different source of standards used in the preparation for the initial calibration. The concentration of the ICV must be at or near the middle of the calibration range. Refer to Table A-XII for ICV compounds and acceptance criteria.

8.2.4.1 Dichlorodifluoromethane is a common poor performer due to its high volatility. It is common for this compound to not pass ICV criteria, proper correction action will be taken.

8.2.5 Internal Standard (IS) solution - An IS solution is prepared. Compounds in the IS Mix are: pentafluorobenzene, 1,4-difluorobenzene, chlorobenzene-d5, 1,4-dichlorobenzene-d4.

8.2.5.1 Internal Standards are added to all standards and samples to result in 25-50 µg/L on-column value.

8.2.5.2 Internal Standards expire six months after the open date (or manufacturer's expiration date, whichever has the stricter criteria).

8.2.6 Surrogate standard spiking solution – Prepared at 125 or 250 µg/mL concentration. Due to variances in autosampler loop volume, on column concentration will vary. Surrogate compounds are listed in Table A-IX. Surrogates expire six months after the open date (or manufacturer's expiration date, whichever has the stricter criteria).

8.2.7 GC/MS tuning standard - A methanol solution containing 25 µg/mL of 4-bromofluorobenzene (BFB) is prepared.

8.2.8 Laboratory Control Sample (LCS) spiking solution – Prepared at 100 µg/ml concentration. LCS compounds are listed in Table A-VII.

8.2.9 Matrix Spike (MS) solution – Same as LCS spiking solution in Section 8.2.8 above.

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9.0 Procedure

9.1 Equipment Preparation

9.1.1 Support Equipment

9.1.1.1 Incubators, water baths, refrigerator units, freezer units, bottle top dispensers, pipettes, thermometers, and ovens are maintained and verified as required by the *Equipment and Instrumentation* SOP [QA SOP ME002JT].

9.1.1.2 The balance is verified at the beginning of each analytical day using a certified weight set. Refer to the *Equipment and Instrumentation* SOP [QA SOP ME002JT] for balance verification procedures and acceptance criteria.

9.1.2 Instrument

9.1.2.1 Routine Instrument Operating Conditions – Refer to Table A-III, Appendix A for recommended instrument conditions.

9.1.2.2 Instrument Tuning – At the beginning of every twelve-hour shift when analyses are to be performed, the GC/MS system must be checked to see if acceptable performance criteria (Table A-IV) has been achieved for BFB (4-Bromofluorobenzene).

9.1.2.2.1 Inject 50 ng (2 µL) of the GC/MS tuning standard (Section 8.2.7) into the GC/MS system. Obtain a background-subtracted mass spectrum of BFB and confirm that all the key m/z criteria in Table A-IV are achieved. If all criteria are not achieved, the analyst must retune the mass spectrometer and repeat the test until all criteria are achieved. The performance criteria must be achieved before any samples, blanks, or standards are analyzed.

9.1.2.2.2 A purged BFB using the surrogate standard (Section 8.2.6) can also be used to evaluate instrument tuning. In this case 25ng of BFB are introduced to the GC/MS system.

9.2 Initial Calibration

9.2.1 **Calibration Design**

9.2.1.1 The instrument is tuned for 4-bromofluorobenzene (BFB), calibrated initially with a five-point calibration curve, and verified each 12-hour shift with one or more continuing calibration standard(s). Recommended instrument conditions are listed in Table A-III. Daily run conditions are documented on forms saved in the source method file for each instrument.

9.2.1.2 All standards and samples are allowed to warm to room temperature before injecting.

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9.2.1.3 Internal Standard Calibration Procedure – Internal standards are listed in Table A-VI. Use the base peak m/z as the primary m/z for quantitation of the standards. If interferences are noted, use one of the next two most intense masses for quantitation.

9.2.1.4 Compounds must be assigned to the Internal Standard (IS) with the closest retention time. See Table A-VI for IS assignments.

9.2.1.5 Prepare calibration standards at a minimum of five concentration levels for each parameter of interest. Additional levels can be analyzed and use the lower five for most analytes and the upper five for analytes that have poor response. Add the internal standard mixture to result in a concentration of 50 µg/L in the solution.

9.2.1.6 Analyze each calibration standard and tabulate the area of the primary characteristic m/z against concentration for each compound and internal standard. Calculate response factors (RF), average response factors, and the percent RSD (relative percent difference) of the response factors for each compound using the equations in Section 10.3.1. The average RF and %RSD must meet the criteria listed in Sections 9.2.3.2 through 9.2.3.6 The ICAL cannot be forced through zero. No sample analysis may be performed unless these criteria are met.

9.2.2 **Calibration Sequence**

9.2.2.1 Follow outlined procedure below to prepare at least a five-point calibration curve at concentrations of 1.0, 5.0, 20.0, 50.0, 100.0, 200.0 parts per billion (ppb). A 0.5 ppb standard may also be made if needed. All dilutions are made in class A volumetric flasks.

9.2.2.2 Using the primary working standards found in Appendix F make the following dilutions:

For Standard (ppb or µg/L)	Dilute (µL)	*into* Water (mL)
5.0	5.0	100
20	20.0	100
50	50.0	100
100	100.0	100
200	200.0	100

9.2.2.3 Using second preparation of the 50ppb standard above, make the following dilutions:

For Standard (ppb or µg/L)	Dilute (mL)	*into* Water (mL)
0.5	1.0	100
1.0	2.0	100

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9.2.3 **ICAL Evaluation**

9.2.3.1 Weighing of Data Points

9.2.3.1.1 In linear fits, the points at the lower end of the calibration curve have less absolute variance than points at the high concentration end of the curve. This can cause severe errors in quantitation at the low end of the calibration. However, in environmental analysis, accuracy at the low end of the curve is very important. For this reason, it is preferable to increase the weighting of the lower concentration points. 1/Concentrations weighting (often called 1/ X2 weighting) will improve accuracy at the low end of the curve and should be used.

9.2.3.2 System Performance Check Compounds (SPCCs - 8260B only) - The minimum average RF for volatile SPCCs is listed below. If the minimum response factors are not met, the system must be evaluated and corrective action must be taken before sample analysis begins. Some possible problems are standard mixture degradation, injection port contamination, contamination of the front end of the analytical column, active sites in the column or chromatographic system and gas leaks or restrictions. This check must be met before analysis begins.

SPCC Compounds:	Minimum RF	Example Problem
Chloromethane	0.100	Purge flow too fast
1,1-Dichloroethane	0.100	Contaminated transfer lines in PT systems and/or active sites in trapping materials.
Bromoform	0.100	Purge flow too slow. Cold spots, active sites in the transfer lines
1,1,2,2-Tetrachloroethane	0.300	Same as 1
Chlorobenzene	0.300	Same as 1

9.2.3.3 Calibration Check Compounds (CCCs – 8260B only) - The %RSD of the response factors for each CCC in the initial calibration must be ≤ 30% for the initial calibration to be considered valid. This criterion must be met before sample analysis begins. Problems similar to those listed under SPCCs could affect this criterion.

9.2.3.4 CCC Compounds:
1,1-Dichloroethene
Chloroform
2-Dichloropropane
Toluene
Ethylbenzene
Vinyl Chloride

9.2.3.5 The average response factor is used when the %RSD of a compound is ≤ 15%.

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9.2.3.6 For compounds that have % RSD >15% linear regression should be used. The correlation coefficient must be ≥ 0.995. The Target® software calculates the square of correlation coefficient which must be ≥ 0.99.

9.2.3.7 It is NOT acceptable to remove points from a calibration curve for the purpose of meeting criteria, unless the points are the highest or lowest of the curve AND the reporting limit and/or linear range is adjusted accordingly. In any event, at least 5 points must be included in the calibration curve.

9.2.3.8 A level may be removed from the calibration if the reason can be clearly documented, for example a poor purge. A minimum of five levels must remain in the calibration.

9.2.3.9 A level may be reanalyzed within 12 hours of the start of the calibration sequence, if no sample has been processed with the new calibration.

9.2.3.10 As soon as a new initial calibration curve is analyzed, all previous calibration curves are invalid whether the new calibration curve passes or not. The analysts cannot use an old curve to analyze sample.

9.2.3.11 If time remains in the 12-hour period initiated by the BFB injection before the initial calibration, samples may be analyzed. Otherwise, proceed to continuing calibration.

9.2.3.12 Quantitation is performed using average response factor from the initial curve, not the continuing calibration.

9.2.3.13 Relative Error

9.2.3.13.1 Either of the two methods described below may be used to determine calibration function acceptability for linear and non-linear curves. Both procedures refit the calibration data back to the calibration model and evaluates the difference between the measured and the true amounts or concentrations used to create the model.

9.2.3.13.2 % Error:

$$\%\ \text{Error} = \frac{X_i - X'_i}{X_i} \times 100$$

Where:
X'i = Measured amount of analyte at calibration level i, in mass or concentration units.
Xi = True amount of analyte at calibration level i, in mass or concentration units.

Percent error between the calculated and expected amounts of an analyte must be ≤ 30% for all standards, except the lowest calibration standard which must be ≤ 50%.

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9.2.3.13.3 Relative Standard Error (RSE):

$$RSE = \sqrt{\sum_{i=1}^{n}\left[\frac{x'_i - x_i}{x_i}\right]^2 \Big/ (n-p)}$$

Where:
x'i = Measured amount of analyte at calibration level i, in mass or concentration units.
xi = True amount of analyte at calibration level i, in mass or concentration units.
p = Number of terms in fitting equation (average = 1, linear = 2)
n= Number of calibration points.

The RSE acceptance limit criterion for the calibration model is the same as the RSD limit (Section 9.2.3).

9.2.4 **Initial Calibration Verification (ICV)** / Second Source Calibration Verification - A standard that is prepared from a source independent of standards of the initial calibration. The ICV contains all Target compounds and its concentration must be at or near the mid-level of the initial calibration. The concentration of the ICV, determined from the analysis, is compared to the known value of the standard to determine the accuracy of the ICAL. Recovery must be within 70-130% before sample analysis to begin. The ICV must be analyzed immediately after the ICAL.

9.2.5 **Continuing Calibration Verification (CCV)** (also known as the Instrument Performance Check)

9.2.5.1 At the start of each 12-hour period, the GC/MS tuning standard must be analyzed. A ≤50 ng injection of 4-bromofluorobenzene (BFB) must result in a mass spectrum for BFB which meets the criteria given in Table A-IV.

9.2.5.2 Following a successful BFB analysis, the continuing calibration verification (CCV) standard(s) are analyzed. The standards must contain all volatile analytes, including all required surrogates. A mid-level calibration standard is used for the continuing calibration.

9.2.5.3 Continuing Calibration Verification (CCV) technical acceptance criteria:

9.2.5.3.1 The response factor for the SPCC compounds must meet the criteria listed in Section 9.2.3.2.

9.2.5.3.2 The percent difference of the CCC compounds from the initial calibration must be ± 20% difference (8260B only). See Section 10 for calculation. In addition, the percent difference of all other target analytes must meet the criteria in Table A-XIII with the following exceptions:

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9.2.5.3.2.1. One or more CCC's may fail if the CCC is not a target analyte and all target analytes meet the 20% difference or drift criterion.

9.2.5.3.2.2. If the CCC's are not included in the list of analytes for a project, and therefore not included in the calibration standards, then all analytes must meet the 20% difference or drift criterion.

9.2.5.4 The CCV % difference criteria for 8260C/D is 20% for all compounds.

9.2.5.4.1 The internal standard response must be within 50-200% of the response in the mid-level of the initial calibration.

9.2.5.4.2 The internal standard retention times must be within ± 30 seconds of the retention times in the mid-level of the initial calibration.

9.2.5.5 Once the above criteria have been met, sample analysis may begin. Initial calibration average RFs (or the calibration curve) will be used for sample quantitation, not the continuing calibration RFs. Analysis may proceed until 12 hours from the injection of the BFB have passed. (A sample injected less than 12 hours after the BFB is acceptable.)

9.2.5.6 In any case, the criteria for SPCC compounds must be met for 8260B.

9.2.5.7 Corrective Action for CCV Failure

9.2.5.7.1 Check all calculations and integrations. Inspect the GC/MS system for malfunction. Try to determine the cause of the failure. If it appears that the analytical system is in proper working order but the standard has been improperly prepared, degraded, or compromised, a new standard may be prepared and reanalyzed. If it is suspected that the instrument is unstable or malfunctioning then maintenance and/or repair must be performed before running another CCV.

9.2.5.7.1.1. If the 2nd consecutive CCV fails to pass acceptance criteria, the analyst must perform corrective action and demonstrate that the system is stable and in proper working order with two consecutive passing CCV's or an initial calibration (ICAL) must be analyzed before analysis of samples can begin.

9.2.5.7.1.2. An LCS can be used as the second passing CCV if it is run directly after the initial CCV and if it passes all criteria.

9.2.5.7.2 If the system appears to be in working order and standards are prepared correctly corrective action is not required for the following exceptions:

9.2.5.7.2.1. If ≤10% of the analytes exceed the calibration verification criteria, then the initial calibration may still be used for non-detect samples. Any detected analytes exceeding the limit must be reported as estimated.

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9.2.5.7.2.2. Non-detected analytes may be reported if the calibration verification for that specific analyte exceeds the upper acceptance criteria (e.g., > +20%).

9.2.5.7.2.3. In order to report non-detected analytes that exceeds the lower acceptance criteria (e.g., < -20%), a sensitivity verification standard at or below the LOQ must be analyzed in the analytical batch. The analyte must be detected in the LOQ standard and meet all of the qualitative identification criteria. (8260C/D only)

9.2.5.7.2.4. If more than 10% of analytes are exceeding the calibration verification criteria for both detected and non-detected analyte corrective action is required.

9.2.5.7.3 If >10% of the analytes exceed the calibration verification criteria, and instrument maintenance does not correct the problem, then a new ICAL must be analyzed before sample analysis may begin.

9.3 Sample Preparation

9.3.1 High level soil sample preparation procedures are in Appendix D.

9.4 Analysis

9.4.1 Calibrate the instrument as described in Section 9.2. Depending on the target compounds required by the client, it may be necessary to use more than one calibration standard.

9.4.2 All samples must be analyzed using the same instrument conditions as the preceding continuing calibration standard.

9.4.3 The weight for soil sample in water must be determined before analysis can begin. Weigh the vial to the nearest 0.01 gram. Document the sample weights in the VOA Extraction Batch 5035 High Level / Waste Dilution [VOA Forms ME001CY] logbook or in directly into LIMS 4.

9.4.3.1 To account for the weight of the label placed on the sample container during sample receipt, the balance must be tared using a sample label. After taring, remove the label to obtain sample weights.

Note: The presence of excessive amounts of tape or labeling requires documentation in an NCM to ensure this information is provided in the case narrative of the final report.

9.4.4 The frozen soil sample must be warmed to ambient temperature before analysis can begin.

9.4.5 Add internal standard and surrogate standard to the sample to result in 25-50 µg/L concentration in the aqueous solution.

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9.4.6 Load the autosampler and begin the sequence. The procedure for the samples and the standards must be the same.

9.4.7 The data system will determine the concentration of each analyte in the extract using calculations equivalent to those in Section 10. Quantitation is based on the initial calibration, not the continuing calibration.

9.4.8 Identified compounds are reviewed for proper integration. Manual integrations are performed if necessary and are documented by the analyst or automatically by the data system.

9.4.9 Target compounds identified by the data system are evaluated using the criteria listed in Section 10.1.

9.4.10 Library searches of peaks present in the chromatogram that are not target compounds (Tentatively Identified Compounds, TIC) may be performed if required by the client. They are evaluated using the criteria in Section 10.1.2.

9.4.11 Samples with matrices that foam should be treated with antifoaming agent. Antifoam is diluted 20X in deionized water. From this diluted antifoam solution, inject 20 ul into the septa of the vial until the foaming is controlled.

9.4.12 When using antifoam, either a method blank or instrument blank needs to be injected with the largest amount of antifoam used in the samples. The blank should be analyzed prior to the samples in order to confirm there is no contamination in the antifoam solution. An LCS must also be prepared with the largest amount of antifoam used in the samples to verify the antifoam does not contribute any interference. All related QC criteria apply.

9.5 Dilutions

9.5.1 Dilutions must be performed so that the resulting dilution factor is an integer.

9.5.2 For aqueous, high level soil, and waste samples, if the response for any compound exceeds the working range of the GC/MS system, a dilution of the sample or extract is prepared and analyzed. An appropriate dilution should target the CCV (mid-range of the ICAL). Samples may be screened to determine the appropriate dilution for the initial run. If the initial diluted run has no hits or its highest hits are below 25% of the calibration range and the matrix allows for analysis at a lesser dilution, the sample must be reanalyzed at a dilution targeted to bring the largest hit above the CCV (mid-range of the ICAL).

9.5.3 For low level soil samples, if the response for any compound exceeds the working range of the GC/MS system, a high-level soil analysis must be performed. See Appendix D-4 for details.

9.5.4 *Guidance for Dilutions Due to Matrix* – If the sample is initially run at a dilution and the baseline rise is less than the height of the internal standards, or if individual non-target

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peaks are less than two times the height of the internal standards, the sample should be reanalyzed at a less concentrated dilution. This requirement is approximate and subject to analyst judgment. For example, samples containing petroleum fuel may need to be analyzed at a higher dilution to avoid contaminating the purge-and-trap system.

9.5.5 *Reporting Dilutions* – The most concentrated dilution with no target compounds above the calibration range will be reported. Other dilutions will only be reported at client request.

9.5.6 When preparing manual dilutions syringes of 1 mL or less flush 3 times with methanol and syringes greater than 1 mL flush at least 1 time with methanol and then 3 times with DI water between dilutions.

9.6 Internal Standard Criteria for Samples

9.6.1 If the retention time for any internal standard changes by more than 0.5 minutes from the last continuing calibration standard, the chromatographic system must be inspected for malfunctions and corrected. Reanalysis of samples analyzed while the system was malfunctioning is required.

9.6.2 If the retention time of any internal standard in any sample varies by more than 0.1 minute from the preceding continuing calibration standard, the data must be carefully evaluated to ensure that no analytes have shifted outside their retention time windows. Refer to Section 10 for further evaluation of co-eluting pairs.

9.6.3 The internal standard response must be within 50 – 200% of the response in the last continuing calibration standard.

9.7 pH and Chlorine Verifications

9.7.1 All aqueous samples must be checked for pH immediately after analysis. The pH must be taken from the parent sample in the case of a dilution. The pH verification is documented on the Chemstation sequence printout. If the pH is not <2 an NCM must be completed to ensure the anomaly is communicated to the client and reported in the case narrative unless the sample is in an unpreserved vial. If the sample is in an unpreserved vial and the pH <2, this must be noted on the Chemstation sequence printout.

9.7.1.1 EPA 624.1 aqueous samples must be checked for the presence of Chlorine immediately after sample analysis. The Chlorine must be taken from the parent sample in the case of a dilution. The Chlorine verification is documented on the Chemstation sequence printout. If Chlorine is present an NCM is documented and issued to the project manager. The project manager notifies the client of the anomaly in the report narrative

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9.8 Percent Moisture

9.8.1 Analytical results may be reported as dry or wet weight, as required by the client. Percent moisture must be determined if results will be reported as dry weight.

9.8.2 Refer to *the Percent Solid and Percent Moisture in Solids and Semi-Solids* SOP [Wet Chem SOP ME0013F] for percent moisture determination.

9.9 Troubleshooting Guide

9.9.1 Instrument Maintenance – In addition to the checks listed in the instrument maintenance schedule in the Shealy QAMP, the following maintenance activities must be monitored daily and performed if necessary:

- Injection port inspection/maintenance
- Clip column
- Install new or cleaned injection port liner and gold seal
- Install new septum
- Change trap every 6 month or as necessary.
- Perform mass calibration as necessary.

9.9.2 Major Maintenance – A new calibration is necessary following major maintenance. Major maintenance includes changing the column, cleaning the ion electron source, replacing the multiplier, and changing the trap to a new lot number. Refer to the manufacturer's manual for specific guidance. All maintenance must be recorded in the instrument maintenance log with the date and initials.

9.10 Sufficient records must be maintained to allow for the historical reconstruction of testing procedures. Refer to the *Logbook and Data Recording* SOP [QA SOP ME0012T] for details regarding documentation requirements. The following quality documents are included in the technical record for this analysis:

- *Working Standard Prep Log* – Volatiles [VOA form ME001KC]
- *Working Standard Prep Log* – AQ CLP [VOA form ME001KD]
- *VOA Extraction Batch 5035 High Level / Waste Dilution* [VOA Forms ME001CY]

10.0 DATA ANALYSIS AND CALCULATIONS

10.1 Qualitative Identification

10.1.1 An analyte is identified by retention time and by comparison of the sample mass spectrum with the mass spectrum of a standard of the suspected compound (standard reference spectrum). Mass spectra for standard reference may be obtained on the user's GC/MS by analysis of the calibration standards or from the NIST02 library. Two criteria must be satisfied to verify identification: (1) elution of sample component at the same GC retention time as the standard component; and (2) correspondence of the sample component and the standard component characteristic ions. (Note: Care must be taken to ensure that spectral distortion due to co-elution is evaluated.)

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- The sample component retention time must compare to within ± 0.06 RRT units of the RRT of the standard component. For reference, the standard must be run within the same twelve hours as the sample.

- The characteristic ions of a compound must maximize in the same scan or within one scan of each other.

- The relative intensities of ions must agree to within ± 30% for target analytes and ± 20% for TICs (between the standard and sample spectra). (Example: A target ion with an abundance of 50% in the standard spectra, the corresponding sample abundance must be between 20% and 80%).

10.1.1.1 If a compound cannot be verified by all the above criteria, but in the technical judgment of the analyst the identification is correct, the analyst shall report that identification and proceed with quantitation. GC/MS analysts are trained to carefully evaluate data for compounds that have close retention times and share common ions.

10.1.1.1.1 If an alternate compound was selected by the analyst, the compound will be flagged with an “H” by Target®. The triple plots are generated to document that the correct compound was selected.

10.1.1.1.2 If a compound fails the ratio test, the compound will be flagged with a “Q” by Target®. The triple plot must be printed to document that the correct compound was selected.

10.1.1.1.2.1. The following compounds may display the “Q” flag at concentrations > half the calibration range due to shared ions:

Close Eluting Compounds	
Ethylbenzene	m&p-Xylenes
o–Xylene	Styrene
Allyl chloride	Acetonitrile
Allyl chloride	Carbon disulfide
Dichlorobenzenes	Dichlorobenzenes
Vinyl acetate	Diisopropyl ether
trans-1,4-Dichloro-2-butene	1,2,3-Trichloropropane
1,2,4-Trimethylbenzene	1,3,5-Trimethylbenzene

10.1.1.2 Due to the type of column used, there can be considerable breakdown of benzene into 1,2-dichloroethane (1,2-DCA) resulting in possible false positive detection of 1,2-DCA. Anytime a large benzene peak is present, special attention to the spectra must be taken. Ion 98 is only present in 1,2-DCA and not present in benzene so that this ion must be present for 1,2-DCA to be detected. Consult the

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group leader and/or the technical director for further guidance when this issue occurs

10.1.2 Tentatively Identified Compounds (TICS) - For samples containing components not associated with the calibration standards, a library search may be made for the purpose of tentative identification. The necessity to perform this type of identification will be determined by the type of analyses being conducted. Computer generated library search routines must not use normalization routines that would misrepresent the library or unknown spectra when compared to each other. Only after visual comparison of sample spectra with the nearest library searches shall the mass spectral interpretation specialist assign a tentative identification. Guidelines for making tentative identification are:

- Relative intensities of major ions in the reference spectrum (ions > 10% of the most abundant ion) must be present in the sample spectrum.
- The relative intensities of the major ions must agree within ±20%. (Example: For an ion with an abundance of 50% in the standard spectrum, the corresponding sample ion abundance must be between 30% and 70%)
- Molecular ions present in the reference spectrum must be present in the sample spectrum.
- Ions present in the sample spectrum, but not in the reference spectrum, must be reviewed for possible background contamination or presence of co-eluting compounds.
- Ions present in the reference spectrum, but not in the sample spectrum, must be reviewed for possible subtraction from the sample spectrum because of background contamination or co-eluting peaks. Data system library reduction programs can sometimes create these discrepancies.
- Automatic background subtraction can severely distort spectra from samples with unresolved hydrocarbons.

10.1.3 Manual Integration

10.1.3.1 Manual changes to automated integration is called manual integration. Manual integration is sometimes necessary to correct inaccurate automated integrations but must never be used to meet QC criteria or to substitute for proper instrument maintenance and/or method set-up. To assure that all manual integrations are performed consistently and are ethically justified, all manual integrations must be performed, reviewed, and recorded in accordance with corporate SOP ENV-SOP-CORQ-0006, Manual Integration.

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10.2 Quantitative Identification

10.3 Calculations

See the *Laboratory Quality Assurance Manual* [QAMP ME0012K] for equations for common calculations.

10.3.1 Percent Relative Standard Deviation (RSD) for Initial Calibration

$$\%\ \mathrm{RSD} = \frac{\mathrm{SD}}{\overline{\mathrm{RF}}} \times 100$$

Where:

RF = Mean RFs from initial calibration for a compound
SD = Standard deviation of RFs from initial calibration for a compound

$$\mathrm{SD} = \sqrt{\sum_{i=1}^{N} \frac{\left(\mathrm{RF}_i - \overline{\mathrm{RF}}\right)^2}{N-1}}$$

Where:

RF_i = RF for each of the calibration levels.
N = Number of RF values.

10.3.2 Continuing Calibration (CCV) Percent Difference and Percent Drift

$$\%\ \mathrm{Difference} = \frac{\mathrm{RF} - \overline{\mathrm{RF}}}{\overline{\mathrm{RF}}} \times 100$$

Where:

RF = Compound's response factor in the CCV.
$\overline{\mathrm{RF}}$ = Compound's average response factor in the initial calibration.

$$\%\ \mathrm{Drift} = \frac{\mathrm{Calc.\ Conc.} - \mathrm{Theoretical\ Conc.}}{\mathrm{Theoretical\ Conc.}} \times 100$$

10.3.3 Concentration in the Sample – The concentration of each identified analyte and surrogate in the sample is from the average RF of the initial calibratioin.

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10.3.3.1 On-Column Concentration (µg/L)

$$C = \frac{A_x \times C_{is}}{A_{is} \times \overline{RF}}$$

10.3.3.2 Aqueous Sample (µg/L)

Concentration = C x DF

Where:

A_x= Response for analyte, in area count of the characteristic ion.
A_{is} = Response for internal standard.
C_{is} = Concentration of internal standard.
DF = Dilution factor.

10.3.3.3 Sediment/Soil, Sludge (on a dry-weight basis) and Waste (normally on a wet-weight basis)

$$\text{Concentration, µg/kg} = \frac{C \times V_0 \times DF}{W \times D}$$

Where:
V_0 = Volume of sample extract in mLs.
W = Weight of sample extracted or diluted in grams.
D = (100 - % moisture in sample)/100, for a dry weight basis or 1 for a wet weight basis.

10.3.4 MS/MSD Percent Recovery Calculation

$$\text{Matrix Spike Recovery} = \frac{S_{SR} - S_R}{S_A} \times 100\%$$

Where:

S_{SR} = Spike sample result.
S_R = Sample result.
S_A = Spike added.

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10.3.5 Relative % Difference Calculation for the MS/MSD

$$RPD = \frac{MS_R - MSD_R}{½ (MS_R + MSD_R)} \times 100$$

Where:
RPD = Relative percent difference.
MS_R = Matrix spike result.
MSD_R = Matrix spike duplicate result.

10.3.6 Relative Response Factor Calculation

$$RF = \frac{A_x C_{is}}{A_{is} C_x}$$

Where:
A_x= Area of the characteristic ion for the compound being measured.
A_{is}= Area of the characteristic ion for the specific internal standard.
C_x = Concentration of the compound being measured (µg/L).
C_{is} = Concentration of the specific internal standard (µg/L).

10.3.7 Calculation of TICs – The calculation of TICs (tentatively identified compounds) is identical to the above calculations with the following exceptions:

A_x = Area of the total ion chromatogram for the compound being measured.
A_{is} = Area of the total ion chromatogram for the nearest internal standard without interference.
RF = 1.

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11.0 Quality Control and Method Performance

11.1 Quality Control

The following QC samples are prepared and analyzed with each batch of samples.

QC Item	Frequency
Method Blank (MB)	1 per batch
Laboratory Control Sample (LCS)	1 per batch
Laboratory Control Sample Duplicate (LCSD)	As needed
Matrix Spike (MS)	1 per batch
Matrix Spike Duplicate (MSD)	1 per batch
Sample Duplicate	As needed

11.2 Instrument QC

The following Instrument QC checks are performed.

QC Item	Frequency
Initial Calibration	When CCVs do not meet criteria
Initial Calibration Verification	After calibration.
Tuning standard	At the start of each 12 hour period
BFB	After tuning
Continuing Calibration Verification	After BFB
LOQ Verification	Quarterly, or when significant changes are made to prep or analysis procedures
NC LOQ Verification Standard	Each day NC samples are analyzed

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11.3 Acceptance Criteria and Required Corrective Action

11.3.1 Initial and Continuing Demonstration of Capability (IDOC and CDOC) – To establish the ability of an analyst to generate acceptable accuracy, each analyst must make a satisfactory initial demonstration of capability prior to using any method and at any time there is a change instrument type or method. Thereafter, a continuing demonstration of capability is required annually. Refer to the *Demonstration of Capability* SOP [QA SOP ME001F2] for additional information.

11.3.2 Control Limits – In-house historical control limits must be determined for surrogates, matrix spikes, and laboratory control samples (LCS/LCSD). These limits are reviewed regularly and updated as needed. Acceptance limits are calculated by using the mean recovery ± 3 standard deviations. Refer to the LCS section below (Section 11.3.4) for maximum limit ranges.

11.3.2.1 All surrogate, LCS/LCSD, and MS/MSD recoveries must be entered into the Shealy LIMS (when available) or other database so that accurate historical control limits can be generated. Surrogate and matrix spike percent recoveries will be reported for all dilutions.

11.3.2.2 Refer to the Quality Assurance Management Plan [QAMP ME0012K] or the Trend Analysis of *Data Using Control Charts* policy [QA Policy ME001IW] for further details on control limits.

11.3.3 Method Blank (MB) / Laboratory Reagent Blank – A method blank is prepared and analyzed with each batch of samples. The method blank consists of a quality system matrix that is similar to the associated samples (organic free reagent water or Ottawa sand), free of the analytes of interest, and is taken through the entire preparation and analytical procedures. The method blank is used to identify any systemic and process interferences or contamination that may lead to the reporting of elevated concentrations of false positive data. Surrogates and internal standards are added and the method blank is carried through the entire analytical procedure.

11.3.3.1 The method blank must not contain any analyte of interest above 1/2 the LOQ, or project-specific requirements. If the method blank contains an analyte of interest above this limit, the method blank and associated samples must be re-analyzed with a method blank, which passes acceptance criteria. Corrective action may not be required if the samples are not affected. Where permitted by the program area or client, the following exceptions apply. Any method blank that does not meet acceptance criteria, is flagged on the data report with a B flag.

11.3.3.1.1 The sample was non-detect for the contamination.

11.3.3.1.2 The sample concentration was ≥10x the blank concentration.

11.3.3.2 The method blank must have acceptable surrogate recoveries. If surrogate recoveries are not acceptable, sample analysis must stop immediately. Corrective

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action must be taken. A new method blank must be analyzed and meet the surrogate criteria before sample analysis can begin.

11.3.3.3 Sample results are NOT blank subtracted.

11.3.4 Laboratory Control Sample (LCS) - A laboratory control sample (LCS) is prepared from a source independent of the initial calibration standards (8260B only) and analyzed with every batch of samples. The LCS is spiked with the compounds listed in Table A-VII, unless specified by a client or agency. The LCS sample for low level soil (5035) must contain approximately 5 grams of Ottawa sand. The acceptable control limits for LCS/LCSD are statistically derived. However, if the lower control limits are < 70% or the upper control limits are >130%, then the default limits of 70-130% will apply to the compounds in Table A-VII. The only exceptions are the * compounds found in Tables A-XIV and A-XV. These compounds have default control limits of 60-140% (if not statistically more stringent). Refer to Tables A-XIV and A-XV for the entire lists of aqueous and soil LCS recovery limits. Refer to Table DoD-III for DoD control limits. Refer to Table A-VII and Table A-XV for a list of spiked LCS compounds and their spiking concentrations.

11.3.4.1 For 8260D, the LCS may be prepared with standards used for calibration.

11.3.4.2 Marginal Exceedances: When there are a large number of analytes in the LCS or matrix spike, there is a high statistical probability that a few analytes will recover outside of control limits. This may not indicate that the system is out of control, therefore corrective action may not be necessary. The number of allowable marginal exceedances (ME) is based on the number of analytes in the LCS. If more analytes exceed the LCS control limits than is allowed, corrective action is necessary. The number of allowable marginal exceedances is as follows:

Number of Analytes in LCS	Number Allowed as Marginal Exceedances
>90	5
71-90	4
51-70	3
31-50	2
11-30	1
<11	0

11.3.4.2.1 Marginal exceedances must be random. If the same analyte exceeds the LCS control limit repeatedly, it is an indication of a systemic problem. The source of the error must be located and corrective action taken.

Note: Marginal exceedances may not be allowed for some projects (not allowed for South Carolina compliance samples, or DoD without project specific approval). If any compounds fail to meet LCS limits, refer to actions outlined in Section 11.3.4.3.

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11.3.4.3 Corrective Action for LCS failure - If an LCS fails to meet the ME criteria for a target compound, an attempt must be made to determine the source of error and find a solution. A target compound is any compound being reported for that sample. All findings and corrective actions should be documented in the maintenance logbook. The corrective action applied shall be based on professional judgment in the review of other QC measures (i.e. surrogates). If analyte falls outside a second time or if there is not sufficient sample to be reanalyzed, an NCM must be filled out documenting the failure and corrective actions that were applied.

11.3.4.4 If the LCS is failing high and the sample is non-detect an NCM can be generated and reanalysis is not required.

11.3.5 Matrix Spike (MS) and Matrix Spike Duplicate (MSD) – For each QC batch, analyze a matrix spike and a sample duplicate or an MS/MSD if client requested. Spiking compound and levels are given in the appendices. When an MS/MSD is analyzed compare the percent recovery and relative percent difference (RPD) to those in the laboratory specific historically generated limits. MS/MSD failures are flagged in the report.

11.3.5.1 If any individual recovery or RPD falls outside the acceptable range ≤ 30%, corrective action must occur. The initial corrective action will be to check all calculations. If the calculations are correct, check the recovery of that analyte in the Laboratory Control Sample (LCS). If the recovery of the analyte in the LCS is within limits, then matrix interference has been demonstrated and the laboratory operation may proceed.

11.3.5.2 If the recovery for any component is outside QC limits for the matrix spike, sample duplicate, or matrix spike/spike duplicate and the LCS, the laboratory is out of control and corrective action must be taken. Corrective action will include re-preparation and reanalysis of the batch. An NCM must be generated to document this occurrence.

11.3.5.3 Every effort is made to ensure that a Matrix spike and a sample duplicate are included in every batch. On the rare occasion that one is not possible (sample bottle was broken, etc.) then an LCS duplicate must be analyzed or a MS/MSD pair can be analyzed at the client's request.

11.3.5.4 The matrix spike/ matrix spike duplicate must initially be analyzed at the same dilution as the parent sample (or the un-spiked sample). If the sample requires reanalysis at a dilution and objective evidence of matrix interference exists, re-analysis may not be required.

11.3.5.5 The sample duplicate must be analyzed at the same dilution as the parent sample. If the parent sample requires a dilution, the sample duplicate must be re-analyzed at the same dilution if sufficient sample volume is available.

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11.3.6 Surrogates - Every sample, blank, and QC sample is spiked with surrogate standards. Surrogate spike recoveries must be evaluated by determining whether the concentration (measured as percent recovery) falls within the required recovery limits. The compounds routinely included in the surrogate spiking solution, along with recommended standard concentrations, are listed in Table A-IX.

11.3.6.1 If any surrogates are outside limits, the following corrective actions must take place. For high level soil samples in methanol and/or non-aqueous samples with dilutions ≥ 5x, all corrective actions are applicable with the exception of sample reanalysis. If the corrective actions do not fix the problem, an NCM must be written.

- Check all calculations for error.
- Ensure that instrument performance is acceptable.
- Recalculate the data and/or reanalyze the sample if either of the above checks reveals a problem.
- It is only necessary to reanalyze a sample once to demonstrate that poor surrogate recovery is due to matrix effect, unless the analyst believes that the repeated out of control results are not due to matrix effect. A demonstrated matrix effect must be documented on an NCM.

11.3.7 LOQ Verification – A verification of the LOQ is performed quarterly, and whenever significant changes are made to the preparation and/or analytical procedure.

11.3.7.1 The verification is performed by the extraction and analysis of reagent water spiked at 0.5-2 times the established LOQ.

11.3.7.2 The LOQ check is carried through the same preparation and analytical procedures as environmental samples and other QC samples.

11.3.7.3 The LOQ verification is performed after the initial calibration and must be performed on every instrument where data is reported annually.

11.3.7.4 Recovery of the target analytes in the LOQ verification must be within ± 20 % of the LCS criteria, until the laboratory has enough data to establish acceptance limits for the LOQ. This practice acknowledges the potential for greater uncertainty at the low end of the calibration curve.

11.3.7.5 When reporting concentrations below the LOQ, the results are qualified as estimated with a J flag on the analytical report.

11.3.8 North Carolina LOQ Verification Standard – A standard at or below the LOQ must be analyzed each day North Carolina samples are analyzed. To be acceptable, all analytes of interest must be detected. If not, reanalyze the batch. If reanalysis is not possible, generate an NCM.

11.3.9 Trip Blank (TB) – The purpose of the TB is to detect possible volatiles organic contamination of samples to be analyzed for volatile compounds. TBs are prepared by

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filling volatile sampling vials with deionized water. TBs accompany volatile sample collection vials to the sample site, back to the laboratory, and are stored with the collected samples before analysis. TB are treated just like any other sample within the analysis batch, but must not be used as matrix spikes or matrix spike duplicates.

11.3.9.1 Trip blanks shall only be re-run when QC suggests the re-run is needed.

Note: Refer to appendices for state and/or program specific method performance criteria, which superseded and/or supplement the general method performance criteria prescribed in this SOP.

11.4 Method Performance

11.4.1 Method Validation

11.4.1.1 Detection Limits

Detection limits (DL) and limits of quantitation (LOQ) are established at initial method setup and verified on an on-going basis thereafter. Refer to Pace ENV corporate SOP ENV-SOP-CORQ-0011 Method Validation and Instrument Verification and to the Method Validation SOP [QA Policy ME003BF] for these procedures.

11.4.1.2 Non-Standard Analytes

For non-standard analytes, an MDL study must be performed and calibration curve generated before analyzing any samples, unless lesser requirements are previously agreed to with the client. In any event, the minimum initial demonstration required is analysis of an extracted standard at the reporting limit and a single point calibration.

11.4.1.3 Data Quality Objectives (DQO)

Refer to project-specific Quality Assurance plans for DQO information.

11.5 Analyst Qualifications and Training

Employees that perform any step of this procedure must have a completed Read and Acknowledgment Statement for this version of the SOP in their training record. In addition, prior to unsupervised (independent) work on any client sample, analysts that prepare or analyze samples must have successful initial demonstration of capability (IDOC) and must successfully demonstrate on-going proficiency on an annual basis. Successful means the initial and on-going DOC met criteria, documentation of the DOC is complete, and the DOC record is in the employee's training file. Refer to the *Demonstration of Capability* SOP [QA SOP ME001F2] for more information.

12.0 Data Review and Corrective Action

12.1 Data Review

Pace's data review process includes a series of checks performed at different stages of the analytical process by different people to ensure that SOPs were followed, the analytical

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record is complete and properly documented, proper corrective actions were taken for QC failure and other nonconformance(s), and that test results are reported with proper qualification.

The review steps and checks that occur as employee's complete tasks and review their own work is called primary review.

All data and results are also reviewed by an experienced peer or supervisor. Secondary review is performed to verify SOPs were followed, that calibration, instrument performance, and QC criteria were met and/or proper corrective actions were taken, qualitative ID and quantitative measurement is accurate, all manual integrations are justified and documented in accordance with the Pace ENV's SOP for manual integration, calculations are correct, the analytical record is complete and traceable, and that results are properly qualified.

A third-level review, called a completeness check, is performed by reporting or project management staff to verify the data report is not missing information and project specifications were met.

Refer to the *Data Review* SOP [QA SOP ME003LP] for specific instructions and requirements for each step of the data review process.

12.2 Corrective Action

Corrective action is expected any time QC or sample results are not within acceptance criteria. If corrective action is not taken or was not successful, the decision/outcome must be documented in the analytical record. The primary analyst has primary responsibility for taking corrective action when QA/QC criteria are not met. Secondary data reviewers must verify that appropriate action was taken and/or that results reported with QC failure are properly qualified.

Corrective action is also required when carryover is suspected and when results are over range.

Samples analyzed after a high concentration sample must be checked for carryover and reanalyzed if carryover is suspected. Carryover is usually indicated by low concentration detects of the analyte in successive samples analyzed after the high concentration sample.

Sample results at concentrations above the upper limit of quantitation must be diluted and reanalyzed. The result in the diluted samples should be within the upper half of the calibration range. Results less than the mid-range of the calibration indicate the sample was over diluted and analysis should be repeated with a lower level of dilution. If dilution is not performed, any result reported above the upper range is considered a qualitative measurement and must be qualified as an estimated value.

Refer to Appendix B for a complete summary of QC, acceptance criteria, and recommended corrective actions for QC associated with this test method.

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13.0 Pollution Prevention

Pace proactively seeks ways to minimize waste generated during our work processes. Some examples of pollution prevention include but are not limited to: reduced solvent extraction, solvent capture, use of reusable cycletainers for solvent management, and real-time purchasing.

The EPA requires that laboratory waste management practice to be conducted consistent with all applicable federal and state laws and regulations. Excess reagents, samples and method process wastes must be characterized and disposed of in an acceptable manner in accordance with Pace's Chemical Hygiene Plan / Safety Manual.

14.0 Modifications

A modification is a change to a reference test method made by the laboratory. For example, changes in stoichiometry, technology, quantitation ions, reagent or solvent volumes, reducing digestion or extraction times, instrument runtimes, etc. are all examples of modifications. Refer to Pace ENV corporate SOP ENV-SOP-CORQ-0011 Method Validation and Instrument Verification for the conditions under which the procedures in test method SOPs may be modified and for the procedure and document requirements.

For compliance samples, all procedures outlined in this SOP must be followed without exception. In the event that a deviation from this SOP cannot be avoided (i.e., demonstrated and uncorrectable matrix interference, non-compatible matrix, insufficient sample amount due to client or laboratory error) it is imperative that an NCM is completed that clearly documents the anomaly. This anomaly must be communicated to the client such that corrective action activity including sample recollection can be performed. Based upon the type and severity of anomaly, the results may not be appropriate for compliance reporting. Discussions between the client, the appropriate regulatory authority, and the laboratory will be necessary to resolve certain anomalies. In any case, it is essential that any anomaly be documented on an NCM.

14.1 The quantitation and qualifier ions for some compounds have been changed from those recommended in SW-846 in order to improve the reliability of qualitative identification.

14.2 Directions for analysis of Method 624.1 are in Appendix C.

14.3 The reporting limit for total xylene is 5.0 µg/L. If m/p xylenes and o-xylene are detected at less than 5 µg/L each, but the sum is more than 5 µg/L, the total value will be reported.

14.4 All Department of Defense (DOD) / Department of Energy (DOE) requirements are found in Appendix DoD.

14.5 Historically the surrogate compounds have been included in the multi-point initial calibration at variable concentrations in order to evaluate the linear response as with any target analyte. However, with improvements in instrumentation and more reliance on the autosampler, an option is available depending on the project-specific data quality requirements for allowing the autosampler (or using a manual technique) to spike the initial calibration standards with surrogates in the same manner as the samples are spiked. With this option the surrogate

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standards in the initial calibration can be averaged to develop a response factor and an effective one-point calibration with the sole purpose to measure the surrogate recovery using the same concentration for each sample analysis. For this calibration option the surrogate linear response is less important, since multiple concentrations of surrogates are not being measured. Instead, the surrogate concentration remains constant throughout and the recovery of this known concentration can easily be attained without demonstrating if the response is linear.

14.6 Directions for analysis of Method 8260B/C/D and 624.1 for 1,4-Dioxane by Selected Ion Monitoring can be found in Appendix E.

15.0 Responsibilities

Pace ENV employees that perform any part this procedure in their work activities must have a signed Read and Acknowledgement Statement in their training file for this version of the SOP. The employee is responsible for following the procedures in this SOP and handling temporary departures from this SOP in accordance with Pace's policy for temporary departure.

Pace supervisors/managers are responsible for training employees on the procedures in this SOP and monitoring the implementation of this SOP in their work area.

16.0 Attachments

16.1 Appendix A: Tables

16.1.1 Table A-1: CAS Numbers and Reporting Limits

16.1.2 Table A-II: Reportable Analytes for TCLP

16.1.3 Table A-III: Recommended Instrument Conditions

16.1.4 Table A-IV: BFB Key Ions and Ion Abundance Criteria

16.1.5 Table A-V: Characteristic Ions

16.1.6 Table A-VI: VOA Target Compounds and Surrogates with Corresponding Internal Standards for Quantiation

16.1.7 Table A-VII: 8260B/C/D LCS/MS/MSD Compounds

16.1.8 Table A-VIII: TCLP LCS/MS/MSD Compounds

16.1.9 Table A-VIX: 8260B/C/D Surrogate Compounds

16.1.10 Table A-X: Calibration Levels, Aqueous (µg/L) and Solid (µg/kg), Regular Level

16.1.11 Table A-XI: Low Level Calibration Levels, Aqueous (µg/L)

16.1.12 Table A-XII: ICV Acceptance Criteria

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16.1.13 Table A-XIII: CCV Acceptance Criteria

16.1.14 Table A-XIV: Aqueous LCS Recovery Limits

16.1.15 Table A-XV: Solid LCS Recovery Limits

16.2 Appendix B: Level 1 and Level 2 Data Review Guidance

16.3 Appendix C: Requirements for Method 624.1

16.3.1 Table C-I: Method 624.1 Standard Reporting List and Reporting Limits

16.3.2 Table C-II: Method 624.1 Calibration and QC Acceptance Criteria

16.3.3 Table C-III: Method 624.1 LCS and MS Compounds and Spike Concentrations

16.4 Appendix D: Batch QC Requirement Summary

16.5 Appendix E: 1,4-Dioxane by Selected Ion Monitoring

16.5.1 Table E-I: Calibration Level Aqueous (µg/L) and Solid (µg/kg)

16.5.2 Table E-II: Characteristic Ions

16.5.3 Table E-III: Aqueous and Solid Control Limits

16.6 Appendix F: Preparation of Standards

16.6.1 Table F-I: 8260 Primary Standard (Total volume 5mL in Methanol)

16.6.2 Table F-II: 8260 Primary Extra Standard (Total volume 5mL in Methanol)

16.6.3 Table F-III: 8260 Secondary Standard (Total volume 5mL in Methanol)

16.6.4 Table F-IV: 8260 Secondary Extra Standard (Total volume 5mL in Methanol)

16.6.5 Table F-V: Modified 8260 Primary Standard for OxyBTEX (Total volume 5mL in Methanol)

16.6.6 Table F-VI: Method 8260 Secondary Standard for OxyBTEX (Total volume 5mL in Methanol)

16.6.7 Table F-VII: 8260 internal Standard (Total volume 5mL in Methanol)

16.6.8 Table F-VIII: 8260 Surrogate Standard (Total volume 50mL in Methanol)

16.6.9 Table F-VIX: 8260 Primary gas Standard (Total volume 5mL in Methanol)

16.6.10 Table F-X: 8260 Secondary Gas Standard (Total volume 5mL in Methanol)

16.6.11 Table F-XI: 8260 Primary Pentachloroethane Standard (Total volume 2mL in Methanol)

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16.6.12 Table F-XII: 8260 Secondary Pentachloroethane Standard (Total volume 2mL in Methanol)

16.7 Appendix G: SW-846 8260C Requirements

16.7.1 Table G-I: Recommended Minimum Relative Response Factor Criteria for Initial and Continuing Calibration Verification

16.8 Appendix H: Changes to 8260D Rev 4 Compared to 8260C Rev 3 (as pertains to this SOP)

16.9 Appendix DoD: DoD/DOE Method Specific Quality Control Requirements

16.9.1 Table DoD-I: Volatile Organic Compounds and Standard Reporting Limits

16.9.2 Table DoD-II: Volatile Organic Surrogate Compounds and Control Limits

16.9.3 Table DoD-III: LCS/MS Control Limits for Volatile Organic Compounds

16.9.4 Table DoD-IV: Characteristic Ions for Volatile Organic Compounds

17.0 References

Note: Where reference exclude a date or edition, the latest edition of the referenced document adopted/recognized by the laboratory's accreditation bodies applies. Refer to the *Laboratory Quality Manual* [QAMP ME0012K] for details.

17.1 SW-846, Test Methods for Evaluating Solid Waste, Third Edition, Update III, December 1996, Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS), Method 8260B.

17.2 SW-846, Test Methods for Evaluating Solid Waste, Revision 4, Update V, July 2014, Determinative Chromatographic Separations, Method 8000D.

17.3 SW-846, Test Methods for Evaluating Solid Waste, Third Edition, Update III, December 1996, Purge-and-Trap for Aqueous Samples, Method 5030B.

17.4 SW-846, Test Methods for Evaluating Solid Waste, Third Edition, Update III, December 1996, Closed-System Purge-and-Trap and Extraction for Volatile Organics in Soil and Waste Samples, Method 5035, Revision 0.

17.5 SW-846, Test Methods for Evaluating Solid Waste, Third Edition, Update III, December 1996, Sample Preparation for Organic Volatile Compounds, Method 5000B.

17.6 SW-846, Test Methods for Evaluating Solid Waste, Third Edition, Update III, December 1996, Sample Preparation for Organic Volatile Compounds, Method 3585.

17.7 Consolidated Quality System Manual (QSM) for Environmental Laboratories. Department of Defense (DoD) / Department of Energy (DoE).

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17.8 Standard Methods for the Examination of Water and Wastewater, 22nd Edition, 2011 – Purge and Trap Capillary-Column Gas Chromatographic/Mass Spectrometric Method, Method 6200 B-2011.

17.9 South Carolina Department of Health and Environmental Control (DHEC). Certification of the Oxygenate Compounds, February 2017.

17.10 SW-846, Test Methods for Evaluating Solid Waste, August 2006, Revision 3, Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS), Method 8260C.

17.11 SW-846, Test Methods for Evaluating Solid Waste, June 2018, Revision 4, Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry, Method 8260D.

17.12 Laboratory Accreditation Standards. TNI Standard. The NELAC Institute.

17.13 General Requirements for the Competence of Testing and Calibration Laboratories. International Standard ISO/IEC 17025.

18.0 Revision History

Revision #	Revision Date	Section Modified	Modification	Reason for Modification
-22	**09/23/2021**	Signature Page	Updated to QM to Kelly Nance and added Kristina Bouknight as EHSO	Personnel update
		All	Re-wrote and re-formatted entire document	Compliance with Pace policy
		7	Moved Ottawa sand from Reagents and Standards to Equipment and Supplies	Clarification
		7.2	Added pH and chlorine test strips	SC DHEC audit finding #18
		9.8.2	Added reference to % Solids SOP	SC DHEC audit finding #18
		Table A-XIII	Updated to 8260D acceptance criteria	SC DHEC audit finding #18
		Appendix C C.1.1	Added that 'X' and 's' criteria in Table C-II must be met for the EPA 624.1 initial demonstration of capability (IDOC).	SC DHEC audit finding #18

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Appendix A: Tables

TABLE A-I: CAS Numbers and Reporting Limits

Analytes	CAS Number	Standard Reporting Limits				
		Trace Aqueous µg/L	Low Level Aqueous µg/L	Aqueous µg/L	Low Soil µg/kg	High Soil µg/kg
Acetone	67-64-1	N/A	N/A	20	20	1000
Acetonitrile	75-05-8	N/A	N/A	10	10	500
Acrolein	107-02-8	N/A	N/A	50	50	2500
Acrylonitrile	107-13-1	N/A	N/A	50	50	2500
Benzene	71-43-2	0.5	1	5	5	250
Benzyl chloride	100-44-7	N/A	N/A	5	5	250
Bromobenzene	108-86-1	0.5	1	5	5	250
Bromochloromethane	74-97-5	0.5	1	5	5	250
Bromodichloromethane	75-27-4	0.5	1	5	5	250
Bromoform	75-25-2	0.5	1	5	5	250
Bromomethane (Methyl bromide)	74-83-9	0.5	1	5	5	250
2-Butanone (MEK)	78-93-3	N/A	N/A	10	10	500
n-Butylbenzene	104-51-8	0.5	1	5	5	250
tert-Butylbenzene	98-06-6	0.5	1	5	5	250
sec-Butylbenzene	135-98-8	0.5	1	5	5	250
Carbon disulfide	75-15-0	0.5	1	5	5	250
Carbon tetrachloride	56-23-5	0.5	1	5	5	250
Chlorobenzene	108-90-7	0.5	1	5	5	250
2-Chloro-1,3-Butadiene (Chloroprene)	126-99-8	N/A	N/A	5	5	250
Chloroethane	75-00-3	0.5	1	5	5	250
2-Chloroethyl vinyl ether	110-75-8	N/A	N/A	10	10	500
Chloroform	67-66-3	0.5	1	5	5	250
Chloromethane (Methyl chloride)	74-87-3	0.5	1	5	5	250
3-Chloropropene (Allyl chloride)	107-05-1	N/A	N/A	10	10	500
2-Chlorotoluene	95-49-8	0.5	1	5	5	250
4-Chlorotoluene	106-43-4	0.5	1	5	5	250
Cyclohexane	110-82-7	N/A	1	5	5	250
Cyclohexanone	108-94-1	N/A	N/A	50	50	2500
Dibromochloromethane	124-48-1	0.5	1	5	5	250
1,2-Dibromo-3-chloropropane (DBCP)	96-12-8	0.5	1	5	5	250
1,2-Dibromoethane (EDB)	106-93-4	0.5	1	5	5	250
Dibromomethane (Methylene bromide)	74-95-3	0.5	1	5	5	250
1,2-Dichlorobenzene	95-50-1	0.5	1	5	5	250
1,3-Dichlorobenzene	541-73-1	0.5	1	5	5	250

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TABLE A-I: CAS Numbers and Reporting Limits (continued)

Analytes	CAS Number	Standard Reporting Limits				
		Trace Aqueous µg/L	Low Level Aqueous µg/L	Aqueous µg/L	Low Soil µg/kg	High Soil µg/kg
1,4-Dichlorobenzene	106-46-7	0.5	1	5	5	250
trans-1,4-Dichloro-2-butene	110-57-6	N/A	N/A	10	10	500
Dichlorodifluoromethane	75-71-8	0.5	1	5	5	250
1,1-Dichloroethane	75-34-3	0.5	1	5	5	250
1,2-Dichloroethane	107-06-2	0.5	1	5	5	250
cis-1,2-Dichloroethene	156-59-2	0.5	1	5	5	250
trans-1,2-Dichloroethene	156-60-5	0.5	1	5	5	250
1,1-Dichloroethene	75-35-4	0.5	1	5	5	250
1,3-Dichloropropane	142-28-9	0.5	1	5	5	250
2,2-Dichloropropane	594-20-7	0.5	1	5	5	250
1,1-Dichloropropene	563-58-6	0.5	1	5	5	250
cis-1,3-Dichloropropene	10061-01-5	0.5	1	5	5	250
trans-1,3-Dichloropropene	10061-02-6	0.5	1	5	5	250
1,2-Dichloropropane	78-87-5	0.5	1	5	5	250
Diisopropyl ether (IPE)	108-20-3	0.5	1	5	5	250
3,3-dimethyl-1-butanol	624-95-3	N/A	N/A	100	N/A	N/A
1,4-Dioxane	123-91-1	5	10	250	250	12,000
Ethyl acetate	141-78-6	N/A	N/A	5	5	250
Ethanol	64-17-5	N/A	N/A	100	N/A	N/A
Ethyl ether	60-29-7	0.5	1	5	5	250
Ethylbenzene	100-41-4	0.5	1	5	5	250
Ethyl methacrylate	97-63-2	N/A	N/A	5	5	250
Ethyl-tert-butyl ether	637-92-3	N/A	N/A	1.0	N/A	N/A
Hexachlorobutadiene	87-68-3	N/A	N/A	5	5	250
Hexane	110-54-3	N/A	0.5	2.5	2.5	125
2-Hexanone	591-78-6	N/A	N/A	10	10	500
Isopropyl acetate	108-21-4	N/A	N/A	2.5	N/A	N/A
Isopropylbenzene	98-82-8	0.5	1	5	5	250
p-Isopropyltoluene	99-87-6	0.5	1	5	5	250
Isobutyl alcohol	78-83-1	N/A	N/A	50	50	2500
Methacrylonitrile	126-98-7	N/A	N/A	5	5	250
Methyl acetate	79-20-9	N/A	N/A	5	5	250
Methylcyclohexane	108-87-2	N/A	N/A	5	5	250
Methyl iodide (Iodomethane)	74-88-4	N/A	N/A	5	5	250
Methyl methacrylate	80-62-6	N/A	N/A	5	5	250
4-Methyl-2-Pentanone	108-10-1	N/A	N/A	10	10	500
Methyl tert butyl ether (MTBE)	1634-04-4	0.5	1	5	5	250
Methylene chloride	75-09-2	0.5	1	5	5	250

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TABLE A-I: CAS Numbers and Reporting Limits (continued)

Analytes	CAS Number	Standard Reporting Limits				
		Trace Aqueous µg/L	Low Level Aqueous µg/L	Aqueous µg/L	Low Soil µg/kg	High Soil µg/kg
Naphthalene	91-20-3	0.5	1	5	5	250
2-Nitropropane	79-46-9	N/A	N/A	5	N/A	N/A
n-Butyl acetate	123-86-4	N/A	2	10	N/A	N/A
n-Propylbenzene	103-65-1	0.5	1	5	5	250
Propionitrile (Ethyl cyanide)	107-12-0	NA	NA	50	50	2500
Styrene	100-42-5	0.5	1	5	5	250
tert-amyl Alcohol	75-85-4	N/A	N/A	20	N/A	N/A
tert-amyl-methyl ether	994-05-8	N/A	N/A	10	N/A	N/A
tert-Butyl Alcohol	75-65-0	N/A	N/A	20	N/A	N/A
tert-Buytl Formate	762-75-4	N/A	N/A	5.0	N/A	N/A
1,1,1,2-Tetrachloroethane	630-20-6	0.5	1	5	5	250
1,1,2,2-Tetrachloroethane	79-34-5	0.5	1	5	5	250
Tetrachloroethene	127-18-4	0.5	1	5	5	250
Tetrahydrofuran	109-99-9	NA	NA	10	10	500
Toluene	108-88-3	0.5	1	5	5	250
1,2,4-Trichlorobenzene	120-82-1	0.5	1	5	5	250
1,2,3-Trichlorobenzene	87-61-6	0.5	1	5	5	250
1,1,1-Trichloroethane	71-55-6	0.5	1	5	5	250
1,1,2-Trichloroethane	79-00-5	0.5	1	5	5	250
Trichloroethene	79-01-6	0.5	1	5	5	250
Trichlorofluoromethane	75-69-4	0.5	1	5	5	250
1,1,2-Trichloro-1,2,2-Trifluoroethane (Freon 113)	76-13-1	0.5	1	5	5	250
1,2,3-Trichloropropane	96-18-4	0.5	1	5	5	250
1,2,4-Trimethylbenzene	95-63-6	0.5	1	5	5	250
1,3,5-Trimethylbenzene	108-67-8	0.5	1	5	5	250
Vinyl acetate	108-05-4	0.5	1	5	5	250
Vinyl Chloride	75-01-4	0.5	1	2	10	500
Xylenes (total)	1330-20-7	0.5	1	5	5	250
m/p-Xylenes	108-38-3	0.5	1	5	5	250
o-Xylenes	95-47-6	0.5	1	5	5	250

Note: The reporting limits for non-aqueous waste samples which are prepared by waste dilution are 10x the high soil limits.

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TABLE A-II: Reportable Analytes for TCLP

Analytes	CAS Number
Benzene	71-43-2
2-Butanone (MEK)	78-93-9
Carbon tetrachloride	56-23-5
Chlorobenzene	108-90-7
Chloroform	75-00-3
1,2-Dichloroethane	107-06-2
1,1-Dichloroethene	75-35-4
Tetrachloroethene	127-18-4
Trichloroethene	79-01-6
Vinyl Chloride	75-01-4

TABLE A-III: Recommended Instrument Conditions

Mass range	35-300 amu
Scan time	£ 1 second/scan
Initial column temperature / Hold time	45°C for 3.50 minutes
Column temperature program	10 °C/min to 100°C, 25 °C/min to 225 °C
Final column temperature / Hold time	225 °C for 3 minutes
Injector temperature	220°C
MS interface transfer line temperature	225 °C
Source temperature	According to manufacturer's specifications
Carrier gas	Helium at 0.5-1ml/min, constant flow
Trap	OI #10, #11 or #7
Purge gas	Helium at 40ml/min
Purge time	11 min
Sample heater	50 °C soils, ambient or heated for waters
Dry purge	0 min
Desorb preheat	180°C
Desorb	200°C for 1 min
Bake	210°C for 5-7 min
Transfer line/Valve temperature	110ºC-140ºC

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TABLE A-IV: BFB Key Ions and Ion Abundance Criteria

Mass	Ion Abundance Criteria
50	15 – 40% of mass 95
75	30 – 60% of mass 95
95	Base peak, 100% relative abundance
96	5 – 9% of mass 95
173	Less than 2% of mass 174
174	Greater than 50 % of mass 95
175	5 – 9% of mass 174
176	Greater than 95% but less than 101% of mass 174
177	5 – 9 % of mass 176

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TABLE A-V: Characteristic Ions

Analyte	Primary	Secondary	Tertiary
Acetone	43	58	
Acetonitrile	40	39	41
Acrolein	56	55	
Acrylonitrile	53	52	51
Benzene	78		
Benzyl chloride	91	126	
Bromobenzene	156	77	158
Bromochloromethane	128	49	130
Bromodichloromethane	83	85	
Bromoform	173	175	
Bromomethane (Methyl bromide)	94	96	
2-Butanone (MEK)	72	43	57
n-Butyl acetate	43	56	
n-Butylbenzene	91	92	134
tert-Butylbenzene	119	91	134
sec-Butylbenzene	105	134	
Carbon disulfide	76	78	
Carbon tetrachloride	119	117	121
Chlorobenzene	112	77	114
2-Chloro-1,3-Butadiene (Chloroprene)	53	88	51
Chloroethane	64	66	
2-Chloroethyl vinyl ether	63	65	106
Chloroform	83	85	
Chloromethane (Methyl chloride)	50	52	
3-Chloropropene (Allyl chloride)	76	78	41
4-Chlorotoluene	126	91	
Cyclohexane	41	56	
Cyclohexanone	55	69	98
Dibromochloromethane	129	127	
1,2-Dibromo-3-chloropropane (DBCP)	75	155	157
1,2-Dibromoethane (EDB)	107	109	
Dibromomethane (Methylene bromide)	93	174	95
2-Chlorotoluene	91	126	

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TABLE A-V: Characteristic Ions (continued)

Analyte	Primary	Secondary	Tertiary
1,2-Dichlorobenzene	146	148	111
1,3-Dichlorobenzene	146	148	111
1,4-Dichlorobenzene	146	148	111
trans-1,4-Dichloro-2-butene	53	88	
Dichlorodifluoromethane	85	87	
1,1-Dichloroethane	63	65	
1,2-Dichloroethane	62	64	
cis-1,2-Dichloroethene	96	61	
trans-1,2-Dichloroethene	96	61	98
1,1-Dichloroethene	96	61	63
1,2-Dichloropropane	63	76	
1,3-Dichloropropane	76	78	
2,2-Dichloropropane	77	79	
1,1-Dichloropropene	75	110	77
cis-1,3-Dichloropropene	75	77	
trans-1,3-Dichloropropene	75	77	
Diisopropyl ether (IPE)	87	59	69
3,3-dimethyl-1-butanol	57	69	
1,4-Dioxane	88	58	
Ethyl acetate	43	88	
Ethanol	45	46	
Ethyl ether	59	45	74
Ethylbenzene	106	91	
Ethyl methacrylate	69	41	
Ethyl-tert-butyl ether	59	87	
Hexachlorobutadiene	225	223	227
Hexane	57	43	86
2-Hexanone	43	58	
Isopropyl acetate	43	61	87
Isopropylbenzene	105	120	
p-Isopropyltoluene	119	134	
Isobutyl alcohol	42	43	41
Methacrylonitrile	67	41	39
Methyl acetate	43	74	
Methyl iodide (Iodomethane)	142	127	
Methyl methacrylate	41	69	
4-Methyl-2-Pentanone	43	58	
Methyl tertiary butyl ether (MTBE)	73	57	

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TABLE A-V: Characteristic Ions (continued)

Analyte	Primary	Secondary	Tertiary
Methylcyclohexane	83	55	98
Methylene chloride	84	49	51
Naphthalene	128		
2-Nitropropane	43	41	
n-Propylbenzene	91	120	
Propionitrile (Ethyl cyanide)	54	52	55
Styrene	104	78	
tert-amyl Alcohol	59	73	55
tert-amyl-methyl ether	87	73	
tert-Butyl Alcohol	59	57	
tert-Butyl Formate	59	57	
1,1,1,2-Tetrachloroethane	131	133	
1,1,2,2-Tetrachloroethane	83	85	
Tetrachloroethene	164	129	131
Tetrahydrofuran	42	72	
Toluene	92	91	
1,2,4-Trichlorobenzene	180	182	145
1,2,3-Trichlorobenzene	180	182	145
1,1,1-Trichloroethane	97	101	
1,1,2-Trichloroethane	97	83	85
Trichloroethene	130	95	97
Trichlorofluoromethane	101	103	
1,1,2-Trichloro-1,2,2-Trifluoroethane (Freon 113)	101	103	151
1,2,3-Trichloropropane	110	75	77
1,2,4-Trimethylbenzene	105	120	
1,3,5-Trimethylbenzene	105	120	
Vinyl Acetate	86	44	
Vinyl Chloride	62	64	
m/p-Xylenes	106	91	
o-Xylenes	106	91	
Xylenes (total)	Summation	Summation	
*Pentafluorobenzene (IS)	168		
*1,4-Difluorobenzene (IS)	114		
*Chlorobenzene-d5 (IS)	117	82	119
*1,4-Dichlorobenzene-d4 (IS)	152	150	
$1,2-Dichloroethane-d4 (SS)	65	102	
$Toluene-d8 (SS)	98		
$4-Bromofluorobenzene (SS)	95	174	176

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TABLE A-VI: VOA Target Compounds and Surrogates with Corresponding Internal Standards for Quantitation

Group 1: Pentafluorobenzene		
Dichlorodifluoromethane	Allyl Chloride	Propionitrile
Chloromethane	Methylene Chloride	Ethyl acetate
Vinyl Chloride	Tert-Butyl Alcohol	Methacrylonitrile
Bromomethane	Acrylonitrile	Bromochloromethane
Chloroethane	trans-1,2-Dichloroethene	Tetrahydrofuran
Trichlorofluoromethane	tert-Butyl methyl ether (MTBE)	Chloroform
Ethanol	Hexane	Tert-Butyl Formate
Ethyl ether	1,1-Dichloroethane	1,1,1-Trichloroethane
Acrolein	Vinyl acetate	Cyclohexane
Acetone	Diisopropyl ether (IPE)	1,1-Dichloropropene
1,1-Dichloroethene	Chloroprene	Carbon Tetrachloride
1,1,2-Trichloro-1,2,2-Trifluoroethane (Freon 113)	Ethyl-Tert-Butyl Ether	Isobutyl Alcohol
	cis-1,2-Dichloroethene	Tert-Amyl Alcohol
Methyl Iodide	2-Butanone (MEK)	Dibromofluoromethane (Surrogate, DOD only)
Carbon Disulfide	2,2-Dichloropropane	
Acetonitrile		
Methyl acetate		
Group 2: 1,4-Difluorobenzene		
Benzene	1,2-Dichloropropane	2-Chloroethylvinyl ether
Isopropyl Acetate	Dibromomethane	cis-1,3-Dichloropropene
1,2-Dichloroethane	Methyl Methacrylate	4-Methyl-2-pentanone
Tert-Amyl Methyl Ether	1,4-Dioxane	Toluene
Trichloroethene	Bromodichloromethane	1,2-Dichloroethane-d4 (Surrogate)
Methylcyclohexane	2-nitropropane	
Group 3: Chlorobenzene-d5		
trans-1,3-Dichloropropene	3,3-Dimethyl-1-butanol	Bromoform
Ethyl Methacrylate	1,2-Dibromoethane (EDB)	Isopropylbenzene
1,1,2-Trichloroethane	Chlorobenzene	Cyclohexanone
Tetrachloroethene	1,1,1,2-Tetrachloroethane	Toluene-d8 (Surrogate)
1,3-Dichloropropane	Ethylbenzene	Bromofluorobenzene (Surrogate)
2-Hexanone	m+p-Xylene	
Dibromochloromethane	o-Xylene	
n-Butyl acetate	Styrene	
Group 4: 1,4-Dichlorobenzene-d4		
Isopropylbenzene	1,3,5-Trimethylbenzene	Benzyl Chloride
Cyclohexanone	4-Chlorotoluene	n-Butybenzene
Bromobenzene	tert-Butylbenzene	1,2-Dichlorobenzene
1,1,2,2-Tetrachloroethane	1,2,4-Trimethylbenzene	1,2-Dibromo-3-chloropropane
1,2,3-Trichloropropane	sec-Butylbenzene	1,2,4-Trichlorobenzene
trans-1,4-Dichloro-2-butene	1,3-Dichlorobenzene	Hexachlorobutadiene
n-Propylbenzene	1-Isopropyltoluene	Naphthalene
2-Chlorotoluene	1,4-Dichlorobenzene	1,2,3-Trichlorobenzene

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TABLE A-VII: 8260B/C/D LCS/MS/MSD Compounds

LCS Compounds	Spiking Level in Extract (mg/L)
Acetone	100
Acetonitrile	500
Acrolein	500
Acrylonitrile	100
Benzene	50
Benzyl chloride	50
Bromobenzene	50
Bromochloromethane	50
Bromodichloromethane	50
Bromoform	50
Bromomethane (Methyl bromide)	50
2-Butanone (MEK)	100
n-Butyl Acetate	50
n-Butylbenzene	50
tert-Butylbenzene	50
sec-Butylbenzene	50
Carbon disulfide	50
Carbon tetrachloride	50
Chlorobenzene	50
2-Chloro-1,3-Butadiene (Chloroprene)	50
Chloroethane	50
2-Chloroethyl vinyl ether	50
Chloroform	50
Chloromethane (Methyl chloride)	50
3-Chloropropene (Allyl chloride)	50
2-Chlorotoluene	50
4-Chlorotoluene	50
Cyclohexane	50
Cyclohexanone	500
Dibromochloromethane	50
1,2-Dibromo-3-chloropropane (DBCP)	50
1,2-Dibromoethane (EDB)	50
Dibromomethane (Methylene bromide)	50
1,2-Dichlorobenzene	50
1,3-Dichlorobenzene	50
1,4-Dichlorobenzene	50
trans-1,4-Dichloro-2-butene	50
Dichlorodifluoromethane	50
1,1-Dichloroethane	50
1,2-Dichloroethane	50
cis-1,2-Dichloroethene	50
trans-1,2-Dichloroethene	50

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TABLE A-VII: 8260B/C/D LCS/MS/MSD Compounds (continued)

LCS Compounds	Spiking Level in Extract (mg/L)
1,1-Dichloroethene	50
1,3-Dichloropropane	50
2,2-Dichloropropane	50
1,1-Dichloropropene	50
cis-1,3-Dichloropropene	50
trans-1,3-Dichloropropene	50
1,2-Dichloropropane	50
Diisopropyl ether (IPE)	50
3,3-dimethyl-1-butanol	1000
1,4-Dioxane	500
Ethylbenzene	50
Ethanol	5000
Ethyl acetate	50
Ethyl ether	50
Ethyl methacrylate	50
Ethyl-tert-butyl ether	50
Hexachlorobutadiene	50
Hexane	50
2-Hexanone	100
Isopropyl acetate	50
Isopropylbenzene	50
p-Isopropyltoluene	50
Isobutyl alcohol	500
Methacrylonitrile	250
Methyl acetate	50
Methylcyclohexane	50
Methyl iodide (Iodomethane)	50
Methyl methacrylate	50
4-Methyl-2-Pentanone	100
Methyl tertiary butyl ether (MTBE)	50
Methylene chloride	50
Naphthalene	50
2-Nitropropane	50
n-Propylbenzene	50
Propionitrile (Ethyl cyanide)	500
Styrene	50
Tert-amyl Alcohol	1000
Tert-amyl-methyl ether	50
Tert-Butyl Alcohol	1000
Tert-Butyl Formate	250
1,1,1,2-Tetrachloroethane	50
1,1,2,2-Tetrachloroethane	50

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TABLE A-VII: 8260B/C/D LCS/MS/MSD Compounds (continued)

LCS Compounds	Spiking Level in Extract (mg/L)
Tetrachloroethene	50
Tetrahydrofuran	50
Toluene	50
1,2,4-Trichlorobenzene	50
1,2,3-Trichlorobenzene	50
1,1,1-Trichloroethane	50
1,1,2-Trichloroethane	50
Trichloroethene	50
Trichlorofluoromethane	50
1,1,2-Trichloro-1,2,2-Trifluoroethane (Freon 113)	50
1,2,3-Trichloropropane	50
1,2,4-Trimethylbenzene	50
1,3,5-Trimethylbenzene	50
Vinyl acetate	50
Vinyl Chloride	50
m/p-Xylenes	50
o-Xylenes	50
Xylenes (total)	100

TABLE A-VIII: TCLP LCS/MS/MSD Compounds

LCS Compounds	Spiking Level in Sample (mg/L)
Benzene	50
2-Butanone (MEK)	100
Carbon tetrachloride	50
Chlorobenzene	50
Chloroform	50
1,2-Dichloroethane	50
1,1-Dichloroethene	50
Tetrachloroethene	50
Trichloroethene	50
Vinyl chloride	50

Recovery limits for the LCS and for matrix spikes are generated from historical data. Refer to Appendix C and D for recovery limits.

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TABLE A-IX: 8260B/C/D Surrogate Compounds

Surrogate Compounds	Spiking Level in extract (mg/L or mg/kg)
1,2-Dichloroethane-d4	50
Toluene-d8	50
4-Bromofluorobenzene	50

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TABLE A-X: Calibration Levels, Aqueous (µg/L) and Solid (µg/kg), Regular Level

Aqueous Analyte	Level 1	Level 2	Level 3	Level 4	Level 5
Acetone	10	40	100	200	400
Acetonitrile	50	200	500	1000	2000
Acrolein	50	200	500	1000	2000
Acrylonitrile	10	40	100	200	400
Benzene	5.0	20	50	100	200
Benzyl chloride	5.0	20	50	100	200
Bromobenzene	5.0	20	50	100	200
Bromochloromethane	5.0	20	50	100	200
Bromodichloromethane	5.0	20	50	100	200
Bromoform	5.0	20	50	100	200
Bromomethane (Methyl bromide)	5.0	20	50	100	200
2-Butanone (MEK)	10	40	100	200	400
n-Butyl acetate	5.0	20	50	100	200
n-Butylbenzene	5.0	20	50	100	200
tert-Butylbenzene	5.0	20	50	100	200
sec-Butylbenzene	5.0	20	50	100	200
Carbon disulfide	5.0	20	50	100	200
Carbon tetrachloride	5.0	20	50	100	200
Chlorobenzene	5.0	20	50	100	200
2-Chloro-1,3-Butadiene (Chloroprene)	5.0	20	50	100	200
Chloroethane	5.0	20	50	100	200
2-Chloroethyl vinyl ether	5.0	20	50	100	200
Chloroform	5.0	20	50	100	200
Chloromethane (Methyl chloride)	5.0	20	50	100	200
3-Chloropropene (Allyl chloride)	5.0	20	50	100	200
2-Chlorotoluene	5.0	20	50	100	200
4-Chlorotoluene	5.0	20	50	100	200
Cyclohexane	5.0	20	50	100	200
Cyclohexanone	50	200	500	1000	2000
Dibromochloromethane	5.0	20	50	100	200
1,2-Dibromo-3-chloropropane (DBCP)	5.0	20	50	100	200
1,2-Dibromoethane (EDB)	5.0	20	50	100	200
Dibromomethane (Methylene bromide)	5.0	20	50	100	200
1,2-Dichlorobenzene	5.0	20	50	100	200
1,3-Dichlorobenzene	5.0	20	50	100	200
1,4-Dichlorobenzene	5.0	20	50	100	200
trans-1,4-Dichloro-2-butene	5.0	20	50	100	200
Dichlorodifluoromethane	5.0	20	50	100	200

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TABLE A-X: Calibration Levels, Aqueous (µg/L) and Solid (µg/kg), Regular Level (continued)

Aqueous Analyte	Level 1	Level 2	Level 3	Level 4	Level 5
1,1-Dichloroethane	5.0	20	50	100	200
1,2-Dichloroethane	5.0	20	50	100	200
cis-1,2-Dichloroethene	5.0	20	50	100	200
trans-1,2-Dichloroethene	5.0	20	50	100	200
1,1-Dichloroethene	5.0	20	50	100	200
1,3-Dichloropropane	5.0	20	50	100	200
2,2-Dichloropropane	5.0	20	50	100	200
1,1-Dichloropropene	5.0	20	50	100	200
cis-1,3-Dichloropropene	5.0	20	50	100	200
trans-1,3-Dichloropropene	5.0	20	50	100	200
1,2-Dichloropropane	5.0	20	50	100	200
Diisopropyl ether (IPE)	5.0	20	50	100	200
3,3-dimethyl-1-butanol	100	400	1000	2000	4000
1,4-Dioxane	50	200	500	1000	2000
Ethanol	500	2000	5000	10000	20000
Ethyl acetate	5.0	20	50	100	200
Ethyl ether	5.0	20	50	100	200
Ethylbenzene	5.0	20	50	100	200
Ethyl methacrylate	5.0	20	50	100	200
Ethyl-tert-butyl ether	5.0	20	50	100	200
Hexachlorobutadiene	5.0	20	50	100	200
Hexane	5.0	20	50	100	200
2-Hexanone	10	40	100	200	400
Isopropyl acetate	5.0	20	50	100	200
Isopropylbenzene	5.0	20	50	100	200
p-Isopropyltoluene	5.0	20	50	100	200
Isobutyl alcohol	50	200	500	1000	2000
Methacrylonitrile	25.0	100	250	500	1000
Methyl acetate	5.0	20	50	100	200
Methylcyclohexane	5.0	20	50	100	200
Methyl iodide (Iodomethane)	5.0	20	50	100	200
Methyl methacrylate	5.0	20	50	100	200
4-Methyl-2-Pentanone	10	40	100	200	400
Methyl tertiary butyl ether (MTBE)	5.0	20	50	100	200
Methylene chloride	5.0	20	50	100	200
Naphthalene	5.0	20	50	100	200
2-Nitropropane	5.0	20	50	100	200
n-Propylbenzene	5.0	20	50	100	200
Propionitrile (Ethyl cyanide)	50	200	500	1000	2000

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TABLE A-X: Calibration Levels, Aqueous (µg/L) and Solid (µg/kg), Regular Level (continued)

Aqueous Analyte	Level 1	Level 2	Level 3	Level 4	Level 5
Styrene	5.0	20	50	100	200
Tert-amyl Alcohol	100	400	1000	2000	4000
Tert-amyl-methyl ether	5.0	20	50	100	200
Tert-Butyl Alcohol	100	400	1000	2000	4000
Tert-Butyl Formate	25	100	250	500	1000
Tetrahydrofuran	5.0	20	50	100	200
Toluene	5.0	20	50	100	200
1,2,4-Trichlorobenzene	5.0	20	50	100	200
1,2,3-Trichlorobenzene	5.0	20	50	100	200
1,1,1-Trichloroethane	5.0	20	50	100	200
1,1,2-Trichloroethane	5.0	20	50	100	200
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)	5.0	20	50	100	200
Trichloroethene	5.0	20	50	100	200
Trichlorofluoromethane	5.0	20	50	100	200
1,2,3-Trichloropropane	5.0	20	50	100	200
1,2,4-Trimethylbenzene	5.0	20	50	100	200
1,3,5-Trimethylbenzene	5.0	20	50	100	200
Vinyl acetate	5.0	20	50	100	200
Vinyl Chloride	5.0	20	50	100	200
Xylenes (total)	10	40	100	200	400
m/p-Xylenes	5.0	20	50	100	200
o-Xylenes	5.0	20	50	100	200

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TABLE A-XI: Low Level Calibration Levels, Aqueous (µg/L)

Low Level Aqueous Analyte	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
Acetone	1.0	2.0	10	40	100	200	400
Acetonitrile	5.0	10	50	200	500	1000	2000
Acrolein	5.0	10	50	200	500	1000	2000
Acrylonitrile	1.0	2.0	10	40	100	200	400
Benzene	0.5	1.0	5.0	20	50	100	200
Benzyl chloride	0.5	1.0	5.0	20	50	100	200
Bromobenzene	0.5	1.0	5.0	20	50	100	200
Bromochloromethane	0.5	1.0	5.0	20	50	100	200
Bromodichloromethane	0.5	1.0	5.0	20	50	100	200
Bromoform	0.5	1.0	5.0	20	50	100	200
Bromomethane (Methyl bromide)	0.5	1.0	5.0	20	50	100	200
2-Butanone (MEK)	1.0	2.0	10	40	100	200	400
n-Butyl acetate	0.5	1.0	5.0	20	50	100	200
n-Butylbenzene	0.5	1.0	5.0	20	50	100	200
tert-Butylbenzene	0.5	1.0	5.0	20	50	100	200
sec-Butylbenzene	0.5	1.0	5.0	20	50	100	200
Carbon disulfide	0.5	1.0	5.0	20	50	100	200
Carbon tetrachloride	0.5	1.0	5.0	20	50	100	200
Chlorobenzene	0.5	1.0	5.0	20	50	100	200
2-Chloro-1,3-Butadiene (Chloroprene)	0.5	1.0	5.0	20	50	100	200
Chloroethane	0.5	1.0	5.0	20	50	100	200
2-Chloroethyl vinyl ether	0.5	1.0	5.0	20	50	100	200
Chloroform	0.5	1.0	5.0	20	50	100	200
Chloromethane (Methyl chloride)	0.5	1.0	5.0	20	50	100	200
3-Chloropropene (Allyl chloride)	0.5	1.0	5.0	20	50	100	200
2-Chlorotoluene	0.5	1.0	5.0	20	50	100	200
4-Chlorotoluene	0.5	1.0	5.0	20	50	100	200
Cyclohexane	0.5	1.0	5.0	20	50	100	200
Cyclohexanone	5	10	50	200	500	1000	2000
Dibromochloromethane	0.5	1.0	5.0	20	50	100	200
1,2-Dibromo-3-chloropropane (DBCP)	0.5	1.0	5.0	20	50	100	200
1,2-Dibromoethane (EDB)	0.5	1.0	5.0	20	50	100	200
Dibromomethane (Methylene bromide)	0.5	1.0	5.0	20	50	100	200
1,2-Dichlorobenzene	0.5	1.0	5.0	20	50	100	200
1,3-Dichlorobenzene	0.5	1.0	5.0	20	50	100	200
1,4-Diclorobenzene	0.5	1.0	5.0	20	50	100	200

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TABLE A-XI: Low Level Calibration Levels, Aqueous (µg/L) (continued)

Low Level Aqueous Analyte	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
trans-1,4-Dichloro-2-butene	0.5	1.0	5.0	20	50	100	200
Dichlorodifluoromethane	0.5	1.0	5.0	20	50	100	200
1,1-Dichloroethane	0.5	1.0	5.0	20	50	100	200
1,2-Dichloroethane	0.5	1.0	5.0	20	50	100	200
cis-1,2-Dichloroethene	0.5	1.0	5.0	20	50	100	200
trans-1,2-Dichloroethene	0.5	1.0	5.0	20	50	100	200
1,1-Dichloroethene	0.5	1.0	5.0	20	50	100	200
1,3-Dichloropropane	0.5	1.0	5.0	20	50	100	200
2,2-Dichloropropane	0.5	1.0	5.0	20	50	100	200
1,1-Dichloropropene	0.5	1.0	5.0	20	50	100	200
cis-1,3-Dichloropropene	0.5	1.0	5.0	20	50	100	200
trans-1,3-Dichloropropene	0.5	1.0	5.0	20	50	100	200
1,2-Dichloropropane	0.5	1.0	5.0	20	50	100	200
Diisopropyl ether (IPE)	0.5	1.0	5.0	20	50	100	200
3,3-dimethyl-1-butanol	NA	20	100	400	1000	2000	4000
1,4-Dioxane	5.0	10	50	200	500	1000	2000
Ethanol	NA	100	500	2000	5000	10000	20000
Ethyl acetate	0.5	1.0	5.0	20	50	100	200
Ethyl ether	0.5	1.0	5.0	20	50	100	200
Ethylbenzene	0.5	1.0	5.0	20	50	100	200
Ethyl methacrylate	0.5	1.0	5.0	20	50	100	200
Ethyl-tert-butyl ether	NA	1.0	5.0	20	50	100	200
Hexachlorobutadiene	0.5	1.0	5.0	20	50	100	200
2-Hexanone	1.0	2.0	10	40	100	200	400
Isopropylbenzene	0.5	1.0	5.0	20	50	100	200
p-Isopropyltoluene	0.5	1.0	5.0	20	50	100	200
Isobutyl alcohol	5.0	10	50	200	500	1000	2000
Methacrylonitrile	2.5	5.0	25	100	250	500	1000
Methyl acetate	0.5	1.0	5.0	20	50	100	200
Methylcyclohexane	0.5	1.0	5.0	20	50	100	200
Methyl iodide (Iodomethane)	0.5	1.0	5.0	20	50	100	200
Methyl methacrylate	0.5	1.0	5.0	20	50	100	200
4-Methyl-2-Pentanone	1.0	2.0	10	40	100	200	400
Methyl tertiary butyl ether (MTBE)	0.5	1.0	5.0	20	50	100	200
Methylene chloride	0.5	1.0	5.0	20	50	100	200
Naphthalene	0.5	1.0	5.0	20	50	100	200
n-Propylbenzene	0.5	1.0	5.0	20	50	100	200
Propionitrile (Ethyl cyanide)	5.0	10	50	200	500	1000	2000
Styrene	0.5	1.0	5.0	20	50	100	200
Tert-amyl Alcohol	NA	20	100	400	1000	2000	4000
Tert-amyl-methyl ether	NA	1.0	5.0	20	50	100	200

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TABLE A-XI: Low Level Calibration Levels, Aqueous (µg/L) (continued)

Low Level Aqueous Analyte	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
Tert-Butyl Alcohol	NA	20	100	400	1000	2000	4000
Tert-Buytl Formate	NA	5.0	25	100	250	500	1000
1,1,1,2-Tetrachloroethane	0.5	1.0	5.0	20	50	100	200
1,1,2,2-Tetrachloroethane	0.5	1.0	5.0	20	50	100	200
Tetrachloroethene	0.5	1.0	5.0	20	50	100	200
Tetrahydrofuran	0.5	1.0	5.0	20	50	100	200
Toluene	0.5	1.0	5.0	20	50	100	200
1,2,4-Trichlorobenzene	0.5	1.0	5.0	20	50	100	200
1,2,3-Trichlorobenzene	0.5	1.0	5.0	20	50	100	200
1,1,1-Trichloroethane	0.5	1.0	5.0	20	50	100	200
1,1,2-Trichloroethane	0.5	1.0	5.0	20	50	100	200
Trichloroethene	0.5	1.0	5.0	20	50	100	200
Trichlorofluoromethane	0.5	1.0	5.0	20	50	100	200
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)	0.5	1.0	5.0	20	50	100	200
1,2,3-Trichloropropane	0.5	1.0	5.0	20	50	100	200
1,2,4-Trimethylbenzene	0.5	1.0	5.0	20	50	100	200
1,3,5-Trimethylbenzene	0.5	1.0	5.0	20	50	100	200
Vinyl acetate	0.5	1.0	5.0	20	50	100	200
Vinyl Chloride	0.5	1.0	5.0	20	50	100	200
m/p-Xylenes	0.5	1.0	5.0	20	50	100	200
o-Xylenes	0.5	1.0	5.0	20	50	100	200
Xylenes (total)	1.0	2.0	10	40	100	200	400

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TABLE A-XII: ICV Acceptance Criteria

Analyte	%Difference or %Drift
Acetone	± 30
Acetonitrile	± 30
Acrolein	± 30
Acrylonitrile	± 30
Benzene	± 30
Benzyl chloride	± 30
Bromobenzene	± 30
Bromochloromethane	± 30
Bromodichloromethane	± 30
Bromoform	± 30
Bromomethane (Methyl bromide)	± 30
2-Butanone (MEK)	± 30
n-Butyl acetate	± 30
n-Butylbenzene	± 30
tert-Butylbenzene	± 30
sec-Butylbenzene	± 30
Carbon disulfide	± 30
Carbon tetrachloride	± 30
Chlorobenzene	± 30
2-Chloro-1,3-Butadiene (Chloroprene)	± 30
Chloroethane	± 30
2-Chloroethyl vinyl ether	± 30
Chloroform	± 30
Chloromethane (Methyl chloride)	± 30
3-Chloropropene (Allyl chloride)	± 30
2-Chlorotoluene	± 30
4-Chlorotoluene	± 30
Cyclohexane	± 30
Cyclohexanone	± 40
Dibromochloromethane	± 30
1,2-Dibromo-3-chloropropane (DBCP)	± 30
1,2-Dibromoethane (EDB)	± 30
Dibromomethane (Methylene bromide)	± 30
1,2-Dichlorobenzene	± 30
1,3-Dichlorobenzene	± 30
1,4-Dichlorobenzene	± 30
trans-1,4-Dichloro-2-butene	± 30
Dichlorodifluoromethane	± 30
1,1-Dichloroethane	± 30
1,2-Dichloroethane	± 30

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TABLE A-XII: ICV Acceptance Criteria (continued)

Analyte	%Difference or %Drift
cis-1,2-Dichloroethene	± 30
trans-1,2-Dichloroethene	± 30
1,1-Dichloroethene	± 30
1,3-Dichloropropane	± 30
2,2-Dichloropropane	± 30
1,1-Dichloropropene	± 30
cis-1,3-Dichloropropene	± 30
trans-1,3-Dichloropropene	± 30
1,2-Dichloropropane	± 30
Diisopropyl ether (IPE)	± 30
3,3-dimethyl-1-butanol	± 30
1,4-Dioxane	± 30
Ethanol	± 30
Ethyl acetate	± 30
Ethyl ether	± 30
Ethylbenzene	± 30
Ethyl methacrylate	± 30
Ethyl-tert-butyl ether	± 30
Hexachlorobutadiene	± 30
Hexane	± 30
2-Hexanone	± 30
Isopropyl acetate	± 30
Isopropylbenzene	± 30
p-Isopropyltoluene	± 30
Isobutyl alcohol	± 30
Methacrylonitrile	± 30
Methyl acetate	± 30
Methylcyclohexane	± 30
Methyl iodide (Iodomethane)	± 30
Methyl methacrylate	± 30
4-Methyl-2-Pentanone	± 30
Methyl tertiary butyl ether (MTBE)	± 30
Methylene chloride	± 30
Naphthalene	± 30
2-Nitropropane	± 30
n-Propylbenzene	± 30
Propionitrile (Ethyl cyanide)	± 30
Styrene	± 30
Tert-amyl Alcohol	± 30
Tert-amyl-methyl ether	± 30
Tert-Butyl Alcohol	± 30
Tert-Butyl Formate	± 30

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TABLE A-XII: ICV Acceptance Criteria (continued)

Analyte	%Difference or %Drift
1,1,1,2-Tetrachloroethane	± 30
Tetrachloroethene	± 30
Tetrahydrofuran	± 30
Toluene	± 30
1,2,4-Trichlorobenzene	± 30
1,2,3-Trichlorobenzene	± 30
1,1,1-Trichloroethane	± 30
1,1,2-Trichloroethane	± 30
Trichloroethene	± 30
Trichlorofluoromethane	± 30
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)	± 30
1,2,3-Trichloropropane	± 30
1,2,4-Trimethylbenzene	± 30
1,3,5-Trimethylbenzene	± 30
Vinyl acetate	± 30
Vinyl Chloride	± 30
Xylenes (total)	± 30
m/p-Xylenes	± 30
o-Xylenes	± 30

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TABLE A-XIII: CCV Acceptance Criteria

Analyte	%Difference or %Drift
Acetone	20
Acetonitrile	20
Acrolein	20
Acrylonitrile	20
Benzene	20
Benzyl chloride	20
Bromobenzene	20
Bromochloromethane	20
Bromodichloromethane	20
Bromoform	20
Bromomethane (Methyl bromide)	20
2-Butanone (MEK)	20
n-Butyl acetate	20
n-Butylbenzene	20
tert-Butylbenzene	20
sec-Butylbenzene	20
Carbon disulfide	20
Carbon tetrachloride	20
Chlorobenzene	20
2-Chloro-1,3-Butadiene (Chloroprene)	20
Chloroethane	20
2-Chloroethyl vinyl ether	20
Chloroform	20
Chloromethane (Methyl chloride)	20
3-Chloropropene (Allyl chloride)	20
2-Chlorotoluene	20
4-Chlorotoluene	20
Cyclohexane	20
Cyclohexanone	20
Dibromochloromethane	20
1,2-Dibromo-3-chloropropane (DBCP)	20
1,2-Dibromoethane (EDB)	20
Dibromomethane (Methylene bromide)	20
1,2-Dichlorobenzene	20
1,3-Dichlorobenzene	20
1,4-Dichlorobenzene	20
trans-1,4-Dichloro-2-butene	20
Dichlorodifluoromethane	20
1,1-Dichloroethane	20
1,2-Dichloroethane	20
cis-1,2-Dichloroethene	20

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TABLE A-XIII: CCV Acceptance Criteria (continued)

Analyte	%Difference or %Drift
trans-1,2-Dichloroethene	20
1,1-Dichloroethene	20
1,3-Dichloropropane	20
2,2-Dichloropropane	20
1,1-Dichloropropene	20
cis-1,3-Dichloropropene	20
trans-1,3-Dichloropropene	20
1,2-Dichloropropane	20
Diisopropyl ether (IPE)	20
3,3-dimethyl-1-butanol	20
1,4-Dioxane	20
Ethanol	20
Ethyl acetate	20
Ethyl ether	20
Ethylbenzene	20
Ethyl methacrylate	20
Ethyl-tert-butyl ether	20
Hexachlorobutadiene	20
Hexane	20
2-Hexanone	20
Isopropyl acetate	20
Isopropylbenzene	20
p-Isopropyltoluene	20
Isobutyl alcohol	20
Methacrylonitrile	20
Methyl acetate	20
Methylcyclohexane	20
Methyl iodide (Iodomethane)	20
Methyl methacrylate	20
4-Methyl-2-Pentanone	20
Methyl tertiary butyl ether (MTBE)	20
Methylene chloride	20
Naphthalene	20
2-Nitropropane	20
n-Propylbenzene	20
Propionitrile (Ethyl cyanide)	20
Styrene	20
Tert-amyl Alcohol (TAA)	20
Tert-amyl-methyl ether (TAME)	20
Tert-Butyl Alcohol (TBA)	20
Tert-Butyl Formate (TBF)	20
1,1,1,2-Tetrachloroethane	20

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TABLE A-XIII: CCV Acceptance Criteria (continued)

Analyte	%Difference or %Drift
1,1,2,2-Tetrachloroethane	20
Tetrachloroethene	20
Tetrahydrofuran	20
Toluene	20
1,1,1-Trichloroethane	20
1,1,2-Trichloroethane	20
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)	20
Trichloroethene	20
Trichlorofluoromethane	20
1,2,3-Trichloropropane	20
1,2,4-Trimethylbenzene	20
1,3,5-Trimethylbenzene	20
Vinyl acetate	20
Vinyl Chloride	20
Xylenes (total)	20
m/p-Xylenes	20
o-Xylenes	20

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TABLE A-XIV: Aqueous LCS Recovery Limits

Aqueous LCS/D Analyte	Lower % Recovery Limit	Upper % Recovery Limit
Acetone	*60	*140
Acetonitrile	*60	*140
Acrolein	*60	*140
Acrylonitrile	70	130
Benzene	70	130
Benzyl chloride	*60	*140
Bromobenzene	70	130
Bromochloromethane	70	130
Bromodichloromethane	70	130
Bromoform	70	130
Bromomethane (Methyl bromide)	70	130
2-Butanone (MEK)	70	130
n-Butyl acetate	70	130
n-Butylbenzene	70	130
tert-Butylbenzene	70	130
sec-Butylbenzene	70	130
Carbon disulfide	70	130
Carbon tetrachloride	70	130
Chlorobenzene	70	130
2-Chloro-1,3-Butadiene (Chloroprene)	70	130
Chloroethane	70	130
2-Chloroethyl vinyl ether	70	130
Chloroform	70	130
Chloromethane (Methyl chloride)	*60	*140
3-Chloropropene (Allyl chloride)	70	130
2-Chlorotoluene	70	130
4-Chlorotoluene	70	130
Cyclohexane	70	130
Cyclohexanone	70	130
Dibromochloromethane	70	130
1,2-Dibromo-3-chloropropane (DBCP)	70	130
1,2-Dibromoethane (EDB)	70	130
Dibromomethane (Methylene bromide)	70	130
1,2-Dichlorobenzene	70	130
1,3-Dichlorobenzene	70	130
1,4-Dichlorobenzene	70	130
trans-1,4-Dichloro-2-butene	70	130
Dichlorodifluoromethane	*60	*140
1,1-Dichloroethane	70	130
1,2-Dichloroethane	70	130
cis-1,2-Dichloroethene	70	130
trans-1,2-Dichloroethene	70	130

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TABLE A-XIV: Aqueous LCS Recovery Limits (continued)

Aqueous LCS/LCSD Analyte	Lower % Recovery Limit	Upper % Recovery Limit
1,1-Dichloroethene	70	130
1,3-Dichloropropane	70	130
2,2-Dichloropropane	70	130
1,1-Dichloropropene	70	130
cis-1,3-Dichloropropene	70	130
trans-1,3-Dichloropropene	70	130
1,2-Dichloropropane	70	130
Diisopropyl ether (IPE)	70	130
3,3-dimethyl-1-butanol	70	130
1,4-Dioxane	*60	*140
Ethanol	70	130
Ethyl acetate	70	130
Ethyl ether	70	130
Ethylbenzene	70	130
Ethyl methacrylate	70	130
Ethyl tert butyl ether	70	130
Hexachlorobutadiene	*60	*140
Hexane	70	130
2-Hexanone	70	130
Isopropyl acetate	70	130
Isopropylbenzene	70	130
p-Isopropyltoluene	70	130
Isobutyl alcohol	*60	*140
Methacrylonitrile	70	130
Methyl acetate	70	130
Methylcyclohexane	70	130
Methyl iodide (Iodomethane)	70	130
Methyl methacrylate	70	130
4-Methyl-2-Pentanone	70	130
Methyl tertiary butyl ether (MTBE)	70	130
Methylene chloride	70	130
Naphthalene	70	130
2-Nitropropane	70	130
n-Propylbenzene	70	130
Propionitrile (Ethyl cyanide)	70	130
Styrene	70	130
Tert-amyl Alcohol (TAA)	70	130
Tert-amyl-methyl-ether (TAME)	70	130
Tert-Butyl Alcohol (TBA)	70	130
Tert-Butyl Formate (TBF)	70	130
1,1,1,2-Tetrachloroethane	70	130
1,1,2,2-Tetrachloroethane	70	130
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)	70	130
Tetrachloroethene	70	130
Tetrahydrofuran	70	130
Toluene	70	130

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TABLE A-XIV: Aqueous LCS Recovery Limits (continued)

Aqueous LCS/D Analyte	Lower % Recovery Limit	Upper % Recovery Limit
1,2,4-Trichlorobenzene	70	130
1,2,3-Trichlorobenzene	70	130
1,2,3-Trichloropropane	70	130
1,1,1-Trichloroethane	70	130
1,1,2-Trichloroethane	70	130
Trichloroethene	70	130
Trichlorofluoromethane	70	130
1,2,4-Trimethylbenzene	70	130
1,3,5-Trimethylbenzene	70	130
Vinyl acetate	*60	*140
Vinyl Chloride	70	130
Xylenes (total)	70	130
m/p-Xylenes	70	130
o-Xylenes	70	130

* These compounds are poor performing analytes which cannot exceed 60-140% recovery. All others cannot exceed 70-130%.

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TABLE A-XV: Solid LCS Recovery Limits

Solid LCS/LCSD Analyte	Lower % Recovery Limit	Upper % Recovery Limit
Acetone	70	130
Acetonitrile	*60	*140
Acrolein	*60	*140
Acrylonitrile	*60	*140
Benzene	70	130
Benzyl chloride	70	130
Bromobenzene	70	130
Bromochloromethane	70	130
Bromodichloromethane	70	130
Bromoform	70	130
Bromomethane (Methyl bromide)	70	130
2-Butanone (MEK)	70	130
n-Butylbenzene	70	130
tert-Butylbenzene	70	130
sec-Butylbenzene	70	130
Carbon disulfide	70	130
Carbon tetrachloride	70	130
Chlorobenzene	70	130
2-Chloro-1,3-Butadiene	70	130
2-Chloroethylvinyl ether	70	130
Chloroethane	70	130
Chloroform	70	130
Chloromethane (Methyl chloride)	*60	*140
3-Chloropropene (Allyl chloride)	*60	*140
2-Chlorotoluene	70	130
4-Chlorotoluene	70	130
Cyclohexane	70	130
Cyclohexanone	70	130
Dibromochloromethane	70	130
1,2-Dibromo-3-chloropropane	70	130
1,2-Dibromoethane (EDB)	70	130
Dibromomethane (Methylene	70	130
1,2-Dichlorobenzene	70	130
1,3-Dichlorobenzene	70	130
1,4-Dichlorobenzene	70	130
trans-1,4-Dichloro-2-butene	70	130
Dichlorodifluoromethane	*60	*140
1,1-Dichloroethane	70	130
1,2-Dichloroethane	70	130
cis-1,2-Dichloroethene	70	130
trans-1,2-Dichloroethene	70	130
1,1-Dichloroethene	70	130

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TABLE A-XV: Solid LCS Recovery Limits (continued)

Solid LCS/LCSD Analyte	Lower % Recovery Limit	Upper % Recovery Limit
1,3-Dichloropropane	70	130
2,2-Dichloropropane	70	130
1,1-Dichloropropene	70	130
cis-1,3-Dichloropropene	70	130
trans-1,3-Dichloropropene	70	130
1,2-Dichloropropane	70	130
Diisopropyl ether (IPE)	70	130
1,4-Dioxane	*60	*140
Ethyl acetate	70	130
Ethyl ether	70	130
Ethylbenzene	70	130
Ethyl methacrylate	70	130
Hexachlorobutadiene	70	130
Hexane	70	130
2-Hexanone	70	130
Isopropylbenzene	70	130
p-Isopropyltoluene	70	130
Isobutyl alcohol	*60	*140
Methacrylonitrile	70	130
Methyl acetate	70	130
Methylcyclohexane	70	130
Methyl iodide (Iodomethane)	70	130
Methyl methacrylate	70	130
4-Methyl-2-Pentanone	70	130
Methyl tertiary butyl ether (MTBE)	70	130
Methylene chloride	70	130
Naphthalene	70	130
n-Propylbenzene	70	130
Propionitrile (Ethyl cyanide)	70	130
Styrene	70	130
1,1,1,2-Tetrachloroethane	70	130
1,1,2,2-Tetrachloroethane	70	130
Tetrachloroethene	70	130
Tetrahydrofuran	70	130
Toluene	70	130
1,2,4-Trichlorobenzene	70	130
1,2,3-Trichlorobenzene	70	130
1,1,1-Trichloroethane	70	130
1,1,2-Trichloroethane	70	130
Trichloroethene	70	130
Trichlorofluoromethane	70	130

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TABLE A-XV: Solid LCS Recovery Limits (continued)

Solid LCS/LCSD Analyte	Lower % Recovery Limit	Upper % Recovery Limit
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)	70	130
1,2,3-Trichloropropane	70	130
1,2,4-Trimethylbenzene	70	130
1,2,3-Trichloropropane	70	130
1,2,4-Trimethylbenzene	70	130
1,3,5-Trimethylbenzene	70	130
Vinyl acetate	70	130
Vinyl Chloride	70	130
Xylenes (total)	70	130
m/p-Xylenes	70	130
o-Xylene	70	130

* These compounds are poor performing analytes which cannot exceed 60-140% recovery. All others cannot exceed 70-130%.

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APPENDIX B: LEVEL 1 AND LEVEL 2 DATA REVIEW GUIDANCE

All data generated by the instruments in Target must be reviewed for accuracy and compliance with Shealy SOPs and the Shealy QAMP to include calibrations, quality controls, and client samples.

B.1. Level 1 review shall be done by the analyst running each instrument or another qualified analyst when following completion of the batch. Review may be started while the batch is running provided all QC passes and there is no requirement for a closing CCV (i.e. 6200, DoD QSM).

B.2. Level 2 review must be completed after level 1 review is done. Level 2 must be completed by a peer.

B.3. ***Level 1 review of the analytical batch***

- Verification of passing tune using the correct BFB method.
- Ensure last sample is within 12-hours of BFB injection.
- Target review of CCV, LCS, and Method Blank for correct integrations.
- Review of Target Sample and ISTD reports for CCV acceptability.
- Review of Recovery Reports, and ISTD reports for LCS acceptability.
- Review of Method blank for acceptability of required LOQ for each program area.
- Export sample information from LIMS 4 batch.
- Re-quantitation or reprocessing of samples to ensuring Lab Sample IDs, Client Sample IDs, and dilution factors are correct.
    - For solids, verify the correct sample weight and % moisture.
    - Target review of samples for proper integrations.
    - Mark manual integrations with correct reason code.
- Note any over range/over dilute compounds for reanalysis in run log.
- Target review MS/MSD samples for proper integrations.

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- Review Recovery Reports and ISTD reports for acceptability.
- Import data into LIMS 4 batch, calculate, and verify any flags.
- Mark L1 complete
- Generate Nonconformance memo(s), if applicable
- Upload

B.4. ***Level 1 review of initial calibrations***

- Target method zeroed and all analytes reset to “averaged” prior to processing any points.
- Correct peak selection/retention times are verified by processing the midpoint first. (Level 5 for aqueous, level 4 for solid.)
- Target integration events are verified using the lowest level each analyte is reported from. (e.g. integration events for benzene must be set at the level 1 standard, but acetone integration events must be set at the level 3 standard.)
- All levels of the ICAL are processed and target reviewed for proper peak selection and integrations. Manual integrations in initial calibrations should be avoided. Integration events must be auto calculated and/or modified to achieve proper integration for each analyte. This will ensure these analytes are properly detected in client samples while using that method.
- Verify all compounds meet the requirements outlined in Section 10.7.5 including CCCs and SPCCs.
- Note any levels removed, compounds marked linear/weighted linear or failing compounds.
- Disable all points on compounds that fail completely either at the ICAL stage or the ICV stage.
    - Must be designated “Averaged” to avoid unwanted flags in ICAL report.
- Verify reporting parameters for each compound.
- Once completed, save method to “Source Methods.”
- Reprocess Initial Calibration Verification (ICV) and check for acceptability according to Table A-XII.

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- Reprocess all data files that have been completed with the newly saved method.

B.5. ***Level 2 review of the analytical batch***

- Verify passing tune and tune window.
- Verify files are looking to correct location for Internal Standard quantitation according to program area requirements.
- Verify CCV, LCS, and Method Blanks meet acceptable criteria.
- Verify manual integrations, recovery reports, and ISTD reports for all samples within the batch.
- Verify all data uploaded to LIMS are calculated properly.

B.6. ***Level 2 review of initial calibrations will include any appropriate requirements of Appendix B, Section 4 in addition to the following items***:

- Verification of CCCs and SPCCs acceptability according to appropriate method requirements.
- Verify using Initial Calibration Report that all compounds have enough points in their curves and they pass appropriate RSD/r2 requirements.
- Ensure any compound that fails calibration is disabled.
- Verify method has correct %D or %Difference and response factor criteria
- Verify correct surrogate addition loop size.
- Verify files are looking to correct location for Internal Standard quantitation according to program area requirements.

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APPENDIX C: REQUIREMENTS FOR METHOD 624.1

C.1. Method 624.1 is required for demonstration of compliance with NPDES wastewater discharge permits. The standard analyte list and reporting limits are listed in Table C-I.

C.1.1. For demonstration of capability (DOC), the 'X' and 's' criteria in Table C-II must be met.

C.2. This method can be applied only to aqueous matrices. If 2-chloroethyl vinyl ether is an analyte of interest the sample must be collected in unpreserved 40 ml VOC vials and analyzed within 7 days of collection. If acrolein is to be determined, analyze the sample within 3 days. To extend the holding time to 14 days, acidify a separate sample to pH 4 - 5 with HCl. The pH adjustment is not required when analyzing for acrylonitrile if acrolein will not be measured.

C.3. Samples must be checked for the presence of chlorine. Chlorine is checked after the samples are analyzed and is documented on the Chemstation sequence print out. If chlorine is present a nonconformance memo (NCM) must be issued to the project manager.

C.4. The tune period for this method is defined as 12 hours. The tuning criteria are the same as for method 8260B/C/D (Table A-IV).

C.4.1. *Initial calibration curve requirements*

C.4.1.1. The initial calibration curve for this method requires at least five levels.

C.4.1.2. Target® compounds must have RSD ≤ 35%.

C.4.1.3. If this requirement cannot be met, a regression curve must be constructed for the non-compliant compounds.

C.4.2. *Continuing calibration verification (CCV)*

C.4.2.1. A continuing calibration verification standard must be analyzed at the start of every 20 samples. The concentration and acceptance criteria for the CCV are listed in Table C-II. This standard must be prepped from a source different than the calibration and can be used as the LCS for the batch.

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C.4.2.2. If the responses for all parameters of interests fall within the designated ranges, analysis of actual samples can begin. If any individual response falls outside the range, repeat the test only for those parameters that failed to meet the calibration acceptance criteria. If the response for a parameter does not fall within the range in this second test, a new calibration curve or RF must be prepared for that parameter.

C.4.2.3. The analyst may choose to proceed with the analysis of sample and report only those parameters that meet the acceptance criteria.

1C.4.2.3.1. Matrix Spike and LCS requirements - A full analyte spike is required for method 624.1. The spiking levels are given in Table C-III. For every batch, one LCS and one MS/MSD are required. Each compound of interest must have an acceptable recovery in either the LCS or MS/MSD. Acceptance criteria are listed in Table C-II.

C.4.3. *Qualitative identification*

C.4.3.1. The mass spectrum for each analyte must be comprised of a minimum of 2 m/z's. Refer to table A-V for primary and secondary m/z's

C.4.3.2. The retention time must fall within ±30 seconds of the retention time of the authentic compound.

C.4.3.3. The relative intensities of ions must agree to within ± 20% between the standard and sample spectra. (Example: For an ion with an abundance of 50% in the standard spectra, the corresponding sample abundance must be between 30% and 70%.)

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TABLE C-I: Shealy Method 624.1 Standard Reporting List and Reporting Limits

Analytes	CAS Number	Aqueous (mg/L)
Acetone	67-64-1	20
Acrolein	107-02-8	5
Acrylonitrile	107-13-1	5
Benzene	71-43-2	2
Bromodichloromethane	75-27-4	2
Bromoform	75-25-2	2
Bromomethane (Methyl bromide)	74-83-9	2
Carbon tetrachloride	56-23-5	2
Chlorobenzene	108-90-7	2
Chloroethane	75-00-3	2
2-Chloroethyl vinyl ether	110-75-8	5
Chloroform	67-66-3	2
Chloromethane (Methyl chloride)	74-87-3	2
Cis-1,2-Dichloroethene	156-59-2	2
Cis-1,3-Dichloropropene	10061-01-5	2
Dibromochloromethane	124-48-1	2
1,2-Dichlorobenzene	95-50-1	2
1,3-Dichlorobenzene	541-73-1	2
1,4-Dichlorobenzene	106-46-7	2
1,1-Dichloroethane	75-34-3	2
1,2-Dichloroethane	107-06-2	2
1,1-Dichloroethene	75-35-4	2
1,2-Dichloropropane	78-87-5	2
1,4-Dioxane	123-91-1	250
Ethylbenzene	100-41-4	2
Methylene chloride	75-09-2	2
1,1,2,2-Tetrachloroethane	79-34-5	2
Tetrachloroethene	127-18-4	2
Toluene	108-88-3	2
trans-1,2-Dichloroethene	156-60-5	2
Trans-1,3-Dichloropropene	10061-02-6	2
1,1,1-Trichloroethane	71-55-6	2
1,1,2-Trichloroethane	79-00-5	2
Trichloroethene	79-01-6	2
Trichlorofluoromethane	75-69-4	2
1,2,4-Trimethylbenzene	95-63-6	2
Vinyl Chloride	75-01-4	2
Xylenes (total)	1330-20-7	5

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TABLE C-II: Method 624.1 Calibration and QC Acceptance Criteria

Analytes	Standard Conc (µg/L)	%Recovery Range for Ccal (%)	Limit [2] for s (%)	Range [3] For $\bar{X}$ (%)	%Recovery Range for LCS and MS/MSD	Limit for RPD
Acrolein[4]	200	60-140	30	50-150	40-160	60
Acrylonitrile[4]	40	60-140	30	50-150	40-160	60
Benzene	20	65-135	33	75-125	37-151	61
Bromodichloromethane	20	65-135	34	50-140	35-155	56
Bromoform	20	70-130	25	57-156	45-169	42
Bromomethane (Methyl bromide)	20	15-185	90	D-206	D-242	61
Carbon tetrachloride	20	70-130	26	65-125	70-140	41
Chlorobenzene	20	65-135	29	82-137	37-160	53
Chloroethane	20	40-160	47	42-202	14-230	78
2-Chloroethyl vinyl ether	20	D [1]-225.0	130	D-252	D-305	71
Chloroform	20	70-135	32	68-121	51-138	54
Chloromethane (Methyl chloride)	20	D-205	472	D-230	D-273	60
Cis-1,2-Dichloroethene	20	N/A	N/A	N/A	N/A	
Cis-1,3-Dichloropropene	20	25-175	79	5-195	D-227	58
Dibromochloromethane	20	70-135	30	69-133	53-149	50
1,2-Dichlorobenzene	20	65-135	31	59-174	18-190	57
1,3-Dichlorobenzene	20	70-130	24	75-144	59-156	43
1,4-Dichlorobenzene	20	65-135	31	59-174	18-190	57
1,1-Dichloroethane	20	70-130	24	71-143	59-155	40
1,2-Dichloroethane	20	70-130	29	72-137	49-155	49
1,1-Dichloroethene	20	50-150	40	19-212	D-234	32
1,2-Dichloropropane	20	35-165	69	19-181	D-210	55
1,4-Dioxane	200	N/A	N/A	N/A	N/A	
Ethylbenzene	20	60-140	34	75-134	37-162	63
Methylene chloride	20	60-140	192	D-205	D-221	28
1,1,2,2-Tetrachloroethane	20	60-140	36	68-136	46-157	61
Tetrachloroethene	20	70-130	23	65-133	64-148	39
Toluene	20	70-130	22	75-134	47-150	41
trans-1,2-Dichloroethene	20	70-130	27	68-143	54-156	45
Trans-1,3-Dichloropropene	20	50-150	52	38-162	17-183	86
1,1,1-Trichloroethane	20	70-130	21	69-151	52-162	36
1,1,2-Trichloroethane	20	70-130	27	75-136	52-150	45
Trichloroethene	20	65-135	29	75-138	70-157	48
Trichlorofluoromethane	20	50-150	50	45-158	17-181	84
1,2,4-Trimethylbenzene	20	N/A	N/A	N/A	N/A	
Vinyl Chloride	20	5-195	100	D-218	D-251	66
Xylenes	40	N/A	N/A	N/A	N/A	

[1]Based on Table 7 of EPA Method 624.1. D = Detected; result must be greater than zero.
For compounds without acceptance criteria, the criteria for method 8260B/C should be followed.
[2]Standard deviation of four recovery measurements.
[3]Average recovery of four recovery measurements.
Criteria were calculated assuming a QC check sample concentration of 50 µg

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TABLE C-III: Method 624.1 LCS and MS Compounds and Spike Concentrations

LCS Compounds	Spiking Level in Extract (mg/L)
Acrolein	200
Acrylonitrile	40
Benzene	20
Bromodichloromethane	20
Bromoform	20
Bromomethane (Methyl bromide)	20
Carbon tetrachloride	20
Chlorobenzene	20
Chloroethane	20
2-Chloroethyl vinyl ether	20
Chloroform	20
Chloromethane (Methyl chloride)	20
Cis-1,3-Dichloropropene	20
Dibromochloromethane	20
1,2-Dichlorobenzene	20
1,3-Dichlorobenzene	20
1,4-Dichlorobenzene	20
1,1-Dichloroethane	20
1,2-Dichloroethane	20
1,1-Dichloroethene	20
1,2-Dichloropropane	20
Ethylbenzene	20
Methylene chloride	20
1,1,2,2-Tetrachloroethane	20
Tetrachloroethene	20
Toluene	20
trans-1,2-Dichloroethene	20
Trans-1,3-Dichloropropene	20
1,1,1-Trichloroethane	20
1,1,2-Trichloroethane	20
Trichloroethene	20
Trichlorofluoromethane	20
Vinyl Chloride	20

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APPENDIX D: BATCH QC REQUIREMENT SUMMARY

D.1. ***Summary***

D.1.1. This appendix is added to clarify batch QC requirements.

D.2. ***General Principle***

D.2.1. If two different types of analyses, i.e. soil preserved in sodium bisulfate and soil in reagent water, are combined in the same analytical sequence, an NCM is required.

D.3. ***Method 624.1 QC Requirements***

D.3.1. 12-hour tune window.

D.3.2. Up to 20 samples in a batch.

D.3.3. CCV at 20 µg/L, meets criteria for Target® compounds (Table C-II). Can be the same as LCS below.

D.3.4. Method blank.

D.3.5. Full list LCS (Table C-III) at 20 µg/L, including gaseous compounds, meets the recovery criteria for Target® compounds (Table C-II).

D.3.6. If 8260B/C/D analyses are performed in the same sequence, one CCV, one method blank and one LCS can be analyzed and evaluated for both methods for up to 20 samples. The LCS should be prepared at 20 µg/L.

D.3.7. One MS/MSD per batch at 20 µg/L. (separate MS/MSD or MS/DUP for 8260B/C/D)

D.3.8. Surrogate acceptance limits are 70-130%.

D.4. ***5035/8260B/C/D High Level Sample***

D.4.1. *Preparation Procedure*

D.4.1.1. If samples are not field preserved with methanol, approximately 5 grams of soil must be preserved with 5.0 mL of methanol within 48 hours of sample collection.

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D.4.1.2. Add 5 µL of 2500 µg/mL surrogate standards.

D.4.1.3. Shake manually or vortex for approximately 2 minutes.

D.4.1.4. Allow the solvent and solid to separate.

D.4.1.5. Add 100µL (or lesser amount if dilution is required) of the extract into a 43 mL VOC vial containing 5mL reagent water and a stir bar.

D.4.1.6. The sample is ready for analysis.

D.4.2. *QC Requirements and Preparation*

D.4.2.1. An extraction batch is created for up to 20 samples when surrogate addition is complete.

D.4.2.2. A batch must contain a method blank (MB) and an LCS.

D.4.2.3. The MB and LCS contain 5.0 mL of methanol.

D.4.2.4. Add 5.0 µL of 2500 ug/ml surrogate standards to both the MB and LCS. Additionally add 125 µL of 100 µg/mL secondary standards to the LCS.

D.4.2.5. Follow steps 3 through 6 in the preceding section to prepare sample for analysis.

D.4.2.6. Samples can be added to the extraction batch within 24 hours of the initiation of the batch.

D.4.3. *Corrective Actions*

D.4.3.1. Analyst should establish surrogate recovery acceptance criteria for high level soil samples with at least 20 data points. The criteria are updated annually. The range is $\bar{x} \pm 3 * s$, in which $\bar{x}$ is the average recovery of all data points; s is the standard deviation of all data points.

D.4.3.2. If the extraction blank and sample fail to meet the surrogate recovery acceptance criteria, they must be reanalyzed.

D.5. ***Non-aqueous VOC Sample*** (soluble in methanol)

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D.5.1. *Prep Procedure*

D.5.1.1. If sample's solubility in methanol is low, refer to the procedure for 5035B High Level Sample Prep Procedure. (Appendix D, Section 4)

D.5.1.2. Weigh approximately 1.0 gram of the sample into a 40-mL vial, add methanol to bring the final volume to 10 mL.

D.5.1.3. Mix the sample thoroughly by inverting the vial at least 3 times.

D.5.1.4. Add 0.86 mL (or lesser amount if dilution is required) of the waste dilution into a 43 mL VOC vial containing approximately 30 mL of reagent water. Fill to the top and slowly invert 3 times.

D.5.1.5. The sample is ready for analysis.

D.5.2. *QC Requirement*

D.5.2.1. A batch contains up to 20 samples.

D.5.2.2. A method blank with 10 mL of methanol should be prepared following the steps outlined in Section D.5.1.

D.5.2.3. Samples can be added to the batch within 24 hours of the initiation of the batch.

D.6. ***TCLP VOC QC Requirements***

D.6.1. A leachate blank is analyzed with each leaching batch.

D.6.2. A matrix spike containing all the TCLP compounds (Table A - VIII) is analyzed for each leaching batch.

D.6.3. A reagent water LCS containing all the TCLP compounds (Table A - VIII) and a leachate blank (reagent water MB) is analyzed for each analytical batch in addition to the regular batch LCS for 8260B/C/D or 624.1.

D.6.4. For aqueous TCLP batches, the regular LCS and MB for 8260B/C/D or 624.1 can be used as the TCLP QC. Only a separate MS is required per leachate batch.

D.7. ***Method SM 6200B-2011 QC Requirements***

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D.7.1. 12-hour tune window.

D.7.2. Up to 20 samples in a batch.

D.7.3. Perform a CCV every 20 samples or every 12 hours whichever is more frequent. Criteria 70-130%, except for the gases which are 60-140%.

D.7.4. A closing standard must be analyzed at the end of a batch. The criteria for the closing CCV is 70-130%, except for the gases which are 60-140%. An LCS can be analyzed at the end of a batch in lieu of an 8260B/C/D/624.1 CCV (for this method the LCS and CCV are the same).

D.7.5. Method blank.

D.7.6. One LCS at minimum with each sample batch, which can be the same as the CCV from above.

D.7.7. If 8260B/C/D analyses are performed in the same sequence, one CCV, one method blank and one LCS can be analyzed and evaluated for all methods for up to 20 samples. The CCV should be prepared at 50 µg/L.

D.7.8. One MS and MSD per batch

D.7.9. Internal Standard and Surrogate acceptance limits are 70-130%.

D.8. ***Method 8260C QC Requirements***

D.8.1. See Appendix G for 8260C QC requirements

D.9. ***Method 8260D***

D.9.1. See Appendix H for changes to 8260D compared with 8260C.

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APPENDIX E - 1,4-Dioxane by Selected Ion Monitoring

1,4-Dioxane may be detected at concentrations below what is possible by typical full scan electron impact mass spectroscopy by utilizing Selected Ion Monitoring (SIM). Primary and secondary ions are selected for quantitative and monitoring purposes. A heated purge is used to enhance the purge efficiency for 1,4-Dioxane and the associated internal standard (IS) 1,4-Dioxane-d8. An appropriate surrogate is selected to monitor recovery efficiency for the analyses. IS 1,4-Dioxane-d8 is added to each calibration standard, sample and QC sample at 100 ug/L. The surrogate is added to each sample and QC sample at 50 ug/L with a recovery limit of 70-130%. The table below outlines the calibration standard concentrations for 1,4-Dioxane and associated surrogate.

TABLE E-I: Calibration Level Aqueous (µg/L) and Solid (µg/kg)

Aqueous Analyte	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
1,4-Dioxane	2	10	25	50	100	150
1,2-Dichloroethane-d4 (surr)	2	10	25	50	100	150

The following table lists the ions selected for monitoring for each analyte of interest:

TABLE E-II: Characteristic Ions

Analyte	Primary Ion	Secondary Ion
1,4-Dioxane	88	58
1,2-Dichloroethane-d4 (surr)	65	102
1,4-difluorobenzene (IS)	1144	NA
1,4-Dioxane-d8 (IS)	96	NA

The following table lists the control limits for each analyte of interest:

TABLE E-III: Aqueous and Solid Control Limits

Analyte	Lower Control Limit	Upper Control Limit
1,4-Dioxane	70	130
1,2-Dichloroethane-d4 (surr)	70	130
1,4-Dioxane-d8 (IS)	50	200

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APPENDIX F - PREPARATION OF STANDARDS

Note: Refer to *Working Standard Prep Log – Volatiles* [VOA form ME001KC] and *Working Standard Prep Log – AQ CLP* [VOA form ME001KD] for forms used for standard preparation

TABLE F-I: 8260 Primary Standard (Total volume 5mL in Methanol)

Component	Volume Added (µl)	Final Concentration (µg/mL)
2-CEVE STD	250	100
VINYL ACETATE	250	100
8260/624 ADDITIONS MIX	250	100
KETONES	100	200
8260/624 MEGA MIX	250	100

TABLE F-II: 8260 Primary Extra Standard (Total volume 5mL in Methanol)

Component	Volume Added (µl)	Final Concentration (µg/mL)
CYCLOHEXANONE	250	1000
ACROLEIN	250	1000

TABLE F-III: 8260 Secondary Standard (Total volume 5mL in Methanol)

Component	Volume Added (µl)	Final Concentration (µg/mL)
2-CEVE STD	250	100
VINYL ACETATE	250	100
8260/624 ADDITIONS MIX	250	100
KETONES	100	200
8260/624 MEGA MIX	250	100

TABLE F-IV: 8260 Secondary Extra Standard (Total volume 5mL in Methanol)

Component	Volume Added (µL)	Final Concentration (µg/mL)
CYCLOHEXANONE	250	1000
ACROLEIN	250	1000

TABLE F-V: Modified 8260 Primary Standard for OxyBTEX (Total volume 5mL in Methanol)

Component	Volume Added (µl)	Final Concentration (µg/mL)
8260 SURROGATE STD	200	100
SPCC MIX	250	100
CUSTOM OXYBTEX STD	500	100

TABLE F-VI: Modified 8260 Secondary Standard for OxyBTEX (Total volume 5mL in Methanol)

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Component	Volume Added (µl)	Final Concentration (µg/mL)
CUSTOM BTEX+ STD	500	100
Oxygenates STD	250	100

TABLE F-VII: 8260 Internal Standard (Total volume 50mL in Methanol)

Component	Volume Added (ml)	Final Concentration (µg/mL)
8260 INTERNAL STD	5	250

TABLE F-VIII: 8260 Surrogate Standard (Total volume 50mL in Methanol)

Component	Volume Added (ml)	Final Concentration (µg/mL)
8260 SURROGATE STD	5	250

TABLE F-IX: 8260 Primary Gas Standard (Total volume 5mL in Methanol)

Component	Volume Added (µl)	Final Concentration (µg/mL)
GASES STD	250	100

TABLE F-X: 8260 Secondary Gas Standard (Total volume 5mL in Methanol)

Component	Volume Added (µl)	Final Concentration (µg/mL)
GASES STD	250	100

TABLE F-XI: 8260 Primary Pentachloroethane Standard (Total volume 2mL in Methanol)

Component	Volume Added (µl)	Final Concentration (µg/mL)
PENTACHLOROETHANE STD	100	100

TABLE F-XII: 8260 Secondary Pentachloroethane Standard (Total volume 2mL in Methanol)

Component	Volume Added (µl)	Final Concentration (µg/mL)
PENTACHLOROETHANE STD	100	100

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APPENDIX G: SW-846 8260C Requirements

G.1. ***ICAL***

G.1.1. No CCC's.

G.1.2. RSD criteria for all target analytes ≤ 20 %.

G.1.3. Minimum RFs as per Table G-1 below.

G.1.4. If linear or non-linear calibration used must verify the RL by re-calculating concentrations in the lowest calibration standard using calibration curve. Acceptance criteria is 70-130% Recovery.

G.1.5. SIM - must monitor a minimum of 2 ions per analyte (primary and confirmation)

G.1.6. Must recalibrate if >10% of targets exceed the %RSD or regression criteria.

G.2. ***ICV***

G.2.1. Acceptance criteria 70-130% Recovery. Difficult analytes must meet 40-160% Recovery. Write NCM for all failures (even difficult compounds outside of the 70-130%).

G.3. ***CCV***

G.3.1. Evaluate minimum RFs specified in Table G-I below.

G.3.2. The IS area counts must be 50-200% of area counts in the associated mid-level ICAL std.

G.3.3. %D ≤20 for all targets (recalibrate if >20% targets exceed the %D criteria).

G.4. ***MB***

G.4.1. No corrective action required if concentration of contaminant in sample is >10X the concentration detected in the method blank.

G.5. ***LCS***

G.5.1. See 8260C for defined difficult compounds.

G.5.2. No second source requirement.

G.6. ***LCSD***

G.6.1. RPD acceptance criteria ≤20 (aqueous and solid).

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G.7. ***MS/MSD***

G.7.1. RPD acceptance criteria ≤20% aqueous and ≤30% for solids.

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TABLE G-I: Recommended Minimum Relative Response Factor Criteria for Initial and Continuing Calibration Verification

Volatile Compounds	Minimum Response Factor (RF)a	Typical Response Factor (RF)b
Dichlorodifluoromethane	0.100	0.327
Chloromethane	0.100	0.537
Vinyl chloride	0.100	0.451
Bromomethane	0.100	0.255
Chloroethane	0.100	0.254
Trichlorofluoromethane	0.100	0.426
1,1-Dichloroethene	0.100	0.313
1,1,2-Trichloro-1,2,2-trifluoroethane	0.100	0.302
Acetone	0.100	0.151
Carbon disulfide	0.100	1.163
Methyl Acetate	0.100	0.302
Methylene chloride	0.100	0.380
trans-1,2-Dichloroethene	0.100	0.351
cis-1,2-Dichloroethene	0.100	0.376
Methyl tert-Butyl Ether	0.100	0.847
1,1-Dichloroethane	0.200	0.655
2-Butanone	0.100	0.216
Chloroform	0.200	0.557
1,1,1-Trichloroethane	0.100	0.442
Cyclohexane	0.100	0.579
Carbon tetrachloride	0.100	0.353
Benzene	0.500	1.368
1,2-Dichloroethane	0.100	0.443
Trichloroethene	0.200	0.338
Methylcyclohexane	0.100	0.501
1,2-Dichloropropane	0.100	0.382
Bromodichloromethane	0.200	0.424
cis-1,3-Dichloropropene	0.200	0.537
trans-1,3-Dichloropropene	0.100	0.515
4-Methyl-2-pentanone	0.100	0.363
Toluene	0.400	1.577
1,1,2-Trichloroethane	0.100	0.518
Tetrachloroethene	0.200	0.606
2-Hexanone	0.100	0.536
Dibromochloromethane	0.100	0.652
1,2-Dibromoethane	0.100	0.634
Chlorobenzene	0.500	1.733
Ethylbenzene	0.100	2.827
meta-/para-Xylene	0.100	1.080
ortho-Xylene	0.300	1.073
Styrene	0.300	1.916

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TABLE G-I: Recommended Minimum Relative Response Factor Criteria for Initial and Continuing Calibration Verification (Continued)

Volatile Compounds	Minimum Response Factor (RF)a	Typical Response Factor (RF)b
Bromoform	0.100	0.413
Isopropylbenzene	0.100	2.271
1,1,2,2-Tetrachloroethane	0.300	0.782
1,3-Dichlorobenzene	0.600	1.408
1,4-Dichlorobenzene	0.500	1.427
1,2-Dichlorobenzene	0.400	1.332
1,2-Dibromo-3-chloropropane	0.050	0.129
1,2,4-Trichlorobenzene	0.200	0.806

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APPENDIX H: Changes to 8260D Rev 4 Compared to 8260C Rev. 3 (as pertains to this SOP)

H.1. The term mass was replaced with m/z to reflect what is actually being measured by the detector. Area or height was replaced with response.

H.2. Trichlorotrifluoroethane was split into two isomers: 1,1,2-Trichlorofluoroethane and 1,1,1-Trichlorotrifluoroethane.

H.3. A paragraph was added about performing ICV with an alternate source (Section 7.11.3 of SW-846, Test Methods for Evaluating Solid Waste, June 2018, Revision 4, Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry, Method 8260D.

H.4. Tune verification was updated from once every 12 hours to once prior to ICAL (Note: as stated in this SOP, the practice of verifying the tune once every 12 hours will continue). The calibration verification frequency was updated to allow for last initial calibration standard to be the start of 12-hour clock for samples analyzed after initial calibration. Clarification was added that a blank is required after initial calibration and continuing calibration verification. Clarification was added requiring monitoring of ISs in CCVs.

Note: Since numerous methods are covered under this SOP, the current practice will be in most cases to follow the most stringent criteria.

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Appendix DoD: DoD/DOE Method Specific Quality Control Requirements

Sections found in this appendix supersede and/or supplement the existing sections of this SOP. In addition to the general method performance criteria, these requirements must be met when analyzing samples for the Department of Defense (DoD) and the Department of Energy (DOE) as stipulated in the DoD/DOE Quality System Manual.

Table B-4. Organic Analysis by Gas Chromatography/Mass Spectrometry (GC/MS)

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Tune Check	Prior to ICAL and prior to each 12-hour period of sample analysis.	Specific ion abundance criteria of BFB or DFTPP from method.	Retune instrument and verify.	Flagging is not appropriate.	No samples shall be analyzed without a valid tune.
Performance Check (Method 8270 only)	At the beginning of each 12-hour period, prior to analysis of samples.	Degradation ≤ 20% for DDT. Benzidine and pentachlorophenol shall be present at their normal responses and shall not exceed a tailing factor of 2.	Correct problem, then repeat performance checks.	Flagging is not appropriate.	No samples shall be analyzed until performance check is within criteria. The DDT breakdown and Benzidine/ pentachlorophenol tailing factors are considered overall system checks to evaluate injector port inertness and column performance and are required regardless of the reported analyte list.
Initial calibration (ICAL) for all analytes (including surrogates)	At instrument set-up and after ICV or CCV failure, prior to sample analysis.	Each analyte must meet one of the three options below: Option 1: RSD for each analyte ≤ 15%; Option 2: linear least squares regression for each analyte: $r^2 \geq 0.99$; *(continued next page)*	Correct problem then repeat ICAL.	Flagging is not appropriate.	Minimum 5 levels for linear and 6 levels for quadratic. No samples shall be analyzed until ICAL has passed.

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Table B-4. Organic Analysis by Gas Chromatography/Mass Spectrometry (GC/MS)

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Initial calibration (ICAL) for all analytes (including surrogates) *(Continued)*		Option 3: non-linear least squares regression (quadratic) for each analyte: $r^2 \geq 0.99$.			If the specific version of a method requires additional evaluation (e.g., RFs or low calibration standard analysis and recovery criteria) these additional requirements must also be met.
Retention Time window position establishment	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.	NA.	Calculated for each analyte and surrogate.
Evaluation of Relative Retention Times (RRT)	With each sample.	RRT of each reported analyte within ± 0.06 RRT units.	Correct problem, then rerun ICAL.	NA.	After maintenance is performed which may affect retention times, RRTs may be updated based on the daily CCV. RRTs shall be compared with the most recently updated RRTs.
Initial Calibration Verification (ICV)	Once after each ICAL, analysis of a second source standard prior to sample analysis.	All reported analytes within ± 20% of true value.	Correct problem. Rerun ICV. If that fails, repeat ICAL.	Flagging is not appropriate.	No samples shall be analyzed until calibration has been verified with a second source.

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Table B-4. Organic Analysis by Gas Chromatography/Mass Spectrometry (GC/MS)

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Continuing Calibration Verification (CCV)	Daily before sample analysis; after every 12 hours of analysis time; and at the end of the analytical batch run.	All reported analytes and surrogates within ± 20% of true value. All reported analytes and surrogates within ± 50% for end of analytical batch CCV.	Immediately analyze two additional consecutive CCVs. If both pass, samples may be reported without reanalysis. If either fails or if two consecutive CCVs cannot be run, perform corrective action(s) and repeat CCV and all associated samples since last successful CCV. Alternately, recalibrate if necessary; then reanalyze all associated samples since the last acceptable CCV.	If reanalysis cannot be performed, data must be qualified and explained in the Case Narrative. Apply Q-flag to all results for the specific analyte(s) in all samples since last acceptable calibration verification.	Results may not be reported without valid CCVs. Flagging is only appropriate in cases where the samples cannot be reanalyzed. If the specific version of a method requires additional evaluation (e.g., average RFs) these additional requirements must also be met.
Internal Standards (IS)	Every field sample, standard, and QC sample.	Retention time within ± 10 seconds from retention time of the midpoint standard in the ICAL; EICP area within – 50% to +100% of ICAL midpoint standard. On days when ICAL is not performed, the daily initial CCV can be used.	Inspect mass spectrometer and GC for malfunctions and correct problem. Reanalysis of samples analyzed while system was malfunctioning is mandatory.	If corrective action fails in field samples, data must be qualified and explained in the Case Narrative. Apply Q-flag to analytes associated with the non-compliant IS. Flagging is not appropriate for failed standards.	NA.

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Table B-4. Organic Analysis by Gas Chromatography/Mass Spectrometry (GC/MS)

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Method Blank (MB)	One per preparatory batch.	No analytes detected > ½ LOQ or > 1/10th the amount measured in any sample or 1/10th the regulatory limit, whichever is greater. Common contaminants must not be detected > LOQ.	Correct problem. If required, reprep and reanalyze MB and all QC samples and field samples processed with the contaminated blank.	If reanalysis cannot be performed, data must be qualified and explained in the Case Narrative. Apply B-flag to all results for the specific analyte(s) in all samples in the associated preparatory batch.	Results may not be reported without a valid Method Blank. Flagging is only appropriate in cases where the samples cannot be reanalyzed.
Laboratory Control Sample (LCS)	One per preparatory batch.	A laboratory must use the DoD/DOE QSM Appendix C Limits for batch control if project limits are not specified. If the analyte(s) are not listed, use in-house LCS limits if project limits are not specified.	Correct problem, then reprep and reanalyze the LCS and all samples in the associated preparatory batch for failed analytes if sufficient sample material is available.	If reanalysis cannot be performed, data must be qualified and explained in the Case Narrative. Apply Q-flag to specific analyte(s) in all samples in the associated preparatory batch.	Must contain all surrogates and all analytes to be reported. Results may not be reported without a valid LCS. Flagging is only appropriate in cases where the samples cannot be reanalyzed.

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Table B-4. Organic Analysis by Gas Chromatography/Mass Spectrometry (GC/MS)

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Matrix Spike (MS)	One per preparatory batch.	A laboratory must use the DoD/DOE QSM Appendix C Limits for batch control if project limits are not specified. If the analyte(s) are not listed, use in-house LCS limits if project limits are not specified.	Examine the project-specific requirements. Contact the client as to additional measures to be taken.	For the specific analyte(s) in the parent sample, apply J-flag if acceptance criteria are not met and explain in the Case Narrative.	Must contain all surrogates and all analytes to be reported. For matrix evaluation only. If MS results are outside the limits, the data shall be evaluated to determine the source(s) of difference, i.e., matrix effect or analytical error.
Matrix Spike Duplicate (MSD) or Matrix Duplicate (MD)	One per preparatory batch.	A laboratory must use the DoD/DOE QSM Appendix C Limits for batch control if project limits are not specified. If the analyte(s) are not listed, use in-house LCS limits if project limits are not specified. MSD or MD: RPD of all analytes ≤ 20% (between MS and MSD or sample and MD).	Examine the project-specific requirements. Contact the client as to additional measures to be taken.	For the specific analyte(s) in the parent sample, apply J-flag if acceptance criteria are not met and explain in the Case Narrative.	MSD: Must contain all surrogates and all analytes to be reported. 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.

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Table B-4. Organic Analysis by Gas Chromatography/Mass Spectrometry (GC/MS)

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Surrogate Spike	All field and QC samples.	QC acceptance criteria specified by the project if available; otherwise use DoD/DOE QSM Appendix C limits or in-house LCS limits if analyte(s) are not listed.	Correct problem, then reprep and reanalyze all failed samples for all surrogates in the associated preparatory batch if sufficient sample material is available. If obvious chromatographic interference is present, reanalysis may not be necessary, but the client must be notified prior to reporting data and the failures must be discussed in the Case Narrative.	Apply Q-flag to all associated analytes if acceptance criteria are not met and explain in the Case Narrative.	Alternative surrogates are recommended when there is obvious chromatographic interference.

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Additional requirements not required by DoD:

Calibration Check Compounds (CCCs) (8260B only) – The %RSD of the response factors for each CCC in the initial calibration must be ≤ 20% for the initial calibration to be considered valid. This criterion must be met before sample analysis begins. Problems similar to those listed under SPCCs could affect this criterion.

CCC Compounds: 1,1-Dichloroethene
Chloroform
1,2-Dichloropropane
Toluene
Ethylbenzene
Vinyl Chloride

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Table DoD-I: Volatile Organic Compounds and Standard Reporting Limits

Analytes	CAS Number	Standard Reporting Limits	
		Aqueous and Low-Level Soil mg/L or mg/kg	High Soil mg/kg
Acetone	67-64-1	20	1000
Acetonitrile	75-05-8	10	500
Acrolein	107-02-8	50	2500
Acrylonitrile	107-13-1	50	2500
Benzene	71-43-2	5	250
Benzyl chloride	100-44-7	5	250
Bromobenzene	108-86-1	5	250
Bromochloromethane	74-97-5	5	250
Bromodichloromethane	75-27-4	5	250
Bromoform	75-25-2	5	250
Bromomethane (Methyl bromide)	74-83-9	5	250
2-Butanone (MEK)	78-93-9	10	500
n-Butyl acetate	123-86-4	10	NA
n-Butylbenzene	104-51-8	5	250
tert-Butylbenzene	98-06-06-	5	250
sec-Butylbenzene	135-98-8	5	250
Carbon disulfide	75-15-0	5	250
Carbon tetrachloride	56-23-5	5	250
Chlorobenzene	108-90-7	5	250
Chloroethane	75-00-3	5	250
2-Chloroethyl vinyl ether	110-75-8	10	500
Chloroform	75-00-3	5	250
Chloromethane (Methyl chloride)	74-87-3	5	250
3-Chloropropene (Allyl chloride)	107-05-1	10	500
2-Chlorotoluene	95-49-8	5	250
4-Chlorotoluene	106-43-4	5	250
Cyclohexane	110-82-7	5	250
Cyclohexanone	108-94-1	50	2500
Dibromochloromethane	124-48-1	5	250
1,2-Dibromo-3-chloropropane (DBCP)	96-12-8	5	250
1,2-Dibromoethane (EDB)	106-93-4	5	250
Dibromomethane (Methylene bromide)	74-95-3	5	250
1,2-Dichlorobenzene	95-50-1	5	250
1,3-Dichlorobenzene	541-73-1	5	250
1,4-Dichlorobenzene	106-46-7	5	250
trans-1,4-Dichloro-2-butene	110-57-6	10	500
Dichlorodifluoromethane	75-71-8	5	250
1,1-Dichloroethane	75-34-3	5	250
1,2-Dichloroethane	107-06-2	5	250
cis-1,2-Dichloroethene	156-59-2	5	250
trans-1,2-Dichloroethene	156-60-5	5	250

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TABLE DoD-I: Volatile Organic Compounds and Standard Reporting Limits (continued)

Analytes	CAS Number	Standard Reporting Limits	
		Aqueous and Low-Level Soil mg/L or mg/kg	High Soil mg/kg
1,1-Dichloroethene	75-35-4	5	250
1,2-Dichloropropane	78-87-5	5	250
1,3-Dichloropropane	142-28-9	5	250
2,2-Dichloropropane	594-20-7	5	250
1,1-Dichloropropene	563-58-6	5	250
cis-1,3-Dichloropropene	10061-01-5	5	250
trans-1,3-Dichloropropene	10061-02-6	5	250
1,2-Dichloropropane	78-87-5	5	250
Diisopropyl ether	108-20-3	5	250
1,4-Dioxane	123-91-1	250	12,000
Ethanol	64-17-5	100	NA
Ethyl acetate	141-78-6	5	250
Ethyl methacrylate	97-63-2	5	250
Ethyl tert-butyl ether	637-92-3	1.0	NA
Ethylbenzene	100-41-4	5	250
Ethyl methacrylate	97-63-2	5	250
Hexachlorobutadiene	87-68-3	5	250
Hexane	105-54-3	2.5	125
2-Hexanone	591-78-6	10	500
Methyl iodide (Iodomethane)	74-88-4	5	250
Isobutyl alcohol	78-83-1	50	2500
Isopropyl acetate (Acetic acid)	108-21-4	2.5	NA
Isopropylbenzene	98-82-8	5	250
p-Isopropyltoluene	99-87-6	5	250
Methacrylonitrile	126-98-7	5	250
Methyl acetate	79-20-9	5	250
Methyl methacrylate	80-62-6	5	250
4-Methyl-2-Pentanone	108-10-1	10	500
Methyl tertiary butyl ether (MTBE)	1634-04-4	5	250
Methylene chloride	75-09-2	5	250
Naphthalene	91-20-3	5	250
2-Nitropropane	79-46-9	5	NA
n-Propylbenzene	103-65-1	5	250
Propionitrile (Ethyl cyanide)	107-12-0	50	2500
Pentachloroethane	76-01-7	5	5
Styrene	100-42-5	5	250
tert-Amyl Alcohol	75-85-4	100	NA
tert-Amyl methyl ether (TAME)	994-05-8	5	NA
tert-Butyl alcohol	75-65-0	100	NA
tert-Butyl Formate	762-75-4	25	NA
1,1,1,2-Tetrachloroethane	630-20-6	5	250
1,1,2,2-Tetrachloroethane	79-34-5	5	250

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TABLE DoD-I: Volatile Organic Compounds and Control Limits (continued)

Analytes	CAS Number	Standard Reporting Limits	
		Aqueous and Low-Level Soil mg/L or mg/kg	High Soil mg/kg
Tetrachloroethene	127-18-4	5	250
Tetrahydrofuran	109-99-9	10	500
Toluene	108-88-3	5	250
1,2,4-Trichlorobenzene	96-18-4	5	250
1,2,3-Trichlorobenzene	95-63-6	5	250
1,1,1-Trichloroethane	71-55-6	5	250
1,1,2-Trichloroethane	79-00-5	5	250
Trichloroethene	79-01-6	5	250
Trichlorofluoromethane	75-69-4	5	250
1,2,3-Trichloropropane	96-18-4	5	250
1,2,4-Trimethylbenzene	95-63-6	5	250
1,3,5-Trimethylbenzene	108-67-8	5	250
Vinyl acetate	108-05-4	5	250
Vinyl Chloride	75-01-4	2	500
Xylenes (total)	1330-20-7	5	250
m/p-Xylenes	108-38-3	5	250
o-Xylenes	95-47-6	5	250

TABLE DoD-II: Volatile Organic Surrogate Compounds and Control Limits

Surrogate Compounds	Concentration in Standard (µg/L or mg/kg)	Aqueous Control Limits		Solid Control Limits	
		Lower	Upper	Lower	Upper
1,2-Dichloroethane-d4	50	81	118	71	136
4-Bromofluorobenzene	50	85	114	79	119
Toluene-d8	50	89	112	85	116
Dibromofluoromethane	50	80	119	78	119

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TABLE DoD-III: LCS/MS Control Limits for Volatile Organic Compounds

Analyte	Aqueous Control Limits		Soil Control Limits	
	Lower	Upper	Lower	Upper
Acetone	39	160	36	164
Acetonitrile	50	142	54	143
Acrolein	39	155	47	155
Acrylonitrile	63	135	65	134
Allyl chloride	68	130	68	135
Benzene	79	120	77	121
Benzyl chloride	42	138	64	120
Bromobenzene	80	120	78	121
Bromochloromethane	78	123	78	125
Bromodichloromethane	79	125	75	127
Bromoform	66	130	67	132
Bromomethane (Methyl bromide)	53	141	53	143
2-Butanone (MEK)	56	143	51	148
n-Butyl acetate	69	125	62	128
n-Butylbenzene	75	128	70	128
tert-Butylbenzene	78	124	73	125
sec-Butylbenzene	77	126	73	126
Carbon disulfide	64	133	63	132
Carbon tetrachloride	72	136	70	135
Chlorobenzene	82	118	79	120
Chloroethane	60	138	59	139
2-Chloroethyl vinyl ether	51	139	43	149
Chloroform	79	124	78	123
Chloromethane (Methyl chloride)	50	139	50	136
2-Chlorotoluene	79	122	75	122
4-Chlorotoluene	78	122	72	124
Cyclohexane	71	130	67	131
Cyclohexanone	NA	NA	30	156
Dibromochloromethane	74	126	74	126
1,2-Dibromo-3-chloropropane (DBCP)	62	128	61	132
1,2-Dibromoethane (EDB)	77	121	78	122
Dibromomethane (Methylene bromide)	79	123	78	125
1,2-Dichlorobenzene	80	119	78	121
1,3-Dichlorobenzene	80	119	77	121
1,4-Dichlorobenzene	79	118	75	120
Dichlorodifluoromethane	32	152	29	149
1,1-Dichloroethane	77	125	76	125
1,2-Dichloroethane	73	128	73	128
cis-1,2-Dichloroethene	78	123	77	123
trans-1,2-Dichloroethene	75	124	74	125
1,1-Dichloroethene	71	131	70	131
1,2-Dichloropropane	78	122	76	123

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TABLE DoD-III: LCS/MS Control Limits for Volatile Organic Compounds (continued)

Analyte	Aqueous Control Limits		Soil Control Limits	
	Lower	Upper	Lower	Upper
1,3-Dichloropropane	80	119	77	121
2,2-Dichloropropane	60	139	67	133
1,1-Dichloropropene	79	125	76	125
cis-1,3-Dichloropropene	75	124	74	126
trans-1,3-Dichloropropene	73	127	71	130
Trans-1,4-Dichloro-2-butene	43	140	62	136
1,4-Dioxane	59	139	55	138
3,3-Dimethyl-1-butanol	49	133	NA	NA
Diisopropyl ether	67	128	69	127
Ethanol	48	151	45	159
Ethyl acetate	55	138	52	139
Ethyl methacrylate	72	126	69	129
Ethyl tert-butyl ether	70	127	72	126
Ethylbenzene	79	121	76	122
Hexachlorobutadiene	66	134	61	135
Hexane	48	143	45	142
2-Hexanone	57	139	53	145
Isobutyl alcohol	63	133	60	135
Isopropyl acetate	63	133	58	131
Isopropylbenzene	72	131	68	134
p-Isopropyltoluene	77	127	73	127
Methacrylonitrile	63	133	66	132
Methyl acetate	56	136	53	144
Methyl methacrylate	67	128	63	134
4-Methyl-2-Pentanone	67	130	65	135
Methyl iodide (Iodomethane)	69	131	71	131
Methyl tertiary butyl ether (MTBE)	71	124	73	125
Methylcyclohexane	72	132	66	133
Methylene chloride	74	124	70	128
Naphthalene	61	128	62	129
2-Nitropropane	49	136	47	150
n-Propylbenzene	76	126	73	125
Pentachloroethane	69	133	69	135
Propionitrile	64	136	68	134
Styrene	78	123	76	124
tert-Amyl methyl ether [TAME]	68	128	73	126
tert-Butyl alcohol	68	129	68	133
1,1,1,2-Tetrachloroethane	78	124	78	125
1,1,2,2-Tetrachloroethane	71	121	70	124
Tetrachloroethene	74	129	73	128
Tetrahydrofuran	57	133	61	135
Toluene	80	121	77	121

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TABLE DoD-III: LCS/MS Control Limits for Volatile Organic Compounds (continued)

Analyte	Aqueous Control Limits		Soil Control Limits	
	Lower	Upper	Lower	Upper
1,2,4-Trichlorobenzene	69	130	67	129
1,2,3-Trichlorobenzene	69	129	66	130
1,1,1-Trichloroethane	74	131	73	130
1,1,2-Trichloroethane	80	119	78	121
1,1,2-Trifluoro-1,2,2-trichloroethane (Freon- 113)	70	136	66	136
Trichloroethene	79	123	77	123
Trichlorofluoromethane	65	141	62	140
1,2,3-Trichloropropane	73	122	73	125
1,2,4-Trimethylbenzene	76	124	75	123
1,3,5-Trimethylbenzene	75	124	73	124
Vinyl acetate	54	146	50	151
Vinyl Chloride	58	137	56	135
Xylenes (total)	79	121	78	124
m/p-Xylenes	80	121	77	124
o-Xylene	78	122	77	123

Note: Marginal exceedances are not allowed for those analytes determined by a project to be target analytes without project specific approval.

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TABLE DoD-IV: Characteristic Ions for Volatile Organic Compounds

Analyte	Primary	Secondary	Tertiary
Acetone	58	43	
Acetonitrile	40	39	41
Acrolein	56	55	
Acrylonitrile	53	52	51
Benzene	78		
Benzyl chloride	91	126	
Bromobenzene	77	156	158
Bromochloromethane	128	49	130
Bromodichloromethane	83	85	
Bromoform	173	171	
Bromomethane (Methyl bromide)	94	96	
2-Butanone (MEK)	43	72	
n-Butyl acetate	43	56	
n-Butylbenzene	91	134	
tert-Butylbenzene	119	134	
sec-Butylbenzene	105	134	
Carbon disulfide	76		
Carbon tetrachloride	117	119	
Chlorobenzene	112	114	
Chloroethane	64		
Chloroform	83	85	
Chloromethane (Methyl chloride)	50	52	
2-Chloroethyl vinyl ether	63	65	106
2-Chlorotoluene	91	126	
4-Chlorotoluene	91	126	
Cyclohexane	56	69	84
Cyclohexanone	55	69	98
3-Chloroprene (Ally chloride)	76	78	41
Diisopropyl ether (IPE)	87	59	69
Dibromochloromethane	129	127	
1,2-Dibromo-3-chloropropane (DBCP)	75	157	155
1,2-Dibromoethane (EDB)	107	109	
Dibromomethane (Methylene bromide)	93	174	95
1,2-Dichlorobenzene	146	148	113
1,3-Dichlorobenzene	146	148	113
1,4-Dichlorobenzene	146	148	113
Dichlorodifluoromethane	85		
1,1-Dichloroethane	63	65	
1,2-Dichloroethane	62	64	98
cis-1,2-Dichloroethene	96	61	
trans-1,2-Dichloroethene	96	61	98

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TABLE DoD-IV: Characteristic Ions for Volatile Organic Compounds (continued)

Analyte	Primary	Secondary	Tertiary
1,1-Dichloroethene	96	61	63
1,3-Dichloropropane	76	78	
2,2-Dichloropropane	77	79	
1,1-Dichloropropene	75	110	77
cis-1,3-Dichloropropene	75	77	
trans-1,3-Dichloropropene	75	77	
1,2-Dichloropropane	63	76	
1,4-Dioxane	88	58	
Ethanol	45	46	
Ethyl acetate	43	88	
Ethylbenzene	106	91	
Ethyl methacrylate	69	41	
Hexachlorobutadiene	225	223	227
2-Hexanone	43	58	
Isopropylbenzene	105	120	
p-Isopropyltoluene	119	134	
4-Methyl-2-Pentanone	43	58	
Methyl tertiary butyl ether (MTBE)	73	57	
Methylene chloride	84	49	51
Naphthalene	128		
2-Nitropropane	43	41	
n-Propylbenzene	91	120	
Pentachloroethane	167	130	132
Propionitrile (Ethyl cyanide)	54	52	55
Styrene	104	51	78
tert-Amyl methyl ether	87	73	
tert-Butyl alcohol	59	57	
1,1,1,2-Tetrachloroethane	131	133	
1,1,2,2-Tetrachloroethane	83	85	
Tetrachloroethene	164	129	131
Tetrahydrofuran	42	72	
Toluene	92	91	
1,2,4-Trichlorobenzene	180	182	145
1,2,3-Trichlorobenzene	180	182	145
1,1,1-Trichloroethane	97	99	61
1,1,2-Trichloroethane	97	83	85
Trichloroethene	130	95	97
Trichlorofluoromethane	101	103	
1,2,3-Trichloropropane	110	97	
1,2,4-Trimethylbenzene	105	120	
1,3,5-Trimethylbenzene	105	120	
Vinyl acetate	86	44	

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TABLE DoD-IV: Characteristic Ions for Volatile Organic Compounds (continued)

Analyte	Primary	Secondary	Tertiary
Vinyl Chloride	62	64	
Xylenes (total)	Summation	Summation	
m/p-Xylenes	106	91	
o-Xylenes	106	91	
Pentafluorobenzene (Internal Standard)	168		
1,2-Dichloroethane-d4 (Surrogate Standard)	65	102	
1,4-Difluorobenzene (Internal Standard)	114		
Toluene-d8 (Surrogate Standard)	98		
Chlorobenzene-d5 (Internal Standard)	117	82	119
4-Bromofluorobenzene (Surrogate Standard)	95	174	176
1,4-Dichlorobenzene-d4 (Internal Standard)	152	150	

NEW YORK STATE OF OPPORTUNITY. Department of Health

ANDREW M. CUOMO
Governor

HOWARD A. ZUCKER, M.D., J.D.
Commissioner

LISA J. PINO, M.A., J.D.
Executive Deputy Commissioner

LAB ID: 12064

April 01, 2021

MR. NILS K. MELBERG
PACE ANALYTICAL SERVICES, LLC - GREENBAY WI
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SUITE 9
GREEN BAY, WI 54302

Certificate Expiration Date:
April 01, 2022

Dear Mr. Melberg,

Enclosed are certificate(s) of approval issued to your environmental laboratory for the current permit year. The certificate(s) supersede(s) any previously issued one(s) and is(are) in effect through the expiration date listed. Please carefully examine the certificate(s) to insure that the categories, subcategories, analytes, and methods for which your laboratory is approved are correct. In addition, verify that your laboratory's name, address, lead technical director, and identification number are accurate.

Pursuant to NYCRR Subpart 55-2.2, original certificates must be posted conspicuously in the laboratory and copies shall be made available to any client of the laboratory upon request.

Pursuant to NYCRR Subpart 55-2.6, any misrepresentation of the fields of accreditation (category - method - analyte) for which your laboratory is approved may result in denial, suspension, or revocation of your certification. Any use of the Environmental Laboratory Approval Program (ELAP) or National Environmental Laboratory Accreditation Program (NELAP) name, reference to the laboratory's approval status, and/or using the NELAP logo in any catalogs, advertising, business solicitations, proposals, quotations, laboratory analytical reports, or other materials must include the laboratory's ELAP identification number and distinguish between testing for which the laboratory is approved and testing for which the laboratory is not approved.

If you have any questions, please contact us at the Environmental Laboratory Approval Program, Wadsworth Center, New York State Department of Health, Empire State Plaza, Albany NY, 12237; by phone at (518) 485-5570; by facsimile at (518) 485-5568; and by email at elap@health.ny.gov.

Sincerely,

Victoria Pretti

Victoria Pretti
Director and QA Officer
Environmental Laboratory Approval Program

NEW YORK STATE DEPARTMENT OF HEALTH
WADSWORTH CENTER

Expires 12:01 AM April 01, 2022
Issued April 01, 2021

CERTIFICATE OF APPROVAL FOR LABORATORY SERVICE

Issued in accordance with and pursuant to section 502 Public Health Law of New York State

MR. NILS K. MELBERG
PACE ANALYTICAL SERVICES, LLC - GREENBAY WI
1241 BELLEVUE STREET SUITE 9
GREEN BAY, WI 54302

NY Lab Id No: 12064

is hereby APPROVED as an Environmental Laboratory in conformance with the National Environmental Laboratory Accreditation Conference Standards (2016) for the category ENVIRONMENTAL ANALYSES NON POTABLE WATER
All approved analytes are listed below:

Miscellaneous

Organic Carbon, Total	SM 5310C-2011

NEW YORK STATE OF OPPORTUNITY. Department of Health

Serial No.: 63326

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WADSWORTH CENTER

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Issued April 01, 2021

CERTIFICATE OF APPROVAL FOR LABORATORY SERVICE

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1241 BELLEVUE STREET SUITE 9
GREEN BAY, WI 54302

NY Lab Id No: 12064

is hereby APPROVED as an Environmental Laboratory in conformance with the National Environmental Laboratory Accreditation Conference Standards (2016) for the category ENVIRONMENTAL ANALYSES SOLID AND HAZARDOUS WASTE
All approved analytes are listed below:

Miscellaneous

Organic Carbon, Total	Lloyd Kahn Method

NEW YORK STATE OF OPPORTUNITY. Department of Health

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LAB ID: 12142

April 15, 2021

MR. BRADLEY BELDING
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April 01, 2022

Dear Mr. Belding,

Enclosed are certificate(s) of approval issued to your environmental laboratory for the current permit year. The certificate(s) supersede(s) any previously issued one(s) and is(are) in effect through the expiration date listed. Please carefully examine the certificate(s) to insure that the categories, subcategories, analytes, and methods for which your laboratory is approved are correct. In addition, verify that your laboratory's name, address, lead technical director, and identification number are accurate.

Pursuant to NYCRR Subpart 55-2.2, original certificates must be posted conspicuously in the laboratory and copies shall be made available to any client of the laboratory upon request.

Pursuant to NYCRR Subpart 55-2.6, any misrepresentation of the fields of accreditation (category - method - analyte) for which your laboratory is approved may result in denial, suspension, or revocation of your certification. Any use of the Environmental Laboratory Approval Program (ELAP) or National Environmental Laboratory Accreditation Program (NELAP) name, reference to the laboratory's approval status, and/or using the NELAP logo in any catalogs, advertising, business solicitations, proposals, quotations, laboratory analytical reports, or other materials must include the laboratory's ELAP identification number and distinguish between testing for which the laboratory is approved and testing for which the laboratory is not approved.

If you have any questions, please contact us at the Environmental Laboratory Approval Program, Wadsworth Center, New York State Department of Health, Empire State Plaza, Albany NY, 12237; by phone at (518) 485-5570; by facsimile at (518) 485-5568; and by email at elap@health.ny.gov.

Sincerely,

Victoria Pretti

Victoria Pretti
Director and QA Officer
Environmental Laboratory Approval Program

RECEIVED
BY kmn2 DATE 4/28/21

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WADSWORTH CENTER

Expires 12:01 AM April 01, 2022
Issued April 15, 2021

CERTIFICATE OF APPROVAL FOR LABORATORY SERVICE

Issued in accordance with and pursuant to section 502 Public Health Law of New York State

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PACE ANALYTICAL SERVICES, LLC
106 VANTAGE POINT DRIVE
WEST COLUMBIA, SC 29172

NY Lab Id No: 12142

is hereby APPROVED as an Environmental Laboratory in conformance with the National Environmental Laboratory Accreditation Conference Standards (2016) for the category ENVIRONMENTAL ANALYSES POTABLE WATER
All approved analytes are listed below:

Perfluorinated Alkyl Acids

Perfluorooctanesulfonic acid (PFOS)	EPA 533
	EPA 537.1
Perfluorooctanoic acid (PFOA)	EPA 533
	EPA 537.1

NEW YORK STATE OF OPPORTUNITY. Department of Health

Serial No.: 63534

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Document Information

Document Number: ENV-MAN-WCOL-0001 **Revision:** 00

Document Title: Laboratory Quality Manual

Department(s): Quality

Date Information

Effective Date: 01 Feb 2021

Notes

Document Notes:

All Dates and Times are listed in: Central Time Zone

Signature Manifest

Document Number: ENV-MAN-WCOL-0001 **Revision:** 00

Title: Laboratory Quality Manual

All dates and times are in Central Time Zone.

ENV-MAN-WCOL-0001

QM Approval

Name/Signature	Title	Date	Meaning/Reason
Kelly Nance (090523)	Manager - Quality	22 Jan 2021, 10:22:54 AM	Approved

Management Approval

Name/Signature	Title	Date	Meaning/Reason
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Kristina Bouknight (090465)	Quality Analyst 1	22 Jan 2021, 11:15:36 AM	Approved
Daniel Wright (090548)	General Manager 1	25 Jan 2021, 08:20:51 AM	Approved
Bradley Belding (090462)	Manager - Operations	25 Jan 2021, 10:57:44 AM	Approved
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Stephanie Atkins (090460)	Manager - Quality Program	29 Jan 2021, 12:18:50 PM	Approved
Michael Kilpatrick (090505)	Manager	01 Feb 2021, 03:04:56 PM	Approved

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TITLE PAGE

LABORATORY QUALITY MANUAL

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Quality Manual Approval Signatories

Approval of this quality manual by managerial personnel is recorded on the Signature Manifest located before the Title Page of this manual.

The individuals listed below represent the management team that was in place on the effective date of this version of the manual for the following location:

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Each of the following individuals is a signatory for the quality manual for the location listed above. The application of their signature to the manual signifies their commitment to communicate, implement, and uphold the requirements, policies and procedures specified in this manual and their commitment to continuously improve the effectiveness of the quality management system based on customer feedback and internal assessment.

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Kristina Bouknight	Health & Safety, however named.	All locations listed above	Above
Cheryl Melton	IT Manager	All locations listed above	Above
Robert Zhu	Technical Specialist[3]	Analytical Laboratory – West Columbia, SC	Above
Bradley Belding	Operations Manager	Analytical Laboratory – West Columbia, SC	Above
Michael Kilpatrick	Client Services Manager – Acting Director for Charlotte Service Center	Charlotte Service Center – Charlotte, NC	Above
Lucas Odom	Project Manager – Acting Director for Greenville Service Center	Greenville Service Center – Greenville, SC	Above

[1] Members of the local management team are subject to change during the lifecycle of this document version.
[2] Include if different from the physical address and phone number of the facility.
[3] This individual serves as an Acting Technical Manager for TNI for one or more fields of accreditation.

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1.0 PURPOSE AND SCOPE

1.1 Purpose

This quality manual (manual) outlines the quality management system (QMS) and management structure of the laboratories and service centers affiliated with the environmental sciences (ENV) division of Pace Analytical Services, LLC (PAS). A laboratory is defined by ENV as any facility, however named, that provides testing, sampling, or field measurement services. When the term 'laboratory" is used in this manual, the term refers to all locations listed on the Title Page of this manual and in Section 4.1.3 unless otherwise specified.

The ENV quality management system is also referred to as the quality program throughout this document. In this context, the phrase "quality management system" and "quality program" are synonymous and may be referred to by the acronym QMS.

The quality management system is the collection of policies and processes established by ENV management to consistently meet customer requirements and expectations, and to achieve the goals of providing PAS customers with high quality, cost-effective, analytical measurements and services.

The quality management system is also intended to establish conformance[1] and compliance with the current versions of the following international and national quality system standards:

- ISO/IEC 17025: *General requirements for the competence of testing and calibration laboratories*
- NELAC/TNI Standard Volume 1: *Management and Technical Requirements for Laboratories Performing Environmental Analysis*

[1]The statement of conformity to these Standards pertains only to testing and sampling activities carried out by the laboratory at its physical address, in temporary or mobile facilities, in-network, or by laboratory personnel at a customer's facility.

In addition to the international and national standards, the quality management system is designed to achieve regulatory compliance with the various federal and state programs for which the laboratory provides compliance testing and/or holds certification or accreditation. When federal or state requirements do not apply to all ENV locations, the requirements for compliance to those specifications are provided in addendum to this manual or in other documents that supplement the manual. Customer-specific project and program requirements are not included in the manual in order to maintain client confidentiality.

- A list of accreditation and certifications held by each laboratory associated with this manual is provided in Appendix A.
- A list of analytical testing capabilities offered by each laboratory associated with this manual is provided in Appendix B.

1.2 Scope and Application

This manual applies to each of the PAS locations listed on the Title Page.

The manual was prepared from the quality manual template (template) created by ENV corporate quality personnel. The template outlines the minimum requirements ENV management considers necessary for every ENV location, regardless of scope of services or number of personnel, to establish in order to maintain a quality management system that achieves the objectives of the Quality Policy (See 4.2.2). In this regard, the template is the mechanism used by the corporate officers (a.k.a. 'top

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management') to communicate their expectations and commitment for the quality program to ENV personnel.

Each location also has the responsibility to comply with federal and state regulatory and program requirements for which it provides analytical services and holds certification or accreditation. When those requirements are more stringent than the template, the requirements for compliance are provided in addendum to this manual or in other documents that supplement the manual. This document structure maintains consistency in the presentation of the quality management system across the network while providing the location a mechanism to describe and achieve compliance requirements on a program basis.

1.2.1 Quality Manual Template

The quality manual template is developed by the Corporate Quality Director with contribution and input from corporate quality personnel and the corporate officers. Approval of the template by the corporate officers (aka "top management") confirms their commitment to develop and maintain a quality management system appropriate for the analytical services offered by the organization and to communicate their expectations of the quality program to all personnel.

The template and instructions for use of the template are released by corporate quality personnel to the quality assurance manager responsible for each location (Local QM). The local QM uses the template to prepare the laboratory's manual by following the instructions provided. Since the template provides the minimum requirements by which ENV locations must abide, the laboratory may not alter the font, structure or content of the template except where specified by instruction to do so. As previously stated, program specific requirements are provided in addendum or in documents that supplement this manual.

The template is reviewed by corporate quality personnel annually and updated if needed. More frequent review and revision may be necessary to manage change, to maintain conformance and compliance to relevant standards, or to meet customer expectations.

See standard operating procedure (SOP) ENV-SOP-CORQ-00015 *Document Management and Control* for more information.

1.2.2 Laboratory Quality Manual

The manual is approved and released to personnel under the authority of local management whose signatures are identified on the Manual Signatory Page of this manual. The manual is reviewed annually, and location specific information is updated, if needed. More frequent review and revision may be necessary when there are significant changes to the organizational structure, capabilities, and resources of the laboratory. Review and revision of the manual is managed by the local QM. If review indicates changes to the main body of the manual are necessary to maintain conformance and compliance to relevant standards, or to meet customer expectations, the local QM will notify corporate quality personnel to initiate review and/or revision of the template.

See SOP ENV-SOP-CORQ-00015 *Document Management and Control* for more information.

1.2.3 References to Supporting Documents

The template and the manual include references to other laboratory documents that support the quality management system such as policies and standard operating procedures (SOPs).

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These references include the document's document control number and may include the document title.

This information is subject to change. For example, an SOP may be converted to a policy or the document's title may change. For these types of administrative changes, the manual and template are updated to reflect the editorial change during the manual's next scheduled review/revision cycle or the next time a new version of the manual is released, whichever is sooner.

The local QM maintains a current list of controlled documents used at each location that support the quality management system. This list, known as the "Master List", lists each document used by document control number, title, version, effective date, and reference to any document(s) that the current version supersedes. When there is a difference between the manual and the Master List, the document information in the Master List takes precedence. The current Master List is readily available to personnel for their use and cross-reference. Parties external to the laboratory should contact the laboratory for the most current version.

2.0 REFERENCES

References used to prepare this manual include:

- "Guidelines Establishing Test Procedures for the Analysis of Pollutants Under the Clean Water Act." Federal Register, 40 CFR Part 136, most current version.
- "Test Methods for Evaluating Solid Wastes: Physical/Chemical Methods." SW-846.
- "Methods for Chemical Analysis of Water and Wastes", EPA 600-4-79-020, 1979 Revised 1983, U.S. EPA.
- U.S. EPA Contract Laboratory Program Statement of Work for Organic Analysis, current version.
- U.S. EPA Contract Laboratory Program Statement of Work for Inorganic Analysis, current version.
- U.S. EPA Contract Laboratory Program Statement of Work for Superfund Analytical Methods, current version.
- "Standard Methods for the Examination of Water and Wastewater." Current Edition APHA-AWWA-WPCF.
- "Annual Book of ASTM Standards", Section 4: Construction, Volume 04.04: Soil and Rock; Building Stones, American Society of Testing and Materials.
- "Annual Book of ASTM Standards", Section 11: Water and Environmental Technology, American Society of Testing and Materials.
- "NIOSH Manual of Analytical Methods", U.S. Department of Health and Human Services, National Institute for Occupational Safety and Health, most current version.
- "Methods for the Determination of Organic Compounds in Finished Drinking Water and Raw Source Water", U.S. EPA, Environmental Monitoring and Support Laboratory – Cincinnati (Sep 1986).
- Quality Assurance of Chemical Measurements, Taylor, John K.; Lewis Publishers, Inc. 1987.
- Methods for Non-conventional Pesticides Chemicals Analysis of Industrial and Municipal Wastewater, Test Methods, EPA-440/1-83/079C.

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- Environmental Measurements Laboratory (EML) Procedures Manual, HASL-300, US DOE, February 1992.
- Requirements for Quality Control of Analytical Data, HAZWRAP, DOE/HWP-65/R1, July 1990.
- Quality Assurance Manual for Industrial Hygiene Chemistry, AIHA, most current version.
- National Environmental Laboratory Accreditation Conference (NELAC) Standard- most current version.
- ISO/IEC 17025, General requirements for the competence of testing and calibration laboratories, 2nd Edition 2005-05-15; 3rd Edition 2017-11

  The following are implemented by normative reference to ISO/IEC 17025:

  - ISO/IEC Guide 99, *International vocabulary of metrology –Basic and general concepts and associated terms*
  - ISO/IEC 17000, *Conformity assessment – Vocabulary and general principles*
- Department of Defense Quality Systems Manual (QSM), most current version.
- TNI (The NELAC Institute) Standard, 2009 and 2016 versions.
- UCMR Laboratory Approval Requirements and Information Document, most current version.
- US EPA Drinking Water Manual, most current version.

3.0 TERMS AND DEFINITIONS

Refer to Appendix C for terms, acronyms, and definitions used in this manual and in other documents used by the laboratory to support the quality management system.

4.0 MANAGEMENT REQUIREMENTS

4.1 Organization

4.1.1 Legal Identity

Pace Analytical Services, LLC is authorized under the State of Minnesota to do business as a limited liability company.

4.1.1.1 Change of Ownership

If there is a change of ownership, if a location goes out of business, or if the entire organization ceases to exist, Pace Analytical Services, LLC ensures that regulatory authorities are notified of the change within the time-frame required by each state agency for which the location is certified or accredited.

Requirements for records and other business information are addressed in the ownership transfer agreement or in accordance with appropriate regulatory requirements, whichever takes precedence.

4.1.2 Compliance Responsibility

Laboratory management has the responsibility and authority to establish and implement procedures and to maintain sufficient resources necessary to assure its activities are carried out in such a way to meet the compliance requirements of the quality management system.

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4.1.3 Scope of the Quality Management System

The quality management system applies to work carried out at each location covered by this manual including permanent facilities, at sites away from its permanent facilities, or in associated temporary or mobile facilities.

The permanent and mobile facilities to which this manual applies are listed on the Title Page of this manual.

4.1.4 Organization History and Information

Founded in 1978, Pace Analytical Services, LLC (PAS) is a privately held scientific services firm operating one of the largest full-service contract laboratory and service center networks in the United States. The company's network offers inorganic, organic and radiochemistry testing capabilities; specializing in the analysis of trace level contamination in air, drinking water, groundwater, wastewater, soil, biota, and waste.

With over 90 laboratories and services centers in the contiguous US and in Puerto Rico, the network provides project support for thousands of industry, consulting, engineering and government professionals.

PAS delivers the highest standard of testing and scientific services in the market. We offer the most advanced solutions in the industry, backed by truly transparent data, a highly trained team, and the service and support that comes from four decades of experience.

4.1.4.1 Organization Structure

Each location maintains a local management structure under the oversight and guidance of corporate personnel. Local management is responsible for making day-to-day decisions regarding the operations of the facility, implementing the quality management system, upholding the requirements of the quality program, and for supervision of personnel.

Local management is provided by the Regional Vice-President - Operations (RVPO), Corporate Quality Program Manager (QPM), General Manager (GM), Quality Manager (QM), and department specific management and supervisory personnel.

The GM reports to a Vice-President of Operations (RVPO), who is responsible for the management of multiple laboratories and service centers across the division. The RVPO reports directly to the Chief Operating Officer (COO).

The QM reports to a Quality Program Manager (QPM), who is responsible for managing quality personnel for multiple locations across the division. The QPM reports directly to the Corporate Quality Director (CQD). The QM also maintains an indirect reporting relationship to the GM of each location that the QM manages.

Technical oversight for each location is provided by corporate personnel, RVPO, QPM, GM, QM, and department-specific management.

Refer to the organization charts provided in Appendix D to view the management structure, reporting relationships, and the interrelationships between positions.

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4.1.5 Management Requirements

4.1.5.1 Personnel

The laboratory is staffed with administrative and technical personnel who perform and verify work under the supervision of managerial personnel.

- Technical personnel include analysts and technicians that generate or contribute to the generation of analytical data and managerial personnel that oversee day to day supervision of laboratory operations. Including the reporting of analytical data and results, monitoring QA/QC performance, and monitoring the validity of analysis to maintain data integrity and reliability.
- Administrative personnel support the day-to-day activities of the laboratory.
- IT personnel maintain the information technology systems and software used at the laboratory.
- Client services personnel include project managers and support staff that manage projects.
- Managerial personnel make day-to-day and long-term decisions regarding the operations of the facility, supervise personnel, implement the quality management system and uphold the requirements of the quality program.

All personnel regardless of responsibilities are expected to carry out their duties in accordance with the policies and processes outlined in this manual and in accordance with standard operating procedures (SOPs) and other quality system documents. The laboratory's policies and procedures are designed for impartiality and integrity. When these procedures are fully implemented, personnel remain free from undue pressure and other influences that adversely impact the quality of their work or data.

4.1.5.1.1 Key Personnel

Key personnel include the management positions that have the authority and responsibility to plan, direct, and control, activities of the division (corporate) or the laboratory.

The following tables list key personnel positions by PAS job title and the position's primary deputy:

Key Personnel: Corporate

Key Personnel	Primary Deputy
Chief Executive Officer	Chief Operating Officer
Chief Operating Officer	Chief Executive Officer
Chief Compliance Officer	Quality Director
Corporate Quality Director	Chief Compliance Officer
Health and Safety Director	Chief Compliance Officer
IT Director	LIMS Administrator, however named.

Key Personnel: Laboratory

Key Personnel	Primary Deputy

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Regional Vice President - Operations	Chief Operating Officer or as designated.
Quality Program Manager	A different QPM or Corporate Quality Director
General Manager	Regional Vice President of Operations
Quality Manager	Quality Program Manager
Manager – Client Services	General Manager or as designated.
Local IT	Corporate IT Director or as designated.
Department Manager	General Manager
Technical Director[1]/Manager[1] Acting Technical Manager TNI	Another qualified employee
Operations Manager[1]	General Manager

[1] *Position may not be staffed at each location.*

Some state certification programs require the agency to be notified when there has been a change in key personnel. Program-specific requirements and timeframes for notification by agency, are tracked and upheld by the local QM, when these requirements apply.

4.1.5.2 Roles and Responsibilities

The qualifications, duties, and responsibilities for each position are detailed in job descriptions maintained by PAS's corporate Human Resource's Department (HR).

The following summaries briefly identify the responsibility of key personnel positions in relation to the ENV quality management system.

Chief Executive Officer (CEO): The CEO has overall responsibility for performance of the organization and endorses the quality program. Working with corporate and laboratory management, the CEO provides the leadership and resources necessary for ENV locations to achieve the goals and objectives of the quality management system and quality policy statement.

Chief Operating Officer (COO): The COO oversees all aspects of operations management including, strategic planning, budget, capital expenditure, and management of senior management personnel for ENV In this capacity, the COO provides leadership and resources necessary to help top management at each ENV location achieve the goals and objectives of the quality management system and quality policy statement.

Chief Compliance Officer (CCO): The CCO oversees the quality assurance and environmental health and safety programs (EHS) for each business unit. The CCO is responsible for planning and policy development for these groups to ensure regulatory compliance and to manage risk. The position provides leadership and guidance necessary for all PAS locations to achieve the goals and objectives of the quality and EHS programs.

The CCO also serves as the Ethics Officer (ECO). The ECO develops the Ethics and Data Integrity Policy and Training Program and provides oversight for reporting and investigation of ethical misconduct to maintain employee confidentiality during the process. The ECO provides guidance and instruction for follow-up actions necessary to remedy the situation and deter future recurrence.

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Corporate Director of Quality (CQD): The Corporate Director of Quality is responsible for developing and maintaining the ENV quality program under guidance and assistance from the CEO, COO, and CCO. This position develops corporate quality policy and procedure and analyzes metric data and other performance indicators to assess and communicate the effectiveness of the quality program to top management. The position provides leadership and guidance for implementation of the quality program across all ENV locations.

Corporate Quality Program Manager (QPM): The Quality Program Manager is responsible for managing the implementation of the ENV quality program for one or more locations in the network. Working with the CQD and local laboratory management to which they are assigned, the QPM provides leadership, guidance and resources, including allocation of personnel, necessary to achieve the goals of ENV quality program.

Corporate Director of Information Technology: The Corporate Director of IT oversees the systems and processes of information technology used to support the quality program. These systems include Laboratory Information Management Systems (LIMS); data acquisition, reduction, and reporting software; virus-protection, communication tools, and ensuring the integrity and security of electronic data.

Regional Vice-President of Operations): The RVPO has full responsibility for administrative and operations management and performance of a group of ENV laboratories and service centers. Working with the COO and local laboratory management, the RVPO provides leadership, guidance and resources, including allocation of personnel, necessary to achieve the goals of ENV quality program.

General Manager (GM): The GM is responsible for the overall performance and administrative and operations management of an ENV location and associated service center(s). This position is responsible to provide leadership and resources, including allocation and supervision of personnel, necessary for the location to implement and achieve the goals of the PAS quality program. In this capacity, the position assures laboratory personnel are trained on and understand the structure and components of the quality program defined in this manual as well as the policies and procedures in place to implement the quality management system.

The GM of NELAC/TNI Accredited laboratories is also responsible for the designation of technical personnel to serve as acting technical managers for TNI for the fields of accreditation held by the laboratory (See Section 4.1.5.2.1) and for notifying the accreditation body (AB) of any extended absence or reassignment of these designations.

Quality Manager (QM): The QM oversees and monitors implementation of the quality management system for each ENV location assigned and communicates deviations to laboratory management. The QM is independent of the operation activities for which they provide oversight and has the authority to carry out the roles and responsibilities of their position without outside influence.

Additionally, in accordance with the TNI Standard, the QM:

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- serves as the focal point for QA/QC and oversees review of QC data for trend analysis;
- evaluates data objectively and perform assessments without outside influence;
- has documented training and experience in QA/QC procedures and the laboratory's quality system;
- has a general knowledge of the analytical methods offered by the laboratory;
- coordinates and conducts internal systems and technical audits;
- notifies laboratory management of deficiencies in the quality system;
- monitors corrective actions;
- provides support to technical personnel and may serve as the primary deputy for the acting TNI Technical Manager(s).

Manager-Client Services (CSM): This position is responsible for training and management of client facing staff that serve as the liaison between PAS and the customer to ensure that projects are successfully managed to meet the expectations and needs of PAS customers. This position is also responsible for sharing positive and negative customer feedback with laboratory management so that this information may be used to improve the quality program.

Local IT Manager, however named: Local IT managers are responsible for maintaining the IT systems used to support the quality program. These systems include Laboratory Information Management Systems (LIMS); data acquisition, reduction, and reporting software; virus-protection, communication tools, and ensuring the integrity and security of electronic data.

Department Manager (DM): The DM is responsible for administrative and operations management and implementation of the quality management system in the work area he/she oversees. These responsibilities include but are not limited to: training and supervision of personnel, monitoring work activity to maintain compliance with this manual, SOPs, policies and other instructional documents that support the quality management system; method development, validation and the establishment and implementation of SOPs to assure regulatory compliance and suitability for intended purpose; monitoring QA/QC performance, proper handling and reporting of nonconforming work, purchasing of supplies and equipment adequate for use, maintaining instrumentation and equipment in proper working order and calibration, and general maintenance of administrative and technical processes and procedures established by the laboratory.

Operations Manager (OM): The OM is responsible for management of production and/or other duties assigned by the GM.

4.1.5.2.1 Acting Technical Manager (TNI Accreditation):

For ENV locations that are NELAC/TNI accredited:

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The TNI Standard specifies requirements for the qualification and duties of technical personnel with managerial responsibility. These requirements are associated in the Standard to the designation 'technical manager(s), however named'. These responsibilities may be assigned to multiple individuals and are not associated with any specific job title.

The TNI requirements for personnel that provide technical oversight correlate with ENV job descriptions for Department Manager or Supervisor. However, the duties may be assigned to any PAS employee that meets the TNI specified qualifications.

Personnel assigned this designation retain their assigned job title. The job title may be appended with *"acting as technical manager for TNI"* and the technology or field of accreditation for which the employee is approved, if necessary.

When TNI Accreditation Bodies (AB) refer to these employees as 'technical manager' or 'technical director' on the official certificate or the scope of accreditation, this reference is referring to their approval to carry out duties of the 'technical manager, however named' as specified in the TNI Standard.

In accordance with the TNI Standard, the acting Technical Manager(s) for TNI are responsible for monitoring the performance of QC/QA in the work areas they oversee.

If the absence of any employee that is approved as acting technical manager for TNI exceeds 15 calendar days, the duties and responsibilities specified in the TNI Standard are temporarily reassigned to another employee that meets the qualifications for the technology or field of accreditation. If the employee's absence exceeds 35 calendar days, the QM will formally notify the TNI primary AB of the absence and the details of reassignment of duties in writing.

Refer to the applicable TNI Standard for requirements for technical oversight and required qualifications of the acting Technical Manager(s) for each discipline (chemical, limited inorganic chemistry, and microbiology).

4.1.5.3 Conflict of Interest

A conflict of interest is a situation where a person has competing interests. Laboratory management looks for potential conflict of interest and undue pressures that might arise in work activities and then includes countermeasures in policies and procedures to mitigate or eliminate the conflict.

See policy COR-POL-0004 *Ethics Policy* for more information.

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4.1.5.4 Confidentiality

Laboratory management is committed to preserving the confidentiality of PAS customers and confidentiality of business information.

Procedures used by the laboratory to maintain confidentiality include:

- A Confidentiality Agreement which all employees are required to sign at the time of employment and abide by the conditions of throughout employment;
- Record retention and disposal procedures that assure confidentiality is maintained;
- Physical access controls and encryption of electronic data; and
- Protocol for handling Confidential Business Information (CBI).

Client information obtained or created during work activities is considered confidential and is protected from intentional release to any person or entity other than the client or the client's authorized representative, except when the laboratory is required by law to release confidential information to another party, such as a regulatory agency or for litigation purposes. In which case, the laboratory will notify the client of the release of information and the information provided.

The terms of client confidentiality are included in ENV Standard Terms and Conditions (T&C). With the acceptance of ENV Terms and Conditions and/or the implicit contract for analytical services that occurs when the client sends samples to the laboratory for testing, the client authorizes PAS to release confidential information when required.

See policy COR-POL-0004 *Ethics Policy* for more information.

4.1.5.5 Communication

Communication is defined as the imparting or exchanging of news and information. Effective (good) communication occurs when the person(s) you are exchanging information with actively gets the point and understands it.

4.1.5.5.1 Workplace Communication

Good communication in the workplace is necessary to assure work is done correctly, efficiently, and in accordance with client expectations.

Instructions for how to carry out work activities are communicated to personnel via written policy, standard operating procedures, and standard work instructions.

Information about laboratory performance (positive and negative) and ideas for improvement are communicated using various communication channels such as face to face meetings, video conferencing, conference calls, email, memoranda, written reports, and posters.

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4.1.5.5.2 External Communication

Communication with external parties such as customers, vendors, business partners, and regulatory agencies takes place every day.

Laboratory management ensure personnel learn to communicate in professional and respectful ways in order to build strong relationships and learn to communicate effectively to avoid misunderstanding.

4.2 Quality Management System

4.2.1 Quality Management System Objectives

The objectives of the laboratory's quality management system are to provide clients with consistent, exemplary professional service, and objective work product that is of known and documented quality that meets their requirements for data usability and regulatory compliance.

Objective work product is analytical services, data, test results, and information that is not influenced by personal feeling or opinions. The quality of being objective is also known as 'impartiality'.

4.2.1.1 Impartiality

The laboratory achieves and maintains impartiality by implementing and adhering to the policies and processes of the quality management system, which are based on industry accepted standards and methodologies.

The laboratory's procedures for handling nonconforming work (See 4.9), corrective and preventive actions (See 4.11, 4.12) and management review (See 4.15) are the primary mechanisms used to identify risk to impartiality and to prompt actions necessary to eliminate or reduce the threat when risk to impartiality is suspected or confirmed.

4.2.1.2 Risk and Opportunity Assessment

Risks are variables that make achieving the goals and objectives of the quality management system uncertain. An opportunity is something that has potential positive consequences for the laboratory.

Laboratory personnel manage risks and opportunities on a daily basis by carrying out the processes that make up the quality management system. Some of the ways in which the quality management system is designed to identify, minimize, or eliminate risk on a daily basis include but are not limited to:

- Capability and capacity reviews of each analytical service request to assure the laboratory can meet the customer's requirements;
- Maintenance of accreditation and certification for test methods in multiple states and programs to cover a broad range of jurisdiction for regulatory compliance;
- SOPs and other controlled instructional documents are provided to personnel to eliminate variability in process. These documents include actions to counter risk

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factors inherent in the process and are reviewed on a regular basis for on-going suitability and relevancy;

- Participation in proficiency testing programs and auditing activities to verify on-going competency and comparability in performance;
- Provision of on-the-job training and established protocol for quality control (QC) corrective action for nonconforming events;
- An established program for ethics, and data integrity;
- Tiered data review process;
- Culture of continuous improvement;
- Monitoring activities to assess daily and long-term performance; and
- Annual critical review of the effectiveness of the quality management system.

ENV also promotes a continuous improvement culture based on the principles of lean manufacturing. These principles include 3P (Process, Productivity, Performance) and Kaizen. 3P is a platform used by Pace to share best practices and standardization across the network to achieve operational excellence. Kaizen is a team-based process used to implement tools and philosophies of lean to reduce waste and achieve flow with the purpose of improving both external and internal customer satisfaction. ENV's lean programs and activities help to mitigate risk because they generate a collective understanding of vulnerabilities and utilize group-effort to develop and implement solutions at all levels.

Risk and opportunities may also be formally identified using specific risk and opportunity assessment methods such as SWOT Analysis (Strength, Weakness, Opportunity, Threats) and 3-Stage Impact/Probability Grids.

4.2.1.3 Communication of the Quality Management System

This manual is the primary mechanism used by laboratory management to communicate the quality management system to laboratory personnel.

To assure personnel understand and implement the quality program outlined in the manual:

- All laboratory personnel are required to sign a Read and Acknowledgement Statement to confirm the employee has: 1) been informed of the manual by laboratory management, 2) has access to the manual, 3) has read the manual 4) understands the content of the manual, and 5) agrees to abide by the requirements, policies and procedures therein.
- Personnel are informed that the manual provides the "what" of the quality management system. The "how to" implementation of the quality management system is provided in policy, SOPs, standard work instructions, and other controlled instructional documents.

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4.2.2 Quality Policy Statement

The quality policy of the laboratory is to provide customers with data of known and documented quality fit for their intended purpose. The laboratory achieves this policy by implementing the quality management system defined in this manual, by following industry accepted protocol for analytical testing and quality assurance and quality control (QA/QC) activities, by conformance with published and industry accepted testing methodologies, and by compliance with international and national standards for the competency and/or accreditation of testing laboratories.

Intrinsic to this policy statement is each of the following principles:

- The laboratory will provide customers with reliable, consistent, and professional service. This is accomplished by making sure the laboratory has the resources necessary to maintain capability and capacity; that staff are trained and competent to perform the tasks they are assigned; that client-facing staff are trained and prepared to find solutions to problems and to assist customers with their needs for analytical services. Customer feedback, both positive and negative, is shared with personnel and used to identify opportunities for improvement.
- The laboratory maintains a quality program that complies with applicable state, federal, and industry standards for analytical testing and competency.

  ISO/IEC 17025 and the TNI (The NELAC Institute) Standard is used by ENV to establish the minimum requirements of the ENV quality program.

  ISO/IEC 17025 is a competency standard that outlines the general requirements for the management system for calibration and testing laboratories. It is the primary quality system standard from which other quality system standards, such as the TNI Standard, are based. The TNI Standards are consensus standards that provides management and technical requirements for laboratories performing environmental analysis.
- Laboratory management provides training to personnel so that all personnel are familiar with the quality management system outlined in this manual and that they understand that implementation of the quality management system is achieved by adherence to the organization's policies and procedures.
- Laboratory management continuously evaluates and improves the effectiveness of the quality management system by responding to customer feedback, and other measures of performance, such as but not limited to: the results of internal/external audits, proficiency testing, metrics, trend reports, and annual and periodic management reviews.

4.2.2.1 Ethics Policy / Data Integrity Program

PAS has established a comprehensive ethics and data integrity program that is communicated to all PAS employees in order that they understand what is expected of them. The program is designed to promote a mindset of ethical behavior and professional conduct that is applied to all work activities.

The key elements of the PAS Ethics / Data Integrity Program include:

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- Ethics Policy (COR-POL-0004);
- Ethics Officer;
- Standardized data integrity training course taken by all new employees on hire and a yearly refresher data integrity training course for all existing employees;
- Policy Acknowledgement Statements that all PAS personnel, including contract and temporary, are required to sign at the time of employment and again during annual refresher training to document the employee's commitment and obligation to abide by the company's standards for ethics, data integrity and confidentiality;
- SOPs that provide instructions for how to carry out a test method or process to assure tasks are done correctly and consistently by each employee;
- On the Job Training;
- Data integrity monitoring activities which include, but are not limited to, primary, secondary and completeness data reviews, internal technical and system audits, data audits, data surveillance, and proficiency testing; and
- Confidential reporting process for alleged ethics and data integrity issues.

All laboratory managers are expected to provide a work environment where personnel feel safe and can report unethical or improper behavior in complete confidence without fear of retaliation. Retaliation against any employee that reports a concern is not tolerated.

PAS has engaged Lighthouse Services, Inc. to provide personnel with an anonymous reporting process available to them 24 hours a day/7 days per week. The alert line may be used by any employee to report possible violations of the company's ethics and data integrity program. When using the reporting process, the employee does need to specify the location of concern and when reporting by email, also include the company name. Messages are collected, documented, reviewed, and will be followed up on by the Ethics Compliance Officer to resolve the matter. Investigations concerning data integrity are kept confidential.

Lighthouse Compliance Alert Lines:

English Speaking US & Canada	(844) 940-0003
Spanish Speaking North America	(800) 216-1288
Internet	www/lighthouse-services.com/pacelabs
Email	reports@lighthouse-services.com

4.2.3 Management Commitment: Quality Management System

Evidence of management's commitment for the development, maintenance, and on-going improvement of the quality management system is provided by the application of their signature of approval to this manual. Their signature confirms they understand their responsibility to implement the quality management system outlined in this manual, to

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communicate the quality program to personnel, and to uphold requirements of the program during work activities.

4.2.4 Management Commitment: Customer Service

Management communicates the importance of meeting customer and regulatory requirements to personnel by training personnel on the quality management system outlined in this manual, implementing the quality management system outlined in this manual, and upholding these requirements for all work activities.

4.2.5 Supporting Procedures

Documents that support this manual and quality management system are referenced throughout this manual. The structure of the document management system is outlined in SOP ENV-SOP-CORQ-0015 *Document Management and Control* and summarized in the following subsections.

4.2.5.1 Quality Management System Document Structure

Documents associated with the quality management system are classified into document types that identify the purpose of the document and establish how the document is managed and /or controlled.

Document types are ranked to establish which documents takes precedence when there is an actual or perceived conflict between documents and to establish the hierarchal relationships between documents. The ranking system also provides information to document writers and reviewers to assure downline documents are in agreement with documents of higher rank. Project specific documents are not ranked because client specific requirements are not incorporated into general use documents in order to maintain client confidentiality.

Examples: ENV QMS Documents: Internal

Document Type	Purpose
Quality Manual	Outlines the laboratory's quality management system and structure and how it works for a system including policy, goals, objectives and detailed explanation of the system and the requirements for implementation of system. Includes roles and responsibilities, relationships, procedures, systems and other information necessary to meet the objectives of the system described.
Policy	Provide requirements and rules for a PAS process and is used to set course of actions and to guide and influence decisions. Policy describes the "what", not the "how".
Standard Operating Procedure	Provide written and consistent set of instructions or steps for execution of a routine process, method, or set of tasks performed by PAS. Includes both fundamental and operational elements for implementation of the systems described in PAS manual(s). Assures that activities are performed properly in accordance with applicable requirements. Designed to ensure consistency, protect EHS of employees and environment, prevent failure in the process and ensure compliance with company and regulatory requirements. SOPs describes the "how" based on policy.
Standard Work Instruction	Provide step by step visual and/or written instruction to carry out a specific task to improve competency, minimize variability, reduce work injury and strain, or to boost efficiency and quality of work (performance). SWI are associated with an SOP unless the task described is unrelated to generation of or contribution to environmental data or analytical results.
Template	Pre-formatted document that serves as a starting point for a new document.

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Guide	Provide assistance to carry out a task.
Form	Used for a variety of purposes such as to provide a standardized format to record observations, to provide information to supplement an SOP.
Guidance	Non-binding advice used to explain internal policies, procedures, or practices.

Example: ENV QMS Documents: External

Certificate	Lists parameters, methods, and matrices for which the laboratory is certified/accredited to perform within the jurisdiction of the issuing regulatory agency or accreditation body.
Reference Document	Provide information, protocol, instructions, and/or requirements. Issued by the specifier. Examples include quality system standards such as ISO/IEC, TNI, DoD and published referenced methods such as Standard Methods, ASTM, SW846, EPA, and federal and state regulatory bodies.
Project Document	Provides requirements necessary to meet individual client expectations for intended use of data. Examples include project quality assurance plans (QAPP), client-program technical specifications, contracts, and other agreements.

Document Hierarchy

Rank	Document
1	Reference Documents
2	Corporate Manual
3	Corporate Policy
4	Corporate SOP
5	Corporate SWI, Templates, Guides, Forms, Guidance
6	Laboratory Manual
7	Laboratory SOP
8	Laboratory SWI, Templates, Guide, Forms, Guidance
NA	Project Documents

4.2.6 Roles and Responsibilities

The roles and responsibilities for technical management and the quality manager is provided in section 4.1.5.2.

4.2.7 Change Management

When significant changes to the ENV quality management system are planned, these changes are managed by corporate quality personnel to assure that the integrity of the quality management system is maintained.

4.3 Document Control

4.3.1 General

The laboratory's procedures for document control are provided in SOP ENV-SOP-CORQ-0015 *Document Management and Control.*

The laboratory uses electronic document management software (eDMS) to carry out the document control procedures of the SOP. eDMS automates the process for unique document identification, version control, approval, access, and archival. The eDMS software used by ENV restricts access to archived documents except to authorized users to prevent the use of obsolete documents.

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The local QM maintains a master list of controlled documents used at the laboratory. The master list includes the document control number, document title, and current revision status and is made available to personnel for their reference.

See SOP ENV-SOP-CORQ-0015 *Document Management and Control* for more information.

4.3.2 Document Approval and Issue

Documents that support the quality management system are reviewed by qualified personnel and approved by laboratory management prior to release for general use.

Only the approved versions of documents are available to personnel for use unless use of a draft document is authorized by management.

See SOP ENV-SOP-CORQ-0015 *Document Management and Control* for more information.

4.3.3 Document Review and Change

Unless a more frequent review is required by regulatory, certification or accreditation program the laboratory formally reviews documents at least every two years to ensure the document remains current, appropriate, and relevant.

Documents are also informally reviewed every time the document is used. Personnel are expected to refer to and follow instructions in controlled documents when they carry out their work activities. Consequently, any concerns or problems with the document should be caught and brought to the attention of laboratory management on an on-going basis.

Documents are revised whenever necessary to ensure the document remains usable and correct. Older document versions and documents no longer needed are made obsolete and archived for historical purposes.

ENV does not allow hand-edits to documents. If an interim change is needed pending re-issue of the document, the interim change is communicated to those that use the document using a formal communication channel, such as SOP Change in Progress form, email, or memorandum.

The document review, revision, and archival process is managed by quality personnel at the location from which the document was released using the procedures established in SOP ENV-SOP-CORQ-0015 *Document Management and Control.*

4.4 Analytical Service Request, Tender, and Contract Review

The laboratory's management and/or client service personnel perform thorough reviews of requests and contracts for analytical services to verify the laboratory has the capability, capacity, and resources necessary to successfully meet the customer's needs. These review procedures are described in laboratory SOP *Project Management* [AD SOP ME001HD].

The procedures in this SOP(s) are established to ensure that:

- The laboratory understands the purpose of data collection in order to ensure the test methods requested are appropriate for the intended use of the data and capable of meeting the client's data quality objectives;

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- The laboratory and any subcontractor has the capability, capacity, and resources to meet the project requirements and expectations within the requested time frame for delivery of work product;
- Any concerns that arise from review are discussed and resolved with the client; and
- The results of review and any correspondence with the client related to this process and/or any changes made to the contract are recorded and retained for historical purposes.

Capability review confirms that the in-network laboratories and any potential subcontractors hold required certification/accreditation for the test method, matrix, and analyte and verifies the laboratory can achieve the client's target compound list and data quality objectives (DQOs) for analytical sensitivity and reporting limits, QA/QC protocol, and hardcopy test report and electronic data deliverable (EDD) formats.

Capacity review verifies that the in-network laboratories and any potential subcontractors are able to handle the sample load and deliver work production within the delivery timeframe requested.

Resource review verifies that the laboratory and any potential subcontractors have adequate qualified personnel with the skills and competency to perform the test methods and services requested and sufficient and proper equipment and instrumentation needed to perform the services requested.

4.5 Subcontracting and In-Network Work Transfer

The terms 'subcontract' and "subcontracting" refers to work sent to a business external to Pace Analytical Services, LLC (PAS) and the term 'subcontractor' refers to these external businesses, which are also called vendors.

Work transferred within the ENV network is referred to as interregional work orders (IRWO) and network laboratories are referred to as IRWO, IR, or a network laboratory.

The network of ENV laboratories offers comprehensive analytical capability and capacity to ensure PAS can meet a diverse range of client needs for any type of project. If the laboratory receives a request for analytical services and it cannot fulfill the project specifications, the laboratory's client services team will work with the client to place the work within the ENV network. When it is not possible to place the work within network, the laboratory will, with documented client approval, subcontract the work to a subcontractor that has the capabilities to meet the project specifications and can meet the same commitment agreed on between the laboratory and the client. Some client programs require client consent even for in-network work transfer, and when this applies, the client services team obtains consent as required. The laboratory retains the record of client notification and their consent in the project record for historical purposes.

Whenever work is transferred to a subcontractor or an in-network laboratory, the laboratory responsible for management of the project verifies each of these qualifications:

- The subcontractor or in network laboratory has the proper accreditation/certifications required for the project and these are current; and
- The use of the subcontractor or in network laboratory is approved by the client and/or regulatory agency, when approval is required. Record of approval is retained in the project record.

All subcontractor laboratories must maintain a quality management system like ENV and that complies with ISO/IEC 17025 and the TNI Standard(s).

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ENV also evaluates and pre-qualifies subcontractors as part of the company's vendor qualification program. The complete list of approved vendors is maintained by the corporate procurement department and is made available to all ENV locations. Pre-qualification of a subcontractor does not negate the requirement for the placing laboratory to verify the capability, capacity, and resources of any selected subcontractor on a project-specific basis to confirm the subcontractor can meet the client's needs.

For both subcontracting and in-network work transfer, the project specifications are always communicated to the subcontractor or the in-network laboratory by the project manager so that the laboratory performing the work is aware of and understands these requirements.

The procedures for subcontracting are outlined in laboratory SOP *Sample Receiving* [AD SOP ME0013H].

4.6 Purchasing Services and Supplies

Vendors that provide services and supplies to the laboratory are prequalified to verify the vendor's capability to meet the needs of PAS. These needs include but are not limited to competitive pricing, capacity to fill purchase orders, quality of product, customer service, and business reputation and stability. The records of vendor evaluation and the list of approved vendors is maintained by the corporate procurement department.

The procedures for vendor qualification are specified in the corporate process for vendor qualification, however named.

The laboratory may purchase goods and services from any supplier on the approved vendor list.

The specifications (type, class, grade, tolerance, purity, etc.) of supplies, equipment, reagents, standard reference materials and other consumables used in the testing process are specified in SOPs. The SOP specifications are based on the governing requirements of the approved reference methods and any additional program driven regulatory specification, such as drinking water compliance. All requisitions for materials and consumables are approved by the department supervisor to confirm the purchase conforms with specified requirements. After approval the requisition is handled by the laboratory's designated purchasing agent. On receipt, the product is inspected and verified before use, when applicable.

The laboratory's procedure for the purchase of services and supplies is specified in laboratory SOP *Procurement of Laboratory Supplies, Services, and Equipment* [AD SOP ME0015U].

4.7 Customer Service

Project details and management is handled by the laboratory's customer service team. Each customer is assigned a Project Manager (PM) that is responsible for review of contract requirements and handling laboratory to customer communication about the project status.

4.7.1 Commitment to Meet Customer Expectations

The laboratory cooperates and works closely with our customers to ensure their needs are met and to establish their confidence in the laboratory's capability to meet their needs for analytical services and expectations for service.

The PM is the customer's primary point of contact for each analytical service request. The PM gathers information from the customer to ensure the details of their request are understood. After samples are received, the PM monitors the progress of the project and alerts

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the customer of any delays or excursions that may adversely impact data usability. Laboratory supervisors are expected to keep the PM informed of project status and any delays or major issues, so that the PM can keep the client informed.

The laboratory encourages customers to visit the laboratory to learn more about the laboratory's capabilities, observe performance and to meet laboratory personnel.

ENV customers expect confidentiality. Laboratory personnel will not divulge or release information to a third party without proper authorization unless the information is required for litigation purposes. See Section 4.1.5.4 of this manual and policy COR-POL-0004 *Ethics Policy* for more information on the laboratory's policy for client confidentiality.

4.7.2 Customer Feedback

The laboratory actively seeks positive and negative feedback from customers through surveys and direct communication. Information from the client about their experience working with the laboratory and their satisfaction with work product is used to enhance processes and practices and to improve decision making. Customer feedback is communicated to laboratory management and corporate personnel in management reports and analyzed yearly during management review (See 4.15) to identify risk and opportunity. Corrective, preventive, or continuous improvement actions are taken based on nature of and/or feedback trends.

Also see sections 4.9, 4.10, 4.11, 4.12, 4.14, and 4.15 for more information about how customer feedback is managed by the laboratory and used to enhance the quality management system.

4.8 Complaints

Complaints provide opportunities to improve processes and build stronger working relationships with our clients.

The laboratory's complaint resolution process includes three steps. First, handle and resolve the complaint to mutual satisfaction. Second, perform corrective action to prevent recurrence (See 4.11). Third, record and track the complaint and use these records for risk and opportunity assessment and preventive action (See 4.12).

4.9 Nonconforming Work

4.9.1 Definition of Nonconforming Work

Nonconforming work is work that does not conform to customer requirements, standard specifications, laboratory policies and procedures, or that does not meet acceptance criteria.

The discovery of non-conforming work comes from various sources which include, but are not limited to:

- results of quality control samples and instrument calibrations;
- quality checks on consumables and materials;
- general observations of laboratory personnel;
- data review;
- proficiency testing;
- internal and external audits;

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- complaints and feedback;
- management review and reports; and
- regulatory and certification and accreditation actions.

The way in which the laboratory handles nonconforming work depends on the significance and impact (risk) of the issue. Some issues may simply require correction, others may require investigation, corrective action (See 4.11) and/or data recall (See 4.16). When the laboratory releases data and test results associated with nonconforming QC and acceptance criteria, test results are qualified, or non-conformances are noted in the final analytical report to apprise the data user of the situation. (See 5.10)

Nonconforming work also includes unauthorized departure from laboratory policies, procedures and test methods. Authorized departures are explained in the following subsections. Situations that do not conform to these conditions are considered unauthorized departure(s).

4.9.1.1 Authorized Departure from SOP

An authorized departure from a test method SOP is one that has been reviewed and approved by the Department Manager, designated Acting Technical Manager for TNI for the discipline the SOP pertains to (Chemistry, Inorganic Chemistry, Microbiology), Quality Manager, or the General Manager. Management review is conducted to confirm the departure does not conflict with regulatory compliance requirements for which the data will be used or does not adversely affect data integrity. The departure may originate from client request or may be necessary to overcome a problem.

An authorized departure from administrative or process-oriented SOP is typically necessary to correct an error in the SOP. These departure requests are reviewed and pre-approved by the QA Manager.

Documentation of SOP departures and approval decisions are retained by the laboratory as evidence that the departure was authorized. When necessary, approved departures from test method SOPs are noted in the final test report to advise the data user of any ramification to data quality.

4.9.1.2 Authorized Departure from Test Methods (Method Modifications)

When test results are associated to a published reference test method, the laboratory's test method SOP must be consistent with the test method. If the test method is mandated for use by a specific regulatory program such as drinking water or wastewater or a certification or accreditation program, such as TNI/NELAC, the SOP must also comply with or include these requirements. If the procedures in the SOP are modified from the test method, these modifications must be clearly identified in the SOP. The conditions under which the laboratory may establish an SOP that is modified from these reference documents, and what is considered a modification are specified in ENV-SOP-CORQ-0011 *Method Validation and Instrument Verification*.

Modifications that do not meet the requirements of this SOP (ENV-SOP-CORQ-0011) are unauthorized. Client requests to deviate from the test method are handled

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as client requests to depart from the test method SOP since it is the SOP that the laboratory follows when performing work.

4.9.1.3 Stop Work Authority

Stop Work Authority provides laboratory personnel with the responsibility and obligation to stop work when there is a perceived unsafe condition or behavior that may result in an unwanted event.

All laboratory and corporate personnel have the authority to stop work when needed to preserve data integrity or safety of workers.

Once a stop work order has been initiated and the reason for doing so is confirmed valid; laboratory management is responsible for immediate correction and corrective action (see section 4.11) before resumption of work.

4.10 Continuous Improvement

The laboratory's quality management system is designed to achieve continuous improvement through the implementation of the quality policy and objectives outlined in this manual. Information about the laboratory's activities and performance is gained from many sources such as customer feedback, audits, QC, trend analysis, business analytics, management reports, proficiency testing, and management systems review. This information is subsequently used during the laboratory's corrective action (see section 4.11) and preventive action (see section 4.12) processes and during annual review of the management system (see section 4.15) to establish goals and objectives for improvement.

ENV also promotes a continuous improvement culture based on the principles of lean manufacturing. These principles include 3P (Process, Productivity, Performance) and Kaizen. 3P is a platform used by Pace to share best practices and standardization across the network to achieve operational excellence. Kaizen is a team-based process used to implement tools and philosophies of lean to reduce waste and achieve flow with the purpose of improving both external and internal customer satisfaction.

4.11 Corrective Action

Corrective action is a process used to eliminate the cause of a detected nonconformity. It is not the same as a correction. A correction is an action taken to fix an immediate problem. The goal of the corrective action process is to find the underlying cause(s) of the problem and to put in place fixes to prevent the problem from happening again. The corrective action process, referred to as CAPA by ENV, is one of the most effective tools used by the laboratory to prevent nonconforming work, identify risk and opportunity, and improve service to our customers.

The laboratory has two general processes for corrective action:

The process used for actions taken in response to day to day quality control (QC) and acceptance criteria exceptions (nonconformance) that occur during the day to day testing process are called corrections. These events do not usually include formal methods for cause analysis; instead the reason for the failure is investigated through troubleshooting or other measures. Required actions for correction of routine nonconformance is specified in laboratory SOPs. When corrective action is not taken, cannot be taken, or is not successful, test results associated with the nonconforming work are qualified in the final test report. Documentation of the nonconformance and corrective action taken is documented in the analytical record.

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A 7-stage corrective action process is used when there is a problem or departure from the quality management system, technical activities, or when the extent of a single problem has significant impact on data, regulatory compliance or customer needs. These problems are identified through various activities such as but not limited to: quality control trends, internal and external audits, management review, customer feedback, and general observation.

The laboratory's 7 Stage CAPA Process includes:

1) Identification and Containment
2) Evaluation
3) Investigation
4) Cause Analysis
5) Action Plan
6) Implementation
7) Follow Up and Effectiveness Review

The 7 stage CAPA process may be initiated by any employee. Once the process is initiated it is overseen and coordinated by laboratory management. The CAPA process is documented using a software-based workflow process called Qualtrax. The Qualtrax CAPA record includes tracking information, dates, individuals involved, those responsible for action plan implementation and follow-up, and timelines and due dates.

ENV's procedures for corrective action, are specified in corporate SOP ENV-SOP-CORQ-0018, *Procedure for Corrective and Preventive Action.* Additional explanation about certain aspects of the laboratory's corrective action process are outlined in the next three subsections.

4.11.1 Cause Analysis

Cause analysis is the process of investigation used by the laboratory to identify the underlying cause(s) of the problem. Once causal factors are identified, ways to mitigate the causal factors are reviewed and corrective action(s) most likely to eliminate the problem are selected.

The laboratory uses different methods to conduct this analysis. The most common approach is 5-Why, but fishbone diagrams, or even brainstorming may be appropriate depending on the situation. The method used is documented in the CAPA record.

4.11.2 Effectiveness Review

Monitoring corrective actions for effectiveness is an activity shared by laboratory supervisors and quality assurance personnel. Effectiveness means the actions taken were sustainable and appropriate. Sustainable means the change is still in place. Appropriate means the action(s) taken prevented recurrence of the problem since the time corrective action was taken.

The timeframe in which effectiveness review takes place depends on the event and is recorded in the CAPA record with any addition actions that need to be taken.

Corrective action trends are also monitored by laboratory management and used to identify opportunities for preventive action or to gain lessons learned when actions taken were not adequate to solve the problem. See Section 4.12 (Preventive Action) and 4.15 (Management Review) for more information.

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4.11.3 Additional Audits

When non-conformities or other problems cast doubt on compliance with the laboratory's policies, procedures, or compliance to regulatory requirements; the quality manager schedules a special audit of the area of activity in accordance with Section 4.14.1 as soon as possible. These special audits are used to determine the scope of the problem and to provide information for the CAPA process. Additional full-scale audits are done when a serious issue or risk to the laboratory's business is identified.

4.12 Preventive Action

Preventive action is an action taken to eliminate the cause of a potential nonconformity and to achieve improvement. Preventive action is a forward-thinking process designed to prevent problems opposed to reacting to them (corrective action).

Some examples of preventative action include, but are not limited to:

- Scheduled instrument maintenance (Preventative maintenance)
- Addition of Staff and Equipment
- Professional Development Activities
- Implementation of New Technology

The laboratory looks for opportunities for preventive action from a variety of sources including but not limited to: employee idea's, customer feedback, business partners input, trend analysis, business analytics, management reviews, proficiency testing results, lean management events, and risk-benefit analysis.

Laboratory management evaluates the success of preventive actions taken in any given year during annual management review. See Section 4.15 for more information.

4.12.1 Change Management

Preventive actions may sometimes result in significant changes to processes and procedures used by the laboratory. Laboratory management evaluates the risks and benefits of change and includes in its implementation of change process, actions to minimize or eliminate any risk. The types of changes for which risk are considered and managed include: infrastructure change, change in analytical service offerings, certification or accreditation status, instrumentation, LIMS changes, and changes in key personnel.

4.13 Control of Records

A record is a piece of evidence about the past, especially an account of an act or occurrence kept in writing or some other permanent form. Laboratory records document laboratory activities and provide evidence of conformity to the requirements established in the quality management system. These records may be hardcopy or electronic on any form of media.

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4.13.1 General Requirements

4.13.1.1 Procedure

The requirements for control of records is specified in corporate policy ENV-POL-CORQ-0013 *Record Management*. The procedure used to implement the policy is described in laboratory SOP *Document and Record Control* [QA SOP ME001HX].

The policy is established to assure quality and technical records are identified, retained, indexed, and filed to allow for retrieval during the entire retention time frame. During storage, records are kept secure and protected from deterioration. At the end of the retention time, the records are disposed of properly in order to maintain client confidentiality and to protect the interests of the company.

In general, laboratory records fall into three categories: quality, technical, and administrative.

Examples of each are provided in the following table:

Record Type	Includes Records of:
Quality	Document Types listed in SOP ENV-SOP-CORQ-0015 Audits: Internal and External Certificates and Scopes of Accreditation Corrective & Preventive Action Management Review Data Investigations Method Validation Instrument Verification Training Records
Technical	Raw Data Logbooks Certificates of Traceability Analytical Record Test Reports & Project Information Technical Training Records & Demonstration of Capability
Administrative	Personnel Records Finance/Business

4.13.1.2 Record Legibility and Storage

Records are designed to be legible and to clearly identify the information recorded. Manual entries are made in indelible ink; automated entries are in a typeface and of sufficient resolution to be read. The records identify laboratory personnel that performed the activity or entered the information. Records are archived and stored in a way that they are retrievable. Access to archived records is controlled and managed.

For records stored electronically, the capability to restore or retrieve the electronic record is maintained for the entire retention period. Hardcopy records are filed and stored in a suitable environment to protect from damage, deterioration, or loss. Hardcopy records may be scanned to PDF for retention. Scanned records must be checked against the hardcopy to verify the scan is complete and legible.

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Administrative records are kept for a minimum of 5 years and technical and quality records are kept for 10 years unless otherwise specified by the client or regulatory program.

The date from which retention time is calculated depends on the record. In general, the retention time of technical records of original observation and measurement is calculated from the date the record is created. If the technical record is kept in a chronological logbook, the date of retention may be calculated from the date the logbook is archived. The retention time of test reports and project records, which are considered technical records, is calculated from the date the test report was issued. The retention time of quality records is usually calculated from the date the record is archived.

Refer to the record management policy and the laboratory SOP for more information.

4.13.1.3 Security

The laboratory is a secure facility and access to records is restricted to laboratory personnel.

4.13.1.4 Electronic Records

The data systems used to store electronic records is backed up in accordance with laboratory SOP *Laboratory Information Management System* (LIMS) [AD Sop ME00161]. Access to archived records stored electronically is maintained by personnel responsible for management of the electronic system.

4.13.1.5 Electronic Signature Policy

Work done by ENV locations include activities that require the application of a signature. Some of this work product is in electronic format and signatures are applied electronically.

The Electronic Signatures in Global and National Commerce Act (E-Sign Act) clarifies that electronic signatures are legally valid and enforceable under United States law.

ENV's policy for use and application of electronic signatures is specified in corporate policy ENV-POL-CORQ-0014 *Electronic Signature Policy*.

All employees of ENV, including temporary and contract personnel, must sign an Electronic Signature Agreement to acknowledge that they understand and accept that work activities performed by them may be authenticated with application of an electronic signature and that electronic signature has the same validity as a handwritten signature. Their signed agreement also confirms the individual has read and understands the policy and agrees to abide by the requirements for use of electronic signature stated in the policy.

4.13.2 Technical Records

In addition to the requirements specified in subsections 4.13.1.1 through 4.13.1.5, the requirements in the following subsections also apply to technical records.

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4.13.2.1 Description

Technical records are the accumulation of data and information generated from the analytical process. These records may include forms, worksheets, workbooks, checklists, notes, raw data, calibration records, final test reports, and project record. The accumulated record essentially needs to provide adequate detail to historically reconstruct the process and identify the personnel that performed the tasks associated with a test result.

4.13.2.2 Real Time Recordkeeping

Personnel are instructed and expected to always record observations, data, and calculations at the time they are made. Laboratory managers are responsible to assure that data entries, whether made electronically or on hardcopy, are identifiable to the task.

4.13.2.3 Error Correction

Errors in records must never be erased, deleted or made illegible. Use of correction fluid, such as white-out is prohibited. In hardcopy records, the error is corrected by a single strike through the original entry and the new entry recorded alongside or footnoted to allow for readability. Corrections are initialed and dated by the person making the correction. If the correction is not self-explanatory, a reason for the correction is recorded.

For electronic records, equivalent measures of error correction or traceability of changes made is kept. For example, audit trails provide records of change.

Maintenance of proper practices for error correction is monitored through the tiered data review process described in Section 5.9.3. Laboratory records are reviewed throughout the data review process. Individuals performing these reviews flag errors that are not properly corrected and bring these to the attention of the department manager or supervisor of the work area in which the record was generated so that the problem may be addressed and corrected with the individual(s) that did not make the correction properly.

4.14 Audits

The laboratory performs internal systems and technical audits to assess implementation of the QMS and compliance to this manual and to procedures, such as policy, SOP and SWI. Since the processes in this manual are based on the relevant quality system standards and regulatory and accreditation/certification program requirements the laboratory provides services for, the internal audits also assess on-going compliance to these programs.

The laboratory is also audited by external parties such as regulatory agencies, customers, consultants and non-government assessment bodies (NGAB).

Information from internal and external audits is used by laboratory management to address compliance concerns and opportunities where improvement will increase the reliability of data.

Deficiencies, observations and recommendations from audits are managed by the local QM using the laboratory's formal CAPA process. See Section 4.11 for more information.

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4.14.1 Internal Audit

The laboratory's internal audit program is managed by the local QM in accordance with an audit plan established at the beginning of each calendar year. The schedule is prepared to assure that all areas of the laboratory are reviewed over the course of the year. Conformance to the schedule is reported to both laboratory management and corporate quality personnel in a monthly QA report prepared by the quality manager.

Although the local QM creates the audit schedule, it is the shared responsibility of local management to assure the schedule is maintained. Laboratory supervisors cooperate with the quality personnel to provide the auditors with complete access to the work area, personnel, and records needed.

Internal audits are performed by personnel approved by the quality manager. In general, personnel may not audit their own activities unless it can be demonstrated that an effective and objective audit will be carried out. The auditor must be trained, qualified, and familiar enough with the objectives, principles, and procedures of laboratory operations to be able to perform a thorough and effective evaluation.

The laboratory's internal audit program ensures daily practice is consistent with laboratory's SOPs and to verify SOPs are compliant with policy and procedures. Test reports are audited to verify the final product is consistent with customer/project requirements, the work was carried out in accordance with policy and SOPs, the SOP complies with the cited reference method, test results are accurate, and of known and documented quality and properly qualified, when necessary.

Special audits are performed ad hoc to follow up on a specific issue such as a client complaint, negative feedback, concerns of data integrity or ethics, or a problem identified through other audits. Special audits may be scheduled or unscheduled. Unscheduled internal audits are conducted whenever doubts are cast on the laboratory's compliance with regulatory requirements or its own policies and procedures. These unscheduled internal audits may be conducted at any time and may be performed without an announcement to laboratory personnel.

When observations and findings from any audit (internal or external) cast doubt on the validity of the laboratory's testing results, the laboratory takes immediate action to initiate investigate the problem and take corrective action. (Also see 4.11 and 4.16)

The laboratory's internal audit program and auditing procedures are further described in laboratory SOP *Internal Audits* [QA SOP ME0015T].

4.14.1.1 Corporate Compliance Audit

ENV locations are also periodically audited by corporate quality personnel to assess the location's compliance to ENV's quality management program and to evaluate the effectiveness of implementation of the policies and procedures that make up the quality management system. The purpose of the compliance audit is to identify risks and opportunities and to assist laboratory management achieve the goals and objectives of the company's quality program.

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4.15 Management Review

The management team formally reviews the management system of each location under their purview on an annual basis to assess for on-going suitability and effectiveness and to establish goals, objectives, and action plans for the upcoming year.

The process and procedures used to conduct this review are outlined in corporate SOP ENV-SOP-CORQ-0005 *Management Review*.

At a minimum, the following topics are reviewed and discussed:

- The on-going suitability of policies and procedures including EHS and waste management;
- Reports from managerial and supervisory personnel including topics discussed at regular management meetings held throughout the year;
- The outcome of recent internal audits;
- Corrective and preventive actions;
- Assessments by external bodies;
- The results of interlaboratory comparisons or proficiency tests;
- Changes in the volume and type of the work;
- Customer and personnel feedback, including complaints;
- Effectiveness of improvements / preventive actions made since last review;
- Internal and external issues of relevance and risk identification;
- A review of the status of actions from prior management reviews; and
- Other relevant factors, such as quality control activities, resources, and staff training.

The discussion and results of this review are documented in a formal report prepared by laboratory management. This report includes a determination of the effectiveness of the management system and its processes; goals and objectives for improvements in the coming year with timelines and responsibilities, and any other need for change.

Goals and action items from annual management systems review are shared with local employees and with corporate management to highlight focus areas for improvement in addition to areas in which the laboratory has excelled.

4.16 Data Integrity

ENV's procedures for the investigation and response to events that may affect data integrity are described in the corporate SOPs for data inquiries and data recall and corrective and preventive action, however named.

Customers whose data are affected by these events are notified in a timely manner, usually within 30 days after the impact of the problem is understood. Some accreditation programs also require notification to the accreditation body (AB) within a certain timeframe from date of discovery when

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the underlying cause of the issue impacts accreditation. The laboratory follows any program or project specific client notification requirements for notification, when applicable.

5.0 TECHNICAL REQUIREMENTS

5.1 General

Many factors contribute to the correctness and reliability of the technical work performed by the laboratory. These factors fall under these general categories:

- Human Performance
- Facility and Environmental Conditions
- Test Method Performance and Validation
- Measurement Traceability
- Handling of Samples

The impact of each of these factors varies based on the type of work performed. To minimize negative effects from each of these factors, the laboratory accounts for the contribution from each of these categories when developing test method and process (administrative) SOPs, evaluating personnel qualifications and competence, and in the selection of equipment and supplies used.

5.2 Personnel

5.2.1 Personnel Qualifications

The laboratory's program for personnel management is structured to ensure personnel are selected, qualified, and competent to perform the roles and responsibilities of their position based on education, experience, and training.

Qualifications, duties, responsibilities, and authorities of each position are specified in job descriptions maintained by corporate HR (See Section 5.2.4). These job descriptions provide the general basis for the selection of personnel for hire and are used by the laboratory to communicate to personnel the duties, responsibilities, and authorities of their position.

The term "personnel" refers to individuals employed by the laboratory directly as full-time, part-time, or temporary, and individuals employed by the laboratory by contract, such as through an employment agency. The term "personnel" is used interchangeably with the term "employee" throughout this manual. For purposes of this manual, these terms are equivalent.

The personnel management program is structured to establish and maintain records for each of the following:

- Selection of personnel;
- Training of personnel;
- Supervision of personnel;
- Authorization of personnel; and
- Monitoring Competence of personnel.

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5.2.1.1 Competence

Competence is the ability to apply a skill or series of skills to complete a task or series of tasks correctly within defined expectations.

Competence for technical personnel authorized by ENV to provide opinion and interpretation of data to customers also includes the demonstrated ability to:

- Apply knowledge, experience, and skills needed to safely and properly use equipment, instrumentation, and materials required to carry out testing and other work activities in accordance with manufacturer specifications and laboratory SOPs;
- Understand and apply knowledge of general regulatory requirements necessary to achieve regulatory compliance in work product; and
- Understand the significance of departures and deviations from procedure that may occur during the analytical testing process and the capability and initiative to troubleshoot and correct the problem, document the situation and decision-making process, and to properly qualify the data and analytical results.

The laboratory's requirements for the competence of personnel (education, qualification, work experience, technical skills, and responsibilities) are specified in job descriptions created by management and kept by human resources (HR). The job description provides the basis for the selection of personnel for each position.

An employee is considered competent when he/she has completed required training.

The policies and standard operating procedures (SOPs) for the following topics are established by management as minimum required training for all personnel:

- Ethics and Data Integrity
- Quality Manual
- Safety Manual
- Quality Management System
- Technical Process and Procedure relevant to their job tasks
- Successful Demonstration of Capability (DOC) – Analytical Personnel Only

Personnel are initially authorized competent to independently carry out their assigned duties when required training is complete and documented.

Records of required training and qualification provide the record of competence for the individual. Qualification records may include but are not limited to diploma, transcripts, and curriculum vitae (CV).

The on-going competence of each employee is monitored by laboratory management through on-the-job performance. Analytical employees are also required to successfully complete another demonstration of capability for each test method performed on an annual basis.

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5.2.2 Training (Required)

ENV's training requirements are outlined in policies COR-POL-0023 *Mandatory Training Policy,* COR-POL-0004 *Ethics Policy*, and laboratory SOP *Employee Orientation and Training* [QA SOP ME003LN].

5.2.2.1 Required Training

The laboratory's training program includes these elements:

- Scheduling of Required Training
- Execution of Required Training
- Documentation and Tracking of Required Training
- Evaluation of Training Effectiveness

Required training is delivered using various methods that incorporate techniques that appeal to the main learning styles: visual, aural, linguistic, and kinesthetic. Techniques include, on-the-job, instructor-led, self-study, eLearning, and blended.

The employee's direct supervisor is responsible for oversight of completion of the employee's required training and for providing adequate time to the employee to complete training assignments. Both the supervisor and employee are responsible to make sure the employee's training status and training records for required training are current and complete.

The status of completion of required training is monitored by the local QM, who provides the status to the GM at least monthly or more frequently, if necessary, to ensure required training for personnel is complete and up to date.

The following subsections describe the elements of ENV's required training program.

5.2.2.1.1 New Hire Training

New hire training requirements apply to new personnel and to existing employees starting in a new position or different work area.

Required new hire training includes each of the following:

- Ethics and Data Integrity (See 5.2.2.1.3)
- Quality Manual / Quality Management System (See 5.2.2.1.4)
- Safety Manual and any training requirements specified in the manual.
- Policies & SOPs relevant to their job tasks
- Technical personnel that test samples must also successfully complete an initial demonstration of capability (IDOC) for the test methods performed before independently testing customer samples. (See 5.2.2.1.5). Independent testing means handling of client samples without direct supervision of the work activity by the supervisor or a qualified trainer.

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All required training must be current and complete before the employee is authorized to work independently. Until then, the employee's direct supervisor is responsible for review and acceptance of the employee's work product.

5.2.2.1.2 On-Going Training

Personnel receive on-going training in each of the following topics:

- Ethics and Data Integrity (See 5.2.2.1.3)
- Quality Manual / Quality Management System (See 5.2.2.1.4)
- Safety Training
- Changes to Policies & SOPs
- Technical employees that carry out testing must also successfully complete on-going demonstration of capability (CDOC) for all test methods performed on an annual basis. (See 5.2.2.1.5)

Personnel are expected to maintain their DOCs current and complete and to complete training assignments in a timely manner.

5.2.2.1.3 Ethics and Data Integrity Training

Data integrity training is provided to all new personnel and refresher data integrity training is provided to all employees on an annual basis. Personnel are required to acknowledge they understand that any infractions of the laboratory data integrity procedures will result in a detailed investigation that could lead to very serious consequences including immediate termination, debarment, or civil/criminal prosecution.

Completion of data integrity training is documented by employee signature to provide evidence that the employee has participated in training on this topic and understand their obligations related to data integrity.

The following topics and activities are covered:

- Policy for honesty and full disclosure in all analytical reporting;
- Prohibited Practices;
- How and when to report data integrity issues;
- Record keeping. The training emphasizes the importance of proper written documentation on the part of the analyst with respect to those cases where analytical data may be useful, but are in one sense or another partially nonconforming;
- Training Program, including discussion regarding all data integrity procedures;
- Data integrity training documentation;

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- In-depth procedures for data monitoring; and
- Specific examples of breaches of ethical behavior such as improper data manipulations, adjustments of instrument time clocks, and inappropriate changes in concentrations of standards.

All PAS personnel, including contract and temporary, are required to sign an "Attestation of Ethics and Confidentiality" at the time of employment and during annual refresher training. This document clearly identifies inappropriate and questionable behavior. Violations of this document result in serious consequences, including prosecution and termination, if necessary.

Also see SOP-ENV-COR-POL-0004 *Ethics Policy* for more information.

5.2.2.1.4 Management System Document Training

The Quality Manual and ENV manuals, policies, and SOPs are the documents used by regulatory bodies and PAS customers to verify the laboratory's capability, competency, and compliance with their requirements and expectations.

In addition to on-the-job training, employees must have a signed Read and Acknowledgement Statement (R&A) on record for the laboratory quality manual, and the policies and SOPs relating to his/her job responsibilities. This statement, whether signed by the employee electronically or by wet signature, confirms that the employee has received, read, and understands the content of the document, that the employee agrees to follow the document when carrying out their work tasks; and the employee understands that unauthorized change to procedures in an SOP is not allowed except in accordance with the SOP departure policy (See 4. 9.1).

See SOP ENV-CORQ-0016 *Standard Operating Procedures and Standard Work Instructions* for more information.

5.2.2.1.5 Demonstration of Capability (DOC)

Demonstration of capability is based on the employee's capability to achieve acceptable precision and accuracy for each analyte reported by the laboratory for the test method using the laboratory's test method SOP.

Technical employees must complete an initial demonstration of capability (IDOC) prior to independent work on client samples analyzed by the test methods they perform. After successful IDOC, the employee must demonstrate continued proficiency (CDOC) for the test method on an annual basis. If more than a year has passed since the employee last performed the method; then capability must be re-established with an IDOC.

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Records of IDOC and CDOC are kept in the employee's training file.

5.2.2.2 Effectiveness of Training

The results of the performance measures used to identify training needs are the same measures used by the laboratory to measure effectiveness of the training program. Improvement in key performance measures suggest the training program is successful (See 5.2.2.1).

Effectiveness of individual employee training is measured by their demonstrated ability to comprehend the training material and apply knowledge and skills gained to their job task. Measurements include but are not limited to:

- Testing of the employee's knowledge of the quality management system, policies, and technical and administrative procedures through various mechanisms, such as quizzes, observation, and interviews.
- Demonstrated ability to convey information correctly and factually in written and verbal communication to internal and external parties.
- Demonstrated ability to carry out tasks in accordance with SOPs and other work instructions.
- Demonstrated ability to make sound decisions based on guidance and information available.
- Demonstrated initiative to seek help or guidance when the employee is unsure of how to proceed.

5.2.2.3 Supplemental Learning

Supplemental learning objectives are established for newly hired personnel to aid in their development of administrative and technical skills. These learning objectives and materials, referred to as Learning Plans (LP), are created and maintained by ENV's 3P program and managed by the employee's direct supervisor.

In addition to LPs, PAS maintains a wide variety of supplemental learning courses that are made available to all PAS employees for professional development. These learning materials, maintained by PAS's corporate training personnel, are accessed via the company's employee portal, PaceConnect. The learning may be self-initiated based on an employee's interest or may be assigned to the employee at the discretion of management as professional development as part of an employee's annual goals. Supplemental learning courses and learning plan activities are not prerequisites for competency (Section 5.2.1.1) and are not part of the required QMS training specified in Section 5.2.2.1.

5.2.3 Personnel Supervision

Every employee is assigned a direct supervisor, however named, who is responsible for their supervision. Supervision is the set of activities carried out by the supervisor to oversee the progress and productivity of the employees that report to them.

General supervisory responsibilities may include but are not limited to:

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- Hiring Employees
- Training Employees
- Performance Management
- Development, oversight, and execution of personnel training plans
- Monitoring personnel work product to assure the work is carried out in accordance with this quality manual, policies, SOPs, and other documents that support the quality management system.

5.2.4 Job Descriptions

Job Descriptions that define the required education, qualifications, experience, skills, roles and responsibilities, and reporting relationships for each PAS position are established by top management and kept by corporate HR. PAS laboratories use these job descriptions as the source of positions and job titles for the laboratory. The job descriptions apply to employees who are directly employed by PAS, part-time, temporary, technical and administrative and by those that are under contract with PAS through other means.

The job descriptions include the education, expertise, and experience required for the position and the responsibilities and duties, including any supervisory or managerial duties assigned to the position.

5.2.5 Authorization of Technical Personnel

Laboratory management authorizes technical personnel to perform the technical aspects of their position after it has been verified that the employee meets the qualifications for the position, has successfully completed required training (Section 5.2.2.1), and the employee has completed initial demonstrated capability (Section 5.2.2.1.5). After initial authorization, technical personnel are expected to maintain a current and complete training record, demonstrate on-going capability at least annually for each test method performed, and produce reliable results through accurate analysis of certified reference materials, proficiency testing samples, and/or routine quality control samples in order to remain authorized to continue to perform their duties.

Records to support authorization including, education, experience, training, and other evaluations are kept by the laboratory.

5.3 Accommodations and Facilities

5.3.1 Facilities

The laboratory is designed to support the correct performance of procedures and to not adversely affect measurement integrity or safety. Access to the laboratory is controlled by various measures, such as card access, locked doors, main entry. Visitors to the laboratory are required to sign-in and to be escorted by laboratory personnel during their visit. A visitor is any person that is not an employee of the laboratory.

5.3.2 Environmental Conditions

The laboratory is equipped with energy sources, lighting, heating, and ventilation necessary to facilitate proper performance of calibrations and tests. The laboratory ensures that

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housekeeping, electromagnetic interference, humidity, line voltage, temperature, sound and vibration levels are appropriately controlled to ensure the integrity of specific measurement results and to prevent adverse effects on accuracy or increases in the uncertainty of each measurement.

Environmental conditions are monitored, controlled, and recorded as required by the relevant specifications, methods, and procedures. Laboratory operations are stopped if it is discovered that the laboratory's environmental conditions jeopardize the analytical results.

5.3.3 Separation of Incompatible Activities

The layout and infrastructure of each work area including air handling systems, power supplies, and gas supplies of each laboratory work area is specifically designed for the type of analytical activity performed. Effective separation between incompatible work activities is maintained. For example, sample storage, preparation, and chemical handling for volatile organic analysis (VOA) is kept separate from semi-volatile organic (SVOA).

The laboratory separates samples known or suspected to contain high concentration of analytes from other samples to avoid the possibility for cross-contamination. If contamination is found, the source of contamination is investigated and resolved in accordance with laboratory SOPs.

5.3.4 Laboratory Security

Security is maintained by controlled access to the building and by surveillance of work areas by authorized personnel. Access is controlled to each area depending on the required personnel, the sensitivity of the operations performed, and possible safety concerns. The main entrance is kept unlocked during normal business hours for visitors and is continuously monitored by laboratory staff. All visitors must sign a visitor's log, and a staff member must accompany them during the duration of their stay.

5.3.5 Good Housekeeping

The laboratory ensures good housekeeping practices in work areas to maintain a standard of cleanliness necessary for analytical integrity and personnel health and safety. Minimally, these measures include regular cleaning of the work area. Where necessary, areas are periodically monitored to detect and resolve specific contamination and/or possible safety issues.

5.4 Test Methods

5.4.1 General Requirements

The laboratory uses test methods and procedures that are appropriate for the scope of analytical services the laboratory offers.

Instructions on the use and operation of equipment and sample handling, preparation, and analysis of samples are provided in SOPs. The instructions in SOPs may be supplemented with other documents including but not limited to, standard work instructions (SWI), manuals, guides, project documents and reference documents.

These documents are managed using the procedures described in SOP ENV-SOP-CORQ-0015 *Document Management and Control* and SOP ENV-SOP-CORQ-0016 *Standard Operating Procedures and Standard Work Instructions.*

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5.4.2 Method Selection

The test methods and protocols used by the laboratory are selected to meet the needs of the customer, are appropriate for the item tested and intended use of the data, and to conform with regulatory requirements when regulatory requirements apply.

In general, the test methods offered are industry accepted methods published by international, regional, or national standards. The laboratory bases its procedure on the latest approved edition of a method unless it is not appropriate or possible to do so, or unless regulatory requirements specify otherwise.

The laboratory confirms that it can perform the test method and achieve desired outcome before analyzing samples (see section 5.4.5). If there is a change in the published analytical method, then the confirmation is repeated.

When a customer does not specify the test method(s) to be used, the laboratory may suggest test methods that are appropriate for the intended use of the data and the type of samples to be tested. The laboratory will also inform customers when test methods requested are considered inappropriate for their purpose and/or out of date. This discourse takes place during review of analytical service requests (See Section 4.4).

5.4.3 Laboratory Developed Methods

A laboratory developed method is a method developed from scratch (no published source method), a procedure that modifies the chemistry from the source method, or a procedure that exceeds the scope and application of the source method.

Laboratory developed methods must be validated prior to use (see section 5.4.5) and the procedure documented in a test method SOP.

The requirements for non-standard methods (Section 5.4.4) also apply to laboratory developed methods.

5.4.4 Non-standard Methods

A non-standard method is a method that is not published or approved for use by conventional industry standards for the intended purpose of the data. Non-standard methods must be validated prior to use (see section 5.4.5) and the procedure developed and documented in a test method SOP.

At a minimum, the following information must be included in the procedure:

- Title / Identification of Method;
- Scope and Application;
- Description of the type of item to be analyzed;
- Parameters or quantities and ranges to be determined;
- Apparatus and equipment, including technical performance requirements;
- Reference standards and reference materials required;
- Environmental conditions required and any stabilization period needed; and
- Description of the procedure, including:

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- Affixing identification marks, handling, transporting, storing and preparing of items;
- Checks to be made before the work is started;
- Verifying equipment function and, where required, calibrating and/or adjusting the equipment before each use;
- Method of recording the observations and results;
- Any safety measures to be observed;
- Criteria and/or requirements for approval/rejection;
- Data to be recorded and method of analysis and presentation; and
- Uncertainty or procedure for estimating uncertainty.

Use of a non-standard method for testing must be agreed upon with the customer. The agreement, which is retained by the laboratory in the project record, must include the specifications of the client's requirements, the purpose of testing, and their authorization for use of the non-standard method.

5.4.5 Method Validation

5.4.5.1 Validation Description

Validation is the process of conformation and the provision of objective evidence that the stated requirements for a specific method/procedure are fulfilled.

The laboratory's requirements and procedures for method validation are outlined in SOP ENV-SOP-CORQ-0011 *Method Validation and Instrument Verification.*

5.4.5.2 Validation Summary

All test methods offered by the laboratory are validated before use to confirm the procedure works and the data and results achieved meet the goals for the method and repeated when there are major changes to the laboratory procedure.

Results of validation are retained are kept in accordance with method validation SOP and the corporate policy ENV-CORQ-POL-0013 *Record Management*.

5.4.5.3 Validation of Customer Need

The validation process includes review of accuracy, precision, sensitivity, selectivity, linearity, repeatability, reproducibility, robustness, and cross-sensitivity of the procedure against general customer needs to ensure the laboratory's procedure will meet those needs.

The following subsections highlight some of these concepts:

5.4.5.3.1 Accuracy

Accuracy is the degree to which the result of a measurement, calculation, or specification conforms to the correct value or a standard. When the result recovers within a range from the known

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value (control limit); the result generated using the laboratory's test method SOP is considered accurate.

5.4.5.3.2 Precision

Precision refers to the closeness of two or more measurements to each other. It is generally measured by calculating the relative percent difference (RPD) or relative standard deviation (RSD) from results of separate analysis of the same sample. Precision provides information about repeatability, reproducibility, and robustness of the laboratory's procedure.

5.4.5.3.3 Limits of Detection (LOD) (Chemistry)

The LOD is the minimum result which can be reliably discriminated from a blank with a predetermined confidence level. The LOD establishes the limit of method sensitivity and is also known as the detection limit (DL) or the method detection limit (MDL).

Values below the LOD cannot be reliably measured and are not reported by the laboratory unless otherwise specified by regulatory program or test method.

The LOD is established during method validation and after major changes to the analytical system or procedure that affect sensitivity are made.

5.4.5.3.4 Limits of Quantitation (LOQ) and Reporting Limit (RL)

The LOQ is the minimum level, concentration, or quantity of a target analyte that can be reported with a specified degree of confidence. The LOQ is established at the same time as the LOD.

The LLOQ is the value of the lowest calibration standard included in the calibration curve. The LLOQ establishes the lower limit of quantitation.

The LOQ and LLOQ represent quantitative sensitivity of the test method.

- The LOQ must always be equal to or greater than the LLOQ and the LLOQ must always be greater than the LOD.
- Any reported value (detect or non-detect) less than the LLOQ is a qualitative value.

The RL is the value to which the presence of a target analyte is reported as detected or not detected. The RL is project-defined based on project data quality objectives (DQO). In the absence of project specific requirements, the RL is usually set to the LOQ or the LLOQ.

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The laboratory's procedures for LOD/LOQ determination is detailed in laboratory SOP *Method Validation* [QA Policy ME003BF].

The local SOP is based on guidance provided by corporate quality and must comply with 40CFR 136 Appendix B and the TNI Standard.

5.4.5.3.5 Linearity

Linearity is a mathematical concept applied to calibration models that employ multiple points to establish a calibration range used for quantitative analysis. Linearity is measured differently based on the calibration model. In general, if linearity is demonstrated then the slope of the response of standards are sufficiently close to one another. The accuracy of the linear regression and non-linear curves is verified by checking percent error or relative standard error (RSE), which is the process of refitting calibration data back to the model to determine if the results are accurate. For linear curves that use average calibration or response factor, error is measured by relative standard difference (RSD).

Linearity also establishes the range of quantitation for the test method used which directly impacts the sensitivity of the test method and uncertainty in measurement results. As previously noted, the LLOQ establishes the lower limit of quantitation. Similarly, the upper range of linearity establishes the upper limit of quantitation. In general, results outside of this range are considered qualitative values. However, some inorganic methods allow for extension of the linear range above the upper limit of quantitation when accuracy at this value is verified.

Linearity can also be used to establish repeatability, reproducibility, and robustness of the laboratory's test method. When linearity is demonstrated using a specific calibration model during method validation, then use of this same calibration model to achieve linearity on a day to day basis confirms the laboratory's method is repeatable, reproducible, and robust.

5.4.5.3.6 Demonstration of Capability (DOC)

The DOC performed during method validation confirms that the procedure demonstrated acceptable precision and accuracy. The procedure used for DOC for method validation is the same as described in section 5.2.2.1.5 for demonstration of analyst capability.

5.4.6 Measurement Uncertainty

The laboratory provides an estimate of uncertainty in testing measurements when required or on client request. In general, the uncertainty of the test method is reflected in the control limits used to evaluate QC performance. (See 5.9.1.1.9). ISO/IEC supports this concept with language that reads when a well-recognized test method specifies limits to the values of the major source of uncertainty of measurement and specifies the form of presentation of

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calculated results, the laboratory has satisfied the requirements on analytical uncertainty by following the test method and reporting instructions.

When measurement uncertainty cannot be satisfied through control limits, the laboratory will provide a reasonable estimation of uncertainty. A reasonable estimation is based on knowledge of method performance and previous experience. When estimating the analytical uncertainty, all uncertainty components which are of importance in the given situation are taken into account.

5.4.7 Control of Data

The laboratory has policies and processes in place to assure that reported data is free from calculation and transcription errors, that quality control is reviewed and evaluated before data is reported, and to address manual calculation and integration.

5.4.7.1 Calculations, Data Transfer, Reduction and Review

Whenever possible, calculations, transfer of data, and data reduction are performed using validated software programs (See 5.4.7.2).

If manual calculations are performed, the results of these calculations are verified during the data review process outlined in section 5.9.3.

5.4.7.1.1 Manual Integration

The laboratory's policy and procedures for manual integration are provided in corporate SOP ENV-SOP-CORQ-0006 *Manual Integration*.

This SOP includes the conditions under which manual integration is allowed and the requirements for documentation.

Required documentation of manual integration includes:

- complete audit trail to permit reconstruction of before and after results;
- identification of the analyst that performed the integration and the reason the integration was performed; and
- identification of the individual(s) that reviewed the integration and verified the integration was done and documented in compliance with the SOP.

5.4.7.2 Use of Computers and Automated Acquisition

Whenever possible the laboratory uses software and automation for the acquisition, processing, recording, reporting, storage, and/or retrieval of data.

Software applications developed by PAS are validated by corporate IT for adequacy before release for general use. Commercial off the shelf software is considered sufficiently validated when the laboratory follows the manufacturer or vendor's manual for set-up and use. Records of validation are kept by the corporate information technology (IT) group or by the local laboratory, whichever group performed the validation.

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The laboratory's process for the protection of data stored in electronic systems include:

- Individual user names and passwords for Laboratory Information Management Systems (LIMS) and auxiliary systems used to store or process data.
- Employee Training in Computer Security Awareness
- Validation of spreadsheets used for calculations to verify formulas and logic yield correct results and protection of these cells to prevent unauthorized change.
- Operating system and file access safeguards
- Protection from Computer Viruses
- Regular system backup; and testing of retrieved data

The laboratory's process for software development and testing process includes:

- Verification the software application works as expected and is adequate for use and fulfills compliance requirements, such as the need to record date/time of data generation.
- Change control to assure requests for changes are reviewed and approved by management before the change is made.
- Communication channels to assure all staff are aware of changes made.
- Version Control and maintenance of historical records.

These procedures are detailed in laboratory SOPs *Laboratory Information Management System (LIMS)* [AD SOP ME00161] and *Document and Record Control* [QA SOP ME001HX].

5.5 Equipment

5.5.1 Availability of Equipment

The laboratory is furnished with all equipment and instrumentation necessary to correctly perform the tests offered in compliance with the specifications of the test method and to achieve the accuracy and sensitivity required.

5.5.2 Calibration

Equipment and instrumentation are checked prior to use to verify it performs within tolerance for its intended application.

Laboratory management is made aware of the status of equipment and instrumentation and any needs for either on a daily basis. This information is obtained during laboratory walkthroughs (LDM) that are conducted as part of the laboratory's lean program.

5.5.2.1 Support Equipment

The laboratory confirms support equipment is in proper working order and meets the specifications for general laboratory use prior to placement in service with

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intermediate checks thereafter. Equipment that does not meet specifications is removed from service until repaired or replaced. Records of repair and maintenance activities are maintained.

Procedures used to carry out and record these checks are outlined laboratory in SOP *Equipment and Instrumentation* [QA SOP ME002JT].

5.5.2.2 Analytical Instruments

Analytical instruments are checked prior to placement in service in accordance with SOP ENV-SOP-CORQ-0011 *Method Validation and Instrument Verification.* After the initial service date, the calibration of instruments and verification calibration is performed in accordance with local test method SOPs.

The calibration procedures in the test method SOPs comply with the requirements for acceptable calibration practices outlined in corporate policy ENV-POL-CORQ-0005 *Acceptable Calibration Practices*, the reference methods, and any applicable regulatory or program requirements.

5.5.3 Equipment Use and Operation

Equipment is operated and maintained by laboratory personnel that are trained on the test method SOP. Up-to-date instructions and procedures for the use and maintenance of analytical equipment are included in SOPs and/or supplemental documents such as standard work instructions (SWI) or instrument manuals which are made readily accessible in the work area to all laboratory personnel.

5.5.4 Equipment Identification

The laboratory uniquely identifies equipment by serial number or any other unique ID system, when practical. The identifier is included in the equipment list maintained by the quality department.

5.5.5 Equipment Lists and Records

5.5.5.1 Equipment List

The laboratory maintains a master list of equipment that includes information about the equipment including a description, manufacturer, serial number, date placed in service, condition when received, identity, and the current location in the laboratory. The date of purchase is tracked by the procurement record. The equipment list(s) for each location covered by this manual is provided in Appendix E.

5.5.5.2 Equipment Records

In addition to the equipment list, the laboratory maintains records of equipment that include:

- Verification that equipment conforms with specifications.
- Calibration records including dates, results, acceptance criteria, and next calibration dates.
- Maintenance plan and records

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- Records of damage, malfunction, or repair

The laboratory follows an equipment maintenance program designed to optimize performance and to prevent instrument failure which is described in laboratory SOP *Equipment and Instrumentation* [QA SOP ME002JT] or in individual test method SOPs.

The maintenance program includes routine maintenance activities which are performed as recommended by the manufacturer at the frequency recommended and non-routine maintenance, which is performed to resolve a specific problem such as degradation of peak resolution, shift in calibration relationship, loss of sensitivity, or repeat failure of instrument performance checks and quality control samples.

Maintenance is performed by laboratory personnel or by outside service providers.

All maintenance activities performed by laboratory personnel are recorded by the individual(s) that performed the activity at the time the maintenance was performed in an instrument maintenance log.

The maintenance record minimally includes the date of maintenance, the initials of the person(s) performing maintenance, a description of the activity performed, why (when the maintenance is non-routine), and the return to analytical control. When maintenance is performed by an external vendor, the laboratory staples the service record into hardcopy maintenance logs or scans the record for easy retrieval. The laboratory provides unrestricted access to instrument maintenance logs in order to promote good instrument maintenance and recordkeeping practices.

If an instrument must be moved, the laboratory will use safe practices for handling and transport to minimize damage and contamination.

5.5.6 Out of Service Protocol

Equipment that has been subjected to overloading, mishandling, gives suspect results, has been shown to be defective, or is performing outside of specified limits is taken out of service and either removed from the work area or labeled to prevent accidental use until it has been repaired and verified to perform correctly.

When analytical equipment is taken out of service, the laboratory examines the potential effect it may have had on previous analytical results to identify any non-conforming work. (See section 4.9).

5.5.7 Calibration Status

The laboratory labels support equipment to indicate calibration status, whenever practicable or otherwise maintains the calibration status in a visible location in the work area. These procedures are described in laboratory SOP *Equipment and Instrumentation* [QA SOP ME002JT].

The calibration status of analytical instruments is documented in the analytical record. Analysts verify on-going acceptability of calibration status prior to use and with instrument performance check standards. These procedures are described in test method SOPs.

5.5.8 Returned Equipment Checks

When equipment or an instrument is sent out of the laboratory for service, the laboratory ensures that the function and calibration status of the equipment is checked and shown to be

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satisfactory before the equipment is returned to service. These procedures are outlined in SOP ENV-SOP-CORQ-0011 *Method Validation and Instrument Verification.*

5.5.9 Intermediate Equipment Checks

The laboratory performs intermediate checks on equipment to verify the on-going calibration status. For example, most test methods require some form of continuing calibration verification check and these procedures are included in the test method SOP. Periodic checks of support equipment are also performed; see laboratory *Equipment and Instrumentation* [QA SOP ME002JT]. for more information.

5.5.10 Safeguarding Equipment Integrity

The laboratory safeguards equipment integrity using a variety of mechanisms that include but are not limited to:

- Adherence to manufacturer's specification for instrument use so that settings do not exceed manufacturer's recommendation or stress the performance of the equipment.
- Established maintenance programs.
- Transparent maintenance records and unrestricted access to maintenance logs.
- Validation and approval of software before use.
- Audits to confirm instrument settings are consistent with SOPs.
- On-the-job training for safe and proper use of laboratory equipment.

5.6 Measurement Traceability

5.6.1 General

Measurement traceability refers to a property of a measurement result whereby the result can be related to a reference through an unbroken chain of calibration, each contributing to the measurement uncertainty. Traceability requires an established calibration hierarchy of equipment (instruments) used during testing including equipment used for subsidiary measurements. The laboratory assures this equipment is calibrated prior to being put into service and that the reference standard and materials used for calibration are traceable to the international standard of units (SI) or national measurement standard.

When strict traceability to SI units cannot be made, the laboratory establishes traceability with the use of reference standards and equipment obtained from competent suppliers that provide calibration certificates and/or certificates of analysis (COA).

5.6.2 Equipment Correction Factors

When correction factors are used to adjust results the laboratory will assure that results in computer software are also updated. For example, if the direct instrument or reading output must be corrected based on preparation factor or concentration factors, laboratory management will assure the corrected result is also updated in the software.

5.6.3 Specific Requirements

5.6.3.1 Requirements for Calibration Laboratories

The laboratory does not offer calibration services to customers.

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5.6.3.2 Requirements for Testing Laboratories

The laboratory has procedures in place to verify equipment is calibrated prior to being put into service (See 5.5.2) and ensures the reference standard and materials used for calibration are traceable to the international standard of units (SI) or national measurement standard. When strict traceability to SI units cannot be made, the laboratory establishes traceability with the use of reference standards and equipment obtained from competent suppliers that provide calibration certificates and/or certificates of analysis (COA).

5.6.4 Reference Standards and Reference Materials

5.6.4.1 Reference Standards

The laboratory uses reference standards of measurement to verify adequacy of working weights and thermometers. The working weight is the weight(s) used for daily balance calibration checks and the working thermometers are used for temperature measurements on a daily basis.

Intermediate checks of the working reference measurement standards are performed to verify adequacy between calibration from an external calibration laboratory. The measurements from working weights and thermometers are compared to measurements taken by the reference standard which is traceable to SI or a national standard. The reference weights and thermometers are used solely for verification purposes unless the laboratory can prove that daily use does not adversely affect performance of the reference standard.

The laboratory performs intermediate checks of the working weights at least annually.

Working thermometers (glass and digital) are checked against the reference thermometer prior to placement in service to establish a correction factor and then rechecked annually (glass) or quarterly (digital) thereafter.

The calibration of liquid in glass reference thermometers is verified every 5 years and the calibration of digital reference thermometers is verified annually by an ISO/IEC 17025 accredited calibration laboratory or service provider that provides traceability to a national standard.

The calibration of the reference weight(s) is verified every 5 years by an ISO/IEC 17025 accredited calibration laboratory.

If criteria for the intermediate checks or recertification is not acceptable, the impact on previously reported results is evaluated using the process for evaluation of nonconforming work (See 4.9).

See laboratory SOPs *Equipment and Instrumentation* [QA SOP ME002JT] and *Procurement of Laboratory Supplies, Services, and Equipment* [AD SOP ME0015U] for more information about this process.

5.6.4.2 Reference Materials

The laboratory purchases chemical reference materials (also known as stock standards) from vendors that are accredited to ISO 17034 or Guide 34. Purchased

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reference materials must be received with a Certificate of Analysis (COA) where available. If a reference material cannot be purchased with a COA, it must be verified by analysis and comparison to a certified reference material and/or there must be a demonstration of capability for characterization. COA are reviewed for adequacy and retained by the laboratory for future reference.

All prepared standards, reference materials, and reagents are verified to meet the requirements of the test method through routine analyses of quality control samples.

The laboratory procedure for traceability and use of these materials is provided in laboratory SOP *Procurement of Laboratory Supplies, Services, and Equipment* [AD SOP ME0015U] and *Preparation and Documentation of Laboratory Standards and Reagents* [QA SOP ME001HG].

This SOP includes each of the following requirements:

- Procedures for documentation of receipt and tracking. The record of entry includes name of the material, the lot number, receipt date, and expiration date.
- Storage conditions and requirements. Reference materials must be stored separately from samples, extracts, and digestates.
- Requirements to assure that preparations of intermediate or working solutions are recorded and assigned a unique identification number for tracking. Records of preparation include the lot number of the stock standard(s) used, the type and lot number of the solvent, the formulation, date, expiration date, and the preparer's initials. The lot number of the working standards is recorded in the analytical record to provide traceability to the standard preparation record. The preparation record provides traceability to the COA, which is traceable to SI or the national measurement standard.
- A requirement that the expiration dates of prepared standards may not exceed the expiration date of the parent standard. Standards, reference materials, and reagents are not used after their expiration dates unless it is not possible to procure a new standard and the reliability of the expired material is verified and documented by the laboratory using a procedure approved by corporate quality personnel. Otherwise, the expired material is promptly removed from the work area or clearly labeled as acceptable for qualitative/troubleshooting purposes only.
- The second source materials used for verification of instrument calibration are obtained from a different manufacturer or may be a different lot from the same manufacturer.
- Procedures to check reference materials for degradation and replacement of material if degradation or evaporation is suspected.
- Procedures for labeling. At a minimum the container must identify the material, the ID of the material and the expiration date. Original containers should also be labeled with date opened.

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5.6.4.3 Intermediate Checks

Checks to confirm the calibration status of standards and materials are described in laboratory SOPs. These checks include use of second source standards and reference materials reserved only for the purpose of calibration checks.

5.6.4.4 Transport and Storage

The laboratory handles and transports reference standards and materials in a manner that protects the integrity of the materials. Reference standard and material integrity is protected by separation from incompatible materials and/or minimizing exposure to degrading environments or materials. Standards and reference materials are stored separately from samples, extracts, and digestates. All standards are stored according to the manufacturer's recommended conditions. Temperatures colder than the manufacturer's recommendation are acceptable if it does not compromise the integrity of the material (e.g. remains in liquid state and does not freeze solid). In the event a standard is made from more than a single source with different storage conditions, the standard will be stored according to the conditions specified in the analytical method.

See the applicable analytical SOPs for specific reference material storage and transport protocols.

5.7 Sampling

Sampling refers to the field collection of samples and to subsamples taken by the laboratory for analysis from the field collected sample.

Subsampling procedures are included in each test method SOP or a stand-alone SOP to assure the aliquot used for testing is representative of the field collected sample.

The requirements in the following subsections apply when field sampling is performed by the laboratory.

5.7.1 Sampling Plans and SOPs

When the laboratory performs field collection of samples, sampling is carried out in accordance with a written sample plan prepared by the customer or by the laboratory and by relevant sampling SOPs. These documents are made readily accessible at the sampling location. Sampling plans and SOPs are, whenever reasonable, based on appropriate governing methods and address the factors to be controlled to ensure the validity of the analytical results.

5.7.2 Customer Requested Deviations

When the customer requires deviations, additions, or exclusions from the documented laboratory sampling plan and/or procedure, the laboratory records the client's change request in detail with the sampling record, communicates the change to sampling personnel, and includes this information in the final test report.

5.7.3 Recordkeeping

The laboratory assures the sampling record includes the sampling procedure used, any deviations from the procedure, the date and time of sampling, the identification of the sampler, environmental conditions (if relevant), and the sampling location.

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5.8 Sample Management & Handling

5.8.1 Procedures

The laboratory's procedures for sample management and handling are outlined in laboratory SOP *Sample Receiving* [AD SOP ME0013H].

The procedures in these SOPs are established to maintain the safe handling and integrity of samples from transport, storage, to disposal and during all processing steps to maintain client confidentiality, and to protect the interests of PAS and its customers.

5.8.1.1 Chain of Custody

All samples received by the laboratory must be accompanied with a Chain of Custody (COC) record. The COC provides information about the samples collected and submitted for testing and documents the possession of samples from time of collection to receipt by the laboratory.

The COC record must minimally include the following information:

- Client name, address, phone number;
- Project Reference;
- Client Sample Identification (Client ID);
- Date, Time, and Location of Sampling;
- Sampler's Name or Initials;
- Matrix;
- Type of container, and total number collected for each sample;
- Preservatives;
- Analyses Requested;
- Mode of collection;
- Any special instructions; and
- The date and time and signature of each sample transfer from time of collection to receipt in the laboratory. When the COC is transported inside the cooler, independent couriers do not sign the COC, the shipping manifests and/or air bills are the records of possession during transport. The shipping manifest must be retained as part of the COC record and included in the test report when required (See Section 5.10.3).

A complete and legible COC is required. If the laboratory observes that the COC is incomplete or illegible, the client is contacted for resolution. The COC must be filled out in indelible ink. Personnel correct errors by drawing a single line through the initial entry so the entry is not obscured, entering the correct information, and initialing, and dating the change.

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5.8.1.2 Legal Chain of Custody

Legal chain of custody is a chain of custody protocol used for evidentiary or legal purposes. The protocol is followed by the laboratory when requested by customer or where mandated by a regulatory program.

Legal chain of custody (COC) protocol establishes an intact, continuous record of the physical possession*, storage, and disposal of "samples" which includes sample aliquots, and sample extracts/digestates/distillates.

Legal COC records account for all time periods associated with the samples and identifies all individuals who physically handled individual samples. Legal COC begins at the point established by legal authority, which is usually at the time the sample containers are provided by the laboratory for sample collect or when sample collection begins.

*A sample is in someone's custody if:

- It is in one's physical possession;
- It is in one's view after being in one's physical possession;
- It has been in one's physical possession and then locked or sealed so that no one can tamper with it; and/or
- It is kept in a secure area, restricted to authorized personnel only.

Refer to laboratory SOP *Sample Receiving* [AD SOP ME0013H] for more information.

5.8.2 Unique Identification

Each sample is assigned a unique identification number by the laboratory (Lab ID) after the sample has been checked and accepted by the laboratory in accordance with the laboratory's sample acceptance policy (See 5.8.3). The Lab ID is affixed to the sample container using a durable label.

The unique identification of samples also applies to subsamples, and prepared samples, such as extracts, digestates, etc.

The lab ID is linked to the field ID (client ID) in the laboratory's record. Both IDs are linked to the testing activities performed on the sample and the documentation records of the test.

Also see 5.8.4.

5.8.3 Sample Receipt Checks and Sample Acceptance Policy

The laboratory checks the condition and integrity of samples on receipt and compares the labels on the sample containers to the COC record. Any problem or discrepancy is recorded. If the problem impacts the suitability of the sample for analysis or if the documentation is incomplete, the client is notified for resolution. Decisions and instructions from the client are maintained in the project record.

5.8.3.1 Sample Receipt Checks

The following checks are performed:

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- Verification that the COC is complete and legible.
- Verification that each sample's container label includes the client sample ID, the date and time of collection and the preservative in indelible ink.
- The container type and preservative are appropriate for each test requested.
- Adequate volume is received for each test requested.
- Visual inspection for damage or evidence of tampering.
- Visual inspection for presence of headspace in VOA vials. (VOA = volatile organic analysis).
- Thermal Preservation: Generally, for chemical testing methods for which thermal preservation is required, temperature on receipt is acceptable if the measurement is above freezing but <6°C. The requirements for thermal preservation vary based on test method or by regulatory program. For example, for microbiology, temperature on receipt is acceptable if the measurement is <10°C. Refer to the laboratory's SOP for sample receipt for specific requirements. For samples that are hand-delivered to the laboratory immediately after sample collection, there must be evidence that the chilling process began immediately after sample collection and prior to delivery of the samples to the laboratory or service center, such as arrival of the samples on ice.
- Chemical Preservation
- Holding Time: Sample receiving personnel are trained to recognize tests where the holding time is 48 hours or less and to expedite the log-in of these samples. Except for tests with immediate holding times (15 minutes from time of collection or less), when samples are received out of hold, the laboratory will notify the client and request instruction. If the decision is made to proceed with analysis, the final test report will include notation of this instruction.

5.8.3.2 Sample Acceptance Policy

The laboratory maintains a sample acceptance policy in accordance with regulatory guidelines to clearly establish the circumstances in which sample receipt is accepted or rejected.

When receipt does not meet criteria for any one of these conditions, the laboratory must document the noncompliance, contact the customer, and either reject the samples or fully document any decisions to proceed with testing. In accordance with regulatory specifications, test results associated with receipt conditions that do not meet criteria are qualified in the final test report.

All samples received must meet each of the following criteria:

- Be listed on a complete and legible COC;
- Be received in properly labeled sample containers;
- Be received in appropriate containers that identify preservative;

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- The COC must include the date and time of collection for each sample;
- The COC must include the test method requested for each sample;
- Be in appropriate sample containers with clear documentation of the preservatives used;
- Be received within holding time. Any samples received beyond the holding time will not be processed without prior customer approval;
- Have sufficient sample volume to proceed with the analytical testing. If insufficient sample volume is received, analysis will not proceed without customer approval; and
- Be received within appropriate temperature ranges unless program requirements or customer contractual obligations mandate otherwise. The cooler temperature is recorded directly on the COC.

  Samples that are delivered to the laboratory immediately after collection are considered acceptable if there is evidence that the chilling process has been started. For example, by the arrival of the samples on ice. If samples arrive that are not compliant with these temperature requirements, the customer will be notified. The analysis will NOT proceed unless otherwise directed by the customer. If less than 72 hours remain in the hold time for the analysis, the analysis may be started while the customer is contacted to avoid missing the hold time. Data associated with any deviations from the above sample acceptance policy requirements will be appropriately qualified.

5.8.4 Sample Control and Tracking

The samples are controlled and tracked using the Laboratory Information Management System (LIMS). The LIMS stores information about the samples and project. The process of entering information into the LIMS is called log-in and these procedures are described in laboratory SOP *Sample Receiving* [AD SOP ME0013H]. After log-in, a label is generated and affixed to each sample container. Information on this label, such as the lab ID, links the sample container to the information in LIMS.

At a minimum, the following information is entered during log-in:

- Client Name and Contact Information;
- The laboratory ID linked to the client ID;
- Date and time of sample collection;
- Date and time of sample receipt;
- Matrix; and
- Tests Requested.

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5.8.5 Sample Storage, Handling, and Disposal

The laboratory procedures for sample storage, handling and disposal are detailed in laboratory SOPs *Sample Receiving* [AD SOP ME0013H] and *Hazardous and Non-Hazardous Waste Management Plan* [HS SOP ME0012A.

5.8.5.1 Sample Storage

The samples are stored according to method and regulatory requirements as per test method SOPs. Samples are stored away from all standards, reagents, or other potential sources of contamination and stored in a manner that prevents cross contamination. Volatile samples are stored separately from other samples. All sample fractions, extracts, leachates, and other sample preparation products are stored in the same manner as actual samples or as specified by the analytical method.

Refrigerated storage areas are maintained at ≤6°C (but not frozen) and freezer storage areas are maintained at <-10°C, unless otherwise required per method or program. The temperature of each storage area is checked and documented at least once for each day of use. If the temperature falls outside the acceptable limits, then corrective actions are taken and appropriately documented.

The laboratory is operated under controlled access protocols to ensure sample and data integrity. Visitors must register at the front desk and be properly escorted while on-site. Samples are taken to the appropriate storage location immediately after sample receipt and log-in procedures are completed. All sample storage areas have limited access. Samples are removed from storage areas by designated personnel and returned to the storage areas as soon as possible after the required sample quantity has been taken.

5.8.5.2 Sample Retention and Disposal

The procedures used by the laboratory for sample retention and disposal are detailed in laboratory SOP *Hazardous and Non-Hazardous Laboratory Waste Management Plan* [HS SOP ME0012A].

In general, unused sample volume and prepared samples such as extracts, digestates, distillates and leachates (samples) are retained by the laboratory for the timeframe necessary to protect the interests of the laboratory and the customer.

Samples may be stored at ambient temperature when all analyses are complete, the hold time is expired, the report has been delivered, and/or when allowed by the customer or program. Samples requiring storage beyond the minimum sample retention time due to special requests or contractual obligations may be stored at ambient temperature unless the laboratory has a capacity and their presence does not compromise the integrity of other samples.

After this period expires, non-hazardous samples are properly disposed of as non-hazardous waste. The preferred method for disposition of hazardous samples is to return the excess sample to the customer.

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5.9 Assuring the Quality of Test Results

5.9.1 Quality Control (QC) Procedures

The laboratory monitors the validity and reliability of test results using quality control (QC) samples that are prepared and analyzed concurrently with field samples in the same manner as field samples. QC results are always associated to and reported with the field samples they were prepared and analyzed with from the same preparation or analytical batch. See the glossary for definition of preparation and analytical batch.

The results of QC performed during the testing process are used by the laboratory to assure the results of analysis are consistent, comparable, accurate, and/or precise within a specified limit. When the results are not within acceptance criteria or expectations for method performance, correction and corrective action(s) are taken. These actions may include retesting or reporting of data with qualification to alert the end user of the situation.

Other QC measures performed include the use of certified reference materials (see 5.6.4), participation in interlaboratory proficiency testing (see 5.9.1.2), verification that formulae used for reduction of data and calculation of results is accurate (see 5.9.3), on-going monitoring of environmental conditions that could impact test results (see 5.3.2), and evaluation and verification of method selectivity and sensitivity (see 5.4.5).

QC results are also used by the laboratory to monitor performance statistical trends over time and to establish acceptance criteria when no method or regulatory criteria exist. (See 5.9.1.1.9)).

5.9.1.1 Essential QC

Although the general principles of QC for the testing process apply to all testing, the QC protocol used for each test depends on the type of test performed.

QC protocol used by the laboratory to monitor the validity of the test are specified in test method SOPs. The SOP includes QC type, frequency, acceptance criteria, corrective actions, and procedures for reporting of nonconforming work.

These requirements in the SOP conform to the reference method and any applicable regulations or certification and accreditation program requirement for which results of the test are used. When a project requires more stringent QC protocol than specified in the SOP, project specification is followed. When the project requires less stringent QC protocol, the project specification may be followed as an authorized departure from the SOP when the project specifications meet the requirements in the mandated method and any regulatory compliance requirements for which the data will be used.

The following are examples of essential QC for Chemistry:

5.9.1.1.1 Second Source Standard (ICV/QCS)

The second source standard is a standard obtained from a different vendor than the vendor of the standards used for calibration or it may be from a different lot from the same vendor when there are limited vendors that offer the material. It is a positive control used to verify the accuracy of a new calibration relative to the purity of the standards used for calibration. This check is referred to in test

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method and quality system standards as the initial calibration verification (ICV) or quality control sample (QCS). The second source standard is analyzed immediately after the calibration and before analysis of any samples. When the ICV is not within acceptance criteria, a problem with the purity or preparation of the standards may be indicated.

5.9.1.1.2 Continuing Calibration Verification (CCV)

CCV results are used to determine if the analytical response has significantly changed since initial calibration. If the response of the CCV is within criteria, the calibration is considered valid. If not, there is a problem that requires further investigation. Actions taken are technology and method specific.

5.9.1.1.3 Method Blank (MB) / Other Blanks

A method blank is a negative control used to assess for contamination during the prep/analysis process. The MB consists of a clean matrix, similar to the associated samples that is known to be free of analytes of interest. The MB, unless otherwise specified by the test method, is processed with and carried through all preparation and analytical steps as the associated samples.

In general, contamination is suspected when the target analyte is detected in the MB above the reporting limit. Some programs may require evaluation of the MB to ½ the reporting limit or the detection limit. When contamination is evident, the source is investigated, and corrections are taken to reduce or eliminate it. Analytical results associated with MB that does not meet criteria are qualified in the final test report.

Other types of blanks that serve as negative controls in the process may include:

- Trip Blanks (VOA)
- Storage Blanks
- Equipment Blanks
- Field Blanks
- Calibration Blanks
- Cleanup Blanks
- Instrument Blanks

5.9.1.1.4 Laboratory Control Sample (LCS)

The LCS is positive control used to measure the accuracy of process in a blank matrix. The LCS is spiked by the laboratory with a known amount of analyte. The spike is a standard solution that is pre-made or prepared from a certified reference standard. Like the MB, unless otherwise specified in the test method, the LCS is processed with

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and carried through all preparation and analytical steps as the associated samples.

When the percent recovery (%R) of the LCS is within the established control limit, sufficient accuracy has been achieved. If not, the source of the problem is investigated and corrected, and the procedure may be repeated. Analytical results associated with LCS that does not meet criteria are qualified in the final test report.

5.9.1.1.5 Matrix Spike (MS) and Matrix Spike Duplicate (MSD)

Matrix spikes measure the effect the sample matrix has on precision and accuracy of the determinative test method. The MS and MSD are replicates of a client sample that is spiked with known amount of target analyte.

Due to the heterogeneity of matrices even of the same general matrix type, matrix spike results mostly provide information on the effect of the matrix to the client whose sample was used and on samples of the same matrix from the same sampling site. Therefore, MS should be client-specific when the impact of matrix on accuracy and precision is a project data quality objective. When there is not a client-specified MS for any sample in the batch, the laboratory randomly selects a sample from the batch; the sample selected at random is called a "batch" matrix spike.

The MS/MSD results for percent recovery and relative percent difference are checked against control limits. Because the performance of matrix spikes is matrix-dependent, the result of matrix spikes is not used to determine the acceptability of the test.

5.9.1.1.6 Sample Duplicate (SD)

A sample duplicate is a second replicate of sample that is prepared and analyzed in the laboratory along another replicate. The SD is used to measure precision.

The relative percent difference between replicates are evaluated against the method or laboratory derived criteria for relative percent difference (RPD), when this criterion is applicable. If RPD is not met, associated test results are reported with qualification.

5.9.1.1.7 Surrogates

Surrogates are compounds that mimic the chemistry of target analytes but are not expected to occur naturally in real world samples. Surrogates are added to each sample and matrix QC samples (MS, MSD, SD) at known concentration to measure the impact of the matrix on the accuracy of method performance. Surrogates are also added to the positive and negative control samples (MB, LCS) to evaluate performance in a clean matrix, and included in the calibration standards and calibration check standards.

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The percent recovery of surrogates is evaluated against method-specified limits or statistically derived in-house limits. Project-specific limits and/or program-specific limits are used when required. Results with surrogate recovery out of limits in samples are reported with qualification. Samples with surrogate failures can also be re-extracted and/or re-analyzed to confirm that the out-of-control value was caused by the matrix of the sample and not by some other systematic error.

5.9.1.1.8 Internal Standards

Internal Standards are compounds not expected to occur naturally in field samples. They are added to every standard and sample at a known concentration prior to analysis for the purpose of adjusting the response factor used in quantifying target analytes. The laboratory follows specific guidelines for the treatment of internal standard recoveries and further information can be found in the applicable laboratory SOP.

5.9.1.1.9 QC Acceptance Criteria and Control Limits

The QC acceptance criteria are specified in test method SOPs. The criteria in the SOP are based on the requirements in the published test method or regulatory program. When there are no established acceptance criteria, the laboratory develops acceptance criteria in accordance with recognized industry standards.

Some methods and programs require the laboratory to establish control limits for LCS, MS/MSD, and surrogate evaluation using historical data. Laboratory developed limits are referred to as "in-house" control limits. In-house control limits represent ± 3 Standard Deviations (99% confidence level) from the average recovery of at least 20 data points generated using the same preparation and analytical procedure in a similar matrix.

See laboratory SOP *Trend Analysis of Data Using Control Charts* [QA Policy ME001IW] for more information about the procedures used to establish in-house control limits.

5.9.1.2 Proficiency Testing (PT)

The laboratory participates in interlaboratory proficiency testing (PT) studies to measure performance of the test method and to identify or solve analytical problems. PT samples measure laboratory performance through the analysis of unknown samples provided by an external source.

The PT samples are obtained from accredited proficiency testing providers (PTP) and handled as field samples which means they are included in the laboratory's normal analytical processes and do not receive extraordinary attention due to their nature.

The laboratory does not share PT samples with other laboratories, does not communicate with other laboratories regarding current PT sample results during the

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duration of the study, and does not attempt to obtain the assigned value of any PT sample from the PT provider.

The laboratory investigates and implements corrective action whenever PT results are scored unacceptable by the PT provider.

The frequency of PT participation is based on the certification and accreditation requirements held by the laboratory.

5.9.2 QC Corrective Action

When the results of QC are not within acceptance criteria or expectations for method performance, correction and corrective action(s) are taken per the specifications in the test method SOP. These actions may include retesting or reporting of data with qualification to alert the end user of the situation.

5.9.3 Data Review

The laboratory uses a tiered system for data review. The tiered process provides sequential checks to verify data transfer is complete; manual calculations, if performed, are correct, manual integrations are appropriate and documented, calibration and QC requirements are met, appropriate corrective action was taken when required, test results are properly qualified, process and test method SOPs were followed, project specific requirements were met, when applicable, and the test report is complete.

The sequential process includes three tiers referred to as primary review, secondary review, and administrative/completeness review.

Detailed procedures for the data review process are described in laboratory SOP *Data Review* [QA SOP ME003LP]. The general expectations for the tiered review process are described in the following sections:

5.9.3.1 Primary Review

Primary review is performed by the individual that performed the task. All laboratory personnel are responsible for review of their work product to assure it is complete, accurate, documented, and consistent with policy and SOPs.

Checks performed during primary review include but are not limited to:

- Verification that data transfer and acquisition is complete
- Manual calculations, if performed, are documented and accurate
- Manual integrations, if performed, are documented and comply with SOP ENV-SOP-CORQ-006 *Manual Integration*
- Calibration and QC criteria were met, and/or proper correction and corrective actions were taken, and data and test results associated with QC and criteria exceptions are properly qualified
- Work is consistent with SOPs and any other relevant instructional document such as SWI, program requirements, or project QAPP

5.9.3.2 Secondary Review

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Secondary review is performed by a qualified peer or supervisor. Secondary review is essentially a repeat of the checks performed during primary review by another person. In addition to the checks of primary review, secondary review includes chromatography review to check the accuracy of quantitative analyte identification.

5.9.3.3 Completeness Review

Completeness review is an administrative review performed prior to release of the test report to the customer. Completeness review verifies that the final test report is complete and meets project specification. This review also assures that information necessary for the client's interpretation of results are explained in the case narrative or footnoted in the test report.

5.9.3.4 Data Audits

In addition to the 3-tier data review process, test reports may be audited by local quality personnel to verify compliance with SOPs and to check for data integrity, technical accuracy, and regulatory compliance. These audits are not usually done prior to issuance of the test report to the customer. The reports chosen for the data audits are selected at random.

If any problems with the data or test results are found during the data audit, the impact of the nonconforming work is evaluated using the process described in Section 4.9.

Also see Section 4.14 for internal audits.

5.9.4 Calibration Certificates

The laboratory does not perform calibration activities for its customers and calibration certificates are not offered or issued.

5.9.5 Opinions and Interpretations

The laboratory provides objective data and information to its customers of sufficient detail for their interpretation and decision making. Objective data and information are based solely on fact and does not attempt to explain the meaning (interpret) or offer a view or judgement (opinion). Sometimes the customer may request the laboratory provide opinion or interpretation to assist them with their decisions about the data.

When opinions and interpretations are included in the test report, the laboratory will document the basis upon which the opinions and interpretations have been made and clearly identify this content as opinion or interpretation in the test report.

Examples of opinion and interpretation include but are not limited to:

- The laboratory's viewpoint on how a nonconformance impacts the quality of the data or usability of results.
- The laboratory's judgment of fulfillment of contractual requirements.
- Recommendations for how the customer should use the test results and information.
- Suggestions or guidance to the customer for improvement.

When opinions or interpretations are verbally discussed with the customer, the content of these conversations is summarized by the laboratory and kept in the project record.

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5.9.6 Subcontractor Reports

When analytical work has been subcontracted to an organization external to PAS, the test report from the subcontractor is included in its entirety as an amendment to the final test report.

Test results performed by multiple locations within the PAS network may be merged into a single test report. The test report issued clearly identifies the location and address of each network location that performed testing, and which tests they performed. (See 5.10.2)

5.9.7 Electronic Transmission of Results

When test results and/or reports are submitted to the customer through electronic transmission, the procedures established in this manual for confidentiality and protection of data apply.

5.9.8 Format of Test Reports

The test formats offered by the laboratory are designed to accommodate each type of analytical test method carried out by the laboratory and to minimize the possibility of misunderstanding or misuse of analytical results. The format of electronic data deliverables (EDD) follow the specifications for the EDD.

5.9.9 Amendments to Test Reports

Test reports that are revised or amended by the laboratory after date of release of the original final test report to the customer are issued as a new test report that is clearly identified as an amendment or revision and that includes a reference to the originally issued final test report.

The customer is the organization doing business with PAS external to PAS.

Changes made to test results and data before the final test report is issued to the customer are not amendments or revisions, these are corrections to errors found during the laboratory's data verification and review process.

The laboratory's procedure for report amendments and revision are outlined in laboratory SOP *Project Management* [AD SOP ME001HD].

5.10 Reporting

5.10.1 General Requirements

The laboratory reports results of testing in a way that assures the results are clear, and unambiguous. All data and results are reviewed prior to reporting to assure the results reported are accurate and complete.

Test results are summarized in test reports that include all information necessary for the customer's interpretation of the test results. Additional information necessary to clarify the data or disclose nonconformance, exceptions, or deviations that occurred during the analytical process are also reported to the customer in the test report.

The specifications for test reports and EDD are established between the laboratory and the customer at the time the request for analytical services is initiated. The report specifications include the test report format, protocol for the reporting limit (RL), conventions for the reporting of results less than the limit of quantitation (LOQ), and specification for the use of

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project or program specific data qualifiers. Information about review of analytical service requests is provided in Section 4.4.

5.10.2 Test Reports: Required Items

Test Reports are prepared by the laboratory at the end of the testing process. The format of the report depends on the level of reporting requested by the customer. The laboratory offers a variety of standardized test report formats and can provide custom test report formats, when necessary.

The level of detail required in the test report depends on the customer's needs for data verification, validation, and usability assessments that occur after the laboratory releases the test report to the customer. The test report formats offered by the laboratory provide gradient levels of detail to meet the unique needs of each customer. The laboratory project manager helps the customer select the test report format that best meets their needs. When a specific report format or protocol is required for a regulatory or program compliance, the laboratory project manager must ensure the test report selected meets those requirements.

Every test report issued by the laboratory includes each of the following items:

a) Title

b) Name and phone number of a point of contact from the laboratory issuing the report.

c) Name and address of the laboratory where testing was performed. When testing is done at multiple locations within network (IRWO), the report must clearly identify which network laboratory performed each test and must include the physical address of each laboratory.

d) Unique identification of the test report and an identifier on each page of the report to link each page to the test report and clear identification of the end of the report.

e) The name and address of the customer

f) Identification of test methods used

g) Cross reference between client sample identification number (Sample ID) and the laboratory's identification number for the sample (Lab ID) to provide unambiguous identification of samples.

h) The date of receipt of samples, condition of samples on receipt, and identification of any instance where receipt of the samples did not meet sample acceptance criteria.

i) Date and times of sample collection, receipt, preparation, and analysis.

j) Test results and units of measurement, and qualification of results associated with QC criteria exceptions, and identification of reported results outside of the calibration range.

k) All chains of custody (COC) including records of internal transfer between locations within the PAS network.

l) Name, title, signature of the person(s) authorizing release of the test report and date of release.

m) A statement that the results in the test report relate only to the items tested.

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n) Statement that the test report may not be reproduced except in full without written approval from the laboratory.

5.10.3 Test Reports: Supplemental Items

5.10.3.1 Supplemental Requirements

The following items are included in the test report when required or relevant:

a) Shipping manifests / bill of ladings as applicable when common couriers are utilized for shipment of samples,

b) Explanation of departure from test method SOPs including, what the departure was and why it was necessary.

c) Statistical methods used. (Required for Whole Effluent Toxicity)

d) For solid samples, specification that results are reported on a dry weight or wet weight basis.

e) Signed Affidavit, when required by client or regulatory agency.

f) A statement of compliance / non-compliance with requirements or specifications (client, program, or standard) that includes identification of test results that did not meet acceptance criteria.

g) When requested by the client, statement of estimated measurement uncertainty. In general, for environmental testing, estimated uncertainty of measurement is extrapolated from LCS control limits. Control limits incorporate the expected variation of the data derived from the laboratory's procedure. When the control limits are specified by the test method or regulatory program, the control limits represent the expected variation of the test method and/or matrices for which the test method was designed.

h) Opinions and Interpretations

i) If a claim of accreditation/certification is included in the test report, identification of any test methods or analytes for which accreditation/certification is not held by the laboratory if the accrediting body offers accreditation/certification for the test method/analyte. The fields of accreditation/certification vary between agencies and it cannot be presumed that because accreditation/certification is not held that it is offered or required.

j) Certification Information, including certificate number and issuing body.

5.10.3.2 Test Reports: Sampling Information

The following items are included in the test report when samples are collected by the laboratory or when this information is necessary for the interpretation of test results:

a) Date of Sampling.

b) Unambiguous identification of material samples.

c) Location of sampling including diagrams, sketches, or photographs.

d) Reference to the sampling plan and procedures used.

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e) Details of environmental conditions at time of sample that may impact test results.

f) Any standard or other specification for the sampling method or procedure, and deviations, additions to or exclusions from the specification concerned.

6.0 REVISION HISTORY

This Version:

Section	Description of Change
Manual Approval Signatory Page	Added "Quality" before Manual. Updated the list of required signatories and changed job titles to match current job descriptions.
All	Replaced "PAS" with "ENV" to denote that ENV is division of PAS. References to PAS were left in some sections when the policy or procedure applies to all business units in addition to environmental sciences.
All	Corrected spelling, typographical, and format errors.
All	Changed "laboratory" to "location" when requirement applies to non-testing locations, such as service centers.
All	References to "Local QA" was replaced with "Local QM"
1.2.1	Changed frequency of review from every 2 years to annually.
1.2.2	Clarified local management refers to the signatories of the manual.
2.0	Replaced reference "current version" for ISO Standard with 2nd and 3rd Editions and publication dates.
4.1.3	Removed table and inserted reference to Title Page, where locations covered by the manual are listed.
4.1.4.1	Updated content to match current organization structure and job titles maintained by corporate HR.
4.5.1.1	Updated content to match current organization structure and job titles maintained by corporate HR.
4.5.1.2	Added new positions, updated job titles to current HR job titles, removed obsolete job titles.
4.5.2.1	Added timeframe for AB notification for absence of acting TNI Technical Manager.
4.2.2.1	Replaced term "tertiary" with completeness and replaced reference to MintMiner with data surveillance.
4.2.5.1	Updated definition of Guide; Added Guidance
4.5	Changed reference to procurement program to vendor qualification program.
4.6	Added reference to corporate SOP for vendor qualification.
4.7.1	Removed reference to SME, the SME program was not formalized as planned.
4.7.2	Removed reference to monthly; the frequency of management reports is established by the executive leadership team based on need.
4.11	Replaced reference to local SOP with corporate SOP. The corporate SOP replaced all local SOPs for the process. Updated 7 Stage process to match SOP.
4.11.1	Changed reference to root cause analysis to cause analysis.
4.12	Removed 7 step process for preventive action. PA is rolled into the 7 stage process for CAPA.
4.12.1	Removed reference to preventive action SOP – this was a typo for this section.
4.13.1	Added reference to the corporate policy for records.
4.13.1.2	Updated record retention time frame to match policy.

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4.13.1.5	Added this section to incorporate electronic signature policy.
4.14.1	Rewrote paragraph that describes audit program.
4.15	Replaced reference to local SOP with corporate SOP. The corporate SOP replaced all local SOPs for the process.
4.16	Rewrote paragraph for clarity and updated SOP references.
5.2.2	Updated section to match current requirements.
5.2.2.1	Changed "monitor" to "tracks" to clarify expectation.
5.2.2.3	Added this section.
5.2.2.1.3	Changed "attendance sheet" to signature record.
5.4.5.2	Replaced local SOP reference with referral to corporate policy.
5.4.5.3.4	Fixed typographical error related to RL as qualitative/quantitative value. Moved SOP reference from section 5.4.5.3.3 to this section.
5.5.2.2	Updated policy reference.
5.5.9	Replaced typographical error reference to Appendix E with reference to local SOP.
5.6.4.2	Clarified requirements for expired reference materials.
5.8.1.1	Added requirement for locations to retain shipping manifest as COC record.
5.8.3.1	Updated requirements for thermal preservation.
5.9.1.1.1	Updated section to specify the second source standard may also be a different lot from the same manufacturer.
5.9.1.1.3	Added unless otherwise specified by test method exception.
5.9.1.1.4	Added unless otherwise specified by test method exception.
5.9.1.1.9	Clarified that in-house limits are calculated using historical data.
5.10.2	Added requirement that all test reports must include copies of the COCs, including COC for in-network transfer. (CAR to State Audit Deficiency)
Glossary	Added Definition of MRL (CAR to State Audit Deficiency)
Glossary	Changed definition of MintMiner
Appendix 8.1	Added DoD/DOE requirements for LOD/LOQ
Appendix B	Added footnote specification for test methods that are not TNI accredited; applies to TNI accredited labs only.

This document supersedes the following documents:

Document Number	Title	Version
ME0012K	Quality Assurance Management Plant	14

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7.0 APPENDICES

7.1 Appendix A: Certification / Accreditation Listing

The certifications / accreditation lists provided in this manual represent those that were held by the named location on the effective date of this manual. This information is subject to change without notice and must not be considered valid proof of certification or accreditation status. Current certificates are maintained by the local QM and a copy of the certificate is posted to ENV eDMS Portal for access by all ENV employees. External parties should contact the laboratory for the most current information.

7.1.1 PAS-WCOL [Analytical Laboratory]

Authority	ID	Authority	ID
US EPA CLP	Contract EP-W-14-035	**Kentucky DEP – WW**	KY98037
US EPA CLP	Contract 68HERH20D0015	**Massachusetts DEP**	NA [Approval Letter]
Alabama DEM	42000	**Michigan DEQ**	9999
Alaska DEC	20-002	**Michigan EGLE**	9999
Alaska DEC (DW)	SC00162	**New Jersey DEP – NELAP**	SC006
California NELAP	3049	**North Carolina DEQ – WW & GW**	329
Delaware ODW	NA [Approval Letter]	**Ohio EPA**	41251
ANAB ISO/IEC 17025-2017 and DoD ELAP	L2224	**North Carolina DEQ – WW & GW – Charlotte Service Center [Field]**	5639
ANAB ISO/IEC 17025-2017 and DOE ELAP	L2224.01	**South Carolina DHEC – Main Laboratory**	32010001
Florida – NELAP [Primary AB]	E87653	**South Carolina DHEC – Charlotte Service Center [Field]**	99064001
Georgia DPD	C049	**South Carolina DHEC – Greenville Service Center [Field]**	23615001
Illinois EPA	200055	**Virginia DLCS – NELAP**	10541
Kansas DHE	E-10417	**Wisconsin DNR**	NA [Approval Letter]
Kentucky DEP – UST Branch	AI# 103582		

7.1.2 PAS-WCOL [Charlotte Service Center]

Authority	ID	Authority	ID
North Carolina DEQ	5639	**South Carolina DHEC**	99064001

7.1.3 PAS-WCOL [Greenville Service Center]

Authority	ID	Authority	ID
South Carolina DHEC	23615001		

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7.2 Appendix B: Capability Listing

The capabilities listed in this Appendix were held by the location referenced on the effective date of this manual. This information is subject to change without notice. External parties should contact the laboratory for the most current information.

Table Legend:

- Air = Air
- DW = Drinking Water
- NPW = Non-Potable Water
- SCM = Solid and Chemical Materials
- Waste = Non-Aqueous Phase Liquid (NAPL), Oil
- Tissue = Biota and Tissue

7.2.1 PAS-WCOL [Analytical Laboratory]

Parameter	Method	Matrices			
		DW	NPW	SCM	Tissue
Alkalinity as CaCO3 (Titration)	SM 2320 B-2011	X	X		
Alkalinity, Bicarbonate (Calculation)[1]	SM 2320 B-2011		X		
Alkalinity, Carbonate (Calculation) [1]	SM 2320 B-2011		X		
Alkalinity, Hydroxide (Calculation) [1]	SM 2320 B-2011		X		
Ammonia - N by Gas Diffusion	EPA 350.1		X	X	
Anions by IC	EPA 300.0	X	X	X	
Anions by IC	EPA 9056A		X	X	
Bacteria - Biosolids Preparation	EPA/625/R-92/013 APP F		X		
Bacteria - Escherichia coli (MPN)	SM 9223 B-2004	X	X		
Bacteria - Fecal Coliform	COLILERT®-18		X		
Bacteria - Fecal Coliform (MF)	SM 9222 D-2006		X		
Bacteria - Fecal Coliform (MPN) [1]	SM 9221-C E-2006		X		
Bacteria - Heterotrophic[1]	SIMPLATE	X			
Bacteria - Total Coliforms	SM 9223 B-2004	X			
Biochemical Oxygen Demand (BOD)	SM 5210 B-2011	X	X		
Calcium Hardness (Titration) [1]	SM 3500-Ca B-2011	X			
Carbon Dioxide (CO2) (Calculation) [1]	SM 4500-CO2 D-2011		X		
Carbonaceous BOD (CBOD)	SM 5210 B-2011		X		
Chemical Oxygen Demand (COD)	SM 5220 D-2011		X		
Chlorine, Residual (DPD) [1]	SM 4500-CL G-2011	X	X		

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Parameter	Method	Matrices			
		DW	NPW	SCM	Tissue
Color, ADMI Weighted-Ordinate	SM 2120 F-2011		X		
Color, Platinum Cobalt	SM 2120 B-2011	X	X		
Corrosivity (Electrode)	EPA 9040C		X	X	
Corrosivity (Electrode)	EPA 9045C/D			X	
Cyanide, Amenable to Chlorination	EPA 9012B		X		
Cyanide, Amenable to Chlorination	Kelada-01	X			
Cyanide, Amenable to Chlorination	SM 4500-CN^- G-2011		X		
Cyanide, Total	Kelada-01	X	X		
Cyanide, Total (UV/VIS)	EPA 335.4	X	X		
Cyanide, Total (UV/VIS)	EPA 9012B		X	X	
Cyanide, Total (UV/VIS)	SM 4500 CN^- E-2011		X		
Dissolved Oxygen (DO) [1]	HACH 10360		X		
Dissolved Oxygen (DO) [1]	SM 4500-O G-2011		X		
Ferrous Iron (UV/VIS) [1]	SM 3500-Fe B-2011		X		
Hardness, Total (as CaC3) (Calculation) [1]	SM 2340 B-2011		X		
Hardness, Total (as CaCO3) (Titration)	SM 2340 C-2011		X		
Hexavalent Chromium (Discrete Analyzer)	SM 3500-Cr B-2011		X		
Hexavalent chromium (IC)	EPA 218.6		X		
Hexavalent chromium (IC)	EPA 7199		X	X	
Hexavalent chromium (UV/VIS)	EPA 7196A		X	X	
Ignitability (Pensky-Martens)	EPA 1010A/B		X	X	
Metals - Determination in Water Samples and Waste Extracts or Digests by ICP/MS	EPA 6020A/B		X	X	
Metals - Low Level Mercury (CVAA)	EPA 1631E		X		
Metals - Mercury (CVAA)	EPA 245.1	X	X		
Metals - Mercury (CVAA)	EPA 7470A		X	X	
Metals - Mercury (CVAA)	EPA 7471B			X	
Metals - Trace Elements in Aqueous Solutions by ICP/AES	EPA 6010C/D		X	X	
Metals - Trace Elements in Waters and Wastes by ICP/MS	EPA 200.8	X	X		
Metals - Trace Metals by ICP/AES	EPA 200.7	X	X		
Nitrate as N (IC)	EPA 300.0	X	X	X	

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Parameter	Method	Matrices			
		DW	NPW	SCM	Tissue
Nitrate as N (IC)	EPA 9056A		X	X	
Nitrate as N (UV/VIS) - NO3-NO2 Minus NO2	EPA 353.2	X	X	X	
Nitrate-Nitrite (UV/VIS)	EPA 353.2	X	X	X	
Nitrite as N (IC)	EPA 300.0	X	X	X	
Nitrite as N (IC)	EPA 9056A		X	X	
Nitrite as N (UV/VIS)	EPA 353.2	X	X	X	
Oil & Grease	EPA 9071B		X	X	
Oil & Grease (Gravimetric)	EPA 1664B		X		
Orthophosphate (UV/VIS)	EPA 365.1	X	X		
Paint Filter Test (Filtration)	EPA 9095B		X	X	
Per- and Polyfluoroalkyl Substances (PFAS - DAI) by LC/MS/MS	SES SOP ME00217/LC-MS-MS ID		X		
Per- and Polyfluoroalkyl Substances (PFAS - ID) by LC/MS/MS	SES SOP ME00213/LC-MS-MS ID		X	X	
Per- and Polyfluoroalkyl Substances (PFAS) LC/MS/MS	EPA 533	X			
Per- and Polyfluoroalkyl Substances (PFAS) LC/MS/MS	EPA 537	X			
Per- and Polyfluoroalkyl Substances (PFAS) LC/MS/MS	EPA 537.1	X			
Per- and Polyfluoroalkyl Substances (PFAS) LC/MS/MS	PFAS by LCMSMS Compliant with QSM 5.3 Table B-15		X	X	
pH (Electrode)	EPA 150.1	X			
pH (Electrode)	SM 4500-H+ B-2011	X	X		
Phenolics (UV/VIS)	EPA 420.4		X		
Phenolics (UV/VIS)	EPA 9065		X	X	
Phenolics (UV/VIS) [1]	EPA 9066		X	X	
Phosphorus (UV/VIS)	EPA 365.1	X	X	X	
Preparation - Acid Digestion of Aqueous Samples and TCLP/SPLP Extracts for ICP analysis	EPA 3010A		X	X	
Preparation - Acid Digestion of Aqueous Samples for ICP Spectroscopy	EPA 3030C		X		
Preparation - Acid Digestion of Waters for Total or Dissolved Metals	EPA 3005A			X	
Preparation - Alkaline Digestion for Hexavalent Chromium	EPA 3060A		X	X	
Preparation - Bomb	EPA 5050			X	

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Parameter	Method	Matrices			
		DW	NPW	SCM	Tissue
Preparation - Closed-System Purge-and-Trap for Volatile Organics in Soil and Waste Samples	EPA 5035		X	X	
Preparation - Continuous Liquid-Liquid Extraction	EPA 3520C		X		
Preparation - Continuous Liquid-Liquid Extraction, Reduced Volume	EPA 3520C-RVE			X	
Preparation - Florisil Cleanup Procedure	EPA 3620B		X	X	
Preparation - GPC Cleanup Procedure	EPA 3640C		X	X	
Preparation - Metals Digestion, Soils by Hotblock	EPA 3050B			X	
Preparation - Metals Digestion, Waters by Hotblock	EPA 3005A		X		
Preparation - Micro-Dist for Cyanide	Lachat 10-204-00-1-X		X		
Preparation - Microwave Extraction	EPA 3546			X	
Preparation - Preliminary Treatment and Distillation for Cyanide	SM 4500-CN^- B,C-2011		X		
Preparation - Purge-and-Trap for Aqueous Samples	EPA 5030B		X	X	
Preparation - Soil by Sonication	EPA 3550C			X	
Preparation - Solid-Phase Extraction (SPE)	EPA 3535A		X		
Preparation - Soxhlet Extraction	EPA 3540C				X
Preparation - Sulfur Cleanup Procedure	EPA 3660B		X	X	
Preparation - Sulfuric Acid Cleanup Procedure	EPA 3665A		X	X	
Preparation - Synthetic Precipitation Leaching Procedure (SPLP)	EPA 1312		X	X	
Preparation - Toxicity Characteristic Leaching Procedure (TCLP)	EPA 1311		X	X	
Preparation - Waste Dilution	EPA 3580A		X	X	
Preparation - Waste Dilution for Volatile Organics	EPA 3585		X	X	
Reactive Cyanide	Sec. 7.3.3 SW-846		X	X	
Reactive Sulfide	Sec. 7.3.4 SW-846		X	X	
Salinity	SM 2520 B-2011		X		
Sampling for Low-Level Metals	EPA 1669		X		
Solids - Residue-total (TS)	SM 2540 B-2011		X		
Solids - Total Dissolved Solids (TDS)	SM 2540 C-2011	X	X		

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Parameter	Method	Matrices			
		DW	NPW	SCM	Tissue
Solids - Total Fixed and Volatile Solids (TVS) [1]	SM 2540 G-2011		X		
Solids - Total Suspended Solids (TSS)	SM 2540 D-2011		X		
Solids - Volatile Residue (VS) [1]	EPA 160.4		X		
Specific Conductance	SM 2510 B-2011	X	X		
Specific Conductance (Electrode)	EPA 120.1		X		
Sulfide (Titration)	SM 4500 S^{2-} F-2011		X		
Sulfide Preparation	SM 4500-S^{2-} C-2011		X		
Sulfite-SO3 (Titration)	SM 4500 $SO3^{2-}$ B-2011		X		
Surfactants - CTAS[1]	SM 5540 D-2011		X		
Surfactants – MBAS	SM 5540 C-2011		X		
Surfactants - Separation by Sublation	SM 5540 B-2011		X		
SVOC - Base/Neutrals and Acids - GC/MS	EPA 625.1-RVE		X		
SVOC - Base/Neutrals and Acids by GC/MS	EPA 625.1		X		
SVOC - Determination by GC/MS	EPA 8270D				X
SVOC - Determination by GC/MS	EPA 8270C,D,E		X	X	
SVOC - Determination by GC/MS	EPA 8270E SIM		X	X	
SVOC - Diesel Range Organics (DRO) by GC/FID	EPA 8015C		X	X	
SVOC - Diesel Range Organics (DRO) by GC/FID	MADEP-EPH (MA-EPH)		X		
SVOC - EDB & DBCP by GC/ECD	EPA 8011		X	X	
SVOC - EDB, DBCP, TCP by GC/ECD	EPA 504.1	X			
SVOC - Explosives by HPLC[1]	EPA 8330A		X	X	
SVOC - Explosives by HPLC	EPA 8330B		X	X	
SVOC - Extractable Petroleum Hydrocarbons (EPH) Modified by GC/FID	MADEP-EPH		X	X	
SVOC - Herbicides GC	EPA 8151A		X	X	
SVOC - Organochlorine Pesticides & PCBs	EPA 608.3		X		
SVOC - Organochlorine Pesticides & PCBs	EPA 608.3-RVE		X		
SVOC - PCBs	EPA 8081		X		
SVOC - PCBs GC	EPA 8082A		X	X	X
SVOC - Pesticides GC	EPA 8081B		X	X	X
SVOC - Total Petroleum Hydrocarbons (TPH) by GC/FID	MADEP-EPH (MA-EPH)			X	

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Parameter	Method	Matrices			
		DW	NPW	SCM	Tissue
SVOC - Total Petroleum Hydrocarbons (TPH) GC	FL-PRO		X	X	
SVOC - WI-Diesel Range Organics (DRO) by GC/FID	EPA 8015C		X	X	
Temperature	SM 2550 B-2010	X	X		
TKN (UV/VIS)	EPA 351.2		X	X	
TOC (Heated Persulfate - Wet Oxidation)	SM 5310 C-2011		X		
TOC (Titration)	Walkley-Black			X	
TOC (Wet Oxidation)	EPA 9060A		X	X	
Turbidity (Electrode)	EPA 180.1	X	X		
VOC - 1,4-Dioxane by GC/MS	EPA 8260B,C SIM		X	X	
VOC - 1,4-Dioxane by GC/MS	EPA 8260D SIM			X	
VOC - Alcohols and Glycols by Direct Aqueous Injection GC/FID	EPA 8015C		X	X	
VOC - Gasoline Range Organics (GRO) by GC/FID	EPA 8015C		X	X	
VOC - Gasoline Range Organics (GRO) by Purge and Trap GC/PID/FID	MADEP-VPH (MA-VPH)		X	X	
VOC - Methane, Ethane, Ethene by GC/FID	RSK - 175		X		
VOC - Oxyenate Volatile Organics by GC/MS	EPA 8260B-OXY			X	
VOC - Purgeable Organic Compounds by GC/MS	EPA 524.2	X			
VOC - Purgeable Organics by GC/MS	EPA 624.1		X		
VOC - Purgeable Organics by GC/MS[1]	SM 6200 B-2011		X		
VOC - Volatile Petroleum Hydrocarbons (VPH) by Purge & Trap GC/PID/FID	MADEP-VPH		X	X	
VOC - Volatiles by GC/MS	EPA 8260D		X	X	
VOC - WI-Gasoline Range Organics (GRO) by GC/FID[1]	EPA 8015C		X	X	

[1] = Laboratory does not hold TNI Accreditation for this test method.

7.2.2 PAS-WCOL [Charlotte Service Center]

Parameter	Method	Matrices			
		DW	NPW	SCM	Tissue
Chlorine, Residual (DPD)	SM 4500-CL G-2011		X		

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Parameter	Method	Matrices			
		DW	NPW	SCM	Tissue
Specific Conductance (Electrode)	EPA 120.1		X		
Dissolved Oxygen (DO)	SM 4500-O G-2011		X		
Temperature	SM 2550 B-2010		X		
pH (Electrode)	SM 4500-H+ B-2011		X		

7.2.3 PAS-WCOL [Greenville Service Center]

Parameter	Method	Matrices			
		DW	NPW	SCM	Tissue
Chlorine, Residual (DPD)	SM 4500-CL G-2011		X		
Dissolved Oxygen (DO)	SM 4500-O G-2011		X		
Temperature	SM 2550 B-2010		X		
pH (Electrode)	SM 4500-H+ B-2011		X		

7.3 Appendix C: Glossary

This glossary provides common terms and definitions used in the laboratory. **It is not intended to be a complete list of all terms and definitions used.** The definitions have been compiled mostly from the TNI Standard and DoD QSM. Although this information has been reproduced with care, errors cannot be entirely excluded. Definitions for the same term also vary between sources. When the meaning of a term used in a laboratory document is different from this glossary or when the glossary does not include the term, the term and definition is included or defined in context in the laboratory document.

Term	Definition
3P Program	PAS-The continuous improvement program used by PAS that focuses on Process, Productivity, and Performance.
Acceptance Criteria	TNI- Specified limits placed on characteristics of an item, process, or service defined in requirement documents.
Accreditation	TNI- The process by which an agency or organization evaluates and recognizes a laboratory as meeting certain predetermined qualifications or standards, thereby accrediting the laboratory. DoD- Refers to accreditation in accordance with the DoD ELAP.
Accreditation Body (AB)	TNI- The organization having responsibility and accountability for environmental laboratory accreditation and which grants accreditation under this program. DoD- Entities recognized in accordance with the DoD-ELAP that are required to operate in accordance with ISO/IEC 17011, *Conformity assessment: General requirements for accreditation bodies accrediting conformity assessment bodies.* The AB must be a signatory, in good standing, to the International Laboratory Accreditation Cooperation (ILAC) mutual recognition arrangement (MRA) that verifies, by evaluation and peer assessment, that its signatory members are in full compliance with ISO/IEC 17011 and that its accredited laboratories comply with ISO/IEC 17025.
Accuracy	TNI- 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) components that are due to sampling and analytical operations; a data quality indicator.
Activity, Absolute	TNI- Rate of nuclear decay occurring in a body of material, equal to the number of nuclear disintegrations per unit time. NOTE: Activity (absolute) may be expressed in becquerels (Bq), curies (Ci), or disintegrations per minute (dpm), and multiples or submultiples of these units.

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Term	Definition
Activity, Areic	TNI- Quotient of the activity of a body of material and its associated area.
Activity, Massic	TNI- Quotient of the activity of a body of material and its mass; also called specific activity.
Activity, Volumic	TNI- Quotient of the activity of a body of material and its volume; also called activity concentration. NOTE: In this module [TNI Volume 1, Module 6], unless otherwise stated, references to activity shall include absolute activity, areic activity, massic activity, and volumic activity.
Activity Reference Date	TNI- The date (and time, as appropriate to the half-life of the radionuclide) to which a reported activity result is calculated. NOTE: The sample collection date is most frequently used as the Activity Reference Date for environmental measurements, but different programs may specify other points in time for correction of results for decay and ingrowth.
Aliquot	DoD- A discrete, measured, representative portion of a sample taken for analysis.
American Society for Testing and Materials (ASTM)	An international standards organization that develops and publishes voluntary consensus standards for a wide range of materials, products, systems and services.
Analysis	DoD- A combination of sample preparation and instrument determination.
Analysis Code (Acode)	All the set parameters of a test, such as Analytes, Method, Detection Limits and Price.
Analysis Sequence	A compilation of all samples, standards and quality control samples run during a specific amount of time on a particular instrument in the order they are analyzed.
Analyst	TNI- The designated individual who performs the "hands-on" analytical methods and associated techniques and who is the one responsible for applying required laboratory practices and other pertinent quality controls to meet the required level of quality.
Analyte	TNI- A substance, organism, physical parameter, property, or chemical constituent(s) for which an environmental sample is being analyzed. DoD- The specific chemicals or components for which a sample is analyzed; it may be a group of chemicals that belong to the same chemical family and are analyzed together.
Analytical Method	DoD- A formal process that identifies and quantifies the chemical components of interest (target analytes) in a sample.
Analytical Uncertainty	TNI- A subset of Measurement Uncertainty that includes all laboratory activities performed as part of the analysis.
Aliquot	DoD- A discrete, measured, representative portion of a sample taken for analysis.
Annual (or Annually)	Defined by PAS as every 12 months ± 30 days.
Assessment	TNI - The evaluation process used to measure or establish the performance, effectiveness, and conformance of an organization and/or its system to defined criteria (to the standards and requirements of laboratory accreditation). DoD- An all-inclusive term used to denote any of the following: audit, performance evaluation, peer review, inspection, or surveillance conducted on-site.
Atomic Absorption Spectrometer	Instrument used to measure concentration in metals samples.
Atomization	A process in which a sample is converted to free atoms.
Audit	TNI- A systematic and independent examination of facilities, equipment, personnel, training, procedures, record-keeping, data validation, data management, and reporting aspects of a system to determine whether QA/QC and technical activities are being conducted as planned and whether these activities will effectively achieve quality objectives.
Batch	TNI- Environmental samples that are prepared and/or analyzed together with the same process and personnel, using the same lot(s) of reagents. A **preparation batch** is composed of one to 20 environmental samples of the same quality systems matrix, meeting the above-mentioned criteria and with a maximum time between the start of processing of the first and last sample in the batch to be 24 hours or the time-frame specified by the regulatory program. An **analytical batch** is composed of prepared environmental samples (extracts, digestates or concentrates) which are analyzed together as a group. An analytical batch can include prepared samples originating from various quality system matrices and can exceed 20 samples.
Batch, Radiation Measurements (RMB)	TNI- An RMB is composed of 1 to 20 environmental samples that are counted directly without preliminary physical or chemical processing that affects the outcome of the test (e.g., non-destructive gamma spectrometry, alpha/beta counting of air filters, or swipes on gas proportional detectors). The samples in an RMB share similar physical and chemical parameter, and analytical configurations (e.g., analytes, geometry, calibration, and background corrections). The maximum time between the start of processing of the first and last in an RMB is 14 calendar days.

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Term	Definition
Bias	TNI- The systematic or persistent distortion of a measurement process, which causes errors in one direction (i.e., the expected sample measurement is different from the sample's true value).
Blank	TNI and DoD- A sample that has not been exposed to the analyzed sample stream in order to monitor contamination during sampling, transport, storage or analysis. The blank is subjected to the usual analytical and measurement process to establish a zero baseline or background value and is sometimes used to adjust or correct routine analytical results (See Method Blank). DoD- Blank samples are negative control samples, which typically include field blank samples (e.g., trip blank, equipment (rinsate) blank, and temperature blank) and laboratory blank samples (e.g., method blank, reagent blank, instrument blank, calibration blank, and storage blank).
Blind Sample	A sub-sample for analysis with a composition known to the submitter. The analyst/laboratory may know the identity of the sample but not its composition. It is used to test the analyst's or laboratory's proficiency in the execution of the measurement process.
BNA (Base Neutral Acid compounds)	A list of semi-volatile compounds typically analyzed by mass spectrometry methods. Named for the way they can be extracted out of environmental samples in an acidic, basic or neutral environment.
BOD (Biochemical Oxygen Demand)	Chemical procedure for determining how fast biological organisms use up oxygen in a body of water.
Calibration	TNI- A set of operations that establish, under specified conditions, the relationship between values of quantities indicated by a measuring instrument or measuring system, or values represented by a material measure or a reference material, and the corresponding values realized by standards. 1) In calibration of support equipment, the values realized by standards are established through the use of reference standards that are traceable to the International System of Units (SI); 2) In calibration according to test methods, the values realized by standards are typically established through the use of Reference Materials that are either purchased by the laboratory with a certificate of analysis or purity, or prepared by the laboratory using support equipment that has been calibrated or verified to meet specifications.
Calibration Curve	TNI- The mathematical relationship between the known values, such as concentrations, of a series of calibration standards and their instrument response.
Calibration Method	A defined technical procedure for performing a calibration.
Calibration Range	DoD- The range of values (concentrations) between the lowest and highest calibration standards of a multi-level calibration curve. For metals analysis with a single-point calibration, the low-level calibration check standard and the high standard establish the linear calibration range, which lies within the linear dynamic range.
Calibration Standard	TNI- A substance or reference material used for calibration.
Certified Reference Material (CRM)	TNI- Reference material accompanied by a certificate, having a value, measurement uncertainty, and stated metrological traceability chain to a national metrology institute.
Chain of Custody	An unbroken trail of accountability that verifies the physical security of samples, data, and records.
Chain of Custody Form (COC)	TNI- Record that documents the possession of the samples from the time of collection to receipt in the laboratory. This record generally includes: the number and type of containers; the mode of collection, the collector, time of collection; preservation; and requested analyses.
Chemical Oxygen Demand (COD)	A test commonly used to indirectly measure the amount of organic compounds in water.
Client (referred to by ISO as Customer)	Any individual or organization for whom items or services are furnished or work performed in response to defined requirements and expectations.
Code of Federal Regulations (CFR)	A codification of the general and permanent rules published in the Federal Register by agencies of the federal government.
Comparability	An assessment of the confidence with which one data set can be compared to another. Comparable data are produced through the use of standardized procedures and techniques.
Completeness	The percent of valid data obtained from a measurement system compared to the amount of valid data expected under normal conditions. The equation for completeness is: % Completeness = (Valid Data Points/Expected Data Points)*100
Confirmation	TNI- Verification of the identity of a component through the use of an approach with a different scientific principle from the original method. These may include, but are not limited to: second-column confirmation; alternate wavelength; derivatization; mass spectral interpretation; alternative detectors; or additional cleanup procedures. DoD- Includes verification of the identity and quantity of the analyte being measured by another means (e.g., by another determinative method, technology, or column). Additional cleanup procedures alone are not considered confirmation techniques.

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Term	Definition
Conformance	An affirmative indication or judgment that a product or service has met the requirements of the relevant specifications, contract, or regulation; also the state of meeting the requirements.
Congener	A member of a class of related chemical compounds (e.g., PCBs, PCDDs).
Consensus Standard	DoD- A standard established by a group representing a cross-section of a particular industry or trade, or a part thereof.
Continuing Calibration Blank (CCB)	A blank sample used to monitor the cleanliness of an analytical system at a frequency determined by the analytical method.
Continuing Calibration Check Compounds (CCC)	Compounds listed in mass spectrometry methods that are used to evaluate an instrument calibration from the standpoint of the integrity of the system. High variability would suggest leaks or active sites on the instrument column.
Continuing Calibration Verification	DoD- The verification of the initial calibration. Required prior to sample analysis and at periodic intervals. Continuing calibration verification applies to both external and internal standard calibration techniques, as well as to linear and non-linear calibration models.
Continuing Calibration Verification (CCV) Standard	Also referred to as a Calibration Verification Standard (CVS) in some methods, it is a standard used to verify the initial calibration of compounds in an analytical method. CCVs are analyzed at a frequency determined by the analytical method.
Continuous Emission Monitor (CEM)	A flue gas analyzer designed for fixed use in checking for environmental pollutants.
Continuous Improvement Plan (CIP)	The delineation of tasks for a given laboratory department or committee to achieve the goals of that department.
Contract Laboratory Program (CLP)	A national network of EPA personnel, commercial labs, and support contractors whose fundamental mission is to provide data of known and documented quality.
Contract Required Detection Limit (CRDL)	Detection limit that is required for EPA Contract Laboratory Program (CLP) contracts.
Contract Required Quantitation Limit (CRQL)	Quantitation limit (reporting limit) that is required for EPA Contract Laboratory Program (CLP) contracts.
Control Chart	A graphic representation of a series of test results, together with limits within which results are expected when the system is in a state of statistical control (see definition for Control Limit)
Control Limit	A range within which specified measurement results must fall to verify that the analytical system is in control. Control limit exceedances may require corrective action or require investigation and flagging of non-conforming data.
Correction	DoD- Action taken to eliminate a detected non-conformity.
Corrective Action	DoD- The action taken to eliminate the causes of an existing non-conformity, defect, or other undesirable situation in order to prevent recurrence. A root cause analysis may not be necessary in all cases.
Corrective and Preventative Action (CAPA)	The primary management tools for bringing improvements to the quality system, to the management of the quality system's collective processes, and to the products or services delivered which are an output of established systems and processes.
Critical Value	TNI- Value to which a measurement result is compared to make a detection decision (also known as critical level or decision level). NOTE: The Critical Value is designed to give a specified low probability α of false detection in an analyte-free sample, which implies that a result that exceeds the Critical Value, gives high confidence $(1 - \alpha)$ that the radionuclide is actually present in the material analyzed. For radiometric methods, α is often set at 0.05.
Customer	DoD- Any individual or organization for which products or services are furnished or work performed in response to defined requirements and expectations.
Data Integrity	TNI- The condition that exists when data are sound, correct, and complete, and accurately reflect activities and requirements.
Data Quality Objective (DQO)	Systematic strategic planning tool based on the scientific method that identifies and defines the type, quality, and quantity of data needed to satisfy a specified use or end user.
Data Reduction	TNI- The process of transforming the number of data items by arithmetic or statistical calculation, standard curves, and concentration factors, and collating them into a more usable form.
Definitive Data	DoD- Analytical data of known quantity and quality. The levels of data quality on precision and bias meet the requirements for the decision to be made. Data that is suitable for final decision-making.

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Term	Definition
Demonstration of Capability (DOC)	TNI- A procedure to establish the ability of the analyst to generate analytical results of acceptable accuracy and precision. DoD- A procedure to establish the ability of the analyst to generate analytical results by a specific method that meet measurement quality objectives (e.g., for precision and bias).
Department of Defense (DoD)	An executive branch department of the federal government of the United States charged with coordinating and supervising all agencies and functions of the government concerned directly with national security.
Detection Limit (DL)	DoD- The smallest analyte concentration that can be demonstrated to be different than zero or a blank concentration with 99% confidence. At the DL, the false positive rate (Type 1 error) is 1%. A DL may be used as the lowest concentration for reliably reporting a detection of a specific analyte in a specific matrix with a specific method with 99% confidence.
Detection Limit (DL) for Safe Drinking Water Act (SDWA) Compliance	TNI- Laboratories that analyze drinking-water samples for SDWA compliance monitoring must use methods that provide sufficient detection capability to meet the detection limit requirements established in 40 CFR 141. The SDWA DL for radioactivity is defined in 40 CFR Part 141.25.c as the radionuclide concentration, which can be counted with a precision of plus or minus 100% at the 95% confidence level (1.96σ where σ is the standard deviation of the net counting rate of the sample).
Deuterated Monitoring Compounds (DMCs)	DoD- SIM specific surrogates as specified for GC/MS SIM analysis.
Diesel Range Organics (DRO)	A range of compounds that denote all the characteristic compounds that make up diesel fuel (range can be state or program specific).
Digestion	DoD- A process in which a sample is treated (usually in conjunction with heat and acid) to convert the target analytes in the sample to a more easily measured form.
Document Control	The act of ensuring that documents (and revisions thereto) are proposed, reviewed for accuracy, approved for release by authorized personnel, distributed properly and controlled to ensure use of the correct version at the location where the prescribed activity is performed.
Documents	DoD- Written components of the laboratory management system (e.g., policies, procedures, and instructions).
Dry Weight	The weight after drying in an oven at a specified temperature.
Duplicate (also known as Replicate or Laboratory Duplicate)	The analyses or measurements of the variable of interest performed identically on two subsamples of the same sample. The results of duplicate analyses are used to evaluate analytical or measurement precision but not the precision of sampling, preservation or storage internal to the laboratory.
Electron Capture Detector (ECD)	Device used in GC methods to detect compounds that absorb electrons (e.g., PCB compounds).
Electronic Data Deliverable (EDD)	A summary of environmental data (usually in spreadsheet form) which clients request for ease of data review and comparison to historical results.
Eluent	A solvent used to carry the components of a mixture through a stationary phase.
Elute	To extract, specifically, to remove (absorbed material) from an absorbent by means of a solvent.
Elution	A process in which solutes are washed through a stationary phase by movement of a mobile phase.
Environmental Data	DoD- Any measurements or information that describe environmental processes, locations, or conditions; ecological or health effects and consequences; or the performance of environmental technology.
Environmental Monitoring	The process of measuring or collecting environmental data.
Environmental Protection Agency (EPA)	An agency of the federal government of the United States which was created for the purpose of protecting human health and the environment by writing and enforcing regulations based on laws passed by Congress.

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Term	Definition
Environmental Sample	A representative sample of any material (aqueous, non-aqueous, or multimedia) collected from any source for which determination of composition or contamination is requested or required. Environmental samples can generally be classified as follows: • Non Potable Water (Includes surface water, ground water, effluents, water treatment chemicals, and TCLP leachates or other extracts) • Drinking Water - Delivered (treated or untreated) water designated as potable water • Water/Wastewater - Raw source waters for public drinking water supplies, ground waters, municipal influents/effluents, and industrial influents/effluents • Sludge - Municipal sludges and industrial sludges. • Soil - Predominately inorganic matter ranging in classification from sands to clays. • Waste - Aqueous and non-aqueous liquid wastes, chemical solids, and industrial liquid and solid wastes
Equipment Blank	A sample of analyte-free media used to rinse common sampling equipment to check effectiveness of decontamination procedures.
Extracted Internal Standard Analyte	Isotopically labeled analogs of analytes of interest added to all standards, blanks and samples analyzed. Added to samples and batch QC samples prior to the first step of sample extraction and to standards and instrument blanks prior to analysis. Used for isotope dilution methods.
Facility	A distinct location within the company that has unique certifications, personnel and waste disposal identifications.
False Negative	DoD- A result that fails to identify (detect) an analyte or reporting an analyte to be present at or below a level of interest when the analyte is actually above the level of interest.
False Positive	DoD- A result that erroneously identifies (detects) an analyte or reporting an analyte to be present above a level of interest when the analyte is actually present at or below the level of interest.
Field Blank	A blank sample prepared in the field by filling a clean container with reagent water and appropriate preservative, if any, for the specific sampling activity being undertaken.
Field Measurement	Determination of physical, biological, or radiological properties, or chemical constituents that are measured on-site, close in time and sPAS to the matrices being sampled/measured, following accepted test methods. This testing is performed in the field outside of a fixed-laboratory or outside of an enclosed structure that meets the requirements of a mobile laboratory.
Field of Accreditation	TNI- Those matrix, technology/method, and analyte combinations for which the accreditation body offers accreditation.
Field of Proficiency Testing (FoPT)	TNI- Matrix, technology/method, analyte combinations for which the composition, spike concentration ranges and acceptance criteria have been established by the PTPEC.
Finding	TNI- An assessment conclusion referenced to a laboratory accreditation standard and supported by objective evidence that identifies a deviation from a laboratory accreditation standard requirement. DoD- An assessment conclusion that identifies a condition having a significant effect on an item or activity. An assessment finding may be positive, negative, or neutral and is normally accompanied by specific examples of the observed condition. The finding must be linked to a specific requirement (e.g., this standard, ISO requirements, analytical methods, contract specifications, or laboratory management systems requirements).
Flame Atomic Absorption Spectrometer (FAA)	Instrumentation used to measure the concentration of metals in an environmental sample based on the fact that ground state metals absorb light at different wavelengths. Metals in a solution are converted to the atomic state by use of a flame.
Flame Ionization Detector (FID)	A type of gas detector used in GC analysis where samples are passed through a flame which ionizes the sample so that various ions can be measured.
Gas Chromatography (GC)	Instrumentation which utilizes a mobile carrier gas to deliver an environmental sample across a stationary phase with the intent to separate compounds out and measure their retention times.
Gas Chromatograph/ Mass Spectrometry (GC/MS)	In conjunction with a GC, this instrumentation utilizes a mass spectrometer which measures fragments of compounds and determines their identity by their fragmentation patterns (mass spectra).
Gasoline Range Organics (GRO)	A range of compounds that denote all the characteristic compounds that make up gasoline (range can be state or program specific).
Graphite Furnace Atomic Absorption Spectrometry (GFAA)	Instrumentation used to measure the concentration of metals in an environmental sample based on the absorption of light at different wavelengths that are characteristic of different analytes.

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Term	Definition
High Pressure Liquid Chromatography (HPLC)	Instrumentation used to separate, identify and quantitate compounds based on retention times which are dependent on interactions between a mobile phase and a stationary phase.
Holding Time	TNI- The maximum time that can elapse between two specified activities. 40 CFR Part 136- The maximum time that samples may be held prior to preparation and/or analysis as defined by the method and still be considered valid or not compromised. For sample prep purposes, hold times are calculated using the time of the start of the preparation procedure. DoD- The maximum time that may elapse from the time of sampling to the time of preparation or analysis, or from preparation to analysis, as appropriate.
Homogeneity	The degree to which a property or substance is uniformly distributed throughout a sample.
Homologue	One in a series of organic compounds in which each successive member has one more chemical group in its molecule than the next preceding member. For instance, methanol, ethanol, propanol, butanol, etc., form a homologous series.
Improper Actions	DoD- Intentional or unintentional deviations from contract-specified or method-specified analytical practices that have not been authorized by the customer (e.g., DoD or DOE).
Incremental Sampling Method (ISM)	Soil preparation for large volume (1 kg or greater) samples.
In-Depth Data Monitoring	TNI- When used in the context of data integrity activities, a review and evaluation of documentation related to all aspects of the data generation process that includes items such as preparation, equipment, software, calculations, and quality controls. Such monitoring shall determine if the laboratory uses appropriate data handling, data use and data reduction activities to support the laboratory's data integrity policies and procedures.
Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)	Analytical technique used for the detection of trace metals which uses plasma to produce excited atoms that emit radiation of characteristic wavelengths.
Inductively Coupled Plasma- Mass Spectrometry (ICP/MS)	An ICP that is used in conjunction with a mass spectrometer so that the instrument is not only capable of detecting trace amounts of metals and non-metals but is also capable of monitoring isotopic speciation for the ions of choice.
Infrared Spectrometer (IR)	An instrument that uses infrared light to identify compounds of interest.
Initial Calibration (ICAL)	The process of analyzing standards, prepared at specified concentrations, to define the quantitative response relationship of the instrument to the analytes of interest. Initial calibration is performed whenever the results of a calibration verification standard do not conform to the requirements of the method in use or at a frequency specified in the method.
Initial Calibration Blank (ICB)	A blank sample used to monitor the cleanliness of an analytical system at a frequency determined by the analytical method. This blank is specifically run in conjunction with the Initial Calibration Verification (ICV) where applicable.
Initial Calibration Verification (ICV)	DoD- Verifies the initial calibration with a standard obtained or prepared from a source independent of the source of the initial calibration standards to avoid potential bias of the initial calibration.
Injection Internal Standard Analyte	Isotopically labeled analogs of analytes of interest (or similar in physiochemical properties to the target analytes but with a distinct response) to be quantitated. Added to all blanks, standards, samples and batch QC after extraction and prior to analysis.
Instrument Blank	A clean sample (e.g., distilled water) processed through the instrumental steps of the measurement process; used to determine instrument contamination.
Instrument Detection Limits (IDLs)	Limits determined by analyzing a series of reagent blank analyses to obtain a calculated concentration. IDLs are determined by calculating the average of the standard deviations of three runs on three non-consecutive days from the analysis of a reagent blank solution with seven consecutive measurements per day.
Interference, spectral	Occurs when particulate matter from the atomization scatters incident radiation from the source or when the absorption or emission from an interfering species either overlaps or is so close to the analyte wavelength that resolution becomes impossible.
Interference, chemical	Results from the various chemical processes that occur during atomization and later the absorption characteristics of the analyte.
Internal Standard	TNI and DoD- A known amount of standard added to a test portion of a sample as a reference for evaluating and controlling the precision and bias of the applied analytical method.

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Term	Definition
International Organization for Standardization (ISO)	An international standard-setting body composed of representatives from various national standards organizations.
Intermediate Standard Solution	Reference solutions prepared by dilution of the stock solutions with an appropriate solvent.
International System of Units (SI)	The coherent system of units adopted and recommended by the General Conference on Weights and Measures.
Ion Chromatography (IC)	Instrumentation or process that allows the separation of ions and molecules based on the charge properties of the molecules.
Isomer	One of two or more compounds, radicals, or ions that contain the same number of atoms of the same element but differ in structural arrangement and properties. For example, hexane (C6H14) could be n-hexane, 2-methylpentane, 3-methylpentane, 2,3-dimethylbutane, 2,2-dimethylbutane.
Laboratory	A body that calibrates and/or performs testing..
Laboratory Control Sample (LCS)	TNI- (also known as laboratory fortified blank (LFB), spiked blank, or QC check sample): A sample matrix, free from the analytes of interest, spiked with verified known amounts of analytes or a material containing known and verified amounts of analytes and taken through all sample preparation and analytical steps of the procedure unless otherwise noted in a reference method. It is generally used to establish intra-laboratory or analyst-specific precision and bias or to evaluate the performance of all or a portion of the measurement system.
Laboratory Duplicate	Aliquots of a sample taken from the same container under laboratory conditions and processed and analyzed independently.
Laboratory Information Management System (LIMS)	DoD- The entirety of an electronic data system (including hardware and software) that collects, analyzes, stores, and archives electronic records and documents.
Learning Management System (LMS)	A web-based database used by the laboratories to track and document training activities. The system is administered by the corporate training department and each laboratory's learn centers are maintained by a local administrator.
Legal Chain-of-Custody Protocols	TNI- Procedures employed to record the possession of samples from the time of sampling through the retention time specified by the client or program. These procedures are performed at the special request of the client and include the use of a Chain-of-Custody (COC) Form that documents the collection, transport, and receipt of compliance samples by the laboratory. In addition, these protocols document all handling of the samples within the laboratory.
Limit(s) of Detection (LOD)	TNI- The minimum result, which can be reliably discriminated from a blank with predetermined confidence level. DoD- The smallest concentration of a substance that must be present in a sample in order to be detected at the DL with 99% confidence. At the LOD, the false negative rate (Type II error) is 1%. A LOD may be used as the lowest concentration for reliably reporting a non-detect of a specific analyte in a specific matrix with a specific method at 99% confidence.
Limit(s) of Quantitation (LOQ)	TNI- The minimum levels, concentrations, or quantities of a target variable (e.g., target analyte) that can be reported with a specified degree of confidence. DoD- The smallest concentration that produces a quantitative result with known and recorded precision and bias. For DoD/DOE projects, the LOQ shall be set at or above the concentration of the lowest initial calibration standard and within the calibration range.
Linear Dynamic Range	DoD- Concentration range where the instrument provides a linear response.
Liquid chromatography/ tandem mass spectrometry (LC/MS/MS)	Instrumentation that combines the physical separation techniques of liquid chromatography with the mass analysis capabilities of mass spectrometry.
Lot	TNI- A definite amount of material produced during a single manufacturing cycle, and intended to have uniform character and quality.
Management	Those individuals directly responsible and accountable for planning, implementing, and assessing work.
Management System	System to establish policy and objectives and to achieve those objectives.
Manager (however named)	The individual designated as being responsible for the overall operation, all personnel, and the physical plant of the environmental laboratory. A supervisor may report to the manager. In some cases, the supervisor and the manager may be the same individual.
Matrix	TNI- The substrate of a test sample.
Matrix Duplicate	TNI- A replicate matrix prepared in the laboratory and analyzed to obtain a measure of precision.

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Term	Definition
Matrix Spike (MS) (spiked sample or fortified sample)	TNI- A sample prepared, taken through all sample preparation and analytical steps of the procedure unless otherwise noted in a referenced method, by adding a known amount of target analyte to a specified amount of sample for which an independent test result of target analyte concentration is available. Matrix spikes are used, for example, to determine the effect of the matrix on a method's recovery efficiency.
Matrix Spike Duplicate (MSD) (spiked sample or fortified sample duplicate)	TNI- A replicate matrix spike prepared in the laboratory and analyzed to obtain a measure of the precision of the recovery for each analyte.
Measurement Performance Criteria (MPC)	DoD- Criteria that may be general (such as completion of all tests) or specific (such as QC method acceptance limits) that are used by a project to judge whether a laboratory can perform a specified activity to the defined criteria.
Measurement Quality Objective (MQO)	TNI- The analytical data requirements of the data quality objectives are project- or program-specific and can be quantitative or qualitative. MQOs are measurement performance criteria or objectives of the analytical process. Examples of quantitative MQOs include statements of required analyte detectability and the uncertainty of the analytical protocol at a specified radionuclide activity, such as the action level. Examples of qualitative MQOs include statements of the required specificity of the analytical protocol, e.g., the ability to analyze for the radionuclide of interest given the presence of interferences.
Measurement System	TNI- A method, as implemented at a particular laboratory, and which includes the equipment used to perform the test and the operator(s). DoD- A test method, as implemented at a particular laboratory, and which includes the equipment used to perform the sample preparation and test and the operator(s).
Measurement Uncertainty	DoD- An estimate of the error in a measurement often stated as a range of values that contain the true value within a certain confidence level. The uncertainty generally includes many components which may be evaluated from experimental standard deviations based on repeated observations or by standard deviations evaluated from assumed probability distributions based on experience or other information. For DoD/DOE, a laboratory's Analytical Uncertainty (such as use of LCS control limits) can be reported as the minimum uncertainty.
Method	TNI- A body of procedures and techniques for performing an activity (e.g., sampling, chemical analysis, quantification), systematically presented in the order in which they are to be executed.
Method Blank	TNI- A sample of a matrix similar to the batch of associated samples (when available) that is free from the analytes of interest and is processed simultaneously with and under the same conditions as samples through all steps of the analytical procedures, and in which no target analytes or interferences are present at concentrations that impact the analytical results for sample analyses.
Method Detection Limit (MDL)	TNI- One way to establish a Detection Limit; defined as the minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero and is determined from analysis of a sample in a given matrix containing the analyte.
Method of Standard Additions	A set of procedures adding one or more increments of a standard solution to sample aliquots of the same size in order to overcome inherent matrix effects. The procedures encompass the extrapolation back to obtain the sample concentration.
Minimum Detectable Activity (MDA)	TNI- Estimate of the smallest true activity that ensures a specified high confidence, $1 - \beta$, of detection above the Critical Value, and a low probability β of false negatives below the Critical Value. For radiometric methods, β is often set at 0.05. NOTE 1: The MDS is a measure of the detection capability of a measurement process and as such, it is an a priori concept. It may be used in the selection of methods to meet specified MQOs. Laboratories may also calculate a "sample specific" MDA, which indicates how well the measurement process is performing under varying real-world measurement conditions, when sample-specific characteristics (e.g., interferences) may affect the detection capability. However, the MDA must never be used instead of the Critical Value as a detection threshold. NOTE 2: For the purpose of this Standard, the terms MDA and minimum detectable concentration (MDC) are equivalent.
Minimum Reporting Limit (MRL)	the lowest concentration of standard used for calibration – Drinking Water Manual
MintMiner	Commercial software program used to scan large amounts of chromatographic data to monitor for errors or data integrity issues.
Mobile Laboratory	TNI- A portable enclosed structure with necessary and appropriate accommodation and environmental conditions for a laboratory, within which testing is performed by analysts. Examples include but are not limited to trailers, vans, and skid-mounted structures configured to house testing equipment and personnel.

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Term	Definition
National Environmental Laboratory Accreditation Conference (NELAC)	See definition of The NELAC Institute (TNI).
National Institute of Occupational Safety and Health (NIOSH)	National institute charged with the provision of training, consultation and information in the area of occupational safety and health.
National Institute of Standards and Technology (NIST)	TNI- A federal agency of the US Department of Commerce's Technology Administration that is designed as the United States national metrology institute (or NMI).
National Pollutant Discharge Elimination System (NPDES)	A permit program that controls water pollution by regulating point sources that discharge pollutants into U.S. waters.
Negative Control	Measures taken to ensure that a test, its components, or the environment do not cause undesired effects, or produce incorrect test results.
Nitrogen Phosphorus Detector (NPD)	A detector used in GC analyses that utilizes thermal energy to ionize an analyte. With this detector, nitrogen and phosphorus can be selectively detected with a higher sensitivity than carbon.
Nonconformance	An indication or judgment that a product or service has not met the requirement of the relevant specifications, contract, or regulation; also the state of failing to meet the requirements.
Not Detected (ND)	The result reported for a compound when the detected amount of that compound is less than the method reporting limit.
Operator Aid	DoD- A technical posting (such as poster, operating manual, or notepad) that assists workers in performing routine tasks. All operator aids must be controlled documents (i.e., a part of the laboratory management system).
Performance Based Measurement System (PBMS)	An analytical system wherein the data quality needs, mandates or limitations of a program or project are specified and serve as criteria for selecting appropriate test methods to meet those needs in a cost-effective manner.
Physical Parameter	TNI- A measurement of a physical characteristic or property of a sample as distinguished from the concentrations of chemical and biological components.
Photo-ionization Detector (PID)	An ion detector which uses high-energy photons, typically in the ultraviolet range, to break molecules into positively charged ions.
Polychlorinated Biphenyls (PCB)	A class of organic compounds that were used as coolants and insulating fluids for transformers and capacitors. The production of these compounds was banned in the 1970's due to their high toxicity.
Positive Control	Measures taken to ensure that a test and/or its components are working properly and producing correct or expected results from positive test subjects.
Post-Digestion Spike	A sample prepared for metals analyses that has analytes spike added to determine if matrix effects may be a factor in the results.
Power of Hydrogen (pH)	The measure of acidity or alkalinity of a solution.
Practical Quantitation Limit (PQL)	Another term for a method reporting limit. The lowest reportable concentration of a compound based on parameters set up in an analytical method and the laboratory's ability to reproduce those conditions.
Precision	TNI- The degree to which a set of observations or measurements of the same property, obtained under similar conditions, conform to themselves; a data quality indicator. Precision is usually expressed as standard deviation, variance or range, in either absolute or relative terms.
Preservation	TNI and DoD- Any conditions under which a sample must be kept in order to maintain chemical, physical, and/or biological integrity prior to analysis.
Primary Accreditation Body (Primary AB)	TNI- The accreditation body responsible for assessing a laboratory's total quality system, on-site assessment, and PT performance tracking for fields of accreditation.
Procedure	TNI- A specified way to carry out an activity or process. Procedures can be documented or not.
Proficiency Testing (PT)	TNI- A means to evaluate a laboratory's performance under controlled conditions relative to a given set of criteria, through analysis of unknown samples provided by an external source.
Proficiency Testing Program (PT Program)	TNI- The aggregate of providing rigorously controlled and standardized environmental samples to a laboratory for analysis, reporting of results, statistical evaluation of the results and the collective demographics and results summary of all participating laboratories.
Proficiency Testing Provider (PT Provider)	TNI- A person or organization accredited by a TNI-approved Proficiency Testing Provider Accreditor to operate a TNI-compliant PT Program.

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Term	Definition
Proficiency Testing Provider Accreditor (PTPA)	TNI- An organization that is approved by TNI to accredit and monitor the performance of proficiency testing providers.
Proficiency Testing Reporting Limit (PTRL)	TNI- A statistically derived value that represents the lowest acceptable concentration for an analyte in a PT sample, if the analyte is spiked into the PT sample. The PTRLs are specified in the TNI FoPT tables.
Proficiency Testing Sample (PT)	TNI- A sample, the composition of which is unknown to the laboratory, and is provided to test whether the laboratory can produce analytical results within the specified acceptance criteria.
Proficiency Testing (PT) Study	TNI- a) Scheduled PT Study: A single complete sequence of circulation and scoring of PT samples to all participants in a PT program. The study must have the same pre-defined opening and closing dates for all participants; b) Supplemental PT Study: A PT sample that may be from a lot previously released by a PT Provider that meets the requirements for supplemental PT samples given in Volume 3 of this Standard [TNI] but that does not have a pre-determined opening date and closing date.
Proficiency Testing Study Closing Date	TNI- a) Scheduled PT Study: The calendar date by which all participating laboratories must submit analytical results for a PT sample to a PT Provider; b) Supplemental PT Study: The calendar date a laboratory submits the results for a PT sample to the PT Provider.
Proficiency Testing Study Opening Date	TNI- a) Scheduled PT Study: The calendar date that a PT sample is first made available to all participants of the study by a PT Provider; b) Supplemental PT Study: The calendar date the PT Provider ships the sample to a laboratory.
Protocol	TNI- A detailed written procedure for field and/or laboratory operation (e.g., sampling, analysis) that must be strictly followed.
Qualitative Analysis	DoD- Analysis designed to identify the components of a substance or mixture.
Quality Assurance (QA)	TNI- An integrated system of management activities involving planning, implementation, assessment, reporting and quality improvement to ensure that a process, item, or service is of the type and quality needed and expected by the client.
Quality Assurance Manual (QAM)	A document stating the management policies, objectives, principles, organizational structure and authority, responsibilities, accountability, and implementation of an agency, organization, or laboratory, to ensure the quality of its product and the utility of its product to its users.
Quality Assurance Project Plan (QAPP)	A formal document describing the detailed quality control procedures by which the quality requirements defined for the data and decisions pertaining to a specific project are to be achieved.
Quality Control (QC)	TNI- The overall system of technical activities that measures the attributes and performance of a process, item, or service against defined standards to verify that they meet the stated requirements established by the customer; operational techniques and activities that are used to fulfill requirements for quality; also the system of activities and checks used to ensure that measurement systems are maintained within prescribed limits, providing protection against "out of control" conditions and ensuring that the results are of acceptable quality.
Quality Control Sample (QCS)	TNI- A sample used to assess the performance of all or a portion of the measurement system. One of any number of samples, such as Certified Reference Materials, a quality system matrix fortified by spiking, or actual samples fortified by spiking, intended to demonstrate that a measurement system or activity is in control.
Quality Manual	TNI- A document stating the management policies, objectives, principles, organizational structure and authority, responsibilities, accountability, and implementation of an agency, organization, or laboratory, to ensure the quality of its product and the utility of its product to its users.
Quality System	TNI and DoD- A structured and documented management system describing the policies, objectives, principles, organizational authority, responsibilities, accountability, and implementation plan of an organization for ensuring quality in its work processes, products (items), and services. The quality system provides the framework for planning, implementing, and assessing work performed by the organization and for carrying out required quality assurance and quality control activities.

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Term	Definition
Quality System Matrix	TNI and DoD- These matrix definitions shall be used for purposes of batch and quality control requirements and may be different from a field of accreditation matrix: • **Air and Emissions**: Whole gas or vapor samples including those contained in flexible or rigid wall containers and the extracted concentrated analytes of interest from a gas or vapor that are collected with a sorbant tube, impinger solution, filter, or other device • **Aqueous**: Any aqueous sample excluded from the definition of Drinking Water or Saline/Estuarine. Includes surface water, groundwater effluents, and TCLP or other extracts. • **Biological Tissue**: Any sample of a biological origin such as fish tissue, shellfish or plant material. Such samples shall be grouped according to origin. • **Chemical Waste**: A product or by-product of an industrial process that results in a matrix not previously defined. • **Drinking Water**: Any aqueous sample that has been designated a potable or potentially potable water source. • **Non-aqueous liquid**: Any organic liquid with <15% settleable solids • **Saline/Estuarine**: Any aqueous sample from an ocean or estuary, or other salt water source such as the Great Salt Lake. • **Solids**: Includes soils, sediments, sludges, and other matrices with >15% settleable solids.
Quantitation Range	DoD- The range of values (concentrations) in a calibration curve between the LOQ and the highest successively analyzed initial calibration standard used to relate instrument response to analyte concentration. The quantitation range (adjusted for initial sample volume/weight, concentration/dilution and final volume) lies within the calibration range.
Quantitative Analysis	DoD- Analysis designed to determine the amounts or proportions of the components of a substance.
Random Error	The EPA has established that there is a 5% probability that the results obtained for any one analyte will exceed the control limits established for the test due to random error. As the number of compounds measured increases in a given sample, the probability for statistical error also increases.
Raw Data	TNI- The documentation generated during sampling and analysis. This documentation includes, but is not limited to, field notes, electronic data, magnetic tapes, untabulated sample results, QC sample results, print outs of chromatograms, instrument outputs, and handwritten records.
Reagent Blank (method reagent blank)	A sample consisting of reagent(s), without the target analyte or sample matrix, introduced into the analytical procedure at the appropriate point and carried through all subsequent steps to determine the contribution of the reagents and of the involved analytical steps.
Reagent Grade	Analytical reagent (AR) grade, ACS reagent grade, and reagent grade are synonymous terms for reagents that conform to the current specifications of the Committee on Analytical Reagents of the American Chemical Society.
Records	DoD- The output of implementing and following management system documents (e.g., test data in electronic or hand-written forms, files, and logbooks).
Reference Material	TNI- Material or substance one or more of whose property values are sufficiently homogenized and well established to be used for the calibration of an apparatus, the assessment of a measurement method, or for assigning values to materials.
Reference Method	TNI- A published method issued by an organization generally recognized as competent to do so. (When the ISO language refers to a "standard method", that term is equivalent to "reference method"). When a laboratory is required to analyze by a specified method due to a regulatory requirement, the analyte/method combination is recognized as a reference method. If there is no regulatory requirement for the analyte/method combination, the analyte/method combination is recognized as a reference method if it can be analyzed by another reference method of the same matrix and technology.
Reference Standard	TNI- Standard used for the calibration of working measurement standards in a given organization or at a given location.
Relative Percent Difference (RPD)	A measure of precision defined as the difference between two measurements divided by the average concentration of the two measurements.
Reporting Limit (RL)	The level at which method, permit, regulatory and customer-specific objectives are met. The reporting limit may never be lower than the Limit of Detection (i.e., statistically determined MDL). Reporting limits are corrected for sample amounts, including the dry weight of solids, unless otherwise specified. There must be a sufficient buffer between the Reporting Limit and the MDL. DoD- A customer-specified lowest concentration value that meets project requirements for quantitative data with known precision and bias for a specific analyte in a specific matrix.

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Term	Definition
Reporting Limit Verification Standard (RLVS)	A standard analyzed at the reporting limit for an analysis to verify the laboratory's ability to report to that level.
Representativeness	A quality element related to the ability to collect a sample reflecting the characteristics of the part of the environment to be assessed. Sample representativeness is dependent on the sampling techniques specified in the project work plan.
Requirement	Denotes a mandatory specification; often designated by the term "shall".
Retention Time	The time between sample injection and the appearance of a solute peak at the detector.
Revocation	TNI- The total or partial withdrawal of a laboratory's accreditation by an accreditation body.
Sample	Portion of material collected for analysis, identified by a single, unique alphanumeric code. A sample may consist of portions in multiple containers, if a single sample is submitted for multiple or repetitive analysis.
Sample Condition Upon Receipt Form (SCURF)	Form used by sample receiving personnel to document the condition of sample containers upon receipt to the laboratory (used in conjunction with a COC).
Sample Delivery Group (SDG)	A unit within a single project that is used to identify a group of samples for delivery. An SDG is a group of 20 or fewer field samples within a project, received over a period of up to 14 calendar days. Data from all samples in an SDG are reported concurrently.
Sample Receipt Form (SRF)	Letter sent to the client upon login to show the tests requested and pricing.
Sample Tracking	Procedures employed to record the possession of the samples from the time of sampling until analysis, reporting and archiving. These procedures include the use of a chain-of-custody form that documents the collection, transport, and receipt of compliance samples to the laboratory. In addition, access to the laboratory is limited and controlled to protect the integrity of the samples.
Sampling	TNI- Activity related to obtaining a representative sample of the object of conformity assessment, according to a procedure.
Selected Ion Monitoring (SIM)	A mode of analysis in mass spectrometry where the detector is set to scan over a very small mass range, typically one mass unit. The narrower the range, the more sensitive the detector. DoD- Using GC/MS, characteristic ions specific to target compounds are detected and used to quantify in applications where the normal full scan mass spectrometry results in excessive noise.
Selectivity	TNI- The ability to analyze, distinguish, and determine a specific analyte or parameter from another component that may be a potential interferent or that may behave similarly to the target analyte or parameter within the measurement system.
Sensitivity	TNI- The capability of a method or instrument to discriminate between measurement responses representing different levels (e.g., concentrations) of a variable of interest.
Serial Dilution	The stepwise dilution of a substance in a solution.
Shall	Denotes a requirement that is mandatory whenever the criterion for conformance with the specification requires that there be no deviation. This does not prohibit the use of alternative approaches or methods for implementing the specification as long as the requirement is fulfilled.
Should	Denotes a guideline or recommendation whenever noncompliance with the specification is permissible.
Signal-to-Noise Ratio (S/N)	DoD- A measure of signal strength relative to background noise. The average strength of the noise of most measurements is constant and independent of the magnitude of the signal. Thus, as the quantity being measured (producing the signal) decreases in magnitude, S/N decreases and the effect of the noise on the relative error of a measurement increases.
Source Water	TNI- When sampled for drinking water compliance, untreated water from streams, rivers, lakes, or underground aquifers, which is used to supply private and public drinking water supplies.
Spike	A known mass of target analyte added to a blank sample or sub-sample; used to determine recovery efficiency or for other quality control purposes.
Standard (Document)	TNI- The document describing the elements of a laboratory accreditation that has been developed and established within the consensus principles of standard setting and meets the approval requirements of standard adoption organizations procedures and policies.
Standard (Chemical)	Standard samples are comprised of a known amount of standard reference material in the matrix undergoing analysis. A standard reference material is a certified reference material produced by US NIST and characterized for absolute content, independent of analytical test method.
Standard Blank (or Reagent Blank)	A calibration standard consisting of the same solvent/reagent matrix used to prepare the calibration standards without the analytes. It is used to construct the calibration curve by establishing instrument background.

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Term	Definition
Standard Method	A test method issued by an organization generally recognized as competent to do so.
Standard Operating Procedure (SOP)	TNI- A written document that details the method for an operation, analysis, or action with thoroughly prescribed techniques and steps. SOPs are officially approved as the methods for performing certain routine or repetitive tasks.
Standard Reference Material (SRM)	A certified reference material produced by the US NIST or other equivalent organization and characterized for absolute content, independent of analytical method.
Statement of Qualifications (SOQ)	A document that lists information about a company, typically the qualifications of that company to compete on a bid for services.
Stock Standard	A concentrated reference solution containing one or more analytes prepared in the laboratory using an assayed reference compound or purchased from a reputable commercial source.
Storage Blank	DoD- A sample of analyte-free media prepared by the laboratory and retained in the sample storage area of the laboratory. A storage blank is used to record contamination attributable to sample storage at the laboratory.
Supervisor	The individual(s) designated as being responsible for a particular area or category of scientific analysis. This responsibility includes direct day-to-day supervision of technical employees, supply and instrument adequacy and upkeep, quality assurance/quality control duties and ascertaining that technical employees have the required balance of education, training and experience to perform the required analyses.
Surrogate	DoD- A substance with properties that mimic the analyte of interest. It is unlikely to be found in environmental samples and is added to them for quality control purposes.
Suspension	TNI- The temporary removal of a laboratory's accreditation for a defined period of time, which shall not exceed 6 months or the period of accreditation, whichever is longer, in order to allow the laboratory time to correct deficiencies or area of non-conformance with the Standard.
Systems Audit	An on-site inspection or assessment of a laboratory's quality system.
Target Analytes	DoD- Analytes or chemicals of primary concern identified by the customer on a project-specific basis.
Technical Director	Individual(s) who has overall responsibility for the technical operation of the environmental testing laboratory.
Technology	TNI- A specific arrangement of analytical instruments, detection systems, and/or preparation techniques.
Test	A technical operation that consists of the determination of one or more characteristics or performance of a given product, material, equipment, organism, physical phenomenon, process or service according to a specified procedure. The result of a test is normally recorded in a document sometimes called a test report or a test certificate.
Test Method	DoD- A definitive procedure that determines one or more characteristics of a given substance or product.
Test Methods for Evaluating Solid Waste, Physical/ Chemical (SW-846)	EPA Waste's official compendium of analytical and sampling methods that have been evaluated and approved for use in complying with RCRA regulations.
Test Source	TNI- A radioactive source that is tested, such as a sample, calibration standard, or performance check source. A Test Source may also be free of radioactivity, such as a Test Source counted to determine the subtraction background, or a short-term background check.
The NELAC Institute (TNI)	A non-profit organization whose mission is to foster the generation of environmental data of known and documented quality through an open, inclusive, and transparent process that is responsive to the needs of the community. Previously known as NELAC (National Environmental Laboratory Accreditation Conference).
Total Petroleum Hydrocarbons (TPH)	A term used to denote a large family of several hundred chemical compounds that originate from crude oil. Compounds may include gasoline components, jet fuel, volatile organics, etc.
Toxicity Characteristic Leaching Procedure (TCLP)	A solid sample extraction method for chemical analysis employed as an analytical method to simulate leaching of compounds through a landfill.
Traceability	TNI- The ability to trace the history, application, or location of an entity by means of recorded identifications. In a calibration sense, traceability relates measuring equipment to national or international standards, primary standards, basic physical conditions or properties, or reference materials. In a data collection sense, it relates calculations and data generated throughout the project back to the requirements for the quality of the project.
Training Document	A training resource that provides detailed instructions to execute a specific method or job function.

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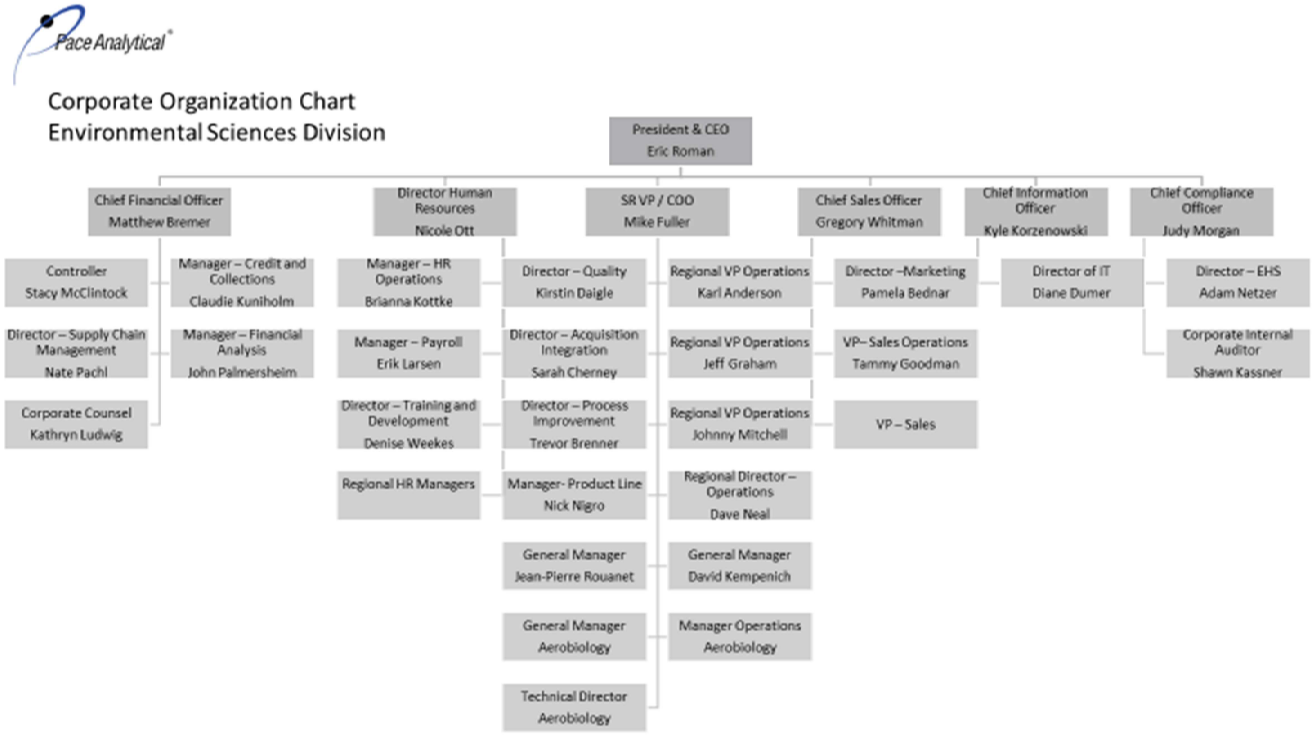
Term	Definition
Trip Blank	This blank sample is used to detect sample contamination from the container and preservative during transport and storage of the sample. A cleaned sample container is filled with laboratory reagent water and the blank is stored, shipped, and analyzed with its associated samples.
Tuning	A check and/or adjustment of instrument performance for mass spectrometry as required by the method.
Ultraviolet Spectrophotometer (UV)	Instrument routinely used in quantitative determination of solutions of transition metal ions and highly conjugated organic compounds.
Uncertainty, Counting	TNI- The component of Measurement Uncertainty attributable to the random nature of radioactive decay and radiation counting (often estimated as the square root of observed counts (MARLAP). Older references sometimes refer to this parameter as Error, Counting Error or Count Error (c.f., Total Uncertainty).
Uncertainty, Expanded	TNI- The product of the Standard Uncertainty and a coverage factor, k, which is chosen to produce an interval about the result that has a high probability of containing the value of the measurand (c.f., Standard Uncertainty). NOTE: Radiochemical results are generally reported in association with the Total Uncertainty. Either if these estimates of uncertainty can be reported as the Standard Uncertainty (one-sigma) or as an Expanded Uncertainty (k-sigma, where k > 1).
Uncertainty, Measurement	TNI- Parameter associated with the result of a measurement that characterizes the dispersion of the values that could reasonably be attributed to the measurand.
Uncertainty, Standard	TNI- An estimate of the Measurement Uncertainty expressed as a standard deviation (c.f., Expanded Uncertainty).
Uncertainty, Total	TNI- An estimate of the Measurement Uncertainty that accounts for contributions from all significant sources of uncertainty associated with the analytical preparation and measurement of a sample. Such estimates are also commonly referred to as Combined Standard Uncertainty or Total Propagated Uncertainty, and in some older references as the Total Propagated Error, among other similar items (c.f., Counting Uncertainty).
Unethical actions	DoD- Deliberate falsification of analytical or quality control results where failed method or contractual requirements are made to appear acceptable.
United States Department of Agriculture (USDA)	A department of the federal government that provides leadership on food, agriculture, natural resources, rural development, nutrition and related issues based on public policy, the best available science, and effective management.
United States Geological Survey (USGS)	Program of the federal government that develops new methods and tools to supply timely, relevant, and useful information about the Earth and its processes.
Unregulated Contaminant Monitoring Rule (UCMR)	EPA program to monitor unregulated contaminants in drinking water.
Validation	DoD- The confirmation by examination and provision of objective evidence that the particular requirements for a specific intended use are fulfilled.
Verification	TNI- Confirmation by examination and objective evidence that specified requirements have been met. In connection with the management of measuring equipment, verification provides a means for checking that the deviations between values indicated by a measuring instrument and corresponding known values of a measured quantity are consistently smaller than the maximum allowable error defined in a standard, regulation or specification peculiar to the management of the measuring equipment.
Voluntary Action Program (VAP)	A program of the Ohio EPA that gives individuals a way to investigate possible environmental contamination, clean it up if necessary and receive a promise from the State of Ohio that no more cleanup is needed.
Whole Effluent Toxicity (WET)	The aggregate toxic effect to aquatic organisms from all pollutants contained in a facility's wastewater (effluent).

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7.4 Appendix D: Organization Chart(s)

7.4.1 Corporate Organization Chart

Disclaimer: The following organization chart shows the structure of the and the relationships and relative ranks of its parts and positions/jobs in place on the date this version of this manual was published. This information is subject to change; contact the Quality Manager for the most current version.

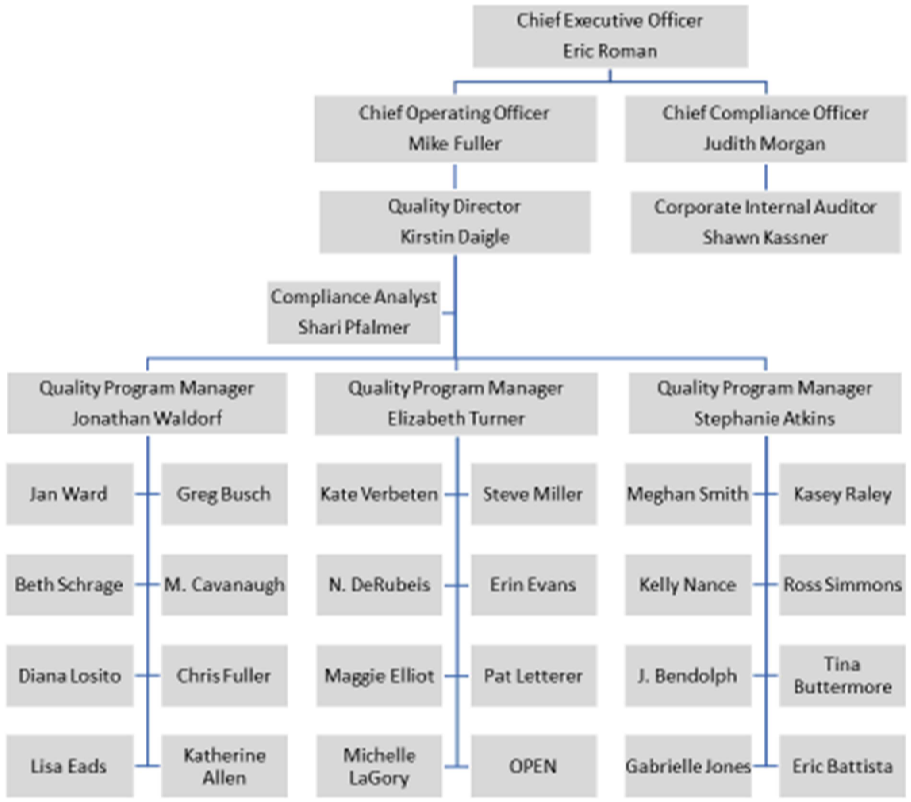


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7.4.2 Quality Systems Management

Disclaimer: The following organization chart shows the structure of the and the relationships and relative ranks of its parts and positions/jobs in place on the date this version of this manual was published. This information is subject to change; contact the Quality Manager for the most current version.

Quality Systems Management
Environmental Sciences Division

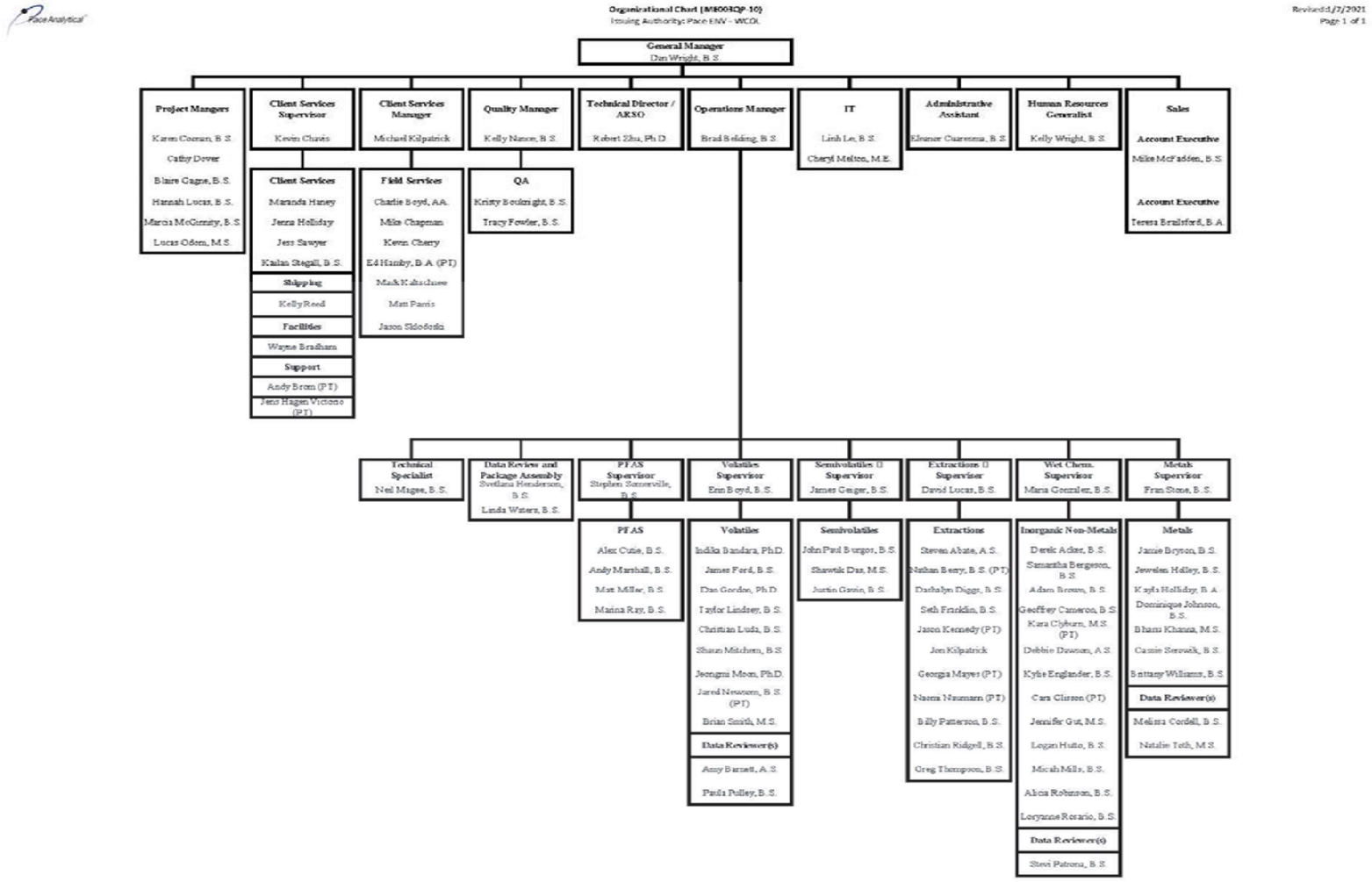


Local Quality Managers

Each QM has a direct reporting relationship to a Quality Program Manager and an indirect reporting relationship to the General Manager of each location for which the QM is assigned.

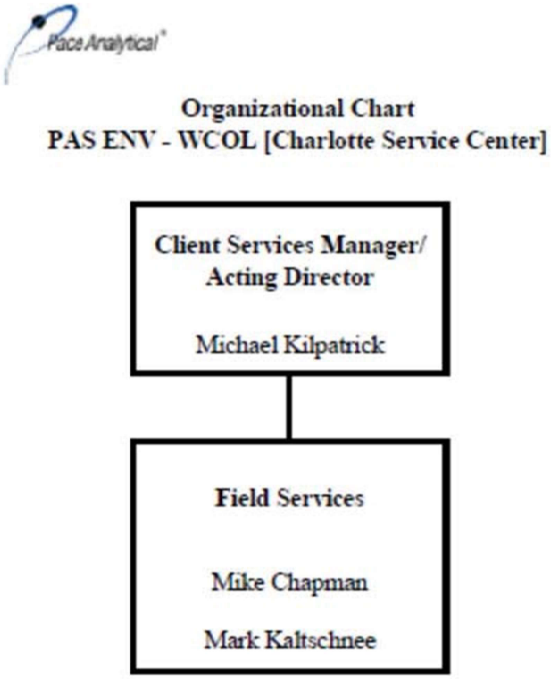
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7.4.3 PAS-WCOL [Analytical Laboratory] – Organization Chart



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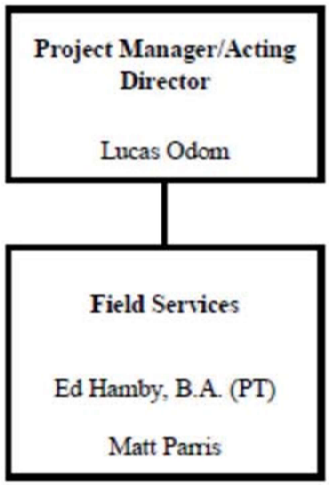
7.4.4 PAS-WCOL [Charlotte Service Center] – Organization Chart



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7.4.5 PAS-WCOL [Greenville Service Center] – Organization Chart

Organizational Chart
PAS ENV - WCOL [Greenville Service Center]



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7.5 Appendix E: Equipment Listing

The equipment listed represents equipment were held by each location on the effective date of this manual. This information is subject to change without notice. External parties should contact the location for the most current information.

7.5.1 PAS-WCOL [Analytical Laboratory]

Description	Manufacturer	Model	Serial Number	Service Date	Condition	Location	Internal ID	Location of Manual
Composite Sampler	Isco	3710	218J00263	09/01/2018	New	Field Services - Columbia	Composite Sampler #18-0901	EQLIMS
Composite Sampler	Isco	3710	205E01372	Unknown	Unknown	Field Services - Columbia	Composite Sampler #18-1115A	EQLIMS
Composite Sampler	Isco	3710	200A01650	Unknown	Unknown	Field Services - Columbia	Composite Sampler #18-1115B	EQLIMS
Composite Sampler	Isco	3710	212B00320	Unknown	Unknown	Field Services - Columbia	Composite Sampler #18-1115C	EQLIMS
Composite Sampler	Isco	3710	205K0152	Unknown	Unknown	Field Services - Columbia	Composite Sampler #18-1115E	EQLIMS
Composite Sampler	Isco	3710	213F01221	Unknown	Unknown	Field Services - Columbia	Composite Sampler #18-1115F	EQLIMS
Composite Sampler	Isco	3710	218M00077	01/09/2019	New	Field Services - Columbia	Composite Sampler #19-0109B	EQLIMS
DO Meter	YSI	Pro ODO	18B103680	03/08/2018	New	Field Services - Columbia	DO Meter #6	EQLIMS
DO Probe	YSI	Pro ODO Probe	18B103921	03/08/2018	New	Field Services - Columbia	DO Meter #6 Probe	EQLIMS
Multimeter	YSI	Pro1030	16K102983	09/11/2016	Unknown	Field Services - Columbia	Multimeter #2	EQLIMS

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Description	Manufacturer	Model	Serial Number	Service Date	Condition	Location	Internal ID	Location of Manual
Peristaltic Pump	Isco	150	203G01007	2004	Unknown	Field Services - Columbia	Peristaltic Pump #1	NA
pH Meter	ThermoFisher Scientific	Orion Star A321	G07576	10/06/2016	New	Field Services - Columbia	pH Meter #101	EQLIMS
pH Meter	YSI	Pro 10	18B102977	03/08/2018	New	Field Services - Columbia	pH Meter #104	EQLIMS
pH Meter	ThermoFisher Scientific	STARA3210	G12519	11/25/2019	New	Field Services - Columbia	pH Meter #19-1125	EQLIMS
pH Meter	ThermoFisher Scientific	Orion Star A321	G03795	02/04/2013	Unknown	Field Services - Columbia	pH Meter #37	EQLIMS
TRC Meter	Hach	Pocket Colorimeter II	18060E360317	05/31/2019	New	Field Services - Columbia	TRC Meter #19-0531	EQLIMS
TRC Meter	Hach	Pocket Colorimeter II	12070E203659	10/09/2012	Unknown	Field Services - Columbia	TRC Meter #TRCM-1210	EQLIMS
Turbidimeter	Hach	2100Q	13080C027705	11/14/2013	Unknown	Field Services - Columbia	Turbidimeter #TM-1114	EQLIMS
Balance - Top Loader	Mettler Toledo	ME303E	B908280591	03/18/2019	New	Metals	Balance #19-0318	EQLIMS
Centrifuge	VWR International	Clinical 200	68165129	03/13/2017	New	Metals	Centrifuge #4	EQLIMS
Chiller	ThermoFisher Scientific	121123010000008	1171044001200304	6/8/2020	New	Metals	Chiller # 11	NA
Chiller	ThermoFisher Scientific	121123010000008	0110795501131104	Unknown	Unknown	Metals	Chiller #1	NA
Chiller	ThermoFisher Scientific	121123010000008	1122870601191031	Unknown	Unknown	Metals	Chiller #10	NA

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Description	Manufacturer	Model	Serial Number	Service Date	Condition	Location	Internal ID	Location of Manual
Chiller	ThermoFisher Scientific	121123010000008	1171199501200813	10/22/2020	New	Metals	Chiller #12	NA
Chiller	ThermoFisher Scientific	121123010000008	1171283901201019	11/1/2020	New	Metals	Chiller #13	NA
Chiller	ThermoFisher Scientific	121123010000008	0110399701130116	Unknown	Unknown	Metals	Chiller #2	NA
Mercury Analyzer CVAA	Leeman Labs	Hydra AA	4004	02/2014	Unknown	Metals	Hg #4	Software
Quick Trace Mercury Analyzer (CVAF)	Teledyne Cetac Technologies	M-8000	US17076012	02/05/2017	New	Metals	Hg #5	Software
Mercury Analyzer CVAA	Leeman Labs	Hydra IIAA	US18193023	09/10/2018	Unknown	Metals	Hg #6	Software
Quick Trace Autosampler	Teledyne Cetac Technologies	ASX-560	03174A560	02/05/2017	Unknown	Metals - Attached to Hg # 5	Hg Autosampler #5	NA
Hot Block Graphite Heater	Environmental Express	SC154	2018CECW4978	09/26/2018	New	Metals	Hot Block #10	NA
Hot Block Graphite Heater	Environmental Express	SC154	2019CECw5105	06/18/2019	New	Metals	Hot Block #11	NA
Hot Block Graphite Heater	Environmental Express	SC154	3098CEC15414	01/04/2011	Unknown	Metals - Storage	Hot Block #4	NA
Hot Block Graphite Heater	CPI	MOD/BLOCK	NA	02/2016	Unknown	Metals - Storage	Hot Block #6	NA
Hot Block Graphite Heater	CPI	MOD/BLOCK	NA	06/2016	Unknown	Metals	Hot Block #7	NA
Hot Block Graphite Heater	Environmental Express	SC154	2018CEC4882	06/28/2018	New	Metals	Hot Block #9	NA

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Description	Manufacturer	Model	Serial Number	Service Date	Condition	Location	Internal ID	Location of Manual
Inductively Coupled Plasma-Trace	ThermoFisher Scientific	iCAP6500	20074003	01/8/2002	New	Metals	ICP #4	Software
Inductively Coupled Plasma-Trace	ThermoFisher Scientific	iCAP7600	IC76DU134102	01/2014	New	Metals	ICP #5	Software
ICP Autosampler	Teledyne Cetac Technologies	ASX-560	111742A560	01/19/2018	Unknown	Metals - Attached to ICP-MS # 4	ICP Autosampler #5	NA
ICP Autosampler	Teledyne Cetac Technologies	ASX-560	1118107A560	12/21/2018	Unknown	Metals - Storage	ICP Autosampler #6	Software
ICP Autosampler	Teledyne Cetac Technologies	ASX-560	011969A560	03/15/2019	Unknown	Metals - Attached to ICP # 5	ICP Autosampler #7	NA
ICP Autosampler	Teledyne Cetac Technologies	ASX-560	0319125A560	04/15/2019	Unknown	Metals - Attached to ICP-MS # 2	ICP Autosampler #8	NA
ICP Autosampler	Teledyne Cetac Technologies	ASX-560	121845A560	04/22/2019	Unknown	Metals - Attached to ICP # 4	ICP Autosampler #9	NA
ICP-MS	ThermoFisher Scientific	XSERIES 2	01686C	06/2011	New	Metals	ICP-MS #2	Software
ICP-MS	ThermoFisher Scientific	iCAP RQ	iCAPRQ00715	01/11/2018	New	Metals	ICP-MS #4	Software
Autoclave	Market Forge	Sterilmatic	NA	05/30/2013	Unknown	Microbiology	Autoclave #3	NA
Black Light Lamp	Spectroline	B-260	1959859	09/30/2015	Unknown	Microbiology	Black Light Lamp #1	NA
Blender	Black & Decker	PB1002	NA	08/31/2015	Unknown	Microbiology	Blender #M2	NA
Homgenizer	VWR International	250	V-28-045	2017	New	Microbiology	Homgenizer #1	NA

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Description	Manufacturer	Model	Serial Number	Service Date	Condition	Location	Internal ID	Location of Manual
Incubator	Thelco	51220112	699010336	04/1999	Unknown	Microbiology	Incubator #M3	NA
Incubator	Thelco	51221118	604081265	8/2004	Unknown	Microbiology	Incubator #M4	NA
Microscope	LW Scientific	Dual Mag	HG814817	08/02/2017	New	Microbiology	Microscope #2	NA
Quanti-Tray Sealer	IDEXX	89-0003936-00	QTP131716024 19	06/23/2017	New	Microbiology	Quanti-Tray Sealer #2	NA
Quanti-Tray Sealer	IDEXX	89-0003936-00	QTP132014009 63	6/18/2020	New	Microbiology	Quanti-Tray Sealer #4	NA
Refrigerator	ThermoFisher Scientific	GT20FREEFSA	300420890	10/8/2020	New	Microbiology	Refrigerator # 33	NA
Water Bath	ThermoFisher Scientific	TSCIR35	300182961	12/29/2017	New	Microbiology	Water Bath #M10	NA
Water Bath	ThermoFisher Scientific	TSCIR35	300261529	7/26/2019	New	Microbiology	Water Bath #M11	NA
Water Bath	Shel Lab	SWB2	8018015	08/15/2010	New	Microbiology	Water Bath #M8	NA
Balance - Top Loader	Mettler Toledo	ML802E/03	B326486754	10/16/2013	Unknown	Organic Prep.	Balance #13-1016	EQLIMS
Balance - Top Loader	Mettler Toledo	PB1502-S	1120493684	08/08/2012	Unknown	Organic Prep.	Balance #25B	EQLIMS
Chiller	ThermoFisher Scientific	121123010000 008	112261770119 0523	06/05/2019	New	Organic Prep.	Chiller #7	NA
Chiller	ThermoFisher Scientific	121123010000 008	112277790119 0903	09/10/2019	New	Organic Prep.	Chiller #9	NA



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Description	Manufacturer	Model	Serial Number	Service Date	Condition	Location	Internal ID	Location of Manual
Drying Oven	Baxter	DK43	189001	1998	Unknown	Organic Prep.	Drying Oven #5	NA
Drying Oven	Quincy Lab	10GCE	G1E-00440	06/06/2018	New	Organic Prep.	Drying Oven #7	NA
Freezer	Frigidaire	FFU1464FWO	WB64933777	02/04/2012	Unknown	Organic Prep.	Freezer #16	NA
Freezer	Fisher Scientific	20FFEEFSA	015849640116 0516	05/24/2016	New	Organic Prep.	Freezer #17	NA
Muffle Furnace	ThermoScientifi c Lindberg/Blue M	BF51828C-1	J11A-164949-JA	09/17/2015	New	Organic Prep.	Furance #5	EQLIMS
Muffle Furnace	ThermoScientifi c Lindberg/Blue M	BF51828C-1	P04N-623993-PN	06/2003	Unknown	Organic Prep.	Furnace #1	EQLIMS
Muffle Furnace	ThermoScientifi c Lindberg/Blue M	BF51828C-1	112630560119 0221	03/05/2019	New	Organic Prep.	Furnace #6	EQLIMS
Muffle Furnace	ThermoScientifi c Lindberg/Blue M	BF51828C-1	112630590119 0222	03/05/2019	New	Organic Prep.	Furnace #7	EQLIMS
GPC	J2 Scientific	AccuPrep	03H-1083-3.0	12/2003	Unknown	Organic Prep.	GPC #1	Software
GPC	J2 Scientific	AccuPrep MPS	05C-1148-4.0	01/05/2011	Unknown	Organic Prep.	GPC #2	Software
Microwave Reaction System	CEM	MARS6 230/60	MJ6109	05/2015	New	Organic Prep.	MCW #2	Software
Refrigerator	Fisher Scientific	20FREEFSA	012542840115 0205	12/02/2015	New	Organic Prep.	Refrigerator #24	NA
Refrigerator	Black & Decker	BCRK43	184300118	12/02/2019	Unknown	Organic Prep.	Refrigerator #32	NA

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Description	Manufacturer	Model	Serial Number	Service Date	Condition	Location	Internal ID	Location of Manual
Shaker	Glas-Col	099A DPM12	11905743	05/24/2019	New	Organic Prep.	Shaker #2	EQLIMS
Speed Vap	Horizon Tech	Speed-vap IV	15-0039	09/17/2015	New	Organic Prep.	Speed Vap #2	Software
Hazardous Waste Filtration System	Millipore Corporation	YT30142HW	NA	Unknown	New	Organic Prep.	TCLP Filter System # 1	NA
TCLP Rotary Sample Agiator	Environmental Express	EN60034-1	GF189N060-BMYJ1C	2/17/2020	New	Organic Prep.	TCLP Rotary Sample Agitator # 4	NA
TCLP Rotary Sample Agitator	Associated Design	3740-12-BRE 12 Station	1528	1998	Unknown	Organic Prep.	TCLP Rotary Sample Agitator #1	NA
TCLP Rotary Sample Agitator	Associated Design	3740-12-BRE 12-11	1957	03/27/2019	Unknown	Organic Prep.	TCLP Rotary Sample Agitator #3	NA
Turbo Vap II Concentrator	Biotage	Turbo Vap II	181200445	06/06/2018	New	Organic Prep.	Turbo Vap II Concentrator #10	Software
Turbo Vap II Concentrator	Biotage	Turbo Vap II	181400458	06/06/2018	New	Organic Prep.	Turbo Vap II Concentrator #11	Software
Turbo Vap II Concentrator	Biotage	Turbo Vap II	193101237	11/12/2019	New	Organic Prep.	Turbo Vap II Concentrator #13	Software
Turbo Vap II Concentrator	Biotage	Turbo Vap II	194501417	01/23/2020	Unknown	Organic Prep.	Turbo Vap II Concentrator #14	Software
Turbo Vap II Concentrator	Biotage	Turbo Vap II	TV1434N20575	10/23/2014	Unknown	Organic Prep.	Turbo Vap II Concentrator #6	Software
Turbo Vap II Concentrator	Biotage	Turbo Vap II	172500072	09/12/2017	New	Organic Prep.	Turbo Vap II Concentrator #8	Software
Turbo Vap II Concentrator	Biotage	Turbo Vap II	173000101	09/13/2017	New	Organic Prep.	Turbo Vap II Concentrator #9	Software

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Description	Manufacturer	Model	Serial Number	Service Date	Condition	Location	Internal ID	Location of Manual
Automated Turner	DFIT	Custom Build	Custom Build	05/01/2017	New	Organic Prep.	Turner #1	NA
Ultrasonic Disruptor	Misonix (Qsonica)	Sonicator 3000	R02998	2006	Unknown	Organic Prep.	Ultrasonic Disruptor #1	NA
Ultrasonic Disruptor	Misonix (Qsonica)	Sonicator 3000	R2374	Unknown	Unknown	Organic Prep.	Ultrasonic Disruptor #2	NA
Ultrasonic Processor	Misonix (Qsonica)	Sonicator Q700	78274E	01/16/2014	Unknown	Organic Prep.	Ultrasonic Processor #2	NA
Ultrasonic Processor	Qsonica	Sonicator Q700	86849J	09/22/2015	New	Organic Prep.	Ultrasonic Processor #3	NA
Vortex Mixer	Fisher Scientific	SA8	R800010121	Unknown	Unknown	Organic Prep.	Vortex Mixer #3	NA
Water Bath	Boekel	1494	190921153	05/24/2019	New	Organic Prep.	Water Bath #4	EQLIMS
Zero Headspace Extractor	Associated Design	3745 ZHE	NA	Unknown	New	Organic Prep.	ZHE # 2	NA
Zero Headspace Extractor	Associated Design	3745 ZHE	RW-273	Unknown	New	Organic Prep.	ZHE # 273	NA
Zero Headspace Extractor	Associated Design	3745 ZHE	RW-274	Unknown	New	Organic Prep.	ZHE # 274	NA
Zero Headspace Extractor	Associated Design	3745 ZHE	RW-275	Unknown	New	Organic Prep.	ZHE # 275	NA
Zero Headspace Extractor	Associated Design	3745 ZHE	RW-276	Unknown	New	Organic Prep.	ZHE # 276	NA
Zero Headspace Extractor	Associated Design	3745 ZHE	RW-277	Unknown	New	Organic Prep.	ZHE # 277	NA

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Description	Manufacturer	Model	Serial Number	Service Date	Condition	Location	Internal ID	Location of Manual
Zero Headspace Extractor	Associated Design	3745 ZHE	NA	Unknown	New	Organic Prep.	ZHE # 3	NA
Zero Headspace Extractor	Associated Design	3745 ZHE	NA	Unknown	New	Organic Prep.	ZHE # 4	NA
Zero Headspace Extractor	Associated Design	3745 ZHE	NA	Unknown	New	Organic Prep.	ZHE # 5	NA
Zero Headspace Extractor	Associated Design	3745 ZHE	NA	Unknown	New	Organic Prep.	ZHE # 7	NA
Zero Headspace Extractor	Associated Design	3745 ZHE	NA	Unknown	New	Organic Prep.	ZHE #1	NA
Centrifuge	Hettich Zentrifugen	Rotanta 460	0000280-03-01	5/22/2020	Used	PFAS (LC/MS/MS)	Centrifuge # 5	NA
HPLC / Triple Quad Detector	Agilent Technologies	1260 HiP Degasser (G4225A) 4465800	JPAAB07343	11/01/2016	New	PFAS (LC/MS/MS)	LCMSMS1	Software
HPLC / Triple Quad Detector	Agilent Technologies	1260 HiP Degasser (G4225A) 4465800	JPAAB08258	10/24/2018	New	PFAS (LC/MS/MS)	LCMSMS2	Software
Shaker	VWR International	3500 Std. 120V	17127011	03/14/2017	New	PFAS (LC/MS/MS)	Shaker #1	NA
Sonicator	VWR International	97043-976	1717A0842	04/2017	New	PFAS (LC/MS/MS)	Sonicator #1	NA
Turbo Vap LV	Biotage	Turbo Vap LV	174100205	07/10/2018	DEMO	PFAS (LC/MS/MS)	TurboVap LV #1	Software
Vortex Mixer	Fisher Scientific	SA8	R800010110	Unknown	Unknown	PFAS (LC/MS/MS)	Vortex Mixer # 2	NA

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Description	Manufacturer	Model	Serial Number	Service Date	Condition	Location	Internal ID	Location of Manual
HPLC / Triple Quad Detector	Agilent Technologies	1260 Binary Pump (G1312B)	DEACB10794	11/01/2016	New	PFAS (LC/MS/MS) - Attached to LCMSMS1	NA	Software
HPLC / Triple Quad Detector	Agilent Technologies	1260 ALS (G1329B)	DEAAC42719	11/01/2016	New	PFAS (LC/MS/MS) - Attached to LCMSMS1	NA	Software
HPLC / Triple Quad Detector	Agilent Technologies	1260 TCC (G1316A)	DEACN45680	11/01/2016	New	PFAS (LC/MS/MS) - Attached to LCMSMS1	NA	Software
HPLC / Triple Quad Detector	Sciex	5020102	BJ29321608	11/01/2016	New	PFAS (LC/MS/MS) - Attached to LCMSMS1	NA	Software
HPLC / Triple Quad Detector	Agilent Technologies	1260 Bin Pump (G1312B)	DEACB11117	10/24/2018	New	PFAS (LC/MS/MS) - Attached to LCMSMS2	NA	Software
HPLC / Triple Quad Detector	Agilent Technologies	1290 Thermostat (G1330B)	DEBAK32602	10/24/2018	New	PFAS (LC/MS/MS) - Attached to LCMSMS2	NA	Software
HPLC / Triple Quad Detector	Agilent Technologies	1260 TCC (G1316A)	DEACN47046	10/24/2018	New	PFAS (LC/MS/MS) - Attached to LCMSMS2	NA	Software
HPLC / Triple Quad Detector	Sciex	5060884 (QTRAP 4500)	EB250231807	10/24/2018	New	PFAS (LC/MS/MS) - Attached to LCMSMS2	NA	Software
Pancake Probe	Ludlum Measurements Inc	44-9	PR385660	08/13/2019	Unknown	Sample Receiving	Pancake Probe #1	NA
Walk-in Cooler	Polar King	DT820	A16097900	11/1/2019	Used	Sample Receiving	Polar Walk-In Cooler #30	NA

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Description	Manufacturer	Model	Serial Number	Service Date	Condition	Location	Internal ID	Location of Manual
Survey Meter	Ludlum Measurements Inc	12	162119	10/2014	Unknown	Sample Receiving	Survey Meter #SM-2	NA
Walk-in Cooler (SR)	Climate Control	Unknown	Unknown	Unknown	Unknown	Sample Receiving	Walk-in Cooler #1	NA
Autosampler	Agilent Technologies	7683B	CN54028057	11/2005	Unknown	Semi-Volatiles	Autosampler #27	Software
Autosampler	Hewlett Packard	Series 7683	US95110869	08/2009	Unknown	Semi-Volatiles	Autosampler #29	NA
Autosampler	Agilent Technologies	7683	US92107420	02/10/2006	Unknown	Semi-Volatiles	Autosampler #31	Software
GC Dual ECD	Agilent Technologies	6890N	CN10518005	06/2005	Unknown	Semi-Volatiles	GC #10	EQLIMS
GC Dual ECD	Agilent Technologies	6890N	CN10633092	02/10/2006	Unknown	Semi-Volatiles	GC #11	EQLIMS
GC Dual FID	Agilent Technologies	6890N	CN10650056	07/2007	Unknown	Semi-Volatiles	GC #12	EQLIMS
GC Dual ECD	Agilent Technologies	7890B	US13463049	12/2013	Unknown	Semi-Volatiles	GC #14	Software
GC Dual ECD	Hewlett Packard	6890	US00022182	08/1998	Unknown	Semi-Volatiles	GC #5	EQLIMS
GC Dual ECD	Agilent Technologies	6890N	US10212124	2001	Unknown	Semi-Volatiles	GC #7	EQLIMS
HPLC	Agilent Technologies	1200 Series Degasser	JP62357625	07/2007	Unknown	Semi-Volatiles	HPLC #1	Software
HPLC	Agilent Technologies	1260 Series Quat Pump	DEAB702492	12/15/2002	Unknown	Semi-Volatiles	HPLC #2	Software

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Description	Manufacturer	Model	Serial Number	Service Date	Condition	Location	Internal ID	Location of Manual
Hydrogen Generator	Parker	60HMD	13HMD0167	2015	New	Semi-Volatiles	Hydrogen Generator #1	NA
GC/MS	Agilent Technologies	GC-6890N / MS-5975	US10542069 / US53931266	11/2005	Unknown	Semi-Volatiles	MSD #10	EQLIMS
GC/MS	Agilent Technologies	GC-6890N / MS-5975B	CN10633016 / US53931266	02/10/2006	Unknown/ New	Semi-Volatiles	MSD #11	EQLIMS
GC/MS	Agilent Technologies	GC- 6890 / MS-5973	CN10305019 / US33220170	08/2009	Unknown	Semi-Volatiles	MSD #12	EQLIMS
GC/MS	Agilent Technologies	GC- G3440B / MS- G7077B	US18073048 / US1807M004	04/01/2018	New	Semi-Volatiles	MSD #16	Software
GC/MS	Hewlett Packard	GC- 6890 / MS-5973	US00009998 / US72010678	1997	Unknown	Semi-Volatiles	MSD #4	EQLIMS
Refrigerator	Fisher Scientific	3751FS	Unknown	01/03/2013	Unknown	Semi-Volatiles	Refrigerator #20	NA
Refrigerator	Fisher Scientific	20FREEFSA	015849620116 0516	05/26/2016	New	Semi-Volatiles	Refrigerator #26	NA
Refrigerator	Fisher Scientific	20FREEFSA	116354150119 1121	11/22/2019	New	Semi-Volatiles	Refrigerator #31	NA
Zero Air Generator	Parker	UHP35ZASW	13Z016	11/2016	New	Semi-Volatiles	Zero Air Generator #2	NA
Autosampler	Agilent Technologies	7683	US12419286	08/1998	Unknown	Semi-Volatiles - Attached to GC # 10	Autosampler #34	NA
Autosampler	Agilent Technologies	G2913A	CN52125269	08/2019	Unknown	Semi-Volatiles - Attached to GC # 11	Autosampler #39	NA
Autosampler	Agilent Technologies	G2613A	US90204405	7/10/2020	Unknown	Semi-Volatiles - Attached to GC # 12	Autosampler #42	Software

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Description	Manufacturer	Model	Serial Number	Service Date	Condition	Location	Internal ID	Location of Manual
Autosampler	Agilent Technologies	7693	CN 13450127	12/2013	Unknown	Semi-Volatiles - Attached to GC # 14	Autosampler #30	NA
Autosampler	Agilent Technologies	7683	UF91606711	08/07/2009	Unknown	Semi-Volatiles - Attached to GC # 5	Autosampler MSD #12	NA
Autosampler	Agilent Technologies	7683	US81501052	2001	Unknown	Semi-Volatiles - Attached to GC # 7	Autosampler #33	NA
HPLC	Agilent Technologies	1260 Series DAD	DEAA301229	12/23/2019	Unknown	Semi-Volatiles - Attached to HPLC # 1	NA	Software
HPLC	Agilent Technologies	1200 Series Quat Series	DE43631807	1/29/2019	Unknown	Semi-Volatiles - Attached to HPLC # 1	NA	Software
HPLC	Agilent Technologies	1200 Series ALS	DE64761071	07/2007	Unknown	Semi-Volatiles - Attached to HPLC # 1	NA	Software
HPLC	Agilent Technologies	1200 Series TCC	DE63061942	07/2007	Unknown	Semi-Volatiles - Attached to HPLC # 1	NA	Software
HPLC	Agilent Technologies	1260 Series DAD	DEAA301472	10/5/2018	Unknown	Semi-Volatiles - Attached to HPLC # 2	NA	Software
HPLC	Agilent Technologies	1260 Series ALS	DEAB305754	12/15/2002	Unknown	Semi-Volatiles - Attached to HPLC # 2	NA	Software
HPLC	Agilent Technologies	1290 Series Thermostat	DEBAK13589	12/15/2002	Unknown	Semi-Volatiles - Attached to HPLC # 2	NA	Software
HPLC	Agilent Technologies	1260 Series TCC	DEACN06491	12/15/2002	Unknown	Semi-Volatiles - Attached to HPLC # 2	NA	Software
Autosampler	Agilent Technologies	7683B	CN62940495	02/10/2006	Unknown	Semi-Volatiles - Attached to MSD # 10	Autosampler #26	NA
Autosampler	Agilent Technologies	7683B	CN53827750	01/14/2019	Unknown	Semi-Volatiles - Attached to MSD # 11	Autosampler #37	NA

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Description	Manufacturer	Model	Serial Number	Service Date	Condition	Location	Internal ID	Location of Manual
Autosampler	Agilent Technologies	7683B / 7683	CN71343516 / US12419304	07/2007	Unknown	Semi-Volatiles - Attached to MSD # 12	Autosampler #GC 12	NA
Autosampler	Agilent Technologies	G4513A	CN18090084	04/01/2018	Unknown	Semi-Volatiles - Attached to MSD # 16	Autosampler #38	NA
Autosampler	Hewlett Packard	HP6890	US73503279	1997	Unknown	Semi-Volatiles - Attached to MSD # 4	Autosampler #28	NA
Geiger Counter	Eberline Instrument Corporation	E-120E	13618	05/2012	Unknown	Storage - RSO	Geiger Counter #1	NA
Geiger Counter Probe	ThermoFisher Scientific	HP-190A	1092	Unknown	Unknown	Storage - RSO	Geiger Counter Probe #1	NA
Survey Meter	Ludlum Measurements Inc	12	305064	10/21/2014	Unknown	Storage - RSO	Survey Meter #SM-1	NA
Tritium Detector, Large Area	Ludlum Measurements Inc	44-110	PR327579	10/21/2014	Unknown	Storage - RSO	Tritium Detector #TD-1	NA
Tritium Detector, Large Area	Ludlum Measurements Inc	44-110	PR149565	05/2012	Unknown	Storage - RSO	Tritium Detector #TD-2	NA
Water Bath	Boekel	1494	52202304	06/22/2005	Unknown	Storage in SU3	Water Bath #3	NA
Microwave Reaction System	CEM	MARS6	MN2648	09/26/2018	New	Storage in SU4	MCW #3	Software
Balance - Top Loader	Sartorius	Practum 412-1S	32850362	05/19/2015	New	Volatiles	Balance #VOA-2	EQLIMS
Centrifuge	VWR International	Clinical 200	68145107	11/2014	Unknown	Volatiles	Centrifuge #3	EQLIMS
Freezer	Frigidaire	FFU1464FWO	WB64933778	01/2007	New	Volatiles	Freezer #15	NA

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Description	Manufacturer	Model	Serial Number	Service Date	Condition	Location	Internal ID	Location of Manual
Freezer	Fisher Scientific	20LFEEFSA	116279080117 0807	08/09/2017	New	Volatiles	Freezer #29	NA
GC PID/FID	Agilent Technologies	GC 7890A	CN10815015	02/2009	Unknown	Volatiles	GC #13	Software
GC Dual FID	Hewlett Packard	GC 6890	US00026561	06/1999	Unknown	Volatiles	GC #6	EQLIMS
GC Dual FID	Agilent Technologies	GC 6890	US00042711	10/2002	Unknown	Volatiles	GC #8	EQLIMS
GC PID/FID	Hewlett Packard	GC 6890N	US10403005	04/2004	New	Volatiles	GC #9	EQLIMS
Hydrogen Generator	Parker	H2PEMPD-510-100	19PLD5086	6/28/2019	New	Volatiles	Hydrogen Generator #2	NA
GC/MS	Agilent Technologies	GC 5973 / MS 6890	CN10508043 / US44621283	10/13/2011	Unknown	Volatiles	MSD #13	Software
GC/MS	Agilent Technologies	GC 7890A / MS 5975C	CN12071133 / US11092707	03/2012	Unknown	Volatiles	MSD #14	Software
GC/MS	Agilent Technologies	GC 7890B / MS 5975C	CN14323093 / US13433B01	10/2014	Unknown	Volatiles	MSD #15	Software
GC/MS	Agilent Technologies	GC 5977B (G7077B) / MS 7890B (G3442B)	US1844M023 / CN18033077	01/29/2019	New	Volatiles	MSD #17	Software
GC/MS	Agilent Technologies	GC 8860 / MS 5977B	CN1925C013 / US1925R048	09/30/2019	New	Volatiles	MSD #18	Software
GC/MS	Agilent Technologies	GC 6890 / MS 5973	US00021398 / US80210977	05/1998	Unknown	Volatiles	MSD #5	EQLIMS
GC/MS	Agilent Technologies	GC 6890 / MS 5973N	US00032609 / US90160010	03/2000	Unknown	Volatiles	MSD #6	EQLIMS

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Description	Manufacturer	Model	Serial Number	Service Date	Condition	Location	Internal ID	Location of Manual
GC/MS	Agilent Technologies	GC-6890 / MS-5973N	US00034585 / US01150087	05/2000	Unknown	Volatiles	MSD #7	EQLIMS
GC/MS	Agilent Technologies	GC 6890N / MS 5973N	US10150052 / US10451993	01/2002	Unknown	Volatiles	MSD #8	EQLIMS
GC/MS	Agilent Technologies	GC 6890 / MS 5973I	CN10339035 / US33220060	03/2004	Unknown	Volatiles	MSD #9	EQLIMS
Refrigerator	Kenmore	253.60722	WA73802498	12/2007	Unknown	Volatiles	Refrigerator #18	NA
Refrigerator / Freezer	Whirlpool	ET18JK	E81221051	1991	Unknown	Volatiles	Refrigerator / Freezer #2	NA
Refrigerator / Freezer	General Electric	TBX18G	RT599810	03/1999	Unknown	Volatiles	Refrigerator / Freezer #4	NA
Refrigerator / Freezer	Frigidaire	FRT18B4AW6	BA31031244	08/29/2003	Unknown	Volatiles	Refrigerator / Freezer #9	NA
Ultrasonic Cleaner	VWR International	97043-964	1612A6033	Unknown	Unknown	Volatiles	Ultrasonic #1	NA
Vortex Mixer	Fisher Scientific	G-560	2-32318	Unknown	Unknown	Volatiles	Vortex Mixer #1	NA
Walk-in Cooler	HotPack	1208401	73160	1992	Unknown	Volatiles	Walk-in Cooler #8	NA
Zero Air Generator	Parker	UHP35ZASW	14Z0024	2015	New	Volatiles	Zero Air Generator #1	NA
Autosampler	O.I Analytical	4551-A	D81445B984	05/29/2008	Unknown	Volatiles - Attached to GC # 13	Autosampler #9	NA
Purge & Trap Concentrator	O.I Analytical	4660 Eclipse	B42546655P	10/2003	Unknown	Volatiles - Attached to GC # 13	Purge & Trap #2	NA

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Description	Manufacturer	Model	Serial Number	Service Date	Condition	Location	Internal ID	Location of Manual
Autosampler	Agilent Technologies	7683B	CN54028055	10/2006	Unknown	Volatiles - Attached to GC # 6	Autosampler #7	NA
Autosampler	EST Analytical	LGX50	LGX11062315	08/2015	Unknown	Volatiles - Attached to GC # 8	Autosampler #16	NA
Autosampler	EST Analytical	LGX50	LGX120070119	08/01/2019	Unknown	Volatiles - Attached to GC # 9	Autosampler #24	NA
Autosampler	O.I Analytical	4100	B508410225	Unknown	Unknown	Volatiles - Attached to MSD # 13	Autosampler #21	NA
Purge & Trap Concentrator	O.I Analytical	4660 Eclipse	C504466513P	06/2005	Unknown	Volatiles - Attached to MSD # 13	Purge & Trap #5	NA
Autosampler	O.I Analytical	4551-A	F00545B633	02/04/2020	Unknown	Volatiles - Attached to MSD # 14	Autosampler #41	NA
Purge & Trap Concentrator	O.I Analytical	4660	D534466729	Unknown	Unknown	Volatiles - Attached to MSD # 14	Purge & Trap #18	NA
Autosampler	O.I Analytical	4100	A428410167	10/2014	Unknown	Volatiles - Attached to MSD # 15	Autosampler #15-1	NA
Purge & Trap Concentrator	O.I Analytical	4660 (eclipse)	K430466776P	10/2014	Unknown	Volatiles - Attached to MSD # 15	Purge & Trap #15-2	NA
Autosampler	O.I Analytical	4100	E916410597	05/14/2019	Unknown	Volatiles - Attached to MSD # 17	Autosampler #23	NA
Purge & Trap Concentrator	O.I Analytical	4660 Eclipse	H301466056P	04/2013	Unknown	Volatiles - Attached to MSD # 17	Purge & Trap #10	NA
Purge & Trap Concentrator	O.I Analytical	4760 Eclipse	A925447209	02/13/2020	Unknown	Volatiles - Attached to MSD # 18	Purge & Trap #21	NA
Autosampler	O.I Analytical	4100	B509410485	Unknown	Unknown	Volatiles - Attached to MSD # 5	Autosampler #20	NA

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Description	Manufacturer	Model	Serial Number	Service Date	Condition	Location	Internal ID	Location of Manual
Purge & Trap Concentrator	O.I Analytical	4660 Eclipse	A352466312P	02/2005	Unknown	Volatiles - Attached to MSD # 5	Purge & Trap #3	NA
Autosampler	O.I Analytical	4551-A	D51945B229	06/2005	Unknown	Volatiles - Attached to MSD # 6	Autosampler #3	NA
Purge & Trap Concentrator	O.I Analytical	4660 Eclipse	G129466450P	10/2011	Unknown	Volatiles - Attached to MSD # 6	Purge & Trap #8	NA
Autosampler	O.I Analytical	4551-A	F30845B200	04/2013	Unknown	Volatiles - Attached to MSD # 7	Autosampler #14	NA
Purge & Trap Concentrator	O.I Analytical	4660 (eclipse)	K433466705P	10/2014	Unknown	Volatiles - Attached to MSD # 7	Purge & Trap #15-1	NA
Autosampler	O.I Analytical	4551-A	F30845B199	04/2013	Unknown	Volatiles - Attached to MSD # 8	Autosampler #12	NA
Purge & Trap Concentrator	O.I Analytical	4660	C519466231	09/08/2016	Unknown	Volatiles - Attached to MSD # 8	Purge & Trap #17	NA
Autosampler	O.I Analytical	4551-A	F30845B198	04/2013	Unknown	Volatiles - Attached to MSD # 9	Autosampler #13	NA
Purge & Trap Concentrator	O.I Analytical	4660 Eclipse	D637466747P	06/2005	Unknown	Volatiles - Attached to MSD # 9	Purge & Trap #4	NA
Autosampler	Teledyne Cetac Technologies	Atomx XYZ	US18354015	01/29/2019	New	Volatiles - Storage	Autosampler #22	Software
Auto-Titrator System	Man-Tech	PCM-1002/4	NA	12/13/2017	New	Wet Chem.	#AT	EQLIMS
Auto Analyzer System	Lachat	Quick-Chem 8000	A83000-1990	2002	Unknown	Wet Chem.	AA #2	EQLIMS
Automated Chemistry Analyzer 3700	O.I Analytical	329995	B550837557	01/2016	New	Wet Chem.	AA #3	Software

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Description	Manufacturer	Model	Serial Number	Service Date	Condition	Location	Internal ID	Location of Manual
Automated Chemistry Analyzer 3700	O.I Analytical	329995	B549837495	01/2016	New	Wet Chem.	AA #4	Software
Phosphorus and Orthophosate Chemistry Unit	Skalar Analytical	5000	182889	02/11/2019	New	Wet Chem.	AA #5	EQLIMS
Aquakem 200 Analyzer	ThermoFisher Scientific	984206 (type: 973)	22831	05/2013	Unknown	Wet Chem.	Aquakem Analyzer #2	EQLIMS
Balance - Analytical	Mettler Toledo	MS204S	B427764304	06/08/2014	New	Wet Chem.	Balance #11A	EQLIMS
Balance - Analytical	Mettler Toledo	MS-204TS	B539502279	01/10/2015	New	Wet Chem.	Balance #12	EQLIMS
BOD Incubator	Fisher Scientific	304	UF30K-5020/03B-868521	12/2003	Unknown	Wet Chem.	BOD Incubator #B4	NA
BOD Incubator	VWR International	2020	90100	04/2007	Unknown	Wet Chem.	BOD Incubator #B5	NA
BOD Incubator	Fisher Scientific	11-679-25C	2.01808E+12	10/29/2012	Unknown	Wet Chem.	BOD Incubator #B6	NA
BOD Incubator	Fisher Scientific	3720	136748-668	07/16/2013	Unknown	Wet Chem.	BOD Incubator #B8	NA
BOD Incubator	Fisher Scientific	3720A	300044697	09/15/2011	Unknown	Wet Chem.	BOD Incubator #B9	NA
Bomb Calorimeter	Parr	1341EB	7303	1997	Unknown	Wet Chem.	Bomb Calorimeter #1	NA
Centrifuge	VWR International	Clinical 200	68175072	02/07/2018	Unknown	Wet Chem.	Centrifuge #5	EQLIMS
Chiller	Caron	2050-1	2050-1-673	07/05/2019	New	Wet Chem.	Chiller #8	NA

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Description	Manufacturer	Model	Serial Number	Service Date	Condition	Location	Internal ID	Location of Manual
COD Digestion Block	Columbia Analytical Instruments	Smart Block 226	NA	10/02/2014	Unknown	Wet Chem.	COD Digestion Block #3	NA
Conductivity Meter	Extech Instruments	EC100	301884	02/06/2016	New	Wet Chem.	Conductivity Meter #AT2	Software
Conductivity Meter	Man-Tech	4510	66959	12/13/2017	New	Wet Chem.	Conductivity Meter #AT3	Software
Cyanide Hotblock	Andrews	110-10-12	A5P0842	12/14/2015	Unknown	Wet Chem.	Cyanide Hotblock #3	NA
Cyanide Hotblock	Andrews	110-10-P	86N0892	01/25/2017	New	Wet Chem.	Cyanide Hotblock #4	NA
Luminescence Dissolved Oxygen Meter	YSI	ProODO	16B100776	02/18/2016	New	Wet Chem.	DO Meter #5	EQLIMS
ProODO Probe	YSI	ProODO Probe	16B100987	02/18/2016	New	Wet Chem.	DO Meter #5 Probe	NA
Luminescence Dissolved Oxygen Meter	YSI	ProODO	18E102940	05/03/2018	New	Wet Chem.	DO Meter #7	EQLIMS
ProODO Probe	YSI	ProODO Probe	18H108982	01/18/2019	New	Wet Chem.	DO Probe #19-0118	NA
ProODO Probe	YSI	ProODO Probe	19A105401	01/03/2019	New	Wet Chem.	DO Probe #19-0130	NA
Drying Oven	Lindberg/Blue M	G01350C	P18G-33084-PG	1998	Unknown	Wet Chem.	Drying Oven #3	NA
Drying Oven	ThermoFisher Scientific	Heratherm GS180 510288	41746692	01/09/2015	Unknown	Wet Chem.	Drying Oven #6	EQLIMS
Drying Oven	Fisher Scientific	151030520	42516465	2/14/2020	New	Wet Chem.	Drying Oven #8	NA



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Description	Manufacturer	Model	Serial Number	Service Date	Condition	Location	Internal ID	Location of Manual
Flashpoint Tester	Koehler	K16225	00020A	6/19/2019	New	Wet Chem.	Flashpoint Tester #3	NA
Hot Block Graphite Heater	Environmental Express	SC154	NA	11/06/2019	New	Wet Chem.	Hot Block #12	NA
Ion Chromatograph	Dionex	ICS-2100	9050165	06/08/2012	New	Wet Chem.	IC #4	Software
Ion Chromatograph	ThermoFisher Scientific	Dionex ICS-2100	13010346	10/15/2015	New	Wet Chem.	IC #5	Software
Ion Chromatograph	ThermoFisher Scientific	Dionex Integrion RFIC	19010010	02/19/2019	New	Wet Chem.	IC #6	Software
Ion Chromatograph	ThermoFisher Scientific	Dionex Integrion RFIC	16033206	08/13/2019	New	Wet Chem.	IC #7	Software
IC Pump	ThermoFisher Scientific	Dionex AXP	Z0053278	12/2014	New	Wet Chem.	IC Pump #1	Software
Micro Dist Hot Block	Lachat	Micro Dist	11010000294	11/08/2011	Unknown	Wet Chem.	Micro Dist Hot Block #1	EQLIMS
Micro Dist Hot Block	Lachat	Micro Dist A17102	1.412E+11	11/2014	New	Wet Chem.	Micro Dist Hot Block #2	EQLIMS
pH Meter	VWR International	SB70P	D05976	11/22/2010	New	Wet Chem.	pH Meter #12	EQLIMS
pH Meter	ThermoFisher Scientific	STARA1110	J14050	09/08/2016	New	Wet Chem.	pH Meter #14	EQLIMS
Refrigerator	Fisher Scientific	20FREEFSA	1.15067E+15	04/18/2019	New	Wet Chem.	Refrigerator #19-0418	NA
Spectrophotometer	Hach	DR 3900	1606201	06/30/2015	New	Wet Chem.	Spectrophotometer #4	EQLIMS

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Description	Manufacturer	Model	Serial Number	Service Date	Condition	Location	Internal ID	Location of Manual
TDS Stable Weigh Filling Station	Environmental Express	TDS600F	37-7264	11/01/2017	New	Wet Chem.	TDS Filling Station #1	NA
TDS Static Guard	Haug	1781305	15426	11/01/2017	New	Wet Chem.	TDS Static Guard #1	NA
TKN Hot Block	Environmental Express	TKN054	2020TKN203	08/05/2020	New	Wet Chem.	TKN Hot Block #4	EQLIMS
TOC Analyzer	O.I Analytical	1030	J019730196	06/2010	Unknown	Wet Chem.	TOC #1	EQLIMS
Turbidimeter	HF Scientific	Micro 100	201610276	05/12/2016	Unknown	Wet Chem.	Turbidimeter #3	EQLIMS
Walk-in Cooler (INM)	NA	NA	NA	06/29/2018	Unknown	Wet Chem.	Walk-in Cooler #3	NA
IC Variable Wavelength Detector	ThermoFisher Scientific	Dionex VWD	14101375	12/2014	New	Wet Chem. - Attached to IC # 5	IC VWD #1	NA
IC Autosampler	ThermoFisher Scientific	Dionex AS-DV	181214361	02/19/2019	New	Wet Chem. - Attached to IC # 6	IC Autosampler #6	NA
IC Autosampler	ThermoFisher Scientific	Dionex AS-DV	190614911	08/13/2019	New	Wet Chem. - Attached to IC # 7	IC Autosampler #7	NA
Ignition Unit	Parr	2901EB	NA	04/10/2012	Unknown	Wet Chem. - Attached to the Bomb Colorimeter # 1	Ignition Unit #1U1012	Software
Autosampler	Man-Tech	PC-1000-688	261C4N066	2002	Unknown	Wet Chem. - Attached to #AT	NA	EQLIMS
Buret Module	Man-Tech	PC-1000-1040	MT-1G7-200	12/13/2017	New	Wet Chem. - Attached to #AT	NA	EQLIMS
GT-ID-II	Man-Tech	PCM-1000-495	CIL-00296	2002	Unknown	Wet Chem. - Attached to #AT	NA	EQLIMS

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Description	Manufacturer	Model	Serial Number	Service Date	Condition	Location	Internal ID	Location of Manual
Mini Mix Stirrer Controller	Man-Tech	PC-1000-388	MT-1C7-375	12/13/2017	New	Wet Chem. - Attached to #AT	NA	EQLIMS
PC-Tis Interface Module	Man-Tech	PC-1000-102	MS-0E2-308	2002	Unknown	Wet Chem. - Attached to #AT	NA	EQLIMS
PC-Titrate Titra-Rinse/A Module	Man-Tech	PCM-1000-408	MS-0G0-118	2002	Unknown	Wet Chem. - Attached to #AT	NA	EQLIMS
PC-Titrate Titra-Rinse/A Module	Man-Tech	PCM-1000-408	MS-0F1-137	2002	Unknown	Wet Chem. - Attached to #AT	NA	EQLIMS
Peristaltic Pump	Man-Tech	PC-1000-475	MT-1H7-420	12/13/2017	New	Wet Chem. - Attached to #AT	NA	EQLIMS
Titrasip Module	Man-Tech	PC-1300-475	MT-1E7-1014	12/13/2017	New	Wet Chem. - Attached to #AT	NA	EQLIMS
Turbidity Assay Plus	Man-Tech	PC-20013A	209090	2002	Unknown	Wet Chem. - Attached to #AT	NA	EQLIMS
Autosampler	O.I Analytical	ASX-520	0915907A520	01/2016	New	Wet Chem. - Attached to AA # 3	AA #3 Autosampler	NA
Autosampler	O.I Analytical	ASX-130	111504A130	01/2016	New	Wet Chem. - Attached to AA # 4	AA #4 Autosampler	NA
Autosampler	Skalar Analytical	21050900-01	181797	02/11/2019	New	Wet Chem. - Attached to AA #5	NA	EQLIMS
Backpressure Regulator	Skalar Analytical	5530	181210	02/11/2019	New	Wet Chem. - Attached to AA #5	NA	EQLIMS
Cyanide and Phenol Chemistry Unit	Skalar Analytical	5000	182885	02/11/2019	New	Wet Chem. - Attached to AA #5	NA	EQLIMS
Cyanide Kelada	Skalar Analytical	5565	19123	02/11/2019	New	Wet Chem. - Attached to AA #5	NA	EQLIMS

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Description	Manufacturer	Model	Serial Number	Service Date	Condition	Location	Internal ID	Location of Manual
Mixing Device	Skalar Analytical	21050325	18417	02/11/2019	New	Wet Chem. - Attached to AA #5	NA	EQLIMS
Power Supply for UV Lamp	Skalar Analytical	PS-4	NA	02/11/2019	New	Wet Chem. - Attached to AA #5	NA	EQLIMS
Stir Base	Environmental Express	SC160	711326	7/28/2020	New	Wet Chem. - Attached to Hot Block # 12	Stir Base # 1	NA
IC Autosampler	ThermoFisher Scientific	Dionex AS-DV	180513735	06/14/2018	Unknown	Wet Chem. - Attached to IC # 4	IC Autosampler #5	NA
IC Autosampler	ThermoFisher Scientific	Dionex AS-DV	150810037	10/15/2015	New	Wet Chem. - Attached to IC # 5	IC Autosampler #4	NA
TKN Hot Block Controller	Environmental Express	TKN100	2019TKNBC164	08/05/2020	New	Wet Chem. - Attached to TKN # 4	TKN Block Controller #4	NA
TOC Autosampler	O.I Analytical	1088 AS	E018788107	06/2010	Unknown	Wet Chem. - Attached to TOC # 1	TOC Autosampler #1	NA
Luminescence Dissolved Oxygen Meter	YSI	ProODO	15K102490	11/16/2015	New	Wet Chem. - Storage	DO Meter #4	EQLIMS
Luminescence Dissolved Oxygen Meter	YSI	4010-3W	20411391	11/16/2020	New	Wet Chem. - Attached to BOD Robot # 1	DO Meter #8	EQLIMS
BOD Robot	Skalar Analytical	21088903-01	206074	11/16/2020	New	Wet Chem.	BOD Robot # 1	EQLIMS
Dilution Pump	Skalar Analytical	21007985-01	20617	11/16/2020	New	Wet Chem. - Attached to BOD Robot # 1	Pump 3 - Dilution Liquid #1	EQLIMS
Balance - Top Loader	Sartorius	Practum 412-1S	39550090	11/23/2020	New	PFAS (LC/MS/MS)	Balance # 20-1123	NA
Balance - Top Loader	Mettler Toledo	ML802E/03	B345970999	01/2014	New	Storage - QA	Balance # 13-1224	NA

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7.5.2 PAS-WCOL [Charlotte Service Center]

Description	Manufacturer	Model	Serial Number	Service Date	Condition	Location	Internal ID	Location of Manual
Composite Sampler	Isco	3710	212K00187	Unknown	Unknown	Field Services - Charlotte	Composite Sampler #18-1115G	EQLIMS
Composite Sampler	Isco	3700	09078-115	Unknown	Unknown	Field Services - Charlotte	Composite Sampler #18-1115I	EQLIMS
Composite Sampler	Isco	3710	200B02589	Unknown	Unknown	Field Services - Charlotte	Composite Sampler #18-1115K	EQLIMS
Composite Sampler	Isco	2910	197M01047	Unknown	Unknown	Field Services - Charlotte	Composite Sampler #18-1115M	EQLIMS
Composite Sampler	Isco	2910	07983-001	Unknown	Unknown	Field Services - Charlotte	Composite Sampler #18-1115N	EQLIMS
Composite Sampler	Isco	2910	197B01220	Unknown	Unknown	Field Services - Charlotte	Composite Sampler #18-1115P	EQLIMS
Composite Sampler	Isco	3710	217J00432	Unknown	New	Field Services - Charlotte	Composite Sampler #18-1115Q	EQLIMS
Composite Sampler	Isco	3710	212I11172	Unknown	Used	Field Services - Charlotte	Composite Sampler #19-0122	EQLIMS
Conductivity Meter	YSI	32/11SPD	04IJ071BC	05/2007	Unknown	Field Services - Charlotte	Conductivity Meter #1-C	Software
DO Meter	YSI	Pro 20	11A100588	2006	Unknown	Field Services - Charlotte	DO Meter #1	EQLIMS
DO Meter	YSI	Pro 20	13A101442	01/2013	Unknown	Field Services - Charlotte	DO Meter #2	EQLIMS
Low Level TRC Meter	Hach	DR2700	1353696	03/29/2011	Unknown	Field Services - Charlotte	LL TRC Meter #1	Software

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Description	Manufacturer	Model	Serial Number	Service Date	Condition	Location	Internal ID	Location of Manual
Low Level TRC Meter	Hach	DR2800	1177995	Unknown	Used	Field Services - Charlotte	LL TRC Meter #2	Software
pH Meter	ThermoFisher Scientific	Orion Star A221	G07625	03/23/2016	New	Field Services - Charlotte	pH Meter #100	EQLIMS
pH Meter	ThermoFisher Scientific	Orion Star A221	K00642	Unknown	Unknown	Field Services - Charlotte	pH Meter #102	EQLIMS
pH Meter	ThermoFisher Scientific	Orion Star A221	H01668	Unknown	Unknown	Field Services - Charlotte	pH Meter #13-820	EQLIMS
pH Meter	ThermoFisher Scientific	Orion Star A321	G12116	11/21/2019	Unknown	Field Services - Charlotte	pH Meter #19-1121	EQLIMS
TRC Meter	Hach	Pocket Colorimeter II	40700019648	2002	Unknown	Field Services - Charlotte	TRC Meter #8	EQLIMS
TRC Meter	Hach	Pocket Colorimeter II	12070E203555	10/09/2012	Unknown	Field Services - Charlotte	TRC Meter #TRCM-1210A	EQLIMS
TRC Meter	Hach	Pocket Colorimeter II	12070E203545	10/09/2012	Unknown	Field Services - Charlotte	TRC Meter #TRCM-1210B	EQLIMS

7.5.3 PAS-WCOL [Greenville Service Center]

Description	Manufacturer	Model	Serial Number	Service Date	Condition	Location	Internal ID	Location of Manual
Composite Sampler	Isco	3710	216A00118	02/2016	New	Field Services - Greenville	Composite Sampler #16-0201	EQLIMS
Composite Sampler	Isco	3710	218B00157	Unknown	Unknown	Field Services - Greenville	Composite Sampler #18-1115R	EQLIMS

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Description	Manufacturer	Model	Serial Number	Service Date	Condition	Location	Internal ID	Location of Manual
Composite Sampler	Isco	3710	206D00712	Unknown	Unknown	Field Services - Greenville	Composite Sampler #18-1115S	EQLIMS
Composite Sampler	Isco	3710	214H00829	Unknown	Unknown	Field Services - Greenville	Composite Sampler #18-1115T	EQLIMS
Composite Sampler	Isco	3710	218B00159	Unknown	Unknown	Field Services - Greenville	Composite Sampler #18-1115U	EQLIMS
Composite Sampler	Isco	3710	218M00078	01/09/2019	New	Field Services - Greenville	Composite Sampler #19-0109A	EQLIMS
DO Meter	YSI	Pro 20	148104784	Unknown	Unknown	Field Services - Greenville	DO Meter #3	EQLIMS
pH Meter	ThermoFisher Scientific	Orion Star A221	K07028	12/02/2015	New	Field Services - Greenville	pH Meter #0215	EQLIMS
pH Meter	ThermoFisher Scientific	Orion Star A321	G09500	10/12/2017	New	Field Services - Greenville	pH Meter #103	EQLIMS
pH Meter	ThermoFisher Scientific	STARA3210	G11062	12/21/2018	New	Field Services - Greenville	pH Meter #18-1221A	EQLIMS
TRC Meter	Hach	Pocket Colorimeter II	15050E272953	01/07/2015	Unknown	Field Services - Greenville	TRC Meter #TRCM-0615	EQLIMS

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8.0 ADDENDUM: PROGRAM REQUIREMENTS

Program specific information provided in this addendum supplements the main body of this manual. Each subsection is stand-alone, meaning the requirements for the quality management system in each subsection only apply to the program referenced. Additionally, only program requirements for the quality management system that are more stringent than the content of the main body of the manual are included.

8.1 DoD/DOE

PAS-WCOL maintains accreditation for DoD/DoE Environmental Laboratory Approval Program (ELAP)

This addendum outlines additional policies and processes established by this laboratory to maintain compliance with DoD/DOE program specific requirements as outlined in the DoD/DOE Consolidated Quality Systems Manual (QSM) for Environmental Laboratories. The QSM incorporates ISO/IEC 17025 and the TNI Standard and includes additional program-specific requirements for laboratories that perform analytical testing services for DoD and DoE and which must be followed for DoD / DoE projects.

Section 4.2.5: Supporting Documents

Technical SOPs used for DoD/DoE testing must also include instructions for equipment and instrument maintenance, computer software/hardware, and troubleshooting.

The review frequency for technical SOPs used for DoD/DoE testing is annual, instead of every 2 years.

Section 4.4: Review of Analytical Service Requests

If the DoD/DoE customer requests a statement of conformity, the standard used for the decision rule must be communicated to and agreed on with the customer and identified in the final test report.

Laboratory requests to deviate from the requirements specified in the DoD/DoE QSM must be requested on a project-basis and include technical justifications for the deviation. These requests are submitted to and approved by the DoD/DoE project chemist or contractor, however name, in addition to the PAS client.

For DoD / DoE projects, will also seek clarification from the customer when the customer has requested an incorrect, obsolete or improper method for the intended use of data; the laboratory needs to depart from its test method SOP in order to meet project-specific data quality objectives; information in project planning documents is missing or is unclear,

Section 4.5: Subcontracting

In addition to written client approval of any subcontractor for testing, the customer is notified of the laboratory's intent to use a subcontractor for any management system element (such as data review, data processing, project management or IT support) and consent for subcontracting is obtained approved in writing by the DoD/DoE customer and record of consent kept in the project record.

Section 4.6: Purchasing and Supplies

The laboratory procedure for records of receipt of materials and supplies used in testing also include a specification to record the date opened (DoE only).

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Section 4.9.3: Nonconforming Work

The laboratory's procedure for client notification includes the 15-business day DoD /DOE timeframe for notification of the problem and the 30-business day timeframe for submission of the corrective action plan or corrective actions taken. This procedure also includes the DoD/DoE requirement for AB notification of discovery.

Section 4.13: Control of Records

Technical Records: The laboratory's procedure for logbooks includes measures to prevent the removal of or addition of pages to the logbook (applies to both hardcopy and electronic). Hardcopy logbooks are version controlled, pre-numbered and bound. Initials and entries and are signed or initialed and dated by the person making the entry and the entry is made at the time the activity is performed and in chronological order. Each page of the logbook must be closed by the last person making the entry on the page. Closure is recorded by the initial and date of the person making the last entry.

Section 5.4.5.3.3: Limit of Detection

For DoD/DOE the LOD is an estimate of the minimum amount of an analyte that can be reliably detected by an analytical process. For clarification, the LOD is the analyte concentration necessary to distinguish its presence from its absence. The LOD may be used as the lowest concentration for reliably reporting a non-detect (ND). The LOD is specific to each suite of analyte, matrix, and method including sample preparation.

After each DL determination, the laboratory establishes the LOD by spiking a quality system matrix at a concentration of least 2X but no greater than 4X the DL (i.e. 2X DL ≤ LOD Spike ≤ 4X DL). The spike concentration establishes the LOD and the concentration at which the LOD is verified.

The LOD is established during method validation and after major changes to the analytical system or procedure that affects sensitivity of analysis or how the procedure is performed.

An LOD study is not required for any component for which spiking solutions or quality control samples are not available. Additionally, an LOD study is not required if the laboratory does not report data below the LOQ.

The LOD must be verified on a quarterly basis. Each preparation method listed on the scope of accreditation must have quarterly LOD verifications; however, verification of all possible combinations of preparation and clean-up techniques is not required. Where LOD verifications are not performed on all combinations, the LOD verification is based on the worst-case combination (preparation method with all applicable cleanup steps).

The laboratory's procedure for LOD determination and verification is detailed in laboratory SOP *Method Validation* [QA Policy ME003BF].

Section 5.4.5.3.4: Limit of Quantitation

For DoD/DOE, the LOQ is established for each analyte-matrix-method combination, including surrogates. When an LOD is determined or verified by the laboratory, the LOQ must be above the LOD [DL<LOD<LOQ].

At a minimum, the LOQ must be verified quarterly; however, verification of all possible combinations of preparation and clean-up techniques is not required. Where LOQ verifications are not performed

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on all combinations, the LOQ verification on the worst-case combination (preparation method with all applicable cleanup steps).

The laboratory's procedure for LOQ determination and verification is detailed in laboratory SOP INSERT LOCAL SOP REFERENCE.

Section 5.4.7: Control of Data

The laboratory will assure LIMS passwords are changed at least once per year.

An audit of the LIMS will be incorporated into the laboratory's annual internal audit schedule.

The laboratory will have procedures in place to notify DoD/DoE customers of changes to LIMS software or hardware configurations that may impact the customer's integrity of electronic data

Section 5.9.1: Quality Control

For DoD/DOE, storage blanks are essential QC to monitor the storage of samples for volatile organic analysis (VOA). The laboratory's SOP for storage of VOA samples must include a contamination monitoring program based on the performance of storage blanks. (See QSM 5.3.3)

Section 5.8.5: Sample Disposal

For DoE projects, the record of disposal must also include how the sample was disposed and the name of the person that performed the task.

Appendix E: Support Equipment Calibration

Mechanical Volumetric Pipette: In addition to the quarterly verification check, pipettes used for DoD/DoE projects are checked daily before use using the same procedure and criteria specified for the quarterly check.

Water Purification System: The performance of the water purification system is checked daily prior to use in accordance with laboratory SOP *Deionized Water System and Storage Blank Testing* [QA SOP ME0012S].

Radiological Survey Equipment: The performance of the radiological survey equipment is checked daily prior to use in accordance with laboratory SOP *Sample Receiving* [AD SOP ME0013H].

Additional: (DoE): Section 6.0 of the QSM outlines additional management system requirements for the management of hazardous and radioactive materials management and health and safety practices. The laboratory, if approved for DoE, will work with the PAS Health and Safety Director to establish plans, policies and procedures that conform to these comprehensive specifications and incorporate these documents into the quality management system.

8.2 US EPA Contract Laboratory Program (US EPA CLP)

PAS-WCOL holds active CLP contracts for the analysis of multi-media, multi-concentration organic, metals, and inorganic non-metals compounds in water and solid samples by SOM, ISM, and SFAM methodologies. The purpose of this analytical service is to provide analytical data for use by the US EPA in support of the investigation and clean-up activities under the Comprehensive Environmental Response, Compensation, and Liability Action of 980 (CERCLA) and the Superfund Amendments and Reauthorization act of 1986 (SARA). Other EPA Program Offices, as well as customers outside of the EPA, may use this service where similar analytical data needs are required.

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This addendum outlines additional policies and processes established by this laboratory to maintain compliance with US EPA CLP specific requirements as outlined in the *EPA Contract Laboratory Program Statement of Work for Organic Superfund Methods* (SOW SOM) and *Inorganic Superfund Methods* (SOW ISM), as well as *Superfund Analytical Methods* (SFAM SOW). The EPA SOW provides a contractual framework for laboratories to perform analytical services and applies EPA CLP analytical methods for the isolation, detection, and quantitative measurement of target analytes in aqueous/water, soil/sediment, waste, and wipe samples. The analytical service contract provides the methods to be used and the specific contractual requirements by which the EPA will evaluate data. Specific technical requirements are outlined in individual method/analytical SOPs.

SOW Exhibit E Section 3.2 (A): Organization and Personnel

Please contact the laboratory for resumes of key personnel.

SOW Exhibit E Section 3.3.2: Revision Submissions (QM)

The Quality Manual must be amended and submitted to the recipient(s) identified in SOW Exhibit B – Reporting and Deliverables Requirements, Table 1 – Deliverable Schedule, within 14-days of the time when any one of the following circumstances occurs:

- The EPA modifies technical requirements of the Statement of Work or the contract;
- The EPA notifies the laboratory of deficiencies in the Quality Manual;
- The EPA notified the laboratory of deficiencies resulting from the EPA's review of the laboratory's performance;
- The laboratory identified changes in the organization, personnel, facility, equipment, policy, or procedures; or
- The laboratory identified deficiencies resulting from the internal review of their organization, personnel, facility, equipment, policy, procedure, or Quality Manual.

All changes must be clearly marked and the amended section pages must have the date on which the changes were implemented.

SOW Exhibit E Section 4.4.2: Revision Submissions (SOP)

SOPs must be amended and submitted to the recipient(s) identified in SOW Exhibit B – Reporting and Deliverables Requirements, Table 1 – Deliverable Schedule when any one of the following circumstances occurs:

- The EPA modifies the technical requirements of the SOW or the contract;
- The EPA notifies the laboratory of deficiencies in their SOP documentation;
- The EPA notifies the laboratory of deficiencies resulting from the EPA's review of the laboratory's performance;
- The laboratory's procedures change;
- The laboratory identifies deficiencies resulting from the internal review of SOP documentation; or
- The laboratory identifies deficiencies resulting from the internal review of procedures.

The laboratory shall amend and submitted revised or write and submit new SOPs within 14 days of when the circumstances listed above result in a discrepancy between what was previously described

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in the SOP and what is presently occurring at the laboratory. All changes must be clearly marked and the amended/new SOP shall have the date on which the changes were implemented. Documentation of the reason(s) for the changes must be submitted along with the SOP.

TEST METHOD STANDARD OPERATING PROCEDURE
TITLE: The Determination of Total Organic Carbon Using the Multi EA 4000 Instrument
TEST METHOD Lloyd Kahn
ISSUER: Pace ENV – Green Bay Quality – GBAY

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1.0 SCOPE AND APPLICATION

This standard operating procedure (SOP) describes the laboratory procedure for the determination of Total Organic Carbon (TOC) in solid and soil samples using the Multi EA4000 Instrument non-dispersive infrared detection (NDIR) by the Lloyd Kahn Method

1.1 Target Analyte List and Limits of Quantitation

The target analytes and the low-level standard that can be achieved with this procedure are provided in Table 1.

Table 1: Routine Analyte List and Limits of Quantitation (LOQ)[1]

Analyte	CAS#	Matrix	Solid LOQ (mg/Kg)
Total Organic Carbon	7440-44-0	Solid	100

[1] Values in place as of effective date of this SOP and are subject to change. For the most up to date LOQ, refer to the LIMS or contact the laboratory.

LOQ are established in accordance with Pace policy and SOPs for method validation and for the determination of detection limits (DL) and quantitation limits (LOQ). DL and LOQ are routinely verified and updated when needed. The current LOQ for each target analyte that can be determined by this SOP as of the effective date of this SOP is provided in Table 1.

The reporting limit (RL) is the value to which analytes are reported as detected or not detected in the final report. When the RL is less than the lower limit of quantitation (LLOQ), all detects and non-detects at the RL are qualitative. The LLOQ is the lowest point of the calibration curve used for each target analyte.

DL, LOQ, and RL are always adjusted to account for actual amounts used and for dilution.

2.0 SUMMARY OF METHOD

2.1 Inorganic carbon forms from carbonates and bicarbonates are removed by acid treatment and heating.

2.2 The sample is placed in a combustion furnace where it heats up to 1000°C. The product of the decomposed by pyrolysis is CO_2 gas.

2.3 The CO_2 that is formed is determined by direct non-dispersive infrared detection (NDIR). This measurement is proportional to the carbon in the sample.

3.0 INTERFERENCES

3.1 Carbonate and bicarbonate carbon represent interferences under the terms of this test and must be removed or accounted for in the final calculation.

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3.2 Volatile organics in the samples may be lost in the de-carbonation step, resulting in a low bias.

4.0 DEFINITIONS

Refer to the Laboratory Quality Manual for a glossary of common lab terms and definitions.

Total Carbon (TC): The measurement of all the carbon in the sample, both inorganic and organic.

Total Organic Carbon (TOC): All carbon atoms covalently bonded in organic molecules. To measure TOC, all the inorganic carbon is removed by addition of acid and purging: The result is that only organic carbon is left.

Total Inorganic Carbon (TIC): The measurement of the total inorganic carbon is found by subtracting the Total Organic Carbon from the Total Carbon. TIC = TC – TOC.

5.0 HEALTH AND SAFETY

The toxicity or carcinogenicity of each chemical material used in the laboratory has not been fully established. Each chemical should be regarded as a potential health hazard and exposure to these compounds should be as low as reasonably achievable.

The laboratory maintains documentation of hazard assessments and OSHA regulations regarding the safe handling of the chemicals specified in each method. Safety data sheets for all hazardous chemicals are available to all personnel. Employees must abide by the health, safety and environmental (HSE) policies and procedures specified in this SOP and in the Pace Chemical Hygiene / Safety Manual.

Personal protective equipment (PPE) such as safety glasses, gloves, and a laboratory coat must be worn in designated areas and while handling samples and chemical materials to protect against physical contact with samples that contain potentially hazardous chemicals and exposure to chemical materials used in the procedure.

Concentrated corrosives present additional hazards and are damaging to skin and mucus membranes. Use these acids in a fume hood whenever possible with additional PPE designed for handing these materials. If eye or skin contact occurs, flush with large volumes of water. When working with acids, always add acid to water to prevent violent reactions. Any processes that emit large volumes of solvents (evaporation/concentration processes) must be in a hood or apparatus that prevents employee exposure.

Contact your supervisor or local HSE coordinator with questions or concerns regarding safety protocol or safe handling procedures for this procedure.

6.0 SAMPLE COLLECTION, PRESERVATION, HOLDING TIME, AND STORAGE

Samples should be collected in accordance with a sampling plan and procedures appropriate to achieve the regulatory, scientific, and data quality objectives for the project.

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The laboratory does not perform sample collection or field measurements for this test method. To assure sample collection and field checks and treatment are performed in accordance with applicable regulations Pace project managers will inform the client of these requirements at the time of request for analytical services when the request for testing is received prior to sample collection. If samples were already collected, the laboratory will record any nonconformance to these requirements in the laboratory's sample receipt record when sufficient information about sample collection is provided with the samples.

The laboratory will provide containers for the collection of samples upon client request for analytical services. Bottle kits are prepared in accordance with the laboratory SOP ENV-SOP-GBAY-0007 *Bottle Preparation*.

General Requirements

Matrix	Routine Container	Minimum Sample Amount[1]	Preservation	Holding Time
Solid	Clean Amber Glass	Minimum of 4 oz	Thermal: ≤6°C Chemical: None	Collection to Analysis: 14 days

[1]*Minimum amount needed for each discrete analysis.*

Thermal preservation is checked and recorded on receipt in the laboratory in accordance with the laboratory SOP ENV-SOP-GBAY-0006 *Sample Management and Review of Analytical Requests*. Chemical preservation is checked and recorded at time of receipt or prior to sample preparation.

After analysis, unless otherwise specified in the analytical services contract, samples are retained for 21 days from date of final report and then disposed of in accordance with Federal, State, and Local regulations.

7.0 EQUIPMENT AND SUPPLIES

7.1 Equipment

Equipment	Manufacturer/Vendor	Model/Catalog#
TOC Analyzer	Analytikjena	EA4000 with NDIR detector
Autosampler	Analytikjena	TIC Solid Module
Top loading Analytical Balance	Mettler	BA310P
Vented Fume Hood	Hamilton	Fisher
Mechanical Pipette 1.0-5.0 mL	Gilson Pipetman L/Fisher	FA10007G
Mechanical Pipette 100-1,000 µL	Eppendorf Research plus/Fisher	13-690-032 / 3123000063
Mortar and Pestle (500 mL)	Fisher	S337641
Drying Oven	Yamato	DKN600

Or Equivalent

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7.2 Supplies

Supplies	Manufacturer	Catalog number
Ceramic Sampling Boats	Analytikjena	886.130
100 mL Volumetric flasks (class A)	Fisherbrand	10-205C
500 mL Volumetric flasks (class A)	Fisherbrand	10-205E
1000 mL Volumetric flasks (class A)	Fisherbrand	10-205F
2000 mL Volumetric flasks (class A)	Fisherbrand	FB4002000
Pipette Tips 1.0-5.0 mL	Unifit National Scientific/MG Scientific	NUN05ME-BP
Pipette Tips 100-1,250 µL	Fisherbrand SureOne BT	02-707-400
Disposable Transfer Pipettes	Fisherbrand	13-711-9AM
Spoonula (Lab Spoon)	Fisherbrand	14-375-10
Gloves – Heat Resistant	Fisher	17-400-122

Or Equivalent

8.0 REAGENTS AND STANDARDS

8.1 Reagents and Stock Standards

Standard / Reagent	Alias	Purchased From	Catalog Number	Concentration / Purity	Expiration	Storage
NanoPure® Water	Water	In House	NA	ASTM Type I, ≥18 Mega ohm	Generated for use	Room Temp
Hydrochloric Acid	Conc. HCl	JT Baker	9530-33	36-38%	1 year from open	
Compressed Oxygen	O_2	Airgas	UN1072	Ultra High Purity (UHP)	1 year from open	
Primary Stock Standard	1° $CaCO_3$	Ricca Chemical	RDCC0050-500B1	120 g/kg C	5 years from receipt	
Secondary Stock Standard	2° $CaCO_3$	Fisher Scientific	C64-500	120 g/kg C		
Potassium Hydrogen Phthalate*	KHP	EMD	PX1476-3	470.5 g/kg C		
Sand - SiO_2	Sigma	Sigma-Aldrich	S5631-1KG	0.0 g/kg C		

Or Equivalent
*KHP is ground with mortar and pestle and passed through a 60M sieve. Neat standards are dried in oven at 75°C for 1 hour prior to blending/storing in desiccator

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8.2 Working Standards

Standard / Reagent	Alias	Stock or Intermediate	Amount Used	Final Volume (W/Diluent)	Diluent	Final Concentration	Expiration	Storage
10% Hydrochloric Acid	10% HCl	36-38% HCl	20 mL	80 mL	Water	10%	6 months	Room Temp
Primary Source CaCO3/SiO2 Blend **	1°	1° $CaCO_3$	1.000g	6.000g	Sigma - SiO_2	20 g/kg TOC	1 year	Desiccator
Secondary CaCO3/SiO2 Blend**	2°	2° $CaCO_3$	1.000g	6.000g	Sigma - SiO_2	20 g/kg TOC		
$KHP/CaCO_3/SiO_2$ Blend	Secondary Spike	KHP	0.0426g	10.000g	5.9g of Sigma	2.944 g/Kg TC 2.0 g/Kg OC 0.944 g/Kg IC		
		$CaCO_3$	0.0787g		3.9788g of Acros			
Level 0 Calibration Standard, Initial Calibration Blank, Continuing Calibration Blank, Method Blank	CAL0 ICB CCB MB	1° $CaCO_3$	0.0 mg	1,000 mg	Ceramic Boat	0 mg/kg		
Level 1 Calibration Standard and Reporting Limit Verification Standard	CAL1 CRDL	1° $CaCO_3$	5.0 mg	1,000 mg		100 mg/kg		
Level 2 Calibration Standard	CAL2	1° $CaCO_3$	10 mg	1,000 mg		200 mg/kg		
Level 3 Calibration Standard	CAL3	1° $CaCO_3$	50 mg	1,000 mg		1000 mg/kg		
Level 4 Calibration Standard and Continuing Calibration Verification Standard	CAL4 CCV	1° $CaCO_3$	100 mg	1,000 mg		2,000 mg/kg		
Level 5 Calibration Standard	CAL5	1° $CaCO_3$	200 mg	1,000 mg		4,000 mg/kg		
Initial Calibration Verification Standard	ICV	2° $CaCO_3$	100 mg	1,000 mg		2,000 mg/kg		
Laboratory Control Spike	LCS	Secondary Spike	500 mg	1,000 mg		1,000 mg/kg		
Matrix Control Spike/Matrix Control Spike Duplicate	MS MSD	Secondary Spike	250 mg	1,000 mg		500 mg/kg		
IC Check (acidified)	IC Check	2° $CaCO_3$	50 mg	1,000 mg		0 mg/kg		

9.0 PROCEDURE

9.1 Equipment Preparation

9.1.1 Support Equipment

All support equipment used must be calibrated or verified prior to use according to SOP ENV-SOP-GBAY-0115 *Support Equipment and Monitoring of Storage Units.*

9.1.2 Instrument

9.1.2.1 Routine Instrument Operating Conditions

9.1.2.1.1 All instruments maintained per manufacturer's recommendations.

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9.1.2.1.2 Turn on the Furnace unit, main power switch and the Compressed Oxygen.

9.1.2.1.3 EnterMultiWin software through its icon.

9.1.2.1.4 *Activating the instrument.* After software is open, initialize analyzer to start furnace.

9.1.2.1.5 *Each analysis is performed as follows:*

1. Select “Start Measurement” box on main screen. Click on the Plus sign on top and type in a name for the Analysis Group, click OK
2. Select Analysis Group that was created in the right hand column and select OK box at the bottom
3. Enter the Sample names in the “Name” box, and enter the weights in mg in the “Sequence entry” tab on the bottom
4. After all samples are entered, click the checkmark icon on top to activate samples and hit OK
5. When prompted to save under different name, click “Yes” and enter in a name. To load dried samples, return to Sequence > Analysis sequence > Edit to be able to rotate autosampler. To rotate the autosampler, use the blue arrow icons on the top right of toolbar
6. When the temperature is within range, the pump will start. Click the “Start Measurement” button to begin
7. To edit sequence at any time, return to Analysis Sequence edit screen and adjust accordingly.

9.2 Initial Calibration

To perform quantitative measurements, an initial calibration must be established before the analysis of samples. An initial calibration is an evaluation of the relationship between response of the instrument (or process) and the concentration of the target analyte.

All samples, where applicable, must be associated with an acceptable initial calibration. In general, if an initial calibration is not acceptable, corrective actions must be performed and all associated samples reanalyzed. An outlier within the calibration range may be replaced by reanalyzing the calibration curve. If the curve is still not acceptable, find the root cause, correct the problem(s), and reanalyze the curve. If the samples reanalysis is not possible, data associated with an unacceptable initial calibration must be reported with appropriate qualifiers.

9.2.1 Calibration Design

Our practice is to prepare a new calibration curve yearly at minimum, or whenever the continuing calibration standard does not pass control criteria. No injections can be used if they are above the calibration curve. If a sample exceeds the upper end of the calibration curve, a smaller volume of sample must be used and the analysis re-performed.

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9.2.1.1 *Setting up a new curve*

1. First select the method being used by going to Method > Method-Activate if desired method not already in use
2. Then go to Sequence > Calibration-Sequence > New. Click “Next” on method showing, change Sequence Name if desired and hit “Next.”
3. Click “Next” to leave Rack selection and first position at defaults
4. Change calibration points to 5 with constant concentration, then click “Next.”
5. Select the box to measure Boat Blank, hit “Next.”
6. Change nominal value to 120 g/Kg, then hit “OK.”
7. Enter in the exact weights for corresponding IDs, set the boats in the matching number slots on the autosampler, and click the icon on the top with the green checkmark to activate the samples, then hit “OK.”
8. When the temperature is within 50 points of method requirements, the pump will kick in allowing you to hit the Start button to begin

9.2.1.2 *Activating the New Curve*

1. When finished, the window will pop up showing results for each point. Select the points to be used and verify the linear regression for the µg C has a corresponding correlation coefficient ≥ 0.995
2. The software plots the CAL1 through CAL5 standards using µg C (m-Nominal) versus Integral (I-Net in Area Units (AU)) minus the CAL0
3. Under the Parameter tab for the calibration run, select the Link with Method button, when prompted “Link with the calibration method?” select “Yes” Hit “Accept” at the bottom of the next screen
4. Click Close, the calibration is saved and active
5. If a previous calibration range is still showing as part of the new calibration
   a. Go to Method > Edit
   b. Click the Plus sign on the top, then select the “Calibration Data” tab. Click on “Edit” and delete the portions of this curve that are from the previous curve
   c. Finish by clicking “Accept” at the bottom of the window

9.2.1.3 *Running the New Curve*. To run the curve desired, go to Method > Activate and select the method. The new curve should already be linked.

9.2.1.4 *Initial Calibration QC*

1. Select Start Measurement box on main screen. Click the Plus sign icon on top and type in a name for the “Analysis Group”, then click OK
2. Select Analysis Group that was created in the right-hand column and click the OK box at the bottom
3. Enter the Sample names in the “Name” box, and enter the weights in mg in the “Sequence entry” tab on the bottom
4. After all samples are entered, hit the checkmark icon on top to activate samples and click OK

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5. When prompted to save under different name, click “Yes” and enter in a name
6. To load samples, return to Sequence > Analysis sequence > Edit to be able to rotate autosampler
7. To rotate the autosampler, use the blue arrow icons on the top right of toolbar
8. When the temperature is within range, the pump will start. Click the Start Measurement button to begin
9. To edit sequence at any time, return to Analysis Sequence edit screen and adjust accordingly

9.2.1.5 The calibration report and all analyses should be printed to the paperless drive (40WTAA or 40WTAG) with all standards traced back to COA.

9.2.2 Calibration Sequence

Standard ID	Volume (mg)	Concentration (g/kg C)	Method ID	µg C (m-Nominal)
CAL0	0	20	TC	0
CAL1	5	20	TC	100
CAL2	10	20	TC	200
CAL3	50	20	TC	1,000
CAL4	100	20	TC	2,000
CAL5	200	20	TC	4,000

9.2.3 ICAL Evaluation

9.2.3.1 Curve Fit

A linear regression – Refer to Appendix A for details.

9.2.3.2 Relative Standard Error (RSE)

Each time the method is calibrated, the RSE is determined at a low point and midpoint of the calibration curve. See table in Appendix A for acceptability.

9.2.3.3 Initial Calibration Verification

A second source standard is analyzed following the ICAL. See Appendix A for acceptability.

9.2.3.4 Continuing Calibration Verification

A midpoint CCV is analyzed every 10 environmental sample, and at the end of the analytical batch. See table in Appendix A for acceptability

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9.3 Sample Preparation

9.3.1 Homogenization and Subsampling

See SOP-ENV-SOP-GBAY-0129 *Sample Homogenization, Compositing and Sub-Sampling.* Soil samples that are collected in regulated domestic areas or that are of foreign origin must be handled in accordance with SOP ENV-SOP-GBAY-0121 *Regulated Soil Handling.*

9.3.2 Soil Sample Preparation

9.3.2.1 Weigh the sample directly into a combustion boat and note the weight into the rack table.

9.3.2.2 Add 10% HCl drop by drop until no further reaction occurs to each pre-weighted sample. Add 2 additional drops to verify the reaction is complete.

9.3.2.3 Dry the samples in the oven at 75°C to remove excess moisture and HCl.

9.4 Analysis

9.4.1 Example Analytical Sequence

9.4.1.1 *CCV Analysis:* Weigh 100 mg of CAL4 (Primary source CCV standard) in ceramic boat and load into the autosampler. Enter the exact weight into the software program.

9.4.1.2 *CCB Analysis:* Place a blank (empty) boat on the autosampler and enter the weight 1000 mg (the maximum weight used).

9.4.1.3 *CRDL Analysis:* Run a Reporting Limit Verification Standard (CRDL) at the beginning of each batch before the MB/LCS by weighing 5 mg of primary standard.

9.4.1.4 *IC Check:* Run after the ICV/ICB/CRDL and at the beginning of a schedule after the initial CCV/CCB. Prepare by weighing 50 mg of secondary source $CaCO_3$, adding acid and drying in the oven with samples prepped to be run.

9.4.1.5 Batch QC:

9.4.1.5.1 When running a Method Blank (MB), add acid to a blank boat and enter 1000 mg.

9.4.1.5.2 A Laboratory Control Spike (LCS) is run by weighing 500 mg of the blended standard.

9.4.1.5.3 Matrix Spike / Matrix Spike Duplicate (MS/MSD) are run by adding 250 mg of the blended standard along with a variable weight of the parent sample for each the MS and MSD.

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9.4.1.5.4 Batch QC boats are then acidified and dried like samples.

9.4.1.6 *Samples:* For each field sample in an analytical batch weigh 1 g or less into the boat. 1.0000 g must be utilized to determine that the sample concentration is less than the reporting limit. Run a CCV/CCB every 10 samples and at the end of the run.

9.4.1.7 While running samples, no injections can be used if they are above the high point in the calibration curve. If an injection is above the curve, weigh out a smaller amount of the sample and reanalyze the injection.

9.4.1.8 If a sample was diluted due to matrix effects and the result is a non-detect, the result must be qualified with appropriate data qualifier.

9.4.1.9 *Continuing Analytical QC:* Run a CCV/CCB every 10 samples and at the end of the run.

9.4.1.10 *Printing data:* When the run is complete, the results will open. Select the samples desired to print and click the print icon. This will print the summary of each rep. Each file selected can be printed separately giving a detailed analysis by double clicking the individual sample, then clicking the print icon.

9.4.1.11 *Shutdown* - Turn off the furnace unit, main power switch, and the Compressed Oxygen.

10.0 DATA ANALYSIS AND CALCULATIONS

10.1 Qualitative Identification

Not applicable to this SOP

10.2 Quantitative Identification

The instrument software is used to quantify. All data produced by the EA4000 must be processed through the appropriate curve.

10.3 Calculations

See SOP ENV-SOP-GBAY-0153 *Lab Calculations* for equations for common calculations.

$$c = (k1 * I + k0) / V$$

Where:

c = the final concentration (mg/kg)
k0 and k1 = constants derived from the calibration curve
I = the integral area units
V = the sample volume (mg)

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10.4 Final concentration is exported to LIMSLink where it is back calculated to get the posted LIMSLink value.

$$\text{Final Concentration (mg/kg)} \times \left(\frac{\text{Initial weight (mg)}}{\text{1000 (mg)}}\right) = \text{posted LIMSLink value (mg)}$$

10.5 Calculations in LIMS

Soil:

$$\text{LIMSLink result (mg)} \times \left(\frac{\text{1000 (mg)}}{\text{Sample weight (g)}}\right) = \text{TOC (mg/Kg) (TOC1)}$$

10.6 The result in mg/kg is divided by 10,000 to express the result as a percentage (%w/w).

10.7 Precision Control Sample average result calculation as mg/kg:

$$\text{Mean result of 4 Injections} = ((TOC1) + (TOC2) + (TOC3) + (TOC4))/4$$

10.8 Std Deviation = $\sqrt{(((TOC1\text{-}Mean)^2+(TOC2\text{-}Mean)^2+(TOC3\text{-}Mean)^2+(TOC4\text{-}Mean)^2)/3}$

10.9 Relative Standard Deviation = (Standard Deviation/Mean)*100

10.10 MS/MSD calculation

$$\%\ \text{Recovery} = \left(\frac{(SSR - SR)}{SA}\right) \times 100$$

Where:

SSR = Spike sample result

SR = Sample result

SA = Spike added

10.11 Precision (for QC samples):

The precision is calculated based on the % recovery of the matrix spike / matrix spike duplicate (MS/MSD) result.

$$\text{QC Sample \% RPD} = \left(\frac{|MS\text{-}MSD|}{(MS+MSD)/2}\right) \times 100$$

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11.0 QUALITY CONTROL AND METHOD PERFORMANCE

11.1 Quality Control

The following QC samples are prepared and analyzed with each batch of samples. Refer to Appendix A for acceptance criteria and required corrective action.

QC Item	Frequency
Method Blank (MB)	1 per batch of 20 or fewer samples. If batch exceeds, 20 samples, every 20.
Laboratory Control Sample (LCS)	1 per batch of 20 or fewer samples. If batch exceeds, 20 samples, every 20.
Laboratory Control Sample Duplicate (LCSD)	As needed

11.2 Instrument QC

The following Instrument QC checks are performed. Refer to Appendix B for acceptance criteria and required corrective action.

QC Item	Frequency
Initial Calibration	Annually or when QC is no longer passes acceptance criteria, whichever is sooner
Initial Calibration Verification	Immediately after each initial calibration
Initial Calibration Blank	Immediately after each initial calibration
Continuing Calibration Verification	Prior to the analysis of any samples and after every 10 injections thereafter. Samples must be bracketed with a closing CCV standard.
Continuing Calibration Blank	Following every CCV injection

11.2.1 Calibration Blanks – Initial Calibration Blank (ICB) and Continuing Calibration Blank (CCB)

All analyses which detect Integral Area Units (AU) less than the Integral (AU) in the CAL0 of the calibration curve will result in an Integral Area Unit (AU) of 0 “B!”. The B! signifies this on the Analyses Table raw data print-out.

11.3 Method Performance

11.3.1 Method Validation

11.3.1.1 Detection Limits

Detection limits (DL) and limits of quantitation (LOQ) are established at initial method setup and verified on an on-going basis thereafter. Refer to Pace ENV corporate SOP ENV-SOP-CORQ-0011 *Method Validation and Instrument Verification* and to the laboratory’s SOP ENV-SOP-GBAY-0106 *Determination of LOD and LOQ* for these procedures.

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11.4 Analyst Qualifications and Training

Employees that perform any step of this procedure must have a completed Read and Acknowledgment Statement for this version of the SOP in their training record. In addition, prior to unsupervised (independent) work on any client sample, analysts that prepare or analyze samples must have successful initial demonstration of capability (IDOC) and must successfully demonstrate on-going proficiency on an annual basis. Successful means the initial and on-going DOC met criteria, documentation of the DOC is complete, and the DOC record is in the employee's training file. Refer to the SOP ENV-SOP-GBAY-0094 *Orientation and Training Procedures* for more information.

12.0 DATA REVIEW AND CORRECTIVE ACTION

12.1 Data Review

Pace's data review process includes a series of checks performed at different stages of the analytical process by different people to ensure that SOPs were followed, the analytical record is complete and properly documented, proper corrective actions were taken for QC failure and other nonconformance(s), and that test results are reported with proper qualification.

The review steps and checks that occur as employee's complete tasks and review their own work is called primary review.

All data and results are also reviewed by an experienced peer or supervisor. Secondary review is performed to verify SOPs were followed, that calibration, instrument performance, and QC criteria were met and/or proper corrective actions were taken, qualitative ID and quantitative measurement is accurate, all manual integrations are justified and documented in accordance with the Pace ENV's SOP for manual integration, calculations are correct, the analytical record is complete and traceable, and that results are properly qualified.

A third-level review, called a completeness check, is performed by reporting or project management staff to verify the data report is not missing information and project specifications were met.

Refer to the SOP ENV-SOP-GBAY-0120 *Data Review and Final Report Processes* for specific instructions and requirements for each step of the data review process.

12.2 Corrective Action

Corrective action is expected any time QC or sample results are not within acceptance criteria. If corrective action is not taken or was not successful, the decision/outcome must be documented in the analytical record. The primary analyst has primary responsibility for taking corrective action when QA/QC criteria are not met. Secondary data reviewers must verify that appropriate action was taken and/or that results reported with QC failure are properly qualified.

Corrective action is also required when carryover is suspected and when results are over range.

Samples analyzed after a high concentration sample must be checked for carryover and reanalyzed if carryover is suspected. Carryover is usually indicated by low concentration detects of the analyte in successive samples analyzed after the high concentration sample.

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Sample results at concentrations above the upper limit of quantitation must be diluted and reanalyzed. The result in the diluted samples should be within the upper half of the calibration range. Results less than the mid-range of the calibration indicate the sample was over diluted and analysis should be repeated with a lower level of dilution. If dilution is not performed, any result reported above the upper range is considered a qualitative measurement and must be qualified as an estimated value.

Refer to Appendix A for a complete summary of QC, acceptance criteria, and recommended corrective actions for QC associated with this test method.

If a sample was diluted due to matrix effects and the result is non-detect, the result must be flagged with the appropriate qualifier.

13.0 POLLUTION PREVENTION AND WASTE MANAGEMENT

Pace proactively seeks ways to minimize waste generated during our work processes. Some examples of pollution prevention include but are not limited to: reduced solvent extraction, solvent capture, use of reusable cycletainers for solvent management, and real-time purchasing.

The EPA requires that laboratory waste management practice to be conducted consistent with all applicable federal and state laws and regulations. Excess reagents, samples and method process wastes must be characterized and disposed of in an acceptable manner in accordance with Pace's Chemical Hygiene Plan / Safety Manual.

14.0 MODIFICATIONS

A modification is a change to a reference test method made by the laboratory. For example, changes in stoichiometry, technology, quantitation ions, reagent or solvent volumes, reducing digestion or extraction times, instrument runtimes, etc. are all examples of modifications. Refer to Pace ENV corporate SOP ENV-SOP-CORQ-0011 *Method Validation and Instrument Verification* for the conditions under which the procedures in test method SOPs may be modified and for the procedure and document requirements.

The 15 analysis Lloyd Kahn RSD study has been performed and is included. When this study results in 3 times the standard deviation exceeding 40%, then 40% will be used as the acceptance criteria. This is tighter than the how the limits are created based on the Lloyd Kahn Method.

Hydrochloric acid is used in this SOP instead of 1:1 phosphoric acid.

The 1:1 phosphoric acid did not dry when heated to 75°C or at more elevated temperatures of 105°C. Liquid residue was present after 24 hours of heating.

Hydrochloric acid is recommended by the instrument manufacturer.

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15.0 RESPONSIBILITIES

Pace ENV employees that perform any part this procedure in their work activities must have a signed Read and Acknowledgement Statement in their training file for this version of the SOP. The employee is responsible for following the procedures in this SOP and handling temporary departures from this SOP in accordance with Pace's policy for temporary departure.

Pace supervisors/managers are responsible for training employees on the procedures in this SOP and monitoring the implementation of this SOP in their work area.

16.0 ATTACHMENTS

Appendix A: QC Summary

Attachment I: Precision Control Study

Attachment II: Flowchart

17.0 REFERENCES

17.1 Pace® – Green Bay, WI Quality Assurance Manual .

17.2 The NELAC Institute (TNI); Volume 1, Module 2, Quality Systems – current version.

17.3 Determination of Total Organic Carbon in Sediment by Lloyd Kahn Method, July 27, 1988.

17.4 USEPA Test Methods for Evaluating Solid Wastes, SW 846, 3rd Edition, Methods 9060A.

17.5 Multi EA4000 Operation Manual.

18.0 REVISION HISTORY

This Version: ENV-SOP-GBAY-0051-Rev.02

Section	Description of Change
All	Updated to Corporate template
9.2.1	Clarified wording for calibration
9.4.1.6	Clarified wording for sample weight
10.3	Corrected to new Lab Calculations SOP

This document supersedes the following document(s):

Document Number	Title	Version
ENV-SOP-GBAY-0051	EA4000 TOC-Lloyd Kahn_Solids	Rev.00
ENV-SOP-GBAY-0051	EA4000 TOC-Lloyd Kahn_Solids	Rev.01

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Appendix A: QC Summary

QC Item	Frequency	Acceptance Criteria	Corrective Action	Qualification
ICAL	At instrument set up, after CCV failure, or max 1 year	r ≥ 0.995 Standard at or below the reporting limit must recover at 60-140% of the true value. All other standards: %RE 90-110%	Perform maintenance and repeat ICAL.	None. Do not proceed with analysis.
ICV	After Each ICAL, prepared from second source standard at or near the mid-range of calibration curve	90-110% of the true value	Identify source of problem, re-analyze. If repeat failure, repeat ICAL. Analysis may proceed if it can be demonstrated that the ICV exceedance has no impact on analytical measurements. For example, the ICV %R is high, CCV is within criteria, and the analyte is not detected in sample(s).	None. Do not proceed with analysis.
ICB	Immediately after the initial Calibration verification	Result must be less than the absolute value of the Reporting Limit (LOQ).	If the absolute value exceeds the criteria, identify source of problem, correct or reanalyze. If the second analysis is also above the acceptance limit, the cause of the blank failure must be investigated, perform maintenance and recalibrate, and all bracketed samples must be reanalyzed. ***Exception:*** If all samples are non-detect or at least 10x the concentration of the failing result, the sample data may be reported, samples that have no detections may be reported unqualified if the blank measurement is high.	None. Do not proceed with analysis.
CCV	Daily, before sample analysis, after every 10, and at end of analytical window, prepared from same source standard as the calibration curve	90-110% of the true value	Identify source of problem, correct or re-analyze. If repeat failure, perform maintenance and repeat ICAL. All bracketed samples must be reanalyzed.	None. Do not proceed with analysis.
CCB	Immediately following every and CCV.	Result must be less than the absolute value of the Reporting Limit (LOQ).	If the absolute value exceeds the criteria, identify source of problem, correct or reanalyze. If the second analysis is also above the acceptance limit, the cause of the blank failure must be investigated, perform maintenance and recalibrate, and all bracketed samples must be reanalyzed. ***Exception:*** If all the bracketed samples are non-detect or at least 10x the concentration of the failing result, the sample data may be reported, samples that have no detections may be reported unqualified if the blank measurement is high.	Qualify outages and explain in case narrative.

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CRDL	After calibration and then after CCV/CCB of each new batch	60-140% of the true value	Identify source of problem, correct or reanalyze. If the second analysis fails, perform maintenance and recalibrate, and reanalyze all samples back to the last acceptable CRDL.	Recalibrate and reanalyze all samples back to the last acceptable CRDL.
Method Blank (acidified ceramic boat)	Once per batch of up to 20 samples carried through all preparation procedures, for samples that are leached the leach blank is used for the MB.	The absolute value of the MB must be less the LOQ. For samples reporting down to the LOD, the MB measurements are evaluated to the LOD. In these cases, qualify applicable samples for MB measurements from >LOD to <LOQ.	Identify source of problem, correct or re-analyze. If the re-analysis fails, reject all associated sample data, recalibrate the instrument and re-analyze the batch. If sufficient sample and hold time available, re-prep samples. ***Exceptions:*** If associated samples are non-detect or >10x MB detect, the sample data may be reported; If sample result <10x MB detect and sample cannot be reanalyzed, report sample with appropriate qualifier on each of the samples associated with the non-compliant MB. Contact PM regarding occurrence.	Qualify Outages – Positive MB measurements, apply a B data qualifier to the analyte; B = "Analyte was detected in the associated method blank". Negative MB measurement, apply hand entered qualifier and explain in case narrative: "Analyte was measured in the associated method blank at a concentration of -#.# units".
LCS	One LCS per batch of up to 20 samples. Analyze an LCSD if there is insufficient sample volume to perform a MS/MSD or if the clients request one.	80-120% of the true laboratory derived limits Value; Precision between LCS and LCSD is ≤20%	Identify source of problem, correct or re-analyze. If the re-analysis fails, reject all associated sample data, recalibrate the instrument and re-analyze the batch. If sufficient sample and hold time available, re-prep the LCS/LCSD and samples. If it still fails, contact the PM. If insufficient sample, report with appropriate qualifier and contact the PM.	Qualify outages and explain in case narrative.
MS/MSD	One MS/MSD pair per 10 samples with a minimum of one pair per batch. Sample determined by client or chosen at random. No field, trip, or equipment blanks should be used.	80-120% of the true laboratory derived limits Value; Precision between MS and MSD is ≤20%	Identify source of problem and correct. If no errors are found, flag the parent with appropriate qualifier. If concentration of the spike is less than 25% of the concentration of the parent, the MS/MSD recoveries are not evaluated. Any failures are reported with appropriate qualifier.	Qualify outages with appropriate qualifier.
Sample Duplicate	If requested by client, 5% or one per batch if less than 20 samples.	Precision between sample and Dup is ≤20%	Identify source of problem and correct. If no errors are found, flag the parent with appropriate qualifier	Qualify outages with appropriate qualifier.
Inorganic Carbon Check	After the ICV/ICB/CRDL and following the initial CCV/CCB in each analytical sequence.	<LOQ	Identify source of problem, correct or re-analyze. If the re-analysis fails, recalibrate and reanalyze all affected samples.	None. Do not proceed with analysis.

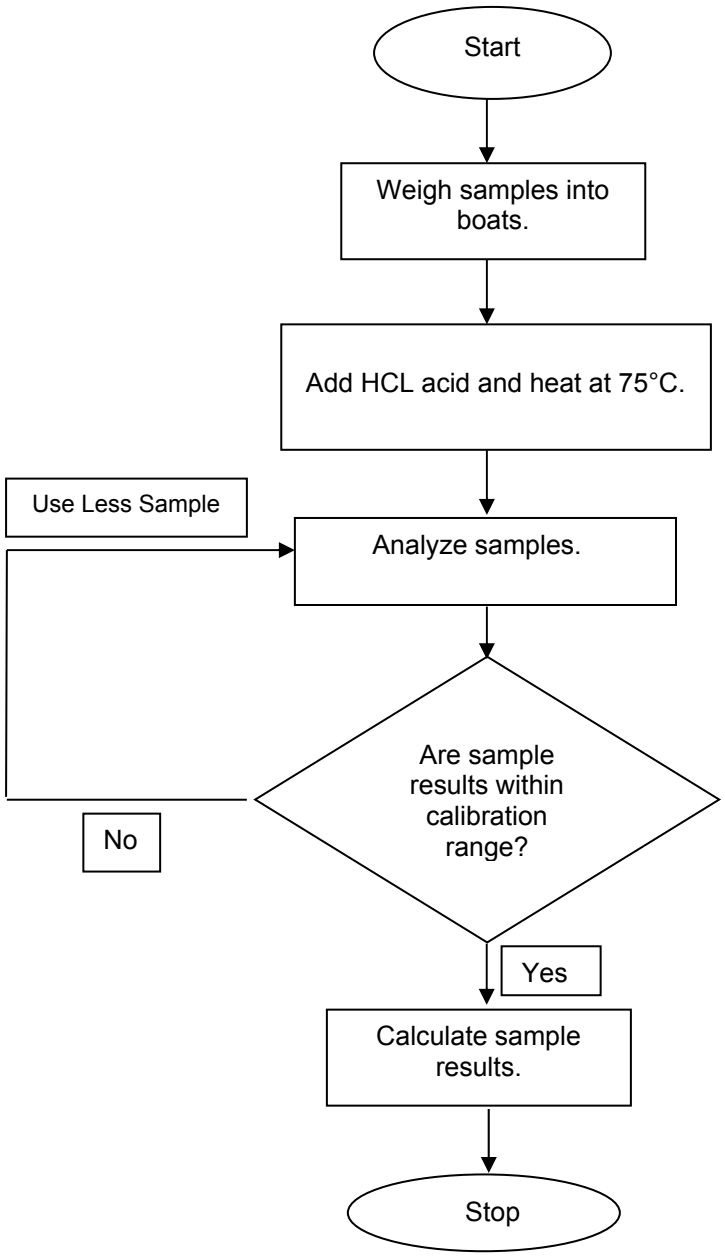
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Attachment I: Precision Control Study

Sample ID	Result mg/Kg
REP 1	18639
REP 2	12215
REP 3	19669
REP 4	23486
REP 5	26832
REP 6	17037
REP 7	21269
REP 8	28646
REP 9	25435
REP 10	31628
REP 11	25059
REP 12	26506
REP 13	22003
REP 14	30472
REP 15	15831
Average	22982
Standard Deviation	5587
3 x STD	16761
RSD	24.3%
3 x RSD	72.9%

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Attachment II: Flowchart



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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.

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.*

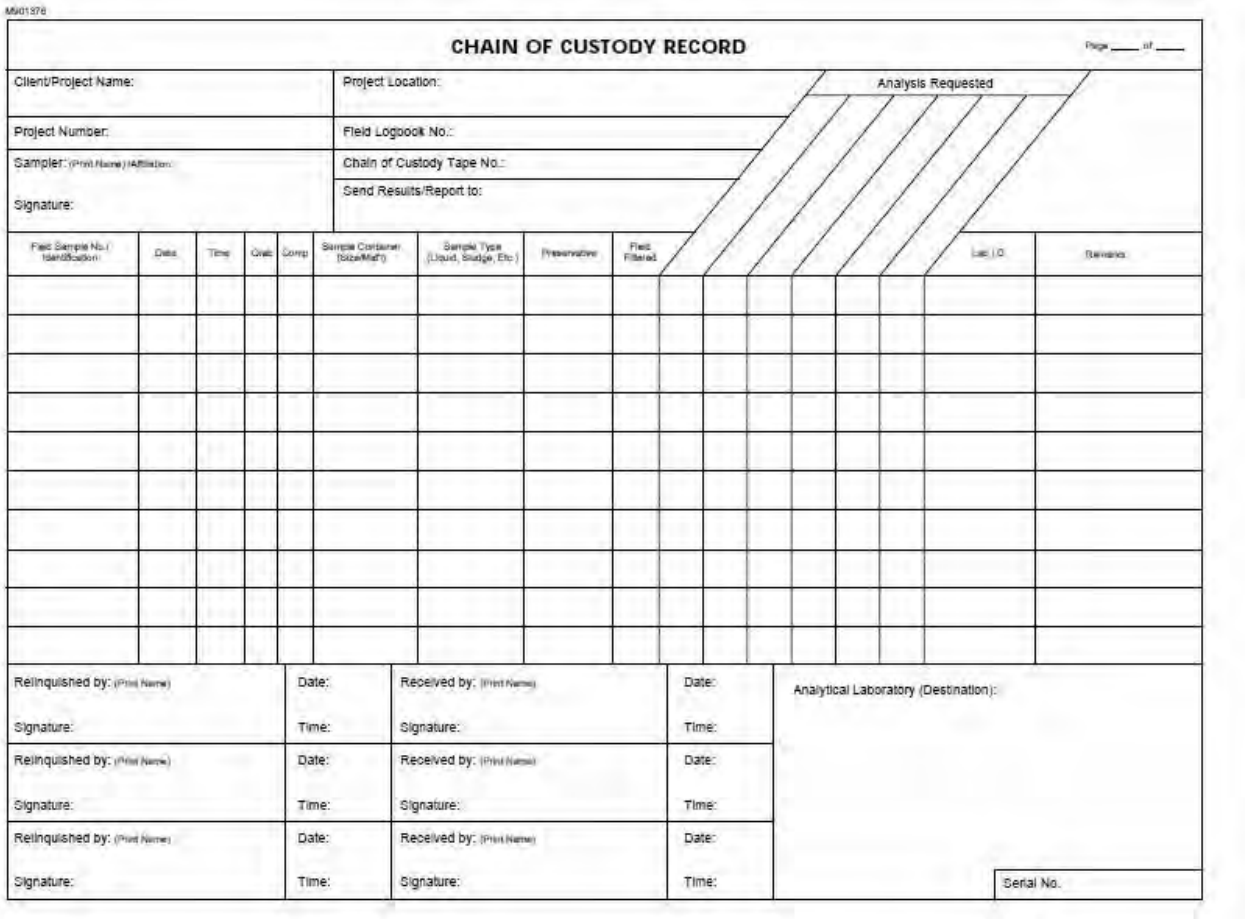
Author	Reviewer	Revisions (Technical or Editorial)
Mark Kromis Program Chemist	Chris Barr Program Quality Manager	Rev 0 – Initial Issue
Ken O'Donnell, PG Geologist	Claire Mitchell, PE, PMP Senior Engineer	Rev 1 – PFAS sampling update (July 2019)

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



MW01376

CHAIN OF CUSTODY RECORD

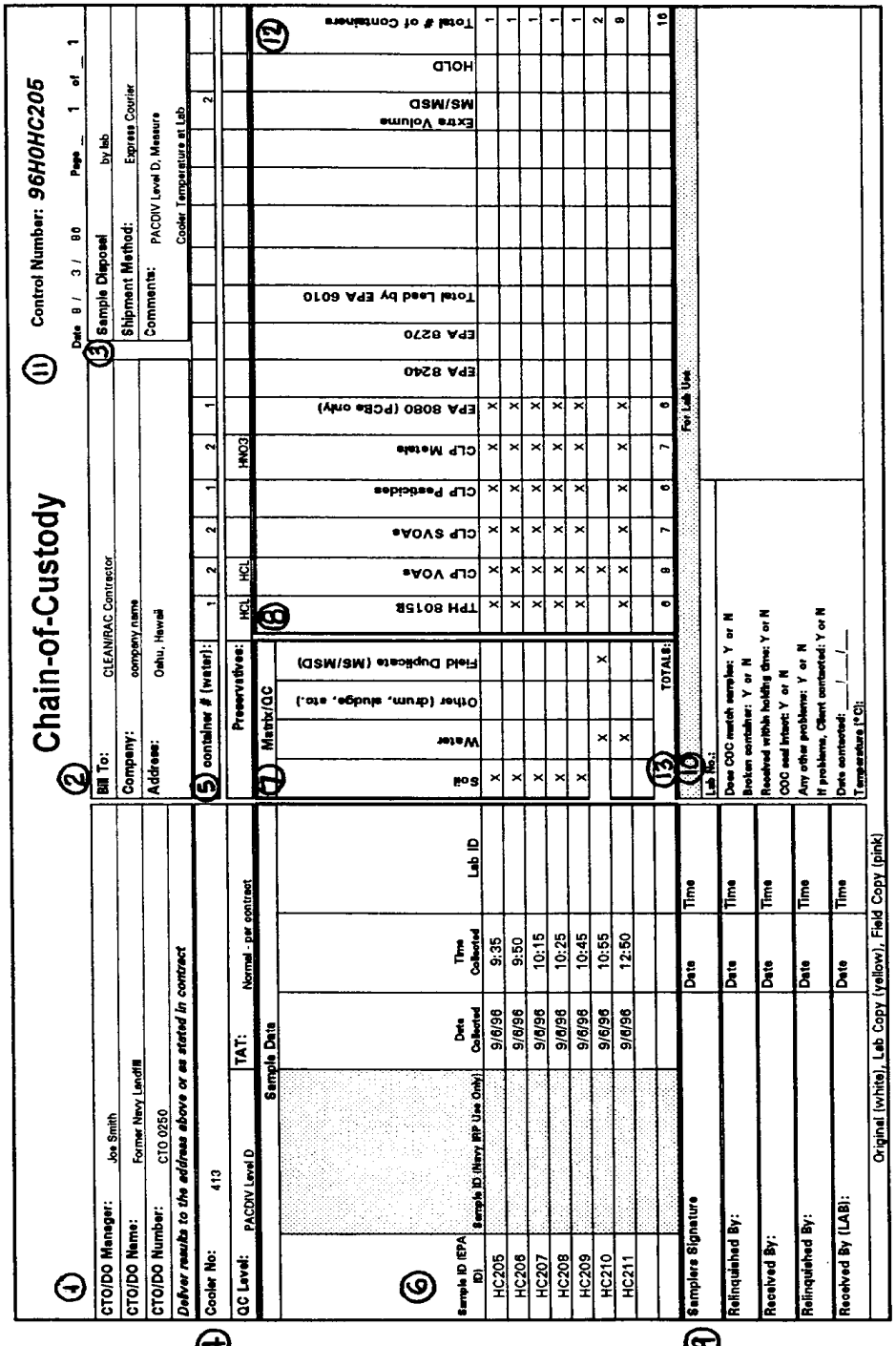
Page ____ of ____

Client/Project Name:	Project Location:	Analysis Requested
Project Number:	Field Logbook No.:	
Sampler: (Print Name) Affiliation:	Chain of Custody Tape No.:	
Signature:	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)	Date:	Received by: (Print Name)	Date:	Analytical Laboratory (Destination):
Signature:	Time:	Signature:	Time:	
Relinquished by: (Print Name)	Date:	Received by: (Print Name)	Date:	
Signature:	Time:	Signature:	Time:	
Relinquished by: (Print Name)	Date:	Received by: (Print Name)	Date:	
Signature:	Time:	Signature:	Time:	Serial No.

Attachment 3
Sample Completed Chain of Custody



Chain-of-Custody

Control Number: 96H0HC205

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
Date 9 / 3 / 96 Page 1 of 1
Sample Disposal: by lab
Shipment Method: Express Courier
Comments: PACDIV Level D, Measure Cooler Temperature at Lab

Sample ID (EPA ID)	Sample ID (Navy ERP 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
				Preservatives:	HCL	HCL							HNO3							
				container # (water):	1	2	2	1	2	1										
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						8
				TOTALS:					8	8	7	6	7	6						16

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):

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

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:

Samples Affected (List by Accession AND Sample No.)

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:	

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:

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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

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

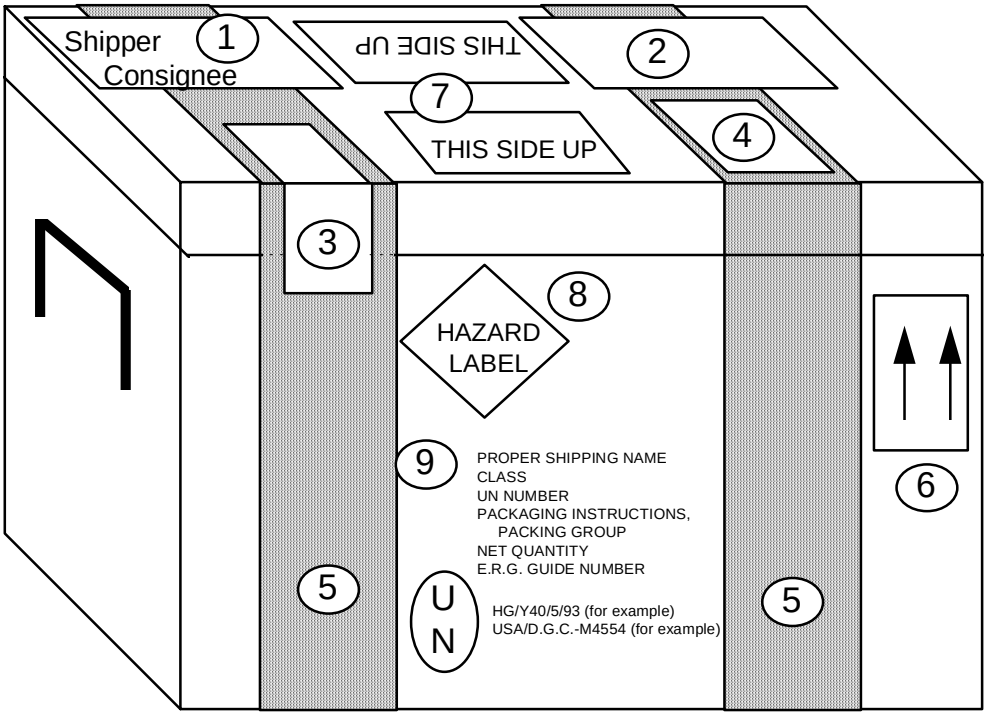
8.8 Attachment 8 – Soil Import Permit

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**

NOTE: SOPs have been updated for PFAS sampling activities; however, AECOM's internal PFAS sampling guidance supersedes materials and methods described in SOPs.
PRINTED COPIES ARE UNCONTROLLED. CONTROLLED COPY IS AVAILABLE ON COMPANY INTRANET.

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.

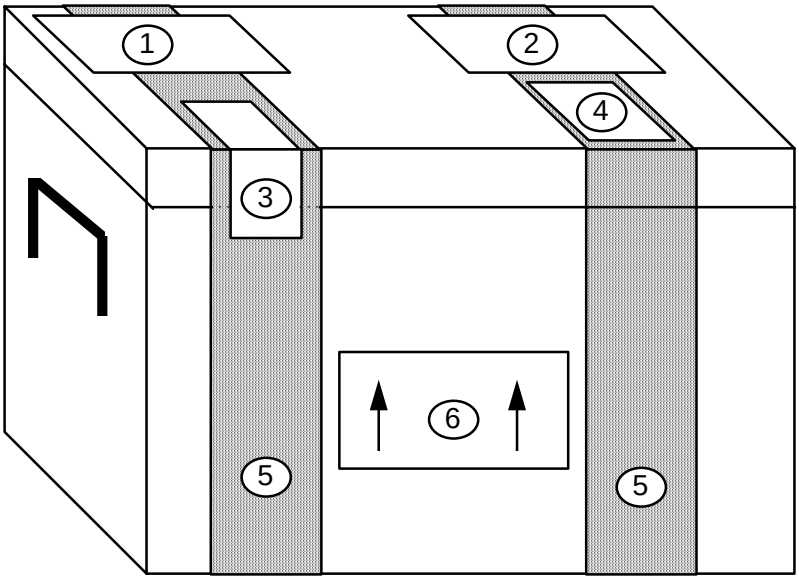
3. Sample preservation should be performed immediately upon sample collection. For composite samples each aliquot should be preserved at the time of collection. When use of an automated sampler makes it impossible to preserve each aliquot, then samples may be preserved by maintaining at 4ºC until compositing 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**

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)

Joe Smith, Ogden	Joe Smith	1/1/94
Name/Title	Signature	Date

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.

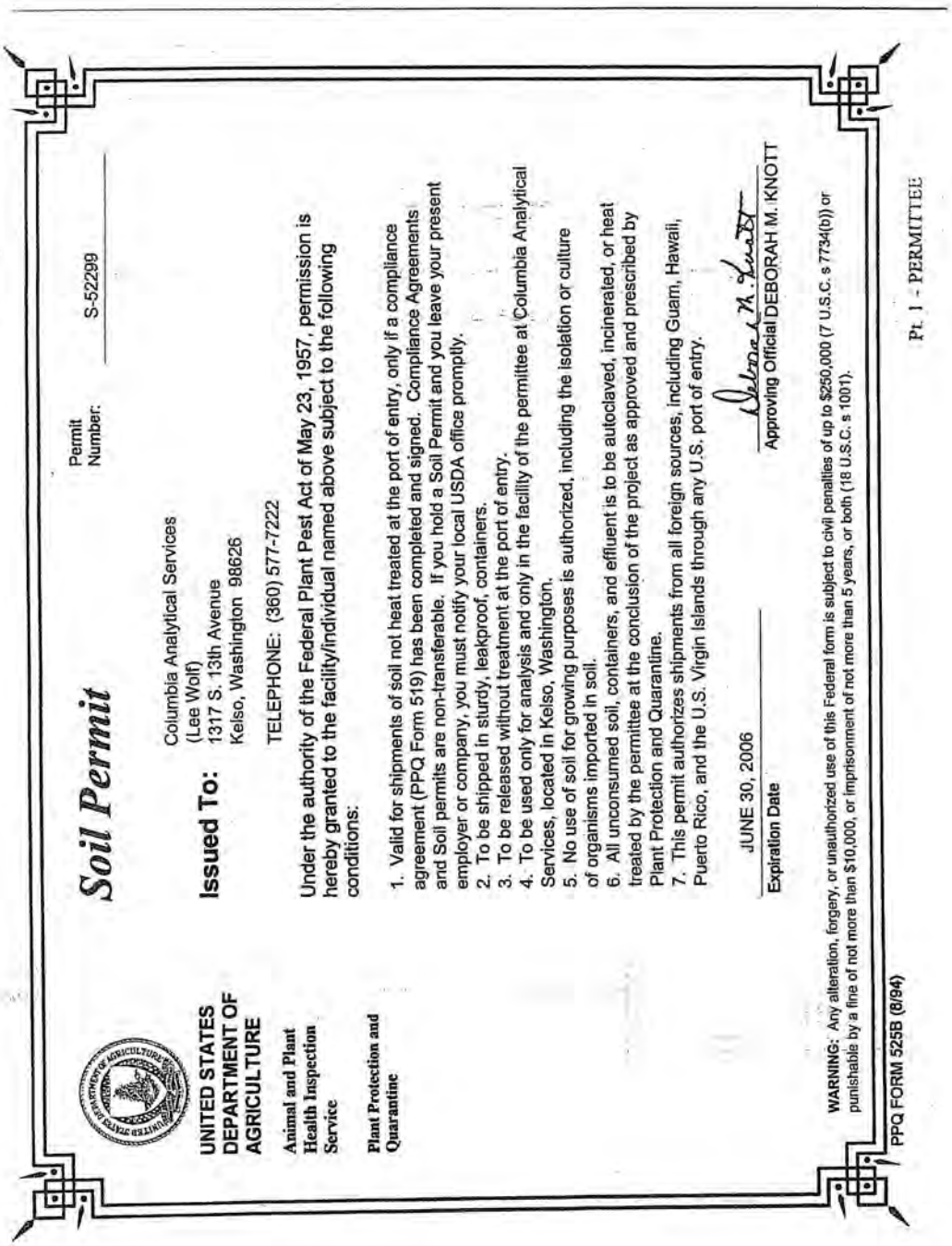
DIVERSION CONTRARY TO UNITED STATES LAW IS PROHIBITED.

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 _____

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

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**

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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.

- 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)

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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GEOPHYSICS

Procedure 3-09

1.0 Purpose and Scope

1.1 This Standard Operating Procedure (SOP) introduces the general methodologies, terms, and procedures for geophysical techniques. Geophysics deploys artificially induced signals or naturally occurring signals to investigate the physical properties of materials through arrays of airborne, surface, or subsurface sensors, and examines how these properties vary spatially and temporally.

A large number of geophysical techniques are employed in the industry, and some applications are rapidly evolving. Accordingly, this SOP describes in broad terms the main methods available, quality control procedures, and interpretation guidelines for subsurface environmental assessments. Project-specific criteria, including performance standards, are specified in Sampling and Analysis Plans (SAPs) or Work Plans (WPs), while further details on emerging technologies may be surmised in a supplemental SOP. Ultimately, the implementation of geophysical technologies should generally be reserved for locations where standard subsurface invasive investigation techniques (e.g., digging, drilling, puncturing, etc.) are deemed too costly or unsafe without supplemental information captured from the geophysical surveys. Even when used in favorable locations, however, geophysical techniques have inherent limitations that must be carefully considered in their deployment.

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 plans and reviews, inclusive of direct notification from a designated program-level geophysicist within AECOM.

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 Health and Safety Plan (HASP). In the absence of a HASP, work will be conducted according to the Task Order (TO) WP and/or direction from the Site Safety Officer.

2.2 Some geophysical techniques, especially those with active transmitters (e.g., resistivity, radar, etc.), pose method-specific hazards. The hazards and procedures for minimizing risk must be explicitly stated in the HASP for all project sites.

3.0 Terms and Definitions

3.1 **Available Technologies**. Geophysical methods commonly applied to environmental issues generally fall into three broad categories: seismic (using a vibration/acoustic signal), electrical (using direct-current, inductive, or naturally occurring electromagnetic field sources), and potentiometric (using natural gravity or magnetic properties). These methods can be applied in boreholes (downhole logging), at the surface, underwater, within subsurface voids, from airborne platforms, and from space, or in various combinations of these configurations. Typical methods include (referring to definitions in Section 3.2):

3.1.1 **Reflection seismic:** Creates a seismic wave using an impact source (hammer on a plate, weight drop, explosive, vibrating device), and measures amplitudes and arrival times of reflected seismic waves from subsurface geology though geophones either planted in the soil or dragged along the surface (“streaming” array). Typically used to map deep structure and lithology for

energy exploration, but in recent decades, evolving technology has allowed work in the sub-10 meter depth range of interest in many environmental investigations. Overall, perhaps the most powerful, highest-resolution geophysical method, though infrequently used for environmental issues.

3.1.2 **Refraction seismic:** Uses an impact source (typically hammer on a plate) and detects refracted waves from a higher-velocity material at depth. Typical application is mapping bedrock at depths of less than 30 meters. Refraction delivers reasonably high resolution. Limitations can arise from the large source-receiver spread, which can extend beyond the bounds of the survey area or be interrupted by surface features.

3.1.3 **Surface wave seismic:** Uses an impact source (typically hammer on a plate) to induce surface waves in the shallow subsurface to measure shear-wave velocity variations, often indicative of matrix stiffness. Used to evaluate landfills, engineering properties of the ground, and map shallow geology. The dominant method is multichannel analysis of surface waves (MASW). Occasionally passive MASW (refraction microtremor, or ReMi) is used to monitor deeper seismic activity, for example from oilfield fracking operations, or image geology in a manner similar to MASW.

3.1.4 **Electrical Resistivity (ER):** Uses multiple grounded electrodes to transmit low-frequency electrical current and receive voltage responses, which are used to construct resistivity images of the subsurface; a less commonly used, shallower application employs capacitively-coupled (ungrounded) electrodes as a towed array. ER uses either frequency-domain or time-domain technologies, which deliver similar results; typical depths of exploration are 1 to 100 meters (but up to 1,000 meters for specially designed surveys). Commonly used in environmental applications, particularly in mapping hydrogeology and karst structure. In addition to its surface-based applications, resistivity is a standard borehole tool. Resistivity has limited effectiveness in areas with highly conductive surface material (e.g., surface water inundation or saturated clays) due to current channeling.

3.1.5 **Induced polarization (IP):** A more powerful version of ER that, in addition to the resistivity parameter, measures voltages at multiple frequencies or time gates to infer the capacitive effect, or electrical polarization, due to certain materials such as clays, sulfide minerals, and alteration environments. Sometimes IP is called spectral induced polarization or complex resistivity. Less frequently used than ER for environmental issues, despite its superior qualities, which are especially useful in landfill and leachate delineation. Applications include hydrogeology, karst, 3D landfill characterization, and alteration from contaminants or remedial processes.

3.1.6 **Spontaneous potential (SP):** A passive method measuring potential differences due to electrochemical effects from variations in lithology, geochemical alteration, or mineralization; or, alternatively, measuring electrokinetic-flow phenomena from leaky membranes such as dams or liners in landfills or ponds. SP uses simple equipment consisting of a high-impedance digital voltmeter, insulated cable, and several nonpolarizing electrodes. In addition to its surface-based applications, SP is a standard borehole tool.

3.1.7 **Frequency domain electromagnetic (FDEM):** Pulses a small coil with a current (typically around 10 kiloHertz) and measures the response from subsurface conductors in a second coil. The response is separated into two components: quadrature (giving the conductivity of the ground) and in-phase (related to metal responses). FDEM is reliable only for low induction numbers (ground resistivity greater than 10 ohm-meters). Generally used to characterize the bulk conductivity of the ground, though some configurations allow limited depth profiling; typical depth penetration is to 5 meters. Surface-based deployment is fast and efficient. Airborne FDEM is commonly used for mining, less so for smaller-sized environmental projects.

3.1.8 **Transient electromagnetic methods:** These typically pulse an antenna with a sharp current and measure the ground's response in a second antenna after current turn-off. Transient methods roughly divide into two categories according to measurement times, which affect depths of investigation: **transient electromagnetics (TEM)** and **metal detectors**. TEM measures the signal decay immediately after current turnoff to investigate subsurface hydrogeology; this method is excellent for finding conductive features but poor for resistive features. Metal detectors analyze the decay curves at later times, after the signals due to natural geology should have dissipated to zero, for sustained signals from metal objects. The latter application is sometimes called time domain electromagnetics (TDEM), often used with a simple antenna configuration at limited time "windows" for fast ground coverage to map metal utilities, drums, tanks, etc. within the top several meters. UXO-focused TEM analyzes a broad time range to detect UXO, discriminate it from inert scrap, and determine the type and burial geometry of the ordnance; these often use 3-axis antennas and sophisticated software. These applications deploy TEM at the ground level or on airborne platforms. Electromagnetic limitations include discerning individual items in cluttered areas, working close to large metal features, and detecting deeper items due to deteriorating signal-to-noise ratios.

3.1.9 **Controlled source audiofrequency magnetotellurics (CSAMT):** Current is injected into a distant array of electrodes; measurements of electric field voltages and the magnetic field are used to map subsurface resistivity patterns. CSAMT is typically used for deeper energy-sector exploration, but occasionally to map aquifers for environmental applications. Natural source variants magnetotellurics (low frequency, deep) and audiofrequency magnetotellurics (intermediate depths) are rarely used in environmental work. A distant cousin to CSAMT, very low frequency, is occasionally used to map shallow bedrock fracturing in water studies.

3.1.10 **Ground penetrating radar (GPR):** GPR transmits signals in the low-MegaHertz (MHz) to GigaHertz range and measures the response due to changes in subsurface dielectric properties, which are largely driven by water content. GPR is a moderate to high resolution method commonly used to map stratigraphy, water saturation, permafrost, and anthropogenic features such as utilities, tanks, and drums. These applications require close coupling of antennas and the ground surface; an adaptation using non-coupled ("air launched") antennas is used for roadway delamination studies, and satellite-based radar (often in the form of synthetic aperture radar) is used for remote sensing. Depth penetration is limited to nearly zero in heavy clay environments, water inundated areas, or reinforced concreted, but can be tens of meters in dry sands.

3.1.11 **Gravity:** A passive method that measures local variations in the earth's gravitational field due to subsurface density changes. Classic applications include mapping voids beneath paved surfaces, caves and other karst features (such as sinkholes), mine shafts and tunnels, and depth to bedrock. Environmental applications typically demand very high precision, for which the term "microgravity" is often applied; the work requires expensive equipment and accurate elevation surveying, making the cost per station rather high.

3.1.12 **Magnetics:** A passive method that measures local variations in the earth's magnetic field due to subsurface changes in ferrous metal. Classic applications include mapping UXO, drums, underground storage tanks, and old building artifacts. The method is specific to ferrous metal and is less effective in high-magnetic environs such as volcanic areas. Anomalies are usually dipolar in nature, complicating interpretation with respect to TEM; but processing often can identify target positions and depths. In ground use, magnetics is often deployed in the vertical gradient mode, which uses two vertically-stacked magnetometers to distinguish local magnetic changes from regional ones. Airborne magnetics is sometimes used, typically on UXO projects, though TEM is more common for UXO.

3.1.13 **Emergent technologies:** Several promising technologies are in research stages, particularly nuclear magnetic resonance, a sensitive detector of water content with ties to geotechnical properties. Ultrasonic methods have been used for mapping fine-scale delamination and voids in concrete, and are being expanded to other targets relevant to environmental interests.

Global positioning system (GPS) equipment is often used for geophysical positioning; GPS standards are covered in SOP 3-07.

3.2 **Definitions:** Geophysical terms are numerous enough to fill an industry dictionary, but some common terms used in environmental work are:

3.2.1 **Arrival:** The return of a transmitted signal after passing through a material.

3.2.2 **Culture:** Anthropogenic features such as fences, pipelines, powerlines, metal well casings, buried debris, etc. that interfere with imaging a target.

3.2.3 **Geophysics:** A collection of techniques that utilize physical property contrasts in the subsurface to detect or image features of interest.

3.2.4 **MEC:** Munitions and explosives of concern.

3.2.5 **Reflection:** The bounce of waves from an interface. Use of the term usually implies the wavelength is much smaller than the target dimensions and depth.

3.2.6 **Refraction:** The bending of waves (usually seismic in geophysics) as the pass between media of different densities.

3.2.7 **UXO:** Unexploded ordnance, an older term still commonly used in geophysics but supplanted by “MEC” in military circles.

4.0 Interferences

4.1 Seismic methods (surface applications):

- Poor geophone coupling, for example in loose sands.
- Connection problems in stressed geophone cables.
- Poor source signal amplitude or frequency.
- High vibrational noise due to surface vibrations or wind.
- Strong topographic relief (surface-wave methods).
- Inadequate gain or stacking in the field.
- Poor target-to-surroundings velocity contrast.
- Terrain, vegetation, water bodies, hazards, site size, and other obstructions to deployment of contiguous lines.

4.2 Electrical methods (direct coupled, surface applications):

- Poor (high impedance) electrode contact.
- Electromagnetic coupling between transmitting and receiving cables (IP systems, especially frequency domain).
- Inadequate hardware and software to reliably record IP data (IP surveys only).

- Strong, undocumented changes in line orientations or electrode spacings; undocumented terrain changes.
- Inadequate signal amplitude for array size.
- Culture, especially parallel to lines, networked, or near electrodes.
- Anthropogenic signals, especially powerlines with poor frequency regulation and cathodically protected pipelines.
- Noise from local or global thunderstorms.
- Inadequate gain or stacking in the field.
- Poor target-to-surroundings resistivity/chargeability contrast.
- Highly conductive surface layer.
- Terrain, vegetation, water bodies, hazards, and obstructions to deployment.

4.3 SP (surface applications):

- Nonpolarizing electrodes insufficiently planted in soil, unprotected from drying or large temperature changes.
- Uncharacterized regional SP drift because of failure to monitor a reference electrode or base station.
- Depending on project objective, interference from redox-alteration effects, electrokinetic (active flow) effects, or biological effects (e.g., algae).
- Poor target-to-surroundings SP contrast.
- Terrain, vegetation, water bodies, hazards, and obstructions to deployment.

4.4 Electromagnetic methods, FDEM (simple surface applications, FDEM):

- Failure to properly set up and verify operation of the instrument according to manufacturer's recommendations.
- Highly conductive geology violates the low induction number assumption.
- Extreme cultural signals such as major overhead powerlines.
- Surface/subsurface clutter and culture (when not the survey objective).
- For subtle targets requiring high data precision and density: acquisition speed too high (leveling errors), line-direction (reciprocity) bias, unmonitored instrument drift, inadequate GPS-positioning accuracy with respect to station spacings.
- Inadequate spatial coverage for size of targets sought.
- Target too small or deep for method.
- Poor target-to-surroundings contrast.
- Terrain, vegetation, water bodies, hazards, and obstructions to deployment.

4.5 Electromagnetic methods, TDEM (surface applications, simple target searches):

- Failure to properly set up and verify operation of the instrument according to manufacturer's recommendations; failure to null the instrument in a nonmetallic area.

- Extreme cultural signals such as major overhead powerlines.
- Metal clutter and culture (when not the survey objective).
- For subtle targets requiring high data precision and density: acquisition speed too high (leveling errors), line-direction (reciprocity) bias, unmonitored instrument drift, inadequate GPS-positioning accuracy with respect to station spacing.
- Inadequate spatial coverage for size of targets sought.
- Target too small or deep for method.
- Poor target-to-surroundings contrast.
- Terrain, vegetation, water bodies, hazards, and obstructions to deployment.

4.6 Electromagnetic methods, TEM (surface applications):

- Failure to properly set up and verify operation of the instrument according to manufacturer's recommendations.
- Extreme cultural signals such as major overhead powerlines.
- Metal clutter and culture, especially culture not symmetric with antenna configurations.
- Target too small or deep for method.
- Poor target-to-surroundings resistivity contrast.
- Unsuitable target, especially a smaller resistive target in a conductive environment.
- Conductivity-thickness ambiguity for a thin conductive layer.
- Inadequate quality control procedures, especially for UXO detection and discrimination (e.g., library target responses, in situ seed target calibrations, noise studies, etc.).
- Inadequate or incorrect application of processing.
- Terrain, vegetation, water bodies, hazards, and obstructions to deployment.

4.7 CSAMT:

- Improper survey design of transmitting antenna location(s) to maximize far-field data.
- Inadequate transmitter signal.
- Infrequent magnetic field characterization in geology where magnetic field changes.
- Use of scalar data for 3-dimensional targets.
- Culture, especially parallel to lines, networked, or near electrodes.
- Anthropogenic signals, especially powerlines with poor frequency regulation and cathodically protected pipelines.
- Natural signals from regional thunderstorms.
- Target too shallow for expected skin depth range.
- Inadequate gain or stacking in the field.
- Terrain, vegetation, water bodies, hazards, and obstructions to deployment.

4.8 GPR:

- Failure to verify the GPR unit is licensed by the Federal Communications Commission or similar agencies for use in the designated country.
- Failure to coordinate high-powered GPR transmissions with nearby airports.
- At UXO sites: failure to verify that GPR is safe to operate in the presence of potentially live electronically-fused ordnance.
- Failure to properly set up and verify operation of the instrument according to manufacturer's recommendations.
- Survey design (antenna frequency/signal wavelength, separation) inadequately matched to expected target.
- Surface/subsurface clutter causing multiple signals.
- Airwaves from nearby trees or structures (particularly for antenna frequencies below 200 MHz).
- Strong radio transmissions nearby (occasional problem).
- Response shifts with changes in ground saturation.
- Inadequate penetration in conductive environments.
- Target too small or deep for method.
- Poor target-to-surroundings dielectric contrast.
- Terrain, vegetation, water bodies, hazards, and obstructions to deployment.

4.9 Gravity:

- Failure to properly set up and verify operation of the instrument according to manufacturer's recommendations.
- Inadequate protection of gravimeter during transport; failure to maintain internal heater temperature in the days preceding and during use.
- Inadequate leveling before acquisition.
- Inadequate base ties to correct instrument drift.
- Survey design (station spacing) inadequately matched to expected target size.
- Surrounding buildings and structures perturbing the gravitational field.
- Inadequate accuracy of station elevations.
- Poor target-to-surroundings density contrast.
- Terrain, vegetation, water bodies, hazards, and obstructions to deployment.

4.10 Magnetics (surface based):

- Failure to properly set up and verify operation of the instrument according to manufacturer's recommendations.
- Heading error when using alkali vapor instruments.

- Application in high magnetic noise environments such as heavy culture (including reinforced concrete pavement), or in areas with magnetic surface geology (e.g., volcanics or sedimentary outwash of volcanic fragments).
- Magnetic items on operator (belt, keys, steel-toed boots).
- Survey design (station spacing) inadequately matched to expected target size.
- Inadequate characterization of ambient magnetic field drift (for total field surveys).
- Metal targets are not ferrous.
- Poor target-to-surroundings ferrous-metal contrast.
- Terrain, vegetation, water bodies, hazards, and obstructions to deployment.

4.11 Airborne FDEM, TEM, Magnetics (in addition to ground-based interferences):

- Inability to minimize flight elevation due to trees and other obstructions.
- Inadequate accuracy of sensor elevation and orientation.
- Improper survey design (flight speed, line spacing, data redundancy and ties, etc.).
- Inadequate correction for helicopter-induced noise.
- Safety issues such as weather, remoteness of the site, flight hazards, etc.

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 SAPs that reflect the procedures and specifications presented in this procedure. 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 geophysics 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 direct supervision of geophysical acquisition and ensuring that procedures and specifications are implemented in the field in accordance with the approved SAP. The qualifications for the **Field Manager** 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.

6.0 Equipment and Supplies

6.1 Materials provided by either AECOM or its subcontractors shall be sufficient to accomplish the survey objectives. The Field Manager shall have, at a minimum:

- Personal protective equipment for all personnel as required by the HASP.
- Planning documents including the site-specific HASP and SAP.
- Copies of other plans and agreements, for example, those in conjunction with UXO sites.

- Field logbook/field forms/site maps.
- Sufficient tools to analyze data adequacy on site.

7.0 Procedure

7.1 **General Note**: because of the wide range of available geophysical techniques and even wider range of variations, as well as varying project objectives, details of required survey procedures appear in individual project SAPs. The following are intended as overall guidelines in executing and interpreting geophysical data.

7.2 Survey Design

- Work through the data quality objectives (DQOs): determine the overall project objectives, define the information desired from geophysics, define specific geophysical targets, and determine how the positive or negative outcome of the geophysics will impact resolution of the project objectives.
- Considering the target's anticipated physical properties, depth, size, and environs, develop a short list of potentially applicable techniques. If appropriate, run a forward model for each considered technology to evaluate the probability of detection/characterization in the presence of expected interferences; run multiple models if there is uncertainty in any of the input parameters. An alternative to modeling is hand-calculations based on expected target geometry and properties, or professional experience based on those properties.
- Determine the most appropriate technology to use. Establish a preliminary level of effort and ballpark cost. Then ask the question: is there a simpler, more cost-effective, or less ambiguous way to define the target with a non-geophysical approach? If not, based on the chosen technology, does geophysics merely add *data* (stuff to go in a report appendix) or does it add *information* (decision-making value)? If the latter, proceed with the survey design.
- Begin the survey design using best professional practices to ensure the target is adequately characterized. Examples of factors to consider: sample density with respect to the smallest likely target size (apply spatial aliasing criteria); adequate signal characteristics to resolve target; adequate depth penetration to reliably sample at the deepest likely target depth; signal-to-noise; interferences; best choice of equipment type and supplier for the site; robust survey logistics to meet challenges such as terrain, obstructions, and property constraints; quality control and verification procedures. Restate these in terms of data quality objectives.
- Envision how the report will be written if everything goes well: how will your project summary materially enhance project decisions? What can be changed now, in the survey-design stage, to maximize the decision-making impact?
- Incorporate these determinations in a SAP, stating performance criteria such as data density, repeatability, and verification.

7.3 Field Execution

- Determine if the field work will be done by AECOM directly or by a subcontractor. Follow standard procurement procedures for ordering equipment or selecting a subcontractor. Subcontracting requires a Statement of Work. All personnel, including subcontractors, must follow the field execution procedures outlined below.
- Equipment must be assembled and tested for correct functioning according to the manufacturer's recommendations. Initial tests may consist of, as examples: internal or external calibrations; comparing instrument response to a known regional response; testing response over visible

cultural or geologic features; or tests over buried “seed” items of known physical characteristics. The tests should be sufficient to demonstrate that the equipment is operating within normal and project-specified tolerances before data acquisition begins. Tests should consider both precision and accuracy, as appropriate to the method and project objectives.

- For appropriate applications and methods (e.g., FDEM, TDEM, gravity and total-field magnetometry), establish a base station in a nominally responsive area on or near the site. Repeat measurements at the base station before, during, and after data collection to ensure proper functioning of the instrument and to establish a response curve for later correction of instrument or field drift. The frequency of base station ties depends upon the variability of the drift being monitored and the DQOs of the survey. For some surveys, particularly total-field magnetometry, a continuously recording base station monitor is desirable. In other cases, such as GPR, the “base station” might be a base line, over which data are repeated to determine effects of rain on target delineation and penetration depth. Base station data are considered part of the official project electronic data record.
- Obtain data in a manner that adheres to the SAP or WP, constitutes reasonable and customary professional geophysical practice, and is continually focused on meeting project objectives.
- Check and document battery levels periodically. Some systems have an incipient data bias as battery voltage drops below a certain threshold, making it difficult to determine what parts of the data are reliable and what parts are not.
- All data should be stored electronically, if practical, and circumstances of field logistics and anything affecting data quality recorded in the field notebook (see Section 9.0).

7.4 Data Processing

- All raw data files downloaded from the instrument must be preserved without modification. Processing is to be performed on *copies* of the raw files.
- The processing stream, including filename protocol and processing algorithms used, must be documented sufficiently to be understandable to and reproducible by a geophysicist with no previous knowledge of the project.
- The level of effort in processing should be appropriate to the project DQOs.
- Whenever possible, data processing should incorporate ground truth information to achieve a more accurate solution. Joint processing of multi-method data sets may be similarly productive.
- A summary of data processing procedures and their rationale should be presented in the project report.

8.0 Quality Control and Assurance

8.1 Field personnel will follow specific quality assurance guidelines as outlined in the SAP and any additional procedures identified in the field as necessary to maintain the integrity of the data.

8.2 System calibration, checks, and live tests shall be analyzed in the field before and during data collection to ensure data accuracy and precision.

9.0 Records, Data Analysis, Calculations

All geophysical data should be stored in a data recorder or laptop during acquisition, if practical. At the earliest practical time, and at least at the conclusion of each field day, data should be downloaded to a separate computer and backed up via external drive or email attachments.

Field notes will be recorded in the field logbook, which is a primary document of record for the project. Accordingly, any circumstances potentially affecting the interpretability of the data should be recorded in the notebook as they occur. Examples: times of arrival/departure and key field activities; health and safety factors and pre-work safety meeting (in addition to the required daily safe work assessment and permit form); weather; calibration/test results; records of base station ties; illustrations of instrument setup; details of instrument deployment; survey lines or points acquired; data results as appropriate; identification of anomalies encountered; records of interfering factors such as culture or ambient noise; descriptions of problems encountered, the data blocks affected, and remedy achieved; sketch maps; notes for subsequent processing; and any deviations from the procedures in this SOP and other project plans.

10.0 Attachments or References

10.1 Butler, D.K., Ed., 1991. Near-Surface Geophysics: Investigations in Geophysics no.13, Society of Exploration Geophysicists.

10.2 Dobrin, M. B., and C. H. Savit, 1988. *Introduction to Geophysical Prospecting*: McGraw-Hill Publishing Environmental.

10.3 Nabighian, M.N., Ed., 1991. Electromagnetic Methods in Applied Geophysics: Investigations in Geophysics no.3, Society of Exploration Geophysicists.

10.4 Sheriff, R. E., 1991. *Encyclopedic Dictionary of Exploration Geophysics*: Society of Exploration Geophysicists.

10.5 Telford, W. M., L. P. Geldart, R. E. Sheriff, and D.A. Keys, 1998. *Applied Geophysics*: Cambridge University Press.

10.6 Ward, S.H., Ed., 1990. Geotechnical and Environmental Geophysics: Investigations in Geophysics no.5, Society of Exploration Geophysicists.

Author	Reviewer	Revisions (Technical or Editorial)
Larry Hughes Senior Geophysicist	Brian Brunette, PGP Technical Lead MMRP	Rev 0 — Initial Issue (April 2013)
Ken O'Donnell, PG Geologist	Claire Mitchell, PE, PMP Senior Engineer	Rev 1 – 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.

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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)

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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

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*.

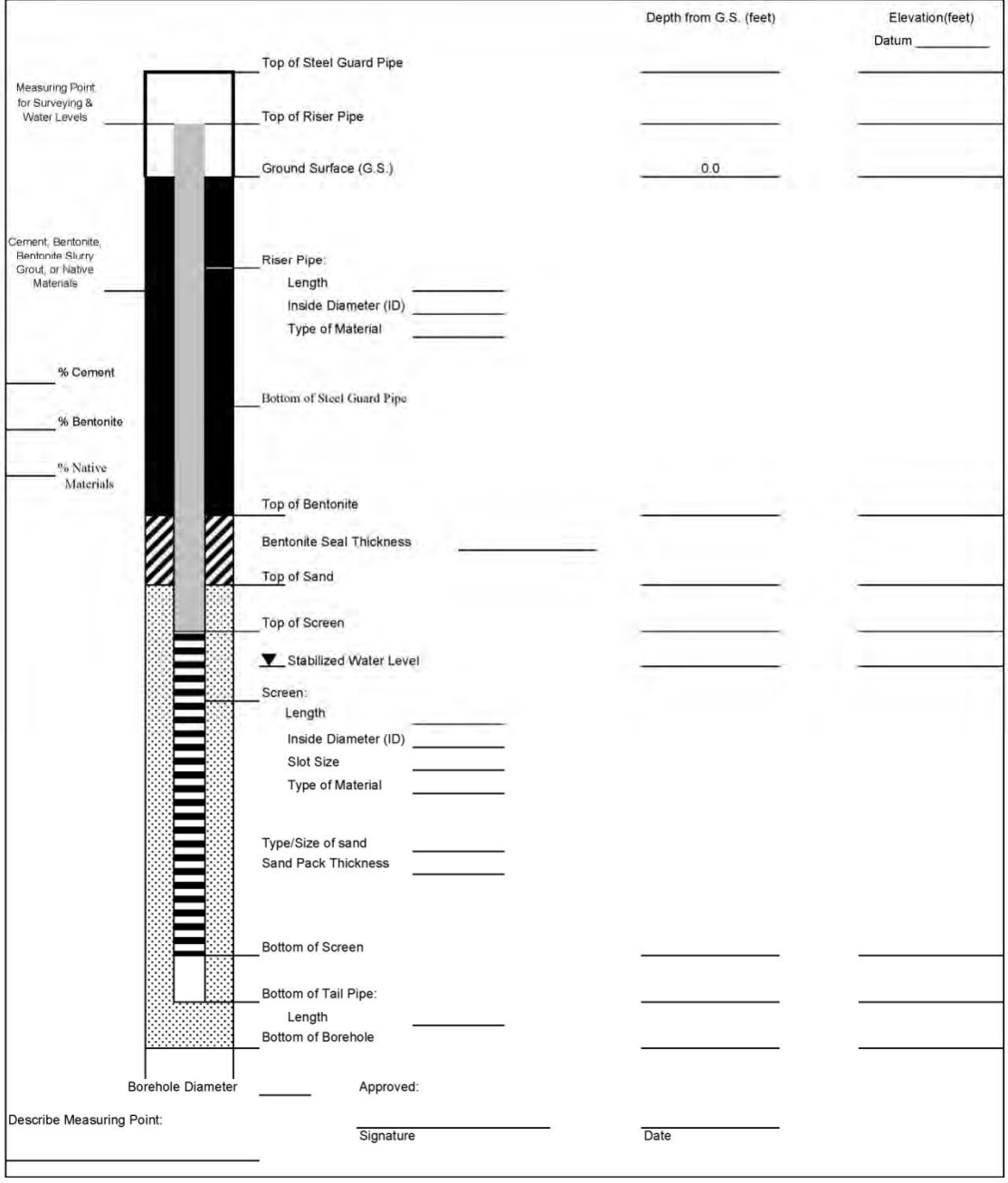
10.10 SOP 3-16, *Soil and Rock Classification.*

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)

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



NOTE: SOPs have been updated for PFAS sampling activities; however, AECOM's internal PFAS sampling guidance supersedes materials and methods described in SOPs.
PRINTED COPIES ARE UNCONTROLLED. CONTROLLED COPY IS AVAILABLE ON COMPANY INTRANET.

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: _____

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

(continued on back)

If no or N/A - Explain below.
_____

3. **SAMPLE COLLECTION:** Method: _____

Sample ID	Container Type	No. of Containers	Preservation	Analysis Req.	Time

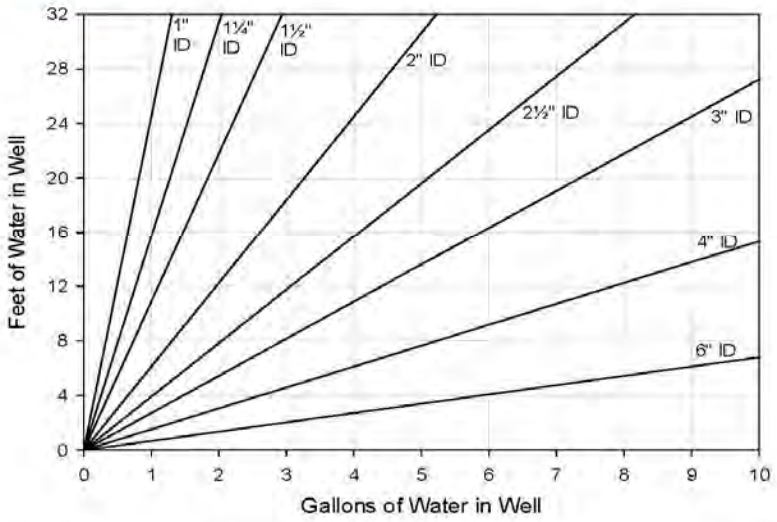
Comments _____

Signature _____ Date _____

Page 1 of 2

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 _____

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

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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)

[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.

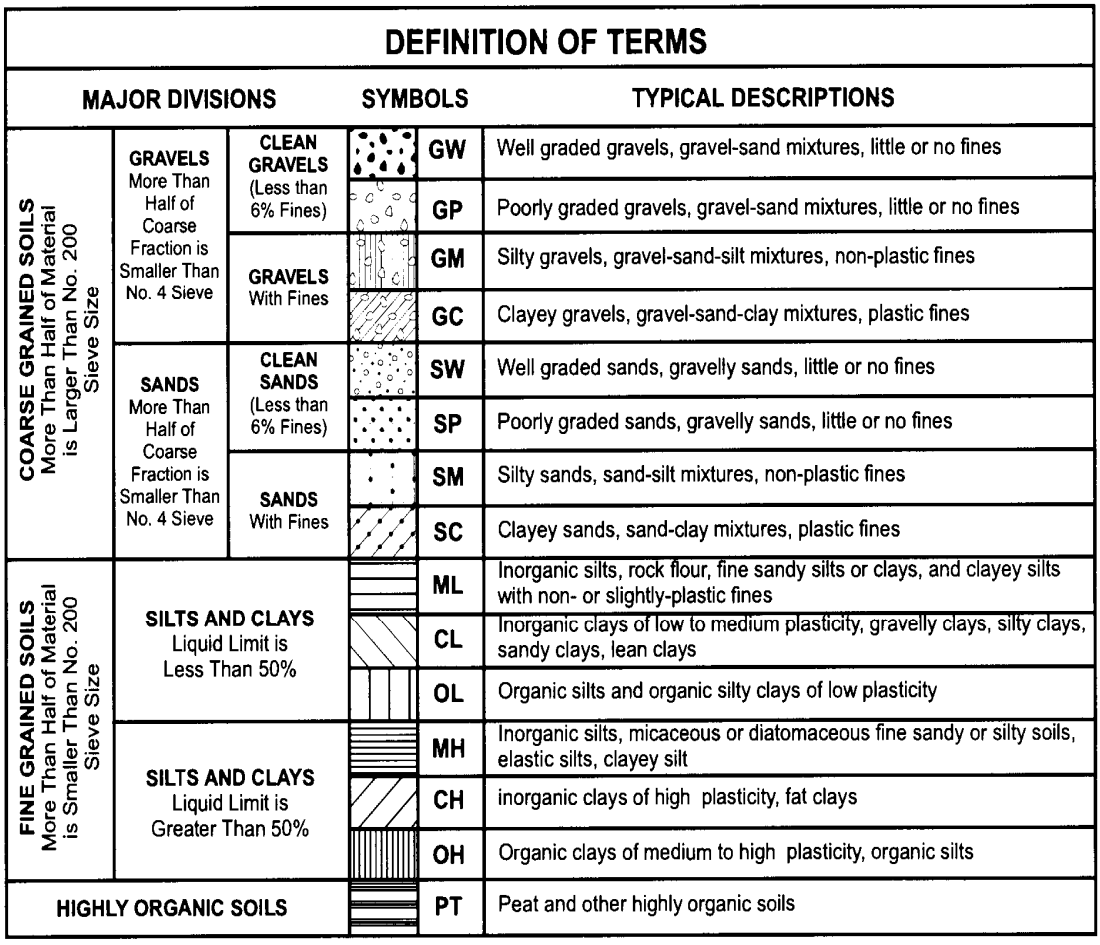
8.1.2.2 Toughness

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.

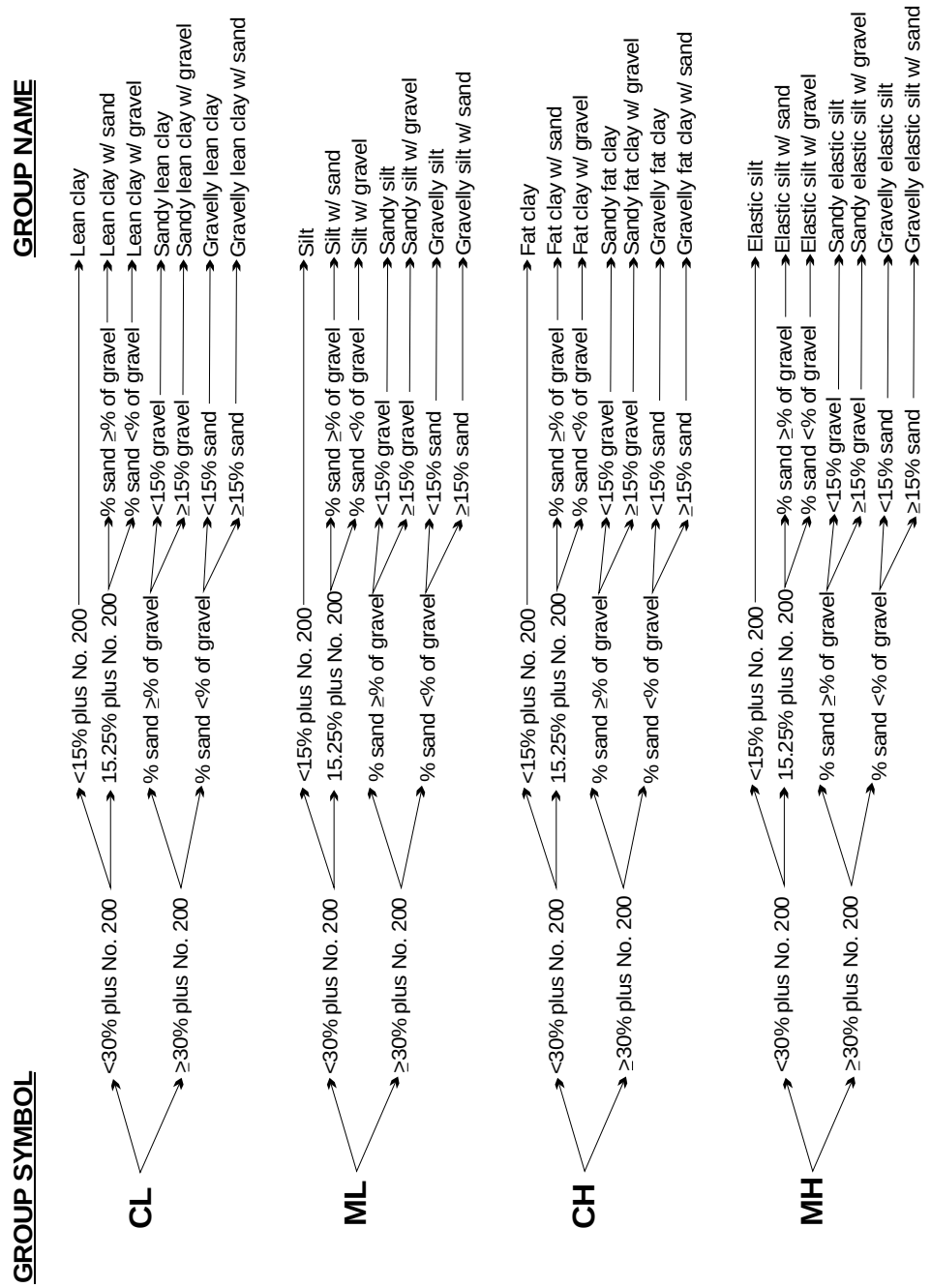
Figure8-1: Unclassified Soil Classification System (USCS)



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

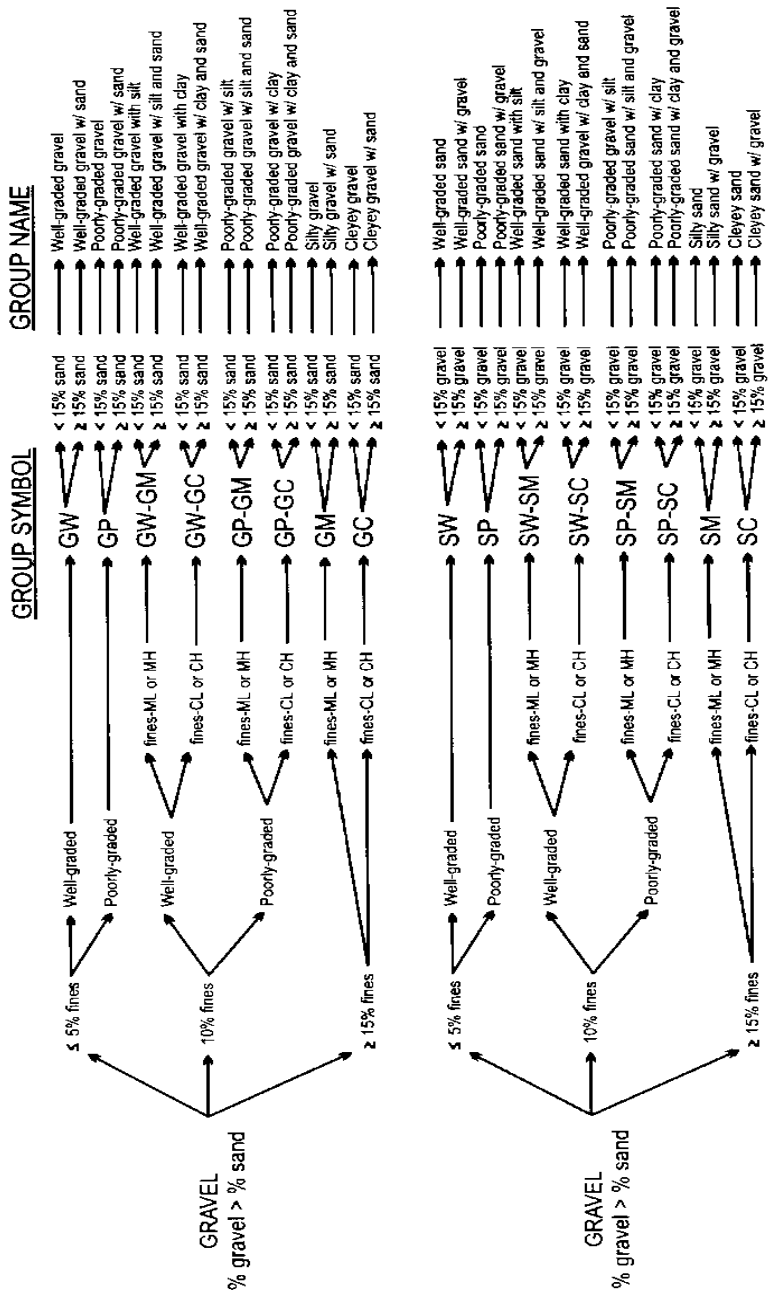
GRAIN SIZES								
SILTS AND CLAYS	SAND			GRAVEL		COBBLES	BOULDERS	
	FINE	MEDIUM	COARSE	FINE	COARSE			
200	40	10	4	3/4"	3"	12"		
U.S. STANDARD SERIES SIEVE				CLEAR SQUARE SIEVE OPENINGS				

Figure 8-2: Flow Chart for Fine Grain Soil Classification



NOTE: SOPs have been updated for PFAS sampling activities; however, AECOM's internal PFAS sampling guidance supersedes materials and methods described in SOPs.
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Figure 8-3: Flow Chart for Soil with Gravel



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

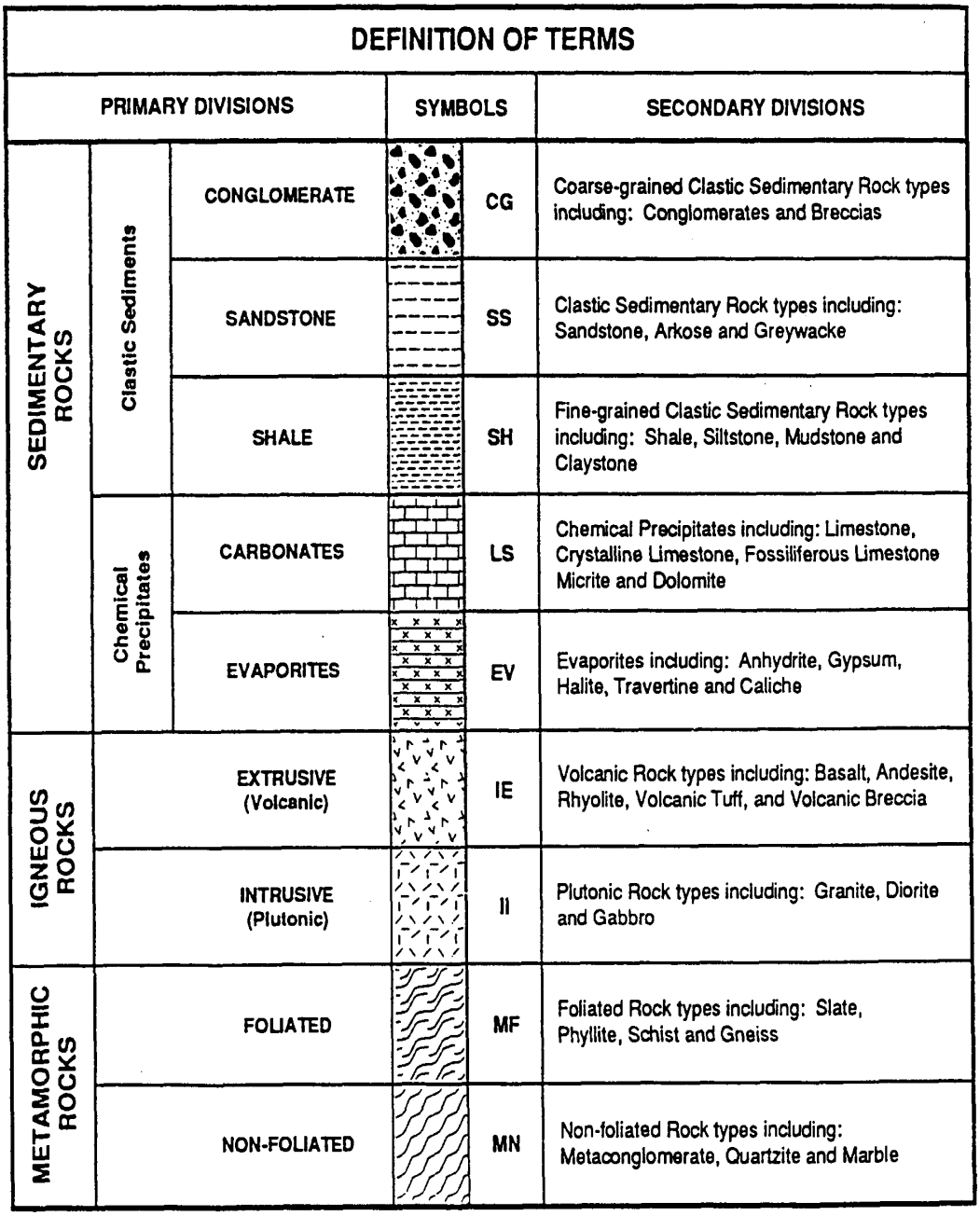
- Classification Name (i.e., schist)
- Color
- Mineralogical composition and percent
- Texture/Grain size (i.e., fine-grained, pegmatitic, aphlitic, glassy)
- Structure (i.e., foliated, fractured, lenticular)
- Rock Quality Designation (sum of all core pieces greater than two times the diameter of the 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

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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

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	Recovery 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.)	

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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)

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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.

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.

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)

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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:

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

- 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

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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)

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

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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:			

Figure 1
Petite Ponar® Grab Sampler and Exploded Diagram



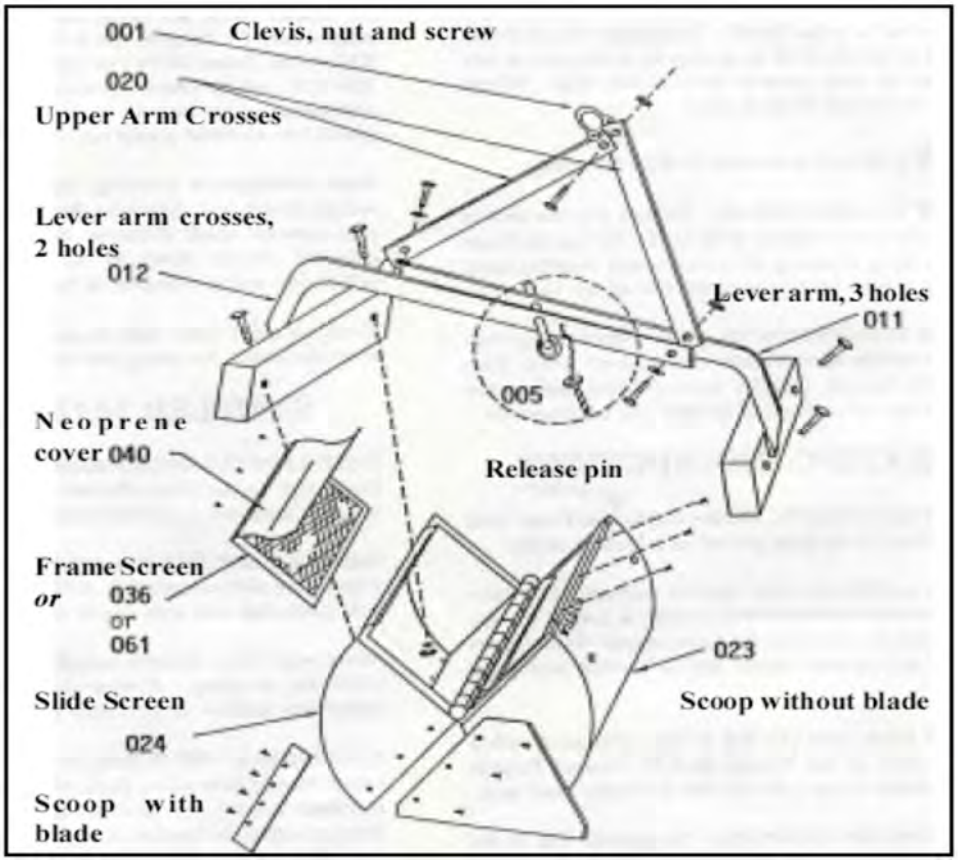


Figure 2

Ekman Bottom Grab Sampler (Large, Tall, and Standard Sizes) and Exploded Diagram

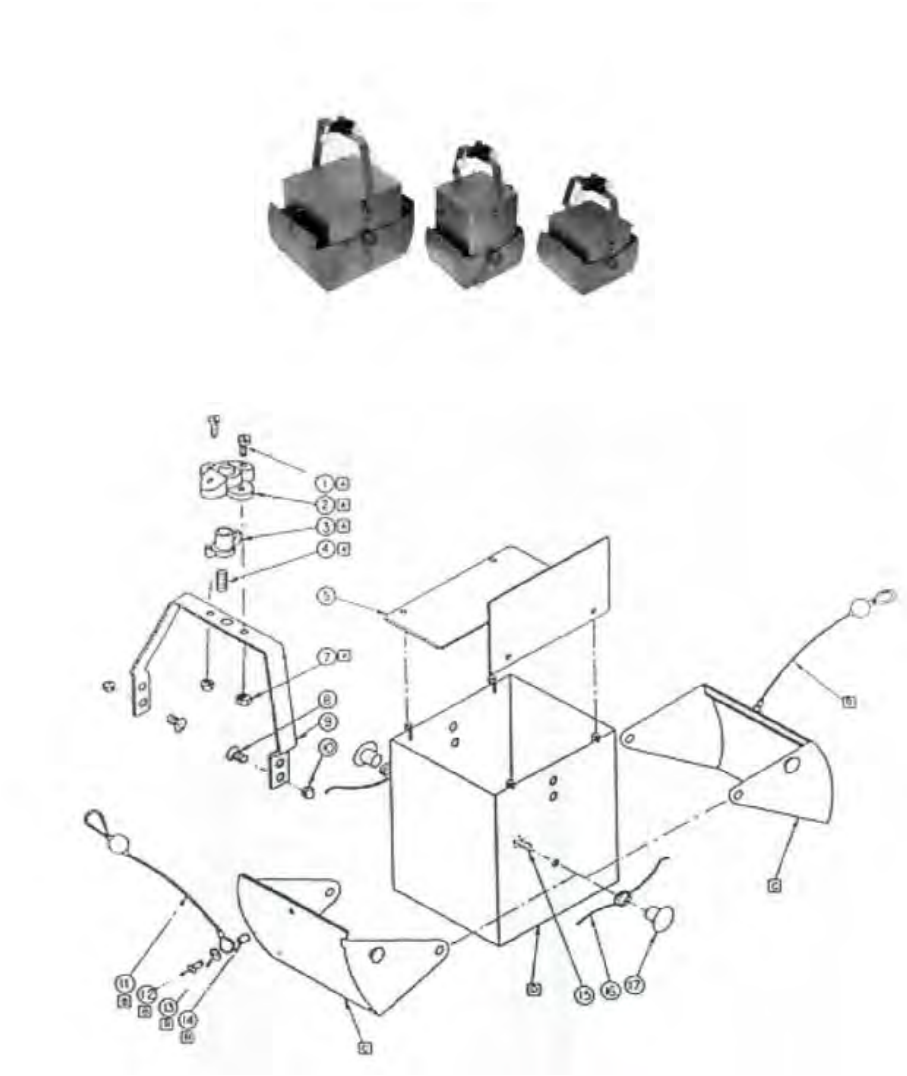
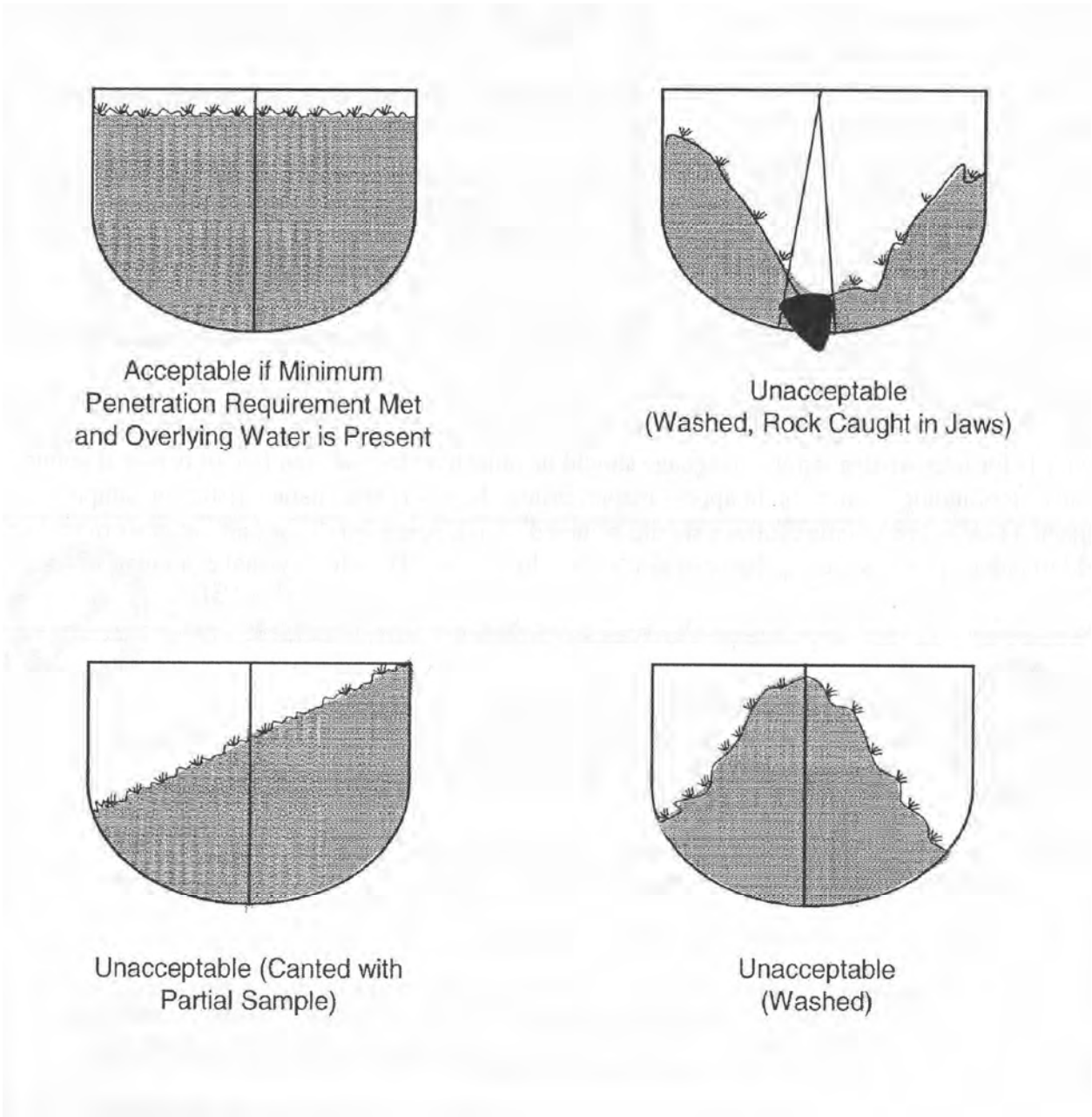


Figure 3
Wildco® Hand Corer (with Case and Accessories) and Exploded Diagram



Figure 4
Illustrations of Acceptable and Unacceptable Grab Samples



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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.

- 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.

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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.

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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	Possible Min	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

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:

$$K = \frac{(Km)}{1 + 0.0191(\mathrm{T} - 25)}$$

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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 Point Calibration	pH	7.0			Initials:	Value:	
	Conductivity (mS/cm)					Value:	
	Turbidity (NTU)	100				Value:	
Third Point 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	**Oxygen Solubility**	**Temperature**	**Oxygen Solubility**
°C	**mg/L**	**°C**	**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

AECOM

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)

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In-Situ Hydraulic Conductivity Testing via Rising or Falling Head Slug Testing

Procedure 3-35

1.0 Purpose and Scope

1.1 This Standard Operating Procedure (SOP) describes the methods used to obtain in-situ hydraulic conductivity test data via rising or falling head slug testing (also commonly referred to as variable head testing). Slug tests are performed to assess the hydraulic conductivity of the soil or rock surrounding the tested monitoring well. Hydraulic conductivity is a measure of the ease of flow of water through a specific porous medium or fracture when subjected to a hydraulic gradient.

Hydraulic conductivity values are used:

- To estimate rates of groundwater flow;
- To estimate responses of aquifers to applied stresses, such as pumping;
- To estimate the rate of movement of various chemicals in subsurface zones; and
- To construct and calibrate groundwater flow models.

1.2 Variable-head tests are performed by causing a sudden (instantaneous) rise or drop of the state water level in a well. Water levels are monitored and recorded until the water level has returned to static conditions or sufficient data is collected to perform the hydraulic conductivity calculations. In-situ hydraulic conductivity tests can be conducted in open boreholes or in monitoring wells and they can be variable-head tests or constant-head tests. The change in water levels can be produced by displacing a known volume of water using a slug or using a pneumatic pump. The change in water levels during the test will be monitored using a pressure transducer capable of electronic data logging. Such pressure transducers can collect many measurements in a short period of time, which is important for evaluating the early-time response of the aquifer to the water displacement. For the purpose of this SOP, the method to perform a variable-head test in a monitoring well using electronic data logging transducers, and either slugs or pneumatic pumps will be outlined

This procedure is the Program-approved professional guidance for work performed by AECOM under the client contract. Specific information regarding the slug testing scope of work can be found in the associated Quality Assurance Project Plan (QAPP).

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

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 performing any hydraulic conductivity tests at the first location. All **Field Personnel** responsible for performing any hydraulic conductivity test 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 tasks. Conduct preliminary area monitoring to determine the potential hazard to **Field**

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 Observe standard health and safety practices according to the project-specific APP/SSHP. Suggested minimum protection during hydraulic conductivity testing 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 PFAS-free 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 Hydraulic conductivity testing may involve chemical hazards associated with exposure to groundwater and the testing equipment that comes in contact with the groundwater. When conducting hydraulic conductivity tests, adequate health and safety measures must be taken to protect **Field Personnel**. These measures are addressed in the project APP/SSHP. All work will be conducted in accordance with the APP/SSHP.

3.0 Terms and Definitions

None.

4.0 Interferences

There are many potential interferences in the performance and analysis of slug tests. For this reason, appropriately trained personnel shall perform the tests in the field and conduct the data analysis. Data and analysis will be reviewed by a qualified senior geologist or hydrogeologist.

One of the primary interferences is due to well construction. For wells screened across the water table, falling head tests may not provide accurate measures of hydraulic conductivity. Therefore, while falling head tests may be conducted in such wells, it may be inappropriate to use their results quantitatively unless the data analysis indicates that an accurate measurement of hydraulic conductivity has been obtained.

5.0 Training and Qualifications

5.1 Qualifications and Training

5.1.1 The individual(s) executing these procedures must have read, and be familiar with, the requirements of this SOP.

5.1.2 Field personnel conducting permeability tests should be experienced geologists familiar with the theory and practice of aquifer testing and analysis, as well as with all necessary equipment and software. Geologists or personnel with geologic experience should supervise hydraulic conductivity testing.

5.1.3 **Field Personnel** must be health and safety certified as specified by the Occupational Safety and Health Administration (OSHA) (29 CFR 1910.120(e)(3)(i)) to work on sites where hazardous materials may be present.

5.1.4 It is the responsibility of the field personnel to be familiar with the hydraulic conductivity testing procedures outlined within this SOP, quality assurance, and health and safety requirements outlined within the Quality Assurance Project Plan (QAPP) and the APP/SSHP. Field personnel are responsible

for the proper testing procedures, decontamination of equipment, as well as proper documentation in the field logbook or field forms (if appropriate

5.2 Responsibilities

5.2.1 The **Task Order (TO) Manager** is responsible for ensuring that the hydraulic conductivity testing activities comply with this procedure. The **TO Manager** or designee shall review all hydraulic conductivity forms prior to use. The **TO Manager** is responsible for ensuring that all **Field Personnel** involved in hydraulic conductivity testing and data analysis 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)** and **Project Hydrogeologist** are responsible for ensuring that all **Field Personnel** involved in hydraulic conductivity testing follow these procedures.

5.2.4 **Field Personnel** are responsible for the implementation of this procedure. Minimum qualifications for **Field Personnel** conducting the permeability tests are outlined above in Section 5.1.

5.2.5 The **Project Hydrogeologist** is responsible for the review of data associated with this procedure. Minimum qualifications for data analysis personnel require the individual be familiar with the theory and practice of slug testing and analysis, as well as with all necessary software. Geologists, hydrogeologist, other personnel with geologic or hydrogeologic experience, or other qualifications based on state-specific requirements, should review the hydraulic conductivity test results and data interpretation.

5.2.6 The **SS** and/or **TO manager** are responsible for directly supervising the hydraulic conductivity field testing to ensure that the testing is conducted in accordance with this procedure and state-specific requirements, should they apply, and for recording all pertinent data collected during testing. 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

General field supplies include the following items:

- Boring logs (if available)
- Well construction diagrams (if available)
- Well development logs (if available)
- Hydraulic Conductivity Test Log (example attached)
- Water level meter (Teflon-free)
- Solid HDPE slugs (if not using pneumatic methods) - diameter is dependent upon well diameter; the slug length is dependent on the length of the water column in the well but should provide a minimum of 1 foot displacement of the water column
- Air compressor or bicycle tire pump for pneumatic tests (if not using a slug)
- Quick-release ball valve (for pneumatic tests)
- Water level probe insertion port (for pneumatic tests)
- Nylon or polypropylene string
- Tape measure
- Pressure gauge and regulator (for pneumatic tests)
- Pressure transducers (Bluetooth enabled)

- Data logging software
- Laptop computer or cell phone with appropriate pressure transducer management software
- Polyethylene plastic sheeting
- Equipment decontamination supplies (as required by AECOM SOP No. 3-06 – Equipment Decontamination)
- Health and safety supplies (as required by the APP/SSHP)
- Approved plans (e.g., APP/SSHP, QAPP)
- Field project logbook/ballpoint pen

7.0 Procedure

7.1 General Preparation

The monitoring wells to be tested should have been previously developed and had sufficient time to equilibrate before the testing process proceeds. Well construction diagrams are necessary to determine the depth of the monitoring well and the screened interval.

All equipment that will come into contact with the groundwater will be decontaminated and tested prior to the start of field activities. Any sharp edges of the well casing will be covered with duct tape to protect transducer cables.

Standard slug testing methods using a physical slug is appropriate for low to moderate aquifer permeabilities and for wells that are screened across the water table regardless of aquifer permeability. Pneumatic slug tests are the preferred method of choice for high permeability aquifers because they can create significantly larger stresses than the standard slug method. However, pneumatic slug test methods cannot be used in water table wells.

The static water level in the well will be measured and recorded in the field logbook or field form. The slug diameter and length to be used in the well will be determined based on the diameter of the well and the length of the water column. In general, the larger the volume of the slug, the greater the displacement of head and the better the definition of response in the resulting data. However, *the slug must be short enough to be completely submerged beneath the static water level, and there must be room beneath the bottom of the slug for the transducer*. The slug length and diameter will be recorded in the field logbook and/or field form for use in the data analysis.

A pressure transducer (programmable down-hole data logger) will be used to record the changes in water level during the test. The transducer must be set at a sufficient distance below the water surface so the slug does not disturb the transducer (if using a slug). If using a pneumatic method, the transducer must be set below the maximum pressurized water depression level so the transducer doesn't become dewatered. After the water level has equilibrated to the static level, the data logger will be programmed according to manufacturer's instructions. The data logger will be programmed to record water levels at logarithmic scale to collect early-response data, which are important for the data analysis.

A measured length of nylon string will be tied to the slug. The line will be of a length that will allow the top of the slug to be submerged beneath the static water level without touching the transducer.

7.2 Falling Head Test

The slug will be lowered part way into the well so that the bottom of the slug is just above the water surface. The data logger will be started (note that data must be recorded before the slug enters the groundwater) and the slug will be simultaneously lowered into the water, so that the top of the slug is below the static water level. Care will be taken to lower the slug fast enough to produce as close to an instantaneous rise in the water level as possible, but not so fast as to produce a wave when the slug enters the water.

When the water level returns to the static level, the falling head test is complete and the rising head test can be started. The data should be saved and a new test set up on the data logger.

If the hydraulic conductivity is low, it may take hours (or more) for the water level to return to static conditions. In this situation, the **Project Hydrogeologist** should determine a maximum duration for each test (typically 30 minutes).

The falling head test may not be accurate for wells with screens that bracket the stabilized water table. These tests may be performed in water table wells, but the results will not be used quantitatively unless the data analysis indicates that an accurate measurement of hydraulic conductivity has been obtained.

7.3 Rising Head Test

If necessary, the data logger is transducer may need to be reset following the falling head test,. Then the rising head test will be started by activating the transducer and simultaneously removing the slug. The slug will be quickly removed from the water so that an instantaneous drop in the water level will occur, but it will be done smoothly enough to not disturb the transducer when removing the slug. When the water has returned to a static condition or the maximum duration of time has elapsed (typically 30 minutes), the test will be terminated.

For this SOP, three rising and three falling head tests will be conducted in each well being tested. Falling head tests will not be performed in wells screened at the top of the groundwater table.

7.4 Pneumatic Test Procedure

Pneumatic slug tests are only to be conducted in wells that are not screened across the water table. The general steps to be performed during pneumatic slug testing are as follows:

- Static water level will be measured to the nearest 0.01 foot.
- A pressure transducer will be placed into the well and the water level allowed to equilibrate to static conditions.
- The water column in the well will be pressurized with the pneumatic pump to depress the water level while simultaneously measuring and recording water levels with the pressure transducer until the water level has equilibrated (“falling head test”).
- The pressure in the well will then be rapidly removed and the water level recovery will be measured and recorded (“rising head test”).
- Slug testing data will be recorded on the Hydraulic Conductivity Test Log shown in the Attachments.

7.5 Data Download

At the completion of the test(s), the data from the slug tests will be downloaded to a laptop computer or other electronic device. If feasible in the field, this data will be plotted on a graph of time versus water level to see if it is acceptable (i.e., adequate water level displacement, sufficient number of data points, a straight-line fit to data, no extraneous fluctuations resulting from inadvertent slug movement and/or pressure waves). If the data are not acceptable, the test(s) will be repeated once water levels have stabilized.

7.6 Equipment Decontamination

All equipment that comes into contact with groundwater (e.g., slugs, transducer, and water level meter) will be decontaminated in accordance with AECOM SOP 3-06 Equipment Decontamination before moving to the next location. The string should be properly discarded and disposed of.

8.0 Quality Assurance/ Quality Control

Quality assurance requirements typically suggest the collection of both the rising head and falling head data. Rising head data are preferred for wells screened across the water table because the hydraulic

conductivity of the saturated portion of the aquifer is reflected, whereas falling head data may reflect the hydraulic conductivity of the unsaturated zone and capillary fringe.

For this SOP, two rising and two falling head tests will be conducted in each well being tested that is not a water table well. In the case where the well screen intersects the water table, three rising head tests will be conducted – no falling head tests will be performed in water table wells.

For quality control purposes, the transducer data logging will be started immediately prior to lowering or removing the slug. The transducer should be activated approximately 1 second prior to ensure that the transducer is recording water level changes and that the transducer is taking readings at frequent intervals during the early part of the well response curve. Care must be taken when lowering or removing the slug to avoid splashing or generating wave effects that would obscure the early-time data.

Data from the rising and falling head tests should be inspected in graphical format to ensure that adequate water level displacement was achieved for both tests, that the transducer data logger recorded all data from the test, and that no fluctuations exist in the data due to rapid slug movement.

Both rising and falling head tests may be conducted to help draw attention to any inconsistencies in the data. If the rising and falling head results are not comparable, the data should be investigated to assess which test may more accurately reflect the hydraulic properties of the aquifer, or whether the pressure transducer recorded accurate data. Knowledge of the boring logs is essential to assessing whether the measured response is consistent with the expected response. If a consistent response is not obtained, the tests should be run again.

9.0 Data and Records Management

9.1 Records Management

The Hydraulic Conductivity Test Log (see attachment) will be completed by the field personnel conducting the slug testing. Background information such as well diameter, depth, and screened interval will be provided from existing monitoring well construction logs. These data will be used in the calculation of hydraulic conductivity, based on the test data. The slug length, slug diameter, water level, well identification number, test type (rising or falling), file name, and time will also be recorded. The actual data of time versus water level will be recorded on the data logger and transferred to a laptop computer or other electronic device. In addition, a field project notebook should be maintained detailing any problems or unusual conditions that may have occurred during the testing process.

The records generated in this procedure will become part of the permanent record supporting the associated field work. All documentation will be retained in the project files following project completion.

Records will be maintained in accordance with SOP 3-03 Recordkeeping, Sample Labeling, and Chain of Custody. A field logbook will be maintained to ensure that adequate documentation is made of hydraulic conductivity testing activities. Information, such as background information such as well diameter, depth, and screened interval, will be documented from existing monitoring well construction logs in the field logbook or other site-specific test log, if applicable. These data will be used in the calculation of hydraulic conductivity, based on the test data. The slug length, slug diameter, water level, well identification number, test type (rising or falling), file name, and time will also be recorded. The actual data of time versus water level will be recorded on the data logger and transferred to a laptop computer. In addition, any problems or unusual conditions that may have occurred during the testing process will also be recorded.

Software files associated with the hydraulic conductivity testing activities will be saved in the associated project files upon completion of the field activities.

The records generated in this procedure will become part of the permanent record supporting the associated fieldwork. All documentation will be retained in the project files following project completion.

The field logbook is kept as a general log of activities and should not be used in place of any site-specific test log, if applicable.

Unanticipated changes to the procedures or materials described in this SOP (deviations) will be appropriately documented in the project records.

Records associated with the activities described in this SOP will be maintained according to the document management policy for the project.

9.2 Data Analysis

The data from these tests will be analyzed by AQTESOLV® according to methods described by Butler (2019) to calculate average hydraulic conductivity values for the aquifer. As described in Butler (2019), several methods are available for analyzing data obtained from in-situ hydraulic conductivity tests. Most methods incorporate graphical techniques, such as semi-log and log-log plots, to evaluate the data and select values for the calculations..

Inherent in the analytical methods are several simplifying assumptions concerning the aquifer properties and test methods. When selecting a particular analytical method, it is important to consider the basic assumptions that underlie the mathematical expressions. In many cases, it may be advisable to evaluate the data using several methods and examine the range of hydraulic conductivity values that are obtained. For this project, it is expected that the data will be analyzed using appropriate methodologies (e.g., Bouwer and Rice, 1976; Kansas Geological Survey methods [Hyder, et al., 1994]; Cooper, et al, 1967).

10.0 Attachments and References

10.1 Attachments

Attachment 1. Hydraulic Conductivity Test Log

10.2 References

Bouwer, H and RC Rice. 1976. A slug test for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells. Water Resources Research, Vol. 12, pp. 423-428.

Butler, JJ. 2019. The Design, Performance, and Analysis of Slug Tests, 2nd Ed., CRC Press, 280 pp.

Cooper, H Jr., D Bredehoeft, and S Papadopulos. 1967. Response of a Finite-Diameter Well to an Instantaneous Charge of Water. Water Resources Research, Vol. 3, No. 1.

Hvorslev, M. 1951. Time Lag and Soil Permeability in Ground-Water Observations, Bulletin Number 36, US Army Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi.

Hyder, Z, JJ Butler, Jr, CD McElwee, and W Liu. 1994. Slug tests in partially penetrating wells. Water Resources Research, Vol. 30, No. 11: 2945-2957.

SOP 3-03, *Recordkeeping, Sample Labelling, and Chain-of-Custody*

SOP 3-06, *Equipment Decontamination*

Author	Reviewer	Revisions (Technical or Editorial)
Naomi Ouellette, Environmental Scientist	Lauren Roberts, Environmental Scientist	Rev 0 – Initial Issue (November 2012)
Ken O'Donnell, PG Geologist	Claire Mitchell, PE, PMP Senior Engineer	Rev 1 – PFAS sampling update (July 2019)
Daniel Folan, PhD, PG, LSP Senior Hydrologist	Amanda Martin, MS Environmental Engineer	Rev 2 – Addition of pneumatic slug testing (February 2021)

AECOM

Well ID:

ATTACHMENT 1 - HYDRAULIC CONDUCTIVITY TEST LOG

Client: _____ Date: _____ Time: Start _____ am/pm
Project No: _____ Finish _____ am/pm
Site Location: _____
Weather Conds: _____ Tester (s): _____

1. WELL INFORMATION

a. Ref. Point Elev. _____
b. Static Depth to GW _____
c. Time of GW reading _____
d. Static GW Elev.(Ho) _____ (a-b)
e. Total Well Depth _____
f. Gravel Pack Diameter _____
g. Water Column Height _____ (e-b)
h. Casing Diameter _____
i. Screen Length _____
j. Geology of Screened Interval _____

2. SLUG INFORMATION (see back for volume calculation)

a. Slug Length _____
b. Slug Diameter _____

3. DATA COLLECTION

a. Method of Data Collection: Manual _____ (see back) Electronic _____

b.Transducer Information
- Make _____
- Model _____
- Serial Number _____
- Offset _____
- Linearity _____
- Scale _____
- Coefficient _____
- Diameter/Length _____

c. Data Logging Information
- Make _____
- Model _____
- Serial Number _____
- Mode _____ (linear or logarithmic)
- Ref. Point (designation) _____ (TOC, Ground Surface, actual elev.)
- Ref. Point value (if elev.) _____
- Positive numbers indicate increase or decrease in water level (circle one)

4. HYDRAULIC TEST INFORMATION

Start Time	Test Type (rising, falling)	Electronic File Name	Comments	End Time

5. MANUAL WATER LEVEL READINGS (as needed for control)

Time	Location	Depth to Water	Time	Location	Depth to Water

Signature _____ Date _____

AECOM

ATTACHMENT 1 - HYDRAULIC CONDUCTIVITY TEST LOG

6. EXPECTED WATER LEVEL DISPLACEMENT CALCULATION (optional)

a. Diameter of Slug (in) _____
b. Length of Slug (ft) _____
c. Volume/Linear ft of Slug (gal/ft from chart) _____
d. Volume of Slug (gal) _____ (b*c)
e. Diameter of Well (in) _____
f. Volume/Linear ft of Well (gal/ft from chart) _____
g. Expected Change in Water Level _____ (d/f)

Note: Water column height (1-g from front page) must be greater than transducer length plus length of slug.

Volume / Linear Ft. of Pipe		
Diam. (in)	Gallon	Liter
0.25	0.0025	0.0097
0.375	0.0057	0.0217
0.5	0.0102	0.0386
0.75	0.0229	0.0869
1	0.0408	0.1544
1.25	0.0637	0.2413
1.5	0.0918	0.3475
2	0.1632	0.6178

7. MANUAL WATER LEVEL MEASUREMENTS

Time (HH:MM)	Elapsed Time (min)	Depth to Water from TOC (ft)	Head, h (TOC - water depth)	h/Ho	Comments
	0			1	

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Benthic Grab Sampling

Procedure 3-36

1.0 Purpose and Scope

The purpose of this Standard Operating Procedure (SOP) is to establish the shipboard procedures for the collection, handling, and packaging of benthic infaunal samples.

2.0 Required Equipment

- 0.04m² van Veen grab
- Wooden stand
- Mud shoe
- Weights
- 37% Formaldehyde (+ MSD Sheet) (screened for PFAS)
- 0.3- or 0.5-mm sieve
- Sieve table
- HDPE or polypropylene Buckets
- HDPE or polypropylene Squirt bottle
- Borax
- HDPE jars
- Whirlpaks
- Paper
- Electrical Tape
- Clear packing tape
- Scissors
- HDPE or polypropylene Funnel
- Clear plastic rulers
- Siphon hose
- Steel or polypropylene Scrub brush
- Heavy duty coolers
- Absorbent packing material
- Heavy duty plastic bags (e.g., Hefty brand)

3.0 Procedure

3.1 Sample Collection

A 0.04-m^2 Ted Young-modified Van Veen grab sampler will be used to collect soft-bottom sediment samples for infaunal analysis. Sufficient weight will be added to the grab frame to allow sufficient penetration. In extremely soft sediment, a mud-shoe will be attached to the underside of the grab and the total weight added adjusted accordingly.

Once the survey vessel is on station and coordinates have been verified, the grab will be deployed. When slack in the winch wire indicates that the grab is on the bottom, the grab and captured sample will be brought back to the surface and gently set on the grab stand. Upon retrieval of the grab, the sample will be inspected for acceptability. The grab sampler must contain sediment to a depth of at least 7 cm (out of a possible 10 cm). The surface must be relatively undisturbed and the grab must be holding water. Any sample with low penetration or where sediment has washed out of the side due to improper closer of the grab sample jaws will be discarded. The grab sampler will be rinsed and redeployed following this same procedure.

Once a collected sample is deemed acceptable, the parameters will be recorded in the field log:

- penetration depth,
- sediment texture,
- sediment color,
- odor,
- infauna, and
- depth of the aRPD

The apparent redox discontinuity depth (aRPD) depth will be estimated visually, by examining the sediment surface. If the surface of the grab sample is black, with few or no infaunal organisms visible, and an odor of hydrogen sulfide is detected, then the sample has no measurable aRPD layer and is considered to be anoxic. If the surface is oxidized, a clear, plastic ruler marked in millimeters will be pushed into the sediment and pulled out toward the investigator. This action creates a vertical profile that can be examined and allows the aRPD to be measured to the nearest millimeter. Alternatively, the same ruler may be used to gently scrape off the surface layers, in millimeter fractions, until the gray-to-black anoxic sediment layer is exposed. The distance from the surface to the uppermost portion of the gray-to-black subsurface sediments is the depth of the aRPD. Any sediment adhering to the surface of the ruler will be rinsed back into the grab for processing with the remainder of the sample. The volume of the grab will be estimated by comparing the measured penetration depth with a prepared table of penetration depths versus grab volumes (Table 3.1). These data will be recorded in the field log.

Table 3.1. Values used to convert Grab penetration to Sediment Volume.

Grab Penetration Depth (cm)	Sediment Volume (L) 0.04-m^2 Grab	Sediment Volume (L) 0.10-m^2 Grab
3.5–4.0	1.0	
5.0	1.5	
6.0–6.5	2.0	
7.0	2.25	4.5
7.5	2.5	5.5
8.0	2.75	6.5
8.5–9.0	3.0	7.5
> 9.5 (over penetration) 0.04-m^2 grab	3.25	8.0
10		9.0
11		9.5
12		10.0
>15 (over penetration) 0.1-m^2 grab		11.0

Once these parameters are recorded, the grab will be placed over a bucket, the jaws opened, and the sample emptied into the bucket. Filtered seawater will be used to gently wash the sample into the bucket using a squirt bottle. Once thoroughly washed (if necessary), the grab will be redeployed until the required numbers of acceptable samples have been obtained for infaunal analysis.

3.2 Sample Processing

A sample jar of appropriate size will be selected for the sample (larger jars for sand or gravel samples). Sample jars will be Nalgene or other sturdy plastic jars with screw-capped lids. A teaspoon of Borax will be added to each jar to buffer the preservative. The Borax should be dissolved with a small amount of water prior to the addition of any sample to the jar. An internal label written in pencil on waterproof paper will be added to the jar and an external label will be taped to the side of the jar. Both labels will contain:

- Project name,
- Sample date,
- Station ID, and
- Sieve size.

The bucket containing the collected sample will be placed on the sieve table. The sample will be gently washed over the appropriate sieve size (0.3- or 0.5-mm) using 5-µm-filtered seawater through a hose. Water pressure will be regulated to allow breaking up of the sediment clumps without causing damage to the organisms. The portion retained on the screens will be rinsed into labeled jars using a squirt bottle of filtered water. Any large mucous excreting or fragile organisms (burrowing anemones, brittle stars, etc.) will be placed in a whirlpak bag, a small amount of formalin and seawater will be added, the bag will be closed, pre-labeled, and placed within the larger sample jar prior to bulk sample fixation. Once the jar is approximately half-full of sediment, 8% buffered formalin will be added to the jar (80-ml per 1-L). Samples should be preserved as quickly as possible to halt the deterioration of the animals. In the staging area, an uppercase “F” will be written on the lid of the jar with a fine-tipped Sharpie marker to denote that formalin was added to the sample.

If more than one jar is needed, the jar labels and lids will clearly be marked “jar 1 of 2”, “jar 2 of 2”, etc. and this information will be recorded in the log book.

The jar will be gently turned around on its side to distribute the formalin evenly throughout the sample. The time formalin was added, the total number of jars/whirlpaks, and the technician sieving each sample will be identified by his or her initials and will be recorded in the survey log.

Sieves and buckets will be thoroughly scrubbed and washed between samples.

3.3 Sample Handling

The lids on the sample jars will be taped with electrical tape and the jars inserted into large zip-locked bags. These individual bags will then be placed in tied plastic bags lined with absorbent padding. They will be packed into sturdy coolers with packing material to prevent shifting of the jars during transport. The chain of custody (CoC) will be placed in a Ziploc bag and taped to the inside lid of the cooler. The cooler will be taped shut and custody seals will be affixed in opposite corners. Level 2 Shipper training is not required for the packaging of formalin containing samples as long as the overall concentration of formalin remains below 10%.

3.4 Sample Archiving

Sample residues will be archived until the acceptance of the data by the client but not exceeding six-months. Identified material will be archived until the data is accepted by the client but not to exceed one-year.

A reference collection will not be generated unless specifically contracted by the client.

4.0 Special Training

5.0 Attachments

5.1 37% Formaldehyde Safety Data Sheet (SDS)

5.2 Sample CoC Form

Author	Reviewer	Revisions (Technical or Editorial)
Stacy Doner Marine Ecologist	James Blake Senior Marine Ecologist	Rev 0
Ken O'Donnell, PG Geologist	Claire Mitchell, PE, PMP Senior Engineer	Rev 1 – PFAS sampling update (July 2019)

Attachment 5.1
Formaldehyde SDS

Fisher Scientific

Part of Thermo Fisher Scientific

Material Safety Data Sheet

Creation Date 08-Feb-2010 Revision Date 05-Jun-2012 Revision Number 2

1. PRODUCT AND COMPANY IDENTIFICATION

Product Name Formaldehyde solution 37%

Cat No. F75F-1GAL; F75P-1GAL; F75P-4; F75P-20; F77-20; F77-200; F77P-4; F77P-20; F79-1; F79-4; F79-4LC; F79-20; F79-200; F79-500; F79P-4; F79P-20

Synonyms Formalin; Methanal; Methylene oxide; Oxymethane; Formic aldehyde; Methyl aldehyde (Preserved/Stabilized/USP/Molecular Biology/Certified ACS)

Recommended Use Laboratory chemicals

Company
Fisher Scientific
One Reagent Lane
Fair Lawn, NJ 07410
Tel: (201) 796-7100

Emergency Telephone Number
CHEMTREC®, Inside the USA: 800-424-9300
CHEMTREC®, Outside the USA: 001-703-527-3887

2. HAZARDS IDENTIFICATION

DANGER!

Emergency Overview

Flammable liquid and vapor. Cancer hazard. Poison, may be fatal or cause blindness if swallowed. Cannot be made non-poisonous. Toxic by inhalation, in contact with skin and if swallowed. Causes burns by all exposure routes. Vapor harmful. May cause an allergic skin reaction. May cause central nervous system effects. WARNING! This product contains a chemical known in the State of California to cause birth defects or other reproductive harm.

Appearance Colorless **Physical State** Liquid **odor** pungent

Target Organs Gastrointestinal tract (GI), Central nervous system (CNS), Eyes, Respiratory system, Skin, Optic nerve, Heart, Liver, Kidney, spleen, Blood

Potential Health Effects

Acute Effects
Principle Routes of Exposure

Eyes	Causes burns.
Skin	Causes burns. Toxic in contact with skin. May produce an allergic reaction.
Inhalation	Causes burns. Toxic by inhalation. Inhalation may cause central nervous system effects.

Ingestion	May be fatal or cause blindness if swallowed. Causes burns. May cause central nervous system effects. May cause adverse liver effects. May cause adverse kidney effects.
Chronic Effects	May cause cancer. Tumorigenic effects have been reported in experimental animals.. Experiments have shown reproductive toxicity effects on laboratory animals. May cause adverse liver effects. May cause adverse kidney effects. Repeated contact may cause allergic reactions in very susceptible persons. Component substance is listed on California Proposition 65 as a developmental hazard.

See Section 11 for additional Toxicological information.

Aggravated Medical Conditions Central nervous system disorders. Gastrointestinal tract. Preexisting eye disorders. Skin disorders.

3. COMPOSITION/INFORMATION ON INGREDIENTS

Haz/Non-haz

Component	CAS-No	Weight %
Water	7732-18-5	45 - 48
Formaldehyde	50-00-0	37 - 40
Methyl alcohol	67-56-1	15

4. FIRST AID MEASURES

Eye Contact	Rinse immediately with plenty of water, also under the eyelids, for at least 15 minutes. Immediate medical attention is required.
Skin Contact	Wash off immediately with plenty of water for at least 15 minutes. Immediate medical attention is required.
Inhalation	Move to fresh air. If breathing is difficult, give oxygen. Do not use mouth-to-mouth resuscitation if victim ingested or inhaled the substance; induce artificial respiration with a respiratory medical device. Immediate medical attention is required.
Ingestion	Do not induce vomiting. Call a physician or Poison Control Center immediately.
Notes to Physician	Treat symptomatically.

5. FIRE-FIGHTING MEASURES

Flash Point	50°C / 122°F
Method	No information available.
Autoignition Temperature	No information available.
Explosion Limits	
Upper	No data available
Lower	No data available
Suitable Extinguishing Media	Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.
Unsuitable Extinguishing Media	No information available.
Hazardous Combustion Products	No information available.

Sensitivity to mechanical impact	No information available.
Sensitivity to static discharge	No information available.

Specific Hazards Arising from the Chemical
Flammable. Risk of ignition. Vapors may form explosive mixtures with air. Vapors may travel to source of ignition and flash back. Containers may explode when heated.

Protective Equipment and Precautions for Firefighters
Thermal decomposition can lead to release of irritating gases and vapors.

NFPA	Health 3	Flammability 2	Instability 0	Physical hazards N/A

6. ACCIDENTAL RELEASE MEASURES

Personal Precautions	Use personal protective equipment. Remove all sources of ignition. Evacuate personnel to safe areas. Keep people away from and upwind of spill/leak. Take precautionary measures against static discharges. Do not get in eyes, on skin, or on clothing.
Environmental Precautions	Should not be released into the environment.
Methods for Containment and Clean Up	Remove all sources of ignition. Soak up with inert absorbent material. Take precautionary measures against static discharges. Keep in suitable, closed containers for disposal..

7. HANDLING AND STORAGE

Handling	Use only under a chemical fume hood. Remove all sources of ignition. Keep away from open flames, hot surfaces and sources of ignition. Take precautionary measures against static discharges. Do not breathe vapors or spray mist. Do not get in eyes, on skin, or on clothing.
Storage	Keep containers tightly closed in a dry, cool and well-ventilated place. Keep away from heat and sources of ignition. Flammables area.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Engineering Measures Use only under a chemical fume hood. Ensure adequate ventilation, especially in confined areas. Use explosion-proof electrical/ventilating/lighting/equipment. Ensure that eyewash stations and safety showers are close to the workstation location.

Exposure Guidelines

Component	ACGIH TLV	OSHA PEL	NIOSH IDLH
Formaldehyde	Ceiling: 0.3 ppm	(Vacated) TWA: 3 ppm (Vacated) STEL: 10 ppm (Vacated) Ceiling: 5 ppm TWA: 0.75 ppm STEL: 2 ppm	IDLH: 20 ppm TWA: 0.016 ppm Ceiling: 0.1 ppm
Methyl alcohol	TWA: 200 ppm STEL: 250 ppm Skin	(Vacated) TWA: 200 ppm (Vacated) TWA: 260 mg/m³ (Vacated) STEL: 250 ppm (Vacated) STEL: 325 mg/m³ Skin TWA: 200 ppm TWA: 260 mg/m³	IDLH: 6000 ppm TWA: 200 ppm TWA: 260 mg/m³ STEL: 250 ppm STEL: 325 mg/m³

Component	Quebec	Mexico OEL (TWA)	Ontario TWAEV
Formaldehyde	Ceiling: 2 ppm Ceiling: 3 mg/m³	Peak: 2 ppm Peak: 3 mg/m³	STEL: 1.0 ppm CEV: 1.5 ppm
Methyl alcohol	TWA: 200 ppm TWA: 262 mg/m³ STEL: 250 ppm STEL: 328 mg/m³ Skin	TWA: 200 ppm TWA: 260 mg/m³ STEL: 250 ppm STEL: 310 mg/m³	TWA: 200 ppm STEL: 250 ppm Skin

NIOSH IDLH: Immediately Dangerous to Life or Health

Personal Protective Equipment

Eye/face Protection Wear appropriate protective eyeglasses or chemical safety goggles as described by OSHA's eye and face protection regulations in 29 CFR 1910.133 or European Standard EN166

Skin and body protection Wear appropriate protective gloves and clothing to prevent skin exposure

Respiratory Protection Follow the OSHA respirator regulations found in 29 CFR 1910.134 or European Standard EN 149. Use a NIOSH/MSHA or European Standard EN 149 approved respirator if exposure limits are exceeded or if irritation or other symptoms are experienced

9. PHYSICAL AND CHEMICAL PROPERTIES

Physical State	Liquid
Appearance	Colorless
odor	pungent
Odor Threshold	No information available.
pH	No information available.
Vapor Pressure	No information available.
Vapor Density	> 1.0
Viscosity	No information available.
Boiling Point/Range	101°C / 213.8°F
Melting Point/Range	0°C / 32°F
Decomposition temperature	No information available.
Flash Point	50°C / 122°F
Evaporation Rate	No information available.
Specific Gravity	No information available.

9. PHYSICAL AND CHEMICAL PROPERTIES

Solubility	Soluble in water
log Pow	No data available

10. STABILITY AND REACTIVITY

Stability	Stable under normal conditions.
Conditions to Avoid	Incompatible products. Heat, flames and sparks.
Incompatible Materials	Strong oxidizing agents, Strong bases, nitriles, Acids, Isocyanates, Acid anhydrides, Metals, Acid chlorides
Hazardous Decomposition Products	Carbon monoxide (CO), Carbon dioxide (CO_2), Hydrogen, Formaldehyde
Hazardous Polymerization	Hazardous polymerization does not occur
Hazardous Reactions .	None under normal processing.

11. TOXICOLOGICAL INFORMATION

Acute Toxicity

Product Information No acute toxicity information is available for this product

Component Information

Component	LD50 Oral	LD50 Dermal	LC50 Inhalation (Dust)
Formaldehyde	500 mg/kg (Rat)	Not listed	0.578 mg/L (Rat) 4 h
Methyl alcohol	5628 mg/kg (Rat)	15800 mg/kg (Rabbit)	64000 ppm (Rat) 4 h 83.2 mg/L (Rat) 4 h

Irritation Causes burns by all exposure routes

Toxicologically Synergistic Products No information available.

Chronic Toxicity

Carcinogenicity The table below indicates whether each agency has listed any ingredient as a carcinogen.

Component	ACGIH	IARC	NTP	OSHA	Mexico
Formaldehyde	A2	Group 1	Reasonably Anticipated	X	A2

ACGIH: (American Conference of Governmental Industrial Hygienists)
A1 - Known Human Carcinogen
A2 - Suspected Human Carcinogen
A3 - Animal Carcinogen
ACGIH: (American Conference of Governmental Industrial Hygienists)

IARC: (International Agency for Research on Cancer)
IARC: (International Agency for Research on Cancer)
Group 1 - Carcinogenic to Humans
Group 2A - Probably Carcinogenic to Humans
Group 2B - Possibly Carcinogenic to Humans
NTP: (National Toxicity Program)
NTP: (National Toxicity Program)
Known - Known Carcinogen
Reasonably Anticipated - Reasonably Anticipated to be a Human Carcinogen

Sensitization	May cause sensitization by skin contact
Mutagenic Effects	Mutagenic effects have occurred in humans.
Reproductive Effects	Experiments have shown reproductive toxicity effects on laboratory animals.
Developmental Effects	Developmental effects have occurred in experimental animals. Component substance is listed on California Proposition 65 as a developmental hazard.
Teratogenicity	Teratogenic effects have occurred in experimental animals..
Other Adverse Effects	Tumorigenic effects have been reported in experimental animals.. See actual entry in RTECS for complete information.
Endocrine Disruptor Information	No information available

12. ECOLOGICAL INFORMATION

Ecotoxicity

. Do not empty into drains.

Component	Freshwater Algae	Freshwater Fish	Microtox	Water Flea
Formaldehyde	Not listed	Leuciscus idus: LC50 = 15 mg/L 96h	Not listed	EC50 = 20 mg/L 96h EC50 = 2 mg/L 48h
Methyl alcohol	Not listed	Pimephales promelas: LC50 > 10000 mg/L 96h	EC50 = 39000 mg/L 25 min EC50 = 40000 mg/L 15 min EC50 = 43000 mg/L 5 min	EC50 > 10000 mg/L 24h

Persistence and Degradability	No information available
Bioaccumulation/ Accumulation	No information available
Mobility	

Component	log Pow
Formaldehyde	-0.35
Methyl alcohol	-0.74

13. DISPOSAL CONSIDERATIONS

Waste Disposal Methods Chemical waste generators must determine whether a discarded chemical is classified as a hazardous waste. Chemical waste generators must also consult local, regional, and national hazardous waste regulations to ensure complete and accurate classification

Component	RCRA - U Series Wastes	RCRA - P Series Wastes
Formaldehyde - 50-00-0	U122	-
Methyl alcohol - 67-56-1	U154	-

14. TRANSPORT INFORMATION

DOT

UN-No	UN1198
Proper Shipping Name	FORMALDEHYDE, SOLUTIONS, FLAMMABLE
Hazard Class	3
Subsidiary Hazard Class	8
Packing Group	III

TDG

UN-No	UN1198
Proper Shipping Name	FORMALDEHYDE, SOLUTIONS, FLAMMABLE
Hazard Class	3
Subsidiary Hazard Class	8
Packing Group	III

IATA

UN-No	UN1198
Proper Shipping Name	FORMALDEHYDE, SOLUTIONS, FLAMMABLE
Hazard Class	3
Subsidiary Hazard Class	8
Packing Group	III

IMDG/IMO

UN-No	UN1198
Proper Shipping Name	FORMALDEHYDE, SOLUTIONS, FLAMMABLE
Hazard Class	3
Subsidiary Hazard Class	8
Packing Group	III

15. REGULATORY INFORMATION

International Inventories

Component	TSCA	DSL	NDSL	EINECS	ELINCS	NLP	PICCS	ENCS	AICS	CHINA	KECL
Water	X	X	-	231-791-2	-		X	-	X	X	X
Formaldehyde	X	X	-	200-001-8	-		X	X	X	X	X
Methyl alcohol	X	X	-	200-659-6	-		X	X	X	X	X

Legend:
X - Listed
E - Indicates a substance that is the subject of a Section 5(e) Consent order under TSCA.

F - Indicates a substance that is the subject of a Section 5(f) Rule under TSCA.
N - Indicates a polymeric substance containing no free-radical initiator in its inventory name but is considered to cover the designated polymer made with any free-radical initiator regardless of the amount used.
P - Indicates a commenced PMN substance
R - Indicates a substance that is the subject of a Section 6 risk management rule under TSCA.
S - Indicates a substance that is identified in a proposed or final Significant New Use Rule
T - Indicates a substance that is the subject of a Section 4 test rule under TSCA.
XU - Indicates a substance exempt from reporting under the Inventory Update Rule, i.e. Partial Updating of the TSCA Inventory Data Base Production and Site Reports (40 CFR 710(B).
Y1 - Indicates an exempt polymer that has a number-average molecular weight of 1,000 or greater.
Y2 - Indicates an exempt polymer that is a polyester and is made only from reactants included in a specified list of low concern reactants that comprises one of the eligibility criteria for the exemption rule.

U.S. Federal Regulations

TSCA 12(b) Not applicable

SARA 313

Component	CAS-No	Weight %	SARA 313 - Threshold Values %
Formaldehyde	50-00-0	37 - 40	0.1
Methyl alcohol	67-56-1	15	1.0

SARA 311/312 Hazardous Categorization

Acute Health Hazard	Yes
Chronic Health Hazard	Yes
Fire Hazard	Yes
Sudden Release of Pressure Hazard	No
Reactive Hazard	No

Clean Water Act

Component	CWA - Hazardous Substances	CWA - Reportable Quantities	CWA - Toxic Pollutants	CWA - Priority Pollutants
Formaldehyde	X	100 lb	-	-

Clean Air Act

Component	HAPS Data	Class 1 Ozone Depletors	Class 2 Ozone Depletors
Formaldehyde	X		-
Methyl alcohol	X		-

OSHA

Component	Specifically Regulated Chemicals	Highly Hazardous Chemicals
Formaldehyde	2 ppm STEL 0.5 ppm Action Level 0.75 ppm TWA	TQ: 1000 lb

CERCLA
This material, as supplied, contains one or more substances regulated as a hazardous substance under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) (40 CFR 302)

Component	Hazardous Substances RQs	CERCLA EHS RQs
Formaldehyde	100 lb	100 lb

Component	Hazardous Substances RQs	CERCLA EHS RQs
Methyl alcohol	5000 lb	-

California Proposition 65
This product contains the following Proposition 65 chemicals:

Component	CAS-No	California Prop. 65	Prop 65 NSRL
Formaldehyde	50-00-0	Carcinogen	40 µg/day
Methyl alcohol	67-56-1	Methanol	-

State Right-to-Know

Component	Massachusetts	New Jersey	Pennsylvania	Illinois	Rhode Island
Formaldehyde	X	X	X	X	X
Methyl alcohol	X	X	X	X	X

U.S. Department of Transportation
Reportable Quantity (RQ): Y
DOT Marine Pollutant N
DOT Severe Marine Pollutant N

U.S. Department of Homeland Security
This product contains the following DHS chemicals:

Component	DHS Chemical Facility Anti-Terrorism Standard
Formaldehyde	11250 lb STQ (solution)

Other International Regulations

Mexico - Grade Moderate risk, Grade 2

Canada

This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations (CPR) and the MSDS contains all the information required by the CPR.

WHMIS Hazard Class
B3 Combustible liquid
D1A Very toxic materials
D2A Very toxic materials
D2B Toxic materials
E Corrosive material





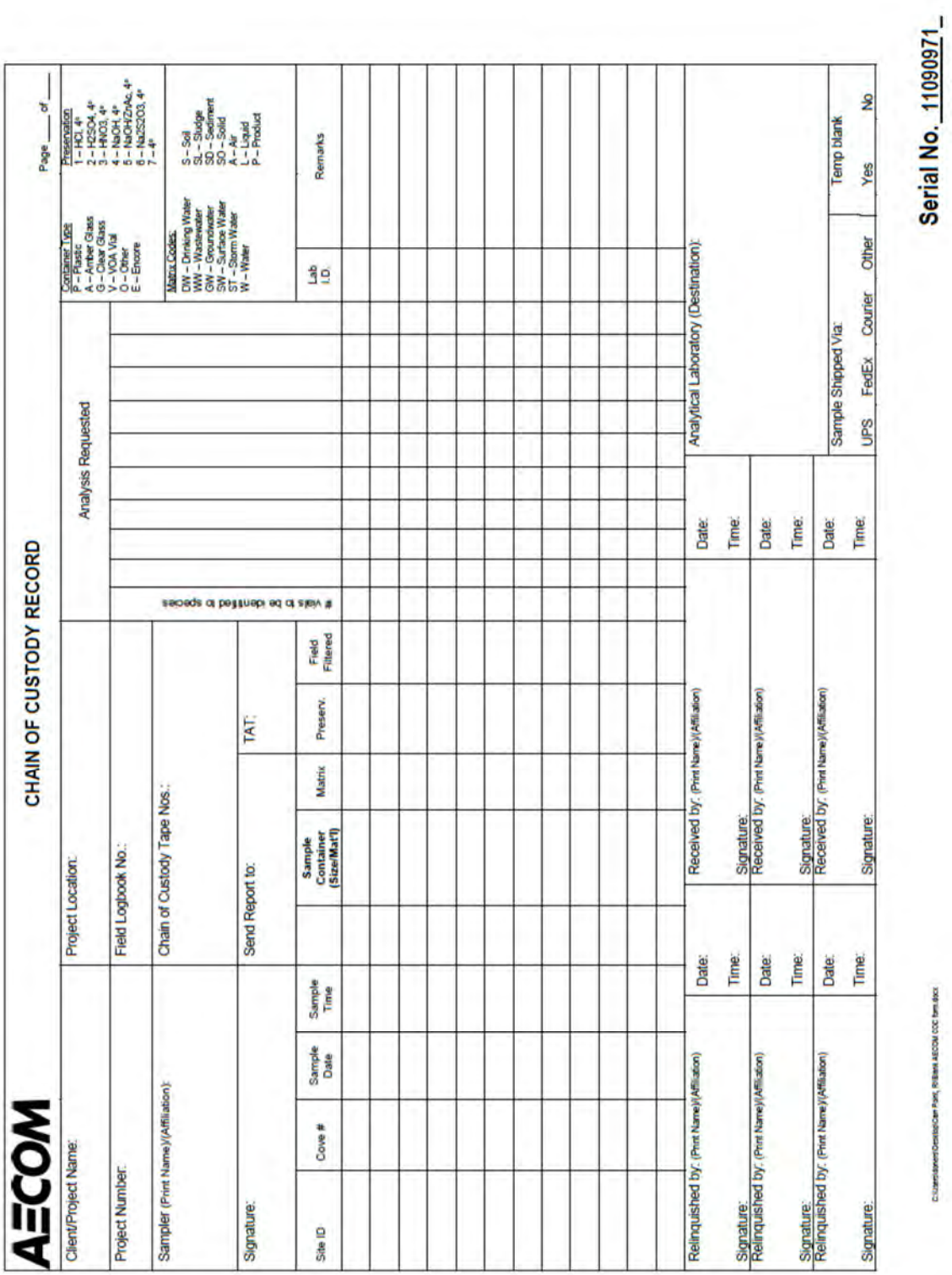
16. OTHER INFORMATION

Prepared By	Regulatory Affairs Thermo Fisher Scientific Email: EMSDS.RA@thermofisher.com
Creation Date	08-Feb-2010
Print Date	05-Jun-2012
Revision Summary	"***", and red text indicates revision

Disclaimer
The information provided on this Safety Data Sheet is correct to the best of our knowledge, information and belief at the date of its publication. The information given is designed only as a guide for safe handling, use, processing, storage, transportation, disposal and release and is not to be considered as a warranty or quality specification. The information relates only to the specific material designated and may not be valid for such material used in combination with any other material or in any process, unless specified in the text.

End of MSDS

Attachment 5.2
Sample Chain of Custody Form



CHAIN OF CUSTODY RECORD

AECOM

Page ____ of ____

Client/Project Name:

Project Location:

Project Number:

Field Logbook No.:

Sampler (Print Name)/(Affiliation):

Chain of Custody Tape Nos.:

Signature:

Send Report to:

TAT:

Analysis Requested

vials to be identified to species

Container Type:
P – Plastic
A – Amber Glass
G – Clear Glass
V – VOA Vial
O – Other
E – Encore

Preservation:
1 – HCl, 4°
2 – H2SO4, 4°
3 – HNO3, 4°
4 – NaOH, 4°
5 – NaOH/ZnAc, 4°
6 – Na2S2O3, 4°
7 – 4°

Matrix Codes:
DW – Drinking Water
WW – Wastewater
GW – Groundwater
SW – Surface Water
ST – Storm Water
W – Water
S – Soil
SL – Sludge
SD – Sediment
SO – Solid
A – Air
L – Liquid
P – Product

Site ID	Cove #	Sample Date	Sample Time	Sample Container (Size/Mat'l)	Matrix	Preserv.	Field Filtered	Lab I.D.	Remarks

Relinquished by: (Print Name)/(Affiliation) Date: Time: Received by: (Print Name)/(Affiliation) Date: Time: Analytical Laboratory (Destination):

Signature: Signature:

Relinquished by: (Print Name)/(Affiliation) Date: Time: Received by: (Print Name)/(Affiliation) Date: Time:

Signature: Signature:

Relinquished by: (Print Name)/(Affiliation) Date: Time: Received by: (Print Name)/(Affiliation) Date: Time: Sample Shipped Via: UPS FedEx Courier Other Temp blank Yes No

Signature: Signature:

Serial No. 11090971_

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

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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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Appendix E
Community Air Monitoring Plan

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Memorandum for Appendix E: Community Air Monitoring Plan
Remedial Investigation
Quality Assurance Project Plan Addendum
Camp Smith, Cortlandt, New York
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

To protect the community from any potential airborne releases that could result from field activities associated with the Remedial Investigation, community air monitoring will be performed in general accordance with the New York State Department of Health (NYSDOH) Generic Community Air Monitoring Plan (CAMP), Attachment 1A of the New York State Department of Environmental Conservation (NYSDEC) Division of Environmental Remediation (DER)-10 Technical Guidance for Site Investigation and Remediation, as attached to this Memorandum (NYSDEC, 2010). A CAMP is required by the NYSDEC whenever intrusive work is conducted as part of an environmental investigation or remediation.

Per DER-10, continuous air monitoring will be performed in the vicinity of the drill rig when intrusive activities are underway. Air monitoring will consist of a dust monitor placed on a tripod adjacent to the work areas, in a downwind location. Background (upwind) levels will be measured each day prior to start-up of site activities and periodically throughout the day. Per the NYSDOH Generic CAMP, the following actions will be taken if acceptable levels of air impacts are exceeded:

- If particulate levels (PM10) are greater than 100 micrograms per cubic meter ($\mu g/m^3$) above background for a 15-minute period, or if airborne dust is observed leaving the work area, dust suppression techniques will be employed. Work will continue with these suppression techniques provided that PM10 levels do not exceed 150 $\mu g/m^3$ above background and no visible dust is migrating from the work area. If PM10 exceeds 150 $\mu g/m^3$ over background, work will be stopped, and a re-evaluation of activities will be initiated.

Signed:



Claire Mitchell, PE, PMP
Project Manager
AECOM Technical Services, Inc.

New York State Department of Health
Generic Community Air Monitoring Plan
(Appendix 1A of the NYSDEC DER-10 Technical Guidance for Site Investigation and Remediation)

Overview

A Community Air Monitoring Plan (CAMP) requires real-time monitoring for volatile organic compounds (VOCs) and particulates (i.e., dust) at the downwind perimeter of each designated work area when certain activities are in progress at contaminated sites. The CAMP is not intended for use in establishing action levels for worker respiratory protection. Rather, its intent is to provide a measure of protection for the downwind community (i.e., off-site receptors including residences and businesses and on-site workers not directly involved with the subject work activities) from potential airborne contaminant releases as a direct result of investigative and remedial work activities. The action levels specified herein require increased monitoring, corrective actions to abate emissions, and/or work shutdown. Additionally, the CAMP helps to confirm that work activities did not spread contamination off-site through the air.

The generic CAMP presented below will be sufficient to cover many, if not most, sites. Specific requirements should be reviewed for each situation in consultation with NYSDOH to ensure proper applicability. In some cases, a separate site-specific CAMP or supplement may be required. Depending upon the nature of contamination, chemical- specific monitoring with appropriately-sensitive methods may be required. Depending upon the proximity of potentially exposed individuals, more stringent monitoring or response levels than those presented below may be required. Special requirements will be necessary for work within 20 feet of potentially exposed individuals or structures and for indoor work with co-located residences or facilities. These requirements should be determined in consultation with NYSDOH.

Reliance on the CAMP should not preclude simple, common-sense measures to keep VOCs, dust, and odors at a minimum around the work areas.

Community Air Monitoring Plan

Depending upon the nature of known or potential contaminants at each site, real-time air monitoring for VOCs and/or particulate levels at the perimeter of the exclusion zone or work area will be necessary. Most sites will involve VOC and particulate monitoring; sites known to be contaminated with heavy metals alone may only require particulate monitoring. If radiological contamination is a concern, additional monitoring requirements may be necessary per consultation with appropriate DEC/NYSDOH staff.

Continuous monitoring will be required for all ground intrusive activities and during the demolition of contaminated or potentially contaminated structures. Ground intrusive activities include, but are not limited to, soil/waste excavation and handling, test pitting or trenching, and the installation of soil borings or monitoring wells.

Periodic monitoring for VOCs will be required during non-intrusive activities such as the collection of soil and sediment samples or the collection of groundwater samples from existing monitoring wells. “Periodic” monitoring during sample collection might reasonably consist of taking a reading upon arrival at a sample location, monitoring while opening a well cap or

overturning soil, monitoring during well baling/purging, and taking a reading prior to leaving a sample location. In some instances, depending upon the proximity of potentially exposed individuals, continuous monitoring may be required during sampling activities. Examples of such situations include groundwater sampling at wells on the curb of a busy urban street, in the midst of a public park, or adjacent to a school or residence.

VOC Monitoring, Response Levels, and Actions

Volatile organic compounds (VOCs) must be monitored at the downwind perimeter of the immediate work area (i.e., the exclusion zone) on a continuous basis or as otherwise specified. Upwind concentrations should be measured at the start of each workday and periodically thereafter to establish background conditions, particularly if wind direction changes. The monitoring work should be performed using equipment appropriate to measure the types of contaminants known or suspected to be present. The equipment should be calibrated at least daily for the contaminant(s) of concern or for an appropriate surrogate. The equipment should be capable of calculating 15-minute running average concentrations, which will be compared to the levels specified below.

1. If the ambient air concentration of total organic vapors at the downwind perimeter of the work area or exclusion zone exceeds 5 parts per million (ppm) above background for the 15-minute average, work activities must be temporarily halted and monitoring continued. If the total organic vapor level readily decreases (per instantaneous readings) below 5 ppm over background, work activities can resume with continued monitoring.

2. If total organic vapor levels at the downwind perimeter of the work area or exclusion zone persist at levels in excess of 5 ppm over background but less than 25 ppm, work activities must be halted, the source of vapors identified, corrective actions taken to abate emissions, and monitoring continued. After these steps, work activities can resume provided that the total organic vapor level 200 feet downwind of the exclusion zone or half the distance to the nearest potential receptor or residential/commercial structure, whichever is less - but in no case less than 20 feet, is below 5 ppm over background for the 15-minute average.

3. If the organic vapor level is above 25 ppm at the perimeter of the work area, activities must be shutdown.

4. All 15-minute readings must be recorded and be available for State (DEC and NYSDOH) personnel to review. Instantaneous readings, if any, used for decision purposes should also be recorded.

Particulate Monitoring, Response Levels, and Actions

Particulate concentrations should be monitored continuously at the upwind and downwind perimeters of the exclusion zone at temporary particulate monitoring stations. The particulate monitoring should be performed using real-time monitoring equipment capable of measuring particulate matter less than 10 micrometers in size (PM-10) and capable of integrating over a period of 15 minutes (or less) for comparison to the airborne particulate action level. The equipment must be equipped with an audible alarm to indicate exceedance of the action level. In addition, fugitive dust migration should be visually assessed during all work activities.

1. If the downwind PM-10 particulate level is 100 micrograms per cubic meter (mcg/m^3) greater than background (upwind perimeter) for the 15-minute period or if airborne dust is observed leaving the work area, then dust suppression techniques must be employed. Work may continue with dust suppression techniques provided that downwind PM-10 particulate levels do not exceed 150 mcg/m^3 above the upwind level and provided that no visible dust is migrating from the work area.

2. If, after implementation of dust suppression techniques, downwind PM-10 particulate levels are greater than 150 mcg/m^3 above the upwind level, work must be stopped and a re-evaluation of activities initiated. Work can resume provided that dust suppression measures and other controls are successful in reducing the downwind PM-10 particulate concentration to within 150 mcg/m^3 of the upwind level and in preventing visible dust migration.

3. All readings must be recorded and be available for State (DEC and NYSDOH) and County Health personnel to review.

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Appendix F
Risk Assessment Work Plan

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DRAFT FINAL
Human Health and Ecological Risk Assessment Work Plan
Camp Smith Training Facility
Cortlandt, New York

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

July 2022

Prepared for:

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List of Acronyms and Abbreviations

%	percent
ABS	absorption factor
AFFF	aqueous film forming foam
AOI	area of interest
ARAR	Applicable or Relevant and Appropriate Requirement
ARNG	Army National Guard
ATSDR	Agency for Toxic Substances and Disease Registry
BERA	Baseline Ecological Risk Assessment
bgs	below ground surface
CalEPA	California Environmental Protection Agency
cm^2	square centimeter
CFR	Code of Federal Regulations
COC	chemicals of concern
COPC	chemicals of potential concern
COPEC	chemicals of potential ecological concern
CSM	conceptual site model
CTE	central tendency exposure
DA	Department of the Army
DERP	Defense Environmental Restoration Program
DoD	Department of Defense
ELCR	excess lifetime cancer risk
EPC	exposure point concentration
ERA	ecological risk assessment
ESV	ecological screening values
ESTCP	Environmental Security Technology Certification Program
FOD	frequency of detection
FS	Feasibility Study
GIABS	gastrointestinal absorption fraction
HA	Health Advisory
HEAST	Health Effects Assessment Summary Tables
HHRA	human health risk assessment
HI	hazard indices
HQ	hazard quotient
IPaC	Information, Planning, and Conservation System
INRMP	Integrated Natural Resources Management Plan
IRIS	Integrated Risk Information System
kg	kilogram
L	liter

L/hour	liters per hour
LOAEL	lowest observed adverse effect level
LOD	limit of detection
mg/cm^2	milligrams per centimeters squared
mg/day	milligram per day
MRL	minimal risk level
NCEA	National Center for Environmental Assessment
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
ND	non-detect
ng/L	nanograms per liter
NOAEL	no observed adverse effect level
NOEC	no observed effect concentration
NYARNG	New York Army National Guard
NYS	New York State
NYSDMNA	New York State Department of Military and Naval Affairs
OEHHA	Office of Environmental Health and Hazard Assessment
OSD	Office of the Assistant Secretary of Defense
PA	Preliminary Assessment
PC99	99 percent protection concentration
PC95	95 percent protection concentration
PFAS	per- and polyfluoroalkyl substances
PFBA	perfluorobutanoic acid
PFBS	perfluorobutanesulfonate
PFDA	perfluorodecanoic acid
PFDoA	perfluorododecanoic acid
PFHpA	perfluoroheptanoic acid
PFHxA	perfluorohexanoic acid
PFHxS	perfluorohexanesulfonic acid
PFNA	perfluorononanoic acid
PFOA	perfluorooccctanoic acid
PFOS	perfluorooctanesulfonate
PFPeA	perfluoropentanoic acid
PFUdA	perfluoroundecanoic acid
PPRTV	Provisional Peer-Reviewed Toxicity Value
PRG	preliminary remediation goal
RBSL	Risk-Based Screening Level
RI	Remedial Investigation
RME	reasonable maximum exposure
RSC	Rapid Site Characterization

RSL	Regional Screening Level
SERDP	Strategic Environmental Research and Development Program
SI	Site Inspection
SL	screening level
SLERA	screening level ecological risk assessment
SMDP	scientific/management decision point
SU	sampling unit
TCRA	Time Critical Removal Action
TRV	toxicity reference value
TSERAWG	Tri-Services Environmental Risk Assessment Work Group
UCL	upper confidence limit
UFP-QAPP	Uniform Federal Policy Quality Assurance Project Plan
US	United States
USEPA	United States Environmental Protection Agency
USFWS	US Fish and Wildlife Service
UU/UE	unlimited use/unrestricted exposure
WP	work plan
WWTP	wastewater treatment plant
VOC	volatile organic compound

Quality Information

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1.0 Introduction

This Risk Assessment Work Plan (WP) is provided as an appendix of the Remedial Investigation (RI) Uniform Federal Policy Quality Assurance Project Plan (UFP-QAPP) for RI activities investigating the potential impacts of per- and polyfluoroalkyl substances (PFAS) associated with historical activities at the Camp Smith Training Facility (Camp Smith, also referred to as the "facility") located in Cortlandt Manor, Westchester County, New York. As described in **Worksheet #10** of the QAPP, Camp Smith can be accessed directly from New York State (NYS) Route 202. Bear Mountain Bridge Road runs along the facility on the western and southern borders, and the United States (US) Military Academy at West Point is located across the Hudson River, approximately 10 miles north (NYS Department of Military and Naval Affairs [NYSDMNA], 2018) (see **Figure 10-2** of the QAPP).

Camp Smith comprises roughly 1,600 acres of training property for the New York Army National Guard (NYARNG). Approximately 94 percent (%) of Camp Smith is rugged, mountainous terrain, while the remaining 95-acre Camp Smith cantonment area consists of outdoor ranges, training simulation facilities, administrative buildings, and maintenance shops that sit on a plateau overlooking the Hudson River (**Figure 10-2** of the QAPP). Camp Smith has no air support facilities. Camp Smith is approximately 30 miles north of New York City and approximately 0.75 miles east of the Hudson River (NYSDMNA, 2018).

Camp Smith is in the Lower Hudson River watershed, which is a part of the 13,300-square mile Hudson River basin. The main channel of the Hudson River spans nearly 1,000 feet of Camp Smith's western and southern boundaries and forms a deep gorge through the Hudson Highlands in this area (NYARNG, 2015). Surface water resources at Camp Smith include natural streams, rivers, and open water features. Several unnamed intermittent tributaries and numerous vernal pools and wetlands are scattered throughout the facility. Surface runoff from the facility eventually drains into the Hudson River.

Dickiebusch Lake is on the northeastern end of Camp Smith (**Figure 10-6** of the QAPP). Dickiebusch Lake covers approximately 6 acres and is connected to several streams, one of which is Putnam Brook. The headwaters of Putnam Brook flow into the northern-most portion of Dickiebusch Lake, which then drains south bordering Camp Smith on the west before draining into the Annsville Creek impoundment. Annsville Creek borders Camp Smith on the eastern side of the facility before turning southwest to border the southern portion.

In 2019, the Army National Guard (ARNG) conducted a Preliminary Assessment (PA) at Camp Smith that identified four potential PFAS release areas where aqueous film forming foam (AFFF) may have been used or released historically were identified (AECOM, 2019a). The potential PFAS release areas were divided into three areas of interest (AOIs) based on their proximity to one another and the assumed groundwater flow direction (**Figure 10-7** of the QAPP). A description of each of the AOIs is provided in **Section 10.5.1** of the QAPP. A 2019 SI was subsequently conducted to determine the presence or absence of perfluorooctanoic acid (PFOA), perfluorooctanesulfonate (PFOS), and perfluorobutanesulfonate (PFBS) at or above screening levels (SLs) in the identified AOIs (AECOM, 2022). The SLs adopted for the SI were extracted from the memorandum from the Office of the Assistant Secretary of Defense (OSD) dated 15 September 2021 (Assistant Secretary of Defense, 2021). Other PFAS were detected in soil, surface water, and sediment during the SI; however, OSD did not develop SLs for them due to the lack of currently available toxicity values for these chemicals from US Environmental Protection Agency's (USEPA's) hierarchy of sources of dose-response values (USEPA, 2003; Assistant Secretary of Defense, 2021). A summary of the results of the SI, focusing on PFOS, PFOA, and PFBS, is as follows:

- At AOI 1 (Former Fire Pit), PFOA in groundwater exceeded the SL of 40 nanogram per liter (ng/L), with a maximum concentration of 58.4 ng/L at location AOI 1-GW3. Based on the results of the SI, further evaluation of AOI 1 is warranted in an RI.
- At AOI 2 (Former Fire Station) and AOI 3 (Former Airfield and Former NYS Academy of Fire Science Annex), PFOS in groundwater exceeded the SL of 40 ng/L, with a maximum concentration of 147 ng/L at location CS-MW003S. Based on the results of the SI, further evaluation of AOIs 2 and 3 are warranted in an RI.
- The detected concentrations of PFOA, PFOS, and PFBS in soil at all AOIs were below the SLs. However, further soil characterization was recommended for the RI.
- PFOA, PFOS, and PFBS were not detected in surface water. PFOA and PFOS were detected in sediment samples, but PFBS was not detected. There are no OSD-established PFAS SLs for sediment; therefore, these results are presented for informational purposes only.
- During SI Mobilization 2, additional information was obtained regarding the onsite wastewater treatment plant (WWTP) and the former Sludge Drying Beds. While there was no evidence to suggest the WWTP was a release area, the Sludge Drying Beds were identified as a potential secondary release area warranting investigation.
- Detections of PFOA, PFOS, and PFOS in groundwater in the northern portion of AOI 1 (north of the Former Burn Pit) at wells AOI 1-GW-3 and CS MW001S/D indicate there may be a potential PFAS source north of AOI 1. Therefore, the Gravel Pit was identified as a potential PFAS release area warranting investigation.

The scope of the RI is generally bounded by the facility boundary. The goal is to investigate the potential environmental impacts associated with AFFF and similar chemical releases suspected at the AOIs identified during the PA and SI (AECOM, 2019b and 2019c). RI Mobilization 1 field activities include sampling two additional potential release areas that were identified after the SI: Sludge Drying Beds and Gravel Pit. RI Mobilization 2 will be conducted at a to-be-determined date to address data gaps from the RI Mobilization 1 and perform any additional sampling required for completion of the risk assessment, if needed.

The objective of the Risk Assessment WP is to provide the approach for the human health risk assessment (HHRA) and ecological risk assessment (ERA) performed as part of the RI. These objectives include identifying the human and ecological receptors and exposure pathways to be evaluated and the sources to be used to identify appropriate SLs, exposure assumptions, and toxicity values. The risk assessment approach was developed in accordance with the USEPA and US Department of the Army (DA) risk assessment guidance, as referenced in this WP.

The term “PFAS”, as used throughout the Risk Assessment WP, refers to a group of related individual chemicals. The individual chemicals are referred to by name (e.g., PFOA). The term PFAS will be used throughout this WP to encompass all PFAS chemicals being evaluated, including PFOA, PFOS, and PFBS, which are the key components of the suspected releases. A summary of the historical PFAS investigations at the facility are summarized in **Worksheet #10** of the QAPP**,** and the full analyte lists for the RI are identified in **Worksheet #15** of the QAPP.

This Risk Assessment approach may be updated as new guidance, reference values, matrices, exposure scenarios, or exposure pathways that warrant an update are identified. In cases where more current reference sources and/or values are available at the time the HHRA or ERA calculations are being performed, the more current sources and values will be applied, as appropriate. Additional background information and a preliminary Conceptual Site Model (CSM) for the study area are provided in **Worksheet #10** of the QAPP.

1.1 Data Selection and Evaluation

The risk assessments will include analytical data discussed in this section, collected as part of the RI field program. These data will be considered representative of current facility conditions and will be collected to meet data quality objectives for use in conducting risk assessments. As described in **Worksheets #14** and **#17**, samples will be collected from soil, groundwater, surface water, and sediment during the RI field investigation. A habitat survey will also be conducted for consideration in the risk assessments.

Data selected for use in the risk assessments, including consideration of the sample locations, potential exposure media, exposure points, exposure pathways, land use(s), and receptors, as applicable, are based on the preliminary facility-specific human health and ecological CSMs presented in **Worksheet #10**.

Soil data collected from sampling units (SUs) located within AOIs 1 through 3 will be grouped into surface soil and subsurface soil depth intervals for evaluation in the risk assessments, as applicable. Each SU will represent a sampling grid located at a suspected PFAS release area (see **Figures 17-4** and **17-5** in the QAPP). **Figures 17-2** and **17-3** in the QAPP show the proposed Rapid Site Characterization (RSC) soil sample grid locations for the Gravel Pit and Sludge Drying Beds that will be sampled during the Mobilization 1 field investigation and will not be used in the risk assessments. Additional RSC surface soil sampling may continue with “step-out” locations until the data are sufficiently to allow for source area identification. Surface soil will be defined as soil collected at a depth within 0 to 2 feet below ground surface (bgs). Subsurface soil will be defined as soil collected at a depth greater than 2 feet bgs. Consistent with typical USEPA risk assessment practice (USEPA Supplemental Risk Assessment Guidance for the Superfund Program [1989]), soils deeper than 15 feet bgs or the top of the water table, whichever is shallower, will not be included in the risk assessment because receptors are not likely to come into contact with these deeper soils. For future scenarios in which development of the area, resulting in the mixing of surface and subsurface soils, may occur, the combined surface and subsurface soil interval (i.e., 0 to 15 feet bgs [or the top of the water table if it is shallower]) will be evaluated in the HHRA. This process represents a conservative evaluation of potential human exposure for purposes of the HHRA.

Groundwater data collected from permanent monitoring wells during the RI field investigation will be evaluated in the HHRA. RSC (i.e., grab) groundwater samples, collected to guide further sampling, will not be used in the risk assessments. Groundwater data collected from permanent monitoring wells will be summarized in two ways for evaluation in the risk assessment, as applicable (as further discussed in **Section 2** [HHRA]): (1) groundwater collected from all depths, and (2) shallow groundwater, defined as groundwater samples collected less than or equal to 15 feet bgs (see **Figure 17-1** in the QAPP). PFAS are the only potential facility-related chemicals of potential concern (COPCs) for the facility being evaluated under the scope of this RI. However, it is unknown whether volatile organic compounds (VOCs) were used as accelerants during fire training activities and may have been released at AOI 1. To address this data gap, groundwater sampling for VOCs will be conducted during RI Mobilization 1 at the wells installed at AOI 1.

The ERA will not utilize groundwater data given that there are no complete exposure pathways between groundwater and ecological receptors and because surface water data reflecting groundwater discharges will be collected as part of the RI field investigation.

Surface water and sediment data will be collected from within the onsite surface water bodies (e.g., Dickiebusch Lake and Putnam Brook) on and near the facility boundary (see **Figures 17-1** and **Figure 17-7** in the QAPP). Surface water and sediment samples will primarily be collected in areas that are considered “wading” depths along the shoreline and will be co-located. Samples

collected from deeper portions of Dickiebusch Lake will likely require a small boat for co-located surface water and sediment sampling. Surface water samples will be collected as un-filtered grab samples from the midpoint in the water column. Sediment data evaluated in the risk assessments will be collected from the top 0 to 0.5 feet. If warranted in RI Mobilization 2, porewater may be collected to support the RI evaluation of the nature and extent of PFAS in shallow groundwater potentially discharging into the downgradient wetlands and surface water bodies.

Worksheet #14 of the QAPP describes the field sampling tasks and **Worksheet #17** provides the sampling design and rationale for each media and area.

1.2 Summary Statistics

For each medium/exposure area, the data will be compiled into summary statistics as discussed below for evaluation in the risk assessments, using the aggregation reporting functions within Earthsoft's EQuIS software (Earthsoft, 2021 (i.e., the software used for analytical data management). For each chemical detected at least once within an area/media/depth interval (i.e., surface soil, subsurface soil, etc.), the summary statistics will include the minimum and maximum detected concentrations, location of maximum detected concentration, frequency of detection (FOD), and the range of detection limits calculated in accordance with USEPA Risk Assessment Guidance for Superfund (USEPA, 1989).

For sample locations in which a duplicate sample was also collected, the duplicate sample results for each chemical/medium/area combination will be processed prior to the calculation of summary statistics. Duplicates will be resolved as follows:

- When both the sample and duplicate are detected, the average of field and duplicate will be used to calculate summary statistics;
- When both the sample and duplicate are non-detects (NDs), the sample with the lower limit of detection (LOD) will be used; and
- When one of the pair is reported as not detected, and the other is detected, the detected result will be used.

2.0 Human Health Risk Assessment

A facility-specific HHRA will be conducted to evaluate whether exposure to PFAS attributable to past operations at the facility may pose a potential cancer risk and/or noncancer hazard to human health above the USEPA target levels defined in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) [40 US Code of Federal Regulations (CFR) § 300.430] (USEPA, 1991; USEPA, 1994). The evaluation will include quantitative estimation of potential cancer risk and noncancer hazard to current and potential future human receptors that may come into contact with Site-related PFAS in soil, groundwater, sediment, and surface water. The HHRA will be conducted in accordance with the USEPA and DA risk assessment guidance and policies, as applicable, and as referenced throughout this WP. Guidance/policies include, but are not limited to, the following:

- USEPA. 1989. *Risk Assessment Guidance for Superfund: Volume I. Human Health Evaluation Manual (Part A)*. Interim Final. Office of Emergency and Remedial Response. US Environmental Protection Agency, Washington, D.C. EPA 540/1-89/002.
- USEPA. 1991. *Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions.* OSWER Directive #9355.0-30. April.
- USEPA. 2003. *Human Health Toxicity Values in Superfund Risk Assessments*. OSWER Directive 9285.7-53. Washington, DC. 5 December.
- USEPA. 2001a. *Risk Assessment Guidance for Superfund: Volume I, Human Health Evaluation Manual (Part D, Standardized Planning, Reporting, and Review of Superfund Risk Assessments)*. Final. Publication 9285.7-047. December.
- USEPA. 2004. *Risk Assessment Guidance for Superfund: Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment)*. Final. OSWER No. 9285.7-02 EP. Office of Emergency and Remedial Response. August.
- USEPA. 2014a. *Human health evaluation manual, supplemental guidance: Update of standard default exposure factors*. Office of Superfund Remediation and Technology Innovation. OSWER Directive 9200.1-120. February 2014, updated September 2015.
- DoD. 2012. *Defense Environmental Restoration Program (DERP) Management Manual, DoDM 4715.20*. 9 March.
- Assistant Secretary of Defense. 2021. *Investigating Per- and Polyfluoroalkyl Substances within the Department of Defense Cleanup Program*. United States Department of Defense. September.
- DA. 1999. *Risk Assessment Handbook, Volume I: Human Health Evaluation*. Engineer Manual. Department of the Army, U.S. Army Corps of Engineers. Washington, DC 20314-1000. EM 200-1-4. 31 January.

The HHRA conclusions will inform risk management decisions. If the results of the HHRA indicate potential risk/hazard in excess of USEPA's target levels, as defined in the NCP [40 CFR § 300.430] (USEPA, 1991; USEPA, 1994), federal and state cleanup standards will be evaluated to determine if they are Applicable or Relevant and Appropriate Requirements (ARARs) as part of the Feasibility Study (FS). A weight of evidence evaluation that considers the HHRA results and ARARs will be conducted to determine the final list of Chemicals of Concern (COCs) for remedial action. 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.

References cited herein are based on the most current versions of sources available as of the date of this Risk Assessment WP. In the case that updates to references become available, the most current version of the references available at the time the HHRA is initiated will be used and appropriately referenced in the HHRA.

USEPA's four step HHRA paradigm (USEPA, 1989) will be followed to conduct the HHRA, as follows. Each of the HHRA steps is discussed in further detail in the following subsections.

- Data Evaluation and Hazard Identification
- Exposure Assessment
- Toxicity Assessment
- Risk Characterization

2.1 Data Evaluation/Hazard Identification

The data evaluation and hazard identification step involves identification and summarization of facility data appropriate for use in the HHRA and the selection of COPCs for quantitative evaluation in the HHRA. Analytical data will be grouped for evaluation in the HHRA, as discussed in **Section 1.1**, following resolution of duplicates, as discussed in **Section 1.2**.

2.1.1 Selection of Chemicals of Potential Concern

COPCs are a subset of the complete list of chemicals detected in environmental media (i.e., soil, groundwater, etc.) that are carried through the quantitative risk assessment process. The HHRA COPC selection process may consider low FOD, low toxicity and low concentration, consistency with background (if available), and whether the chemical is likely to be present due to laboratory contamination. PFAS are the only potential facility-related COPCs for the facility being evaluated under the scope of this RI. However, it is unknown whether VOCs were used as accelerants during fire training activities that may have been released at AOI 1. Groundwater sampling for VOCs will be conducted during RI Mobilization 1 at the wells installed at AOI 1.

2.1.1.1 Frequency of Detection

Chemicals will not be eliminated as COPCs on the basis of low FOD alone, consistent with USEPA guidance (USEPA, 1989). Other lines of evidence to be considered include whether a COPC is also identified in other facility media and if historical and/or current facility-related activities support the presence of the chemical in the affected medium, for example.

2.1.1.2 Comparison to Human-Health Screening Levels

Preliminary COPCs will be identified based on a comparison of the maximum detected concentrations of individual PFAS per media/area/depth interval (as applicable) to human health SLs. State-specific values will not be used to select COPCs for further evaluation in the HHRA. As discussed in the introduction to **Section 2**, if cleanup action is determined to be necessary based upon the results of the HHRA, federal and state ARARs will be incorporated into the selection of PRGs in the FS.

Human health SLs will be selected and/or developed for PFOS, PFOA, and PFBS in accordance with the memorandum from the OSD (Assistant Secretary of Defense, 2021). The SLs presented in this memorandum are herein referred to as the "OSD SLs". Human health SLs will not be developed for PFAS other than PFOS, PFOA, and PFBS due to the lack of currently available toxicity values for these chemicals from USEPA's hierarchy of sources of dose-response values

(USEPA, 2003; 2021a; Assistant Secretary of Defense, 2021). It is expected that toxicity values for additional PFAS compounds will be incorporated into USEPA's hierarchy of sources and the 2021 OSD list of SLs updated and expanded in the future. The screening values and toxicity values current at the time the HHRA is conducted will be used. The potential risks associated with PFAS lacking final toxicity values from USEPA's hierarchy of sources will be discussed qualitatively in the Uncertainty Analysis of the HHRA. PFAS (i.e., those with final toxicity values at the time the HHRA is initiated) detected at concentrations greater than the associated SLs will be identified as COPCs and will be further quantitatively evaluated in the HHRA. Individual PFAS that are either not detected in a particular medium or that are detected at concentrations less than the associated SLs will be excluded from being COPCs and will not be evaluated further in the HHRA.

The human health SLs to be used in the screening assessment for soil, groundwater, sediment, and surface water are discussed by media below. SLs are developed for potentially applicable exposure pathways, including residential and non-residential exposure to soil, exposure to groundwater used as a source of potable water, and exposure to sediment and surface water during recreational activities. **Section 2.2** provides a more detailed discussion of the preliminary human health CSM and the potential exposure pathways.

Soil

Soil SLs used in the HHRA will be equal to the OSD soil SLs (Assistant Secretary of Defense, 2021). If the OSD SLs are updated, or other inputs (i.e., toxicity values, default exposure assumptions, etc.) are updated by USEPA, the most current versions will be used in the HHRA, as applicable.

The current OSD soil SLs for PFBS are the USEPA Regional SLs (RSLs) for residential soil and industrial soil (USEPA, 2021a), respectively, based on a target hazard quotient (HQ) of 0.1 to account for potential cumulative effects per target organ.

Published soil RSLs are not currently available for PFOS and PFOA; therefore, OSD developed soil SLs protective of residential and commercial/industrial incidental ingestion and dermal contact exposure scenarios for PFOS and PFOA using USEPA's RSL Calculator (USEPA, 2021a) based on a target cancer risk level of 1E-6 (applicable to PFOA only) and a target HQ of 0.1 (applicable to PFOA and PFOS). USEPA-recommended default exposure assumptions for residential and industrial soil exposure scenarios were used in the development of the OSD soil SLs. Toxicity values used in the derivation of SLs were selected by OSD as discussed in **Section 2.3**.

The residential soil SLs will be used to select preliminary COPCs for evaluation of non-worker receptors. This method is considered conservative for the trespasser and recreational user scenarios because these receptors are assumed to be exposed to soil fewer days per year and for fewer years than is assumed for a residential scenario.

Potential exposure to airborne particles in outdoor air is not included in the development of human health soil SLs because toxicity values for the inhalation exposure route are not available for PFOA, PFOS, or PFBS from USEPA's recommended hierarchy of sources of dose-response values (USEPA, 2003; 2021a; Assistant Secretary of Defense, 2021). The associated uncertainties will be discussed in the HHRA.

A comparison to SLs protective of the soil to groundwater migration pathway will not be included in the HHRA. Analytical groundwater data will be available and evaluated directly.

Groundwater

As discussed in **Section 1.1**, groundwater data will be summarized in two ways for evaluation in the HHRA: (1) groundwater collected from all depths, and (2) shallow groundwater, defined as groundwater samples collected less than or equal to 15 feet bgs or the top of the water table if it is shallower.

The groundwater SL protective of a residential drinking water pathway will be used. For PFBS, the SL is the OSD tap water SL, which is equal to the USEPA RSL for tap water (USEPA, 2021a), based on a target HQ of 0.1 to account for potential cumulative effects per target organ.

For PFOS and PFOA, two sources of groundwater SLs will be used, as follows:

- USEPA's Lifetime Drinking Water Health Advisory (HA) levels for PFOS and PFOA (as individual chemicals and the combined PFOS + PFOA concentration) (USEPA, 2016b and c); and
- Published USEPA tap water RSLs are not currently available for PFOS and PFOA. Therefore, the OSD groundwater SLs for PFOS and PFOA protective of a residential drinking water pathway will be used (Assistant Secretary of Defense, 2021). These SLs were developed by OSD using USEPA's RSL Calculator (USEPA, 2021a) based on a target cancer risk level of 1E-6 (applicable to PFOA only) and a target HQ of 0.1 (applicable to both PFOA and PFOS). USEPA-default exposure assumptions for a residential drinking water ingestion exposure scenario were used. Toxicity values used in the derivation of SLs were selected by OSD as discussed in **Section 2.3**.

The residential tap water SLs (lower of the HA and OSD groundwater SLs for PFAS) will be used to select preliminary groundwater COPCs for all receptors. This method is conservative for scenarios involving incidental ingestion of groundwater (i.e., construction worker scenario), as opposed to ingestion of groundwater as drinking water.

Sediment

Published human health sediment SLs for PFAS are not available from USEPA (2021a) or Department of Defense (DoD) (Assistant Secretary of Defense, 2021). Therefore, sediment SLs will be derived for PFOS, PFOA, and PFBS using the USEPA RSL Calculator (USEPA, 2021a) based on a target cancer risk level of 1E-6 (applicable to PFOA only) and a target HQ of 0.1. Toxicity values used in the derivation of SLs will be selected as discussed in **Section 2.3**.

Sediment SLs protective of incidental ingestion of and dermal contact with sediment by a recreational user (adult/child) will be developed using USEPA recommended default exposure assumptions, where available. These levels are also protective of an adolescent trespasser's potential sediment exposure. Recreational users may contact sediment while walking/wading through the wetland area. The following conservative inputs protective of a potential facility-specific sediment exposure scenario will be used for preliminary screening purposes:

- Exposure frequency = 35 days per year. Assumes exposure to surface water may occur for 1 days per week for the 8 warmest months (i.e., April through November; 35 weeks) of the year.
- The following inputs are equal to the USEPA RSL calculator default values for a residential soil exposure scenario (USEPA 2014a and 2021a):
    - Exposure duration (years) = 6 (child), 20 (adult)
    - Sediment ingestion rate (milligram per day [mg/day]) = 200 (child), 100 (adult)
    - Skin surface area (square centimeter [cm^2]) = 2373 (child), 6032 (adult)
    - Adherence factor (milligram per cm^2 [mg/cm^2 per event]) = 0.2 (child), 0.07 (adult)

- Event Frequency (events per day) = 1
- Body weight (kilograms [kg]) = 15 (child), 80 (adult)

The above exposure assumptions are intended to be conservative for screening purposes and may be refined for use in further evaluation of COPCs in the facility-specific HHRA. Sediment SLs protective of incidental ingestion and dermal contact will be used to select sediment COPCs for further evaluation of the recreational user, adolescent trespasser, and onsite worker/military personnel (i.e., undergoing an outdoor training exercise) exposure scenarios.

Surface Water

Published human health surface water SLs for PFAS are not available from USEPA (2021a) or DoD (Assistant Secretary of Defense, 2021). Therefore, surface water SLs will be derived for PFOS, PFOA, and PFBS using the USEPA RSL Calculator (USEPA, 2021a) based on a target cancer risk level of 1E-6 (applicable to PFOA only) and a target HQ of 0.1. Toxicity values used in the derivation of SLs will be selected as discussed in **Section 2.3**.

Surface water SLs protective of incidental ingestion of surface water by a recreational user (adult/child) will be developed using USEPA recommended default exposure assumptions, where available. These levels are also protective of an adolescent trespasser's potential surface water exposure. The dermal contact pathway in water will be quantitatively evaluated for PFAS where chemical-specific parameters are available (USEPA, 2021a).

Recreational users may contact surface water while walking/wading through the wetland areas, Putnam Brook, or the shoreline of Dickiebusch Lake. The following conservative inputs protective of a potential facility-specific surface water exposure scenario will be used for preliminary screening purposes:

- Exposure frequency = 35 days per year. Assumes exposure to surface water may occur for 1 days per week for the 8 warmest months (i.e., April through November; 35 weeks) of the year.
- The following inputs are equal to the USEPA RSL calculator default values for a residential water exposure scenario (USEPA, 1989; 2014a; 2021a):
  - Exposure duration (years) = 6 (child), 20 (adult)
  - Surface water ingestion rate (liters [L]/hour) = 0.12 (child), 0.11 (adult) (conservatively equal to the upper percentile water ingestion rates while swimming from Table 3.5 of USEPA, 2011 and Table 3.7 of USEPA, 2019, respectively)
  - Exposure Time (hours per day) = 2.6 hours per day (conservatively equal to the national average exposure time for swimming [Exhibit 6-13 of USEPA, 1989])
  - Skin surface area (cm^2) = 2373 (child), 6032 (adult)
  - Body weight (kg) = 15 (child), 80 (adult)

The above exposure assumptions are intended to be conservative for screening purposes and may be refined for use in further evaluation of COPCs in the facility-specific HHRA. Surface water SLs protective of incidental ingestion and dermal contact exposure will be used to select surface water COPCs for further evaluation of the recreational user, adolescent trespasser, and onsite worker/ military personnel (i.e., undergoing an outdoor training exercise) exposure scenarios.

Sediment and surface water SLs protective of fish ingestion based on the transfer of PFAS from sediment/surface water to fish tissue within a water body will not be utilized in the HHRA because the streams (Putnam Brook) and wetlands are not conducive to fishing. A capture and release policy is in place for Dickiebusch Lake, which is located within a secured area of the facility. If

analytical results from boundary samples indicate migration of PFAS offsite, additional sampling may be considered for evaluation of additional potential exposure scenarios that may be present further downgradient.

2.2 Exposure Assessment

The purpose of the exposure assessment is to provide a quantitative estimate of the magnitude and frequency of potential exposure to COPCs by a receptor. Potentially exposed individuals and the pathways through which those individuals may be exposed to COPCs are identified based on the physical characteristics as well as the current and reasonably foreseeable future uses of the facility. The extent of a receptor's exposure is estimated by constructing exposure scenarios that describe the potential pathways of exposure to COPCs and the activities and behaviors of individuals that might lead to contact with COPCs in the environment. This information is identified based on the preliminary facility-specific CSM, which is presented in **Worksheet #10** of the QAPP and summarized below.

2.2.1 Summary of Human Health CSM

The majority of the roughly 1,600-acre property is an NYARNG installation used for military training. Approximately 94% of Camp Smith is rugged, mountainous terrain. The remaining 95-acre Camp Smith cantonment area consists of outdoor ranges, training simulation facilities, administrative buildings, and maintenance shops that sit on a plateau overlooking the Hudson River (NYSDMNA, 2018). Camp Smith has no air support facilities.

Current human receptors at the facility include onsite workers and approved visitors. It is also conservatively assumed that trespassers may access surface soil at the facility in the future if there is no longer controlled access. Range construction is expected to occur in the next few years and will involve reworking the ranges and potentially filling in Dickiebusch Lake. 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.

The northern portion of the facility is heavily wooded where access is open to the public. Several unnamed intermittent tributaries and numerous vernal pools and wetlands are scattered throughout the facility. Surface runoff from the facility eventually drains into the Hudson River. Surface water features include Putnam Brook, which flows into the northern-most portion of Dickiebusch Lake and then drains south bordering Camp Smith on the west before draining into the Annsville Creek impoundment. Dickiebusch Lake is located within a secured area of the facility; ARNG potentially plans to fill in the lake in the future. Therefore, current recreational users and outdoor workers/military personnel may access the Dickiebusch Lake surface water and sediment, but not under a future use scenario. Recreational users may fish in the lake but a capture and release policy is in place; therefore, consumption of fish tissue exposure pathway will not be evaluated in the HHRA.

Offsite media are not evaluated for the facility because most of the 95-acre Camp Smith cantonment area lies within a shallow valley outwash plain. As for surrounding land use, the nearest residential properties to the facility are along the northern property line. The Camp Smith trail head is approximately 0.5 miles to the west of the facility. Iona Island and the Iona Island Component Hudson River National Estuarine Research Reserve lie two miles to the west of the facility, across the Hudson River.

Two potable wells in the southern portion of the Camp Smith cantonment area, Wells A and B, supply drinking water to the facility. NYARNG began quarterly sampling of drinking water in April 2017 at the two water supply wells (approximate location shown on **Figure 10-4** in the QAPP). From April 2017 to April 2019, PFAS were consistently detected below the USEPA HA of 70 ng/L

in both Well A and Well B. The March 2020 sampling event identified a combined concentration of PFOA and PFOS that was above the USEPA HA, at 72.2 ng/L. The facility now provides filtered drinking water stations. Quarterly sampling at random filtered drinking water stations is being conducted. The facility water treatment plant (WTP) is being upgraded with a granular activated carbon system that will be operational in September 2022. Groundwater exposure for future onsite workers/military personnel and a future onsite hypothetical resident is potentially complete.

Reasonably anticipated future land use is not expected to change from the current land use described above with the exception of range construction and potentially filling in Dickiebusch Lake. However, the HHRA will conservatively evaluate an onsite unlimited use/unrestricted exposure (UU/UE) scenario to inform future risk-management decisions in the FS, if applicable. A remedial response will not necessarily be taken based on the results of the future onsite 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).

2.2.2 Potential Exposure Scenarios

The receptors and exposure pathways that will be evaluated in the HHRA were selected based on current and potential future land use based on the preliminary facility-specific CSM and are presented in the following table. For purposes of the HHRA, it is conservatively assumed that future land-use scenarios may involve some level of construction to convert the area to the desired use. Under this scenario, it is assumed that current subsurface soils may be brought to the surface and mixed with surface soil for exposure by future receptors.

Receptor	Timeframe	Exposure Pathway(s)
Onsite Worker/Military Personnel	Current	Exposure to onsite surface soil (0 to 2 feet bgs) through incidental ingestion and dermal contact.
	Future	Exposure to onsite 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 groundwater via ingestion as drinking water.
Onsite Construction/Utility Worker	Future	Exposure to onsite 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 onsite shallow groundwater (to a maximum depth of 15 feet bgs) via incidental ingestion, and dermal contact.
Onsite Adolescent Trespasser	Future	Exposure to onsite surface soil (0 to 2 feet bgs) through incidental ingestion and dermal contact and exposure to sediment and surface water via incidental ingestion and dermal contact in the onsite streams (Putnam Brook) and wetland areas.

Onsite Recreational User (Adult and Child)	Current	Exposure to onsite 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 sediment and surface water in Putnam Brook and Dickiebusch Lake will be evaluated under a wading scenario.
	Future	Exposure to onsite 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 sediment and surface water via incidental ingestion and dermal contact. Exposure to sediment and surface water via incidental ingestion and dermal contact in Putnam Brook will be evaluated under a wading scenario.
Hypothetical Onsite Resident (Adult/Child)	Future	Exposure to onsite 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 onsite groundwater via ingestion of drinking water, and dermal contact during bathing/showering.

The quantitative exposure assumptions for a reasonable maximum exposure (RME) scenario that will be used in the HHRA were selected in accordance with USEPA guidance (USEPA, 1989, 2002a, 2004, 2011, 2014a, 2014b, 2017, 2019). The RME provides an estimate of the upper range of exposure in a population (the 90th percentile or greater of expected exposure, consistent with USEPA, 2019) and is based on a combination of the upper-bound and central estimates of exposure parameters. Exposure assumptions may differ from default values to factor in facility-specific considerations. A central tendency exposure (CTE) scenario, which uses average exposure parameters to calculate an average exposure to an individual, will only be evaluated in the HHRA if the RME scenario for the associated receptor indicates a potential risk/hazard in excess of USEPA target levels, as defined by the NCP [40 CFR § 300.430] (USEPA, 1991; USEPA, 1994). The CTE scenario is more reflective of the facility-specific exposure scenario. Adjustments to the proposed exposure assumptions may be made based on additional facility-specific information and refinement of the human health CSM during the HHRA. If changes to the proposed exposure assumptions are made, the associated rationale will be provided in the HHRA report. **Figure F-1** presents the human health receptors, exposure areas, exposure media, and exposure pathways that will be evaluated in the HHRA. **Table F-1** through **Table F-8** present the quantitative exposure assumptions that will be used.

For each receptor and exposure area, the exposure dose will be estimated for each COPC via each exposure pathway by which the receptor is assumed to be exposed. Exposure doses for oral and dermal exposure will be calculated following USEPA guidance (1989, 2004). In the absence of dermal toxicity values, oral toxicity values will be utilized with appropriate adjustments (USEPA, 2004). The potential uncertainty associated with this assumption will be discussed in the HHRA.

The dermal contact pathway in water will be quantitatively evaluated for PFAS that are identified as a COPC and where USEPA chemical-specific parameters are available to estimate the dermal

contact pathway (USEPA, 2021a). Potential exposure to airborne particles in outdoor air (from soil) will not be quantitatively evaluated in the HHRA 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 will be discussed in the HHRA.

2.2.3 Exposure Point Concentrations

Exposure point concentrations (EPCs) for evaluation of soil, groundwater, sediment, and surface water will generally be equal to the 95% upper confidence limit (UCL) on the arithmetic mean concentration (USEPA, 2002b) per exposure area. The most current version of USEPA's ProUCL software available at the time the HHRA is started will be used to calculate the ProUCL-recommended UCL (USEPA, 2016a). The approach to be used for calculation of EPCs is discussed by media below.

Soil

Soil EPCs will be calculated for COPCs in surface soil and combined surface and subsurface soil within the facility when Mobilization 1 and 2 activities have finalized the AOIs. The soil sampling design, described in **Worksheet #17**, was established such that the number of soil samples shall be sufficient for calculation of a 95% UCL.

Groundwater

Site groundwater will be evaluated as one exposure area in the HHRA. In accordance with USEPA guidance (2014c), groundwater EPCs will be calculated for COPCs in groundwater and shallow groundwater using analytical groundwater data from permanent monitoring wells identified as being within the core of the plume, if present. In the absence of a clearly defined plume, professional judgment will be used to determine the appropriate dataset for calculation of reasonably conservative groundwater EPCs. Results from multiple sampling events will be reviewed to select the groundwater dataset to most appropriately represent current facility conditions, while accounting for potential variations in concentration over time.

Sediment and Surface Water

Sediment and surface water EPCs will be calculated for COPCs identified in the onsite streams (Putnam Brook), Dickiebusch Lake (current scenarios only), and wetland areas. The sediment and surface water sampling design, described in **Worksheet #17**, was established such that the number of sediment and surface water samples shall be sufficient for calculation of a 95% UCL.

2.3 Toxicity Assessment

The purpose of the toxicity or dose-response assessment is to identify the types of adverse health effects a chemical may potentially cause and to define the relationship between the dose of a chemical and the likelihood or magnitude of an adverse effect (response) (USEPA, 1989). The USEPA's guidance regarding the hierarchy of sources of human health dose-response values in risk assessment will be followed (USEPA, 2003), as follows:

- Tier 1: USEPA's Integrated Risk Information System (IRIS) (USEPA, 2022a);
- Tier 2: Provisional Peer-Reviewed Toxicity Values (PPRTVs) obtained from USEPA via the USEPA National Center for Environmental Assessment (NCEA) in Cincinnati, Ohio (USEPA, 2022b); and

- Tier 3: Other sources of dose-response values will be selected in accordance with USEPA guidance (USEPA, 2013) and include, but are not limited to, California Environmental Protection Agency (CalEPA) Office of Environmental Health and Hazard Assessment (OEHHA) Toxicity Criteria Database (CalEPA, 2022), Minimal Risk Levels (MRLs) published by the Agency for Toxic Substances and Disease Registry (ATSDR, 2022), and the Health Effects Assessment Summary Tables (HEAST) (USEPA, 1997a).

Currently, USEPA has published final toxicity factors for three PFAS; PFOS and PFOA (USEPA, 2016b, c) and PFBS (USEPA, 2021b). Oral reference doses are available for PFOS, PFOA, and PFBS; an oral cancer slope factor is available for PFOA only. These values will be used to quantitatively evaluate PFOS, PFOA, and PFBS in the HHRA. If prior to the time the HHRA is conducted, revised toxicity values are published from a source within USEPA's above hierarchy (2003) and USEPA formally adopts those toxicity values, the updated values will be used in the HHRA. Only final values will be considered in the HHRA (i.e., draft values will not be used).

USEPA guidance for early life exposure to carcinogens (USEPA, 2005a) requires that potential risks from chemicals that act by a mutagenic mode of action be calculated differently than chemicals that do not act via a mutagenic mode of action. PFOS, PFOA, and PFBS are not considered to be mutagenic, and therefore, adjustments to the calculation of potential risks for these PFAS will not be required.

In the absence of dermal toxicity values, oral toxicity values for PFOS, PFOA, and PFBS will be utilized in the HHRA for evaluation of dermal contact. Default values provided by USEPA's RSL calculator (USEPA, 2021a) will be used for the gastrointestinal absorption fraction (GIABS) (1 or 100%) and dermal absorption factor (ABS) (0.1 or 10%) will be used to assess potential risk to COPCs in soil and sediment. These estimates are uncertain and may result in an overestimation or underestimation of potential risk. Dermal exposure to PFOS, PFOA, and PFBS is considered a minor exposure pathway due to studies that suggest dermal absorption of these chemicals is slow and does not result in significant absorption (ATSDR, 2018). The uncertainties associated with the toxicity values used will be discussed in the HHRA.

2.4 Risk Characterization

Risk characterization combines estimates of exposure with toxicity data to develop estimates of the probability that an adverse effect will occur under the specified conditions of exposure. Estimates of potential carcinogenic risks are expressed as probabilities of developing cancer reported as excess lifetime cancer risk (ELCR). Current HHRA practice considers carcinogenic risks to be additive when assessing exposure to a mixture of hazardous substances. Non-carcinogenic hazards are reported as pathway-specific hazard indices (HIs), which are the sum of individual COPC HQs for that pathway. A total HI is calculated for each receptor by summing the pathway-specific HIs within each media (e.g., summing dermal and ingestion soil HI estimates). As a first approximation, all COPCs will be conservatively assumed to have additive effects. If the total HI assuming additive effects is greater than USEPA's target level, HIs will be calculated separately for COPCs that have similar systemic effects (i.e., per target organ endpoint).

USEPA (1991) states that where the cumulative incremental current or future potential ELCR to an individual is less than 1E-4, action generally is not warranted unless there are adverse environmental impacts. USEPA also considers noncancer hazards by using a target HI per target organ of 1 (USEPA, 1991). For each associated exposure scenario (i.e., receptor/medium/exposure area) with a potential ELCR or HI above USEPA risk/HI targets (USEPA, 1991), COCs will be selected from those COPCs significantly contributing to the cumulative ELCR > 1E-4 or target organ HI > 1 (at one significant figure). Risk drivers will be defined as chemicals with an individual chemical-specific ELCR > 1E-6 and/or HQ > 1. A weight-

of-evidence approach will be used to determine COCs. Other lines of evidence that may be considered in selecting COCs include nature and extent, other regulatory requirements, and background concentrations.

2.5 Uncertainty Analysis

Within any of the steps of the HHRA process, assumptions must be made due to a lack of absolute scientific knowledge. Some of the assumptions are supported by considerable scientific evidence, while others have less support. Every assumption introduces some degree of uncertainty into the HHRA process. Regulatory HHRA methodology requires that conservative assumptions be made throughout the HHRA to ensure that public health is protected. Therefore, when all of the assumptions are combined, it is much more likely that potential risks are overestimated rather than underestimated.

The assumptions that introduce the greatest amount of uncertainty in the HHRA, both facility-specific and those inherent to the HHRA process, will be discussed in the uncertainty section of the HHRA. Examples of facility-specific uncertainties are those associated with sampling/analysis methods, the COPC selection process, estimation of EPCs, representativeness of the exposure scenarios and input parameters, the availability of toxicity values, etc. Examples of uncertainties inherent to the HHRA process are the extrapolation of toxicity from animal studies to humans, from high to low doses, and the specific models used to develop dose-response values; the combination of upper-bound exposure estimates with upper-bound toxicity estimates, etc. The majority of the uncertainties associated with the HHRA will be discussed in qualitative terms, because for most of the assumptions, there is not enough information to assign a numerical value to the uncertainty that can be factored into the calculation of potential risk.

3.0 Ecological Risk Assessment

The purpose of the ERA will be to evaluate potential ecological effects of exposures to PFAS detected in media associated with PFAS release areas, including soil and downgradient sediment, and surface water. The outcome of the ERA will provide input to remedial decision-making that will protect the health of local populations and communities of biota. The ERA will be conducted in accordance with USEPA and DA risk assessment guidance and policies, as applicable.

The framework for the ERA will be consistent with USEPA methodology based on the following key guidance documents:

- USEPA. 1997b. *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessment - Interim Final*. US Environmental Protection Agency, Office of Solid Waste and Emergency Response, Office of Emergency and Remedial Response. EPA 540/R-97/006. June.
- USEPA. 1998. *Guidelines for Ecological Risk Assessment*. US Environmental Protection Agency, Washington, D.C. EPA/630/R-95/002F. April.
- USEPA. 2001b. *The Role of Screening-Level Risk Assessments and Refining Contaminants of Concern in Baseline Ecological Risk Assessments*. ECO UPDATE. Interim Bulletin Number 12. US Environmental Protection Agency, Office of Solid Waste and Emergency Response.
- Tri-Services Environmental Risk Assessment Work Group (TSERAWG). 2008. *A Guide to Screening Level Ecological Risk Assessment*. TSERAWG TG-090801.
- USEPA. 2005b. *Guidance for Developing Ecological Soil Screening Levels – Revised Draft*, OSWER Directive 9285.7-55. February.
- DA. 2010. *Risk Assessment Handbook, Volume II: Environmental Evaluation*. Engineer Manual. Department of the Army, U.S. Army Corps of Engineers. Washington, DC 20314-1000. EM 200-1-4. 31 December.

The PFAS technical documents and tools developed by the DoD Environmental Security Technology Certification Program (ESTCP) and Strategic Environmental Research and Development Program (SERDP) and the recently published guidance from the Argonne National Laboratory (Argonne) will also be considered for assessing ecological risk due to exposure to PFAS:

- Grippo, M. J. Hayse, I. Hlohowskyj, and K. Picel. 2021. *Derivation of PFAS Ecological Screening Values.* September. Updated November 2021.
- Conder, J., Arblaster, J., Larson, E., Brown, J., Higgins, C. 2020. *Guidance for Assessing the Ecological Risks of PFAS to Threatened and Endangered Species at Aqueous Film Forming Foam-Impacted Sites*. SERDP Project ER18-1614. January.
- Divine, C., Frenchmeyer, M., Dally, K., Osborn, E., Anderson, P., Zodrow, J. 2020. *Approach for Assessing PFAS Risk to Threatened and Endangered Species.* SERDP Project ER18-1653. March.

Although the SERDP guidance documents (Conder et al., 2020 and Divine et al., 2020) emphasize protection of threatened and endangered species, information is provided that can also be applied in ERAs for common species. These SERDP and Argonne documents reviewed and evaluated toxicity data and other chemical-specific parameters necessary to develop terrestrial and aquatic ecological benchmarks for several PFAS chemicals.

Given the rapidly evolving nature of the PFAS ecotoxicity and exposure evaluation methods, and regulatory and DoD guidance, significant developments may occur within the timeframe of the project. To the extent reasonable and relevant, such developments will be incorporated in the proposed ERA.

A tiered approach will be followed 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 – Screening Level ERA (SLERA); and
- Tier 2 – Baseline ERA (BERA).

Tier 1 – Screening Level Ecological Risk Assessment

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, 1997b) process:

- Identification and summarization of relevant datasets.
- Development of a preliminary CSM, which will identify potentially complete exposure pathways for ecological receptors.
- Comparison of maximum detected concentrations to ecological SLs 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 the event that potentially complete and significant ecological exposure pathways are identified, and maximum concentrations of certain COPECs exceed the generic SLs, additional evaluation may be recommended.

Prior to beginning the 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 adverse effects and accompanying uncertainty is needed (DA, 2010).

Tier 2 – Baseline Ecological Risk Assessment

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, 1997b) process and uses facility-specific information whenever possible:

- Step 3a provides a refinement of the conservative assumptions and resulting risk estimates (e.g., HQs) 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 HQs to below unity prior to implementing a facility-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 conducted 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.

For this evaluation, it is anticipated that a SLERA and Step 3a SLERA refinement will be completed, as needed, using the data collected under Mobilization 1 and Mobilization 2 (if needed) of the RI. If Step 3a identifies the need for further evaluation, an additional sampling effort may be proposed to support the BERA, and additional BERA details will be provided prior to the sampling effort. Risk management decisions related to performing a BERA and the need for additional facility-specific sampling efforts to support a BERA will be made by the project team.

The following sections provide additional details for the SLERA in the context of the following fundamental ERA components:

- Problem Formulation;
- Ecological Effects Assessment and Exposure Assessment; and
- Risk Characterization.

3.1 Screening Level Problem Formulation

The problem formulation provides the framework for the SLERA and serves to define the risk assessment objectives and identify the ecological receptors, exposure pathways, and endpoints to be evaluated. These components are presented in the following sections.

3.1.1 Environmental Setting

As indicated in Section 1.0, Camp Smith comprises roughly 1,600 acres of training property for the NYARNG. The majority of Camp Smith (approximately 94%) is rugged, mountainous terrain, while the remaining 95-acre Camp Smith cantonment area consists of outdoor ranges, training simulation facilities, administrative buildings, and maintenance shops that sit on a plateau overlooking the Hudson River (see **Figure 10-2** of the QAPP). Camp Smith is approximately 30 miles north of New York City and approximately 0.75 miles east of the Hudson River (NYSDMNA, 2018).

The main channel of the Hudson River spans nearly 1,000 feet of Camp Smith's western and southern boundaries (NYARNG, 2015) and surface runoff from the facility eventually drains into the Hudson River. Surface water resources at Camp Smith include natural streams, rivers, and open water features. Several unnamed intermittent tributaries and numerous vernal pools and wetlands are scattered throughout the facility. Two of the key surface water features of interest present onsite downgradient of the PFAS release areas under investigation are Dickiebusch Lake and Putnam Brook.

Dickiebusch Lake on the northeastern end of Camp Smith (see **Figure 10-6** of the QAPP) is the largest surface water feature (approximately 6 acres) on the facility in the vicinity of the AOIs under investigation. Military training activities in the vicinity of the lake include weapons training at a firing range located to the west of the lake and use of a helicopter landing pad located to the east. Vehicle traffic is relatively heavy in the vicinity of the lake and vehicles are stored in lots near the lake. The lake is not routinely used for training activities (Parsons, 1996).

Putnam Brook is a narrow stream that flows approximately 1,900 meters from north of Dickiebusch Lake to Annsville Creek, a tributary to the Hudson River. Putnam Creek is dammed

in the cantonment area to form the Dickiebusch Lake. The outlet from the lake flows underground though a culvert for approximately 200 meters and is tidally influenced at the confluence with Annsville Creek (Parsons, 1996). A brackish wetland is located at the downstream end of Putnam Brook just prior to the confluence with Annsville Creek.

The Putnam Brook watershed above the lake is relatively undisturbed and consists of a mixed hardwood forest community. The watershed below the lake is more disturbed and the ecological communities consist of mowed lawn, mowed lawn with trees, and successional hardwood forest. Firing ranges are located in the vicinity of the stream with several structures, roads, and vehicle storage areas nearby (Parsons, 1996).

Fish collected from within Dickiebusch Lake in May 1996 included bluegill (*Lepomis macrochirus*), pumpkinseed (*L. gibbosus*), American eel (*Anguilla rostrata*), largemouth bass (*Micropterus salmoides*), golden shiner (*Notemigonus crysolencas*), yellow perch (*Perca flavescens*), and black crappie (*Pomoxis nigromaculatus*). Fish collected from Putnam Brook in May 1996 included creek chub (*Semotilus atromaculatus*), blacknose dace (*Rhinichthys atratulus*), American eel, and eastern brook trout (*Salvelinus fontinalis*). Although Dickiebusch Lake was stocked with approximately 500 trout in the spring of 1996, the fish were likely in the deepest portions of the lake beyond the reach of the electrofishing unit used during the May 1996 survey (Parsons, 1996). Trout are no longer stocked and are not known to exist in Putnam Brook.

Macroinvertebrate sampling and habitat assessments conducted during the same sampling event indicated that conditions in Putnam Brook above the lake are considered good and below the lake were considered intermediate; however, some of the differences are attributed to changes in the physical habitat below the lake. The macroinvertebrate sampling in the lake identified a diverse community with many pollution intolerant species present (Parsons, 1996).

Onsite terrestrial habitats in the vicinity of the AOIs under investigations are limited due to the continuing military use and actively disturbed areas. AOIs 2 and 3 are in active portions of the facility in the vicinity of roadways and buildings with mowed lawns. AOI 1 is located along a roadway in a wooded area adjacent to Dickiebusch Lake. Although the AOIs may not provide significant ecological habitat, soil exposures will be evaluated in the SLERA.

The primary exposure pathways for the terrestrial areas with viable habitat includes direct contact with surface soils by terrestrial plants, reptiles (e.g., snakes), amphibians, soil invertebrates, mammals, and birds, and indirect contact (via bioaccumulation) by birds and mammals consuming plants and prey that accumulate PFAS from soil.

In the on-facility aquatic habitats (e.g., streams, wetlands, Dickiebusch Lake, Putnam Brook), PFAS in surface water, surface sediment (including porewater) may be contacted directly by aquatic plants, fish, amphibians, reptiles (e.g., turtles), and aquatic and benthic invertebrates living in the water column or sediment within the wetlands. Wildlife foraging within these areas could also be exposed directly to PFAS in these media through incidental ingestion and indirectly by ingestion and bioaccumulation of PFAS-contaminated plants and prey items.

PFAS in surface water and surface sediment (including porewater) may be contacted directly by aquatic plants, fish, amphibians, reptiles (e.g., turtles), and aquatic and benthic invertebrates living in the water column or sediment within the wetlands. Wildlife foraging within the wetlands could also be exposed directly to PFAS in these media through incidental ingestion and indirectly by ingestion and bioaccumulation of PFAS-contaminated plants and prey items.

As indicated in **Worksheet #14**, a habitat assessment will be conducted as part of RI Mobilization 1 to identify representative habitats and species present in the vicinity of the sampling locations to be evaluated in the risk assessment. The findings of the habitat assessment will be used to refine or confirm the receptors and exposure pathways identified in the preliminary CSM and may

be considered in the characterization of potential adverse effects, if identified based on comparisons to screening values.

3.1.1.1 Critical Habitat and Threatened/ Endangered Species

While much of Camp Smith is forested, the cantonment area that includes the AOIs under investigation contains paved areas and mowed grass surfaces that are generally not attractive habitat for wildlife species. The following species are listed as federally endangered, threatened, proposed, and/or candidate species within Camp Smith according to a query of the online US Fish and Wildlife Service (USFWS) Information, Planning, and Conservation System (IPaC) (USFWS, 2022b):

- Mammal: Northern long-eared bat, *Myotis septentrionalis* (threatened); Indiana bat, *Myotis sodalist* (endangered)
- Reptile: Bog turtle, *Clemmys muhlenbergii* (threatened)
- Insects: Monarch butterfly, *Danaus plexippus* (candidate)

The IPaC review did not identify any critical habitats within Camp Smith.

In addition to the federally listed species identified above, the draft Integrated Natural Resources Management Plan (INRMP) for Camp Smith identified the following state endangered or threatened species that have been historically documented to be present at Camp Smith (NYARNG, 2019)

- Plants: Spongy arrowhead, *Sagittaria calycina var. spongiosa* (threatened)
- Birds: Bald eagle, *Haliaeetus leucocephalus* (threatened)[1]
- Reptiles: Fence lizard, *Sceloporus undulatus* (threatened) and Timber rattlesnake, *Crotalus horridus* (threatened)

The draft INRMP indicated that a healthy population of the state threatened spongy arrowhead occurs in the tidal marsh near the confluence of Putnam Brook and Annsville Creek with approximately 50 to 100 plants observed during surveys conducted in 1996. No training occurs in or near the plant's habitat and the marsh has been identified as an area with a high protection priority (NYARNG, 2019).

A habitat assessment will be conducted as part of RI Mobilization 1 and the biologists conducting the assessment 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.

3.1.2 Selection of Specific Receptors and Exposure Pathways

Potentially complete ecological exposure pathways for ecological receptors potentially occurring in terrestrial habitat in the vicinity of the AOIs and in the downgradient on-facility aquatic habitats (e.g., streams, wetlands, Dickiebusch Lake, Putnam Brook) will be evaluated in the SLERA. Each exposure pathway includes a potential source of COPECs, an environmental medium, and a potential exposure route. In accordance with agency guidance, incomplete routes of exposure will not be evaluated in the SLERA. This approach is used to focus the assessment on exposure pathways that are considered to be potentially complete, and for which there are adequate data pertaining to the receptors, exposure, and toxicity.

The SLERA will not evaluate groundwater data given that there are no complete exposure pathways between groundwater and ecological receptors and because surface water data

[1] The bald eagle is also federally protected under the Bald and Golden Eagle Protection Act.

reflecting groundwater discharges to the surface will be available for screening. Porewater data are not being collected as part of Mobilization 1 but could be collected in the future if needed to assess the potential for adverse effects on benthic receptors due to PFAS potentially discharging from groundwater into sediment of aquatic habitats.

Exposure pathways differ in importance from species to species and from site to site. It is anticipated that ecological receptors may come in contact with soil in the upland habitat and surface water and surface sediment (including porewater) in the aquatic habitat downgradient from the PFAS release areas under investigation (e.g., streams, wetlands, Dickiebusch Lake, Putnam Brook).

The following exposure pathways will be evaluated in the SLERA:

- 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 (0 to 2 feet bgs).
- Benthic invertebrates and aquatic organisms (aquatic plants, aquatic invertebrates, fish, reptiles, and amphibians) directly exposed to PFAS in surface water or sediment in streams, wetlands, and/or other waterbodies.
- 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 or surface water in the aquatic habitat associated with streams, wetlands, and/or other waterbodies.

In the SLERA, exposure to sediment and surface water in the on-facility waterbodies will serve as a conservative surrogate for concentrations that have the potential to migrate into additional downgradient aquatic habitats. These exposure pathways will be refined based on the habitat assessment and analytical data from Mobilization 1 of the RI, and further evaluations of the exposure pathways will be considered during future mobilization(s). Future mobilizations could be conducted, if warranted, to address data gaps such as the need for further delineation or sampling of additional media (e.g., porewater). In cases where receptor-specific PFAS toxicity information is not available, potential impacts on receptors (e.g., reptiles) will be considered qualitatively.

3.1.3 Selection of Biological Endpoints

Based on the identification of potentially complete exposure pathways, SL assessment endpoints and measures of effect were identified. Assessment endpoints describe the characteristics of an ecosystem that have an intrinsic environmental value that is to be protected. Typically, assessment endpoints and receptors are selected for their potential exposure, ecological significance, economic importance, and/or societal relevance. For example, assessment endpoints usually focus on protection at the individual level for state- or federally-protected species (e.g., northern long-eared bat) and on the overall population for common species. The SLERA represents a very conservative SL assessment; the assessment endpoints are stated in generic terms that consider the available habitat within the exposure areas and the management goals of the facility, as appropriate. More specific assessment endpoints will be developed in a BERA, as needed.

Based on the general exposure pathways identified for the facility, the following assessment endpoints and their associated measures of effect will be addressed in the SLERA through comparison of media concentrations to appropriate screening values. The potential for adverse

effects is typically evaluated at the community, rather than individual, level in an ERA. Protection at the individual level will be afforded to special status species, when present.

In the SLERA, an exceedance of a screening value does not indicate that an adverse effect is occurring, only that further evaluation is needed. In the event that concentrations of certain PFAS exceed available screening values, additional evaluation may be conducted in a SLERA refinement step (referred to as Step 3a and described in **Section 3.5**). Observations made during the habitat assessment described in **Worksheet #14** of the QAPP may be considered in the characterization of potential adverse effects, if identified, based on comparisons to screening values.

Assessment Endpoint	Measure of Effect
Protection and maintenance of indigenous terrestrial plant and soil invertebrate communities in upland areas within the facility with viable terrestrial habitat at levels similar to those of nearby populations not exposed to facility-related PFAS.	Comparison of concentrations of PFAS in surface soil to soil screening values derived for the protection of plants and soil invertebrates. PFAS with detected concentrations above screening values will be identified as preliminary COPECs for plants and soil invertebrates that warrant further evaluation in Step 3a.
Protection and maintenance of terrestrial wildlife receptors (i.e., birds and mammals) that may forage in upland areas within the facility with viable terrestrial habitat at levels similar to those of nearby populations not exposed to facility-related PFAS.	Comparison of concentrations of PFAS in surface soil to soil screening values derived for the protection of birds and mammals. PFAS with detected concentrations above screening values will be identified as preliminary COPECs for terrestrial wildlife that warrant further evaluation in Step 3a.
Protection and maintenance of benthic invertebrate communities in the aquatic habitats within the facility at levels similar to those of nearby populations not exposed to facility-related PFAS.	Comparison of concentrations of PFAS in sediment to freshwater sediment screening values. PFAS with detected concentrations above screening values will be identified as preliminary COPECs for benthic invertebrates that warrant further evaluation in Step 3a.
Protection and maintenance of aquatic organism (plants, invertebrates, amphibians, fish) communities in the aquatic habitats within the facility at levels similar to those of nearby populations not exposed to facility-related PFAS.	Comparison of concentrations of PFAS in surface water to freshwater surface water screening values. PFAS with detected concentrations above screening values will be identified as preliminary COPECs for aquatic organisms that warrant further evaluation in Step 3a.
Protection and maintenance of semi-aquatic wildlife receptors (i.e., birds and mammals) that may forage within potentially impacted aquatic habitats within the facility at levels	Comparison of concentrations of PFAS in sediment and surface water to sediment and surface water screening values derived for the protection of birds and mammals.

similar to those of nearby populations not exposed to facility-related PFAS.	PFAS with detected concentrations above screening values will be identified as preliminary COPECs for semi-aquatic wildlife that warrant further evaluation in Step 3a.

In cases where receptor-specific PFAS screening values are not available, exposure pathways will be discussed qualitatively. For example, screening values for reptiles or for amphibians exposed to soil are generally not available, so quantitative evaluations are not possible. In addition, some aquatic organisms that reside in the water column may be exposed to PFAS in sediment via ingestion or direct contact; however, screening values are not available for these exposures, so these pathways will be considered qualitatively in the SLERA.

3.1.4 Conceptual Site Model

The end product of the problem formulation step is the development of an ecological CSM, which describes the COPEC origin, fate, transport, exposure pathways, and receptors of concern. The ecological CSM provides a clear and concise description of how ecological receptors may come into contact with Site-related COPECs via release mechanisms and exposure to soil, sediment (including porewater), and/or surface water. The ecological CSM provides the framework for the ERA and will be used to identify appropriate exposure pathways and receptors for evaluation.

Figure F-2 provides the preliminary ecological CSM for the on-facility terrestrial habitat and the aquatic habitat (e.g., streams, wetlands, Dickiebusch Lake, Putnam Brook).

PFAS release areas include the Former Fire Pit (AOI 1), the Former Fire Station (AOI 2), and the Former Airfield and the Former NYS Academy of Fire Science Annex (AOI 3). Two additional PFAS release areas are also under investigation: the Sludge Drying Beds and the Gravel Pit.

PFAS in soil in these release areas may have leached to groundwater. PFAS in these media may have migrated to surface water and sediment/porewater in the on-facility waterbodies via overland runoff or groundwater migration.

As described in **Worksheet #10** of the QAPP, PFAS are water soluble and can migrate readily from soil to groundwater or surface water via leaching and run-off, can readily migrate within groundwater, and may discharge to downgradient surface water bodies. Infiltration of rainfall recharges shallow groundwater that may discharge to the downgradient surface water bodies.

PFAS in surface soil (0 to 2 feet bgs) may be contacted directly by terrestrial plants, reptiles, amphibians, soil invertebrates, birds, and mammals living in the soil or on the soil surface. PFAS in surface water and sediment/porewater within the wetlands, streams, and lake may be contacted directly by aquatic plants, amphibians and reptiles, aquatic and benthic invertebrates, and fish living in the water column or sediment. Wildlife foraging within the on-facility exposure areas could also be exposed directly to chemicals in these media through incidental ingestion and indirectly by ingestion of contaminated plants and prey items. Other potentially complete but minor pathways, like direct contact with subsurface soil (>2 feet bgs), will be discussed qualitatively for burrowing animals. The findings of the habitat assessment described in **Worksheet #14** of the QAPP will be used to refine or confirm the receptors and exposure pathways identified in the preliminary CSM.

3.2 Screening Level Ecological Effects Assessment and Exposure Assessment

This phase of the SLERA is based on the CSM developed in the problem formulation and characterizes potential ecological exposures and corresponding effects. The ecological exposure assessment involves the identification of potential exposure pathways and an evaluation of the magnitude of exposure by identified ecological receptors. The ecological effects assessment describes the potential adverse effects to ecological receptors from exposure to COPECs in environmental media. The data and methods that will be used to identify and characterize ecological exposure and effects are described in the following subsections.

3.2.1 Data Evaluation and Identification of COPECs

COPECs will be identified by comparing media-specific concentrations to ecologically-protective screening values. Analytical data will be grouped for evaluation in the SLERA, as discussed in **Section 1.1**. Soil data will be reviewed to determine whether soil exposures will be considered on an SU- or facility-wide-basis. SUs may be evaluated as separate exposure areas if PFAS concentrations within the SUs are higher than the overall concentrations at the facility and the exposure potential in the SU is different from the larger area. The soil sampling design, described in **Worksheet #17**, was established such that the size and number of samples per SU shall be sufficient for calculation of a SU-specific 95% UCL in the case that an SU is determined to be the appropriate exposure area based on a review of the analytical data. UCLs may be used to refine the SLERA findings in Step 3a (as described in **Section 3.5**).

Surface water and sediment will be evaluated as four separate exposure areas: Dickiebusch Lake, Putnam Brook upstream of the lake and an unnamed tributary of Dickiebusch Lake (as one exposure area), the brackish wetland portion of Putnam Brook, and the upgradient portion of Putnam Brook (i.e., north of the brackish wetland). These areas will be evaluated as separate exposure areas based on differences in habitat conditions.

COPECs will be identified as PFAS detected in facility media that are carried through the quantitative risk assessment process. COPECs will be established per exposure area, medium, and depth interval (as appropriate). Consistent with the HHRA COPC selection process, preliminary PFAS COPECs will be identified in the SLERA based on a comparison of the maximum detected concentrations of each detected PFAS per media/area/depth interval (as applicable) to ecological screening values (ESVs). The ESVs will be based on conservative endpoints and sensitive ecological effects data and they represent tools used for a preliminary screening of surface soil, surface water, and sediment concentrations.

PFAS detected at concentrations above the ESVs will be identified as preliminary COPECs for further evaluation in Step 3a (as described in **Section 3.5**).

3.2.2 Ecological Effects Assessment

The preliminary ecological effects evaluation is an investigation of the relationship between the exposure to a chemical and the potential for adverse effects resulting from exposure. In this step, conservative ESVs for the ecological media of interest are identified.

Receptor- and media-specific ESVs will be used in the SLERA to identify preliminary COPECs and evaluate the potential for adverse effects on ecological receptors. These ESVs will be based on conservative endpoints and sensitive ecological effects data and will be used for a preliminary screening of PFAS levels to determine if there is a need to conduct further analyses or investigations.

The selected ESVs will focus on protecting the majority of the exposed communities (e.g., 95% of exposed taxa) from adverse effects related to survival, growth and reproduction under conditions of chronic or sensitive life-stage exposure. Currently, ESVs for PFAS are still evolving and lack general consensus; however, there is extensive and increasing literature on biological uptake, bioaccumulation, and ecological toxicity of PFAS. DoD-funded studies under the ESTCP and SERDP have resulted in recent publications containing ecological SLs for soil, sediment and surface water. In addition, PFAS ESVs have been developed under the Interagency Agreement between the US Department of Energy, Air Force Civil Engineer Center, and Argonne (Grippo et al., 2021). These will be the primary sources used to identify ESVs. USEPA published draft aquatic life ambient water quality criteria in April 2022 (USEPA, 2022d,e), and these values are expected to be finalized later in 2022.

The following key sources will be used to select the ESVs for the various facility media. The lowest of the available ESVs for each medium and receptor-group (i.e., plants, soil invertebrates, benthos, aquatic organisms, wildlife) will be selected for the SLERA, and the more facility-specific of these ESVs will be considered for the Tier 2 Step 3a refinement, as needed.

Soil

- Conder et al., 2020 and Divine et al., 2020. No observed effect concentration (NOEC) values with regard to survival, reproduction or growth as the endpoint for terrestrial plants and soil invertebrates.
- Grippo et al., 2021. Geometric mean NOEC values with regard to growth or germination as the typical endpoint for terrestrial plants; and survival, reproduction or growth as the endpoint for soil invertebrates.
- Divine et al., 2020. No observed adverse effect level (NOAEL) based Risk-Based SLs (RBSLs) for terrestrial wildlife derived using food web models based on consumption of plant and prey items impacted by PFAS in soil. SLs were derived for the meadow vole (*Microtus pennsylvanicus*), short-tailed shrew (*Blarina brevicauda*), little brown bat (*Myotis lucifugus*), long-tailed weasel (*Mustela frenata*), American goldfinch (*Spinus tristis*), house wren (*Troglodytes aedon*), and red-tailed hawk (*Buteo jamaicensis*).
- Grippo et al., 2021. Geometric mean NOAEL-based ESV for terrestrial wildlife derived using food web models based on consumption of plant and prey items impacted by PFAS in soil. ESVs were derived for effects on terrestrial species considered to be representative of the prevailing species composition for most geographic areas: mammalian herbivore (the meadow vole), mammalian ground invertivore (short-tailed shrew), mammalian carnivore (long-tailed weasel), avian granivore (mourning dove [*Zenaida macroura*)]), avian ground invertivore (American woodcock [*Scolopax minor*]), and avian carnivore (red-tailed hawk).

Surface Water[2]

- USEPA, 2022d,e. Draft freshwater chronic aquatic life ambient water quality criteria were published for public comment in April 2022. Final criteria will be considered in the SLERA if they are available. USEPA followed the derivation approach outlined by Stephen et al. (1985), and the criteria are protective of 95% of aquatic species.

[2] Freshwater surface water ESVs, rather than marine ESVs, will be used to evaluate brackish surface water samples that may be collected to support the RI. Fewer data are available to derive marine criteria for PFAS (resulting in greater uncertainty in marine criteria than freshwater criteria) and salinity levels for marine criteria are expected to be higher than for brackish water collected at the facility.

- Conder et al., 2020. Freshwater aquatic life protection values referred to as the 5% hazardous concentration. These values are protective of 95% of aquatic species, which reflects the level of protection afforded by USEPA's National Recommended Water Quality Criteria for Aquatic Organisms (USEPA, 2018).
- Divine et al., 2020. Chronic recommended water quality RBSLs for aquatic life derived using USEPA's Water Quality Guidance for the Great Lakes System methodology (USEPA, 2012).
- Grippo et al., 2021. Freshwater ESVs for aquatic life were derived by following the two-tiered approach described in the Great Lakes Initiative (GLI) guidance (USEPA, 1995a, 1995b, 1995c). Final chronic freshwater ESVs for PFOA and PFOS are Tier I ESVs, while the remaining are Tier II ESVs.
- Divine et al., 2020. NOAEL based RBSLs for aquatic wildlife derived using food web models based on consumption of plant and prey items impacted by PFAS in water. SLs were derived for the muskrat (*Ondatra zibethicus*), little brown bat (*Myotis lucifugus*), river otter (*Lontra canadensis*), harbor seal (*Phoca vitulina*), mink (*Neovison vison*), red-winged blackbird (*Agelaius phoeniceus*), tree swallow (*Tachycineta bicolor*), and brown pelican (*Pelecanus occidentalis*).
- Grippo et al., 2021. Geometric mean NOAEL-based ESV for aquatic-dependent birds and mammals were derived using food web models based on consumption of plant and prey items impacted by PFAS in surface water. A two-tiered methodology was used to develop the ESVs, based on the 1995 GLI Tier I and Tier II guidance for deriving water quality criteria to protect wildlife (USEPA, 1995b, 1995c). ESVs were derived for effects on three representative piscivorous birds [the belted kingfisher (*Megaceryle alcyon*), the herring gull (*Larus argentatus*) and osprey (*Pandion haliaetus*)], two non-piscivorous birds [the mallard (*Anas platyrhynchos*) and the spotted sandpiper (*Actitis macularius*)], and two representative piscivorous mammals (the mink and the river otter).

Sediment

- Grippo et al., 2021. ESVs were not developed for sediment because they found that the science is not yet mature enough to develop them. Recent literature from Conder et al. (2020) and Divine, et al. (2020) were reviewed and likewise lacked available data for deriving empirically-based SLs benthic invertebrates.
- Simpson et al., 2021. The 99 percent protection concentration (PC99) for PFOS in estuarine and marine sediment (60 micrograms per kilogram based on 1 percent organic carbon) was selected.
- Divine et al., 2020. NOAEL based RBSLs for aquatic wildlife derived using food web models based on consumption of plant and prey items impacted by PFAS in sediment. SLs were derived for the same aquatic-dependent wildlife listed above for surface water.

The Argonne ESVs (Grippo et al. 2021) were developed to support screening-level assessments at DoD sites in consultation with an interagency team of subject-matter experts from across the DoD services through the DoD TSERAWG. Technical input and advice on the Argonne ESVs were also provided from the USEPA ERA Forum and USEPA program offices.

The Argonne ESV guidance (Grippo et al., 2021) is a living document that is expected to undergo revisions as the state of the science progress, and key updates may or may not be completed by the time the SLERA is performed. In that case, the selection of Argonne ESVs will consider scientific confidence in the Argonne ESVs and new developments in PFAS ecotoxicity.

As noted above, an ESV specifically for freshwater sediment was not identified. The 95 percent protection concentration (PC95) reported in Simpson et al. 2021 may also be considered in the ERA and would be more consistent with the level of protection reflected in the surface water ESVs. The PC99 and PC95 for PFOS are protective against direct toxicity to benthic organisms (via respiration), while the PC99 is also protective against secondary toxicity to benthos through food consumption. Surrogates for PFAS lacking ESVs have not been selected at this time but may be selected in the ERA based on similarities in perfluorinated carbon chain length and/or functional groups (e.g., perfluoroalkyl sulfonic acids, perfluoroalkyl carboxylic acids) (Divine et al. 2020, Zodrow et al. 2020). The available freshwater ESVs for PFAS will be reviewed at the time the ERA is performed to assess whether new sediment ESVs are available for this emerging contaminant.

In addition to the sources of SLs listed above, new literature sources may be considered given the ongoing research and publications on PFAS ecotoxicity. Based on a lack of toxicity information, not all individual PFAS compounds can be evaluated quantitatively in the SLERA. The basis of the selected ESVs and associated data limitations (e.g., ESVs based on limited data) will be discussed in the uncertainty section of the SLERA report.

In general, PFOS has been the focus of most regulatory interest with less toxicity data available for PFOA, PFBS, and other PFAS chemicals. In the recent SERDP studies cited above (Conder et al., 2020 and Divine et al., 2020) and Argonne report (Grippo et al. 2021), toxicity data, and other chemical-specific parameters necessary to develop terrestrial and aquatic ecological benchmarks were compiled to establish SLs for several additional PFAS chemicals.

In soil, in addition to PFOA, PFOS, and PFBS, screening values are also available for perfluorodecanoic acid (PFDA), PFNA, perfluoroheptanoic acid (PFHpA), PFHxS, perfluorobutanoic acid (PFBA), and perfluorohexanoic acid (PFHxA). For sediment and surface water, wildlife-based screening values were available for PFOA, PFOS, PFBS, PFNA, PFHxA, PFHxS (surface water only), and PFBA. For aquatic life, screening values were available for a longer list of PFAS chemicals in addition to PFOS, PFOA, and PFBS: perfluorododecanoic acid (PFDoA), perfluoroundecanoic acid (PFUdA), PFDA, PFNA, PFHxS, PFHpA, PFHxA, perfluoropentanoic acid (PFPeA), and PFBA. For sediment benthic invertebrates, only an estuarine/marine screening value for PFOS was available.

Table F-9 presents the PFAS soil ESVs for plants and invertebrates. **Table F-10** presents the wildlife-ESVs for soil, sediment, and surface water. **Table F-11** and **Table F-12** present the surface water ESVs for aquatic life and sediment ESVs for benthic invertebrates, respectively.

There is notable uncertainty inherent in the food-chain-based ESVs protective of birds and mammals, which tend to be overly stringent. For example, surface water SLs available in the literature incorporate conservative bioaccumulation factors and biomagnification factors to estimate tissue levels in fish from water, are based on conservative avian and mammalian toxicity values, and typically assume receptors consume an exclusive diet of contaminated fish (Divine et al., 2020; Giesy et al., 2010; Dutch National Institute for Public Health and the Environment, 2010). Similarly, a soil ESV based on a small mammal consuming a diet of contaminated earthworms is also likely to be overly conservative for most sites (Divine et al., 2020; Environment and Climate Change Canada, 2017). The uncertainties related to the selected ESVs will be discussed in the context of the potential to result in an over- or under-prediction of potential adverse effects in the exposure areas.

3.2.3 Ecological Exposure Assessment

In order to conclude whether a chemical has the potential to impact an ecological receptor, a relevant chemical concentration or dose must first be determined. That concentration/dose is then compared to the ecological effects data presented above (i.e., the ESVs). For the SLERA, the

maximum detected concentration will be evaluated as the EPC, while a more realistic estimate of exposure by receptor communities and mobile species will be considered in the Tier 2 Step 3a refinement (i.e., the UCL).

Mechanisms for exposure of a representative species to PFAS depend on the physical and behavioral characteristics of the organism. Most exposure mechanisms for sediment invertebrates, aquatic invertebrates, soil invertebrates, and plants can be loosely termed “direct contact”. Sediment and soil invertebrates have in common the ability to absorb chemicals from sediment or moist soil through external body surfaces or by intake of food, sediment, or soil.

Wildlife species may be exposed to PFAS in surface soil, surface water, and sediment directly though ingestion (incidental or intentional) or indirectly by ingestion of contaminated food organisms. Most biological activity occurs at the soil (or sediment) surface.

Step 2 of the of the eight-step process is the SL exposure estimate and comparison to risk-based ESVs. In this step, the maximum detected concentrations in the relevant media will be compared to the associated ESVs. Data treatment and calculation of summary statistics for the SLERA will be consistent with the rules described in **Section 1.2**. Maximum detected concentrations will be identified per exposure area and medium and will be used as the SL EPC for all ecological receptors in the SLERA.

3.2.4 SLERA Calculations

HQs will be calculated for each PFAS analyte in each medium (e.g., surface soil, surface water, and surface sediment) by dividing the maximum detected concentration by the relevant ESVs for terrestrial and aquatic ecological receptors using the following formula:

HQ = Maximum detected concentration ÷ Ecological Screening Value

Individual PFAS that exceed their respective ESVs (i.e., HQs > 1), and analytes, media, and receptor groups without ESVs, will be retained for further evaluation.

Due to the consistently applied conservative assumptions implicit in a SLERA, the presence of HQs above 1 using the maximum detected concentration as the EPC does not necessarily constitute ecological risk; it only indicates the potential for adverse effects and that additional consideration is warranted. If the resulting HQ is equal to or less than 1, the potential for adverse effects due to that chemical can be considered negligible and therefore may be dropped from further consideration for that exposure pathway (DA, 2010).

The selection of preliminary COPECs is the final part of the SLERA. Chemicals selected as preliminary COPECs on the basis of an ESV exceedance will be further evaluated in Step 3a to determine if they should be retained as final COPECs. The preliminary COPECs will be selected if the comparison of soil, surface water, or surface sediment data to ESVs results in HQs above 1. The COPEC refinement process in Step 3a is discussed in **Section 3.5**.

3.3 Screening Level Risk Characterization

The results of the ecological effects assessment and exposure assessment will be analyzed and interpreted to determine the likelihood of adverse environmental effects, and to determine whether particular exposure pathways, receptors, and chemicals can be eliminated from further evaluation. The SL risk characterization will summarize the results of the effects assessment and exposure assessment and provide interpretation of the ecologically significant findings. Aspects of ecological significance that may be considered to help place the SLERA results into a broader ecological context include the management goals plans in place for the facility, the nature and magnitude of effects, the spatial and temporal patterns of effects, and the potential for recovery

once a stressor has been removed. If the potential for adverse effects on ecological receptors is implied through the screening process using literature-based inputs, facility-specific validation studies (e.g., tissue sampling, toxicity testing) conducted in the field or laboratory may be needed to verify these findings as part of the BERA.

The documentation of the risk characterization will include a summary of assumptions, uncertainties (both generic and facility-specific), strengths and weaknesses of the analysis phase of work, and justification of conclusions regarding the ecological significance of the estimated (i.e., risk of harm) or actual (i.e., evidence of harm) potential for adverse effects. Some uncertainties bias the results of the risk assessment towards excessive risk, while others bias towards no significant risk.

All discussions of uncertainty will include examination and review of several aspects of the SLERA including, but not limited to, sampling, data quality, study design, selection of indicator species, estimates of exposure, and selection of ESVs. The uncertainty section of the SLERA will identify limitations and assumptions and relate them to the potential effects these uncertainties may have on the overall conclusions of the SLERA. As mentioned previously, the assumptions inherent in the ESVs for PFAS that are protective of birds and mammals, which may be highly conservative, are of particular interest in the uncertainty assessment. This is due to the strong influence of facility-specific conditions on the bioaccumulation and bioavailability potential of PFAS, as well as the relevancy of the types of species upon which the ESVs are based relative to the avian and mammalian species actually present at or near the Site.

3.4 SLERA Scientific/Management Decision Point

Consistent with USEPA guidance (1997b), a scientific/management decision point (SMDP) will be determined based on the outcome of the SLERA (Steps 1 and 2 of the eight-step USEPA process) to conclude that (1) there is adequate information to conclude that ecological risks are negligible and therefore no need for remediation on the basis of ecological risk, (2) the information is not adequate to make a decision and the ecological risk process will continue to Step 3, or (3) the information indicates a potential for adverse ecological effects, and a more thorough assessment is warranted (e.g., additional sampling or analysis).

If the decision is made that further investigation is warranted for any specific receptors/pathways, a sub-tier of Step 3 (Step 3a) of the USEPA's eight-step ERA process may be conducted. USEPA (2001b) and DoD guidance (TSERAWG, 2008; DA, 2010) provide the basis to introduce sub-tiers into the ERA process and the approach is described in the following sub-section.

3.5 Step 3a SLERA Refinement

Step 3a, a sub-tier of Step 3 (referred to as a refinement of the SLERA by TSERAWG [2008] and DA [2010]), serves to refine the list of preliminary COPECs identified in the conservative evaluation conducted in Steps 1 and 2 by considering additional facility-specific factors. It is anticipated that any preliminary COPECs identified in soil, sediment, or surface water will be further evaluated in Step 3a. The refinement step may include comparisons against background concentrations (if available) or re-evaluation of parameters considered in the SLERA (e.g., assumption of 100% bioavailability).

Only COPECs, pathways, and receptors retained after the Step 3a refinement process would potentially be considered for further evaluation in a BERA. In many cases, the Step 3a refinement provides the basis for defining potential risk drivers, which may be further evaluated for remedial decisions, or alternatively, a complete BERA may be initiated, which applies USEPA Step 3b through Step 8 of the ERA process. It is currently unknown if Step 3a will be warranted for any

ecological receptors evaluated in the SLERA, but the following discussion provides the proposed approach.

The purpose of Step 3a is to reevaluate preliminary COPECs identified in the SLERA to identify and eliminate from further consideration those preliminary COPECs that were identified due to the use of overly conservative exposure scenarios (e.g., maximum concentrations). Using more realistic Step 3a assumptions, the SLERA HQs described in **Section 3.2.4** will be recalculated for the pathways and preliminary COPECs retained at the end of the SLERA and a qualitative weight of evidence evaluation will be conducted to determine whether a BERA is recommended.

It is anticipated that the Step 3a re-evaluation/refinement process will follow these steps:

- Calculate alternative EPCs based on UCLs (rather than maximum concentrations).
- Revise ESV comparisons for community level receptors (e.g., plants and invertebrates) using alternative EPCs and alternative less conservative ESVs, if available, for the particular medium and receptor group (e.g., low effect concentrations rather than no effect concentrations).
- Evaluate food web exposure assumptions and toxicity reference values (TRVs) upon which the bird and mammal ESVs are based to identify exposure and effects inputs that may not be applicable to Site conditions. These inputs may include uptake factors, exposure durations, area use factors, and both NOAEL-based and lowest observed adverse effect level (LOAEL)-based TRVs. Sources for uptake factors and TRVs will include those used to derive NOAEL based RBSLs considered in the SLERA as well as other sources available in the literature (e.g., Zodrow et al., 2020; Grippo et al., 2021).
- Revise ESV comparisons for avian and mammalian receptors using alternative EPCs and less conservative avian and mammalian ESVs (e.g., ESVs adjusted to be more representative of Site receptors or conditions). The development of facility-specific dose and hazard estimates for wildlife receptors may also be considered.
- Identify COPECs with HQs less than 1 in the Step 3a ESV comparisons and eliminate the COPECs from further evaluation.
- For COPECs with a HQ greater than 1, compare media concentrations to background levels (if available). COPECs present at concentrations below or consistent with background levels may be proposed for elimination from further evaluation.
- For COPECs with a HQ greater than 1, consider bioavailability; identify COPECs likely to be biologically unavailable, and propose these for elimination from further evaluation.
- Review FOD to identify COPECs with low detection frequencies (and sufficient data for acceptable Site characterization). If a COPEC was detected in only a very small percentage of the samples collected (5% or less), the potential for adverse effects identified in the SLERA may be overestimated and further evaluation of the COPEC is not warranted.
- Conduct a qualitative weight of evidence evaluation that considers the Step 3a ESV comparisons, available habitat within the areas evaluated, wildlife management goals for the areas evaluated, and other relevant factors, as appropriate, to determine whether a BERA is recommended.

After the re-evaluation/refinement, the decision criteria for Step 3a include:

- If the Step 3a refinement does not identify the potential for adverse effects associated with the preliminary COPECs, then a no further action designation is warranted, and the Site exits the ERA process.

- If the re-evaluation of the conservative exposure assumptions identifies the potential for adverse effects associated with the preliminary COPECs, the BERA process continues to Step 3b and subsequent steps, or to remedial decisions.

In the event a BERA is warranted, the evaluation will be focused only on the receptors, pathways, and PFAS of potential concern identified following the weight of evidence assessment in Step 3a. 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 facility-specific data.

3.6 Completing Steps 3b through Step 7

It is anticipated that the ERA for the exposure areas evaluated following RI Mobilization 1 and Mobilization 2 (if needed) will be completed through the Step 3a phase, and a full Tier 2 BERA will not be warranted. If this is not the case, risk management decisions related to performing a BERA and the need for additional facility-specific sampling efforts to support a BERA will be made by the project team.

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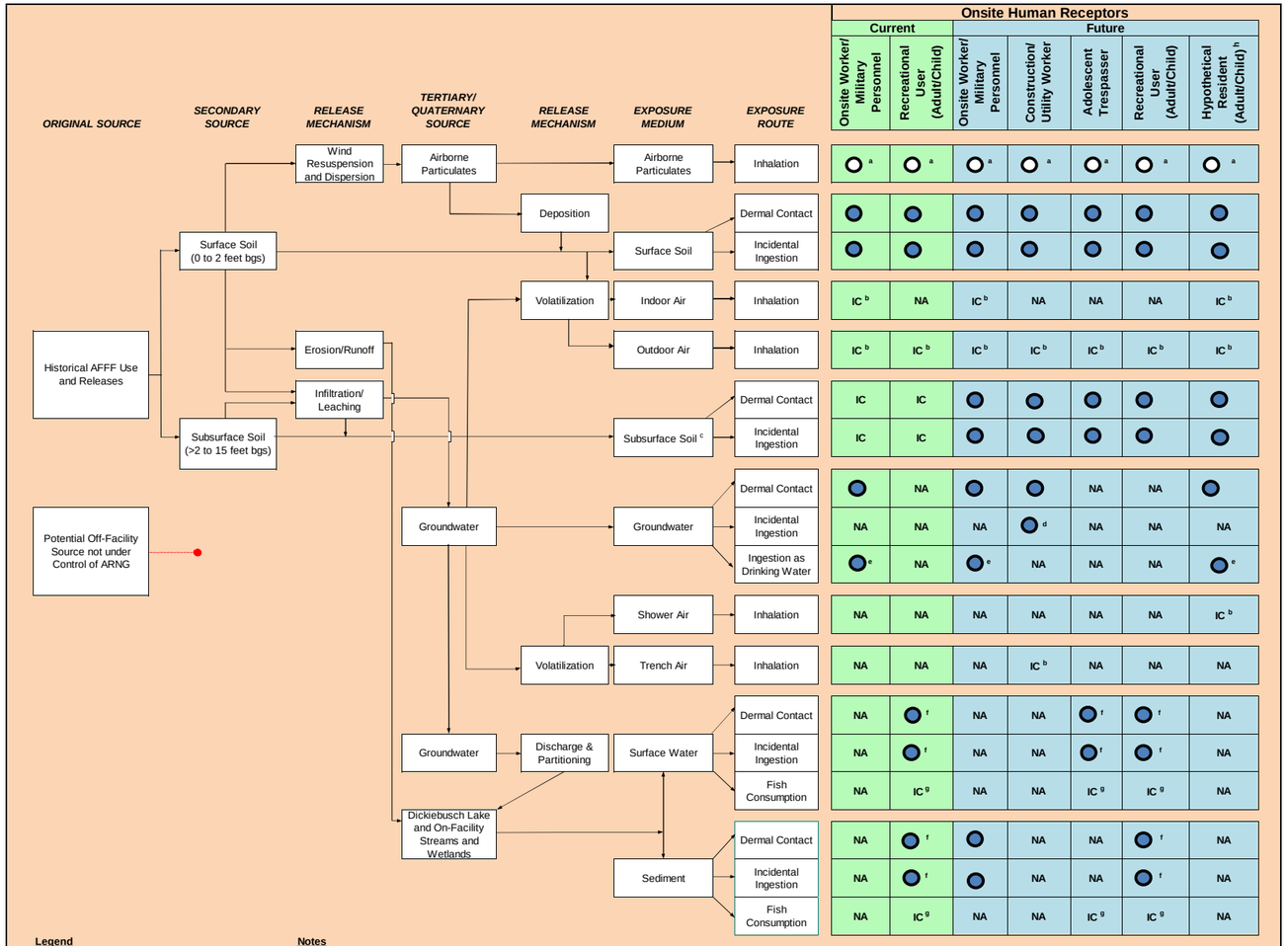
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Attachment A – Figures and Tables

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Legend

- **Potentially complete pathway**
- **Minor or insignificant pathway**
- **IC** Incomplete
- **NA** Not Applicable
- **Flow-Chart Stops**

Notes

AOI - Area of interest.
bgs - below ground surface.
COPC - Chemical of potential concern.
PFAS - Per- and polyfluoroalkyl substances.
PFBS - Perfluorobutanesulfonate.
PFOA - Perfluorooctanoic acid.
PFOS - Perfluorooctanesulfonate.
USEPA - United States Environmental Protection Agency.
VOC - volatile organic compound

The current investigation considers potential on-facility exposure pathways. If sampling identifies the potential for off-facility contaminant migration and exposure, then off-facility pathways will be considered in a later phase of investigation.

(a) Potential exposure with airborne particulates will not be quantitatively evaluated in the HHRA because toxicity values for the inhalation exposure route are not available for PFAS. The associated uncertainties will be discussed in the uncertainty discussion of the HHRA.

(b) PFAS have low volatility and therefore are not considered to volatilize into air. PFAS are the only potential facility-related COPCs for the facility being evaluated under the scope of this Remedial Investigation (RI). However, groundwater sampling for VOCs will be conducted during RI Mobilization 1 at the wells installed at AOI 1. Inhalation of vapors exposure pathway will be revisited, if needed.

(c) It is conservatively assumed that there could be future redevelopment of the Site, and current subsurface soils may be brought to the surface and become available for exposure under a future use scenario.

(d) Incidental ingestion of shallow groundwater may occur during soil disturbing activities.

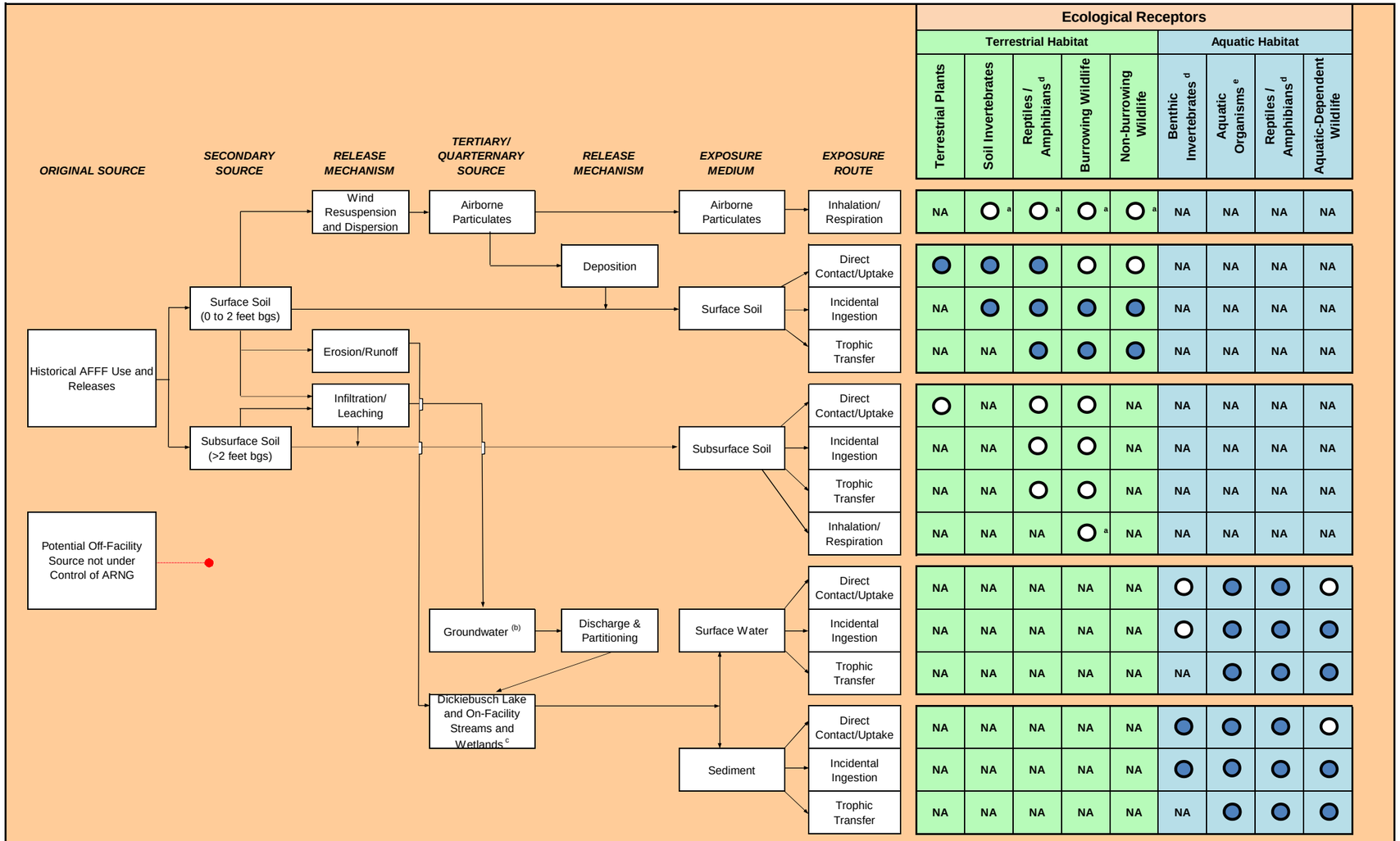
(e) Two potable wells in the southern portion of the Camp Smith cantonment area, Wells A and B, supply drinking water to the facility. The March 2020 sampling event identified a PFOA + PFOS concentration that was above the health advisory level of 70 parts per trillion. Now, the facility provides filtered drinking water stations. Quarterly sampling is conducted at random at the filtered drinking water stations. The facility water treatment plant is being upgraded with a granular activated carbon system that will be operational in September 2022.

(f) Exposure to sediment and surface water in the onsite streams (Putnam Brook), Dickiebusch Lake (current scenarios only) and wetlands will be evaluated via a wading scenario for each scenario due to site conditions of the water bodies.

(g) Consumption of fish tissue will not be evaluated because the streams (Putnam Brook) and wetlands are not conducive to fishing. A capture and release policy is in place for Dickiebusch Lake which is within a secured area of the facility.

(h) A resident is not a reasonable anticipated future use of the Site. However, for purposes of the HHRA, an unlimited use/unrestricted exposure (UU/UE) scenario will be conservatively evaluated for informational purposes.

Project No. 60591182		HUMAN HEALTH CONCEPTUAL SITE MODEL	Figure F-1
Camp Smith Training Facility Cortlandt, NY			



Legend

- Potentially complete pathway
- Minor or insignificant pathway
- NA Not Applicable
- Flow-Chart Stops

Notes

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

The current investigation considers potential on-facility exposure pathways. If sampling identifies the potential for off-facility contaminant migration and exposure, then off-facility pathways will be considered in a later phase of investigation.

(a) Inhalation/respiration of airborne particulates (dust) is expected to be minor compared to soil exposure pathways.

(b) 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 and sediment (including porewater) may be complete.

(c) Potential ecological exposures will be evaluated for sediment and surface water associated with groundwater discharge to on-facility aquatic habitats.

(d) PFAS screening values are generally not available for reptiles, for amphibians exposed to soil, or for benthic invertebrates exposed to sediment. In cases where screening values are not available, these receptors will be considered qualitatively.

(e) Water column receptors (aquatic plants, aquatic invertebrates, fish, and amphibians) may be exposed to PFAS in sediment via ingestion or direct contact; however, sediment screening values are not available for these exposures so these pathways will be considered qualitatively.

Project No. 60591182			
Camp Smith Training Facility Cortlandt, NY		**ECOLOGICAL CONCEPTUAL SITE MODEL**	**Figure F-2**

TABLE F-1

VALUES USED FOR DAILY INTAKE CALCULATIONS - SURFACE SOIL AND COMBINED SURFACE AND SUBSURFACE SOIL

REASONABLE MAXIMUM EXPOSURE

HUMAN HEALTH RISK ASSESSMENT

CAMP SMITH TRAINING FACILITY

CORTLANDT, NEW YORK

Scenario Timeframe(s):	Current; Future
Medium:	Soil
Exposure Media:	Surface soil; Combined Surface and Subsurface Soil

Exposure Route	Receptor Population	Receptor Age	Exposure Point(s) (a)	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Incidental Ingestion	Outdoor Worker/ Military Personnel	Adult	Onsite:	CS	Chemical Concentration in Soil	Chemical Specific	mg/kg	--	Intake (mg/kg-day) =
			Surface soil (current),	IR	Ingestion Rate	100	mg/day	USEPA, 2014	CS x IR x EF x ED x CF x FI x RBA
			Combined surface and	EF	Exposure Frequency	250	days/yr	USEPA, 2014	BW x AT
			subsurface soil (future)	ED	Exposure Duration	25	year	USEPA, 2014	
				FI	Fraction Ingested from Site	1	unitless	(1)	
				CF	Conversion Factor	1.00E-06	kg/mg	--	
				RBA	Relative Bioavailability Factor	1	unitless	--	
				BW	Body Weight	80	kg	USEPA, 2014	
				ATc	Averaging Time - cancer	25,550	days	USEPA, 2014	
				ATnc	Averaging Time - noncancer	9,125	days	USEPA, 2014	
	Resident	Adult	Onsite:	CS	Chemical Concentration in Soil	Chemical Specific	mg/kg	--	Intake (mg/kg-day) =
			Combined surface and	IR	Ingestion Rate	100	mg/day	USEPA, 2014	CS x IR x EF x ED x CF x FI x RBA
			subsurface soil (future)	EF	Exposure Frequency	350	days/yr	USEPA, 2014	BW x AT
				ED	Exposure Duration	20	years	USEPA, 2014	
				FI	Fraction Ingested from Site	1	unitless	(1)	
				CF	Conversion Factor	1.00E-06	kg/mg	--	
				RBA	Relative Bioavailability Factor	1	unitless	--	
				BW	Body Weight	80	kg	USEPA, 2014	
				ATc	Averaging Time - cancer	25,550	days	USEPA, 2014	
				ATnc	Averaging Time - noncancer	7,300	days	USEPA, 2014	
		Child	Onsite:	CS	Chemical Concentration in Soil	Chemical Specific	mg/kg	--	Intake (mg/kg-day) =
			Combined surface and	IR	Ingestion Rate	200	mg/day	USEPA, 2014	CS x IR x EF x ED x CF x FI x RBA
			subsurface soil (future)	EF	Exposure Frequency	350	days/yr	USEPA, 2014	BW x AT
				ED	Exposure Duration	6	years	USEPA, 2014	
				FI	Fraction Ingested from Site	1	unitless	(1)	
				CF	Conversion Factor	1.00E-06	kg/mg	--	
				RBA	Relative Bioavailability Factor	1	unitless	--	
				BW	Body Weight	15	kg	USEPA, 2014	
				ATc	Averaging Time - cancer	25,550	days	USEPA, 2014	
				ATnc	Averaging Time - noncancer	2,190	days	USEPA, 2014	

TABLE F-1

VALUES USED FOR DAILY INTAKE CALCULATIONS - SURFACE SOIL AND COMBINED SURFACE AND SUBSURFACE SOIL

REASONABLE MAXIMUM EXPOSURE

HUMAN HEALTH RISK ASSESSMENT

CAMP SMITH TRAINING FACILITY

CORTLANDT, NEW YORK

Scenario Timeframe(s):	Current; Future
Medium:	Soil
Exposure Media:	Surface soil; Combined Surface and Subsurface Soil

Exposure Route	Receptor Population	Receptor Age	Exposure Point(s) (a)	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Incidental Ingestion	Trespasser	Adolescent	Onsite:	CS	Chemical Concentration in Soil	Chemical Specific	mg/kg	--	Intake (mg/kg-day) =
		(7 to <16 years)	Surface soil (current)	IR	Ingestion Rate	100	mg/day	USEPA, 2014 (2)	CS x IR x EF x ED x CF x FI x RBA
				EF	Exposure Frequency	52	days/yr	(19)	BW x AT
				ED	Exposure Duration	9	years	(4)	
				FI	Fraction Ingested from Site	0.5	unitless	(20)	
				CF	Conversion Factor	1.00E-06	kg/mg	--	
				RBA	Relative Bioavailability Factor	1	unitless	--	
				BW	Body Weight	44	kg	USEPA, 2011 (5)	
				ATc	Averaging Time - cancer	25,550	days	USEPA, 2014	
				ATnc	Averaging Time - noncancer	3,285	days	USEPA, 2014	
	Recreational User	Adult	Onsite:	CS	Chemical Concentration in Soil	Chemical Specific	mg/kg	--	Intake (mg/kg-day) =
			Combined surface and	IR	Ingestion Rate	100	mg/day	USEPA, 2014 (2)	CS x IR x EF x ED x CF x FI x RBA
			subsurface soil (future)	EF	Exposure Frequency	70	days/yr	(3)	BW x AT
				ED	Exposure Duration	20	years	USEPA, 2014 (7)	
				FI	Fraction Ingested from Site	0.5	unitless	(20)	
				CF	Conversion Factor	1.00E-06	kg/mg	--	
				RBA	Relative Bioavailability Factor	1	unitless	--	
				BW	Body Weight	80	kg	USEPA, 2014	
				ATc	Averaging Time - cancer	25,550	days	USEPA, 2014	
				ATnc	Averaging Time - noncancer	7,300	days	USEPA, 2014	
		Child	Onsite:	CS	Chemical Concentration in Soil	Chemical Specific	mg/kg	--	Intake (mg/kg-day) =
			Combined surface and	IR	Ingestion Rate	200	mg/day	USEPA, 2014 (9)	CS x IR x EF x ED x CF x FI x RBA
			subsurface soil (future)	EF	Exposure Frequency	70	days/yr	(3)	BW x AT
				ED	Exposure Duration	6	years	USEPA, 2014 (8)	
				FI	Fraction Ingested from Site	0.5	unitless	(20)	
				CF	Conversion Factor	1.00E-06	kg/mg	--	
				RBA	Relative Bioavailability Factor	1	unitless	--	
				BW	Body Weight	15	kg	USEPA, 2014	
				ATc	Averaging Time - cancer	25,550	days	USEPA, 2014	
				ATnc	Averaging Time - noncancer	2,190	days	USEPA, 2014	

TABLE F-1

VALUES USED FOR DAILY INTAKE CALCULATIONS - SURFACE SOIL AND COMBINED SURFACE AND SUBSURFACE SOIL

REASONABLE MAXIMUM EXPOSURE

HUMAN HEALTH RISK ASSESSMENT

CAMP SMITH TRAINING FACILITY

CORTLANDT, NEW YORK

Scenario Timeframe(s):	Current; Future
Medium:	Soil
Exposure Media:	Surface soil; Combined Surface and Subsurface Soil

Exposure Route	Receptor Population	Receptor Age	Exposure Point(s) (a)	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Incidental Ingestion	Construction/Utility Worker	Adult	Onsite:	CS	Chemical Concentration in Soil	Chemical Specific	mg/kg	--	Intake (mg/kg-day) =
			Combined surface and	IR	Ingestion Rate	330	mg/day	USEPA, 2002	$\frac{CS \times IR \times EF \times ED \times CF \times FI \times RBA}{BW \times AT}$
			subsurface soil (future)	EF	Exposure Frequency	125	days/yr	(17)	
				ED	Exposure Duration	0.5	year	(17)	
				FI	Fraction Ingested from Site	1	unitless	(1)	
				CF	Conversion Factor	1.00E-06	kg/mg	--	
				RBA	Relative Bioavailability Factor	1	unitless	--	
				BW	Body Weight	80	kg	USEPA, 2014	
				ATc	Averaging Time - cancer	25,550	days	USEPA, 2014	
				ATnc	Averaging Time - noncancer	183	days	USEPA, 2014	
Dermal	Outdoor Worker/ Military Personnel	Adult	Onsite:	CS	Chemical Concentration in Soil	Chemical Specific	mg/kg	--	Intake (mg/kg-day) =
			Surface soil (current),	SA	Surface Area	3,527	cm^2	USEPA, 2014 (10)	$\frac{CS \times SA \times AF \times ABS \times EV \times EF \times ED \times CF}{BW \times AT}$
			Combined surface and	AF	Adherence Factor	0.12	mg/cm^2-event	USEPA, 2014 (11)	
			subsurface soil (future)	ABS	Dermal absorption fraction	Chemical Specific	unitless	--	
				EV	Event Frequency	1	event/day	(6)	
				EF	Exposure Frequency	250	days/yr	USEPA, 2014	
				ED	Exposure Duration	25	year	USEPA, 2014	
				CF	Conversion Factor	1.00E-06	kg/mg	--	
				BW	Body Weight	80	kg	USEPA, 2014	
				ATc	Averaging Time - cancer	25,550	days	USEPA, 2014	
				ATnc	Averaging Time - noncancer	9,125	days	USEPA, 2014	

TABLE F-1
VALUES USED FOR DAILY INTAKE CALCULATIONS - SURFACE SOIL AND COMBINED SURFACE AND SUBSURFACE SOIL
REASONABLE MAXIMUM EXPOSURE
HUMAN HEALTH RISK ASSESSMENT
CAMP SMITH TRAINING FACILITY
CORTLANDT, NEW YORK

Scenario Timeframe(s):	Current; Future
Medium:	Soil
Exposure Media:	Surface soil; Combined Surface and Subsurface Soil

Exposure Route	Receptor Population	Receptor Age	Exposure Point(s) (a)	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Dermal	Resident	Adult	Onsite:	CS	Chemical Concentration in Soil	Chemical Specific	mg/kg	--	Intake (mg/kg-day) =
			Combined surface and	SA	Surface Area	6,032	cm^2	USEPA, 2014 (12)	$\frac{CS \times SA \times AF \times ABS \times EV \times EF \times ED \times CF}{BW \times AT}$
			subsurface soil (future)	AF	Adherence Factor	0.07	mg/cm^2-event	USEPA, 2014 (13)	
				ABS	Dermal absorption fraction	Chemical Specific	unitless	--	
				EV	Event Frequency	1	event/day	(6)	
				EF	Exposure Frequency	350	days/yr	USEPA, 2014	
				ED	Exposure Duration	20	years	USEPA, 2014	
				CF	Conversion Factor	1.00E-06	kg/mg	--	
				BW	Body Weight	80	kg	USEPA, 2014	
				ATc	Averaging Time - cancer	25,550	days	USEPA, 2014	
				ATnc	Averaging Time - noncancer	7,300	days	USEPA, 2014	
		Child	Onsite:	CS	Chemical Concentration in Soil	Chemical Specific	mg/kg	--	Intake (mg/kg-day) =
			Combined surface and	SA	Surface Area	2,373	cm^2	USEPA, 2014 (14)	$\frac{CS \times SA \times AF \times ABS \times EV \times EF \times ED \times CF}{BW \times AT}$
			subsurface soil (future)	AF	Adherence Factor	0.2	mg/cm^2-event	USEPA, 2014 (15)	
				ABS	Dermal absorption fraction	Chemical Specific	unitless	--	
				EV	Event Frequency	1	event/day	(6)	
				EF	Exposure Frequency	350	days/yr	USEPA, 2014	
				ED	Exposure Duration	6	years	USEPA, 2014	
				CF	Conversion Factor	1.00E-06	kg/mg	--	
				BW	Body Weight	15	kg	USEPA, 2014	
				ATc	Averaging Time - cancer	25,550	days	USEPA, 2014	
				ATnc	Averaging Time - noncancer	2,190	days	USEPA, 2014	
	Trespasser	Adolescent	Onsite:	CS	Chemical Concentration in Soil	Chemical Specific	mg/kg	--	Intake (mg/kg-day) =
		(7 to <16 years)	Surface soil (current)	SA	Surface Area	3,693	cm^2	USEPA, 2011 (16)	$\frac{CS \times SA \times AF \times ABS \times EV \times EF \times ED \times CF}{BW \times AT}$
				AF	Adherence Factor	0.07	mg/cm^2-event	USEPA, 2004 (13)	
				ABS	Dermal absorption fraction	Chemical Specific	unitless	--	
				EV	Event Frequency	1	event/day	(6)	
				EF	Exposure Frequency	52	days/yr	(19)	
				ED	Exposure Duration	9	years	(4)	
				CF	Conversion Factor	1.00E-06	kg/mg	--	
				BW	Body Weight	44	kg	USEPA, 2011 (5)	
				ATc	Averaging Time - cancer	25,550	days	USEPA, 2014	
				ATnc	Averaging Time - noncancer	3,285	days	USEPA, 2014	

TABLE F-1
VALUES USED FOR DAILY INTAKE CALCULATIONS - SURFACE SOIL AND COMBINED SURFACE AND SUBSURFACE SOIL
REASONABLE MAXIMUM EXPOSURE
HUMAN HEALTH RISK ASSESSMENT
CAMP SMITH TRAINING FACILITY
CORTLANDT, NEW YORK

Scenario Timeframe(s):	Current; Future
Medium:	Soil
Exposure Media:	Surface soil; Combined Surface and Subsurface Soil

Exposure Route	Receptor Population	Receptor Age	Exposure Point(s) (a)	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Dermal	Recreational User	Adult	Onsite AOIs:	CS	Chemical Concentration in Soil	Chemical Specific	mg/kg	--	Intake (mg/kg-day) =
			Combined surface and	SA	Surface Area	6,032	cm^2	USEPA, 2014 (12)	CS x SA x AF x ABS x EV x EF x ED x CF
			subsurface soil (future)	AF	Adherence Factor	0.07	mg/cm^2-event	USEPA, 2014 (2)(13)	BW x AT
				ABS	Dermal absorption fraction	Chemical Specific	unitless	--	
				EV	Event Frequency	1	event/day	(6)	
				EF	Exposure Frequency	70	days/yr	(3)	
				ED	Exposure Duration	20	years	USEPA, 2014 (7)	
				CF	Conversion Factor	1.00E-06	kg/mg	--	
				BW	Body Weight	80	kg	USEPA, 2014	
				ATc	Averaging Time - cancer	25,550	days	USEPA, 2014	
				ATnc	Averaging Time - noncancer	7,300	days	USEPA, 2014	
		Child	Onsite AOIs:	CS	Chemical Concentration in Soil	Chemical Specific	mg/kg	--	Intake (mg/kg-day) =
			Combined surface and	SA	Surface Area	2,373	cm^2	USEPA, 2014 (14)	CS x SA x AF x ABS x EV x EF x ED x CF
			subsurface soil (future)	AF	Adherence Factor	0.2	mg/cm^2-event	USEPA, 2014 (15)	BW x AT
				ABS	Dermal absorption fraction	Chemical Specific	unitless	--	
				EV	Event Frequency	1	event/day	(6)	
				EF	Exposure Frequency	70	days/yr	(3)	
				ED	Exposure Duration	6	years	USEPA, 2014 (8)	
				CF	Conversion Factor	1.00E-06	kg/mg	--	
				BW	Body Weight	15	kg	USEPA, 2014	
				ATc	Averaging Time - cancer	25,550	days	USEPA, 2014	
				ATnc	Averaging Time - noncancer	2,190	days	USEPA, 2014	
	Construction/Utility Worker	Adult	Onsite:	CS	Chemical Concentration in Soil	Chemical Specific	mg/kg	--	Intake (mg/kg-day) =
			Combined surface and	SA	Surface Area	3,527	cm^2	USEPA, 2014 (10)	CS x SA x AF x ABS x EV x EF x ED x CF
			subsurface soil (future)	AF	Adherence Factor	0.3	mg/cm^2-event	USEPA, 2004 (18)	BW x AT
				ABS	Dermal absorption fraction	Chemical Specific	unitless	--	
				EV	Event Frequency	1	event/day	(6)	
				EF	Exposure Frequency	125	days/yr	(17)	
				ED	Exposure Duration	0.5	year	(17)	
				CF	Conversion Factor	1.00E-06	kg/mg	--	
				BW	Body Weight	80	kg	USEPA, 2014	
				ATc	Averaging Time - cancer	25,550	days	USEPA, 2014	
				ATnc	Averaging Time - noncancer	183	days	USEPA, 2014	

TABLE F-1

VALUES USED FOR DAILY INTAKE CALCULATIONS - SURFACE SOIL AND COMBINED SURFACE AND SUBSURFACE SOIL

REASONABLE MAXIMUM EXPOSURE

HUMAN HEALTH RISK ASSESSMENT

CAMP SMITH TRAINING FACILITY

CORTLANDT, NEW YORK

Scenario Timeframe(s):	Current; Future
Medium:	Soil
Exposure Media:	Surface soil; Combined Surface and Subsurface Soil

Exposure Route	Receptor Population	Receptor Age	Exposure Point(s) (a)	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name

Notes:

< = Less than.

RME = Reasonable Maximum Exposure.

USEPA = United States Environmental Protection Agency.

(1) Professional judgment; conservatively assumes 100 percent of soil ingested is from the Site.

(2) Default value for adult resident.

(3) Assumes exposure to soil may occur for 2 days per week for 8 months of the year (i.e., April through November; 35 weeks) when the ground is not frozen or snow-covered, based on professional judgment.

(4) Exposure duration reflects age-range of 7 to <16 years.

(5) Weighted average body weight for adolescent ages 6 to <16 years old used to represent the 7 to <16 year old adolescent.

(6) Professional judgement; assumes one event per day.

(7) Default value for adult resident; assumes an adult recreational user accesses the area for 20 years.

(8) Default value for child resident; assumes a child recreational user accesses the area for 6 years.

(9) Default value for child resident.

(10) Represents the weighted mean surface area for males and females ages 21+, including head, hands, and forearms (USEPA, 2011; Table 7-2).

(11) Represents the arithmetic mean of weighted average of body-specific (hands, forearms, and face) mean adherence factors for adult commercial/industrial activities (USEPA, 2011; Table 7-20).

(12) Represents the weighted mean surface area for male and female adults, including head, hands, forearms, and lower legs (USEPA, 2011; Table 7-2).

(13) Represents the geometric mean (50th percentile) of weighted average body-specific (hands, forearms, lower legs and head) adherence factors for gardeners (USEPA, 2004; Exhibit C-2). See Table A-8 for calculation.

(14) Represents the weighted mean surface area for males and females ages 0 to <6 years old, including head, hands, forearms, lower legs, and feet (USEPA, 2011; Table 7-2).

(15) Represents the geometric mean (50th percentile) of weighted average body-specific (hands, forearms, lower legs and face) adherence factors for children playing (wet soil) (USEPA, 2004; Exhibit C-2).

(16) Represents the weighted mean surface area for males and females ages 7 to <16 years old, including hands, forearms, lower legs, and head (USEPA, 2011; Table 7-2). See Table A-7 for calculation.

(17) Construction/utility activities are assumed to occur for 125 days over the course of a 6 month period, based on professional judgment.

(18) Represents the geometric mean (50th percentile) of weighted average body-specific (face, forearms, and hands) adherence factors for construction workers (USEPA, 2004; Exhibit C-2).

(19) Assumes exposure to soil may occur for an average of 1.5 days per week for 8 months of the year (i.e., April through November; 35 weeks) when the ground is not frozen or snow-covered, based on professional judgment.

(20) Assumes 50 percent of soil ingested is from the associated area, based on professional judgment.

Sources:

USEPA, 2002. Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. OSWER 9355.4-24. December 2002.

USEPA, 2004. Risk Assessment Guidance for Superfund. Part E, Supplemental Guidance for Dermal Risk Assessment. Final. EPA/540/R/99/005.

USEPA, 2011. Exposure Factors Handbook. September 2011.

USEPA, 2014. Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors. February 6, 2014. Revised September 2015.

TABLE F-2

VALUES USED FOR DAILY INTAKE CALCULATIONS - GROUNDWATER

REASONABLE MAXIMUM EXPOSURE

HUMAN HEALTH RISK ASSESSMENT

CAMP SMITH TRAINING FACILITY

CORTLANDT, NEW YORK

Scenario Timeframe(s):	Future
Medium:	Groundwater
Exposure Medium:	Groundwater

Exposure Route	Receptor Population	Receptor Age	Exposure Point(s)	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Ingestion	Outdoor Worker/ Military Personnel	Adult	Onsite	CW	Chemical Concentration in Water	Chemical Specific	ug/L	--	Intake (mg/kg-day) =
				IR	Ingestion Rate	1.25	liters/day	USEPA, 2014 (1)	CW x IR x EF x ED x CF
				EF	Exposure Frequency	250	days/yr	USEPA, 2014	BW x AT
				ED	Exposure Duration	25	years	USEPA, 2014	
				CF	Conversion Factor	0.001	mg/ug	--	
				BW	Body Weight	80	kg	USEPA, 2014	
				ATc	Averaging Time - cancer	25,550	days	USEPA, 2014	
				ATnc	Averaging Time - noncancer	9,125	days	USEPA, 2014	
Ingestion	Resident	Adult	Onsite	CW	Chemical Concentration in Water	Chemical Specific	ug/L	--	Intake (mg/kg-day) =
				IR	Ingestion Rate	2.5	liters/day	USEPA, 2014	CW x IR x EF x ED x CF
				EF	Exposure Frequency	350	days/yr	USEPA, 2014	BW x AT
				ED	Exposure Duration	20	years	USEPA, 2014	
				CF	Conversion Factor	0.001	mg/ug	--	
				BW	Body Weight	80	kg	USEPA, 2014	
				ATc	Averaging Time - cancer	25,550	days	USEPA, 2014	
				ATnc	Averaging Time - noncancer	7,300	days	USEPA, 2014	
		Child	Onsite	CW	Chemical Concentration in Water	Chemical Specific	ug/L	--	Intake (mg/kg-day) =
				IR	Ingestion Rate	0.78	liters/day	USEPA, 2014	CW x IR x EF x ED x CF
				EF	Exposure Frequency	350	days/yr	USEPA, 2014	BW x AT
				ED	Exposure Duration	6	years	USEPA, 2014	
				CF	Conversion Factor	0.001	mg/ug	--	
				BW	Body Weight	15	kg	USEPA, 2014	
				ATc	Averaging Time - cancer	25,550	days	USEPA, 2014	
				ATnc	Averaging Time - noncancer	2,190	days	USEPA, 2014	

TABLE F-2

VALUES USED FOR DAILY INTAKE CALCULATIONS - GROUNDWATER

REASONABLE MAXIMUM EXPOSURE

HUMAN HEALTH RISK ASSESSMENT

CAMP SMITH TRAINING FACILITY

CORTLANDT, NEW YORK

Scenario Timeframe(s):	Future
Medium:	Groundwater
Exposure Medium:	Groundwater

Exposure Route	Receptor Population	Receptor Age	Exposure Point(s)	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Dermal	Resident	Adult	Onsite	CW	Chemical Concentration in Water	Chemical Specific	ug/L	(2)	Organics:
(showering/bathing)				DA	Dose Absorbed per Unit Area per Event	Chemical Specific	mg/cm^2-event	--	Intake (mg/kg-day) =
				SA	Surface Area	19,652	cm^2	USEPA, 2014	
				ET	Event Time	0.71	hour/event	USEPA, 2014	$\frac{DA \times SA \times EV \times EF \times ED}{BW \times AT}$
				EV	Event Frequency	1	event/day	USEPA, 2004	
				EF	Exposure Frequency	350	days/year	USEPA, 2014	
				ED	Exposure Duration	20	years	USEPA, 2014	
				BW	Body Weight	80	kg	USEPA, 2014	
				ATc	Averaging Time - cancer	25,550	days	USEPA, 2014	
				ATnc	Averaging Time - noncancer	7,300	days	USEPA, 2014	
		Child	Onsite	CW	Chemical Concentration in Water	Chemical Specific	ug/L	(2)	Organics:
				DA	Dose Absorbed per Unit Area per Event	Chemical Specific	mg/cm^2-event	--	Intake (mg/kg-day) =
				SA	Surface Area	6,365	cm^2	USEPA, 2014	
				ET	Event Time	0.54	hour/event	USEPA, 2014	$\frac{DA \times SA \times EV \times EF \times ED}{BW \times AT}$
				EV	Event Frequency	1	event/day	USEPA, 2004	
				EF	Exposure Frequency	350	days/yr	USEPA, 2014	
				ED	Exposure Duration	6	years	USEPA, 2014	
				BW	Body Weight	15	kg	USEPA, 2014	
				ATc	Averaging Time - cancer	25,550	days	USEPA, 2014	
				ATnc	Averaging Time - noncancer	2,190	days	USEPA, 2014	

Notes:

N/A = Not Applicable.

RME = Reasonable Maximum Exposure.

USEPA = United States Environmental Protection Agency.

(1) Equal to half of the default ingestion rate for a residential adult recommended by USEPA (2014).

(2) The chemical concentration in water is incorporated into the DA term for evaluation of dermal contact in water.

Sources:

USEPA, 2014. Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors. February 6, 2014. Revised September 2015.

TABLE F-3

VALUES USED FOR DAILY INTAKE CALCULATIONS - SHALLOW GROUNDWATER

REASONABLE MAXIMUM EXPOSURE

HUMAN HEALTH RISK ASSESSMENT

CAMP SMITH TRAINING FACILITY

CORTLANDT, NEW YORK

Scenario Timeframe:	Future
Medium:	Groundwater
Exposure Medium:	Shallow Groundwater

Exposure Route	Receptor Population	Receptor Age	Exposure Point(s)	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Incidental Ingestion	Construction/Utility Worker	Adult	Onsite	CW	Chemical Concentration in Water	Chemical Specific	ug/L	--	Intake (mg/kg-day) =
				IR	Ingestion Rate	0.011	liters/day	USEPA, 2019 (1)	CW x IR x EF x ED x CF
				EF	Exposure Frequency	125	days/yr	(2)	BW x AT
				ED	Exposure Duration	0.5	years	(2)	
				CF	Conversion Factor	0.001	mg/ug	--	
				BW	Body Weight	80	kg	USEPA, 2014	
				ATc	Averaging Time - cancer	25,550	days	USEPA, 2014	
				ATnc	Averaging Time - noncancer	183	days	USEPA, 2014	
Dermal	Construction/Utility Worker	Adult	Onsite	CW	Chemical Concentration in Water	Chemical Specific	ug/L	(5)	Organics:
				DA	Dose Absorbed per Unit Area per Event	Chemical Specific	mg/cm^2-event	--	Intake (mg/kg-day) =
				SA	Surface Area	3,527	cm^2	USEPA, 2014 (4)	
				ET	Event Time	4	hour/event	(3)	DA x SA x EV x EF x ED
				EV	Event Frequency	1	event/day	USEPA, 2004	BW x AT
				EF	Exposure Frequency	125	days/yr	(2)	
				ED	Exposure Duration	0.5	years	(2)	
				BW	Body Weight	80	kg	USEPA, 2014	
				ATc	Averaging Time - cancer	25,550	days	USEPA, 2014	
				ATnc	Averaging Time - noncancer	183	days	USEPA, 2014	

Notes:

RME = Reasonable Maximum Exposure.

USEPA = United States Environmental Protection Agency.

(1) Upper percentile value for wading/splashing used as a proxy for potential ingestion during excavation activities, assuming one groundwater contact event per day. Value obtained from Dorevitch et al, 2011, and recommended by USEPA (2019; Table 3-96).

(2) Construction/utility activities are assumed to occur for 125 days over the course of a 6 month period, based on professional judgment.

(3) Assumes contact with groundwater in an excavation trench occurs for one-half of a typical 8-hour work day, based on professional judgement.

(4) Represents the weighted mean surface area for males and females ages 21+, including head, hands, and forearms (USEPA, 2011; Table 7-2).

(5) The chemical concentration in water is incorporated into the DA term for evaluation of dermal contact in water.

Sources:

Dorevitch et al, 2011. Water ingestion during water recreation. Water Res 45(5):2020−2028.

USEPA, 2004. Risk Assessment Guidance for Superfund. Part E, Supplemental Guidance for Dermal Risk Assessment. Final. EPA/540/R/99/005.

USEPA, 2011. Exposure Factors Handbook. September 2011.

USEPA, 2014. Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors. February 6, 2014. Revised September 2015.

USEPA, 2019. Update for Chapter 3 of the Exposure Factors Handbook. Ingestion of Water and Other Selected Liquids. EPA/600/R-18/259F. February 2019.

TABLE F-4

VALUES USED FOR DAILY INTAKE CALCULATIONS - SEDIMENT

REASONABLE MAXIMUM EXPOSURE

HUMAN HEALTH RISK ASSESSMENT

CAMP SMITH TRAINING FACILITY

CORTLANDT, NEW YORK

Scenario Timeframe:	Current/Future
Medium:	Sediment
Exposure Medium:	Sediment

Exposure Route	Receptor Population	Receptor Age	Exposure Point(s)	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Incidental Ingestion	Trespasser (Wading Scenario)	Adolescent	Waterbodies (Future) Putnam Brook	CS	Chemical Concentration in Sediment	Chemical Specific	mg/kg	--	Intake (mg/kg-day) =
				IR	Ingestion Rate	50	mg/day	USEPA, 2017 (8)	CS x IR x EF x ED x CF x FI x RBA
				EF	Exposure Frequency	26	days/yr	(1)	BW x AT
				ED	Exposure Duration	9	years	(11)	
				FI	Fraction Ingested from Site	0.5	unitless	(2)	
				CF	Conversion Factor	1.00E-06	kg/mg	--	
				RBA	Relative Bioavailability Factor	1	unitless	--	
				BW	Body Weight	44	kg	USEPA, 2011 (10)	
				ATc	Averaging Time - cancer	25,550	days	USEPA, 2014	
				ATnc	Averaging Time - noncancer	3,285	days	USEPA, 2014	
	Recreational User (Wading Scenario)	Adult	Putnam Brook (Current/Future) Dickiebusch Lake (Current)	CS	Chemical Concentration in Sediment	Chemical Specific	mg/kg	--	Intake (mg/kg-day) =
				IR	Ingestion Rate	50	mg/day	USEPA, 2017 (8)	CS x IR x EF x ED x CF x FI x RBA
				EF	Exposure Frequency	35	days/yr	(9)	BW x AT
				ED	Exposure Duration	20	years	USEPA, 2014	
				FI	Fraction Ingested from Site	0.5	unitless	(2)	
				CF	Conversion Factor	1.00E-06	kg/mg	--	
				RBA	Relative Bioavailability Factor	1	unitless	--	
				BW	Body Weight	80	kg	USEPA, 2014	
				ATc	Averaging Time - cancer	25,550	days	USEPA, 2014	
				ATnc	Averaging Time - noncancer	7,300	days	USEPA, 2014	
Incidental Ingestion	Recreational User (Wading Scenario)	Child	Putnam Brook (Current/Future) Dickiebusch Lake (Current)	CS	Chemical Concentration in Sediment	Chemical Specific	mg/kg	--	Intake (mg/kg-day) =
				IR	Ingestion Rate	90	mg/day	USEPA, 2017 (8)	CS x IR x EF x ED x CF x FI x RBA
				EF	Exposure Frequency	35	days/yr	(9)	BW x AT
				ED	Exposure Duration	6	years	USEPA, 2014	
				FI	Fraction Ingested from Site	0.5	unitless	(2)	
				CF	Conversion Factor	1.00E-06	kg/mg	--	
				RBA	Relative Bioavailability Factor	1	unitless	--	
				BW	Body Weight	15	kg	USEPA, 2014	
				ATc	Averaging Time - cancer	25,550	days	USEPA, 2014	
				ATnc	Averaging Time - noncancer	2,190	days	USEPA, 2014	

TABLE F-4
VALUES USED FOR DAILY INTAKE CALCULATIONS - SEDIMENT
REASONABLE MAXIMUM EXPOSURE
HUMAN HEALTH RISK ASSESSMENT
CAMP SMITH TRAINING FACILITY
CORTLANDT, NEW YORK

Scenario Timeframe:	Current/Future
Medium:	Sediment
Exposure Medium:	Sediment

Exposure Route	Receptor Population	Receptor Age	Exposure Point(s)	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
	Trespasser (Wading Scenario)	Adolescent	Waterbodies (Future) Putnam Brook	CS	Chemical Concentration in Sediment	Chemical Specific	mg/kg	--	Intake (mg/kg-day) = $\frac{CS \times SA \times AF \times ABS \times EV \times EF \times ED \times CF}{BW \times AT}$
				SA	Surface Area	1,534	cm^2	USEPA, 2011 (12)	
				AF	Adherence Factor	0.7	mg/cm^2-event	USEPA, 2004; Table F-6	
				ABS	Dermal absorption fraction	Chemical Specific	unitless	--	
				EV	Event Frequency	1	event/day	(5)	
				EF	Exposure Frequency	26	days/yr	(1)	
				ED	Exposure Duration	9	years	(11)	
				CF	Conversion Factor	1.00E-06	kg/mg	--	
				BW	Body Weight	44	kg	USEPA, 2011 (10)	
				ATc	Averaging Time - cancer	25,550	days	USEPA, 2014	
				ATnc	Averaging Time - noncancer	3,285	days	USEPA, 2014	
	Recreational User (Wading Scenario)	Adult	Putnam Brook (Current/Future) Dickiebusch Lake (Current)	CS	Chemical Concentration in Sediment	Chemical Specific	mg/kg	--	Intake (mg/kg-day) = $\frac{CS \times SA \times AF \times ABS \times EV \times EF \times ED \times CF}{BW \times AT}$
				SA	Surface Area	2,275	cm^2	USEPA, 2011 (6)	
				AF	Adherence Factor	0.6	mg/cm^2-event	USEPA, 2011 (3)	
				ABS	Dermal absorption fraction	Chemical Specific	unitless	--	
				EV	Event Frequency	1	event/day	(5)	
				EF	Exposure Frequency	35	days/yr	(9)	
				ED	Exposure Duration	20	years	USEPA, 2014	
				CF	Conversion Factor	1.00E-06	kg/mg	--	
				BW	Body Weight	80	kg	USEPA, 2014	
				ATc	Averaging Time - cancer	25,550	days	USEPA, 2014	
				ATnc	Averaging Time - noncancer	7,300	days	USEPA, 2014	
		Child	Putnam Brook (Current/Future) Dickiebusch Lake (Current)	CS	Chemical Concentration in Sediment	Chemical Specific	mg/kg	--	Intake (mg/kg-day) = $\frac{CS \times SA \times AF \times ABS \times EV \times EF \times ED \times CF}{BW \times AT}$
				SA	Surface Area	852	cm^2	USEPA, 2011 (7)	
				AF	Adherence Factor	0.7	mg/cm^2-event	USEPA, 2004 (4)	
				ABS	Dermal absorption fraction	Chemical Specific	unitless	--	
				EV	Event Frequency	1	event/day	(5)	
				EF	Exposure Frequency	35	days/yr	(9)	
				ED	Exposure Duration	6	years	USEPA, 2014	
				CF	Conversion Factor	1.00E-06	kg/mg	--	
				BW	Body Weight	15	kg	USEPA, 2014	
				ATc	Averaging Time - cancer	25,550	days	USEPA, 2014	
				ATnc	Averaging Time - noncancer	2,190	days	USEPA, 2014	

TABLE F-4

VALUES USED FOR DAILY INTAKE CALCULATIONS - SEDIMENT

REASONABLE MAXIMUM EXPOSURE

HUMAN HEALTH RISK ASSESSMENT

CAMP SMITH TRAINING FACILITY

CORTLANDT, NEW YORK

Scenario Timeframe:	Current/Future
Medium:	Sediment
Exposure Medium:	Sediment

Exposure Route	Receptor Population	Receptor Age	Exposure Point(s)	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name

Notes:

< = Less than.

RME = Reasonable Maximum Exposure.

USEPA = United States Environmental Protection Agency.

(1) Assumes exposure to sediment may occur for 1 day per week for the 6 warmest months (i.e., May through October; 26 weeks) per year, based on professional judgment.

(2) Assumes 50 percent of sediment ingested is from the associated area, based on professional judgment.

(3) Represents the geometric mean weighted adherence factor for reed gatherers (USEPA, 2011; Table 7-20). Assumes contact with sediment in the waterbodies by hands and feet. See Table A-7 for calculation.

(4) Represents the geometric mean weighted adherence factor for children playing in wet soil (USEPA, 2004; Exhibit 3-3). Assumes contact with sediment in the waterbodies by hands and feet. See Table A-8 for calculation.

(5) Professional judgment; assumes one event per day.

(6) Represents the weighted mean surface area for male and female adults (USEPA, 2011; Table 7-12 and 7-13). Assumes contact with sediment in the waterbodies by hands and feet. See Table A-7 for calculation.

(7) Represents the weighted mean surface area for males and females ages 0 to <6 years old (USEPA, 2011; Table 7-2). Assumes contact with sediment in the waterbodies by hands and feet. The skin surface area for a 1 to <7 year old child is used to represent potential exposure by a recreational child, since a <1 year old child is likely to have limited exposure to sediment. See Table A-8 for calculation.

(8) Equal to the recommended upper percentile daily soil ingestion rates for soil for children and adults (as applicable) (USEPA, 2017; Table 5-1). Value does not include indoor settled dust component which is not applicable to sediment. The value for adults is used for evaluation of the adolescent trespasser.

(9) Assumes exposure to sediment in the waterbodies may occur for 1 day per week during the months of the year when the ground is not frozen, conservatively assumed to occur for the 8 months (35 weeks) from April through November, based on professional judgment.

(10) Weighted average body weight for adolescent ages 6 to <16 years old used to represent the 7 to <16 year old adolescent.

(11) Exposure duration reflects age-range of 7 to <16 years.

(12) Represents the weighted mean surface area for males and females ages 7 to <16 years old, including hands and feet (USEPA, 2011; Table 7-2). See Table A-6 for calculation.

Sources:

USEPA, 2004. Risk Assessment Guidance for Superfund. Part E, Supplemental Guidance for Dermal Risk Assessment. Final. EPA/540/R/99/005.

USEPA, 2011. Exposure Factors Handbook. September 2011.

USEPA, 2014. Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors. February 6, 2014. Revised September 2015.

USEPA, 2017. Update for Chapter 5 of the Exposure Factors Handbook. Soil and Dust Ingestion. EPA/600/R-17/384F. September.

TABLE F-5

VALUES USED FOR DAILY INTAKE CALCULATIONS - SURFACE WATER

REASONABLE MAXIMUM EXPOSURE

HUMAN HEALTH RISK ASSESSMENT

CAMP SMITH TRAINING FACILITY

CORTLANDT, NEW YORK

Scenario Timeframe:	Current/Future
Medium:	Surface Water
Exposure Medium:	Surface Water

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Incidental Ingestion	Trespasser (Wading Scenario)	Adolescent	Waterbodies (Future) Putnam Brook	CW	Chemical Concentration in Water	Chemical Specific	ug/L	--	Intake (mg/kg-day) =
				IR	Ingestion Rate	0.013	liters/day	(1)	CW x IR x EF x ED x CF
				EF	Exposure Frequency	26	days/yr	(2)	BW x AT
				ED	Exposure Duration	9	years	(3)	
				CF	Conversion Factor	0.001	mg/ug	--	
				BW	Body Weight	44	kg	USEPA, 2011 (4)	
				ATc	Averaging Time - cancer	25,550	days	USEPA, 2014	
				ATnc	Averaging Time - noncancer	3,285	days	USEPA, 2014	
	Recreational User (Wading Scenario)	Adult	Putnam Brook (Current/Future) Dickiebusch Lake (Current)	CW	Chemical Concentration in Water	Chemical Specific	ug/L	--	Intake (mg/kg-day) =
				IR	Ingestion Rate	0.013	liters/day	(1)	CW x IR x EF x ED x CF
				EF	Exposure Frequency	35	days/yr	(5)	BW x AT
				ED	Exposure Duration	20	years	USEPA, 2014	
				CF	Conversion Factor	0.001	mg/ug	--	
				BW	Body Weight	80	kg	USEPA, 2014	
				ATc	Averaging Time - cancer	25,550	days	USEPA, 2014	
				ATnc	Averaging Time - noncancer	7,300	days	USEPA, 2014	
		Child	Putnam Brook (Current/Future) Dickiebusch Lake (Current)	CW	Chemical Concentration in Water	Chemical Specific	ug/L	--	Intake (mg/kg-day) =
				IR	Ingestion Rate	0.013	liters/day	(1)	CW x IR x EF x ED x CF
				EF	Exposure Frequency	35	days/yr	(5)	BW x AT
				ED	Exposure Duration	6	years	USEPA, 2014	
				CF	Conversion Factor	0.001	mg/ug	--	
				BW	Body Weight	15	kg	USEPA, 2014	
				ATc	Averaging Time - cancer	25,550	days	USEPA, 2014	
				ATnc	Averaging Time - noncancer	2,190	days	USEPA, 2014	

TABLE F-5

VALUES USED FOR DAILY INTAKE CALCULATIONS - SURFACE WATER

REASONABLE MAXIMUM EXPOSURE

HUMAN HEALTH RISK ASSESSMENT

CAMP SMITH TRAINING FACILITY

CORTLANDT, NEW YORK

Scenario Timeframe:	Current/Future
Medium:	Surface Water
Exposure Medium:	Surface Water

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Dermal	Trespasser (Wading Scenario)	Adolescent	Waterbodies (Current) Putnam Brook, Dickiebusch Lake	CW	Chemical Concentration in Water	Chemical Specific	ug/L	(10)	Organics:
				DA	Dose Absorbed per Unit Area per Event	Chemical Specific	mg/cm^2-event	--	Intake (mg/kg-day) =
				SA	Surface Area	1,534	cm^2	USEPA, 2011 (6)	
				ET	Event Time	1	hour/event	(7)	$\frac{DA \times SA \times EV \times EF \times ED}{BW \times AT}$
				EV	Event Frequency	1	event/day	USEPA, 2004	
				EF	Exposure Frequency	26	days/yr	(2)	
				ED	Exposure Duration	9	years	(3)	
				BW	Body Weight	44	kg	USEPA, 2011 (4)	
				ATc	Averaging Time - cancer	25,550	days	USEPA, 2014	
				ATnc	Averaging Time - noncancer	3,285	days	USEPA, 2014	
	Recreational User (Wading Scenario)	Adult	Waterbodies (Future)	CW	Chemical Concentration in Water	Chemical Specific	ug/L	(10)	Organics:
				DA	Dose Absorbed per Unit Area per Event	Chemical Specific	mg/cm^2-event	--	Intake (mg/kg-day) =
				SA	Surface Area	2,275	cm^2	USEPA, 2011 (8)	
				ET	Event Time	1	hour/event	(7)	$\frac{DA \times SA \times EV \times EF \times ED}{BW \times AT}$
				EV	Event Frequency	1	event/day	USEPA, 2004	
				EF	Exposure Frequency	35	days/yr	(5)	
				ED	Exposure Duration	20	years	USEPA, 2014	
				BW	Body Weight	80	kg	USEPA, 2014	
				ATc	Averaging Time - cancer	25,550	days	USEPA, 2014	
				ATnc	Averaging Time - noncancer	7,300	days	USEPA, 2014	
Dermal	Recreational User (Wading Scenario)	Child	Waterbodies (Future)	CW	Chemical Concentration in Water	Chemical Specific	ug/L	(10)	Organics:
				DA	Dose Absorbed per Unit Area per Event	Chemical Specific	mg/cm^2-event	--	Intake (mg/kg-day) =
				SA	Surface Area	852	cm^2	USEPA, 2011 (9)	
				ET	Event Time	1	hour/event	(7)	$\frac{DA \times SA \times EV \times EF \times ED}{BW \times AT}$
				EV	Event Frequency	1	event/day	USEPA, 2004	
				EF	Exposure Frequency	35	days/yr	(5)	
				ED	Exposure Duration	6	years	USEPA, 2014	
				BW	Body Weight	15	kg	USEPA, 2014	
				ATc	Averaging Time - cancer	25,550	days	USEPA, 2014	
				ATnc	Averaging Time - noncancer	2,190	days	USEPA, 2014	

TABLE F-5

VALUES USED FOR DAILY INTAKE CALCULATIONS - SURFACE WATER

REASONABLE MAXIMUM EXPOSURE

HUMAN HEALTH RISK ASSESSMENT

CAMP SMITH TRAINING FACILITY

CORTLANDT, NEW YORK

Scenario Timeframe:	Current/Future
Medium:	Surface Water
Exposure Medium:	Surface Water

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name

Notes:

RME = Reasonable Maximum Exposure.

USEPA = United States Environmental Protection Agency.

(1) Represents the upper confidence limit for incidental surface water ingestion rates for limited-contact recreational exposures to surface water per event (Dorevitch et al, 2011). Assumes one event per day.

(2) Assumes exposure to surface water may occur for 1 day per week for the 6 warmest months (i.e., May through October; 26 weeks) per year, based on professional judgment.

(3) Exposure duration reflects age-range of 7 to <16 years.

(4) Weighted average body weight for adolescent ages 6 to <16 years old used to represent the 7 to <16 year old adolescent.

(5) Assumes incidental ingestion of surface water in the waterbodies may occur for 1 day per week during the months of the year when the surface water is not frozen, conservatively assumed to occur for the 8 months (35 weeks) from April through November, based on professional judgment.

(6) Represents the weighted mean surface area for males and females ages 7 to <16 years old, including hands and feet (USEPA, 2011; Table 7-2). See Table A-6 for calculation.

(7) Assumes exposure to surface water may occur for 1 hour per event, while walking/wading in the waterbodies, based on professional judgment.

(8) Represents the weighted mean surface area for male and female adults (USEPA, 2011; Table 7-12 and 7-13). Assumes contact with surface water in the waterbodies by hands and feet. See Table A-7 for calculation.

(9) Represents the weighted mean surface area for males and females ages 0 to <6 years old (USEPA, 2011; Table 7-2). Assumes contact with surface water in the waterbodies by hands and feet. The skin surface area for a 1 to <7 year old child is used to represent potential exposure by a recreational child, since a <1 year old child is likely to have limited exposure to surface water. See Table A-8 for calculation.

(10) The chemical concentration in water is incorporated into the DA term for evaluation of dermal contact in water.

Sources:

Dorevitch et al, 2011. Water ingestion during water recreation. Water Res 45(5):2020 −2028.

USEPA, 2004. Risk Assessment Guidance for Superfund (Part E, Supplemental Guidance for Dermal Risk Assessment) Final. EPA/540/R/99/005.

USEPA, 2014. Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors. February 6, 2014. Corrected February 2015.

USEPA, 2019. Update for Chapter 3 of the Exposure Factors Handbook. Ingestion of Water and Other Selected Liquids. EPA/600/R-18/259F. February 2019.

TABLE F-6
CALCULATION OF BODY SURFACE AREA EXPOSED AND SOIL AND SEDIMENT ADHERENCE FACTORS FOR ADOLESCENT TRESSPASSEF
HUMAN HEALTH RISK ASSESSMENT
CAMP SMITH TRAINING FACILITY
CORTLANDT, NEW YORK

Adolescent (7 to <16 years, from 7th birthday to the day before 16th birthday)										
Mean Surface Area by Body Part, m^2 (EFH, Table 7-2, USEPA, 2011)										
Age	**legs**	**lower legs (a)**		**feet**	**head**	**face (j)**	**hands**	**arms**	**forearms**	
7<8 (data 6<11)	0.311	0.124	(b)	0.073	0.066	0.022	0.051	0.151	0.059	(d)
8<9 (data 6<11)	0.311	0.124	(b)	0.073	0.066	0.022	0.051	0.151	0.059	(d)
9<10 (data 6<11)	0.311	0.124	(b)	0.073	0.066	0.022	0.051	0.151	0.059	(d)
10<11 (data 6<11)	0.311	0.124	(b)	0.073	0.066	0.022	0.051	0.151	0.059	(d)
11<12 (data 11<16)	0.483	0.193	(c)	0.105	0.073	0.024	0.072	0.227	0.086	(e)
12<13 (data 11<16)	0.483	0.193	(c)	0.105	0.073	0.024	0.072	0.227	0.086	(e)
13<14 (data 11<16)	0.483	0.193	(c)	0.105	0.073	0.024	0.072	0.227	0.086	(e)
14<15 (data 11<16)	0.483	0.193	(c)	0.105	0.073	0.024	0.072	0.227	0.086	(e)
15<16 (data 11<16)	0.483	0.193	(c)	0.105	0.073	0.024	0.072	0.227	0.086	(e)
Average (age 7 to <16) (cm^2)	**4,066**	**1,626**		**908**	**699**	**233**	**627**	**1,932**	**741**	
Soil: hands, forearms, lower legs, and head (cm^2) =									**3,693**	

Adolescent Trespasser (Onsite Soil)				
Body Part	**Body Surface Area Exposed to Soil (cm^2)**	**Soil Loading Rate (f) (mg/cm^2)**		**Total Soil Mass (mg)**
Head	699	0.052	(g)	36
Hands	627	0.190		119
Forearms	741	0.052	(h)	39
Lower legs (a)	1,626	0.033	(i)	54
Total	3,693	–		248
Area-Weighted Adherence Factor (mg/cm^2) = Soil mass/Surface area =				**0.07**

Adolescent Trespasser (Water Bodies)				
Body Part	**Body Surface Area Exposed to Surface Sediment (cm^2)**	**Sediment Loading Rate (f) (mg/cm^2)**		**Total Sediment Mass (mg)**
Hands	627	0.656		411
Feet	908	0.656	(j)	596
Total	1,534	–		1,007
Area-Weighted Adherence Factor (mg/cm^2) = Sediment mass/Surface area =				**0.7**

Notes:
EFH - 2011 Edition of the Exposure Factors Handbook (USEPA, 2011)

(a) Lower leg surface area = leg surface area x average of the ratios of the lower leg to the leg (EFH Table 7-8), average of male and female, consistent with methods used in USEPA, 2014.
(b) Ratios of the lower leg to the leg for the 6, 8 and 10 year-olds (0.4) (Table 7-8).
(c) Ratio of the lower leg to the leg for the 12 and 14 year-olds (0.4) (Table 7-8).
(d) Surface area for the arm x average of the ratios of the forearm to the arm for 6, 8 and 10 year-olds (0.39) (EFH Table 7-8).
(e) Surface area for the arm x average of the ratios of the forearm to the arm for 12 and 14 year-olds (0.38) (EFH Table 7-8).
(f) Data from USEPA (2004, Exhibit C-2). Geometric mean value, children playing in wet soil
(g) Data for head are not available. Therefore, face data are used as a proxy
(h) Data for forearms are not available. Therefore, arm data are used as a proxy
(i) Data for lower legs are not available. Therefore, leg data are used as a proxy
(j) Data for feet are not available. Therefore, hand data are used as a proxy

Sources:
USEPA, 2004. Risk Assessment Guidance for Superfund. Vol. 1: Human Health Evaluation Manual Part E, Supplemental Guidance for Dermal Risk Assessment Final. EPA/540/R/99/005
USEPA, 2011. Exposure Factors Handbook: 2011 Edition. EPA/600/R-09/052F.
USEPA, 2014. Human Health Evaluation Manual, Supplemental Guidance: Update of Standar Default Exposure Factors. OSWER Directive 9200.1-120.

TABLE F-7
CALCULATION OF BODY SURFACE AREA EXPOSED AND SEDIMENT ADHERENCE FACTORS FOR RECREATIONAL ADULT
HUMAN HEALTH RISK ASSESSMENT
CAMP SMITH TRAINING FACILITY
CORTLANDT, NEW YORK

Adult (21 years and older)			
	Mean Body Surface Area for Adult EFH Tables 7-12 and 7-13 (USEPA 2011)		Average of Males and Females
Body Part	Male m^2	Female m^2	cm^2
Head	0.136	0.114	1,250
Face	0.045	0.038 (c)	417
Upper extremities			
Arms	0.314	0.237	2,755
Upper arms	0.172	0.13035 (a)	1,512
Forearms	0.148	0.11139 (a)	1,297
Hands	0.107	0.089	980
Lower extremities			
Legs	0.682	0.598	6,400
Lower legs	0.268	0.233	2,505
Feet	0.137	0.122	1,295
Sediment: hands, lower legs, and feet (cm^2) =			**4,780**
Sediment: hands and feet (cm^2) =			**2,275**

Adult Recreational User (Waterbodies)			
Body Part	Body Surface Area Exposed to Surface Sediment (cm^2)	Sediment Loading Rate (b) (mg/cm^2)	Total Sediment Mass (mg)
Hands	980	0.66	647
Feet	1,295	0.63	816
Total	2,275	–	1,463
Area-Weighted Adherence Factor (mg/cm^2) = Sediment mass/Surface area =			**0.6**

Notes:
EFH - 2011 Edition of the Exposure Factors Handbook (USEPA, 2011).

(a) In accordance with USEPA 2014 OSWER Directive on Recommended Default Exposure Factors (USEPA, 2014), the female forearms and upper arms surface areas were calculated as follows:
Female arms [0.237] x (Male forearm/Male arms) [0.47]
Female arms [0.237] x (Male upper arms/Male arms) [0.55]
(b) Data from USEPA (2011) Table 7-20. Geometric mean of values for reed gatherers.
(c) Per USEPA (2011) Section 7.2.2, the face is assumed to be 1/3 the surface area of the head.

Sources:
USEPA, 2011. Exposure Factors Handbook: 2011 Edition. EPA/600/R-09/052F.
USEPA, 2014. Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors. OSWER Directive 9200.1-120.

TABLE F-8
CALCULATION OF BODY SURFACE AREA EXPOSED AND SEDIMENT ADHERENCE FACTOR FOR RECREATIONAL CHILD
HUMAN HEALTH RISK ASSESSMENT
CAMP SMITH TRIANING FACILITY
CORTLANDT, NEW YORK

Young Child (1 to <7 years, from 1st birthday to the day before 7th birthday) (j)

Mean Surface Area by Body Part, m^2 (EFH, Table 7-2)

Age	hands	arms	forearms (a)	legs	lower legs (a)	feet
1<2	0.030	0.069	0.028 (b)	0.122	0.051 (e)	0.033
2<3	0.028	0.088	0.035 (b)	0.154	0.065 (e)	0.038
3<4 (data 3<6)	0.037	0.106	0.042 (c)	0.195	0.078 (f)	0.049
4<5 (data 3<6)	0.037	0.106	0.042 (c)	0.195	0.078 (f)	0.049
5<6 (data 3<6)	0.037	0.106	0.042 (c)	0.195	0.078 (g)	0.049
6<7 (data 6<11)	0.051	0.151	0.059 (d)	0.311	0.124 (g)	0.073
Average (cm^2)	**367**	**1,043**	**415**	**1,953**	**791**	**485**
					Sediment: hands, forearms, lower legs, and feet (cm^2) =	**2,057**
					Sediment: hands and feet (cm^2) =	**852**

Child Recreational User (Waterbodies)

Body Part	Body Surface Area Exposed to Surface Sediment (cm^2)	Sediment Loading Rate (h) (mg/cm^2)	Total Sediment Mass (mg)
Hands	367	0.656	241
Feet	485	0.656 (i)	318
Total	852	–	559
Area-Weighted Adherence Factor (mg/cm^2) = Sediment mass/Surface area =			**0.7**

Notes:
EFH - 2011 Edition of the Exposure Factors Handbook (USEPA, 2011).

(a) Lower leg surface area = leg surface area x average of the ratios of the lower leg to the leg
Forearm surface area = arm surface area x ratio of the forearm to the arm
(EFH Table 7-8), average of male and female, consistent with methods used in USEPA, 2014.
(b) Ratio of the forearm to the arm for the 2-year old, average of male and female (0.4) (EFH Table 7-8).
(c) Ratio of the forearm to the arm for the 4-year old, average of male and female (0.4) (EFH Table 7-8).
(d) Ratio of the forearm to the arm for 6, 8 and 10 year-olds (0.39) (EFH Table 7-8).
(e) Ratio of the lower leg to the leg for the 2-year old, average of male and female (0.42) (EFH Table 7-8).
(f) Ratio of the lower leg to the leg for the 4-year old, average of male and female (0.4) (EFH Table 7-8).
(g) Ratio of the lower leg to the leg for the 6, 8 and 10 year-olds (0.4) (EFH Table 7-8).
(h) Data from USEPA (2004, Exhibit C-2). Geometric mean value, children playing in wet soil.
(i) Data for feet are not available. Therefore, hand data are used as a proxy.
(j) The skin surface area for a 1 to <7 year old child is used to represent potential exposure by a recreational child, since a <1 year old child is likely to have limited expoure to sediment.

Sources:
USEPA, 2004. Risk Assessment Guidance for Superfund. Vol. 1: Human Health Evaluation Manual, Part E, Supplemental Guidance for Dermal Risk Assessment Final. EPA/540/R/99/005.
USEPA, 2011. Exposure Factors Handbook: 2011 Edition. EPA/600/R-09/052F.
USEPA, 2014. Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors. OSWER Directive 9200.1-120.

TABLE F-9
PFAS SOIL SCREENING LEVELS FOR TERRESTRIAL PLANTS AND INVERTEBRATES
ECOLOGICAL RISK ASSESSMENT
CAMP SMITH TRAINING FACILITY
CORTLANDT, NEW YORK

		Terrestrial Plant Screening Level				Terrestrial Invertebrate Screening Level			
		ANL Values	SERDP Values			ANL Values	SERDP Values		
Constituent	Abbreviation	NOEC-based ESVs (mg/kg soil) [1]	NOEC Soil Screening Level (mg/kg soil) [2]	LOEC Soil Screening Level (mg/kg soil) [2]	Toxicity Benchmark (NOEC Based) (mg/kg soil) [3]	NOEC-based ESVs (mg/kg soil) [1]	NOEC Soil Screening Level (mg/kg soil) [2]	LOEC Soil Screening Level (mg/kg soil) [2]	Toxicity Benchmark (NOEC Based) (mg/kg soil) [3]
Perfluorooctane sulfonic acid	PFOS	40.2	11	33	3.9	48.1	7.7	141	80
Perfluorooctanoic acid	PFOA	79.5	0.084	0.84	84	22.4	50	NA	10
Perfluorononanoic acid	PFNA	NA	46	NA	NA	10	1	100	NA
Perfluorohexanesulfonic acid	PFHxS	NA	NA	NA	NA	10	1	100	NA
Perfluoroheptanoic acid	PFHpA	NA	NA	NA	NA	NA	1	100	NA
Perfluorobutanesulfonic acid	PFBS	NA	NA	NA	NA	100	10	NA	NA
Perfluorodecanoic acid	PFDA	NA	51	NA	NA	NA	NA	NA	NA
Perfluorobutanoic acid	PFBA	NA	642	NA	NA	NA	NA	NA	NA

Notes:

Shading shows preliminary values to be considered in the Screening Level Ecological Risk Assessment (lowest value).

Other values may be used in Step 3a, as needed.

ANL - Argonne National Laboratory

ESV - Ecological Screening Value

LOEC - Lowest Observed Effect Concentration.

mg/kg - milligram per kilogram.

NA - Not Available.

NOEC - No Observed Effect Concentration.

SERDP - Strategic Environmental Research and Development Program

Sources:

1 - Grippo, M., J. Hayse, I. Hlohowskyj, and K. Picel, 2021. Derivation of PFAS Ecological Screening Values. Argonne National Laboratory, Environmental Science Division. Completed under Interagency Agreement between the U.S. Department of Energy, Argonne National Laboratory, and the Air Force Civil Engineer Center. September. Final.

2 - Divine, C., Frenchmeyer, M., Dally, K., Osborn, E., Anderson, P., Zodrow, J., 2020. Approach for Assessing PFAS Risk to Threatened and Endangered Species. Final Report. SERDP Project ER18-1653. March.

3 - Conder, J., Arblaster, J., Larson, E., Brown, J., Higgins, C., 2020. Guidance for Assessing the Ecological Risks of PFAS to Threatened and Endangered Species at Aqueous Film Forming Foam-Impacted Sites. Guidance Document. SERDP Project ER18-1614. January.

TABLE F-10
PFAS SCREENING LEVELS FOR WILDLIFE RECEPTORS
ECOLOGICAL RISK ASSESSMENT
CAMP SMITH TRAINING FACILITY
CORTLANDT, NEW YORK

		Terrestrial Wildlife Screening Level for Soil								
		ANL Wildlife Values [1]		SERDP Wildlife RBSL [2]						
Feeding Guild				Herbivore	Invertivore	Insectivore	Carnivore	Herbivore	Insectivore	Carnivore
Receptor		ESV for Terrestrial Mammals	ESV for Terrestrial Birds	Meadow Vole	Short-Tailed Shrew	Little Brown Bat	Long-Tailed Weasel	American Goldfinch	House Wren	Red-Tailed Hawk
NOAEL-based RBSLs (mg/kg soil)										
Perfluorooctane sulfonic acid	PFOS	0.0087	0.0386	0.31	0.048	0.03	0.17	0.38	0.013	0.087
Perfluorooctanoic acid	PFOA	3.84	NA	5.8	1.3	0.84	0.57	NA	NA	NA
Perfluorononanoic acid	PFNA	0.0242	NA	2.3	1.5	1	1.5	NA	NA	NA
Perfluorohexanesulfonic acid	PFHxS	0.0028	NA	NA	NA	NA	NA	NA	NA	NA
Perfluorobutanesulfonic acid	PFBS	0.817	15.8	38	14	9.1	78	89	9.3	100
Perfluorodecanoic acid	PFDA	0.0677	NA	NA	NA	NA	NA	NA	NA	NA
Perfluorohexanoic acid	PFHxA	6.2	NA	120	340	250	160	NA	NA	NA
Perfluorobutanoic acid	PFBA	2.98	NA	29	78	58	130	NA	NA	NA
LOAEL-based RBSLs (mg/kg soil)										
Perfluorooctane sulfonic acid	PFOS	NA	NA	0.51	0.079	0.05	0.28	3.8	0.13	0.87
Perfluorooctanoic acid	PFOA	NA	NA	12	2.6	1.7	1.1	NA	NA	NA
Perfluorononanoic acid	PFNA	NA	NA	3	2	1.3	2	NA	NA	NA
Perfluorobutanesulfonic acid	PFBS	NA	NA	150	57	36	310	150	15	170
Perfluorohexanoic acid	PFHxA	NA	NA	260	700	530	330	NA	NA	NA
Perfluorobutanoic acid	PFBA	NA	NA	70	190	140	320	NA	NA	NA

		Aquatic-dependent Wildlife Screening Level for Sediment									
		ANL Wildlife Values [1]		SERDP Wildlife RBSL [2]							
Feeding Guild				Herbivore	Insectivore	Carnivore	Carnivore	Carnivore	Omnivore	Invertivore	Piscivore
Receptor		ESV Aquatic Mammals	ESV Aquatic Birds	Muskrat	Little Brown Bat	River Otter	Harbor Seal	Mink	Red-Winged Blackbird	Tree Swallow	Brown Pelican
NOAEL-based RBSLs (mg/kg sediment)											
Perfluorooctane sulfonic acid	PFOS	NA	NA	0.023	0.0053	0.047	0.046	0.038	0.007	0.0014	0.014
Perfluorooctanoic acid	PFOA	NA	NA	1.2	0.006	0.28	0.19	0.4	NA	NA	NA
Perfluorononanoic acid	PFNA	NA	NA	3.6	0.01	0.24	0.2	0.25	NA	NA	NA
Perfluorobutanesulfonic acid	PFBS	NA	NA	370	1.1	18	16	15	24	0.73	13
Perfluorohexanoic acid	PFHxA	NA	NA	240	1.8	29	26	25	NA	NA	NA
Perfluorobutanoic acid	PFBA	NA	NA	160	1.6	26	23	22	NA	NA	NA
LOAEL-based RBSLs (mg/kg sediment)											
Perfluorooctane sulfonic acid	PFOS	NA	NA	0.038	0.0088	0.077	0.077	0.063	0.07	0.014	0.14
Perfluorooctanoic acid	PFOA	NA	NA	2.3	0.012	0.57	0.39	0.8	NA	NA	NA
Perfluorononanoic acid	PFNA	NA	NA	4.7	0.013	0.32	0.27	0.33	NA	NA	NA
Perfluorobutanesulfonic acid	PFBS	NA	NA	1500	4.3	70	63	60	40	1.2	22
Perfluorohexanoic acid	PFHxA	NA	NA	510	3.8	61	55	53	NA	NA	NA
Perfluorobutanoic acid	PFBA	NA	NA	380	3.8	61	55	53	NA	NA	NA

TABLE F-10
PFAS SCREENING LEVELS FOR WILDLIFE RECEPTORS
ECOLOGICAL RISK ASSESSMENT
CAMP SMITH TRAINING FACILITY
CORTLANDT, NEW YORK

		Aquatic-dependent Wildlife Screening Level for Surface Water									
		ANL Wildlife Values [1]		SERDP Wildlife RBSL [2]							
Feeding Guild				Herbivore	Insectivore	Carnivore	Carnivore	Carnivore	Omnivore	Invertivore	Piscivore
Receptor		ESV Aquatic Mammals	ESV Aquatic Birds	Muskrat	Little Brown Bat	River Otter	Harbor Seal	Mink	Red-Winged Blackbird	Tree Swallow	Brown Pelican
NOAEL-based RBSLs (mg/L water)											
Perfluorooctane sulfonic acid	PFOS	0.000117	0.00257	0.0011	0.00036	0.00028	0.00031	0.00021	0.00034	0.000091	0.000075
Perfluorooctanoic acid	PFOA	1.58	NA	0.018	0.0044	0.012	0.013	0.0094	NA	NA	NA
Perfluorononanoic acid	PFNA	0.00208	NA	0.0022	0.0047	0.0092	0.0097	0.0068	NA	NA	NA
Perfluorohexanesulfonic acid	PFHxS	0.0055	NA	NA	NA	NA	NA	NA	NA	NA	NA
Perfluorobutanesulfonic acid	PFBS	5.71	88.6	76	0.94	2	2.1	1.5	17	0.64	1.3
Perfluorodecanoic acid	PFDA	0.00066	NA	NA	NA	NA	NA	NA	NA	NA	NA
Perfluorohexanoic acid	PFHxA	2.21	NA	6.1	0.21	6.4	5	6.9	NA	NA	NA
Perfluorobutanoic acid	PFBA	8.37	NA	49	1.4	0.86	0.93	0.66	NA	NA	NA
LOAEL-based RBSLs (mg/L water)											
Perfluorooctane sulfonic acid	PFOS	NA	NA	0.0018	0.0006	0.00047	0.00051	0.00036	0.0034	0.00091	0.00075
Perfluorooctanoic acid	PFOA	NA	NA	0.036	0.0089	0.024	0.026	0.019	NA	NA	NA
Perfluorononanoic acid	PFNA	NA	NA	0.0029	0.0063	0.012	0.013	0.009	NA	NA	NA
Perfluorobutanesulfonic acid	PFBS	NA	NA	300	3.8	8	8.5	6	29	1.1	2.1
Perfluorohexanoic acid	PFHxA	NA	NA	13	0.44	13	10	14	NA	NA	NA
Perfluorobutanoic acid	PFBA	NA	NA	120	3.3	2.1	2.2	1.6	NA	NA	NA

Notes:

Shading shows values to be considered in the Screening Level Ecological Risk Assessment (lowest value).

These wildlife-based values do not reflect Site-specific receptors or conditions. If an exceedance of these values is noted in the Screening Level Ecological Risk Assessment, additional screening conducted in Step 3a will consider receptors and assumptions appropriate to the exposure areas.

ANL - Argonne National Laboratory
ESV - Ecological Screening Value
LOAEL - Lowest Observed Adverse Effects Level.
mg/kg - milligram per kilogram.
mg/L - milligrams per liter.
NA - Not Available.
NOAEL - No Observed Adverse Effects Level.
RBSL - Risk-Based Screening Level.
SERDP - Strategic Environmental Research and Development Program

Sources:

1 - Grippo, M., J. Hayse, I. Hlohowskyj, and K. Picel, 2021. Derivation of PFAS Ecological Screening Values. Argonne National Laboratory, Environmental Science Division. Completed under Interagency Agreement between the U.S. Department of Energy, Argonne National Laboratory, and the Air Force Civil Engineer Center. September. Final.
2 - Divine, C., Frenchmeyer, M., Dally, K., Osborn, E., Anderson, P., Zodrow, J., 2020. Approach for Assessing PFAS Risk to Threatened and Endangered Species. Final Report. SERDP Project ER18-1653. March.

TABLE F-11
PFAS SURFACE WATER SCREENING LEVELS FOR AQUATIC LIFE
ECOLOGICAL RISK ASSESSMENT
CAMP SMITH TRAINING FACILITY
CORTLANDT, NEW YORK

		Aquatic Life for Surface Water			
		ANL Values	SERDP Values		USEPA Values
Constituent	Abbreviation	Aquatic Life ESV [1] Freshwater Chronic (ug/L)	Water Quality RBSL [2] Freshwater Chronic (ug/L)	Aquatic Life Protection Values [3] Freshwater - HC5 (ug/L)	Aquatic Life Criteria [4] Freshwater Chronic (ug/L)
Perfluorooctane sulfonic acid	PFOS	22.6	51	5.85	8.4
Perfluorooctanoic acid	PFOA	307	3900	1112	94
Perfluorononanoic acid	PFNA	16.4	120	NA	NA
Perfluorohexanesulfonic acid	PFHxS	65.3	NA	NA	NA
Perfluoroheptanoic acid	PFHpA	NA	870	NA	NA
Perfluorobutanesulfonic acid	PFBS	400	3400	NA	NA
Perfluorodecanoic acid	PFDA	2.94	140	NA	NA
Perfluorododecanoic acid	PFDoDA	NA	72	NA	NA
Perfluorohexanoic acid	PFHxA	28.8	2300	NA	NA
Perfluoroundecanoic acid	PFUnDA	NA	49	NA	NA
Perfluorobutanoic acid	PFBA	64.6	470	NA	NA
Perfluoropentanoic acid	PFPeA	NA	140	NA	NA

Notes:

Shading shows values to be considered in the Screening Level Ecological Risk Assessment (lowest value).

ANL - Argonne National Laboratory
ESV - Ecological Screening Value
HC5 - 5% Hazardous Concentration.
NA - Not Available.
ug/L - microgram per liter
RBSL - Risk-Based Screening Level.
SERDP - Strategic Environmental Research and Development Program
USEPA - United States Environmental Protection Agency.

Sources:

1 - Grippo, M., J. Hayse, I. Hlohowskyj, and K. Picel, 2021. Derivation of PFAS Ecological Screening Values. Argonne National Laboratory, Environmental Science Division. Completed under Interagency Agreement between the U.S. Department of Energy, Argonne National Laboratory, and the Air Force Civil Engineer Center. September. Final.
2 - Divine, C., Frenchmeyer, M., Dally, K., Osborn, E., Anderson, P., Zodrow, J., 2020. Approach for Assessing PFAS Risk to Threatened and Endangered Species. Final Report. SERDP Project ER18-1653. March. Marine screening levels were not derived.
3 - Conder, J., Arblaster, J., Larson, E., Brown, J., Higgins, C., 2020. Guidance for Assessing the Ecological Risks of PFAS to Threatened and Endangered Species at Aqueous Film Forming Foam-Impacted Sites. Guidance Document. SERDP Project ER18-1614. January.
4 - USEPA. 2022. Fact Sheet: Draft 2022 Aquatic Life Ambient Water Quality Criteria for Perfluorooctanoic acid (PFOA) and Perfluorooctane Sulfonic Acid (PFOS). EPA, Office of Water, EPA 842-D-22-005. April 2022.

TABLE F-12
PFAS SEDIMENT SCREENING LEVELS FOR BENTHIC INVERTEBRATES
ECOLOGICAL RISK ASSESSMENT
CAMP SMITH TRAINING FACILITY
CORTLANDT, NEW YORK

Constituent	Abbreviation	PC99 (mg/kg)	PC95 (mg/kg)
Perfluorooctane sulfonic acid	PFOS	0.06	0.25

Notes:

Shading shows values to be considered in the Screening Level Ecological Risk Assessment.

Other values may be used in Step 3a, as needed.

mg/kg - milligram per kilogram.

PC99 - 99 percent protection concentration

PC95 - 95 percent protection concentration

Source:

Simpson et al. 2021. PC99 for PFOS in estuarine and marine sediment (60 µg/kg based on 1 percent organic carbon) selected for screening.