Naval Facilities Engineering Command Northwest
Silverdale, Washington

**Final**

# Sampling and Analysis Plan Supplemental Site Inspection Outlying Landing Field Coupeville

Naval Air Station Whidbey Island
Oak Harbor, Washington

August 2019

## SAP Worksheet #1—Title and Signature Page

Naval Facilities Engineering Command Northwest
Silverdale, Washington

**Final**

# Sampling and Analysis Plan
# Supplemental Site Inspection
# Outlying Landing Field Coupeville

Naval Air Station Whidbey Island
Oak Harbor, Washington

August 2019

Prepared for NAVFAC Northwest
by CH2M HILL, Inc.
Bellevue, Washington
Contract N62470-16-D-9000
CTO 4405

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# SAP Worksheet #1—Title and Signature Page (continued)

Approval Signatures:

Teresie Walker
Naval Facilities Engineering Command Atlantic
Quality Assurance Officer

Other Approval Signatures:

Kendra Leibman
Naval Facilities Engineering Command Northwest
Remedial Project Manager

Chan Pongkhamsing
United States Environmental Protection Agency Region 10
Remedial Project Manager

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# Executive Summary

The Department of the Navy (Navy), Naval Facilities Engineering Command (NAVFAC) Northwest has contracted CH2M HILL, Inc. (CH2M) to conduct a Supplemental Site Inspection (SI) specific to known or suspected releases of per- and polyfluoroalkyl substances (PFAS) to the environment at Outlying Landing Field (OLF) in Coupeville, Washington in Island County. This Uniform Federal Policy-Sampling and Analysis Plan/Quality Assurance Project Plan (SAP) describes the inspection activities to be conducted on-Base at the Coupeville property and at select off-Base locations adjacent to OLF Coupeville. CH2M prepared this document under the NAVFAC Comprehensive Long-term Environmental Action – Navy 9000 Contract N62470-16-D-9000, Contract Task Order 4405, for submittal to NAVFAC Northwest, NAVFAC Atlantic, and the United States Environmental Protection Agency (USEPA).

OLF Coupeville is a military airfield associated with Naval Air Station (NAS) Whidbey Island. It was commissioned for use by the Navy in 1943 and provides support for day and night Field Carrier Landing Practice operations by the Navy for aircraft based out of NAS Whidbey Island. Such operations allow aviators and crew to fly in patterns as well as practice touch-and-go, simulating carrier landings and take offs. During these practice runs, jet aircraft approach the runway and touch down, immediately taking off again and looping around the field to prepare for another landing and takeoff.

There is no formal documentation that aqueous film-forming foam (AFFF) was used at OLF Coupeville. However, PFAS have been detected in groundwater samples collected from on-Base groundwater monitoring wells, with perfluorooctanoic acid (PFOA) and perflouorooctane sulfonate (PFOS) concentrations exceeding the USEPA lifetime health advisory at six locations. PFAS are found in AFFF compounds used in Navy firefighting activities and similar sites at other bases have documented AFFF use. The detected PFAS in samples collected from on-Base wells indicate that AFFF likely was used and released at the site.

Investigations at OLF Coupeville beginning in 2016 have included sampling of on-Base water supply wells and off-Base drinking water wells to identify potentially impacted residences (Navy, 2018a); drilling, installation, and sampling of new on-Base groundwater monitoring wells to better understand the aquifer system and identify the presence/ absence of PFAS on-Base (Navy, 2018a); and aquifer testing and groundwater modeling to improve the understanding of aquifer properties and advance the conceptual model of the system (Navy, 2018b). The results of these previous groundwater and drinking water investigations at OLF Coupeville identified the presence of PFOS and/or PFOA in groundwater in both on-Base groundwater monitoring wells and off-Base drinking water wells at concentrations exceeding the USEPA lifetime health advisory. Additionally, samples collected from the Town of Coupeville's Keystone Hill Well (KHW), a community drinking water well located off-Base to the west of OLF Coupeville, indicate that the KHW exceeds the lifetime health advisory for PFOA. A preliminary assessment (PA) for OLF Coupeville was issued in November 2018 (Navy, 2018c). The PA identified three potential source areas (PSAs) of PFAS that warranted further investigation, two on-Base and one off-Base. As described in **Worksheet #9**, during the initial Supplemental SI scoping meeting, it was determined that the 1982 EA-6B Accident Location, the off-Base PSA identified in the PA, located west of OLF Coupeville, would not be included in the current inspection. Per Navy guidance, off-Base potential PFAS sources are not to be included in the PA or SI.

The Supplemental SI described herein seeks to further assess the distribution and source areas of PFAS and potential PFAS transport pathways and provide the framework/data for a potential future Remedial Investigation. The objectives of the Supplemental SI are to:

- Identify whether there were releases of PFAS-containing compounds from the on-Base PSAs identified in the PA as requiring further investigation (Building 2709 and Facilities 1, 2, and 11) to the environment.

- Refine the understanding of groundwater flow and potential PFAS migration directions between PSAs and/or on-Base groundwater monitoring wells and off-Base drinking water wells with PFOA and/or PFOS exceedances of the lifetime health advisory and impacted off-Base drinking water wells.
- Quantify the hydraulic properties of the aquifer system at OLF Coupeville.
- Refine the understanding of the distribution of PFAS within the groundwater system at OLF Coupeville.

It is anticipated that the Supplemental SI objectives will be accomplished during three field investigation phases, the third of which will be described in a future Addendum to this SAP and conducted when the appropriate real estate agreements are in place. The Phase 1 and 2 investigations will include the following activities:

**Phase 1 Field Investigation**

- Drill and install one monitoring well on-Base in the northeast section of OLF Coupeville to gather additional groundwater elevation data within the intermediate elevation interval of the aquifer system.
- Advance six soil borings (three each near the two on-Base PSAs) with collection of soil samples for analysis of PFAS.
- Conduct depth-discrete groundwater vertical profile sampling at two of the PSA boring locations (one each at the two on-Base PSAs) with analysis of PFAS on expedited turnaround time. The two borings will be converted to groundwater monitoring wells.
- Conduct depth-discrete groundwater vertical profile sampling at two boring locations between the PFAS PSAs identified in the PA and existing monitoring wells with PFAS impacts near the KHW. Groundwater samples will be analyzed for PFAS on expedited turnaround times. The two borings will be converted to groundwater monitoring wells.
- Conduct depth-discrete groundwater vertical profile sampling at three on-Base locations between existing impacted on-Base monitoring wells and impacted drinking water wells south of OLF Coupeville. Groundwater samples will be analyzed for PFAS on an expedited turnaround time. The three borings will be converted to groundwater monitoring wells.
- Collect lithologic data from the newly-installed monitoring well soil borings for further understanding of the overall conceptual site model for the site.
- Collect soil samples for geotechnical parameters to help quantify hydraulic properties of the aquifer system and to provide site-specific input data for solute transport modeling.
- Survey each newly installed groundwater monitoring wells.
- Collect synoptic water level data from existing on-Base groundwater monitoring wells and newly installed on-Base monitoring wells. Collect groundwater samples from 30 existing monitoring wells and the 8 new monitoring wells and submit to an offsite laboratory for PFAS analysis. Field measurements of groundwater quality (pH, dissolved oxygen, temperature, conductivity, oxidation-reduction potential, and turbidity) will be completed during groundwater sampling. This data will be used in determination of Phase 2 well installation locations.

**Phase 2 Field Investigation**

- Drill and install up to an estimated seven monitoring wells at OLF Coupeville following completion of the Phase 1 Supplemental SI. Monitoring well locations and construction will be determined based on evaluation of existing and new lithologic, hydraulic, and analytical data.

- Conduct an aquifer testing program following installation of new (Phase 2) groundwater monitoring wells. The testing will consist of up to an estimated four short-term constant rate pumping tests. Pumping and monitoring wells will be selected to provide representative spatial coverage of the aquifer system.
- Conduct groundwater level monitoring at the pumping well and up to 10 observation wells for each aquifer test.
- Collect synoptic water level data from existing on-Base groundwater monitoring wells and newly installed on-Base groundwater monitoring wells.
- Collect groundwater samples from the (up to) 7 new monitoring wells and submit to an offsite laboratory for PFAS analysis. Field measurements of groundwater quality (pH, dissolved oxygen, temperature, conductivity, oxidation-reduction potential, and turbidity) will be completed during groundwater sampling.
- Survey each newly installed groundwater monitoring well.

This SAP was developed in accordance with the following guidance documents:

- Guidance for Quality Assurance Project Plans (USEPA, 2002)
- Uniform Federal Policy for Quality Assurance Project Plans (USEPA, 2005)
- Guidance on Systematic Planning Using the Data Quality Objectives Process (USEPA, 2006)
- Interim Per- and Polyfluoralkyl Substances (PFAS) Site Guidance for NAVFAC Remedial Project Managers (RPMs)/September 2017 Update (Navy, 2017a) (Brown pers. comm., 2019).

CH2M prepared this SAP in accordance with the Navy's Uniform Federal Policy Sampling and Analysis Plan policy guidance to help ensure that environmental data collected are scientifically sound, of known and documented quality, and suitable for intended uses.

This SAP consists of 37 worksheets specific to the scope of this inspection. All tables are embedded within the worksheets. All figures are included at the end of the document. A geologic map of Coupeville is included as **Appendix A**. Field standard operation procedures (SOPs) are included in **Appendix B**. Department of Defense Environmental Laboratory Accreditation Program (DoD-ELAP) Accreditation letters are included in **Appendix C**. Laboratory SOPs are included in **Appendix D**.

The laboratory information cited in this SAP is specific to Battelle Analytical Services and Core Laboratories, the laboratories that have been selected to support the laboratory needs for this project. If additional laboratory services are necessary to meet the project objectives, revised SAP worksheets will be submitted to NAVFAC Northwest and regulatory agencies (as appropriate) for approval and appended to this SAP. Battelle Analytical Services is DoD-ELAP-accredited. Core Laboratories is not DoD-ELAP-accredited; however, analytical parameters performed by CORE Laboratories are for screening purposes only.

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# SAP Worksheets

## Appendixes

## Tables

## Figures

# Acronyms and Abbreviations

| | |
|---|---|
| ± | plus or minus |
| % | percent |
| > | more than |
| < | less than |
| ≤ | less than or equal to |
| °C | degree Celsius |
| µg/L | micrograms per liter |
| 11C | 11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid |
| 9Cl-PF3ONS | 9-chlorohexadecafluoro-3-oxanone-1-sulfonic acid |
| ADONA | 4,8-dioxa-3H-perfluoronanoic acid |
| AM | Activity Manager |
| AFFF | aqueous film-forming foam |
| amu | atomic mass unit |
| API | American Petroleum Institute |
| AQM | Activity Quality Manager |
| ASTM | ASTM International |
| bgs | below ground surface |
| BH | borehole |
| CA | corrective action |
| CCV | continuing calibration verification |
| CH2M | CH2M HILL, Inc. |
| CLEAN | Comprehensive Long-term Environmental Action—Navy |
| CSM | conceptual site model |
| DL | detection limit |
| DoD | Department of Defense |
| DQI | data quality indicator |
| DV | data validator |
| EDD | electronic data deliverable |
| ELAP | Environmental Laboratory Accreditation Program |
| FD | field duplicate |
| FTL | Field Team Leader |
| gpm | gallons per minute |
| H&S | health and safety |
| HDPE | high density polyethylene |
| HFPO-DA | hexafluoropropylene oxide dimer acid |
| HQ | hazard quotient |
| HSM | Health and Safety Manager |
| HSP | Health and Safety Plan |
| ICAL | initial calibration |
| ICV | initial calibration verification |
| ID | identification |
| IDW | investigation-derived waste |

| | |
|---|---|
| ISC | instrument sensitivity check |
| KHW | Keystone Hill Well |
| LC/MS/MS | liquid chromatography – tandem mass spectrometer |
| LCS | laboratory control sample |
| LCL | lower confidence limit |
| LOD | limit of detection |
| LOQ | limit of quantitation |
| mL | milliliter(s) |
| MPC | measurement performance criteria |
| MS | matrix spike |
| MSD | matrix spike duplicate |
| N/A | not applicable |
| NAS | Naval Air Station |
| NAVD88 | North American Vertical Datum of 1988 |
| NAVFAC | Naval Facilities Engineering Command |
| Navy | Department of the Navy |
| NEtFOSAA | n-ethylperfluoro-1-octancesulfonamidoacetic acid |
| NMeFOSAA | n-methylperfluoro-1-octanesulfonamidoacetic acid |
| NTR | Navy Technical Representative |
| OLF | Outlying Landing Field |
| PA | preliminary assessment |
| PAL | project action limit |
| PC | Project Chemist |
| PFAS | per- and polyfluoroalkyl substances |
| PFBS | perfluorobutane sulfonate |
| PFDA | perfluorodecanoic acid |
| PFDoA | perfluorododecanoic acid |
| PFHxA | perfluorohexanoic acid |
| PFHpA | perfluoroheptanoic acid |
| PFHxS | perfluorohexane sulfonate |
| PFNA | perfluorononanoic acid |
| PFOA | perfluorooctanoic acid |
| PFOS | perfluorooctane sulfonate |
| PFTeDA | perfluorotetradecanoic acid |
| PFTrDA | perfluorotridecanoic acid |
| PFUnA | perfluoroundecanoic acid |
| PID | Photoionization Detector |
| PM | Project Manager |
| POC | point of contact |
| PQL | project quantitation limit |
| PQO | Project Quality Objective |
| PSA | potential source area |
| QA | quality assurance |
| QAO | Quality Assurance Officer |
| QC | quality control |
| QSM | Quality Systems Manual |

| | |
|---|---|
| RL | reporting limit |
| RPD | relative percent difference |
| RPM | Remedial Project Manager |
| RSL | regional screening level |
| SAP | Sampling and Analysis Plan |
| SBO | safe behavior observation |
| SI | site inspection |
| SME | Subject Matter Expert |
| SOP | standard operating procedure |
| SSC | Site Safety Coordinator |
| SSL | soil screening level |
| STC | Senior Technical Consultant |
| TAT | turn-around time |
| TBD | to be determined |
| TM | Task Manager |
| UCL | upper confidence limit |
| UCMR | Unregulated Contaminant Monitoring Rule |
| USGS | United States Geological Survey |
| USEPA | United States Environmental Protection Agency |

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# SAP Worksheet #2—Sampling and Analysis Plan Identifying Information

| | |
|---|---|
| **Site Name/Number:** | Outlying Landing Field (OLF) Coupeville, Naval Air Station (NAS) Whidbey Island |
| **Operable Unit:** | Not Applicable (N/A) |
| **Contractor Name:** | CH2M HILL, Inc. (CH2M) |
| **Contract Number:** | N62470-16-D-9000, Contract Task Order 4405 |
| **Contract Title:** | Comprehensive Long-term Environmental Action – Navy (CLEAN) Program 9000 |
| **Work Assignment:** | Supplemental Site Inspection (SI) specific to known or suspected releases of per- and polyfluoroalkyl substances (PFAS) to the environment for Naval Facilities Engineering Command (NAVFAC) Northwest at the Outlying Landing Field (OLF) in Coupeville, Washington. |

1. This Sampling and Analysis Plan (SAP) was prepared in accordance with the following guidance documents:
   - *Guidance for Quality Assurance Project Plans* (USEPA, 2002)
   - *Uniform Federal Policy for Quality Assurance Project Plans* (USEPA, 2005)
   - *Guidance on Systematic Planning Using the Data Quality Objectives Process* (USEPA, 2006)
   - *Interim Per- and Polyfluoralkyl Substances (PFAS) Site Guidance for NAVFAC Remedial Project Managers (RPMs)/September 2017 Update* (Navy, 2017a)
2. Identify regulatory Program: Comprehensive Environmental Response, Compensation and Liability Act of 1980.
3. This document is a project-specific SAP. The approval entities are the NAVFAC Northwest Remedial Project Manager (RPM) and NAVFAC Northwest Quality Assurance Officer (QAO).
4. List dates of scoping sessions that were held:

| Scoping Session | Date |
|---|---|
| Project Kickoff Call with NAVFAC Northwest RPM | October 12, 2018 |
| Project Scoping Session with NAVFAC Northwest RPM | November 7, 2018 |
| Follow Up Project Scoping Session with NAVFAC Northwest RPM | November 15, 2018 |

5. List dates and titles of any SAP documents written for previous site work that are relevant to the current investigation:

| Document | Date |
|---|---|
| *Sampling and Analysis Plan, Investigation of Perfluorinated Compounds in Drinking Water, Ault Field and Outlying Landing Field Coupeville, Naval Air Station Whidbey Island, Oak Harbor and Coupeville, Washington* (Navy, 2017b) | January 2017 |
| *Sampling and Analysis Plan, Site Inspection for Perfluorinated Compounds in Groundwater, Outlying Landing Field Coupeville, NAS Whidbey Island, Coupeville, Washington* (Navy, 2017c) | January 2017 |
| *Sampling and Analysis Plan, Monitoring Well Installation, Aquifer Testing, Drinking Water Sampling, and Groundwater Sampling, Outlying Landing Field Coupeville, NAS Whidbey Island, Coupeville, Washington* (Navy, 2017d) | December 2017 |

# SAP Worksheet #2—Sampling and Analysis Plan Identifying Information (continued)

6. List organizational partners (stakeholders) and identify the connection with lead organization:

| Organization Partners/Stakeholders | Connection | Date |
|---|---|---|
| CH2M | Contractor | 2016–present |
| NAVFAC Northwest | Kendra Leibman | 2016–present |
| NAVFAC Atlantic - Teresie Walker | QAO | 2016–present |
| United States Environmental Protection Agency (USEPA) Region 10 – Chan Pongkhamsing | Project Manager | 2018-present |
| Island County, Washington – Doug Kelly | Technical Representative/Base Stakeholder | 2016-present |

7. Lead organization: Department of the Navy (Navy) – NAVFAC Northwest
8. If any required SAP elements and required information are not applicable to the project or are provided elsewhere, then note the omitted SAP elements and provide an explanation for their exclusion as follows:
    - Crosswalk table is excluded because all required information is provided in this SAP.

# SAP Worksheet #3—Distribution List

| Name of SAP Recipients | Title/Role | Organization | Telephone Number | E-mail Address or Mailing Address |
|---|---|---|---|---|
| Kendra Leibman | RPM/Task Order Contracting Officer's Representative | NAVFAC Northwest | (360) 396-0022 | kendra.leibman@navy.mil |
| Charlie Escola | Navy Technical Representative (NTR) | NAVFAC Northwest | (503) 201-5020 | charles.escola@navy.mil |
| Steve Skeehan | NTR | NAVFAC Northwest | (253) 279-0212 | Steve.skeehan@navy.mil |
| Teresie Walker | NAVFAC QAO | NAVFAC Atlantic | TBD | Teresie.walker@navy.mil |
| Chan Pongkhamsing | Project Manager (PM) | USEPA Region 10 | (206) 553-1806 | Pongkhamsing.Chan@epamail.epa.gov |
| Doug Kelly | Environmental Health, Hydrogeologist | Island County | (360) 678-7885 | D.Kelly@co.island.wa.us |
| Joe Grogan | Utility Manager | Town of Coupeville | (360) 914-0314 | Utilities1@townofcoupeville.org |
| Jennifer Madsen | Activity Manager (AM) | CH2M | (425) 233-3293 | jennifer.madsen@ch2m.com |
| Rachel Clennon | PM | CH2M | (617) 963-3076 | rachel.clennon@ch2m.com |
| Joe Hauser | PM – Alternate | CH2M | (425) 233-3108 | joe.hauser@ch2m.com |
| Peter Lawson | Senior Technical Consultant (STC) | CH2M | (530) 229-3383 | peter.lawson@ch2m.com |
| Paul Townley | Activity Quality Manager (AQM) | CH2M | (425) 233-5302 | paul.townley@ch2m.com |
| Laura Cook | Subject Matter Expert (SME) | CH2M | (757) 671-6214 | Laura.cook@ch2m.com |
| Tiffany Hill | Project Task Manager (TM) | CH2M | (541) 768-3109 | tiffany.hill@ch2m.com |
| Janna Staszak | Program SAP Quality Reviewer | CH2M | (757) 518-9666 | Janna.staszak@ch2m.com |
| Anita Dodson | Navy PC/SAP Reviewer | CH2M | (757) 671-6218 | anita.dodson@ch2m.com |
| Tiffany Hill | Project Chemist (PC) | CH2M | (541) 768-3109 | tiffany.hill@ch2m.com |
| To be determined (TBD) | Data Validator | CH2M | TBD | TBD |
| TBD | Field Team Leader (FTL) | CH2M | TBD | TBD |
| TBD | Site Safety Coordinator (SSC) | CH2M | TBD | TBD |
| Jonathan Thorn | Laboratory PM | Battelle Analytical Services | (781) 681-5565 | thorn@battelle.org |
| Larry Kunkel | Laboratory PM | Core Laboratories | (661) 325-5657 | larry.kunkel@corelab.com |

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# SAP Worksheet #4—Project Personnel Sign-Off Sheet

| Name | Organization/Title/Role | Telephone Number | Signature/Email Receipt | SAP Section Reviewed | Date SAP Read |
|---|---|---|---|---|---|
| Jennifer Madsen | CH2M/ AM | (425) 233-3293 | | | |
| Peter Lawson | CH2M/STC | (530) 229-3383 | | | |
| Paul Townley | CH2M/AQM | (425) 233-5302 | | | |
| Laura Cook | CH2M/SME | (757) 671-6214 | | | |
| Rachel Clennon | CH2M/Project PM | (617) 963-3076 | | | |
| Joe Hauser | CH2M/ Project PM - Alternate | (425) 233-3108 | | | |
| Janna Staszak | CH2M/SAP Reviewer | (757) 518-9666 | | | |
| Anita Dodson | CH2M/Navy PC/SAP Reviewer | (757) 671-6218 | | | |
| Tiffany Hill | CH2M/PC | (541) 768-3109 | | | |
| TBD | Data Validator | TBD | | | |
| Loren Kaehn | CH2M/Health and Safety Manager (HSM) | (208) 383-6212 | | | |
| TBD | FTL | CH2M | | | |
| TBD | SSC | CH2M | | | |
| Jonathan Thorn | Battelle Analytical Services/Laboratory PM | (781) 681-5565 | | | |
| Larry Kunkel | Core Laboratories/Laboratory PM | (661) 325-5657 | | | |

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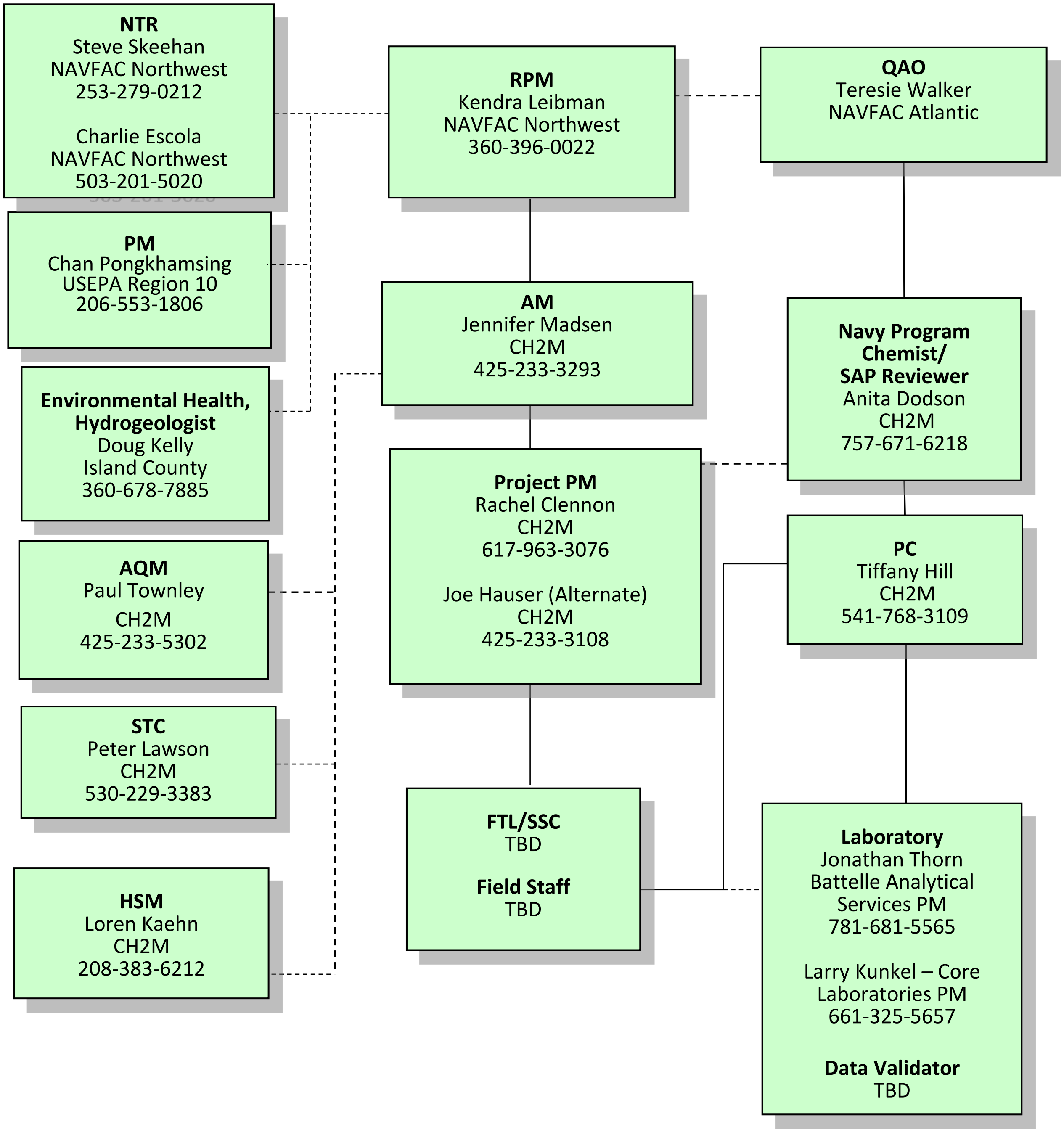
# SAP Worksheet #5—Project Organizational Chart



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# SAP Worksheet #6—Communication Pathways

| Communication Drivers | Responsible Entity | Name | Phone Number | Procedure |
|---|---|---|---|---|
| Communication with Navy (lead agency) | NTR | Steve Skeehan | steve.skeehan@navy.mil<br>(253) 279-0212 | Primary point of contact (POC) for the Navy for the contractor during field work; oversees field work, provides base-specific information, provides coordination with NAS Whidbey Island, and can delegate communication to other internal POCs. |
| Communication with Navy (lead agency) | NTR | Charlie Escola | charles.escola@navy.mil<br>(503) 201-5020 | Primary POC for the Navy for the contractor during field work; oversees field work, provides base-specific information, provides coordination with NAS Whidbey Island, and can delegate communication to other internal POCs. |
| Communication with Navy (lead agency) | RPM | Kendra Leibman | kendra.leibman@navy.mil<br>(360) 396-0022 | Primary POC for the Navy; can delegate communication to other internal or external POCs. CH2M PM will notify the NTR and RPM by email or telephone call within 24 hours for changes affecting the scope or implementation of the SAP. |
| Communication regarding overall project status | AM | Jennifer Madsen | jennifer.madsen@ch2m.com<br>(425) 233-3293 | Oversees project and will be informed of project status by the PM and TM. All data results will be communicated to appropriate team members following data receipt and review. |
| Communication regarding overall project status and implementation and primary POC with RPM and project team | CH2M PM | Rachel Clennon<br>Joe Hauser (Alternate) | rachel.clennon@ch2m.com<br>(617) 963-3076<br>joe.hauser@ch2m.com<br>(425) 233-3108 | Oversees project and will be informed of project status by the TM. If field changes are necessary, PM will work with the RPM to prepare an FCR to be submitted to the NTR and RPM and will communicate in-field changes to the team by email within 24 hours. All data results will be communicated to appropriate team members following data receipt and review. |
| Technical communications for project implementation, and data interpretation | CH2M STC | Peter Lawson | peter.lawson@ch2m.com<br>(530) 229-3383 | Contact STC regarding questions/issues encountered in the field, input on data interpretation, as needed. STC will have 24 hours to respond to technical field questions as necessary. Additionally, STC will review the data as necessary prior to Base and Navy discussions and reporting review. |
| Quality issues | CH2M AQM | Paul Townley | paul.townley@ch2m.com<br>(425) 233-5302 | Contact AQM regarding quality issues during project implementation. The AQM will report to the PM, NTR, and RPM. |

## SAP Worksheet #6—Communication Pathways (continued)

| Communication Drivers | Responsible Entity | Name | Phone Number | Procedure |
|---|---|---|---|---|
| Technical communications for project implementation, and data interpretation | CH2M SME | Laura Cook | laura.cook@ch2m.com<br>(757) 671-6214 | Contact SME regarding questions/issues encountered in the field, input on data interpretation, as needed. SME will have 24 hours to respond to technical field questions as necessary. Additionally, SME will review the data as necessary prior to Base and Navy discussions and reporting review. |
| Communication regarding items specific to OLF tasks and primary POC for field team | CH2M TM | Tiffany Hill | tiffany.hill@ch2m.com<br>(541) 768-3109 | Oversees the investigation task and will be informed of task status by the FTL. If field changes are necessary, TM will work with the PM to produce and FCR for the NTR and RPM and will communicate in-field changes to the team by email within 24 hours. |
| Health and safety (H&S) | CH2M HSM | Loren Kaehn | loren.kaehn@ch2m.com<br>(208) 383-6212 | Responsible for generation of the Health and Safety Plan (HSP) and approval of the activity hazard analyses prior to the start of fieldwork. The PM will contact the HSM as needed regarding questions/issues encountered in the field. |
| H&S | CH2M SSC | TBD | TBD | Responsible for the adherence of team members to the site safety requirements described in the HSP. Will report H&S incidents and near losses to the PM as soon as possible. |
| Stop Work Order | CH2M PM<br>CH2M PM (Alternate)<br>CH2M TM<br>CH2M FTL/SSC<br>Field Team Members | Rachel Clennon<br>Joe Hauser<br>Tiffany Hill<br>TBD<br>TBD | rachel.clennon@ch2m.com<br>(617) 963-3076<br>Joe.hauser@ch2m.com<br>(425) 233-3108<br>tiffany.hill@ch2m.com<br>(541) 768-3109<br>TBD<br>TBD | Any field member can immediately stop work if an unsafe condition that is immediately threatening to human health is observed. The field staff, FTL, or SSC should notify the NTR, RPM, and the CH2M PM immediately. Ultimately, the FTL and PM can stop work for a period of time. NAVFAC Northwest can stop work at any time. |
| Work plan changes in field | FTL | TBD | TBD | Documentation of deviations from the work plan will be made in the field notes, and the PM will be notified immediately. Deviations will be made only with approval from the PM. |
| Field changes/field progress reports | FTL | TBD | TBD | Documentation of field activities and work plan deviations (made with the approval of STC and/or QAO) in field notes; provide daily progress reports to PM. |

# SAP Worksheet #6—Communication Pathways (continued)

| Communication Drivers | Responsible Entity | Name | Phone Number | Procedure |
|---|---|---|---|---|
| Reporting laboratory data quality issues | Battelle Analytical Services PM<br>Core Laboratories PM | Jonathan Thorn<br>Larry Kunkel | thornj@battelle.org (781) 681-5565<br>larry.kunkel@corelab.com<br>(661) 325-5657 | All quality assurance (QA)/quality control (QC) issues with project field samples will be reported within 2 days to the PC by the laboratory. |
| Analytical corrective actions (CAs) | PC | Tiffany Hill | tiffany.hill@ch2m.com (541) 768-3109 | Any CAs for field and analytical issues will be determined by the FTL and/or the PC and reported to the PM within 4 hours. The PM will ensure SAP requirements are met by field staff for the duration of the project. |
| Data tracking from field collection to database upload<br>Release of analytical data | PC | Tiffany Hill | tiffany.hill@ch2m.com (541) 768-3109 | Tracks data from sample collection through database upload daily.<br>No analytical data can be released until validation of the data is completed and has been approved by the PC. The PC will review analytical results within 24 hours of receipt for release to the PM. The PC will inform the Navy CLEAN Program Chemist, who will notify the Navy QAO of any laboratory issues that would prevent the project from meeting project quality objectives or would cause significant delay in the project schedule. |
| Reporting data quality issues | DV | TBD | TBD | The DV reviews and qualifies analytical data as necessary. The data along with a validation narrative are returned to the PC within 7 calendar days. |
| Field CAs | FTL, AM, PM, and Project TM | FTL (TBD)<br>Jennifer Madsen (AM)<br>Rachel Clennon<br>Joe Hauser (PM Alternate)<br>Tiffany Hill | TBD<br>jennifer.madsen@ch2m.com (425) 233-3293<br>rachel.clennon@ch2m.com (617) 963-3076<br>joe.hauser@ch2m.com (425) 233-3108<br>tiffany.hill@ch2m.com (541) 768-3109 | Field and analytical issues requiring CA will be determined by the FTL and/or TM PM on an as-needed basis. The PM will ensure SAP requirements are met by field staff for the duration of the project. The FTL will notify the PM via phone of any need for CA within 4 hours. The PM may notify the NTR and RPM of any field issues that would negatively affect schedule or the ability to meet project data quality objectives. |

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## SAP Worksheet #7—Personnel Responsibilities Table

| Name | Title/Role | Organizational Affiliation | Responsibilities |
|---|---|---|---|
| Kendra Leibman | RPM | NAVFAC Northwest | Oversees project for Navy and provides base-specific information, and coordination with NAS Whidbey Island. |
| Charlie Escola | NTR | NAVFAC Northwest | Oversees field work; provides base-specific information, and coordination with NAS Whidbey Island. |
| Steve Skeehan | NTR | NAVFAC Northwest | Oversees field work; provides base-specific information, and coordination with NAS Whidbey Island. |
| Teresie Walker | NAVFAC QAO/Chemist | NAVFAC Atlantic | Provides QA oversight and reviews SAPs. |
| Jennifer Madsen | AM | CH2M | Oversees and manages project activities. |
| Rachel Clennon | PM | CH2M | Oversees and manages project activities. |
| Joe Hauser | PM – Alternate | CH2M | Oversees and manages project activities. |
| Peter Lawson | STC | CH2M | Provides senior technical support for project approach and execution. |
| Paul Townley | AQM | CH2M | Provides QA oversight. |
| Laura Cook | SME | CH2M | Provides senior technical support for project approach and execution. |
| Tiffany Hill | Project TM | CH2M | Oversees and manages all tasks associated with OLF |
| Janna Staszak | SAP Reviewer | CH2M | Reviews and approves changes or revisions to the SAP. |
| Anita Dodson | Navy PC/SAP Reviewer | CH2M | Provides SAP project delivery support, reviews and approves SAPs, and performs final data evaluation and QA oversight. |
| Tiffany Hill | PC | CH2M | Data management: Performs data evaluation and QA oversight, is the POC with laboratory and validator for analytical issues. |
| Loren Kaehn | HSM | CH2M | Prepares HSP and manages H&S for all field activities. |
| TBD | DV | TBD | Validate laboratory data from an analytical standpoint prior to data use. |
| TBD | FTL | CH2M | Coordinates all field activities and sampling. |
| TBD | Field Staff | CH2M | Conducts field activities. |
| Jonathan Thorn<br>Larry Kunkel | Laboratory PM | Battelle Analytical Services<br>Core Laboratories | Manages samples tracking and maintains good communication with PC. |
| Gail DeRuzzo<br>TBD | Laboratory QAO | Battelle Analytical Services<br>Core Laboratories | Responsible for audits, CA, and checks of QA performance within the laboratory. |

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# SAP Worksheet #8—Special Personnel Training Requirements Table

No specialized training beyond standard H&S training is required for this project.

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# SAP Worksheet #9-1—Project Scoping Session Participants Sheet

| | |
|---|---|
| **Project Name:** Coupeville Supplemental Site Inspection<br>**Projected Date(s) of Sampling:** April – July 2019<br>**PM:** Rachel Clennon/CH2M | **Site Name:** OLF Coupeville<br>**Site Location:** Coupeville, Washington |
| **Date of Session:** Wednesday, November 7, 2018<br>**Scoping Session Purpose:** To obtain consensus on overall objectives of the investigation at OLF Coupeville and discuss proposed investigation scope. | |

| Name | Title/Project Role | Affiliation | Phone # | E-mail Address |
|---|---|---|---|---|
| Kendra Leibman | RPM | NAVFAC Northwest | (360) 396-0022 | Kendra.leibman@navy.mil |
| Rachel Clennon | PM | CH2M | (425) 233-3316 | rachel.clennon@ch2m.com |
| Tiffany Hill | TM/PC | CH2M | (541) 768-3109 | tiffany.hill@ch2m.com |
| Peter Lawson | STC | CH2M | (530) 229-3383 | peter.lawson@ch2m.com |
| Heather Perry | STC | CH2M | (530) 229-3276 | heather.perry@ch2m.com |

### Comments

The purpose of the scoping session was to obtain consensus on overall objectives and path forward for the Supplemental SI at OLF Coupeville and discuss proposed investigation scope, which is a modification of the original scope described in Navy (CLEAN) 9000 Contract N62470-16-D-9000, Contract Task Order 4405.

Field work is expected to begin in April 2019.

### Action Items

- Refine scope details and schedule for two-phase Supplemental SI field investigation.
- Generate the project Work Plan, including SAP, Environmental Protection Plan-Waste Management Plan, and Accident Prevention Plan-Site Safety and Health Plan

### Consensus Decisions

CH2M and the Navy agree on general locations of soil borings near potential source areas (PSAs) and potential monitoring well locations on and off-Base for the Phase 1 inspection contingent upon Navy review of updated scope costing. CH2M and the Navy agree on general scope of work within Phases 1 and 2 of the SI. Specific concurrences include:

- CH2M and the Navy agree to execute Supplemental SI field work in two phases: Phase 1 will work will be mobilized in April 2019, as scoped per original contract. The Phase 2 field investigation will follow after a data evaluation period following Phase 1 field investigation.
- CH2M and the Navy agree to Phase 1 investigation approach:
  - Three monitoring wells will be installed off-Base northeast of the OLF Coupeville.
  - Soil boring advancement and groundwater vertical profiling will be conducted at PFAS PSAs identified in the preliminary assessment (PA).

## SAP Worksheet #9-1—Project Scoping Session Participants Sheet (continued)

  - Evaluation of PFAS in the saturated zone will consist of groundwater vertical profiling sampling conducted at six locations between PFAS-impacted on-Base monitoring wells and the PFAS PSAs and impacted drinking water wells south of OLF Coupeville. One of the locations will be off-Base. During the scoping meeting, the Navy RPM identified the off-Base parcel location favorable to off-Base well installation.
- CH2M and the Navy agree to Phase 2 investigation approach:
  - Utilize a relatively short data evaluation period following the Phase 1 field investigation prior to the start of Phase 2 field investigation to minimize impacts to the overall project schedule. CH2M and the Navy agree to an approximately 1-month data evaluation period following Phase 1 field investigation.
  - Phase 2 field investigation will consist of installation of additional monitoring wells at OLF Coupeville, with locations to be determined based on evaluation of Phase 1 data. The number of additional wells will be determined based on remaining drilling budget and results of the Phase 1 investigation.
  - CH2M will develop the SAP with Phase 2 monitoring well locations unidentified, providing the rationale and a decision tree so locations can be determined following evaluation of Phase 1 data, and Phase 2 can commence without an additional SAP or SAP addendum.
- CH2M and the Navy agree to provide an additional period of time (approximately 1 month) after submittal of the Supplemental SI Report prior to submittal of updated groundwater solute transport model results and evaluation, which will be provided as an Addendum to the Supplemental SI Report.
- CH2M and the Navy agree that investigation of the 1982 EA-6B Accident Location (west of OLF Coupeville) identified in the PA as a PFAS PSA would not be included in the Supplemental SI, per Navy policy guidance not to include off-Base potential PFAS sources in SIs.

# SAP Worksheet #9-2—Project Scoping Session Participants Sheet

| | | | | |
|---|---|---|---|---|
| **Project Name:** Coupeville Supplemental Site Inspection<br>**Projected Date(s) of Sampling:** April – July 2019<br>**PM:** Rachel Clennon/CH2M | | | **Site Name:** OLF Coupeville<br>**Site Location:** Coupeville, Washington | |
| **Date of Session:** Thursday, April 11, 2019 (via teleconference)<br>**Scoping Session Purpose:** Timeline for generation of leases for off-Base well installation and overall schedule for this portion of field work. | | | | |
| **Name** | **Title/Project Role** | **Affiliation** | **Phone #** | **E-mail Address** |
| Kendra Leibman | RPM | NAVFAC Northwest | (360) 396-0022 | Kendra.leibman@navy.mil |
| Rachel Clennon | PM | CH2M | (425) 233-3316 | rachel.clennon@ch2m.com |
| Tiffany Hill | TM/PC | CH2M | (541) 768-3109 | tiffany.hill@ch2m.com |
| Peter Lawson | STC | CH2M | (530) 229-3383 | peter.lawson@ch2m.com |
| Heather Perry | STC | CH2M | (530) 229-3276 | heather.perry@ch2m.com |
| Paul Townley | AQM | CH2M | (425) 233-5302 | Paul.townley@ch2m.com |
| Jennifer Madsen | AM | CH2M | (425) 233-3293 | Jennifer.madsen@ch2m.com |

### Comments

Overall discussion of scope and schedule for proposed off-Base monitoring wells was discussed via teleconference with Navy RPM to determine the most appropriate method for obtaining access agreements and/or leases with property owners. Prior to this teleconference, and upon conference with Navy real estate asset management, it was determined that leases and/or easements would be required to gain access to these properties, and the process to execute the necessary leases will take 12 to 15 months. The timeline was communicated to CH2M by the Navy RPM on April 5, 2019. Subsequently, on April 8, 2019, Navy Real Estate indicated that the execution process could be shortened to 9-12 months.

The Navy RPM provided a revised schedule for execution of the off-Base leases and/or easements via email on April 8, 2019 and requested a meeting to discuss with CH2M. The Navy RPM also sent the survey requirements for leases, with the option for Jacobs to perform the surveying to potentially shorten the lease and/or easement execution process.

Meeting action items and consensus decisions from the April 11 meeting are described below.

### Action Items

- CH2M to revise SAP to reflect changes in scope and schedule due to the extended timeline for execution of off-Base leases and/or easements. The revised SAP will be provided to Navy prior to stakeholder review.
- CH2M will provide (if possible) alternate locations to the proposed off-Base wells if property owners at current proposed locations do not grant access. CH2M will provide Navy a figure showing alternate locations.
- CH2M will incorporate a third mobilization (Phase 3) into Work Plan and field schedule, to include the installation of off-Base wells. This information will be presented in a future Addendum to this SAP.
- A period of performance (POP) extension will be required to extend the project into 2020.

## SAP Worksheet #9-2—Project Scoping Session Participants Sheet (continued)

- Conducting water level gauging at existing off-Base private wells was discussed. However, this task does not appear to be included in the current scope of work. The Navy RPM will talk to Navy contracting to determine whether the current assumptions of scope could be interpreted to include this task.
- The Navy RPM will inquire with Navy Real Estate about the most appropriate type of leases and/or easements for the parcels in question.

**Consensus Decisions**

CH2M and the Navy agree that the proposed off-Base locations are necessary to meet the objectives of the Supplemental SI. The leases and/or easements with property owners of parcels on which the off-Base wells are proposed will be pursued through Navy Real Estate.

A third phase/ mobilization of field work will take place in 2020 to install the proposed off-Base wells. Details regarding this work will be presented under a future Addendum to this SAP.

## SAP Worksheet #10—Conceptual Site Model

OLF Coupeville is located 2 miles southeast of the Town of Coupeville, Washington, in Island County (**Figure 10-1**). **Figure 10-2** presents the layout of OLF Coupeville. **Table 10-1** presents the conceptual site model (CSM) for OLF Coupeville, NAS Whidbey Island, Coupeville, Washington.

Table 10-1. OLF Coupeville Conceptual Site Model

| **Site Name** | OLF Coupeville, NAS Whidbey Island, Coupeville, Washington (**Figures 10-1**, **10-2**, and **10-3**). |
|---|---|
| **Study Area Description** | OLF Coupeville is a military airfield associated with NAS Whidbey Island. It was commissioned for use by the Navy in 1943 and provides support for day and night Field Carrier Landing Practice operations by the Navy for aircraft based out of NAS Whidbey Island. Such operations allow aviators and crew to fly in patterns as well as practice touch-and-go, simulating carrier landings and take offs. During these practice runs, jet aircraft approach the runway and touch down, immediately taking off again and looping around the field to prepare for another landing and takeoff.<br>The area to be investigated includes off-Base groundwater surrounding OLF Coupeville, soil and groundwater inspection at two of the PSAs at OLF Coupeville east of the runway, groundwater between the PSAs and impacted on-Base groundwater monitoring wells, groundwater between impacted on-Base groundwater monitoring wells and impacted off-Base drinking water wells south of OLF Coupeville, and soil and groundwater off-Base to the south of OLF Coupeville (**Figure 10-2**). |
| **Potential Sources** | Potential source areas for on-Base and off-Base drinking water PFAS impacts to be considered in this investigation are on-Base locations of suspected releases of aqueous film-forming foam (AFFF). At OLF Coupeville they include:<br>• Building 2709 (Crash Truck Shelter) – fire trucks containing AFFF are stored and truck washing occurs, off-truck AFFF was stored at this location in the past.<br>• Facilities 1, 2, and 11 (Control Tower, Airfield Operations Building, and Potable Water Well Pump House) – PFAS have been detected in groundwater downgradient of these locations.<br>Groundwater data collected during the 2016-2017 SI and the 2017-2018 aquifer testing and groundwater and drinking water sampling effort are consistent with the identification of these facilities as PSAs. |
| **Study Area Investigation History** | PFAS were first detected in one of the on-Base drinking water wells located in the southwest portion of the OLF Coupeville near Building 2807 during groundwater sampling activities conducted in November 2016 by the Navy under USEPA's Unregulated Contaminant Monitoring Rule (UCMR) 3 (**Figure 10-2**). The PFAS detection prompted initiation of a groundwater investigation at OLF Coupeville (Navy, 2018a). Twenty-seven groundwater monitoring wells were installed and sampled for PFAS between November 2016 and March 2017 (**Figure 10-2**). With one exception (WI-CV-MW14-M), these 27 wells were constructed as paired wells screened at depths of 91.5 to 232 feet below ground surface (bgs), ranging from 95.88 to -38.51 feet above the North American Vertical Datum of 1988 (NAVD88), to provide data on the piezometric surface in each well and vertical distribution of PFAS at each well pair location. The monitoring wells typically were screened at three general elevation intervals (two of the three elevation intervals represented at each well pair): 'shallow elevation interval' wells typically were screened above 50 feet NAVD88; 'intermediate elevation interval' wells were screened 0 to 50 feet NAVD88; and 'deep elevation interval' wells were screened near or below 0-foot NAVD88. Note that the shallow, intermediate, and deep elevation intervals do not indicate three discrete aquifers or water-bearing zones and the 'middle' and 'deep' elevation intervals are located within the source aquifer of drinking water on Whidbey Island (known locally as the Sea Level Aquifer [USGS, 1982]). Two additional groundwater monitoring well pairs (WI-CV-MW-15S/M and WI-CV-MW-16S/M) were installed in December 2017. All four of the wells were completed within the intermediate elevation interval of the aquifer system, although the "S" designated wells were screened at shallower depths relative to the "M" designated wells. Groundwater samples indicated that perfluorooctanoic acid (PFOA) exceeded the USEPA lifetime health advisory at three of the four of the newly installed well locations.<br>The Supplemental SI area includes on-Base areas within the OLF Coupeville (**Figure 10-2**). Two on-Base locations were identified in the *Final Preliminary Assessment for Per- and Polyfluoroalkyl Substances (PFAS) Outlying Landing Field Coupeville* (Navy, 2018c) as potential PFAS source areas in need of site inspection. These areas are Building 2709 (Crash Truck Shelter) and Facilities 1, 2, and 11 (Control Tower, Airfield Operations Building, and Potable Water Well Pump House), considered together as one source area because of proximity. |

# SAP Worksheet #10—Conceptual Site Model (continued)

Table 10-1. OLF Coupeville Conceptual Site Model

| | | |
|---|---|---|
| **Study Area Investigation History (cont.)** | | PFAS compounds are found in AFFF used in Navy firefighting activities, and similar sites at other bases have documented AFFF use. Although there is no available documentation that AFFF was used at the site and there is limited information regarding the storage of AFFF on fire trucks at Building 2709, PFAS have been detected in groundwater samples collected from on-Base wells, with PFOA and/or PFOS exceeding the EPA lifetime health advisory at six locations, indicating that AFFF likely was used/released at the site. |
| | | In November 2016, the Navy initiated off-Base drinking water sampling near OLF Coupeville. The Navy sampled all drinking water wells (with owner approval) within 1 mile of Building 2807 at OLF Coupeville because of the PFOA detection identified during the Navy's UCMR 3 sampling. From November 2016 through October 2017, the Navy sampled 120 drinking water wells near OLF Coupeville, of which one was the Town of Coupeville's Keystone Hill Well (KHW). Eight residential drinking water wells to the south of OLF Coupeville have PFAS concentrations above the USEPA lifetime health advisory (**Figure 10-3**). In October 2017, the Navy began biannual sampling of drinking water wells where PFAS were detected and drinking water wells adjacent to properties with PFAS exceedances. There have been no locations at which PFOS and/or PFOA concentrations exceeded the project action limit (PAL) that had not exceeded the USEPA lifetime health advisory in previous sampling efforts, with the exception of the KHW with PFAS in exceedance of the USEPA lifetime health advisory in September 2018. |
| | | The KHW well is currently used as a potable water source for the Town of Coupeville and it is currently operating at an extraction rate of approximately 150 gallons per minute (gpm) for 21 to 23 hours per day. Water from the KHW is blended with other Town of Coupeville supply wells before treatment at the Town of Coupeville's treatment plant. The blended water is treated for iron and manganese before distribution to the users. The Town's treatment train includes pre-chlorination with sodium hypochlorite, filtration by pressure filters containing manganese dioxide, and post-chlorination with sodium hypochlorite. As part of the long-term solutions, an effort is currently underway to upgrade the Town of Coupeville water treatment plant to include treatment of PFAS compounds and to connect impacted residences to the Town water supply system. |
| **Site Conditions** | **Physical Characteristics** | OLF Coupeville is located on a broad plateau of Smith Prairie in central Whidbey Island at an elevation of approximately 195 feet NAVD88. The paved runway is approximately 5,400 feet long and is bordered by grass maintained by mowing operations extending to the public roads (Navy, 1994). A runway safety area extends approximately 3,300 feet south of the runway footprint and is bordered by trees and residential parcels (**Figure 10-2**). |
| | **Geology and Hydrogeology** | Lithology at OLF Coupeville consists of heterogeneous glacial deposits of gravel, sand, silt, and clay. Lithology observed is consistent with the previous mapping by Polenz et al. (2005) (**Appendix A**). The shallowest deposits represent glaciomarine drift, consisting of sands and gravel extending to approximately 50 feet bgs. These materials are generally unsaturated. The shallow sands and gravel are generally underlain by recessional outwash (Partridge Gravel) consisting primarily of sand and gravel extending to between 80 and 180 feet bgs. Groundwater is present with the Partridge Gravel in perched zones between 90 and 130 feet bgs. The sands and gravel are underlain by Vashon till, consisting of a dark gray, laterally discontinuous, sand, silt, and clay unit present in the many of well borings completed within and around the OLF. The till likely acts as an aquitard in some areas and ranges in depth from 80 to 220 feet bgs (Unit $Qgt_v$ shown on cross section A-A' of **Appendix A)**. Localized saturated conditions exist above the till. However, few nearby water supply wells are completed to depths of less than 180 feet bgs. A highly-transmissive sand and gravel bed (advance outwash; 5 to 10 feet thick) underlies the till and is widely used for water supply purposes. The transmissive unit and surrounding sands are locally referred to as the Sea Level Aquifer (USGS, 1982). Static water levels in wells screened in this sand and gravel typically indicate confined conditions, with hydrostatic heads rising 30 to 40 feet above the base of the till aquitard. The sand and gravel bed is underlain by fine-grained undifferentiated Pleistocene deposits. In the vicinity of OLF Coupeville, these deposits consist of heterogeneous clay, claystone, and silt and frequently contain organic material, such as plant material and peat.<br>Cross sections have been developed to evaluate the comprehensive site hydrogeology and are shown on **Figures 10-4** through **10-8**. |

# SAP Worksheet #10—Conceptual Site Model (continued)

Table 10-1. OLF Coupeville Conceptual Site Model

| | | |
|---|---|---|
| **Site Conditions** | **Geology and Hydrogeology (continued)** | Boring logs from the initial construction of the KHW in 2008 are similar to neighboring OLF Coupeville with silty sand and gravel from the surface to 133 feet bgs. A 7-foot-thick confining layer of silty clay from 133 to 140 feet bgs (likely the Vashon Till) separates the overlying sands and gravels from the underlying fine sand with trace gravel. Total depth of the boring was to 200 feet bgs.<br>The KHW is screened from 142 to 182 feet bgs or 8-48 feet NAVD88 within the fine sand comprising the Sea Level aquifer (intermediate elevation interval as noted in previous investigations) at this location and is separated from overlying transmissive layers by a thin silty clay aquitard (likely the Vashon Till). The initial aquifer test for the KHW had a yield of 302 gpm with approximately 20 feet of drawdown over a 24-hour period and a transmissivity of 79,000 gallons per day per foot (Robinson Noble, Inc., 2008). The current yield of the KHW as operated by the Town of Coupeville is approximately 150 gpm over a 21 to 23-hour period each day.<br>Cross sections have been developed to evaluate the comprehensive site hydrogeology and are shown on **Figures 10-4** through **10-8**. Mixed outwash deposits of the Sea Level aquifer are distributed in beds of inconsistent thickness across the site, which complicates identification of distinct hydrogeologic units.<br>With the exception of shallow perched groundwater bearing units that may occur locally, the three previously discussed elevation intervals occur within a single aquifer system and are in hydraulic connection with one another. The first encountered groundwater in the northern portion of the site is between 90 and 130 feet bgs. A subset of the shallow elevation interval wells may represent localized perched groundwater, but the available data do not confirm this. A discontinuous clay and silt layer is present at some well cluster locations but pinches out in the southern portion of the site. The underlying intermediate elevation interval is likely semiconfined, with confined conditions in some areas of the northern portion of the site and unconfined conditions in the southern portion, near wells WI-CVMW10M and WI-CV-MW12S/D. The potentiometric surface for the intermediate elevation interval is at approximately 60 to 85 feet NAVD88, or 120 to 130 feet bgs. A heterogeneous clay, claystone, and silt confining layer underlies the intermediate elevation interval and is interpreted to define the bottom of the Partridge Gravel. Organic material (for example, plant material and peat) was frequently observed in this interval. Transmissive sand zones are present within and beneath the organic silt and clay unit. Borings completed at the site typically were terminated in the organic clay zone or sand zones within or beneath it. For this assessment, these sand zones are considered part of the deep elevation interval.<br>Groundwater contour maps have been generated for intermediate-and-deep-screened monitoring well networks, included as **Figures 10-9** and **10-10**, respectively. Groundwater levels measured in shallow-screened wells are highly variable suggesting some wells are screened in perched conditions. As such, a groundwater contour map has not been developed for the shallow wells. Groundwater elevation data infer the presence of a groundwater mound (divide) in the northern portion of OLF Coupeville (**Figures 10-9**). This interpretation is supported by the Island County Water Resource Management Plan (Island County, 2005), which suggests that OLF Coupeville is located on a hydrogeologic divide, and groundwater flow is likely to be radial away from OLF Coupeville. The dominant flow direction in the intermediate elevation interval over the majority of OLF Coupeville is to the southwest, shifting to the south-southeast in the southern portion of the site (**Figure 10-9**). Groundwater flow in the deep elevation interval is inferred to be predominantly to the south/southeast (**Figure 10-10**). Vertical gradients on-Base at OLF Coupeville are predominantly downward.<br>A groundwater elevation study conducted in March 2017 indicated groundwater elevation fluctuations in the 27 wells evaluated during a 48-hour monitoring period ranged up to 0.6 foot. Deep elevation interval wells (WI-CV-MW01D, WI-CV-MW03D, WI-CV-MW10D, and WI-CV-MW12D) show a clear semidiurnal tidal influence. Two intermediate elevation intervals (WI-CV-MW06M and WI-CV-MW08M) show a weaker semidiurnal tidal influence. WI-CV-MW14M appears to show a response to nearby pumping, possibly related to operation of the Town of Coupeville KHW. Most other wells show small water level variations that appear to correlate with barometric pressure fluctuations (Navy, 2018a). |

# SAP Worksheet #10—Conceptual Site Model (continued)

Table 10-1. OLF Coupeville Conceptual Site Model

| **Contaminants of Potential Concern** | 18 PFAS compounds (listed in **Worksheet #15**) |
|---|---|
| **Nature and Extent** | <u>Drinking Water</u><br>Off-Base Residential Wells and KHW:<br>PFAS have been detected in exceedance of the USEPA lifetime health advisory in eight off-Base residential wells since the sampling program began in November 2016. As of October 2017, the off-Base residential wells with exceedances are sampled biannually for 18 PFAS compounds. The most recent results from September 2018 indicate that PFOA concentrations exceed the lifetime health advisory in all eight wells, with values ranging from 0.0872 to 0.588 microgram per liter (µg/L). PFOS was detected in one of the eight wells, at a concentration of 0.00378 µg/L, less than the USEPA lifetime health advisory.<br>The KHW is sampled biannually as part of the off-Base drinking water sampling program. Prior to the most recent sampling event in September 2018, PFAS compounds had been detected at concentration less than the USEPA lifetime health advisory. In September 2018, PFOA was detected in exceedance of the EPA lifetime health advisory at 0.0709 µg/L. These results are consistent with the independent testing results conducted by the Town of Coupeville in summer 2018, where PFOA was detected at concentrations exceeding the USEPA lifetime health advisory. PFOS has not been detected in the KHW since the Navy's sampling program began in November 2016.<br><u>Groundwater</u><br>OLF Coupeville:<br>PFOA, PFOS, and perfluorobutane sulfonate (PFBS) were analyzed for groundwater samples collected from 27 wells located within OLF Coupeville in February and March 2017 (Navy, 2018a). Fourteen PFAS compounds were analyzed in groundwater samples collected from 11 groundwater monitoring wells sampled in December 2017 and January 2018 (Navy, 2018b). Groundwater sample results are shown on **Figure 10-11**. PFOS was detected at a concentration exceeding the USEPA lifetime health advisory of 0.07 µg/L at WI-CV-MW02S and at concentrations less than the lifetime health advisory at other on-Base wells. PFOA concentrations at six wells (WI-CV-MW02S, WI-CV-MW05M, and WI-CV-MW14M, WI-CV-MW15S, WI-CV-MW16S, and WI-CV-MW16M) exceeded the lifetime health advisory of 0.07 µg/L for PFOA.<br>The highest combined PFOA and PFOS concentration in the intermittent shallow/perched aquifer was 1.098 µg/L, in the sample from WI-CV-MW02S. This was the only detection in the shallow/perched interval that exceeded the lifetime health advisory for the total concentration of PFOA plus PFOS (0.07 µg/L). The highest detection was of PFOA at a concentration of 1.22 µg/L in the sample collected from WI-CV-MW05M. PFAS concentrations in WI-CV-MW05S, the shallow well for this well pair, were significantly lower with no exceedances of the lifetime health advisory, indicating a possible upgradient source and potential transport pathway between the shallow and intermediate elevation intervals (which could not be positively confirmed with the existing well network). |

# SAP Worksheet #10—Conceptual Site Model (continued)

Table 10-1. OLF Coupeville Conceptual Site Model

| | |
|---|---|
| **Migration Pathways** | • Vertical migration of PFAS from vadose zone PSAs to the underlying groundwater system.<br>• Horizontal and vertical transport within the aquifer system via advection with groundwater flow.<br>• Preferential pathways via non-grouted well casings: The well construction records for the water supply wells at OLF Coupeville show that the steel well casings were not grouted deeper than 18 feet bgs, potentially leaving an open annulus from 18 feet bgs to the bottom of the borehole at 180 feet bgs. The absence of a grout seal could allow shallow, potentially contaminated groundwater, to migrate downward and reach the deeper aquifer used locally for water supply purposes. |
| **Potential Receptors / Exposures Routes** | Current and future off base residents: Ingestion of PFAS in groundwater<br>Current and future drinking water users at OLF Coupeville: Ingestion of PFAS in groundwater<br>Ecological receptors: N/A |

### Data Needs

The following data needs were identified based on the previous investigations summarized in **Table 10-1**.

- Additional data are needed to better understand the location of the groundwater divide and its potential impact on groundwater flow and potential PFAS migration pathways at OLF Coupeville.
- Information on the location and extent of vadose zone source areas is needed. Soil and groundwater sampling data are necessary to evaluate the location and depth of contamination at two on-Base PSAs identified in the preliminary assessment, as well as at the radar facility (Building 2807).
- The distribution of PFAS contamination in groundwater and the primary contaminant transport pathways need to be defined. The current distribution of PFAS in groundwater at the site does not reflect traditional plume configurations. Vertical profiles of the saturated zone are needed to site additional monitoring wells to refine the delineation of groundwater contamination.

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# SAP Worksheet #11—Project Quality Objectives/Systematic Planning Process Statements

## Problem Definition, Environmental Questions, and Project Quality Objectives

As discussed in **Worksheet #10**, investigations at OLF Coupeville began in 2016 and have continued through present. The results of these previous groundwater and drinking water investigations at OLF Coupeville identified the presence of PFOS and/or PFOA in groundwater in both on-Base groundwater monitoring wells and off-Base drinking water wells at concentrations exceeding the lifetime health advisory. Additionally, the PA identified three potential PSAs of PFAS that warranted further investigation, two on-Base and one off-Base. As described in **Worksheet #9**, during the initial Supplemental SI scoping meeting it was determined that the 1982 EA-6B Accident Location (west of OLF Coupeville) would not be included in the current investigation. A Supplemental SI is needed to further assess the distribution and source areas of PFAS and potential PFAS transport pathways and provide the framework/data for potential future Remedial Investigation and Risk Assessment(s). The problem definition, environmental questions, general investigation approaches, and Project Quality Objectives (PQOs) contained in this SAP are described in **Table 11-1** and are based on the USEPA *Guidance on Systematic Planning Using the Data Quality Objectives Process* (USEPA, 2006) and its seven-step process. The detailed sampling approach, including numbers of samples and a full list of analytes, is provided in **Worksheet #17**. Planned sample locations are shown on **Figure 11-1**.

## What are the Project Action Limits?

PALs are media-specific standards and criteria chosen for evaluation to help provide a conservative assessment of site conditions and determine if further evaluation or action is needed to address concentrations of chemicals present onsite. The following list summarizes the PALs applicable to soil and groundwater samples at OLF Coupeville.

- Since there is no Washington State or USEPA action limit for groundwater, this Site Inspection will use the tap water RSL from EPA's online calculator, based on a target HQ of 0.1 (PFOA = 0.04 ug/L, PFOS = 0.04 ug/L, and PFBS = 40 ug/L) for on-Base and groundwater screening levels.
- USEPA lifetime health advisory for PFOA and PFOS in drinking water: 0.07 µg/L, unless both chemicals are detected, then 0.07 µg/L is the lifetime health advisory for the cumulative concentration of the two chemicals; the groundwater screening levels to be used (based on EPA's RSL calculator) are more conservative than USEPA's lifetime health advisory.
- USEPA RSL for PFBS in groundwater: 40 µg/L (based on a HQ = 0.1)
- PALs for PFOS, PFOA, and PFBS in soils: 0.0378 µg/kg, 0.0172 µg/kg, and 13 µg/kg, respectively, derived from USEPA online RSL calculator for soil leaching to groundwater[1]
- PALs currently do not exist for the remaining 15 PFAS compounds for soil or groundwater. At the time of drafting this SAP, there are no USEPA RSLs or any Washington state regulatory screening levels available. According to Navy policy, data need to be collected for all 18 analytes listed in liquid chromatography – tandem mass

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[1] https://epa-prgs.ornl.gov/cgi-bin/chemicals/csl_search

Although the computation of soil screening level values for PFAS compounds do not include some chemical-specific transport properties of the constituents, these values represent generalized screening criteria for evaluation of the presence of PFAS vadose zone source areas. The soil screening level values are not intended for use in remedial action or risk assessment decision-making.

# SAP Worksheet #11—Project Quality Objectives/ Systematic Planning Process Statements (continued)

spectrometer (LC/MS/MS) compliant with Quality Systems Manual (QSM) v. 5.1.1 Table B-15 in both groundwater and soil.

## For What Will the Data be Used?

Data will be used by the Navy, its contractors, and the other stakeholder agencies to address the environmental questions and PQOs listed in **Table 11-1**.

## What types of data are needed?

The types of data needed include:

- Subsurface lithology of the soil borings for observation well installation to determine where semi-confining aquitards and aquifers are present for CSM and numerical groundwater flow model update.
- Synoptic groundwater level surveys from on-Base wells to evaluate groundwater flow and solute transport directions and for use as numerical groundwater flow model calibration targets.
- Soil samples from PSAs will be submitted for PFAS analyses under standard laboratory TAT to help inform the spatial and vertical distribution of PFAS in the vadose zone.
- Field measurements of drinking water quality and groundwater quality (pH, dissolved oxygen, temperature, conductivity, oxidation-reduction potential, and turbidity) will be completed during both vertical profile sampling and sampling of the monitoring well network.
- Depth discrete groundwater samples will be submitted for 72-hour TAT PFAS analysis to inform monitoring well construction and to improve the understanding of the vertical distribution of PFAS in the groundwater system. Following drilling of the borehole, the drill casing will be left in-place to maintain an open borehole pending the analytical results. The expedited TAT for groundwater analyses is intended to minimize the time-frame that drilling equipment is left in the ground prior to monitoring well construction.
- Contemporaneous groundwater sampling for PFAS will be used to estimate the lateral and vertical extent of PFAS compounds in groundwater at OLF Coupeville.
- Time-series drawdown and recovery data from observation wells during aquifer testing will provide estimates of aquifer properties. Aquifer testing data will be incorporated the numerical groundwater flow model calibration target dataset.
- Numerical 3-dimensional groundwater flow modeling and solute transport modeling will be used to improve the understanding of past and potential future PFAS transport at OLF Coupeville.

Samples to be collected and analyzed to meet the project objectives are described in **Table 17-1**. The aquifer testing, well installation methodology, and sampling are included in **Worksheet #14**. Justification for individual sample and transducer locations is provided in **Worksheets #17 and #18**. The specific target analytes and PALs are included in **Worksheet #15**.

## Are there special data quality needs, field or laboratory, to support environmental decisions?

No, there are not special data quality needs.

## SAP Worksheet #11—Project Quality Objectives/Systematic Planning Process Statements (continued)

Table 11-1. Problem Quality Objectives/Systematic Planning Process Statements

| Problem Definition/ Objectives | Environmental Question(s) | General Investigation Approach | PQOs |
|---|---|---|---|
| PFOS and/or PFOA have been detected in on-Base groundwater monitoring wells and off-Base drinking water wells at concentrations exceeding the lifetime health advisory; however, the source of PFAS in groundwater is not known.<br>The objective of this step is to identify whether there were releases of PFAS-containing compounds to the environment from on-Base PSAs identified in the PA as requiring further investigation (Building 2709 and Facilities 1, 2, and 11). | Were there releases of PFAS-containing compounds from the on-Base PSAs identified in the PA as requiring further investigation to the environment? | As part of the Phase 1 Supplemental SI field investigation, soil borings will be advanced at three locations near Building 2709 and three locations near Facilities 1, 2, and 11 (a total of six locations, see **Figure 11-1**) to approximately 100 feet bgs. Soil samples will be collected from up to 5 depths at each of the soil borings (SO01 through SO06) and submitted to Battelle Analytical Services for full PFAS analysis. Depths targeted for analysis will be identified based on boring-specific conditions and will focus on air-water and lithologic interfaces.<br>Depth-discrete groundwater profiling will be conducted at two of the six boring locations (identified as GW01 and GW02) considered to be most likely to have impacted groundwater. These include the gravel wash pad adjacent to Building 2709 and adjacent to the overhead fill-stand at Facility 11 (**see Figure 11-1**). Up to three depth discrete groundwater samples will be collected between the water table and approximately 200 feet bgs. Groundwater samples will be submitted for PFAS analysis with a 72-hour turn-around time (TAT). The borings will be converted to groundwater monitoring wells (WI-CV-MW20 and WI-CV-MW21) with the well screen completed within the depth interval determined by the resulting soil and groundwater analytical results (**see Figure 11-2**). If there are multiple depth-discrete groundwater samples with PFAS detections within a given groundwater profile boring, additional groundwater monitoring wells may be installed during the Phase 2 Supplemental SI field effort (see **Figure 11-3**). | If PFOA, PFOS, or PFBS are detected in soil at concentrations exceeding the PALs, the associated facility will be considered a PFAS vadose zone source area).<br>If PFOA, PFOS, or PFBS concentrations in soil are less than the respective PALs at a particular boring location, the associated facility will not be considered a PFAS vadose zone source area.<br>Analytical data from depth-discrete groundwater and from groundwater monitoring well samples will be used to refine the site CSM with respect to the distribution of PFAS in groundwater at the on-Base PSAs, including potential vertical transport from vadose zone source areas to the groundwater system. |
| The results of groundwater modeling presented in the Data Summary and Groundwater Modeling Report (Navy, 2018b) indicate the presence of a groundwater mound (divide) in the intermediate and deep elevation intervals of the aquifer system centered on the north/northwestern portion of OLF Coupeville. This configuration implies radial flow from this area with PFAS in groundwater (if present) transported in the direction of groundwater flow. Given this interpretation, groundwater flow and PFAS transport from PSAs identified in the PA would be directed to the east. Based on the lack of detected PFAS compounds in drinking water samples from wells to the east of OLF Coupeville, there is uncertainty associated with the current CSM relating to the location of the groundwater divide. Additional data are needed to better understand the location of the groundwater divide and its potential impact on groundwater flow and PFAS transport. Additionally, potential PFAS transport migration pathways in the aquifer system between on-Base PSAs, on-Base groundwater monitoring wells with exceedances of the lifetime health advisory, and off-Base residential wells with exceedances of the lifetime health advisory are not well understood.<br>The objective of this step is to refine the understanding of groundwater flow directions and potential PFAS migration pathways at OLF Coupeville. | What are the groundwater flow and potential PFAS migration directions at OLF Coupeville? | The approach to refining the understanding of groundwater flow directions at/near OLF Coupeville, including identifying the location and configuration of the groundwater divide, will be to drill/install new groundwater monitoring wells and to collect synoptic groundwater level data to generate revised potentiometric surface maps and update the existing groundwater flow model. At the completion of the Phase 2 Supplemental SI field investigation activities, synoptic groundwater level data will be collected from the following sources:<br>• Existing on-Base groundwater monitoring wells.<br>• One new on-Base groundwater well will be drilled and installed in the northeast section of OLF Coupeville (WI-CV-MW17); (see **Figure 11-1**). This well will be screened in the intermediate elevation interval of the aquifer system during the Phase 1 Field Investigation.<br>• Additional groundwater monitoring wells completed within the intermediate elevation interval installed during the Phase 1 and Phase 2 Supplemental SI field investigations.<br>• Off-Base wells included in the Island County groundwater level monitoring network.<br>In addition to using the synoptic groundwater elevation data to develop potentiometric surface maps and revise the CSM of the hydrogeologic system, the data will be incorporated as calibration targets for the groundwater flow model update.<br>The approach to refining the understanding of potential PFAS migration pathways at OLF Coupeville will be to conduct depth discrete groundwater profile sampling and to install new groundwater monitoring wells. As part of the Phase 1 Supplemental SI field investigation, depth-discrete groundwater profile borings will be advanced at two locations to evaluate potential PFAS migration pathways between the on-Base PSAs identified in the PA and existing monitoring wells MW14M, MW15S/M, and MW16S/M (see **Figure 11-1**). Location GW05 will be advanced to approximately 100 feet bgs and one depth-discrete groundwater sample will be collected. Location GW06 will be advanced up to 200 feet bgs and up to 4 depth discrete groundwater samples will be collected. Groundwater samples will be submitted for PFAS analysis with a 72-hour TAT. Depth-discrete groundwater profile borings will be advanced at three on-Base and one off-Base locations between existing on-Base monitoring wells with exceedances of the lifetime health advisory and parcels south of OLF Coupeville with drinking water sample results exceeding the lifetime health advisory (see **Figure 11-1**). On-Base locations GW03, GW04, and GW07 will be advanced up to 200 feet bgs and up to four depth discrete groundwater samples will be collected at each location. | If the synoptic groundwater elevation data suggests that the interpretation of groundwater flow directions at/near OLF Coupeville is consistent with the current understanding, including the location of the groundwater divide, the information would confirm the presence of groundwater flow and potential PFAS transport from on-Base PSAs identified in the PA to the east.<br>If the synoptic groundwater elevation data suggest that the interpretation of groundwater flow directions at/near OLF Coupeville is not consistent with the current understanding, such as an alternate location of the divide, the CSM for groundwater flow and PFAS solute transport directions will be revised accordingly.<br>PFAS results from depth-discrete vertical profile and/or monitoring well sampling will be used to refine the CSM with respect to the understanding of the overall potential PFAS migration pathways in the aquifer system at OLF Coupeville.<br>If PFAS compounds are detected at concentrations exceeding the respective PALs in depth-discrete vertical profile samples and/or newly installed groundwater monitoring wells between the on-Base PSAs identified in the PA and existing monitoring wells MW14M, MW15S/M, and MW16S/M, analytical data will be interpreted as implying potential PFAS migration to the west (toward the KHW).<br>If PFAS compounds are detected at concentrations exceeding the respective PALs in depth-discrete vertical profile samples and/or newly installed groundwater monitoring wells between existing on-Base monitoring wells with exceedances of the PALs and parcels south of OLF Coupeville with drinking water sample results exceeding the lifetime health advisory, analytical data will be interpreted as implying potential migration to the south. |

## SAP Worksheet #11—Project Quality Objectives/Systematic Planning Process Statements (continued)

| Problem Definition Objectives | Environmental Question(s) | General Investigation Approach | PQOs |
|---|---|---|---|
| | | Groundwater samples will be submitted for PFAS analysis with a 72-hour TAT. All vertical profile borings will be converted to groundwater monitoring wells (WI-CV-MW22 through WI-CV-MW26) with the well screen completed within the depth interval determined by the resulting depth-discrete groundwater analytical results (see **Figure 11-2**). If there are multiple depth-discrete groundwater samples with PFAS detections within a given groundwater profile boring, additional groundwater monitoring wells may be installed during the Phase 2 Supplemental SI field effort (see **Figure 11-3**).<br>Lithologic, depth-discrete groundwater profile samples, groundwater analytical data, and elevation data from the completed monitoring wells will be evaluated in conjunction with corresponding data from existing monitoring wells. The data will be used to update the overall CSM for the site. Data also will be used to refine the groundwater flow model and will be incorporated into a PFAS solute transport model. | |
| There are limited existing data to quantify the hydraulic properties of the aquifer system at OLF Coupeville.<br>The objective of this step is to gather data to quantify the hydraulic properties of the aquifer system at OLF Coupeville. | What are the ranges of hydraulic conductivity and storage properties of the aquifer system at OLF Coupeville? | As part of the Phase 1 Supplemental SI field investigation, up to nine soil samples will be collected and submitted for analysis of geotechnical parameters. Soil sample locations will be selected in the field to provide representative horizontal coverage across OLF Coupeville to account for spatial variability in parameters. Soil sample depths will be selected in the field to cover the range of lithologies through which PFAS may be transported. Soil samples will be submitted for laboratory analysis of total porosity, dry bulk density, fraction organic carbon, and grain size analysis.<br>As part of the Phase 2 Supplemental SI field effort, an aquifer testing program will be executed following installation of new groundwater monitoring wells. The aquifer testing program will consist of up to four short-term (up to 12-hour) constant rate pumping tests. The pumping wells will be selected to provide representative spatial coverage of the aquifer system where PFAS is anticipated to be undergoing solute transport.<br>Initial values of hydraulic conductivity and aquifer storage properties will be estimated via analytical solutions. The aquifer test data (pumping rates and measured drawdown over time) also will be incorporated as transient calibration targets during groundwater flow model refinement. | Data from soil samples collected and analyzed for geotechnical parameters will be used to refine the site CSM and will be used to establish parameters for the solute transport model.<br>Data collected during aquifer tests will be used to refine the site CSM and will be incorporated into groundwater flow model refinement and recalibration. |
| Multiple groundwater and drinking water sampling events have been performed at/near OLF Coupeville beginning in 2016; however, the distribution of PFAS in groundwater exceeding the PALs is not well understood.<br>The objective of this step is to further assess the distribution of PFAS compounds exceeding the PAL in groundwater at OLF Coupeville. | What is the distribution of PFAS exceeding the PAL in groundwater at OLF Coupeville? | Following the completion of the Phase 1 Supplemental SI field investigation, a preliminary analysis of lithologic, hydraulic, and analytical data will be performed. After the preliminary data analysis, a second phase of the Supplemental SI field investigation will be performed.<br>The Phase 2 field investigation will involve installation of an estimated seven additional groundwater monitoring wells at/near OLF Coupeville. The location and construction details of the Phase 2 monitoring wells will follow the decision logic presented on **Figure 11-3**.<br>As part of the Phase 1 field investigation, a comprehensive, synoptic groundwater monitoring and sampling event will be conducted. Groundwater samples will be collected from both previously existing groundwater monitoring wells and those installed during the Supplemental SI field investigation. Analytical data from the monitoring wells as well as the depth-discrete groundwater profiling information will be used to determine the locations of Phase 2 monitoring well locations and understand the distribution of PFAS compounds in groundwater at OLF Coupeville. The data will be presented as maps of estimated PFAS exceeding the PALs by aquifer elevation interval. | If the combination of synoptic groundwater sampling results and PFAS solute transport modeling result in definitive delineation of PFAS in groundwater at OLF Coupeville, no further action is required.<br>If uncertainty in the lateral and vertical extents of PFAS in groundwater at OLF Coupeville remains following the Phase 1 and 2 Supplemental SI field efforts and solute transport modeling, additional field data collection and modeling may be performed under a future contract. |

# SAP Worksheet #11—Project Quality Objectives/ Systematic Planning Process Statements (continued)

## Where, when, and how should the data be collected and generated?

- On-Base at OLF Coupeville, Phase 1 Supplemental SI Field Investigation
    - Soil and depth-discrete groundwater sampling and monitoring well installation to investigate potential releases at PSAs
    - Depth discrete groundwater sampling and monitoring well sampling to investigate PFAS transport pathways in the aquifer system
    - On-Base at OLF Coupeville, Phase 2 Supplemental SI Field Investigation
    - Installation of on-Base groundwater monitoring wells to help assess the lateral and vertical extent of PFAS compounds in groundwater at OLF Coupeville
    - Synoptic groundwater level surveying of on-Base monitoring wells, groundwater quality sampling, and aquifer testing

Field activities will be conducted in accordance with **Worksheets #14, #17, and #18**, and the project schedule outlined in **Worksheet #16**. The data will be collected following the standard operating procedures (SOPs) presented in **Worksheet #21**.

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# SAP Worksheet #12-1—Measurement Performance Criteria Table – Field QC Samples

**Matrix:** Groundwater

**Analytical Group:** PFAS

| QC Sample | Analytical Group | Frequency | Data Quality Indicators (DQIs) | Measurement Performance Criteria |
|---|---|---|---|---|
| Matrix Spike (MS)/ Matrix Spike Duplicate (MSD) | PFAS | One per 20 samples | Accuracy/Precision | See **Worksheet #28**. |
| Field Duplicate (FD) | | One per 10 samples | Precision | Relative percent difference (RPD) less than (<) 30% |
| Field Blank | | One per site per day of sampling | Bias/Contamination | No analytes detected greater than (>) ½ limit of quantitation (LOQ) or >1/10 sample concentration, whichever is greater |
| Cooler Temperature Indicator | | One per cooler | Accuracy/Representativeness | Temperature less than or equal to (≤) 10 degrees Celsius (°C), not frozen |

# SAP Worksheet #12-2—Measurement Performance Criteria Table – Field QC Samples

**Matrix:** Soil

**Analytical Group:** PFAS

| QC Sample | Analytical Group | Frequency | DQIs | Measurement Performance Criteria |
|---|---|---|---|---|
| MS/MSD | PFAS | One per 20 samples | Accuracy/Precision | See **Worksheet #28**. |
| Equipment Rinsate Blank | | One per day of field sampling for decontaminated equipment | Bias/Contamination | No target analytes detected > ½ LOQ |
| Field Blank | | One per site | Bias/Contamination | No target analytes detected > ½ LOQ, or greater than 1/10 sample concentration, whichever is greater |
| FD | | One per 10 samples | Precision | RPD less than 30% |
| Cooler Temperature Indicator | | One per cooler | Accuracy/Representativeness | Temperature less than or equal to (≤) 10°C, not frozen |

# SAP Worksheet #13—Secondary Data Criteria and Limitations Table

| **Secondary Data** | **Data Source (originating organization, report title and date)** | **Data Generator(s) (originating organization, data types, data generation/ collection dates)** | **How Data Will Be Used** | **Limitations on Data Use** |
|---|---|---|---|---|
| Groundwater elevation and analytical data and geology data from monitoring and base supply wells within the OLF Coupeville. | Navy. 2018a. *Final Technical Memorandum, Evaluation of Per- and Polyfluoroalkyl Substances in Groundwater Outlying Landing Field Coupeville*. Naval Air Station Whidbey Island Coupeville, Washington. May 2018. | Navy. Groundwater and geology. February and March 2017. | Data will be used to assist the placement of soil borings and vertical profiling locations. | None |
| Groundwater elevation and analytical data and geology data from monitoring wells within the OLF Coupeville. | Navy. 2018b. *Aquifer Test, Groundwater Sampling, and Drinking Water Sampling Data Evaluation and Groundwater Modeling Report, Per- and Polyfluoroalkyl Substances (PFAS), Outlying Landing Field Coupeville,* Naval Air Station Whidbey Island Oak Harbor and Coupeville, Washington. September 2018. | Navy. Groundwater and geology. December 2017 and January 2018. | Data will be used to assist the placement of soil borings and vertical profiling locations. | None |
| Details regarding potential source areas of PFAS on-Base at OLF Coupeville. | Navy. 2018c. *Preliminary Assessment for Per- and Polyfluoroalkyl Substances (PFAS), Outlying Landing Field Coupeville,* Naval Air Station Whidbey Island Oak Harbor and Coupeville, Washington. November. | Navy. Geology, historical information through 2018. | Data will be used to assist the placement of soil borings and vertical profiling locations. | None |
| Well construction and historical well testing data (pumping test results and water quality testing results) from the Keystone Hill well | Robinson Noble, Inc. 2008. *Town of Coupeville Keystone Hill well Construction and Testing Report*. Tacoma, Washington. April 2008. | Robinson Noble, Inc. Well, geology, and groundwater. January through March 2008. | Data will be used as input to the aquifer modeling software and assist in the placement of observation wells, selection of well screen intervals, and design for the aquifer test. | None |
| Geohydrology data | USGS. 1982. *Preliminary Survey of Ground-water Resources for Island County, Washington*. | USGS. Geology. 1979 and 1980. | Data will be used to develop the aquifer test approach. | None |
| Well data | Island County. 2016. *Island County Hydrogeologic Database Well Search Utility Data.* Data Generated on 11/4/2016. | Island County. Well. 1963 to 2016. | Data will be used for input to the groundwater modeling software. | None |

## SAP Worksheet #13—Secondary Data Criteria and Limitations Table (continued)

| Secondary Data | Data Source (originating organization, report title and date) | Data Generator(s) (originating organization, data types, data generation/ collection dates) | How Data Will Be Used | Limitations on Data Use |
|---|---|---|---|---|
| Off-Base Drinking Water Results | CH2M. 2018. *Results of the Investigation of Per- and Polyfluoroalkyl Substances in Drinking Water -Outlying Landing Field Coupeville Naval Air Station Whidbey Island Coupeville, Washington.* September 2018. | Navy. Groundwater. November 2016 through June 2017. | Data will be used to assist in the selection of vertical profiling locations included in this inspection. | None |

## SAP Worksheet #14—Summary of Project Tasks

Applicable SOPs for project tasks outlined in this section are listed in **Worksheet #21** and provided in **Appendix B**.

### Premobilization Tasks

- Work Plan development and approval
- National Historic Preservation Act Section 106 Consultation with the State Historic Preservation Officer and/or the Advisory Council on Historic Preservation to identify possible conflicts between historic preservation objectives and the proposed activities in the clearance area shown on **Figure 11-1**
- Subcontractor procurement
  - Analytical laboratories
  - Data Validation
  - Utility locator
  - Driller
  - Surveyor
  - Investigation-derived waste (IDW) transportation and disposal contractor
- Fieldwork scheduling
- Coordination with NAS Whidbey Island for site access and IDW staging at OLF Coupeville
- Coordination with Island County for monitoring of groundwater levels in off-Base groundwater monitoring and/or drinking water wells owned and/or gauged by Island County.

### Mobilization

Mobilization for the field effort includes procurement of necessary field equipment and initial transport to the site. Equipment and supplies will be brought to the site when the CH2M field team mobilizes for field activities. Before beginning any phase of work, CH2M and its subcontractors will have field meetings to discuss the work items and worker responsibilities, and to familiarize workers with the Accident Prevention Plan and Site-Specific Health and Safety Plan.

### Utility Locating

Utilities will be cleared before beginning intrusive activities. CH2M will coordinate utility clearance. In addition, a third-party utility clearance subcontractor will be procured by CH2M to clearly mark the proposed observation well locations. Any proposed well locations within 5 feet of utility locations will be relocated to avoid impact to utilities. If a well location needs to be relocated, the field team will consult with the CH2M PM and NAVFAC Northwest RPM to establish a new well location.

### Soil Borings, Monitoring Well Installation and Development

During Phase 1 of the Supplemental SI field investigation, four on-Base soil borings (SO01 to SO04) will be advanced for vertical soil profiling (with no groundwater sampling and no monitoring well installation) to a maximum depth of 100 feet bgs.

Two on-Base soil borings (SO05 and SO06/GW01 and GW02) will be advanced for vertical soil profiling to a depth of 100 feet bgs. These boring will be continued to approximately 200 feet bgs for vertical groundwater profiling. The soil borings will be converted to monitoring wells based on vertical profiling sample analytical results.

Observation wells will be installed and developed in accordance with the SOPs listed in **Worksheet #21** and provided in **Appendix B**.

# SAP Worksheet #14—Summary of Project Tasks (continued)

One on-Base monitoring well (WI-CV-MW17) will be installed (with no soil analytical sample collection or vertical groundwater profiling during Phase 1 of the Supplemental SI field investigation.

Five additional on-Base soil borings (GW03 through GW07) will be advanced for soil and groundwater vertical profiling. The borings will be converted to monitoring wells will based on quick turnaround soil and groundwater profiling results. This vertical profiling and resulting monitoring well installation will occur during Phase 1 of the Supplemental SI field investigation.

During Phase 2 of the Supplemental SI field investigation, up to seven additional groundwater monitoring wells will be installed on-Base. The determination of well locations and construction will be determined based on a preliminary analysis of lithologic, hydraulic, and analytical data from the Phase 1 field investigation.

Groundwater monitoring wells will be installed and developed in accordance with the SOPs listed in **Worksheet #21** and provided in **Appendix B**.

### Soil Logging

All soil borings will be logged for lithology and field screened by a photoionization detector (PID) at every interval in accordance with the SOPs listed in **Worksheet #21** and provided in **Appendix B**.

### Surveying

The newly installed observation wells and the will be surveyed by a Washington-licensed surveyor in accordance with the SOPs listed in **Worksheet #21** and provided in **Appendix B**.

### Sampling Tasks

Applicable field notes and forms should be filled out completely each day.

- Soil Sampling
  - Soil sampling will be completed in accordance with the SOPs listed in **Worksheet #21** and provided in **Appendix B**. Soil sampling will occur during Phase 1 of the Supplemental SI field investigation.
  - Up to five soil samples will be collected from soil borings and select vertical profiling locations: SO01, SO02, SO03, SO04, SO05/GW01, and SO06/GW02.
  - Soil samples will be sent to Battelle Analytical Services for PFAS analysis with a 72-hour TAT.
- Groundwater Vertical Profile Sampling
  - Depth-discrete groundwater vertical profile sampling will be completed as part of Phase 1 (locations GW-01 through GW07) of the Supplemental SI field investigation in accordance with the SOPs listed in **Worksheet #21** and provided in **Appendix B**.
  - An estimated three groundwater grab samples will be collected from GW01 and GW02.
  - An estimated four groundwater grab samples will be collected from each of GW03, GW04, GW06, and GW07.
  - An estimated one groundwater grab sample will be collected from GW05
  - Up to four groundwater grab samples will be collected from GW03, GW04, GW06, and GW07. One groundwater grab sample will be collected from GW05.
  - Groundwater grab samples will be sent to Battelle Analytical Services for PFAS analysis with a 72-hour TAT.

## SAP Worksheet #14—Summary of Project Tasks (continued)

- Monitoring Well Sampling
  - Groundwater sampling will be completed at all new and existing monitoring wells in accordance with the SOPs listed in **Worksheet #21** and provided in **Appendix B**. Monitoring well sampling will occur during Phases 1 and 2 of the Supplemental SI field investigation.
  - Groundwater samples will be sent to Battelle Analytical Services for PFAS analysis.

**Synoptic Water Level Survey**

- Manual groundwater levels will be measured at all new and existing groundwater monitoring wells and the Island County water level gauging network (as data received from Island County), during the Phase 1 and Phase 2 Supplemental SI field investigation in accordance with the SOPs listed in **Worksheet #21** and provided in **Appendix B.**

**Aquifer Testing**

- Up to four single well aquifer tests will be conducted at on-Base monitoring wells during the Phase 2 Supplemental SI field investigation in accordance with the SOPs listed in **Worksheet #21** and provided in **Appendix B.** Up to 10 observation wells will be instrumented with data logging pressure transducers during each aquifer test.

**Decontamination**

- All drilling equipment used during well installation, and re-usable sampling equipment will be decontaminated immediately after each use in accordance with applicable SOPs referenced in **Worksheet #21** and provided in **Appendix B**. Sensitive instrumentation such as equipment used to collect water quality parameters will be decontaminated in accordance with the equipment manufacturers' guidelines.

**IDW Handling**

- IDW will be managed in accordance with the Interim Per- and Polyfluoralkyl Substances (PFAS) Site Guidance for NAVFAC Remedial Project Managers (RPMs)/September 2017 Update (Navy, 2017a) and in accordance with SOPs listed in **Worksheet #21** and provided in **Appendix B**.

**Analyses and Testing Tasks**

- Battelle Analytical Services will process and prepare soil samples for analysis and analyze samples in accordance with **Worksheet #18** and **#19**.
- Soil samples will be analyzed for PFAS by Battelle Analytical Services using LC/MS/MS in accordance with **Worksheets #18** and **#19**.
- Groundwater samples will be submitted to Battelle Analytical Services for analysis of 18 PFAS compounds via analytical method PFAS by LC/MS/MS in accordance with **Worksheets #18** and **#19**.

**Modeling**

Data collected during the Phase 1 and Phase 2 SI field investigations will be used to update the site CSM and refine the existing groundwater flow model. Model refinement will include updating the model parameterization, re-evaluation of boundary conditions, re-calibration to steady-state conditions, and re-calibration to transient conditions observed during the recently completed aquifer testing.

A solute transport model will be developed and calibrated during the Phase 3 Supplemental SI, which will be conducted when the appropriate off-Base real estate agreements are approved and described in a future Addendum to this SAP. The modeling effort will assume that HYDRUS software or similar will be used to conceptualize the contaminant transport from the soil source areas to shallow groundwater. The solute mass flux values will be used as contaminant flux boundary conditions for the solute transport model. A solute transport

## SAP Worksheet #14—Summary of Project Tasks (continued)

model for each of six PFAS compounds (perfluorohexane sulfonate [PFHxS], perfluoroheptanoic acid [PFHpA], perfluorononanoic acid [PFNA], PFBS, PFOA, and PFOS) will be developed to evaluate up to three future scenarios (such as changes to pumping rates or distributions).

### QC Tasks

- Implement SOPs for field and laboratory activities being performed.
- QC samples are described on **Worksheet #20**.

### Secondary Data

- See Worksheet #13.

### DV, Review, and Management Tasks

- See **Worksheets #34** through **#36** for discussion of data management procedures.

### Documentation and Reporting

- A summary of field activities as well as a data evaluation will be documented in a Supplemental SI Report and submitted to the NAVFAC Northwest RPM for review and approval.

### Assessment and Audit Tasks

- Worksheets #31 and #32.

### Demobilization

Full demobilization will occur when the project is completed, and appropriate QA/QC checks have been performed. Personnel no longer needed during the course of field operations may be demobilized prior to the final project completion date. The following will occur prior to demobilization:

- Chain-of-custody records will be reviewed to verify that all samples were collected as planned and submitted for appropriate analyses.
- Restoration of the site to an appropriate level will be verified by the CH2M FTL.
- All equipment will be inspected, packaged, and shipped to the appropriate location.

# SAP Worksheet #15-1—Reference Limits and Evaluation Tables

**Matrix:** Groundwater

**Analytical Group:** PFAS – PFAS by LC/MS/MS Compliant with QSM 5.1.1 Table B-15[1]

| Analyte | Chemical Abstract Service Number | USEPA Lifetime Health Advisory (µg/L) | RSLs Tap water HQ = 0.1 (May 2019) (µg/L) | PQL Goal[2] (µg/L) | Laboratory Limits (µg/L) | | | LCS and MS/MSD Recovery Limits and RPD[3] (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | LOQs (µg/L) | LODs (µg/L) | DLs (µg/L) | LCL | UCL | RPD |
| Perfluorooctanoic acid (PFOA) | 335-67-1 | 0.07 | 0.04 | 0.005 | 0.005 | 0.0005 | 0.00018 | 49 | 141 | 30 |
| Perfluorooctane Sulfonate (PFOS) | 1763-23-1 | 0.07 | 0.04 | 0.005 | 0.005 | 0.0005 | 0.00019 | 40 | 144 | 30 |
| Perfluorobutanesulfonic acid (PFBS) | 375-73-5 | -- | 40 | 0.005 | 0.005 | 0.0005 | 0.00013 | 56 | 134 | 30 |
| Perfluorohexanoic acid (PFHxA) | 307-24-4 | -- | -- | 0.005 | 0.005 | 0.0005 | 0.00019 | 51 | 137 | 30 |
| Perfluoroheptanoic acid (PFHpA) | 375-85-9 | -- | -- | 0.005 | 0.005 | 0.0005 | 0.00016 | 48 | 136 | 30 |
| Perfluorohexane sulfonate (PFHxS) | 355-46-4 | -- | -- | 0.005 | 0.005 | 0.0004 | 0.00011 | 52 | 128 | 30 |
| Perfluorononanoic acid (PFNA) | 375-95-1 | -- | -- | 0.005 | 0.005 | 0.001 | 0.00026 | 58 | 122 | 30 |
| Perfluorodecanoic acid (PFDA) | 335-76-2 | -- | -- | 0.005 | 0.005 | 0.0005 | 0.00016 | 59 | 135 | 30 |
| Perfluoroundecanoic acid (PFUnA) | 2058-94-8 | -- | -- | 0.005 | 0.005 | 0.001 | 0.00029 | 64 | 134 | 30 |
| Perfluorododecanoic acid (PFDoA) | 307-55-1 | -- | -- | 0.005 | 0.005 | 0.0005 | 0.00018 | 75 | 131 | 30 |
| Perfluorotridecanoic acid (PFTrDA) | 72629-94-8 | -- | -- | 0.005 | 0.005 | 0.0005 | 0.00015 | 42 | 148 | 30 |
| Perfluorotetradecanoic acid (PFTeDA) | 376-06-7 | -- | -- | 0.005 | 0.005 | 0.001 | 0.00025 | 42 | 158 | 30 |

# SAP Worksheet #15-1—Reference Limits and Evaluation Tables (continued)

**Matrix:** Groundwater

**Analytical Group:** PFAS – PFAS by LC/MS/MS Compliant with QSM 5.1.1 Table B-15[1]

| Analyte | Chemical Abstract Service Number | USEPA Lifetime Health Advisory (µg/L) | RSLs Tap water HQ = 0.1 (May 2019) (µg/L) | PQL Goal[2] (µg/L) | Laboratory Limits (µg/L) | | | LCS and MS/MSD Recovery Limits and RPD[3] (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | LOQs (µg/L) | LODs (µg/L) | DLs (µg/L) | LCL | UCL | RPD |
| N-Ethylperfluoro-1-octanesulfonamidoacetic acid (NEtFOSAA) | 2991-50-6 | -- | -- | 0.005 | 0.005 | 0.001 | 0.00049 | 51 | 131 | 30 |
| N-Methylperfluoro-1-octanesulfonamidoacetic acid (NMeFOSAA) | 2355-31-9 | -- | -- | 0.005 | 0.005 | 0.002 | 0.00056 | 50 | 146 | 30 |
| Hexafluoropropylene oxide dimer acid (HFPO-DA) | 13252-13-6 | -- | -- | 0.005 | 0.005 | 0.0004 | 0.0002 | 70 | 130 | 30 |
| 4,8-dioxa-3H-perfluoronanoic acid (ADONA) | 919005-14-4 | -- | -- | 0.005 | 0.005 | 0.0004 | 0.00018 | 70 | 130 | 30 |
| 9-chlorohexadecafluoro-3-oxanone-1-sulfonic acid (9Cl-PF3ONS) | 763051-92-9 | -- | -- | 0.005 | 0.005 | 0.0004 | 0.00018 | 70 | 130 | 30 |
| 11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (11Cl-PF3OUdS) | 756426-58-1 | -- | -- | 0.005 | 0.005 | 0.0004 | 0.0001 | 70 | 130 | 30 |
| PFOA + PFOS (calculated)[4] | -- | 0.07 | -- | -- | -- | -- | -- | -- | -- | -- |

Notes:

[1] Analytical method is compliant with QSM v. 5.1.1 Table B-15 or the most recent version of the QSM for which Battelle has DoD ELAP certification.

[2] The project quantitation limit (PQL) goal is equal to the laboratory LOQ.

[3] Accuracy and precision limits follow laboratory in-house limits per QSM v. 5.1.1, Table B-15. In house limits, have been established for all analytes with exception to HFPO-DA, ADONA, 9CL-PF3ONS, and 11Cl-PFOUdS. Default limits for these analytes of 70-130% have been set based on the control limits established in Method 537.1.

[4] The USEPA lifetime health advisory of 0.07 µg/L is less conservative than the tap water RSLs presented in the table.

Limits are verified on a quarterly basis per DoD QSM and may be subject to change. Any changes to these limits which impact the project SAP objectives, must be approved by the NAVFAC RPM and NAVFAC LANT project chemist in advance of sample testing.

DL = detection limit
LCL = lower confidence limit
LCS = laboratory control sample
LOD = limit of detection
UCL = upper confidence limit

# SAP Worksheet #15-2—Reference Limits and Evaluation Table

**Matrix:** Soil

**Analytical Group:** PFAS by LCMSMS Compliant with QSM 5.1.1 Table B-15[1]

| Analyte | Chemical Abstract Service (CAS) Number | Calculated Derived Residential Soil HQ = 0.1 from the USEPA RSL Calculator, May 2019 (μg/kg)[2] | Calculated Derived Soil to Groundwater from the USEPA RSL Calculator HQ = 0.1 (May 2019) (μg/kg)[3] | PQL Goal (μg/kg)[5] | Laboratory Limits (μg/L)[4] | | | LCS and MS/MSD Recovery Limits and RPD (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | LOQs (μg/kg) | LODs (μg/kg) | DLs (μg/kg) | LCL[3] | UCL[3] | RPD |
| Perfluorooctane Sulfonate (PFOS) | 1763-23-1 | 126 | 0.0378 | 5.0 | 5.0 | 1.0 | 0.27 | 50 | 130 | 30 |
| Perfluorooctanoic acid (PFOA) | 335-67-1 | 126 | 0.0172 | 5.0 | 5.0 | 1.0 | 0.5 | 56 | 136 | 30 |
| Perfluorobutane sulfonate (PFBS) | 375-73-5 | 126,000 | 13 | 5.0 | 5.0 | 1.0 | 0.36 | 57 | 145 | 30 |
| Perfluorohexanoic acid (PFHxA) | 307-24-4 | -- | -- | 5.0 | 5.0 | 1.0 | 0.33 | 45 | 135 | 30 |
| Perfluoroheptanoic acid (PFHpA) | 375-85-9 | -- | -- | 5.0 | 5.0 | 1.0 | 0.44 | 60 | 128 | 30 |
| Perfluorohexane sulfonate (PFHxS) | 355-46-4 | -- | -- | 5.0 | 5.0 | 0.5 | 0.22 | 52 | 132 | 30 |
| Perfluorononanoic acid (PFNA) | 375-95-1 | -- | -- | 5.0 | 5.0 | 1.0 | 0.43 | 54 | 130 | 30 |
| Perfluorodecanoic acid (PFDA) | 335-76-2 | -- | -- | 5.0 | 5.0 | 1.0 | 0.27 | 55 | 141 | 30 |
| Perfluoroundecanoic acid (PFUnA) | 2058-94-8 | -- | -- | 5.0 | 5.0 | 1.0 | 0.44 | 57 | 137 | 30 |
| Perfluorododecanoic acid (PFDoA) | 307-55-1 | -- | -- | 5.0 | 5.0 | 0.5 | 0.24 | 62 | 134 | 30 |
| Perfluorotridecanoic acid (PFTrDA) | 72629-94-8 | -- | -- | 5.0 | 5.0 | 1.0 | 0.28 | 51 | 127 | 30 |
| Perfluorotetradecanoic acid (PFTeDA) | 376-06-7 | -- | -- | 5.0 | 5.0 | 2.0 | 0.63 | 34 | 162 | 30 |
| N-Ethylperfluoro-1-octancesulfonamidoacetic acid (NEtFOSAA) | 2991-50-6 | -- | -- | 5.0 | 5.0 | 2.0 | 0.57 | 54 | 124 | 30 |
| N-Methylperfluoro-1-octanesulfonamidoacetic acid (NMeFOSAA) | 2355-31-9 | -- | -- | 5.0 | 5.0 | 2.5 | 1.12 | 52 | 146 | 30 |

# SAP Worksheet #15-2—Reference Limits and Evaluation Table (continued)

**Matrix:** Soil

**Analytical Group:** PFAS by LCMSMS Compliant with QSM 5.1.1 Table B-15[1]

| Analyte | Chemical Abstract Service (CAS) Number | Calculated Derived Residential Soil HQ = 0.1 from the USEPA RSL Calculator, May 2019 (µg/kg)[2] | Calculated Derived Soil to Groundwater from the USEPA RSL Calculator HQ = 0.1 (May 2019) (µg/kg)[3] | PQL Goal (µg/kg)[5] | Laboratory Limits (µg/L)[4] | | | LCS and MS/MSD Recovery Limits and RPD (%)[6] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | LOQs (µg/kg) | LODs (µg/kg) | DLs (µg/kg) | LCL | UCL | RPD |
| Hexafluoropropylene oxide dimer acid (HFPO-DA) | 13252-13-6 | -- | -- | 5.0 | 5.0 | 2.0 | 0.57 | 70 | 130 | 30 |
| 4,8-dioxa-3H-perfluorononanoic acid (ADONA) | 919005-14-4 | -- | -- | 5.0 | 5.0 | 1.0 | 0.32 | 70 | 130 | 30 |
| 9-chlorohexadecafluoro-3-oxanone-1-sulfonic acid (9Cl-PF3ONS) | 763051-92-9 | -- | -- | 5.0 | 5.0 | 1.0 | 0.4 | 70 | 130 | 30 |
| 11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (11Cl-PF3OUdS) | 756426-58-1 | -- | -- | 5.0 | 5.0 | 1.0 | 0.45 | 70 | 130 | 30 |

Notes:

[1] Analytical method is compliant with QSM 5.1.1 Table B-15 or the most recent version of the QSM for which Battelle has DoD ELAP certification.

[2] The Project Screening Levels were generated using the USEPA online RSL calculator for Residential Soil, HQ = 0.1 on June 17, 2019. Levels are subject to change. If levels change during the duration of the project, appropriate levels to use will be approved by the NAVFAC RPM and NAVFAC QAO with the project team for use with the final data and/or report.

[3] The Project Screening Levels were generated using the USEPA online RSL calculator for Soil to groundwater, HQ = 0.1 on June 17, 2019. Levels are subject to change. If levels change during the duration of the project, appropriate levels to use will be approved by the NAVFAC RPM and NAVFAC QAO with the project team for use with the final data and/or report.

[4] Results for nonaqueous samples are reported on a dry-weight basis.

[5] The PQLs are listed as the laboratory LOQ. Laboratory limits for PFOS and PFOA are not sensitive enough to meet Soil to Groundwater RSLs. Non-detected values will not be considered as exceedances. Data evaluation will be based on reported concentrations above the DL. In cases where the Soil to Groundwater RSLs is less than the DL and the results are nondetect, results will be discussed in the uncertainty analysis.

[6] Accuracy and precision limits follow laboratory in-house limits per QSM v. 5.1.1, Table B-15. In house limits, have been established for all analytes with exception to HFPO-DA, ADONA, 9CL-PF3ONS, and 11Cl-PFOUdS. Default limits for these analytes of 70-130% have been set based on the control limits established in Method 537.1.

Limits are verified on a quarterly basis per DoD QSM and may be subject to change. Any changes to these limits which impact the project SAP objectives, must be approved by the NAVFAC RPM and NAVFAC LANT Project Chemist in advance of sample testing.

# SAP Worksheet #15-3—Reference Limits and Evaluation Table

**Matrix:** Soil

**Analytical Group**: Geotechnical Parameters

| **Analyte**[1] | **Method** | **CAS No.** [2] | **Units** |
|---|---|---|---|
| Gravel (%) | ASTM D422 | GRAVEL | % |
| Sand (%) | ASTM D422 | 14808-60-7 | % |
| Coarse Sand (%) | ASTM D422 | COARSE SAND | % |
| Very Coarse Sand (%) | ASTM D422 | VERY COARSE SAND | % |
| Medium Sand (%) | ASTM D422 | MEDIUM SAND | % |
| Fine Sand (%) | ASTM D422 | FINE SAND | % |
| Very Fine Sand (%) | ASTM D422 | VERY FINE SAND | % |
| Silt (%) | ASTM D422 | SILT | % |
| Clay (%) | ASTM D422 | CLAY | % |
| Dry Bulk Density | ASTM D2937 | DENSITY | grams per cubic meter |
| Total Porosity | API RP40 | TBD | % |
| Fractional Organic Carbon | Walkley Black | %FOC | % |

Notes:

[1] There are no action limits, laboratory reporting limits, or LCS recovery limits for grain size analytes.

[2] In some instances, a contractor-specific identifier is used.

API = American Petroleum Institute

ASTM = ASTM International

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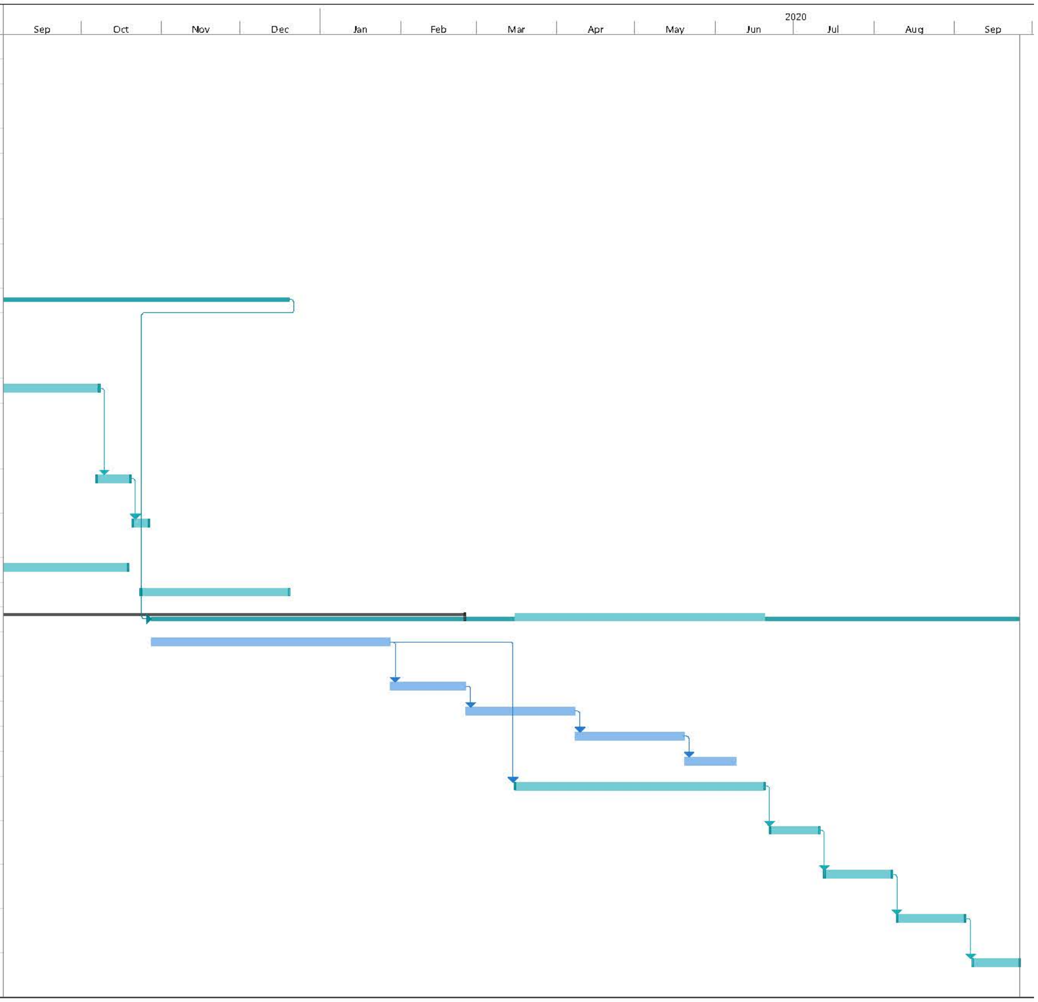
# SAP Worksheet #16—Project Schedule/Timeline Table

| ID | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 1 | Contract Award | 1 day | Wed 9/19/18 | Wed 9/19/18 |
| 2 | **Work Plans** | **140 days** | **Tue 10/23/18** | **Fri 5/10/19** |
| 3 | Prepare Internal Draft Work Plans | 48 days | Tue 10/23/18 | Wed 1/2/19 |
| 4 | Navy Review | 39 days | Thu 1/3/19 | Thu 2/28/19 |
| 5 | Prepare Draft Work Plans, Navy Review of RTCs, Work Plan Revisions | 62 days | Wed 3/13/19 | Fri 5/31/19 |
| 6 | Stakeholder Review | 20 days | Wed 6/19/19 | Fri 7/12/19 |
| 7 | Stakeholder RTCs, Prepare Final Work Plans | 5 days | Mon 7/15/19 | Fri 7/19/19 |
| 8 | **Field Work** | **87 days** | **Thu 4/18/19** | **Fri 8/2/19** |
| 9 | Event 1: Investigation Phase 1 - Soil sampling, groundwater vertical profiling, Survey | 27 days | Mon 7/22/19 | Tue 8/27/19 |
| 10 | Data Evaluation | 31 days | Sun 8/25/19 | Mon 10/7/19 |
| 11 | Event 2 - Investigation Phase 1 - MW sampling - existing wells (30) and new wells (8) | 10 days | Mon 8/19/19 | Fri 8/30/19 |
| 12 | Event 3 - Investigation Phase 2 - Perm. MW Installation, Survey | 10 days | Mon 10/7/19 | Sat 10/19/19 |
| 13 | Survey, Aquifer Testing, MW sampling - new wells (7) | 6 days | Mon 10/21/19 | Sat 10/26/19 |
| 14 | Event 4 - IDW Management | 39 days | Fri 8/23/19 | Fri 10/18/19 |
| 15 | Event 5 - IDW Management | 39 days | Thu 10/24/19 | Thu 12/19/19 |
| 16 | **Site Inspection Report** | **160 days** | **Mon 7/8/19** | **Tue 2/25/20** |
| 17 | Internal Draft Report and Report Addendum (Internal Draft) | 60 days | Mon 10/28/19 | Mon 1/27/20 |
| 18 | Navy Review | 20 days | Tue 1/28/20 | Tue 2/25/20 |
| 19 | Draft Report | 30 days | Wed 2/26/20 | Tue 4/7/20 |
| 20 | Stakeholder Review | 30 days | Wed 4/8/20 | Tue 5/19/20 |
| 21 | Final Reports | 14 days | Wed 5/20/20 | Mon 6/8/20 |
| 22 | Model - Report Addendum - Internal Draft | 70 days | Mon 3/16/20 | Fri 6/19/20 |
| 23 | Model - Report Addendum - Navy Review | 15 days | Mon 6/22/20 | Fri 7/10/20 |
| 24 | Model - Report Addendum - Draft Report | 20 days | Mon 7/13/20 | Fri 8/7/20 |
| 25 | Model - Report Addendum - Stakeholder Review | 20 days | Mon 8/10/20 | Fri 9/4/20 |
| 26 | Model - Report Addendum - Final Report | 14 days | Tue 9/8/20 | Fri 9/25/20 |



Project: CTO4405_OLF Coupevi
Date: Wed 6/19/19

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Task | ▬ | Project Summary | ┌─┐ | Manual Task | ▬ | Start-only | [ | Deadline | ⬇ |
| Split | ┈┈┈ | Inactive Task | ▭ | Duration-only | ▬ | Finish-only | ] | Progress | ─ |
| Milestone | ◆ | Inactive Milestone | ◇ | Manual Summary Rollup | ─ | External Tasks | ▬ | Manual Progress | ─ |
| Summary | ┌─┐ | Inactive Summary | ┌─┐ | Manual Summary | ┌─┐ | External Milestone | ◆ | | |

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# SAP Worksheet #17—Sampling Design and Rationale

The objectives of the investigation described in this worksheet are listed in **Worksheet #11**. Media to be investigated for this SAP is limited to soil collected from on-Base soil borings, groundwater from on-Base and off-Base monitoring wells. The sampling strategy and rationale are detailed in **Table 17-1.**

Table 17-1. Sampling Strategy Table – Phase 1 Supplemental SI

| Location | Matrix | Depth of Samples (feet bgs) | Analysis | Laboratory Method | Number of Samples | Sampling Strategy | Rationale |
|---|---|---|---|---|---|---|---|
| WI-CV-SO01 | Soil | TBD[1] (between the ground surface and the water table) | PFAS | LC/MS/MS Compliant with QSM v. 5.1.1, Table B-15[2] / SOP 5-369-06 | An estimated 5[1] | Soil Samples will be collected for laboratory analysis of PFAS from the soil borings for on-Base PSAs. | Samples will determine the presence of PFAS in soil at on-Base PSAs identified in the PA as requiring further investigation (Building 2709 and Facility 1, 2, and 11). Depths targeted for analysis will be identified based on boring-specific conditions and will focus on air-water and lithologic interfaces. Data will be used to determine if the sampling location (and on-Base PSA) is considered a PFAS vadose zone source area. |
| WI-CV-SO02 | | | | | | | |
| WI-CV-SO03 | | | | | | | |
| WI-CV-SO04 | | | | | | | |
| WI-CV-MW20 (SO05) | | | | | | Soil Samples will be collected for laboratory analysis of PFAS from the soil borings at source area groundwater profiling locations. | |
| WI-CV-MW21 (SO06) | | | | | | | |
| WI-CV-SO01/ WI-CV-SO02/ WI-CV-SO03/ WI-CV-SO04/ WI-CV-MW20 (SO05)/ WI-CV-MW21 (SO06) | Soil | TBD[1] (between the ground surface and the water table) | Total porosity | API RP40 | An estimated 9[1] | Soil samples will be collected for laboratory analysis of geotechnical parameters (total porosity, dry bulk density, fraction organic carbon, and grain size analysis). | Sample locations will be selected in the field to provide representative horizontal coverage across OLF Coupeville to account for spatial variability in geotechnical parameters. Soil sample depths will be selected in the field to cover the range of lithologies through which PFAS may be transported. The results will be used to refine the site CSM and will be used to parameterize the solute transport model. |
| | | | Dry bulk density | ASTM D2937 | | | |
| | | | Fraction organic carbon | Walkley Black | | | |
| | | | Grain size analysis | ASTM D422 | | | |
| GW01/ WI-CV-MW20 (Depth Interval TBD) | GW | TBD (between the water table and approximately 200 feet bgs) [1] | PFAS | LC/MS/MS Compliant with QSM v. 5.1.1, Table B-15[2] / SOP 5-369-06[1] | An estimated 3[1] | Groundwater will be collected as vertical profiling grab samples for in-field water quality parameters and laboratory analysis of PFAS via a drive-point sampling device. Groundwater samples will be submitted for PFAS analysis with a 72-hour turn-around time to allow for determination of monitoring well settings. | Depth-discrete groundwater profiling will be conducted at boring locations considered to be most likely to have impacted groundwater: the gravel wash pad adjacent to Building 2709 and adjacent to the overhead fill-stand at Facility 11. Groundwater sample depths between the water table and approximately 200 feet bgs will be determined in the field based on lithology and aquifer intervals observed. Data will be used to determine if the sampling location (and on-Base PSA) is considered a PFAS vadose zone source area. |
| GW02/ WI-CV-MW21 (Depth Interval TBD) | | | | | An estimated 3[1] | | |
| GW03/ WI-CV-MW22 (Depth Interval TBD) | | | | | An estimated 4[1] | | Depth-discrete groundwater profiling with PFAS sampling will be conducted at locations in the area between the on-Base groundwater monitoring wells with PFOA and/or PFOS concentrations exceeding the lifetime health advisory and off-Base drinking water wells south of OLF Coupeville with exceedances of the lifetime health advisory. Groundwater sample depths between the water table and approximately 200 feet bgs will be determined in the field based on lithology and aquifer intervals observed. Data will be used to determine installation settings for a permanent groundwater monitoring well and refine the CSM with respect to the understanding of potential PFAS migration pathways in the aquifer system at OLF Coupeville. |
| GW04/ WI-CV-MW23 (Depth Interval TBD) | | | | | | | |
| GW05/ WI-CV-MW24 (Depth Interval TBD) | | TBD (between the water table and approximately 100 feet bgs) [1] | | | 1 | | Depth-discrete groundwater profiling with PFAS sampling will be conducted at locations in the area between the PSAs identified in the Preliminary Assessment and on-Base groundwater monitoring wells with PFOA and/or PFOS concentrations exceeding the lifetime health advisory east of the Keystone Hill Well (KHW). Groundwater sample depths between the water table and approximately 200 feet bgs will be determined in the field based on lithology and aquifer intervals observed. One sample, at a depth up to 100 feet bgs, will be collected at WI-CV-MW24. Data will be used to determine installation settings for a permanent groundwater monitoring well and refine the CSM with respect to the understanding of potential PFAS migration pathways in the aquifer system at OLF Coupeville. |
| GW06/ WI-CV-MW25 (Depth Interval TBD) | | TBD (between the water table and approximately 200 feet bgs) [1] | | | An estimated 4[1] | | |
| GW07/ WI-CV-MW26 (Depth Interval TBD) | | | | | | | Depth-discrete groundwater profiling with PFAS sampling will be conducted at locations in the area between the on-Base groundwater monitoring wells with PFOA and/or PFOS concentrations exceeding the lifetime health advisory and off-base drinking water wells south of OLF Coupeville with exceedances of the lifetime health advisory. Groundwater sample depths between the water table and approximately 200 feet bgs will be determined in the field based on lithology and aquifer intervals observed. Data will be used to determine installation settings for a permanent groundwater monitoring well and refine the CSM with respect to the understanding of potential PFAS migration pathways in the aquifer system at OLF Coupeville. |
| WI-CV-MW01M | | Surface Port – Well screened from 148 to 158 feet bgs | | | | Groundwater will be collected for in-field water quality parameters and laboratory analysis of PFAS from a sample port at the wellheads of the monitoring wells. | Groundwater analytical data from existing on-Base wells at OLF Coupeville will be used to further understand the distribution of PFAS compounds in groundwater at OLF Coupeville. |

## SAP Worksheet #17—Sampling Design and Rationale (continued)

| Location | Matrix | Depth of Samples (feet bgs) | Analysis | Laboratory Method | Number of Samples | Sampling Strategy | Rationale |
|---|---|---|---|---|---|---|---|
| WI-CV-MW01D | GW | Surface Port – Well screened from 202 to 212 feet bgs | PFAS | LC/MS/MS Compliant with QSM v. 5.1.1, Table B-15[1] / SOP 5-369-06[2] | 1 | Groundwater will be collected for in-field water quality parameters and laboratory analysis of PFAS from a sample port at the wellheads of the monitoring wells. | Groundwater analytical data from existing on-Base wells at OLF Coupeville will be used to further understand the distribution of PFAS compounds in groundwater at OLF Coupeville. |
| WI-CV-MW02S | | Surface Port – Well screened from 91.5 to 101.5 feet bgs | | | 1 | | |
| WI-CV-MW02M | | Surface Port – Well screened from 153 to 163 feet bgs | | | 1 | | |
| WI-CV-MW03M | | Surface Port – Well screened from 145 to 155 feet bgs | | | 1 | | |
| WI-CV-MW03D | | Surface Port – Well screened from 222 to 232 feet bgs | | | 1 | | |
| WI-CV-MW04S | | Surface Port – Well screened from 111.6 to 121.6 feet bgs | | | 1 | | |
| WI-CV-MW04M | | Surface Port – Well screened from 148.7 to 158.7 feet bgs | | | 1 | | |
| WI-CV-MW05S | | Surface Port – Well screened from 114 to 124 feet bgs | | | 1 | | |
| WI-CV-MW05M | | Surface Port – Well screened from 160 to 170 feet bgs | | | 1 | | |
| WI-CV-MW06S | | Surface Port – Well screened from 130 to 140 feet bgs | | | 1 | | |
| WI-CV-MW06M | | Surface Port – Well screened from 174 to 184 feet bgs | | | 1 | | |
| WI-CV-MW07S | | Surface Port – Well screened from 129.5 to 139.5 feet bgs | | | 1 | | |
| WI-CV-MW07M | | Surface Port – Well screened from 183 to 193 feet bgs | | | 1 | | |
| WI-CV-MW08S | | Surface Port – Well screened from 121 to 131 feet bgs | | | 1 | | |
| WI-CV-MW08M | | Surface Port – Well screened from 150 to 160 feet bgs | | | 1 | | |
| WI-CV-MW09S | | Surface Port – Well screened from 96 to 106 feet bgs | | | 1 | | |
| WI-CV-MW09M | | Surface Port – Well screened from 182 to 192 feet bgs | | | 1 | | |
| WI-CV-MW10M | | Surface Port – Well screened from 144 to 154 feet bgs | | | 1 | | |
| WI-CV-MW10D | | Surface Port – Well screened from 191 to 201 feet bgs | | | 1 | | |

## SAP Worksheet #17—Sampling Design and Rationale (continued)

| Location | Matrix | Depth of Samples (feet bgs) | Analysis | Laboratory Method | Number of Samples | Sampling Strategy | Rationale |
|---|---|---|---|---|---|---|---|
| WI-CV-MW11S | GW | Surface Port – Well screened from 130 to 140 feet bgs | PFAS | LC/MS/MS Compliant with QSM v. 5.1.1, Table B-15[1] / SOP 5-369-06[2] | 1 | Groundwater will be collected for in-field water quality parameters and laboratory analysis of PFAS from a sample port at the wellheads of the monitoring wells. | Groundwater analytical data from existing on-Base wells at OLF Coupeville will be used to further understand the distribution of PFAS compounds in groundwater at OLF Coupeville. |
| WI-CV-MW11M | | Surface Port – Well screened from 155 to 165 feet bgs | | | 1 | | |
| WI-CV-MW12S | | Surface Port – Well screened from 97 to 107 feet bgs | | | 1 | | |
| WI-CV-MW12D | | Surface Port – Well screened from 183 to 193 feet bgs | | | 1 | | |
| WI-CV-MW13S | | Surface Port – Well screened from 105 to 115 feet bgs | | | 1 | | |
| WI-CV-MW13M | | Surface Port – Well screened from 173 to 183 feet bgs | | | 1 | | |
| WI-CV-MW14M | | Surface Port – Well screened from 161 to 171 feet bgs | | | 1 | | |
| WI-CV-MW15S | | Surface Port – Well screened from 132 to 142 feet bgs | | | 1 | | |
| WI-CV-MW15M | | Surface Port – Well screened from 164 to 174 feet bgs | | | 1 | | |
| WI-CV-MW16S | | Surface Port – Well screened from 130 to 140 feet bgs | | | 1 | | |
| WI-CV-MW16M | | Surface Port – Well screened from 165 to 183 feet bgs | | | 1 | | |
| WI-CV-MW17M | | Surface Port – Well expected to be constructed with 10 feet of screen located in intermediate aquifer zone | | | 1 | | Groundwater analytical data from the newly installed on-Base monitoring well located in the northeast portion of OLF Coupeville will be used to further understand the distribution of PFAS compounds in groundwater at OLF Coupeville. |
| WI-CV-MW20 (Depth Interval TBD) | | Surface Port – Well constructions settings TBD | | | 1 | | Groundwater analytical data from newly installed on-Base monitoring wells in the PSAs will be used to further understand the distribution of PFAS compounds in groundwater at OLF Coupeville. |
| WI-CV-MW21 (Depth Interval TBD) | | | | | 1 | | |
| WI-CV-MW22 (Depth Interval TBD) | | | | | 1 | | Groundwater analytical data from newly installed on-Base monitoring wells between on-Base groundwater monitoring wells with PFOA and/or PFOS concentrations exceeding the lifetime health advisory and off-Base drinking water wells south of Coupeville with exceedances of the lifetime health advisory will be used to further understand the distribution of PFAS compounds in groundwater at OLF Coupeville. |
| WI-CV-MW23 (Depth Interval TBD) | | | | | 1 | | |
| WI-CV-MW24 (Depth Interval TBD) | | | | | 1 | | Groundwater analytical data from newly installed on-Base monitoring wells between PSAs and wells with PFOA and/or PFOS concentrations exceeding the lifetime health advisory east of the KHW will be used to further understand the distribution of PFAS compounds in groundwater at OLF Coupeville. |
| WI-CV-MW25 (Depth Interval TBD) | | | | | 1 | | |
| WI-CV-MW26 (Depth Interval TBD) | | | | | 1 | | Groundwater analytical data from newly installed on-Base monitoring wells between on-Base groundwater monitoring wells with PFOA and/or PFOS concentrations exceeding the lifetime health advisory and off-Base drinking water wells south of Coupeville with exceedances of the lifetime health advisory will be used to further understand the distribution of PFAS compounds in groundwater at OLF Coupeville. |

Notes:

[1] The final number and placement of samples may be modified in the field based on the field team's professional opinion in consultation with CH2M PM and the NAVFAC Northwest RPM.

[2] Analytical method is compliant with QSM v. 5.1.1 Table B-15 or the most recent version of the QSM for which Battelle has DoD ELAP certification.

GW = groundwater

## SAP Worksheet #17—Sampling Design and Rationale (continued)

Table 17-2. Sampling Strategy Table – Phase 2 Supplemental SI

| Location | Matrix | Depth of Samples (feet bgs) | Analysis | Laboratory Method | Number of Samples | Sampling Strategy | Rationale |
|---|---|---|---|---|---|---|---|
| WI-CV-MWXX<br>(up to 7 locations) | GW | Surface Port – Well constructions settings TBD | PFAS | LC/MS/MS Compliant with QSM v. 5.1.1, Table B-15[1] /<br>SOP 5-369-06[2] | Up to 7 | Groundwater will be collected for in-field water quality parameters and laboratory analysis of PFAS from a sample port at the wellheads of the monitoring wells. | Groundwater analytical data from newly installed on-Base monitoring wells will be used to further understand the distribution of PFAS compounds in groundwater at OLF Coupeville. |

Notes:

[1] Analytical method is compliant with QSM v. 5.1.1 Table B-15 or the most recent version of the QSM for which Battelle has DoD ELAP certification.

[2] The final number and placement of samples may be modified in the field based on the field team’s professional opinion in consultation with CH2M PM and the NAVFAC Northwest RPM.

# SAP Worksheet #18—Location-Specific Sampling Methods/SOP Requirements Table

| Station Identification (ID) | Sample ID | Matrix | Depth (ft bgs) | Analytical Group | Number of Samples (identify field duplicates) | Sampling SOP Reference |
|---|---|---|---|---|---|---|
| **Phase 1** | | | | | | |
| WI-CV-SO01 | WI-CV-SO01-XXXX | Soil | TBD | PFAS (LC/MS/MS compliant with QSM v. 5.1.1, Table B-15[1]), Grain Size, Total Porosity, Dry Bulk Density, Fractional Organic Carbon[5] | An estimated 5 | **Worksheet #21** |
| WI-CV-SO02 | WI-CV-SO02-XXXX | | | | An estimated 5 | |
| | WI-CV-SO02P-XXXX | | | | 1 | |
| WI-CV-SO03 | WI-CV-SO03-XXXX | | | | An estimated 5 | |
| | WI-CV-SO03-XXXX-MS | | | | 1 (MS) | |
| | WI-CV-SO03-XXXX-MSD | | | | 1 (MSD) | |
| WI-CV-SO04 | WI-CV-SO04-XXXX | | | | An estimated 5 | |
| | WI-CV-SO04P-XXXX | | | | 1 | |
| WI-CV-MW01M | WI-CV-GW01M-MMYY | Groundwater | 148 to 158 | LC/MS/MS Compliant with QSM v. 5.1.1, Table B-15[1]) | 1 – 2 (FD) | **Worksheet #21** |
| | WI-CV-GW01MP-MMYY | | | | | |
| WI-CV-MW01D | WI-CV-GW01D-MMYY | | 202 to 212 | | 1 | |
| WI-CV-MW02S | WI-CV-GW02S-MMYY | | 91.5 to 101.5 | | 1- 3 (MS/MSD) | |
| | WI-CV-GW02S-MMYY-MS | | | | | |
| | WI-CV-GW02S-MMYY-MSD | | | | | |
| WI-CV-MW02M | WI-CV-GW02M-MMYY | | 153 to 163 | | 1 | |
| WI-CV-MW03M | WI-CV-GW03M-MMYY | | 145 to 155 | | 1 | |
| WI-CV-MW03D | WI-CV-GW03D-MMYY | | 222 to 232 | | 1 | |
| WI-CV-MW04S | WI-CV-GW04S-MMYY | | 111.6 to 121.6 | | 1 - 2 (FD) | |
| | WI-CV-GW04SP-MMYY | | | | | |
| WI-CV-MW04M | WI-CV-GW04M-MMYY | | 148.7 to 158.7 | | 1 | |

## SAP Worksheet #18—Location-Specific Sampling Methods/SOP Requirements Table (continued)

| Station Identification (ID) | Sample ID | Matrix | Depth (ft bgs) | Analytical Group | Number of Samples (identify field duplicates) | Sampling SOP Reference |
|---|---|---|---|---|---|---|
| WI-CV-MW05S | WI-CV-GW05S-MMYY | Groundwater | 114 to 124 | PFAS (LC/MS/MS Compliant with QSM v. 5.1.1, Table B-15[1] | 1 – 3 (MS/MSD) | **Worksheet #21** |
| | WI-CV-GW05S-MMYY-MS | | | | | |
| | WI-CV-GW05S-MMYY-MSD | | | | | |
| WI-CV-MW05M | WI-CV-GW05M-MMYY | | 160 to 170 | | 1 | |
| WI-CV-MW06S | WI-CV-GW06S-MMYY | | 130 to 140 | | 1 | |
| WI-CV-MW06M | WI-CV-GW06M-MMYY | | 174 to 184 | | 1 – 2 (FD) | |
| | WI-CV-GW06MP-MMYY | | | | | |
| WI-CV-MW07S | WI-CV-GW07S-MMYY | | 129.5 to 139.5 | | 1 | |
| WI-CV-MW07M | WI-CV-GW07M-MMYY | | 183 to 193 | | 1 | |
| WI-CV-MW08S | WI-CV-GW08S-MMYY | | 121 to 131 | | 1 | |
| WI-CV-MW08M | WI-CV-GW08M-MMYY | | 150 to 160 | | 1 | |
| WI-CV-MW09S | WI-CV-GW09S-MMYY | | 96 to 106 | | 1 | |
| WI-CV-MW09M | WI-CV-GW09M-MMYY | | 182 to 192 | | 1 – 2 (FD) | |
| | WI-CV-GW09MP-MMYY | | | | | |
| WI-CV-MW10M | WI-CV-GW10M-MMYY | | 144 to 154 | | 1 | |
| WI-CV-MW10D | WI-CV-GW10D-MMYY | | 191 to 201 | | 1 | |
| WI-CV-MW11S | WI-CV-GW11S-MMYY | | 130 to 140 | | 1 | |
| WI-CV-MW11M | WI-CV-GW11M-MMYY | | 155 to 165 | | 1 | |
| WI-CV-MW12S | WI-CV-GW12S-MMYY | | 97 to 107 | | 1 | |
| WI-CV-MW12D | WI-CV-GW12D-MMYY | | 183 to 193 | | 1 – 3 (MS/MSD) | |
| | WI-CV-GW12D-MMYY-MS | | | | | |
| | WI-CV-GW12D-MMYY-MSD | | | | | |

# SAP Worksheet #18—Location-Specific Sampling Methods/SOP Requirements Table (continued)

| Station Identification (ID) | Sample ID | Matrix | Depth (ft bgs) | Analytical Group | Number of Samples (identify field duplicates) | Sampling SOP Reference |
|---|---|---|---|---|---|---|
| WI-CV-MW13S | WI-CV-GW13S-MMYY | Groundwater | 105 to 115 | PFAS (LC/MS/MS Compliant in accordance with QSM v. 5.1.1, Table B-15[1]) | 1 | **Worksheet #21** |
| WI-CV-MW13M | WI-CV-GW13M-MMYY | | 173 to 183 | | 1 | |
| WI-CV-MW14M | WI-CV-GW14M-MMYY | | 161 to 171 | | 1 | |
| WI-CV-MW15S | WI-CV-GW15S-MMYY | | 132 to 142 | | 1 | |
| WI-CV-MW15M | WI-CV-GW15M-MMYY | | 164 to 174 | | 1 | |
| WI-CV-MW16S | WI-CV-GW16S-MMYY | | 130 to 140 | | 1 | |
| WI-CV-MW16M | WI-CV-GW16M-MMYY | | 165 to 183 | | 1 | |
| WI-CV-MW17M | WI-CV-GW17M-MMYY | | TBD | | 1 | |
| WI-CV-MW20X[3] (GW01/ SO05) | WI-CV-GW20M-MMYY | | | | An estimated 3 | |
| | WI-CV-BH20-XXYY-MMYY[4] | Soil | TBD | PFAS (LC/MS/MS Compliant with QSM v. 5.1.1, Table B-15[1])<br>Grain Size, Total Porosity, Dry Bulk Density, Fractional Organic Carbon[5] | An estimated 5 | |
| | WI-CV-BH20-XXYY-MMYY-MS[4] | | | | 1 (MS) | |
| | WI-CV-BH20-XXYY-MMYY-MSD[4] | | | | 1 (MSD) | |

## SAP Worksheet #18—Location-Specific Sampling Methods/SOP Requirements Table (continued)

| Station Identification (ID) | Sample ID | Matrix | Depth (ft bgs) | Analytical Group | Number of Samples (identify field duplicates) | Sampling SOP Reference |
|---|---|---|---|---|---|---|
| WI-CV-MW21X[3] (GW02/ SO06) | WI-CV-GW21M-MMYY | Groundwater | TBD | PFAS (LC/MS/MS Compliant with QSM v. 5.1.1, Table B-15[1]) | An estimated 4[6] | **Worksheet #21** |
| | WI-CV-GW21M-MMYY-MS | | | | 1 (MS) | |
| | WI-CV-GW21M-MMYY-MSD | | | | 1 (MSD) | |
| | WI-CV-BH21-XXYY-MMYY[4] | Soil | | PFAS (LC/MS/MS Compliant with QSM v. 5.1.1, Table B-15[1])<br>Grain Size, Total Porosity, Dry Bulk Density, Fractional Organic Carbon[5] | An estimated 5 | |
| | WI-CV-BH21P-XXYY-MMYY[4] | | | PFAS (LC/MS/MS Compliant with QSM v. 5.1.1, Table B-15[1]) | 1 | |
| WI-CV-MW22X[3] (GW03) | WI-CV-GW22X-MMYY | Groundwater | | PFAS (LC/MS/MS Compliant with QSM v. 5.1.1, Table B-15[1]) | An estimated 5[6] | |
| WI-CV-MW23X[3] (GW04) | WI-CV-GW23X-MMYY | | | | An estimated 5[6] | |
| | WI-CV-GW23XP-MMYY | | | | 1 (FD) | |
| WI-CV-MW24X[3] (GW05) | WI-CV-GW24X-MMYY | | | | 2 | |
| WI-CV-MW25X[3] (GW06) | WI-CV-GW25X-MMYY | | | | An estimated 5[6] | |
| WI-CV-MW26X[3] (GW07) | WI-CV-GW26X-MMYY | | | | An estimated 5[6] | |
| | WI-CV-GW26XP-MMYY | | | | 1 (FD) | |

## SAP Worksheet #18—Location-Specific Sampling Methods/SOP Requirements Table (continued)

| Station Identification (ID) | Sample ID | Matrix | Depth (ft bgs) | Analytical Group | Number of Samples (identify field duplicates) | Sampling SOP Reference |
|---|---|---|---|---|---|---|
| **Phase 2** | | | | | | |
| WI-CV-MWXX[3] | WI-CV-GWXX-MMYY | Groundwater | TBD | PFAS (LC/MS/MS Compliant with QSM v. 5.1.1, Table B-15[1]) | TBD | **Worksheet #21** |
| **Field QC Samples** | | | | | | |
| WI-CV-QC[3] | WI-CV-EB01-MMDDYY | QC | N/A | PFAS (LC/MS/MS Compliant with QSM v. 5.1.1, Table B-15[1]) | 1 | **Worksheet #21** |
| | WI-CV-EB02-MMDDYY | | | | 1 | |
| | WI-CV-EBXX-MMDDYY[2] | | | | TBD | |
| | WI-CV-FB01-MMDDYY | | | | 1 | |
| | WI-CV-FB02-MMDDYY | | | | 1 | |
| | WI-CV-FBXX-MMDDYY[2] | | | | TBD | |

Notes:

[1] Analytical method is compliant with QSM v. 5.1.1 Table B-15 or the most recent version of the QSM for which Battelle has DoD ELAP certification.

[2] With site in consideration being OLF Coupeville, one field reagent blank should be collected weekly and one equipment blank should be collected daily with samples.

[3] Depth interval to be determined during drilling.

[4] BH stem in nomenclature indicates borehole number.

[5] For grain size, total porosity, dry bulk density, and fractional organic carbon nine samples will be selected in the field from the 7 different locations which each include up to 5 depth intervals.

[6] Count reflects samples collected in Phase 1 (groundwater grab samples and from newly installed monitoring wells) and Phase 2 (collection from newly installed monitoring wells).

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# SAP Worksheet #19—Analytical SOP Requirement Table

| Matrix | Analytical Group | Analytical and Preparation Method/SOP Reference | Containers | Sample Volume | Preservation Requirements | Maximum Holding Time[1] (preparation/analysis) |
|---|---|---|---|---|---|---|
| Groundwater | PFAS | PFAS by LC/MS/MS Compliant with QSM v. 5.1.1 Table B-15[2]/ SOP 5-370/SOP 5-369 | 2 x 250 milliliters (mL) HDPE bottle | 2 x 250 mL | ≤10°C for up to 48 hours after sampling, upon sample receipt, then stored at laboratory ≤6°C. | 14 days to extraction/ 28 days to analysis |
| Soil | PFAS | PFAS by LC/MS/MS Compliant with QSM v. 5.1.1 Table B-15[2]/ SOP 5-370/SOP 5-369 | One 6-ounce HDPE jar | 20 grams | ≤10°C for up to 48 hours after sampling, upon sample receipt, then stored at laboratory ≤6°C, but not frozen. | 28 days to extraction/ 30 days to analysis |
| Soil | Dry Bulk Density | ASTM D2937 / Dry or Native Bulk Density | 1 x 2” diameter x 6” long sleeve | 100 grams | Cool to ≤6 °C | N/A |
| Soil | Total Porosity | API RP40 /Porosity; Total and Air-Filled | | | | |
| Soil | Fractional Organic Carbon | Walkley Black / Total Organic Carbon | | | | |
| Soil | Grain Size | ASTM D422 / Particle Size by Mechanical Sieve | | | | |

Notes:

[1] Maximum holding time is calculated from the time the sample is collected to the time the sample is prepared/extracted.

[2] Analytical method is compliant with QSM v. 5.1.1 Table B-15 or the most recent version of the QSM for which Battelle has DoD ELAP certification.

HDPE = high density polyethylene

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## SAP Worksheet #20—Field Quality Control Sample Summary Table

| Matrix | Analytical Group | No. of Sampling Locations[1] | No. of Field Duplicates[1] | No. of MS/MSDs[1] | No. of Field Reagent Blanks[1] | No. of Equipment Blanks[1] | Total No. of Samples to Laboratory[1] |
|---|---|---|---|---|---|---|---|
| **Phase I Sampling** | | | | | | | |
| Groundwater | PFAS | An estimated 23 | An estimated 3 | An estimated 2/2 | 1 | As estimated 5 | An estimated 36 |
| Soil | PFAS | An estimated 30 | An estimated 3 | An estimated 2/2 | 1 | An estimated 7 | An estimated 45 |
| Soil | Dry Bulk Density | An estimated 9 | N/A | N/A | N/A | N/A | An estimated 9 |
| Soil | Total Porosity | An estimated 9 | N/A | N/A | N/A | N/A | An estimated 9 |
| Soil | Fractional Organic Carbon | An estimated 9 | N/A | N/A | N/A | N/A | An estimated 9 |
| Soil | Grain Size | An estimated 9 | N/A | N/A | N/A | N/A | An estimated 9 |
| **Phase 2 Sampling** | | | | | | | |
| Groundwater | PFAS | An estimated 46 | An estimated 5 | An estimated 3/3 | 1 | An estimated 7 | An estimated 65 |

Notes:

[1] Samples will be collected as detailed in **Worksheets #14, #17,** and **#18** of this SAP. Field QA/QC samples will be collected as detailed in **Worksheet #12**.

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# SAP Worksheet #21—Project Sampling SOP References Table

| Reference Number | Title, Revision Date and/or Number | Originating Organization of Sampling SOP | Equipment Type | Modified for Project Work? (Y/N) | Comments |
|---|---|---|---|---|---|
| SOP CH2M-1 | Guidelines for Logging Soil Borings | CH2M | None | N | Provides guidance on characterizing soil borings. |
| SOP CH2M-2 | Continuous Water Level Measurements | CH2M | Transducer and datalogger | N | Describes procedure for collecting continuous water level measurements. |
| SOP CH2M-3 | Multi RAE PID | CH2M | Multi RAE PID | N | Describes procedure for operation and general maintenance of the Multi RAE PID. |
| SOP CH2M-4 | Groundwater Sampling for Per- and Polyfluoroalkyl Substances (PFAS) | CH2M | All field equipment within the sample collection area | N | Provides guidance for groundwater sample collection for samples that will be analyzed for PFASs via LC/MS/MS Compliant with QSM v. 5.1.1 (or the most recent version of the QSM for which Battelle has DoD ELAP certification) for Navy CLEAN projects under Contract N62470-16-D-9000. |
| SOP CH2M-5 | Groundwater Vertical Profiling | CH2M | All field equipment within the sample collection area | Y | Provides guidance for groundwater sample collection for samples that will be analyzed for PFASs via LC/MS/MS Compliant with QSM 5.1.1 (or the most recent version of the QSM for which Battelle has DoD ELAP certification) for Navy CLEAN projects under Contract N62470-16-D-9000. |
| SOP CH2M-6 | Soil Sampling for Per- and Polyfluoroalkyl Substances | CH2M | All field equipment within the sample collection area | N | Provides guidance for soil sample collection for samples that will be analyzed for PFASs via LC/MS/MS Compliant with QSM v. 5.1.1 (or the most recent version of the QSM for which Battelle has DoD ELAP certification) for Navy CLEAN projects under Contract N62470-16-D-9000. |
| SOP CH2M-7 | Management of Liquid Waste Containing Per- and Polyfluoroalkyl Substances (PFAS) | CH2M | None | N | Provides guidelines for managing liquid waste containing PFAS or Navy CLEAN projects under Contract N62470-16-D-9000. |
| SOP I-A-1 | Planning Field Sampling Activities, Rev. Feb. 2015 | NAVFAC Northwest | None | N | Establishes SOPs for planning and scheduling field sampling activities. |
| SOP I-A-7 | IDW Management, Rev. Feb. 2015 | NAVFAC Northwest | None | N | Describes activities and responsibilities of NAVFAC Northwest and its subcontractors regarding management of IDW. Field activities will deviate slightly from the SOP to eliminate use of PFAS-containing materials. |
| SOP I-A-9 | General Field Operation, Rev. Feb. 2015 | NAVFAC Northwest | All field equipment | N | Defines organization and structure of sample collection, identification, record keeping, field measurements, and data collection. |
| SOP I-A-10 | Monitoring/Sampling Location Recording, Rev. Feb. 2015 | NAVFAC Northwest | Field logbook | N | Establishes guidelines for generating information to be recorded for each physical location where sampling is conducted. |
| SOP I-A-11 | Sample Naming, Rev. Feb. 2015 | NAVFAC Northwest | None | N | Describes the naming convention to be used for samples collected, analyzed, and reported for NAVFAC Northwest projects. |
| SOP 1-C-1 | Monitoring Well/Piezometer Installation, Rev. Mar. 2015 | NAVFAC Northwest | Drilling equipment | N | Describes the methods by which NAVFAC Northwest field personnel and their contractors will conduct monitoring well installation. |
| SOP 1-C-2 | Monitoring Well Development, Rev. Mar. 2015 | NAVFAC Northwest | Drilling equipment | N | Describes the methods by which NAVFAC Northwest field personnel and their contractors will conduct monitoring well development. |
| SOP 1-C-5 | Low-Flow Groundwater Purging and Sampling, Rev. Mar. 2015 | NAVFAC Northwest | Bladder or peristaltic pump, water level and water quality meters, and buckets. Compressor and controller required for bladder pump. | N | Describes the conventional monitoring well sampling procedures to be used by all NAVFAC Northwest personnel and contractors. |
| SOP 1-C-7 | Aquifer Tests, Rev. Mar. 2015 | NAVFAC Northwest | Bailers, buckets, drums, and data loggers | N | Describes the conventional aquifer testing sampling procedures to be used by all NAVFAC Northwest personnel and contractors. |
| SOP 1-D-5 | Water Level Measurements, Rev. Mar. 2015 | NAVFAC Northwest | Water level meters | N | Establishes standard protocols for all NAVFAC Northwest field personnel for use in making water level measurements. |

## SAP Worksheet #21—Project Sampling SOP References Table (continued)

| Reference Number | Title, Revision Date and/or Number | Originating Organization of Sampling SOP | Equipment Type | Modified for Project Work? (Y/N) | Comments |
|---|---|---|---|---|---|
| SOP I-D-7 | Field Parameter Measurements, Rev. Mar. 2015 | NAVFAC Northwest | Water quality meters | N | Provides instructions for the calibration, use, and checking of instruments and equipment for field measurements. Field activities will deviate slightly from the SOP to eliminate use of PFAS-containing materials. |
| SOP I-G-1 | Land Surveying, Rev. Aug. 2014 | NAVFAC Northwest | Surveying equipment | N | Describes the methods by which NAVFAC Northwest field personnel and their contractors will conduct land surveying. |
| SOP III-B | Field QC Samples (Water, Soil, Sediment, Tissue), Rev. Apr. 2015 | NAVFAC Northwest | Sample containers | | Sets forth the methods by which NAVFAC Northwest field personnel and their contractors shall collect field QC samples for water, soil, sediment, and tissue. |
| SOP III-D | Logbooks, Rev. Apr. 2015 | NAVFAC Northwest | Logbook | | Sets forth the requirements and procedures for NAVFAC Northwest field personnel and their contractors for documenting field events in the logbook. |
| SOP III-E | Record Keeping, Sample Labeling, and Chain-of Custody Procedures, Rev. Apr. 2015 | NAVFAC Northwest | Samples, sample labels, COC | | Sets forth the record keeping, sample labeling, and chain of custody methods for use by NAVFAC Northwest field personnel and their contractors. |
| SOP III-F | Sample Containers and Preservation, Rev. Apr. 2015 | NAVFAC Northwest | Sample Jars | N | Describes conventional containers used for sample collection and discusses sample preservation and holding times |
| SOP III-G | Sample Handling, Storage, and Shipping, Rev. Apr. 2015 | NAVFAC Northwest | Samples | N | Sets forth the methods for use by NAVFAC Northwest field personnel and their contractors engaged in handling, storing, and transporting water, soil and/or sediment samples. Field activities will deviate slightly from the SOP to eliminate use of PFAS-containing materials. |
| SOP III-I | Equipment Decontamination, Rev. Apr. 2015 | NAVFAC Northwest | Nondisposable sampling equipment | N | Describes general methods of equipment decontamination for use by NAVFAC Northwest field personnel and their contractors during field sampling activities. Field activities will deviate slightly from the SOP to eliminate use of PFAS-containing materials. |
| SOP III-J | Equipment Calibration, Operation, and Maintenance, Rev. Apr. 2015 | NAVFAC Northwest | Field meters | N | Describes the activities and responsibilities of the NAVFAC Northwest personnel pertaining to the operation, calibration, and maintenance of equipment used to collect environmental data. Field activities will deviate slightly from the SOP to eliminate use of PFAS-containing materials. |
| N/A | Final Environmental Restoration Program Recordkeeping Manual, Feb. 2017 | NAVFAC | None. | N | Provides instructions on how to submit documents for inclusion in the program's Environmental Document Management System and information about compiling, documenting, managing and maintaining Comprehensive Environmental Response, Compensation, and Liability Act Environmental Restoration Administrative Record Files, Post Decision Files, Site Files and Petroleum, Oil and Lubricant Files. |

# SAP Worksheet #22—Field Equipment Calibration, Maintenance, Testing, and Inspection Table

| Field Equipment | Activity[1] | Frequency | Acceptance Criteria | CA | Resp. Person | SOP Reference[2] | Comments |
|---|---|---|---|---|---|---|---|
| Horiba U-22<br>pH probe | Calibration | Daily, before use | pH reads 4.0 ± 3% | Clean probe with deionized water and calibrate again.<br>Do not use instrument if not able to calibrate properly | FTL | SOP-007 | **Appendix B** |
| Horiba U-22<br>Specific conductance probe | Calibration | Daily, before use | Conductivity reads 4.49 ± 3% | Clean probe with deionized water and calibrate again.<br>Do not use instrument if not able to calibrate properly. | FTL | SOP-007 | **Appendix B** |
| Horiba U-22<br>Turbidity probe | Calibration | Daily, before use | Turbidity reads 0 ± 3% | Clean probe with deionized water and calibrate again.<br>Do not use instrument if not able to calibrate properly. | FTL | SOP-007 | **Appendix B** |
| Horiba U-22 DO and Temperature Probes | Testing | Daily, before use | Consistent with the current atmospheric pressure and ambient temperature | Clean probe with deionized water and calibrate again.<br>Do not use instrument if not able to calibrate properly. | FTL | SOP-007 | **Appendix B** |
| Horiba U-22 | Maintenance- Check mechanical and electronic parts, verify system continuity, check battery, and clean probes.<br>Calibration check | Daily before use, at the end of the day, and when unstable readings occur. | Stable readings after 3 minutes.<br>pH reads 4.0 ± 3%<br>conductivity reads 4.49 ± 3%<br>turbidity reads 0 ± 3% | Clean probe with deionized water and calibrate again.<br>Do not use instrument if not able to calibrate properly. | FTL | SOP-007 | **Appendix B** |
| Transducers and data loggers | Calibrate | Daily, As Needed | Parameter specific per model/ instruction manual | Manufacturer technical support for calibration errors | FTL | SOP CH2M-2, SOP-III-J | **Appendix B** |
| Multi RAE PID | Calibrate using ambient air and isobutylene 100 parts per million calibration gas | Daily and as Needed | Parameter specific per model/ instruction manual | Manufacturer technical support for calibration errors | FTL | SOP CH2M-3, SOP-III-J | **Appendix B** |
| Groundwater sampling pumps and tubing | Inspect pumps, tubing and air/sample line quick-connects | Regularly | Maintained in good working order according to manufacturer's recommendations | Replace items | FTL | SOP-III-J | **Appendix B** |

Notes:

[1] Activities may include: calibration, verification, testing, and maintenance.

[2] Specify the appropriate reference letter or number from the Project Sampling SOP References table (**Worksheet #21**).

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## SAP Worksheet #23—Analytical SOP References Table

| Lab SOP Number | Title, Revision Date, and/or Number | Definitive or Screening Data | Matrix and Analytical Group | Instrument | Organization Performing Analysis | Modified for Project Work (Y/N) |
|---|---|---|---|---|---|---|
| 5-370-08 | *Extraction of Poly and Perfluoroalkyl Substances from Environmental Matrices, 04/16/2019, Rev. 8* | Definitive | Soil/Groundwater /PFAS | N/A | Battelle Analytical Services | N |
| 5-369-06 | *Analysis of Poly and Perfluoroalkyl Substances in Environmental Samples by Liquid Chromatography and Tandem Mass Spectrometry (LC-MS/MS), 05/11/2018, Rev. 6* | Definitive | Soil/Groundwater /PFAS | LC/MS/MS | Battelle Analytical Services | N |
| 6-010-19 | Sample Receipt, Custody, and Handling, 10/16/18, Rev. 19 | N/A | Soil/Groundwater /PFAS | N/A | Battelle Analytical Services | N |
| 5-291-17 | *Determination of Method Detection Limits in the Analytical Laboratory, 09/20/18, Rev. 17* | N/A | Soil/Groundwater /PFAS | N/A | Battelle Analytical Services | N |
| POROSITY; TOTAL and AIR-FILLED | *Porosity; Total and Air-Filled, Rev. 1, 2/21/2014* | Screening | Soil/ Total and Air-Filled Porosity | N/A | CORE Laboratories | N |
| TOTAL ORGANIC CARBON | *Total Organic Carbon, Rev. 1, 3/16/2011* | Screening | Soil / Fractional Organic Carbon | N/A | CORE Laboratories | N |
| PARTICLE SIZE BY MECHANICAL SIEVE | *Particle Size by Mechanical Sieve, Rev. 1, 2/21/2014* | Screening | Soil / Grain Size | N/A | CORE Laboratories | N |
| GRAIN DENSITY ANALYSIS | *Grain Density Analysis – Boyle's Law, Rev. 1, 2/21/2014* | Screening | Soil / Grain Density | N/A | CORE Laboratories | N |

Notes:

Laboratory SOPs meet DoD QSM v. 5.1.1 (DoD, 2018) requirements (Attachment 4) for Battelle Analytical Services. Core Laboratories is performing geotechnical parameters for screening purposes and is not DoD accredited.

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# SAP Worksheet #24—Analytical Instrument Calibration Table

| Instrument | Calibration Procedure | Frequency of Calibration | Acceptance Criteria | CA | Person Responsible for CA | SOP Reference |
|---|---|---|---|---|---|---|
| LC/MS/MS (PFAS) | Initial calibration (ICAL) for all analytes | At instrument set-up and after initial calibration verification (ICV) or continuing calibration verification (CCV) failure, prior to sample analysis. | The available isotopically labeled analog of an analyte (Extracted Internal Standard Analyte) are used for quantitation (except labelled 6:2 FTS)<br>If a labeled analog is not commercially available, the Extracted Internal Standard Analyte with the closest retention time to the analyte must be used for quantitation. (Internal Standard Quantitation)<br>S/N Ratio: ≥ 10:1 for all ions used for quantitation.<br>For analytes having a promulgated standard, (e.g., HA levels for PFOA and PFOS), the qualitative (confirmation) transition ion must have a S/N Ratio of ≥ 3:1.<br>The % relative standard deviation of the response factors for all analytes must be less than 20 percent.<br>Linear or non-linear calibrations must have $r^2 \geq 0.99$ for each analyte. Analytes must be within 70 to 130 percent of their true value for each calibration standard. | If these requirements are not met for the ICAL, CA is performed, and the calibration is repeated. | Analyst / Laboratory Project Manager | 5-369<br>DoD QSM v. 5.1.1 |
| | ICV | Once after each ICAL, analysis of a second source standard prior to sample analysis. | All reported analytes within ± 30% of true value. Internal standard area must be within 50% of L3 of the calibration curve. | Correct problem and verify second source standard. Rerun ICV. If that fails, correct problem and repeat ICAL. | | |
| | Continuing Calibration Verification (CCV) | Beginning of each sample analysis sequence (if not preceded by and ICAL and ICV) analyze a mid-level standard and then after 10 injections during analysis sequence. All samples must be bracketed by the analysis of a standard. | Concentration of analytes must range from the LOQ to the mid-level calibration concentration.<br>Analyte concentrations must be within ± 30% of their true value, labelled analogs must be within 50% of true value. | When a CCV fails to meet any of the above criteria, two additional CCVs are analyzed consecutively. If both additional CCVs pass criteria, the samples can be reported. If either of the two additional CCVs fail criteria or cannot be analyzed all samples that were analyzed after the prior acceptable CCV must be re-analyzed. If a CCV fails because a target analyte exceeded the acceptance limit defined above (over response only) and that analyte was not detected in any samples, then the samples do not need to be reanalyzed. In all other cases, the sample must be reanalyzed after and acceptable CCV has been established or justification for continuing is approved by the project manager and documented. | | |
| | Tune Check | When the masses fall outside of the ± 0.5 atomic mass unit (amu) of the true value (as determined by the product ion formulas). | Mass assignments of tuning standard within 0.5 amu of true value. | Retune instrument and verify. If the tuning will not meet acceptance criteria, an instrument mass calibration must be performed, and the tune check repeated. | | |
| | Mass Calibration | Initially prior to use and after performing major maintenance, as required to maintain documented instrument sensitivity and stability performance. | Calibrate the mass scale of the MS with calibration compounds and procedures described by the manufacturer. Entire range needs to be mass calibrated. | N/A | | |
| | Mass Spectral Acquisition Rate | Each analyte and extracted internal standard analyte. | A minimum of 10 spectra scans are acquired across each chromatographic peak. | N/A | | |

## SAP Worksheet #24—Analytical Instrument Calibration Table (continued)

| Instrument | Calibration Procedure | Frequency of Calibration | Acceptance Criteria | CA | Person Responsible for CA | SOP Reference |
|---|---|---|---|---|---|---|
| LC/MS/MS<br>(PFAS, continued) | Peak Asymmetry | With each calibration | First two eluting peaks in a mid-level calibration standard must have an asymmetry factor between 0.8 and 1.5 | When the asymmetry factor does not pass, perform corrective action to address the issue. Modification of the standard or extract composition to more aqueous content is not permitted. | Analyst / Laboratory Project Manager | 5-369, 5-371,<br>DoD QSM v. 5.1.1 |
| | Calibration,<br>Calibration<br>Verification, and<br>Spiking Standards | All analytes. | Standards containing both branched and linear isomers must be used when commercially available. If not available, the total response of the analyte must be integrated (i.e., accounting for peaks that are identified as linear and branched isomers) and quantitated using a calibration curve which includes the linear isomer only for that analyte (e.g., PFOA). | N/A | | |
| | Ion Transitions<br>(Parent-> Product) | Prior to method implementation. | The chemical derivation of the ion transitions, both those used for quantitation and those used for confirmation, must be documented. Two transitions and the ion transition ratio per analyte shall be monitored and documented with the exception of PFBA and PFPeA. 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:<br>PFOA: 413 —› 369<br>PFOS: 499 —› 80<br>PFHxS: 399 —› 80<br>PFBS: 299 —› 80<br>4:2 FTS: 327 —› 307<br>6:2 FTS: 427 —› 407<br>8:2 FTS: 527 —› 507<br>NEtFOSAA: 584 —› 419<br>NMeFOSAA: 570 —› 419<br>If these transitions are not used, the reason must be technically justified and documented (e.g., alternate transition was used due to observed interferences). | N/A | | |
| | Instrument Blank | Following highest calibration point | ≤1/2 the LOQ | 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.<br>If acceptance criteria are not met after the highest standard which is not included in the calibration, the standard cannot be used to determine the highest concentration in samples at which carryover does not occur.<br>If acceptance criteria are not met after sample, additional instrument blanks must be analyzed until acceptance criteria are met. Additional samples shall not be analyzed until acceptance criteria are met. | | |
| | 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.<br>If problem persists, repeat ICAL.<br>No samples shall be analyzed until ISC has met acceptance criteria.<br>ISC can serve as the initial daily CCV. | | |

Notes:

The specifications in this table meet the requirements of DoD QSM v. 5.1.1.

# SAP Worksheet #25—Analytical Instrument and Equipment Maintenance, Testing, and Inspection Table

| Instrument/ Equipment | Maintenance Activity | Testing Activity | Inspection Activity | Frequency | Acceptance Criteria | Corrective Action | Responsible Person | SOP Reference |
|---|---|---|---|---|---|---|---|---|
| LC/MS/MS | PM | PFAS | N/A | 6 Months | N/A | N/A | Analyst/supervisor | 3-200-01 |
| Balance | Verification | Weight | N/A | Daily | ± 0.02 gram or ± 0.1% of calibration weight used (whichever is greater) | Refer to manufacturer’s instruction manual | Analyst/supervisor | 3-160-09 |
| Balance | Calibration | Weight | N/A | Annually | Per manufacturer | Remove from service, repair, replace | Analyst/supervisor | 3-160-09 |
| Pipette | Verification | Volume | N/A | Daily | ± 2% difference from true value, <1% relative standard deviation (n=3) | Remove from service, repair, replace | Analyst/supervisor | 3-191-05 |
| Pipette | Calibration | Volume | N/A | Quarterly | Per manufacturer | Remove from service, repair, replace | Analyst/supervisor | 3-191-05 |

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# SAP Worksheet #26—Sample Handling System

| **SAMPLE COLLECTION, PACKAGING, AND SHIPMENT** |
|---|
| Sample Collection (Personnel/Organization): Project Field Team, FTL/CH2M. Field SOPs are in **Appendix B** of this SAP. |
| Sample Packaging (Personnel/Organization): Project Field Team, FTL/CH2M. Field SOPs are in **Appendix B** of this SAP. |
| Coordination of Shipment (Personnel/Organization): FTL/CH2M. |
| Type of Shipment/Carrier: FedEx Priority Overnight<br>Samples will be shipped directly to Battelle Analytical Services and CORE Laboratories |
| **SAMPLE RECEIPT AND ANALYSIS** |
| Sample Receipt (Personnel/Organization): Sample Receiving/Battelle Analytical Services, CORE Laboratories |
| Sample Custody and Storage (Personnel/Organization): Sample Receiving/Battelle Analytical Services, CORE Laboratories |
| Sample Preparation (Personnel/Organization): Sample Preparation Staff/Battelle Analytical Services, CORE Laboratories |
| Sample Determinative Analysis (Personnel/Organization): Battelle Analytical Services, CORE Laboratories |
| **SAMPLE ARCHIVING** |
| Field Sample Storage (No. of days from sample collection): 60 days from receipt |
| Sample Extract/Digestate Storage (No. of days from extraction/digestion): 28 days after extraction/digestion |
| Biological Sample Storage (No. of days from sample collection): N/A |
| **SAMPLE DISPOSAL** |
| Personnel/Organization): Sample Disposal/Battelle Analytical Services, CORE Laboratories |
| Number of Days from Analysis: 60 days after final sample results are reported, unless there is a hold on a particular sample or previous arrangements have been made |

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# SAP Worksheet #27—Sample Custody Requirements

**Field Sample Custody Procedures (sample collection, packaging, shipment, and delivery to laboratory):**

Samples will be collected by field team members under the supervision of the FTL. As samples are collected, they will be placed into containers and labeled. Labels will be taped to the jar to ensure they do not separate. Samples will be cushioned with packaging material and placed into coolers containing enough ice to keep the samples 0 to 6°C (but not frozen; requirements for USEPA 537 are less than 10°C for the first 48 hours) until they are received by the laboratory.

The chain-of-custody record will be placed into the cooler in a resealable zip-top plastic bag. Coolers will be taped up and shipped to the laboratories via FedEx overnight, with the airbill number indicated on the chain of custody (to relinquish custody). Upon delivery, the laboratory will log each cooler and report the status of the samples to CH2M.

See **Worksheet #21** for SOPs containing sample custody guidance.

The CH2M field team will ship all environmental samples directly to the laboratory performing the analysis. This will require shipment to Battelle Analytical Services in Norwell, Massachusetts.

**Laboratory Sample Custody Procedures (receipt of samples, archiving, disposal):**

Laboratory custody procedures can be found in the laboratory SOPs, which will be provided upon request.

**Sample Identification (ID) Procedures:**

Sample labels will include, at a minimum, client name, site, sample ID, date/time collected, analysis group or method, preservation, and sampler's initials. The field notes will identify the sample ID with the location and time collected and the parameters requested. The laboratory will assign each field sample a laboratory sample ID based on information in the chain of custody. The laboratory will send sample log-in forms to the CH2M PC to check that sample IDs and parameters are correct.

**Chain-of-Custody Procedures:**

Chain-of-custody records will include, at minimum, laboratory contact information, client contact information, sample information, and relinquished by/received by information. Sample information will include sample ID. Date/time collected, number and type of containers, preservative information, analysis method, and comments. The chain-of-custody record will link location of the sample from the field notes to the laboratory receipt of the sample. The laboratory will use the sample information to populate the Laboratory Information Management Systems database for each sample.

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## SAP Worksheet #28-1—Laboratory QC Sample Table

**Matrix:** Soil/Groundwater

**Analytical Group:** PFAS

**Analytical Method/SOP Reference:** PFAS by LC/MS/MS Compliant with QSM 5.1.1 Table B-15/SOP 5-369-04

| QC Sample | Frequency/Number | Method/ SOP QC Acceptance Limits | Corrective Action | Person(s) Responsible for CA | Data Quality Indicator | Measurement Performance Criteria (MPC) |
|---|---|---|---|---|---|---|
| Aqueous Sample Preparation | Each sample and associated batch QC sample. | Solid Phase Extraction (SPE) must be used unless samples are known to contain high PFAS concentrations (e.g., AFFF formulations). Inline SPE is acceptable.<br>Samples of known high PFAS concentrations can be prepared by serial dilution instead of SPE, with documented project approval. | NA | Analyst/ Laboratory Project Manager | NA | Same as Method/ SOP QC Acceptance Limits |
| Soil and Sediment Sample Preparation | Each sample and associated batch QC sample. | Entire sample received by the laboratory must be homogenized prior to subsampling. | NA | | NA | |
| Sample Cleanup Procedure using ENVI-Carb™ or equivalent | Each sample and associated batch QC sample.<br>Not applicable to AFFF formulation samples. | Removal of interferences from matrix. | NA | | Bias/Contamination | |
| Method Blank | One per prep batch of 20 or fewer samples of similar matrix; or one per day, whichever comes first | No analytes detected > 1/2 LOQ or >1/10 the amount measured in any sample or >1/10 regulatory limit, whichever is greater. | Correct problem. Reprep and reanalyze method blank and all samples processed with the contaminated blank.<br>If reanalysis cannot be performed, the data must be qualified and explained in the case narrative. | | Bias/ Contamination | |
| LCS | One per prep batch of 20 or fewer samples of similar matrix; or one per day, whichever comes first | Blank spiked with all analytes at a concentration ≥LOQ and ≤ the mid-level calibration concentration.<br>DoD QSM v. 5.1.1 limits; (**Worksheet #28-1**) | Correct problem. Reprep and reanalyze the LCS and all samples in the associated preparatory batch, if sufficient sample material is available.<br>If reanalysis cannot be performed, the data must be qualified and explained in the case narrative. | | Precision/ Accuracy/Bias | |
| MS/MSD | One per prep batch of 20 or fewer samples of similar matrix; or one per day, whichever comes first | Sample spiked with all analytes at a concentration ≥LOQ and ≤ the mid-level calibration concentration.<br>DoD QSM v. 5.1.1 limits; (See **Worksheet #28-1** for control limits)<br>RPD ≤ 30% | Examine the project specific requirements. Contact the client as to additional measures to be taken.<br>For the specific analyte(s) in the parent sample, apply J-flag if acceptance criteria are not met and explain in the Case Narrative. | | Precision/ Accuracy/Bias | |

## SAP Worksheet #28-1—Laboratory QC Sample Table (continued)

**Matrix:** Soil/Groundwater

**Analytical Group:** PFAS

**Analytical Method/SOP Reference:** PFAS by LC/MS/MS Compliant with QSM 5.1.1 Table B-15/SOP 5-369-04

| QC Sample | Frequency/Number | Method/ SOP QC Acceptance Limits | Corrective Action | Person(s) Responsible for CA | Data Quality Indicator | Measurement Performance Criteria (MPC) |
|---|---|---|---|---|---|---|
| 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 all 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).<br>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/ Laboratory Project Manager | NA | Same as Method/ SOP QC Acceptance Limits |
| Extracted Internal Standard | Every field sample, spiked sample, standard, blank, and QC sample. | Added to sample prior to extraction.<br>For aqueous samples prepared by serial dilution instead of Solid Phase Extraction, added to samples prior to analysis.<br>Extracted Internal Standard Analyte recoveries must be within 50% to 150% of the true value. | If recoveries are acceptable for QC samples, but not field samples, the field samples must be reprepped and reanalyzed (greater dilution may be needed). If recoveries are unacceptable for the QC samples, correct the problem, and reanalyze all associated filed samples. | | Precision/ Accuracy/Bias | |
| Injected Internal Standards | Every field sample, spiked sample, standard, blank, and QC sample | Added to aliquot of sample dilutions, QC samples, and standards just prior to analysis.<br>Peak areas must be within -50% to +50% of the area measured in the ICAL midpoint standard.<br>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. | | Accuracy | |
| LOD verification | Quarterly for every analyte | Spike a quality system matrix at concentration 2-4x the DL. Must meet 3:1 signal-to-noise ratio, or for data systems that do not measure noise, results must be at least 3 standard deviations greater than the mean method blank concentration. | If verification fails, the DL determination must be repeated and a LOD verification. Alternatively pass two consecutive LOD verification at a higher spike and at the LOD at the higher concentration. | | Accuracy | |
| LOQ verification | Quarterly for every analyte | Spike a quality system matrix at a concentration equal to or greater than the low point of the calibration curve. | Must meet laboratory specified precision and bias limits. If LOQ fails, repeat at a higher level until limits are met. | | Precision/Bias | |

# SAP Worksheet #29—Project Documents and Records Table

| Document | Where Maintained |
|---|---|
| • Field Notebooks<br>• Chain-of-Custody Records<br>• Air Bills<br>• Telephone Logs<br>• Custody Seals<br>• CA Forms<br>• Electronic data deliverables (EDDs)<br>• ID of QC Samples<br>• Meteorological Data from Field<br>• Sampling Instrument Calibration Logs<br>• Sampling Locations and Sampling Plan<br>• Sampling Notes and Drilling Logs<br>• Water Quality Parameter<br>• Sample Receipt, Chain of Custody, and Tracking Records<br>• Standard Traceability Logs<br>• Equipment Calibration Logs<br>• Sample Preparation Logs<br>• Run Logs<br>• Equipment Maintenance, Testing, and Inspection Logs<br>• CA Forms<br>• Reported Field Sample Results<br>• Reported Result for Standards, QC Checks, and QC Samples<br>• Instrument printouts (raw data) for Field Samples, Standards, QC Checks, and QC Samples<br>• Data Package Completeness Checklists<br>• Sample disposal records<br>• Extraction/Clean-up Records<br>• Raw Data (archived per Navy CLEAN contract)<br>• DV Reports<br>• CA Forms<br>• Laboratory QA Plan<br>• Field Performance Audit Checklists<br>• Method Detection Limit Study Information | • Field data deliverables (e.g., field notes entries, chains-of-custody, air bills, and EDDs) will be kept on CH2M's network server.<br>• Field parameter data will be loaded with the analytical data into the Navy database<br>• Analytical laboratory hard copy deliverables and DV reports will be saved on the network server and archived per the Navy CLEAN contract.<br>• Electronic data from the laboratory will be loaded into Navy database<br>• Following project completion, hard copy deliverables (e.g., field notes, chains of custody) will be archived at Iron Mountain:<br>Iron Mountain Headquarters<br>745 Atlantic Avenue<br>Boston, MA 02111<br>(800) 899-IRON<br>• Following project completion, hard copy deliverables including chains of custody and raw data will be archived at the Washington National Records Center:<br>Washington National Records Center<br>4205 Suitland Road<br>Suitland, Maryland 20746-8001<br>301-778-1550 |

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## SAP Worksheet #30—Analytical Services Table

| Matrix | Analytical Group | Sample Locations/ID | Analytical Method | Data Package Turnaround Time | Laboratory/ Organization | Backup Laboratory/ Organization[1] |
|---|---|---|---|---|---|---|
| Groundwater | PFAS | Refer to **Worksheets #18** and **#20** | LC/MS/MS Compliant with QSM v. 5.1.1, Table B-15[2] | 3 Days/28 Days | Battelle Analytical Services<br>141 Longwater Drive<br>Suite 202<br>Norwell, MA 02061<br>POC: Jonathan Thorn<br>(781) 681-5565 | For PFAS:<br>Vista Analytical<br>For Geotechnical Analyses: TBD |
| Soil | | | | 3 Days/28 Days | | |
| Soil | Dry Bulk Density | | ASTM D2937 | 28 days | CORE Laboratories<br>3437 Landco Dr.<br>Bakersfield, CA 93308<br>POC: Larry Kunkel<br>(661) 325-5657 | |
| Soil | Total Porosity | | API RP40 | | | |
| Soil | Fractional Organic Carbon | | Walkley Black | | | |
| Soil | Grain Size | | ASTM D422 | | | |

Notes:

[1] Backup laboratory will be determined if necessary for the geotechnical parameters.

[2] Analytical method is compliant with QSM v. 5.1.1 Table B-15 or the most recent version of the QSM for which Battelle has DoD ELAP certification.

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# SAP Worksheet #31—Planned Project Assessments Table

| Assessment Type | Frequency | Internal or External | Organization Performing Assessment | Person(s) Responsible for Performing Assessment (title and organizational affiliation) | Person(s) Responsible for Responding to Assessment Findings (title and organizational affiliation) | Person(s) Responsible for Identifying and Implementing CA (title and organizational affiliation) | Person(s) Responsible for Monitoring Effectiveness of CA (title and organizational affiliation) |
|---|---|---|---|---|---|---|---|
| Field Performance Audit | One during sampling event | Internal | CH2M | PM<br>CH2M | FTL<br>CH2M | PM<br>CH2M | PM<br>CH2M |
| Safe Work Observation | One during sampling event | Internal | CH2M | SSC<br>CH2M | Field Team Member observed<br>CH2M | HSM<br>CH2M | SSC<br>CH2M |
| Field Document Review | Daily during sampling event | Internal | CH2M | PM or Task Manager<br>CH2M | FTL<br>CH2M | PM<br>CH2M | PM<br>CH2M |

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# SAP Worksheet #32—Assessment Findings and Corrective Action Responses

| Assessment Type | Nature of Deficiencies Documentation | Individual(s) Notified of Findings (name, title, organization) | Timeframe of Notification | Nature of CA Response Documentation | Individual(s) Receiving CA Response (name, title, organization) | Timeframe for Response |
|---|---|---|---|---|---|---|
| Field Performance Audit | Checklist and Written Audit Report | TBD, FTL, CH2M | Within 1 day of audit | Verbal and Memorandum | FTL<br>CH2M | Within 1 day of receipt of CA Form |
| Safe Behavior Observation (SBO) | SBO Form | Loren Kaehn, HSM, CH2M | Within 1 week of SBO | Memorandum | Field Team Member<br>CH2M | Immediately |
| Field Document Review | Markup copy of field documentation | TBD, FTL, CH2M | Within 1 day of review | Verbal and Memorandum | FTL<br>CH2M | Within 1 day of receipt of markup |
| Offsite Laboratory Technical Systems Audit | TBD by Laboratory Accreditation Bureau | TBD, Battelle Analytical Services | Within 2 months of audit | Memorandum | TBD by Laboratory Accreditation Bureau | Within 2 months of receipt of initial notification. |

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# SAP Worksheet #32-1—Laboratory Corrective Action Form

Person initiating CA: ________________________________________________ Date: _____________

Description of problem and when identified:

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

Cause of problem, if known or suspected:

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

Sequence of CA: (including date implemented, action planned and personnel/data affected)

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

CA implemented by: ______________________________________ Date: _________________________

CA initially approved by: ______________________________________ Date: _________________________

Follow-up date: ______________________________________

Final CA approved by: ______________________________________ Date: _________________________

Information copies to:

Anita Dodson, CH2M Navy CLEAN Program Chemist

_________________________________

_________________________________

_________________________________

_________________________________

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# SAP Worksheet #32-2—Field Performance Audit Checklist

## Project Responsibilities

Project No.: ____________________ Date: ____________________

Project Location: ____________________ Signature: ____________________

## Team Members

Yes No 1) Is the approved work plan being followed?

Comments ________________________________________

________________________________________

Yes No 2) Was a briefing held for project participants?

Comments ________________________________________

________________________________________

Yes No 3) Were additional instructions given to project participants?

Comments ________________________________________

________________________________________

## Sample Collection

Yes No 1) Is there a written list of sampling locations and descriptions?

Comments ________________________________________

________________________________________

Yes No 2) Are samples collected as stated in the Master SOPs?

Comments ________________________________________

________________________________________

Yes No 3) Are samples collected in the type of containers specified in the work plan?

Comments ________________________________________

________________________________________

Yes No 4) Are samples preserved as specified in the work plan?

Comments ________________________________________

________________________________________

Yes No 5) Are the number, frequency, and type of samples collected as specified in the work plan?

Comments ________________________________________

________________________________________

## Worksheet #32-2—Field Performance Audit Checklist (continued)

Yes No 6) Are QA checks performed as specified in the work plan?

Comments ______________________________

Yes No 7) Are photographs taken and documented?

Comments ______________________________

**Document Control**

Yes No 1) Have any accountable documents been lost?

Comments ______________________________

Yes No 2) Have any accountable documents been voided?

Comments ______________________________

Yes No 3) Have any accountable documents been disposed of?

Comments ______________________________

Yes No 4) Are the samples identified with sample tags?

Comments ______________________________

Yes No 5) Are blank and duplicate samples properly identified?

Comments ______________________________

Yes No 6) Are samples listed on a chain-of-custody record?

Comments ______________________________

Yes No 7) Is chain of custody documented and maintained?

Comments ______________________________

# SAP Worksheet #32-3—Safe Behavior Observation Form

| | | | |
|---|---|---|---|
| ☐ Federal or ☐ Commercial Sector (check one) | | ☐ Construction or ☐ Consulting (check one) | |
| Project Number: | | Client/Program: | |
| Project Name: | | Observer: | Date: |
| Position/Title of Worker Observed: | | Background Information/ comments: | |
| Task/Observation Observed: | | | |

- ❖ Identify and reinforce safe work practices/behaviors
- ❖ Identify and improve on at-risk practices/acts
- ❖ Identify and improve on practices, conditions, controls, and compliance that eliminate or reduce hazards
- ❖ Proactive PM support facilitates eliminating/reducing hazards (do you have what you need?)
- ❖ Positive, corrective, cooperative, collaborative feedback/recommendations

| Actions & Behaviors | Safe | At-Risk | Observations/Comments |
|---|---|---|---|
| Current and accurate Pre-Task Planning/Briefing (for example, Project Safety Plan, Safety Training and Consulting, activity hazard analysis, Pre-task Safety Plan, tailgate briefing, as needed) | | | **Positive Observations/Safe Work Practices:** |
| Properly trained/qualified/ experienced | | | |
| Tools/Equipment Available and Adequate | | | |
| Proper Use of Tools | | | **Questionable Activity/Unsafe Condition Observed:** |
| Barricades/Work Zone Control | | | |
| Housekeeping | | | |
| Communication | | | |
| Work Approach/Habits | | | |
| Attitude | | | |
| Focus/Attentiveness | | | **Observer's CAs/Comments:** |
| Pace | | | |
| Uncomfortable/Unsafe Position | | | |
| Inconvenient/Unsafe Location | | | |
| Position/Line of Fire | | | |
| Apparel (hair, loose clothing, jewelry) | | | |
| Repetitive motion | | | **Observed Worker's CAs/Comments:** |
| Other | | | |

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# SAP Worksheet #33—QA Management Reports Table

| Type of Report | Frequency (daily, weekly monthly, quarterly, annually, and so forth) | Projected Delivery Date(s) | Person(s) Responsible for Report Preparation (title and organizational affiliation) | Report Recipient(s) (title and organizational affiliation) |
|---|---|---|---|---|
| Field Audit Report | One during sampling event | TBD | PM<br>CH2M | Included in project files |
| QA Management Report/Technical Memorandum | Once results have been assessed for data usability | To be submitted with Final Supplemental SI Report | CH2M Project Chemist | NAVFAC Northwest RPM and will be posted in project file. |

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# SAP Worksheet #34-36—Data Verification and Validation (Steps I and IIa/IIb) Process Table

| Data Review Input | Description[c] | Responsible for Verification or Validation | Step I/IIa/IIb[a] | Internal/ External[b] |
|---|---|---|---|---|
| Field Notebooks | Field notebooks will be reviewed internally and placed into the project file for archival at project closeout. | FTL/CH2M | Step I | Internal |
| Chains-of-Custody and Shipping Forms | Chain of custody 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 chain of custody forms will be initialed by the reviewer, a copy of the chains of custody forms retained in the site file, and the original and remaining copies taped inside the cooler for shipment. Chain of custody forms will also be reviewed for adherence to the SAP by the PC. | FTL/CH2M<br>PC/CH2M | Step I | Internal and External |
| Sample Condition upon Receipt | Any discrepancies, missing, or broken containers will be communicated to the PC in the form of laboratory logins. | PC/CH2M | Step I | External |
| Documentation of Laboratory Method Deviations | Laboratory Method Deviations will be discussed and approved by the PC. Documentation will be incorporated into the case narrative, which becomes part of the final hard copy data package. | PC/CH2M | Step I | External |
| EDDs | EDDs will be compared against hard copy laboratory results (10 percent check). If errors are found during the 10% check, an additional 25% of the EDDs will be checked against hard copy laboratory results. | PC/CH2M | Step I | External |
| Case Narrative | Case narratives will be reviewed by the DV during the DV process. This is verification that they were generated and applicable to the data packages. | DV | Step I | External |
| Laboratory Data | All laboratory data packages will be verified internally by the laboratory performing the work for completeness and technical accuracy prior to submittal. | Laboratory QAO | Step I | Internal |
| Laboratory Data | The data will be verified for completeness by the PC. To ensure completeness, EDDs will be compared to the SAP. This is a verification that all samples were included in the laboratory data and that correct analyte lists were reported. | PC/CH2M | Step I | External |
| Audit Reports | Upon report completion, a copy of all audit reports will be placed in the site file. If CAs are required, a copy of the documented CA taken will be attached to the appropriate audit report in the QA site file. Periodically, and at the completion of site work, site file audit reports and CA forms will be reviewed internally to ensure that all appropriate CAs have been taken and that CA reports are attached. If CAs have not been taken, the site manager will be notified to ensure action is taken. | PM/CH2M<br>PC/CH2M | Step I | Internal |

# SAP Worksheet #34-36—Data Verification and Validation (Steps I and IIa/IIb) Process Table (continued)

| Data Review Input | Description[c] | Responsible for Verification or Validation | Step I/IIa/IIb[a] | Internal/ External[b] |
|---|---|---|---|---|
| CA Reports | CA reports will be reviewed by the PC or PM and placed into the project file for archival at project closeout. | PM/CH2M<br>PC/CH2M | Step I | External |
| Laboratory Methods | During the pre-validation check, ensure that the laboratory analyzed samples using the correct methods specified in the SAP. If methods other than those specified in the SAP were used, the reason will be determined and documented. | PC/CH2M | Step IIa | External |
| Target Compound List and Target Analyte list | During the pre-validation check, ensure that the laboratory reported all analytes from each analysis group as per **Worksheet #15**. If the target compound list is not correct, then it must be corrected prior to sending the data for validation. Once the checks are complete, the project manager is notified via email | PC/CH2M | Step IIa | External |
| Laboratory Limits (DL/LOD/LOQ) | During the pre-validation check, the laboratory limits (DL/LOD/LOQ) will be compared to those listed in the project SAP. If limits were not met, the laboratory will be contacted and asked to provide an explanation, which will then be discussed in the associated project report. Often times the cause for minor laboratory limit deviation from those presented in the SAP is due to the quarterly update of laboratory LOD. | PC/CH2M | Step IIb | External |
| Laboratory SOPs | Ensure that approved analytical laboratory SOPs were followed. Any such discrepancies will be discussed first in the data validation narrative and will be included in the associated project report. | Laboratory QAO | Step I | Internal |
| Sample Chronology | Holding times from collection to extraction or analysis and from extraction to analysis will be considered during the data validation process. | DV | Step IIa and IIb | External |
| Raw Data | Ten percent review of raw data to confirm laboratory calculations. For a recalculated result, the DV attempts to re-create the reported numerical value. The laboratory is asked for clarification if a discrepancy is identified, which cannot reasonably be attributed to rounding. In general, this is outside five percent difference. Conduct a ten percent review of laboratory calculations.  For a recalculated result, the DV attempts to recreate the reported numerical value. The laboratory is asked for clarification if a discrepancy is found, which cannot be reasonably attributed to rounding. If errors are found during the 10% check, an additional 20 percent of the raw data will be checked to confirm calculations. Any discrepancies will be addressed in the data validation narrative. | DV | Step IIa | External |
| Onsite Screening | All non-analytical field data will be reviewed against SAP requirements for completeness and accuracy based on the field calibration records. Screening data will be included in the project report. | FTL/CH2M | Step IIb | Internal |

## SAP Worksheet #34-36—Data Verification and Validation (Steps I and IIa/IIb) Process Table (continued)

| **Data Review Input** | **Description[c]** | **Responsible for Verification or Validation** | **Step I/IIa/IIb[a]** | **Internal/ External[b]** |
|---|---|---|---|---|
| Documentation of Method QC Results | Establish that all required QC samples were run and met limits. Any deviations will be reported in the data validation narrative. | DV | Step IIa | External |
| Documentation of Field QC Sample Results | Establish that all required QC samples were run and met limits and discuss QC sampling in the associated project report. | PC/CH2M | Step IIa | Internal |
| DoD ELAP Evaluation | Ensure that each laboratory is DoD ELAP certified for the analyses they are to perform. Ensure evaluation timeframe does not expire. | PC/CH2M | Step I | External |
| Analytical data for Geotechnical Parameters | Data is for screening purposes only and will be reviewed by project chemist and project team. | PC/CH2M | Step I | Internal |
| Analytical data for PFAS analyzed for soil and groundwater[d] | Analytical methods and laboratory SOPs as presented in this SAP will be used to evaluate compliance against QA/QC criteria. Should adherence to QA/QC criteria yield deficiencies, data may be qualified. Data may be qualified if QA/QC exceedances have occurred. Guidance and qualifiers from “United States Department of Defense General Data Validation Guidelines” (DoD, 2018a) and “Per- and Polyfluoroalkyl Substances (PFAS): Reviewing Analytical Methods for Environmental Samples” Technical brief (USEPA, 2019) will be applied as appropriate. As specific modules for the analytical methods in this project are published, the data validators will refer to those modules for guidance. In the meantime, if specific guidance is not given for these methods in the General Data Validation Guidelines, the data validator may adapt the guidance from "USEPA National Functional Guidelines for Superfund Organic Methods Data Review" (USEPA, 2017a), may also be applicable. | DV | Step IIa and IIb | External |

Notes:

[a] Verification (Step I) is a completeness check that is performed before the data review process continues to determine whether the required information (complete data package) is available for further review. Validation (Step IIa) is a review that the data generated is in compliance with analytical methods, procedures, and contracts. Validation (Step IIb) is a comparison of generated data against measurement performance criteria in the SAP (both sampling and analytical).

[b] Internal or external is in relation to the data generator.

[c] Should CH2M find discrepancies during the verification or validation procedures above, an email documenting the issue will be circulated to the internal project team, and a Corrections to File Memo will be prepared identifying the issues and the corrective action needed. This memo will be sent to the laboratory, or applicable party, and maintained in the project file.

[d] Stage 4 data validation will be performed on 10% of all definitive analyses which will include recalculated results from the raw data to verify calculations. The remaining (90%) of the definitive data will have Stage 2B data validation performed.

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# SAP Worksheet #37—Usability Assessment

**Summarize the usability assessment process and all procedures, including interim steps and any statistics, equations, and computer algorithms that will be used:**

- Non-detected site contaminants will be evaluated to ensure that project required PQLs in **Worksheet #15** were achieved. If PQLs were achieved and the verification and validation steps yielded acceptable data, then the data are considered usable.
- During verification and validation steps, data may be qualified as estimated with the following qualifiers: J or UJ. The qualifiers represent minor QC deficiencies, which will not affect the usability of the data. When major QC deficiencies are encountered, data will be qualified with an R and in most cases is not considered usable for project decisions.
  - J = Analyte present. Reported value may or may not be accurate or precise.
  - J+ = Analyte present. Reported value is estimated and may be biased high.
  - J- = Analyte present. Reported value is estimated and may be biased low.
  - UJ = Analyte not detected. Associated non-detect value may be inaccurate or imprecise.
  - R = Rejected result, team discussion. Result not reliable.
  - X = Result recommended for rejection by the validator. Result not reliable.
- The following additional qualifiers may be given by the validator:
  - N = Tentative ID. Consider Present. Special methods may be needed to confirm its presence or absence in future sampling efforts.
  - NJ = Qualitative ID questionable due to poor resolution. Presumptively present at approximate quantity.
  - U = Not Detected.
- Analytical data will be checked to ensure the values and any qualifiers are appropriately transferred to the electronic database. The checks include comparison of hardcopy data and qualifiers to the EDD. Once the data have been uploaded into the electronic database, another check will be performed to ensure all results were loaded accurately.
- Field and laboratory precision will be compared as RPD between the two results.
- Deviations from the SAP will be reviewed to assess whether CA is warranted and to assess impacts to achievement of project objectives.

**Describe the evaluative procedures used to assess overall measurement error associated with the project.**

- To assess whether a sufficient quantity of acceptable data is available for decision making, the data will be compared to the 95 percent completeness goal and reconciled with MPC following validation and review of DQI.
- If significant biases are detected with laboratory QA/QC samples, they will be evaluated to assess impact on decision making. Low biases will be described in greater detail as they represent a possible inability to detect compounds that may be present at the site.
- If significant deviations are noted between laboratory and field precision, the cause will be further evaluated to assess impact on decision making.

# SAP Worksheet #37—Usability Assessment (continued)

**Describe the documentation that will be generated during the usability assessment and how usability assessment results will be presented so that they identify trends, relationships (correlations), and anomalies:**

The following will be prepared by CH2M and presented to and submitted to NAVFAC Northwest for review and decisions on the path forward for the site:

- Data tables will be produced to reflect detected and non-detected site analytes. Data qualifiers will be reflected in the tables and discussed in the data quality evaluation and will be provided in a technical memorandum.

**Identify the personnel responsible for performing the usability assessment.**

The CH2M team, including the PM and PC, will review the data and present to NAVFAC Northwest for review and approval of usability.

# References

Department of Defense (DoD). 2018. Quality Systems Manual for Environmental Laboratories Version 5.1.1.

Department of Defense (DoD). 2018a. General Data Validation Guidelines. Environmental Data Quality Workgroup. February 9.

Island County. 2005. *Island County Water Resource Management Plan.* 2514 Watershed Planning. Adopted by the Board of Island County Commissioners. June 20.

Island County. 2016. *Island County Hydrogeologic Database Well Search Utility Data*. Data Generated on November 4.

Naval Facilities Engineering Command (NAVFAC). 2017. Interim Per- and Polyfluoroalkyl Substances (PFAS) Site Guidance for NAVFAC Remedial Project Managers. September.

Department of the Navy (Navy). 1994. *Final Remedial Investigation Report for Operable Unit 3, Naval Air Station Whidbey Island. Prepared for Engineering Field Activity Northwest, Naval Facilities Engineering Command by URS Consultants Under Contract No. N62474-89-D-9295, CTO 0074*. January.

Navy. 2017a. *Interim Per- and Polyfluoroalkyl Substances (PFAS) Site Guidance for NAVFAC Remedial Project Managers (RPMs)/September 2017 Update.* September.

Navy. 2017b. *Sampling and Analysis Plan, Investigation of Perfluorinated Compounds in Drinking Water, Ault Field and Outlying Landing Field Coupeville*, Naval Air Station Whidbey Island, Oak Harbor and Coupeville, Washington. January.

Navy. 2017c. *Sampling and Analysis Plan, Site Inspection for Perfluorinated Compounds in Groundwater, Outlying Landing Field Coupeville*, NAS Whidbey Island, Coupeville, Washington. January.

Navy. 2017d. *Sampling and Analysis Plan, Monitoring Well Installation, Aquifer Testing, Drinking Water Sampling, and Groundwater Sampling, Outlying Landing Field Coupeville*, NAS Whidbey Island, Coupeville, Washington. December.

Navy. 2018a. *Final Technical Memorandum Evaluation of Per- and Polyfluoroalkyl Substances in Groundwater Outlying Landing Field Coupeville*, Naval Air Station Whidbey Island Coupeville, Washington. May.

Navy. 2018b. *Aquifer Test, Groundwater Sampling, and Drinking Water Sampling Data Evaluation and Groundwater Modeling Report, Per- and Polyfluoroalkyl Substances (PFAS), Outlying Landing Field Coupeville,* Naval Air Station Whidbey Island Oak Harbor and Coupeville, Washington. September.

Navy. 2018c. *Preliminary Assessment for Per- and Polyfluoroalkyl Substances (PFAS), Outlying Landing Field Coupeville,* Naval Air Station Whidbey Island Oak Harbor and Coupeville, Washington. November.

Polenz, Michael, Stephen L. Slaughter, and Gerald W. Thorsen. 2005. Geologic Map of the Coupeville and Part of the Port Townsend North, 7.5-minute Quadrangles, Island County, Washington. June.

Robinson Noble, Inc. 2008. Town of Coupeville Keystone Hill Well Construction and Testing Report. Tacoma, Washington. April.

United States Environmental Protection Agency (USEPA). 2002. *Guidance for Quality Assurance Project Plans, USEPA QA/G-5.* EPA/240/R-02/009. December.

USEPA. 2005. *Uniform Federal Policy for Quality Assurance Project Plans: Evaluating, Assessing, and Documenting Environmental Data Collection and Use Programs - Part 1: UFP-QAPP Manual.* Intergovernmental Data Quality Task Force. EPA-505-B-04-900A. Final Version 1. March.

USEPA. 2006. *Guidance on Systematic Planning Using the Data Quality Objectives Process. EPA QA/G-4.* EPA/240/B-06/001. February.

USEPA. 2017a. *National Functional Guidelines for Superfund Organic Data Review.*

USEPA. 2019. *Per-and Polyfluoroalkyl Substances (PFAS): Reviewing Analytical Methods for Environmental Samples.* EPA/600/F-19/056. April 2019.

United States Geological Survey (USGS). 1982. Preliminary Survey of Ground-water Resources for Island County, Washington.

# Figures

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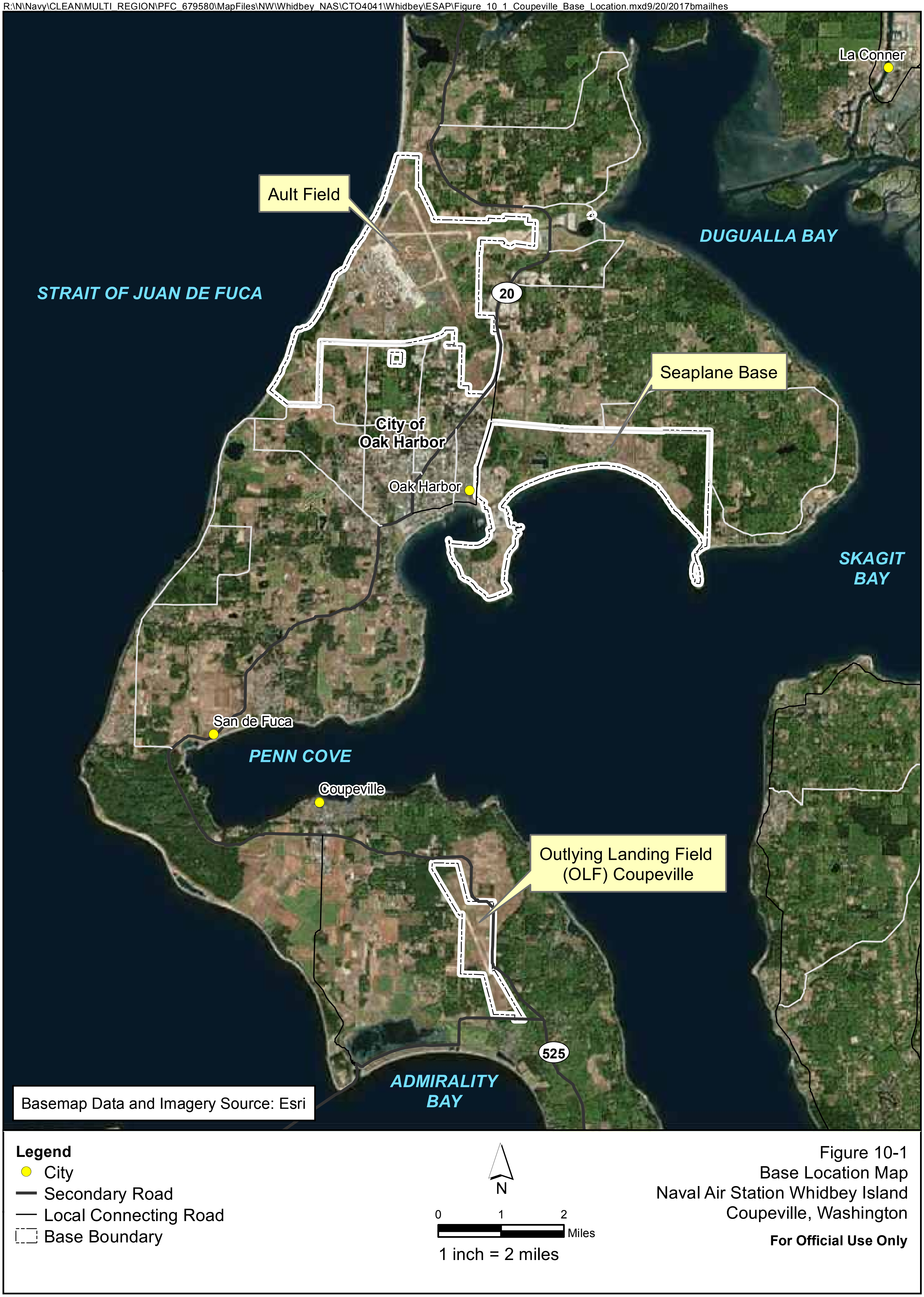
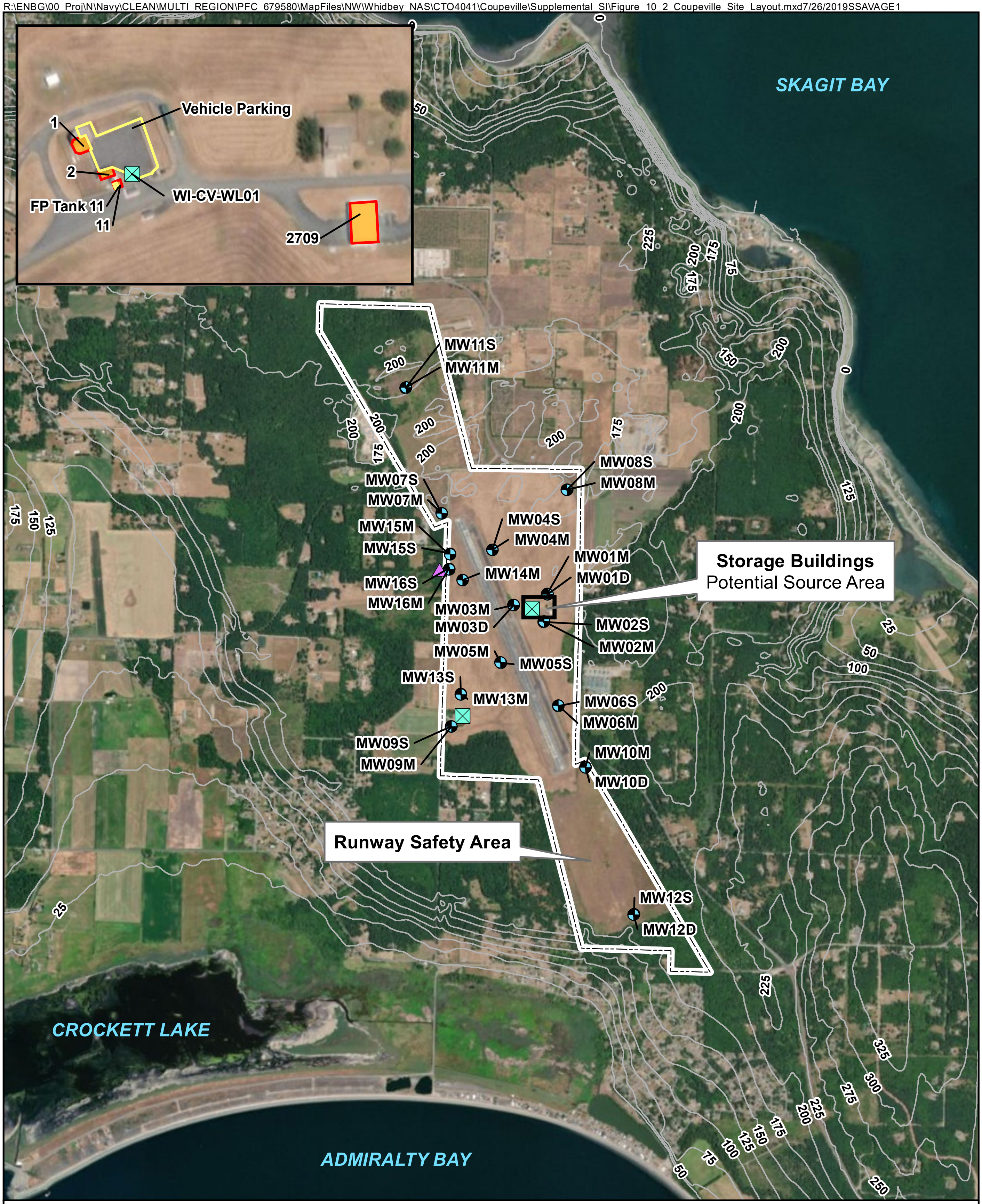


Figure 10-1
Base Location Map
Naval Air Station Whidbey Island
Coupeville, Washington

**For Official Use Only**



**Legend**

◉ Monitoring Well Location

▲ Keystone Hill Well Location

☒ OLF Coupeville Supply Well

— Elevation Contour (25 ft Interval)

☐ Building Location

☐ Structure Location

▇ Potential PFAS Release Area

⬚ Base Boundary

N

0 0.25 0.5 Mile

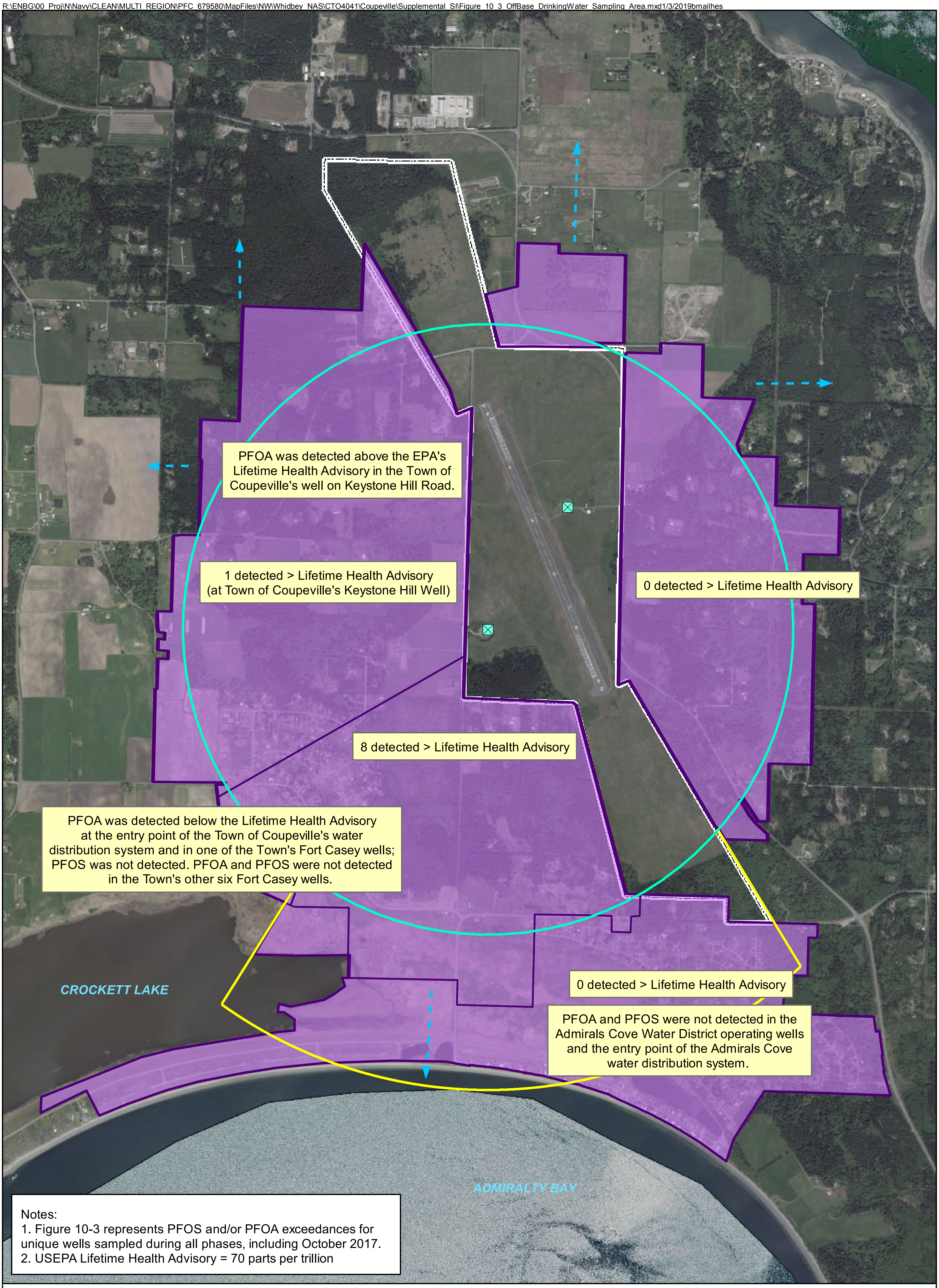
1 inch = 0.5 mile

Imagery Source: Esri

Figure 10-2
Site Layout Map
Outlying Landing Field Coupeville
Coupeville, Washington

**For Official Use Only**

R:\ENBG\00_Proj\N\Navy\CLEAN\MULTI_REGION\PFC_679580\MapFiles\NW\Whidbey_NAS\CTO4041\Coupeville\Supplemental_SI\Figure_10_3_OffBase_DrinkingWater_Sampling_Area.mxd1/3/2019bmailhes



PFOA was detected above the EPA's Lifetime Health Advisory in the Town of Coupeville's well on Keystone Hill Road.

1 detected > Lifetime Health Advisory (at Town of Coupeville's Keystone Hill Well)

0 detected > Lifetime Health Advisory

8 detected > Lifetime Health Advisory

PFOA was detected below the Lifetime Health Advisory at the entry point of the Town of Coupeville's water distribution system and in one of the Town's Fort Casey wells; PFOS was not detected. PFOA and PFOS were not detected in the Town's other six Fort Casey wells.

0 detected > Lifetime Health Advisory

PFOA and PFOS were not detected in the Admirals Cove Water District operating wells and the entry point of the Admirals Cove water distribution system.

Notes:
1. Figure 10-3 represents PFOS and/or PFOA exceedances for unique wells sampled during all phases, including October 2017.
2. USEPA Lifetime Health Advisory = 70 parts per trillion

**Legend**

- ☒ OLF Coupeville Supply Well
- ▭ 1-mile zone
- ▨ Phases 1 and 2 and October 2017 Combined Sampling Area
- — Half-mile Step-out Downgradient
- → Approximate Groundwater Flow Direction
- ⬚ Base Boundary

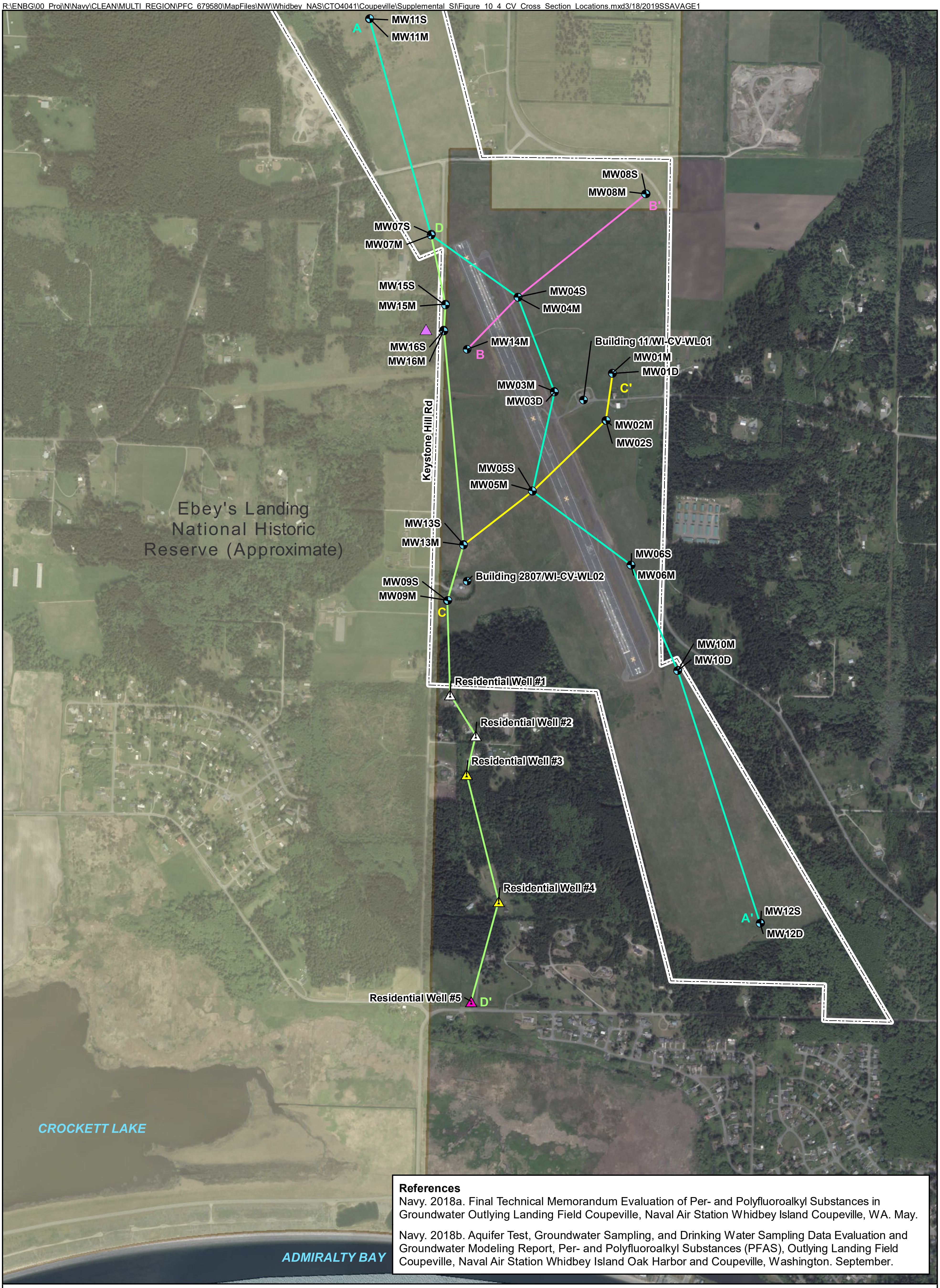
N

0 0.15 0.3 Miles

1 inch = 0.3 miles

Imagery Source: Esri

Figure 10-3
Off-Base Drinking Water Sampling Area
Naval Air Station Whidbey Island
Coupeville, Washington



**References**

Navy. 2018a. Final Technical Memorandum Evaluation of Per- and Polyfluoroalkyl Substances in Groundwater Outlying Landing Field Coupeville, Naval Air Station Whidbey Island Coupeville, WA. May.

Navy. 2018b. Aquifer Test, Groundwater Sampling, and Drinking Water Sampling Data Evaluation and Groundwater Modeling Report, Per- and Polyfluoroalkyl Substances (PFAS), Outlying Landing Field Coupeville, Naval Air Station Whidbey Island Oak Harbor and Coupeville, Washington. September.

**Legend**

- ● Groundwater Well Location
- ▲ Keystone Hill Well Location

**Well Depths**

- ▲ < 60 ft bgs
- △ 151 - 200 ft bgs
- ▲ >201 ft bgs

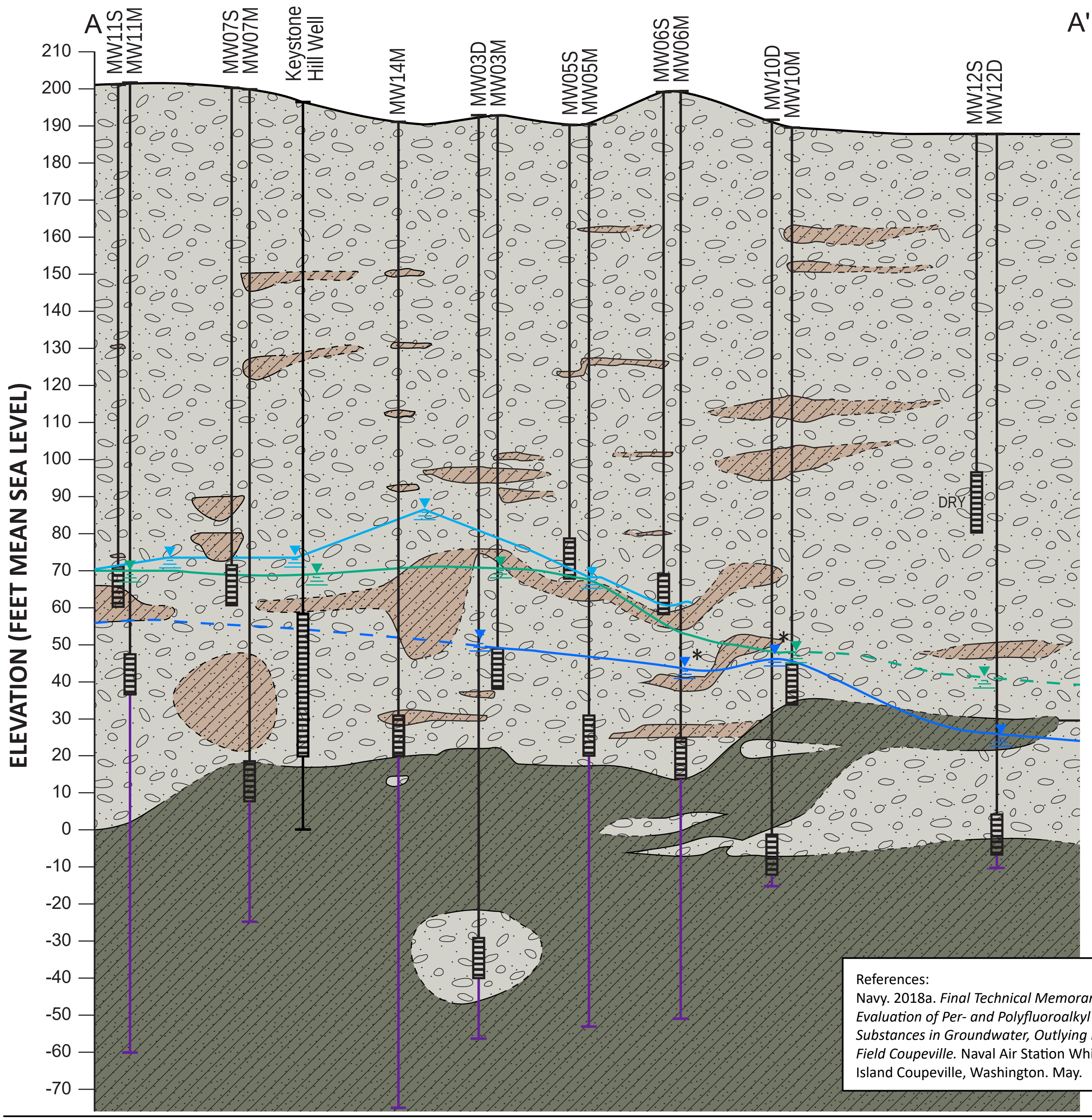
- — Cross Section A-A'
- — Cross Section B-B'
- — Cross Section C-C'
- — Cross Section D-D'
- ⬚ Base Boundary
- ⬚ Ebey's Landing National Historic Reserve (Approximate)

1 inch = 0.2 mile

Imagery Source: Esri

Figure 10-4
Cross Section Locations
Outlying Landing Field Coupeville
Naval Air Station Whidbey Island
Coupeville, Washington

For Official Use Only



**LEGEND**

- ▨ Sand and Gravel, Some Silt and Clay
- ▨ Clay and Silt
- ▨ Clay/Silt, Claystone, Some Organics and Peat
- ▼ Water Table Shallow-Screened Interval (March 3, 2017)
- ▼ Potentiometric Surface Intermediate-Screened Interval (March 3, 2017)
- ▼ Potentiometric Surface Deep-Screened Interval (March 3, 2017)

**Wells**

- MW00X ← Boring Identification Number
- ← Permanent Monitoring Well
- ← Well Screen
- ← Portion of Boring Completed for Lithology Only

Notes:

*Water level anomalous data estimated from March 18, 2017 round.

Cross section is vertically exaggerated for visualization purposes.

Cross section is conceptual in nature; predominant soil type was generally used for stratigraphic interpretation, however, in some cases similar units were combined for the purpose of simplification.

Geologic contacts are dashed where inferred.

| 0 | .25 | .5 |
|---|---|---|

Approximate horizontal scale in miles

References:

Navy. 2018a. *Final Technical Memorandum Evaluation of Per- and Polyfluoroalkyl Substances in Groundwater, Outlying Landing Field Coupeville.* Naval Air Station Whidbey Island Coupeville, Washington. May.

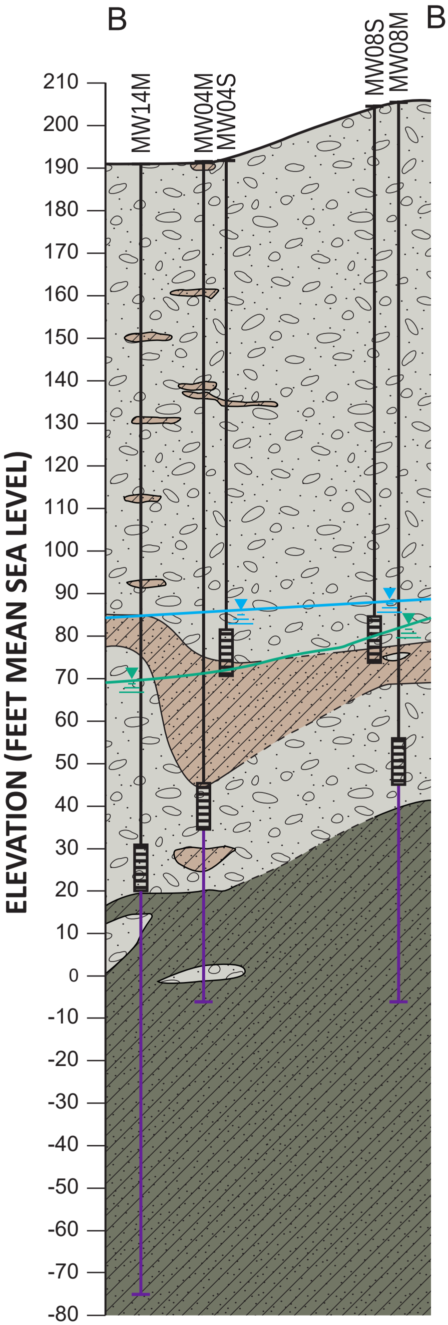
**Figure 10-5**

**Cross Section A-A'**

**Outlying Landing Field Coupeville**

*Naval Air Station Whidbey Island*

*Coupeville, Washington*



**LEGEND**

▨ Sand and Gravel, Some Silt and Clay

▨ Clay and Silt

▨ Clay/Silt, Claystone,
Some Organics and Peat

▼ Water Table Shallow-Screened Interval
(March 3, 2017)

▼ Potentiometric Surface
Intermediate-Screened Interval
(March 3, 2017)

**Wells**

MW00X ← Boring Identification Number

← Permanent Monitoring Well

← Well Screen

← Portion of Boring Completed
for Lithology Only

Notes:

Cross section is vertically exaggerated for visualization purposes.

Cross section is conceptual in nature; predominant soil type was generally used for stratigraphic interpretation, however, in some cases similar units were combined for the purpose of simplification.

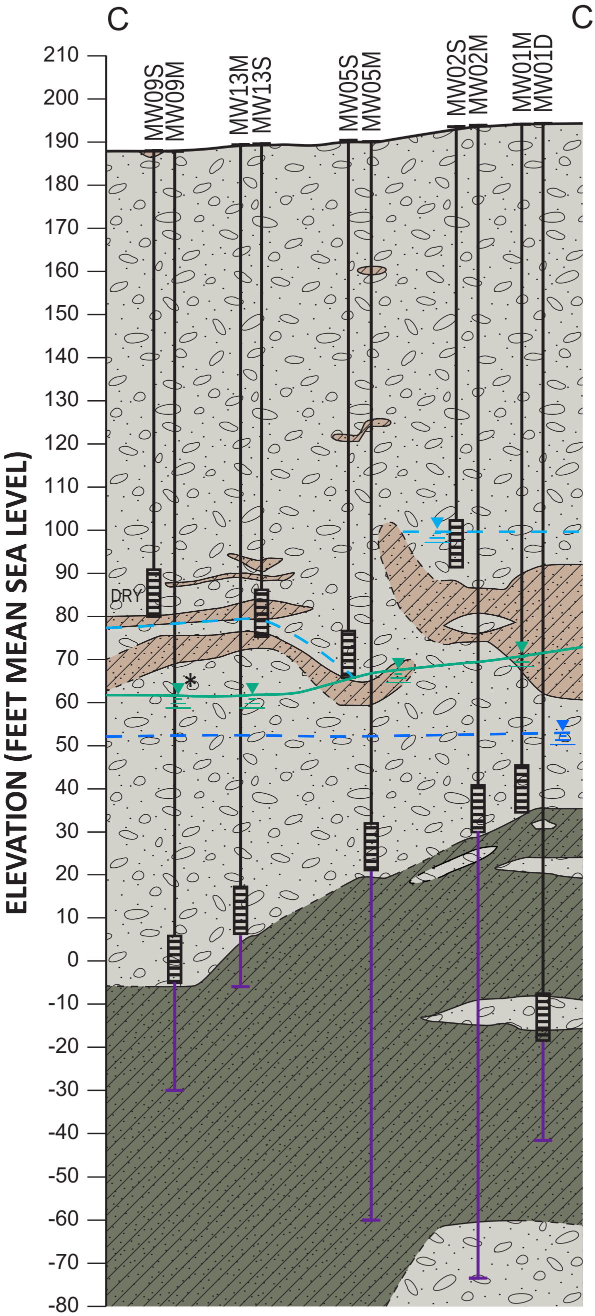
Geologic contacts are dashed where inferred.

0 .25 .5

Approximate horizontal scale in miles

References:
Navy. 2018a. *Final Technical Memorandum Evaluation of Per- and Polyfluoroalkyl Substances in Groundwater, Outlying Landing Field Coupeville.* Naval Air Station Whidbey Island Coupeville, Washington. May.

**Figure 10-6**
**Cross Section B-B'**
**Outlying Landing Field Coupeville**
*Naval Air Station Whidbey Island*
*Coupeville, Washington*



**LEGEND**

▨ Sand and Gravel, Some Silt and Clay

▨ Clay and Silt

▨ Clay/Silt, Claystone,
Some Organics and Peat

▼ Water Table Shallow-Screened Interval
(March 3, 2017)

▼ Potentiometric Surface
Intermediate-Screened Interval
(March 3, 2017)

▼ Potentiometric Surface
Deep-Screened Interval
(March 3, 2017)

**Wells**

MW00X ← Boring Identification Number

← Permanent Monitoring Well

← Well Screen

← Portion of Boring Completed
for Lithology Only

Notes:

*Water level anomalous data estimated from March 18, 2017 round.

Cross section is vertically exaggerated for visualization purposes.

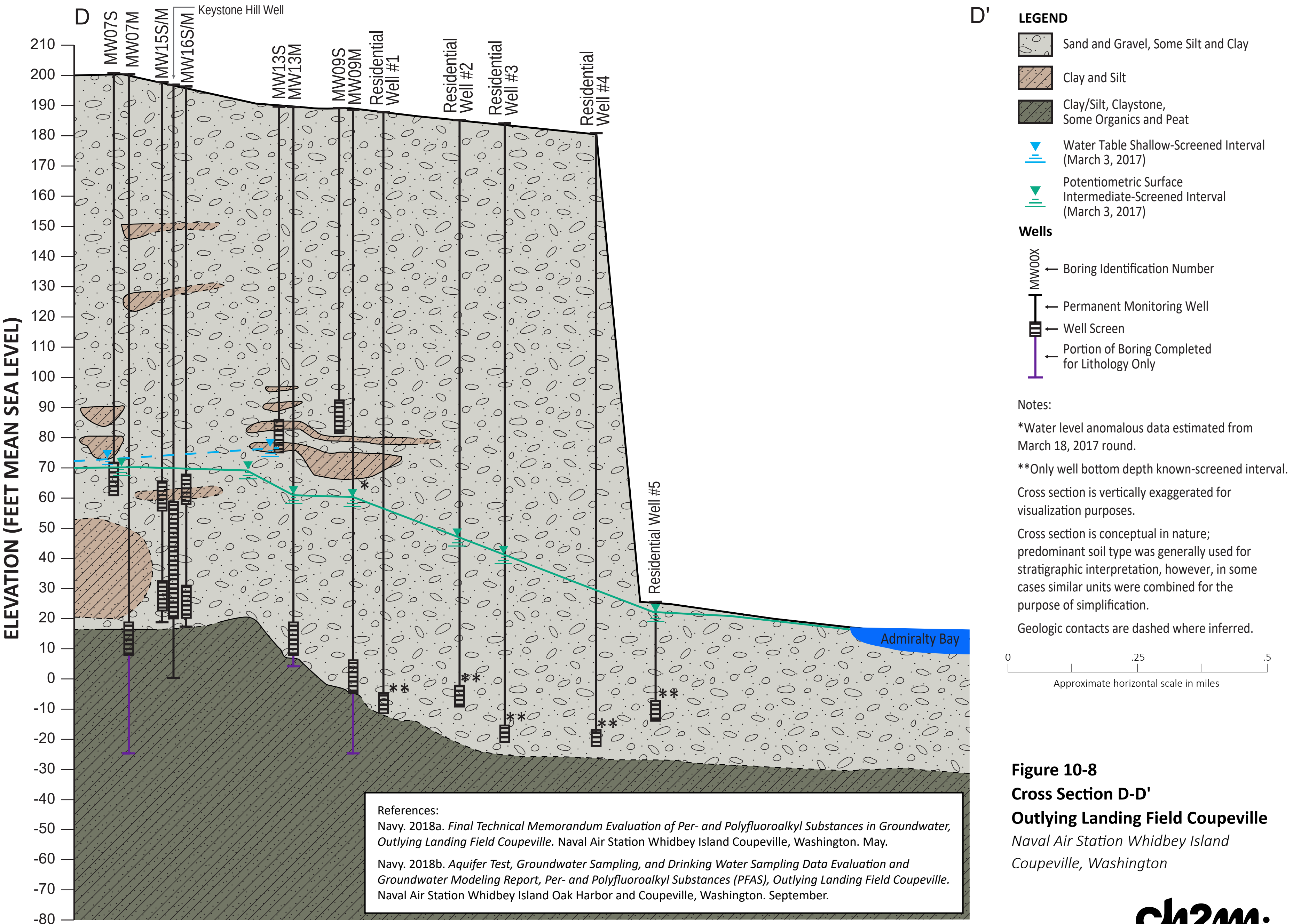
Cross section is conceptual in nature; predominant soil type was generally used for stratigraphic interpretation, however, in some cases similar units were combined for the purpose of simplification.

Geologic contacts are dashed where inferred.

0 .25 .5
Approximate horizontal scale in miles

References:
Navy. 2018a. *Final Technical Memorandum Evaluation of Per- and Polyfluoroalkyl Substances in Groundwater, Outlying Landing Field Coupeville.* Naval Air Station Whidbey Island Coupeville, Washington. May.

**Figure 10-7**
**Cross Section C-C'**
**Outlying Landing Field Coupeville**
*Naval Air Station Whidbey Island*
*Coupeville, Washington*



Notes:

*Water level anomalous data estimated from March 18, 2017 round.

**Only well bottom depth known-screened interval.

Cross section is vertically exaggerated for visualization purposes.

Cross section is conceptual in nature; predominant soil type was generally used for stratigraphic interpretation, however, in some cases similar units were combined for the purpose of simplification.

Geologic contacts are dashed where inferred.

References:

Navy. 2018a. *Final Technical Memorandum Evaluation of Per- and Polyfluoroalkyl Substances in Groundwater, Outlying Landing Field Coupeville.* Naval Air Station Whidbey Island Coupeville, Washington. May.

Navy. 2018b. *Aquifer Test, Groundwater Sampling, and Drinking Water Sampling Data Evaluation and Groundwater Modeling Report, Per- and Polyfluoroalkyl Substances (PFAS), Outlying Landing Field Coupeville.* Naval Air Station Whidbey Island Oak Harbor and Coupeville, Washington. September.

**Figure 10-8**
**Cross Section D-D'**
**Outlying Landing Field Coupeville**
*Naval Air Station Whidbey Island*
*Coupeville, Washington*

**References**
Navy. 2018b. *Aquifer Test, Groundwater Sampling, and Drinking Water Sampling Data Evaluation and Groundwater Modeling Report, Per- and Polyfluoroalkyl Substances (PFAS), Outlying Landing Field Coupeville*, Naval Air Station Whidbey Island Oak Harbor and Coupeville, Washington. September.

**Legend**
- ● Groundwater Well Location
- ☒ OLF Coupeville Supply Well
- ▲ Community Drinking Water Well
- — 5-foot Contour Interval (dashed where inferred)
- → Direction of Intermediate-Screened Interval Groundwater Flow
- ▭ Building Location
- ⬚ Base Boundary

Notes:
1. NAVD88 = North American Vertical Datum of 1988
2. Intermediate elevation interval wells are typically screened between approximately 10 and 60 feet NAVD88.
3. Groundwater elevations shown in feet NAVD88
4. Groundwater level measurements used to generate this contour map were collected on 1/8/2018.
5. Data from well MW06M was not used in the contouring.
6. Full well names include "WI-CV-" preceding the well number; however names have been abbreviated for figure presentation

N

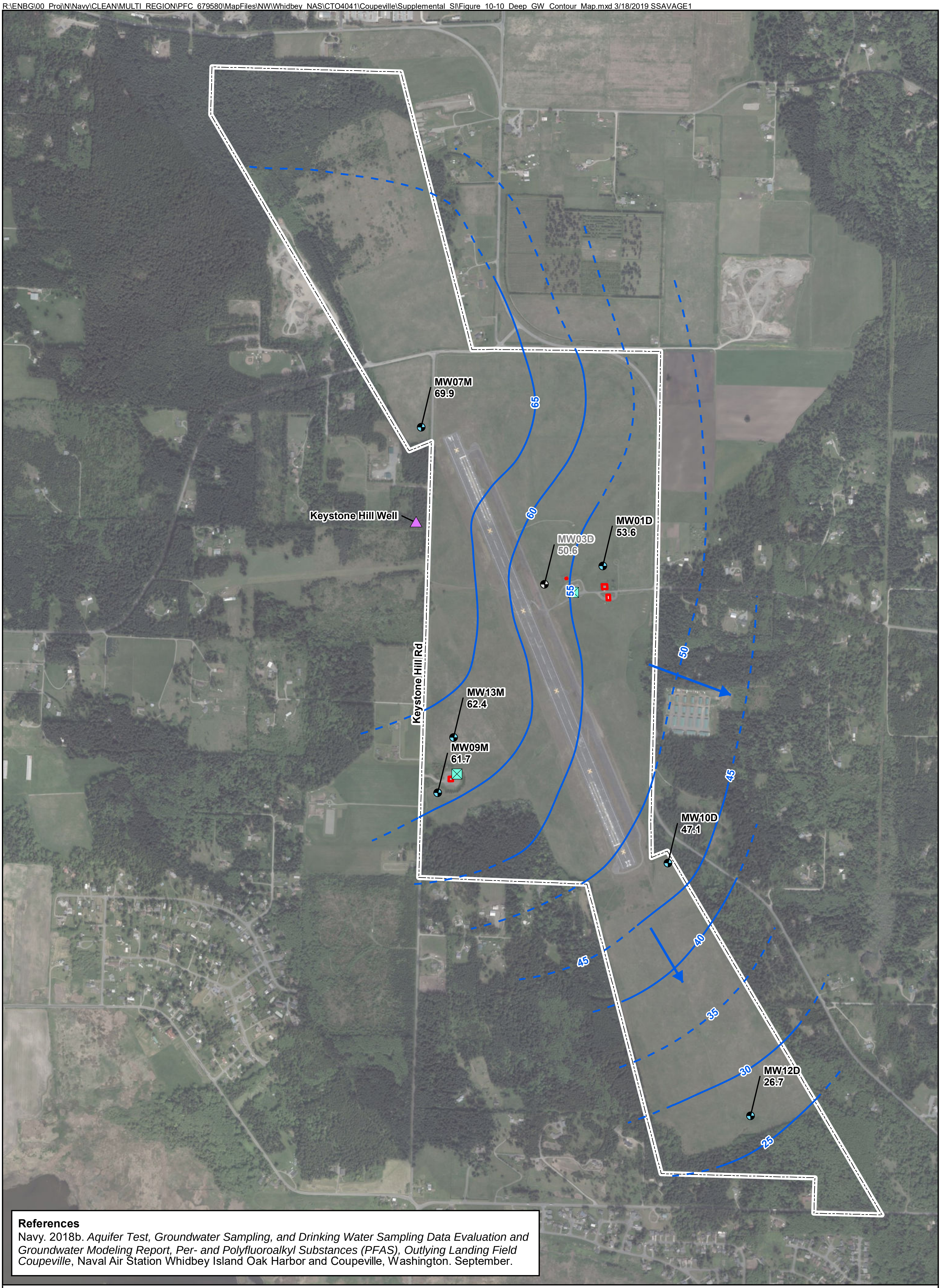
0 0.1 0.2 Miles

1 inch = 0.2 mile

Imagery Source: Esri

Figure 10-9
Groundwater Elevation Contour Map
Intermediate Elevation Interval
Naval Air Station Whidbey Island
Coupeville, Washington

**For Official Use Only**



**References**

Navy. 2018b. *Aquifer Test, Groundwater Sampling, and Drinking Water Sampling Data Evaluation and Groundwater Modeling Report, Per- and Polyfluoroalkyl Substances (PFAS), Outlying Landing Field Coupeville*, Naval Air Station Whidbey Island Oak Harbor and Coupeville, Washington. September.

Notes:
1. NAVD88 = North American Vertical Datum of 1988
2. Deep elevation interval wells are typically screened between approximately 17 and 50 feet NAVD88.
3. Groundwater elevations shown in feet NAVD88
4. Groundwater level measurements used to generate this contour map were collected on 1/8/2018.
5. Data from well MW03D was not used in the contouring.
6. Full well names include "WI-CV-" preceding the well number; however names have been abbreviated for figure presentation.

1 inch = 0.2 mile

Imagery Source: Esri

Figure 10-10
Groundwater Elevation Contour Map
Deep Elevation Interval
Naval Air Station Whidbey Island
Coupeville, Washington

**For Official Use Only**

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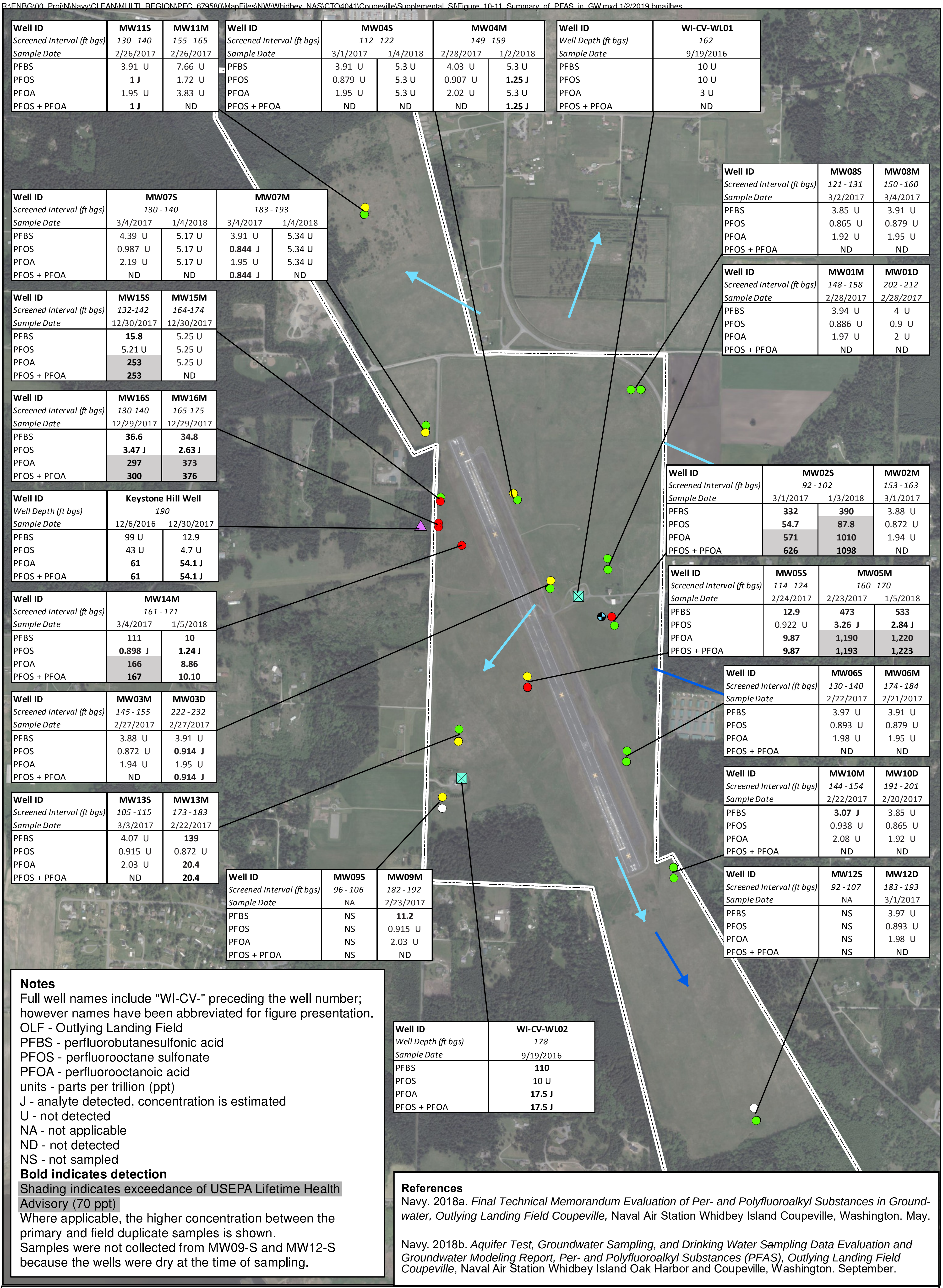

| **Well ID** | **MW11S** | **MW11M** |
|---|---|---|
| *Screened Interval (ft bgs)* | *130 - 140* | *155 - 165* |
| *Sample Date* | 2/26/2017 | 2/26/2017 |
| PFBS | 3.91 U | 7.66 U |
| PFOS | **1 J** | 1.72 U |
| PFOA | 1.95 U | 3.83 U |
| PFOS + PFOA | **1 J** | ND |

| **Well ID** | **MW04S** | | **MW04M** | |
|---|---|---|---|---|
| *Screened Interval (ft bgs)* | *112 - 122* | | *149 - 159* | |
| *Sample Date* | 3/1/2017 | 1/4/2018 | 2/28/2017 | 1/2/2018 |
| PFBS | 3.91 U | 5.3 U | 4.03 U | 5.3 U |
| PFOS | 0.879 U | 5.3 U | 0.907 U | **1.25 J** |
| PFOA | 1.95 U | 5.3 U | 2.02 U | 5.3 U |
| PFOS + PFOA | ND | ND | ND | **1.25 J** |

| **Well ID** | **WI-CV-WL01** |
|---|---|
| *Well Depth (ft bgs)* | *162* |
| *Sample Date* | 9/19/2016 |
| PFBS | 10 U |
| PFOS | 10 U |
| PFOA | 3 U |
| PFOS + PFOA | ND |

| **Well ID** | **MW07S** | | **MW07M** | |
|---|---|---|---|---|
| *Screened Interval (ft bgs)* | *130 - 140* | | *183 - 193* | |
| *Sample Date* | 3/4/2017 | 1/4/2018 | 3/4/2017 | 1/4/2018 |
| PFBS | 4.39 U | 5.17 U | 3.91 U | 5.34 U |
| PFOS | 0.987 U | 5.17 U | **0.844 J** | 5.34 U |
| PFOA | 2.19 U | 5.17 U | 1.95 U | 5.34 U |
| PFOS + PFOA | ND | ND | **0.844 J** | ND |

| **Well ID** | **MW08S** | **MW08M** |
|---|---|---|
| *Screened Interval (ft bgs)* | *121 - 131* | *150 - 160* |
| *Sample Date* | 3/2/2017 | 3/4/2017 |
| PFBS | 3.85 U | 3.91 U |
| PFOS | 0.865 U | 0.879 U |
| PFOA | 1.92 U | 1.95 U |
| PFOS + PFOA | ND | ND |

| **Well ID** | **MW01M** | **MW01D** |
|---|---|---|
| *Screened Interval (ft bgs)* | *148 - 158* | *202 - 212* |
| *Sample Date* | 2/28/2017 | *2/28/2017* |
| PFBS | 3.94 U | 4 U |
| PFOS | 0.886 U | 0.9 U |
| PFOA | 1.97 U | 2 U |
| PFOS + PFOA | ND | ND |

| **Well ID** | **MW15S** | **MW15M** |
|---|---|---|
| *Screened Interval (ft bgs)* | *132-142* | *164-174* |
| *Sample Date* | 12/30/2017 | 12/30/2017 |
| PFBS | **15.8** | 5.25 U |
| PFOS | 5.21 U | 5.25 U |
| PFOA | **253** | 5.25 U |
| PFOS + PFOA | **253** | ND |

| **Well ID** | **MW16S** | **MW16M** |
|---|---|---|
| *Screened Interval (ft bgs)* | *130-140* | *165-175* |
| *Sample Date* | 12/29/2017 | 12/29/2017 |
| PFBS | **36.6** | **34.8** |
| PFOS | **3.47 J** | **2.63 J** |
| PFOA | **297** | **373** |
| PFOS + PFOA | **300** | **376** |

| **Well ID** | **MW02S** | | **MW02M** |
|---|---|---|---|
| *Screened Interval (ft bgs)* | *92 - 102* | | *153 - 163* |
| *Sample Date* | 3/1/2017 | 1/3/2018 | 3/1/2017 |
| PFBS | **332** | **390** | 3.88 U |
| PFOS | **54.7** | **87.8** | 0.872 U |
| PFOA | **571** | **1010** | 1.94 U |
| PFOS + PFOA | **626** | **1098** | ND |

| **Well ID** | **Keystone Hill Well** | |
|---|---|---|
| *Well Depth (ft bgs)* | *190* | |
| *Sample Date* | 12/6/2016 | 12/30/2017 |
| PFBS | 99 U | 12.9 |
| PFOS | 43 U | 4.7 U |
| PFOA | **61** | **54.1 J** |
| PFOS + PFOA | **61** | **54.1 J** |

| **Well ID** | **MW05S** | **MW05M** | |
|---|---|---|---|
| *Screened Interval (ft bgs)* | *114 - 124* | *160 - 170* | |
| *Sample Date* | 2/24/2017 | 2/23/2017 | 1/5/2018 |
| PFBS | **12.9** | **473** | **533** |
| PFOS | 0.922 U | **3.26 J** | **2.84 J** |
| PFOA | **9.87** | **1,190** | **1,220** |
| PFOS + PFOA | **9.87** | **1,193** | **1,223** |

| **Well ID** | **MW14M** | |
|---|---|---|
| *Screened Interval (ft bgs)* | *161 - 171* | |
| *Sample Date* | 3/4/2017 | 1/5/2018 |
| PFBS | **111** | **10** |
| PFOS | **0.898 J** | **1.24 J** |
| PFOA | **166** | **8.86** |
| PFOS + PFOA | **167** | **10.10** |

| **Well ID** | **MW06S** | **MW06M** |
|---|---|---|
| *Screened Interval (ft bgs)* | *130 - 140* | *174 - 184* |
| *Sample Date* | 2/22/2017 | 2/21/2017 |
| PFBS | 3.97 U | 3.91 U |
| PFOS | 0.893 U | 0.879 U |
| PFOA | 1.98 U | 1.95 U |
| PFOS + PFOA | ND | ND |

| **Well ID** | **MW03M** | **MW03D** |
|---|---|---|
| *Screened Interval (ft bgs)* | *145 - 155* | *222 - 232* |
| *Sample Date* | 2/27/2017 | 2/27/2017 |
| PFBS | 3.88 U | 3.91 U |
| PFOS | 0.872 U | **0.914 J** |
| PFOA | 1.94 U | 1.95 U |
| PFOS + PFOA | ND | **0.914 J** |

| **Well ID** | **MW10M** | **MW10D** |
|---|---|---|
| *Screened Interval (ft bgs)* | *144 - 154* | *191 - 201* |
| *Sample Date* | 2/22/2017 | 2/20/2017 |
| PFBS | **3.07 J** | 3.85 U |
| PFOS | 0.938 U | 0.865 U |
| PFOA | 2.08 U | 1.92 U |
| PFOS + PFOA | ND | ND |

| **Well ID** | **MW13S** | **MW13M** |
|---|---|---|
| *Screened Interval (ft bgs)* | *105 - 115* | *173 - 183* |
| *Sample Date* | 3/3/2017 | 2/22/2017 |
| PFBS | 4.07 U | **139** |
| PFOS | 0.915 U | 0.872 U |
| PFOA | 2.03 U | **20.4** |
| PFOS + PFOA | ND | **20.4** |

| **Well ID** | **MW09S** | **MW09M** |
|---|---|---|
| *Screened Interval (ft bgs)* | *96 - 106* | *182 - 192* |
| *Sample Date* | NA | 2/23/2017 |
| PFBS | NS | **11.2** |
| PFOS | NS | 0.915 U |
| PFOA | NS | 2.03 U |
| PFOS + PFOA | NS | ND |

| **Well ID** | **MW12S** | **MW12D** |
|---|---|---|
| *Screened Interval (ft bgs)* | *92 - 107* | *183 - 193* |
| *Sample Date* | NA | 3/1/2017 |
| PFBS | NS | 3.97 U |
| PFOS | NS | 0.893 U |
| PFOA | NS | 1.98 U |
| PFOS + PFOA | NS | ND |

| **Well ID** | **WI-CV-WL02** |
|---|---|
| *Well Depth (ft bgs)* | *178* |
| *Sample Date* | 9/19/2016 |
| PFBS | **110** |
| PFOS | 10 U |
| PFOA | **17.5 J** |
| PFOS + PFOA | **17.5 J** |

## Notes

Full well names include "WI-CV-" preceding the well number; however names have been abbreviated for figure presentation.
OLF - Outlying Landing Field
PFBS - perfluorobutanesulfonic acid
PFOS - perfluorooctane sulfonate
PFOA - perfluorooctanoic acid
units - parts per trillion (ppt)
J - analyte detected, concentration is estimated
U - not detected
NA - not applicable
ND - not detected
NS - not sampled
**Bold indicates detection**
Shading indicates exceedance of USEPA Lifetime Health Advisory (70 ppt)
Where applicable, the higher concentration between the primary and field duplicate samples is shown.
Samples were not collected from MW09-S and MW12-S because the wells were dry at the time of sampling.

## References

Navy. 2018a. *Final Technical Memorandum Evaluation of Per- and Polyfluoroalkyl Substances in Groundwater, Outlying Landing Field Coupeville,* Naval Air Station Whidbey Island Coupeville, Washington. May.

Navy. 2018b. *Aquifer Test, Groundwater Sampling, and Drinking Water Sampling Data Evaluation and Groundwater Modeling Report, Per- and Polyfluoroalkyl Substances (PFAS), Outlying Landing Field Coupeville*, Naval Air Station Whidbey Island Oak Harbor and Coupeville, Washington. September.

## Legend

☒ OLF Coupeville Supply Well
● Monitoring Well with no exceedance of LHA
● Monitoring Well with LHA exceedance
● No detections of PFAS
○ Not Sampled (Dry)
▲ Community Drinking Water Well
→ Direction of Groundwater Flow in the Intermediate Elevation Interval of the Aquifer
→ Direction of Groundwater Flow in the Deep Elevation Interval of the Aquifer
⬚ Base Boundary

1 inch = 0.2 mile
Imagery Source: Esri

Figure 10-11
Summary of Groundwater PFAS Concentrations
Naval Air Station Whidbey Island
Coupeville, Washington

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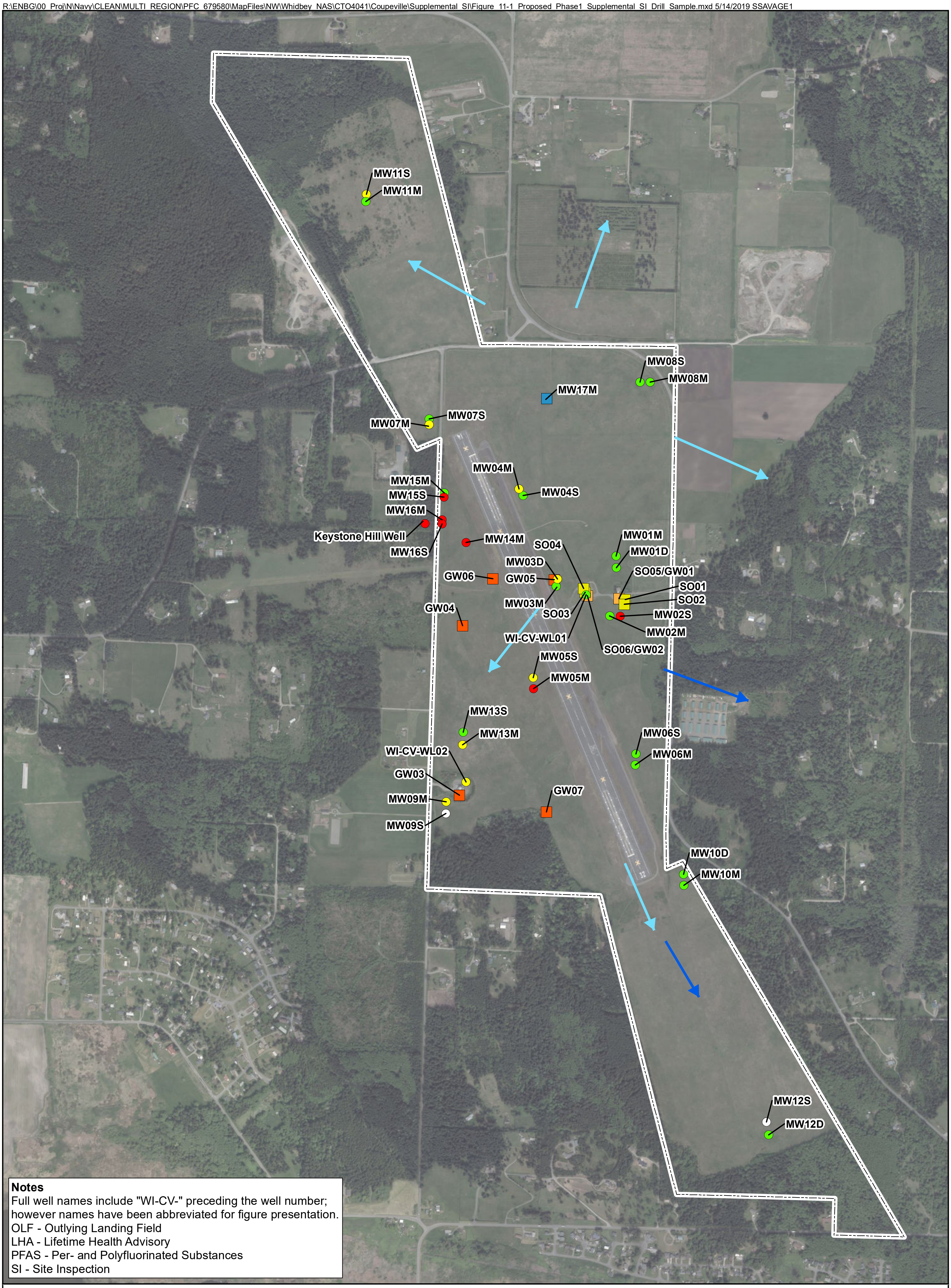
R:\ENBG\00_Proj\N\Navy\CLEAN\MULTI_REGION\PFC_679580\MapFiles\NW\Whidbey_NAS\CTO4041\Coupeville\Supplemental_SI\Figure_11-1_Proposed_Phase1_Supplemental_SI_Drill_Sample.mxd 5/14/2019 SSAVAGE1



**Notes**
Full well names include "WI-CV-" preceding the well number; however names have been abbreviated for figure presentation.
OLF - Outlying Landing Field
LHA - Lifetime Health Advisory
PFAS - Per- and Polyfluorinated Substances
SI - Site Inspection

**Legend**

**Proposed Phase 1 Supplemental SI Location**

- 🟦 Monitoring Well
- 🟨 Soil Sampling
- 🟧 Soil and Vertical Groundwater Profile Sampling and Monitoring Well
- 🟥 Vertical Groundwater Profile Sampling and Monitoring Well
- → Direction of Groundwater Flow in the Intermediate Elevation Interval of the Aquifer
- → Direction of Groundwater Flow in the Deep Elevation Interval of the Aquifer

- 🟡 Existing Monitoring Well with no exceedance of LHA
- 🔴 Existing Monitoring Well with LHA exceedance
- 🟢 Existing Monitoring Well with no Detections of PFAS
- ○ Existing Monitoring well - Not Sampled (Dry)
- ▭ Base Boundary

Imagery Source: Esri

N

0 0.1 0.2 Miles

1 inch = 0.2 mile

**Figure 11-1**
Proposed Phase 1 Supplemental SI Drilling and Sample Locations
Naval Air Station Whidbey Island
Outlying Landing Field Coupeville
Coupeville, Washington

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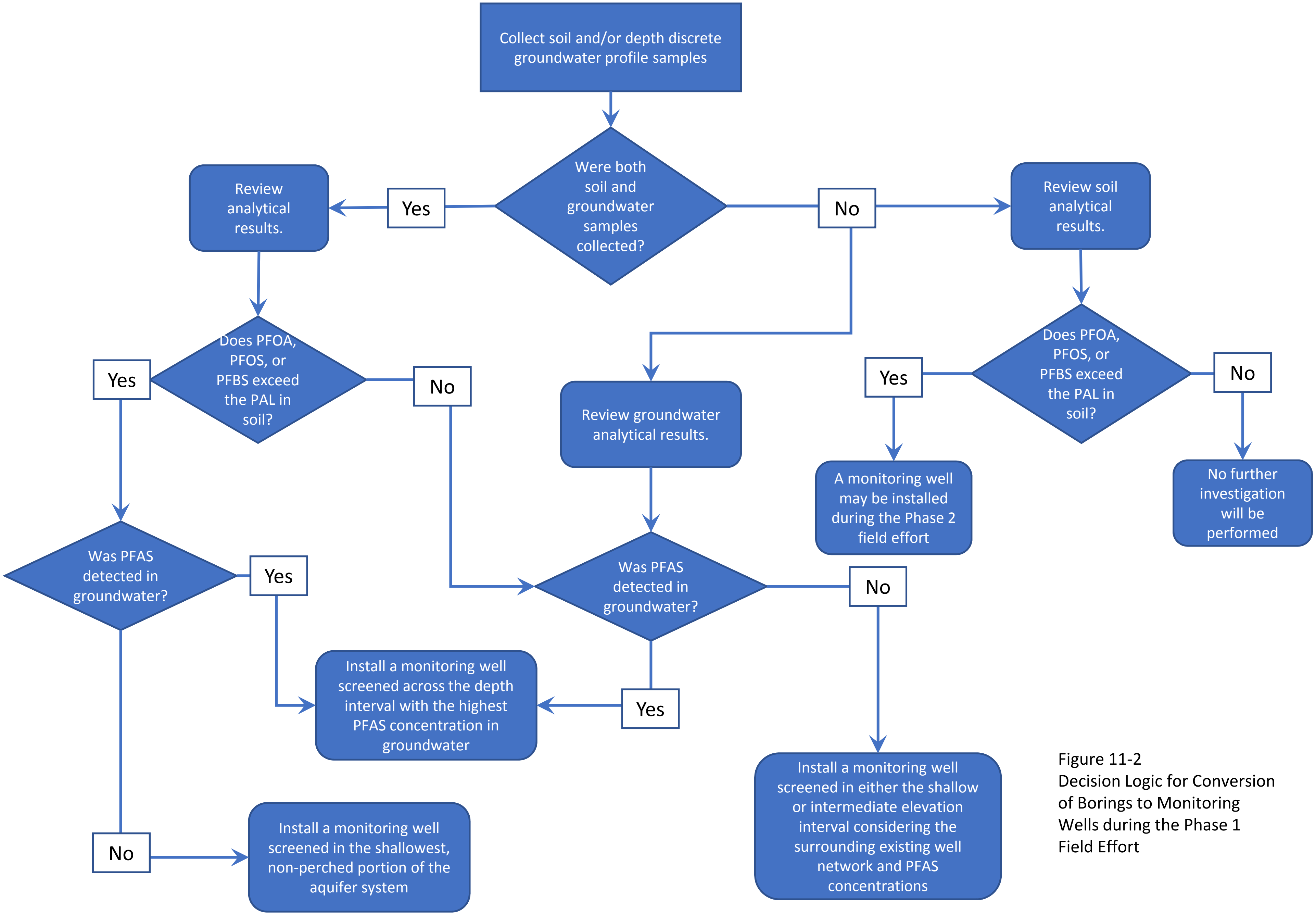


Figure 11-2
Decision Logic for Conversion of Borings to Monitoring Wells during the Phase 1 Field Effort

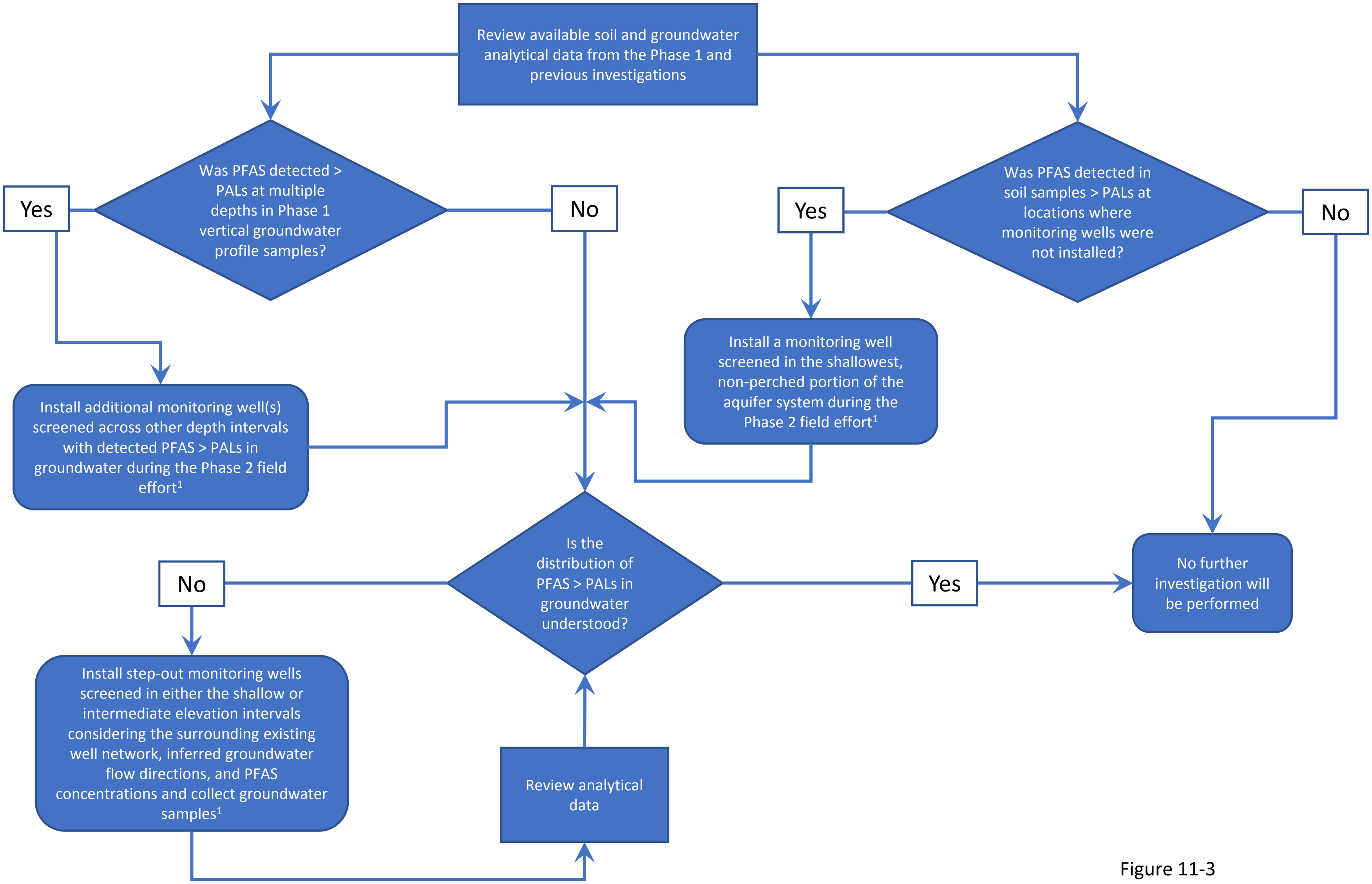


Figure 11-3
Decision Logic for Installation and Location of Monitoring Wells during the Phase 2 Field Effort

Notes:

1. Based on available funds in the current scope, up to 7 groundwater monitoring wells will be installed during the Phase 2 field effort. If the distribution of PFAS > PALs is not well understood with this number of wells, a future contract may be needed to fill the data gaps.

# Appendix A

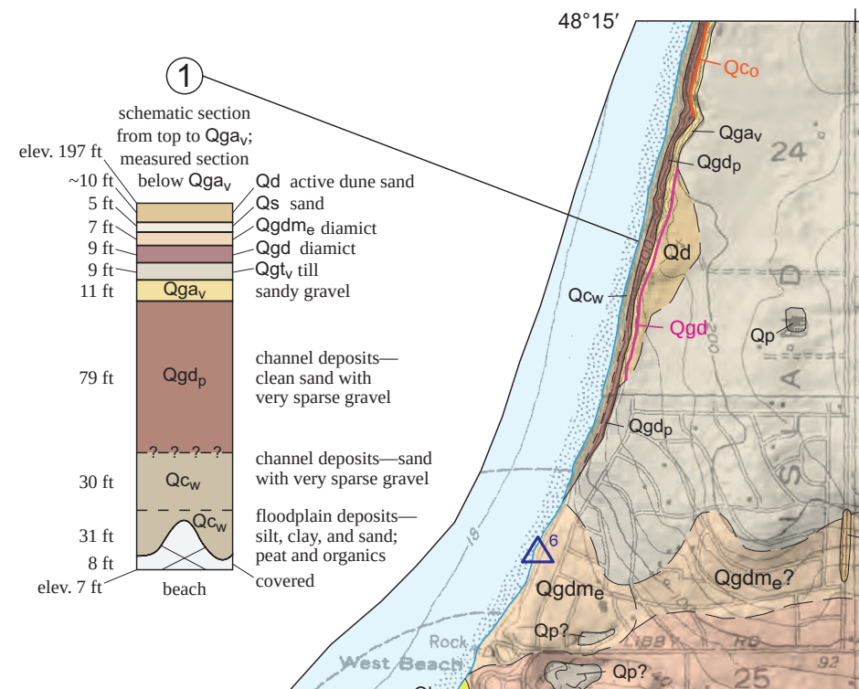
# Geologic Map of Coupeville

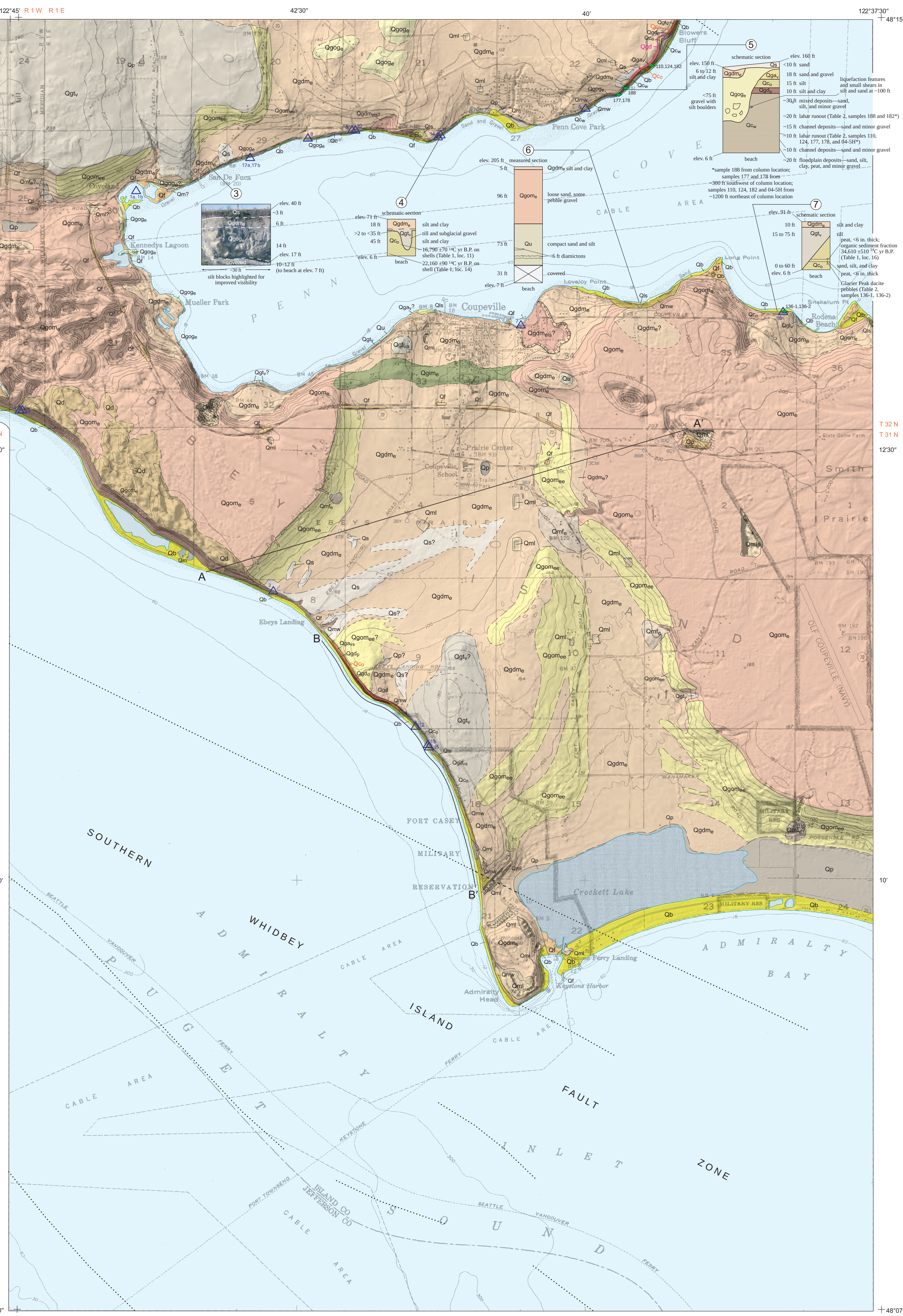
WASHINGTON STATE DEPARTMENT OF
**Natural Resources**
Doug Sutherland - Commissioner of Public Lands
Division of Geology and Earth Resources
Ron Teissere - State Geologist

# Geologic Map of the Coupeville and Part of the Port Townsend North 7.5-minute Quadrangles, Island County, Washington

by Michael Polenz, Stephen L. Slaughter, and Gerald W. Thorsen

June 2005





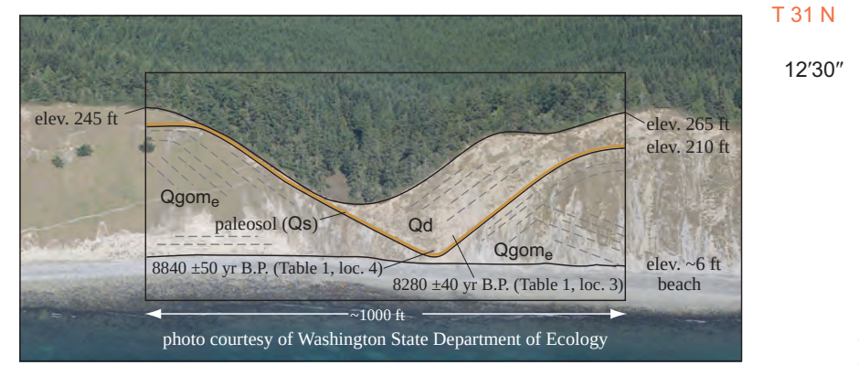


photo courtesy of Washington State Department of Ecology

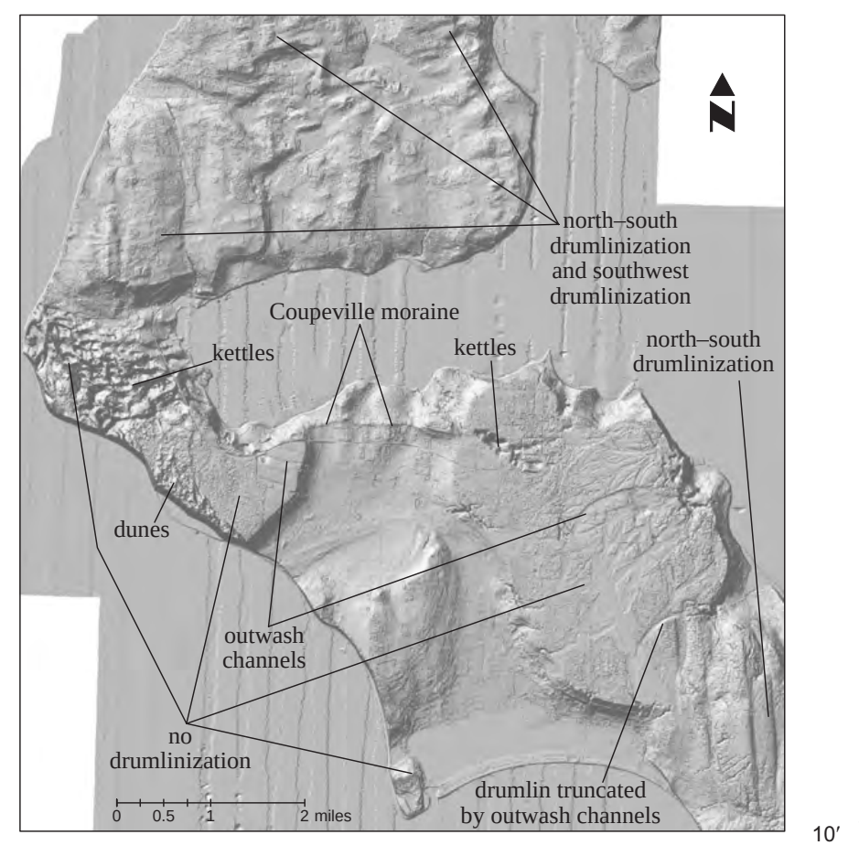
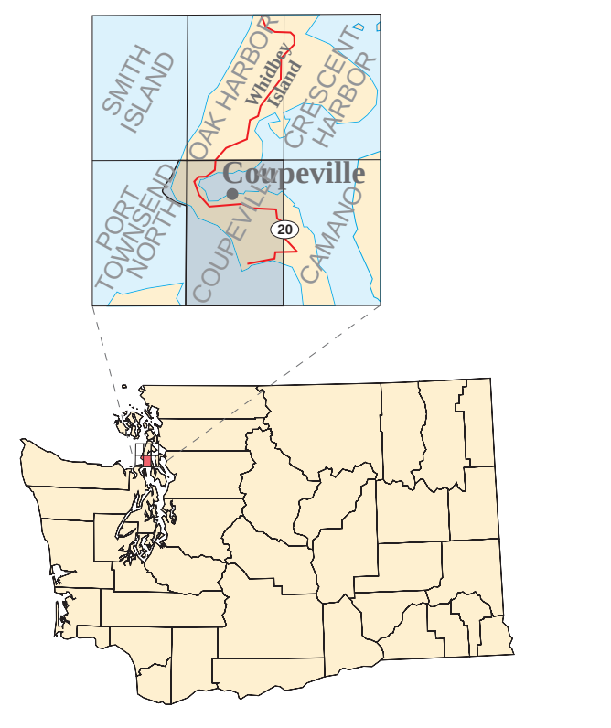


**Figure 1.** Lidar-based hillshade image of central Whidbey Island. Vertical exaggeration is 6 times. Simulated sun angle is 45 degrees; sun azimuth, 315 degrees. The image illustrates the systematic distribution of landforms in the area. Strong north-south drumlinization in the southeast reflects south-directed Vashon ice movement; weak north-south drumlinization and an overprint of southwest-trending drumlinization in the north reflect south-directed ice movement followed by southwest-directed ice movement. The Coupeville moraine in the center marks a one-time ice margin; east and west of the moraine, elevated outwash terraces with braided relict channels and kettles reflect ice-proximal, marine-deltaic deposition of Partridge Gravel outwash. Smooth lowlands north and south of the moraine represent paleo-sea floor.



Lambert conformal conic projection
North American Datum of 1927; to place on North American Datum of 1983, move the projection lines 70 feet north and 300 feet east as shown by crosshair corner ticks
Base map from scanned and rectified U.S. Geological Survey 7.5-minute Coupeville and Port Townsend North quadrangles, 1973
Shaded relief generated from lidar; sun azimuth 315 degrees; sun angle 45 degrees; vertical exaggeration 5x
Digital cartography by Anne C. Heinitz
Editing and production by Karen D. Meyers

SCALE 1:24,000

1 0.5 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 0.5 0 1 KILOMETER

contour interval 20 feet

**Table 1.** Age control data from the map area and surrounding areas. New analyses for this report were performed by Beta Analytic, Inc. (Miami, Fla.). Uncertainty values preceded by '±' are one standard deviation (68% confidence interval); age ranges reported as two numbers separated by a dash span two standard deviations (95% confidence interval). 'Cal yr B.P.' is calibrated age in calendar years before 1950 as reported by lab or prior publication; 'ka' is thousands of calendar years before 1950. Ages less than 1000 Cal yr B.P. are converted to AD. Ages are 'conventional' (adjusted for measured $^{13}C/^{12}C$ ratio) if a $^{13}C/^{12}C$ ratio is shown; other entries may be 'measured' or 'conventional'. Elevations are estimated in feet above mean sea level; elevations in quotation marks are as reported by referenced sources (we converted some from metric). AMS, accelerator mass spectrometry

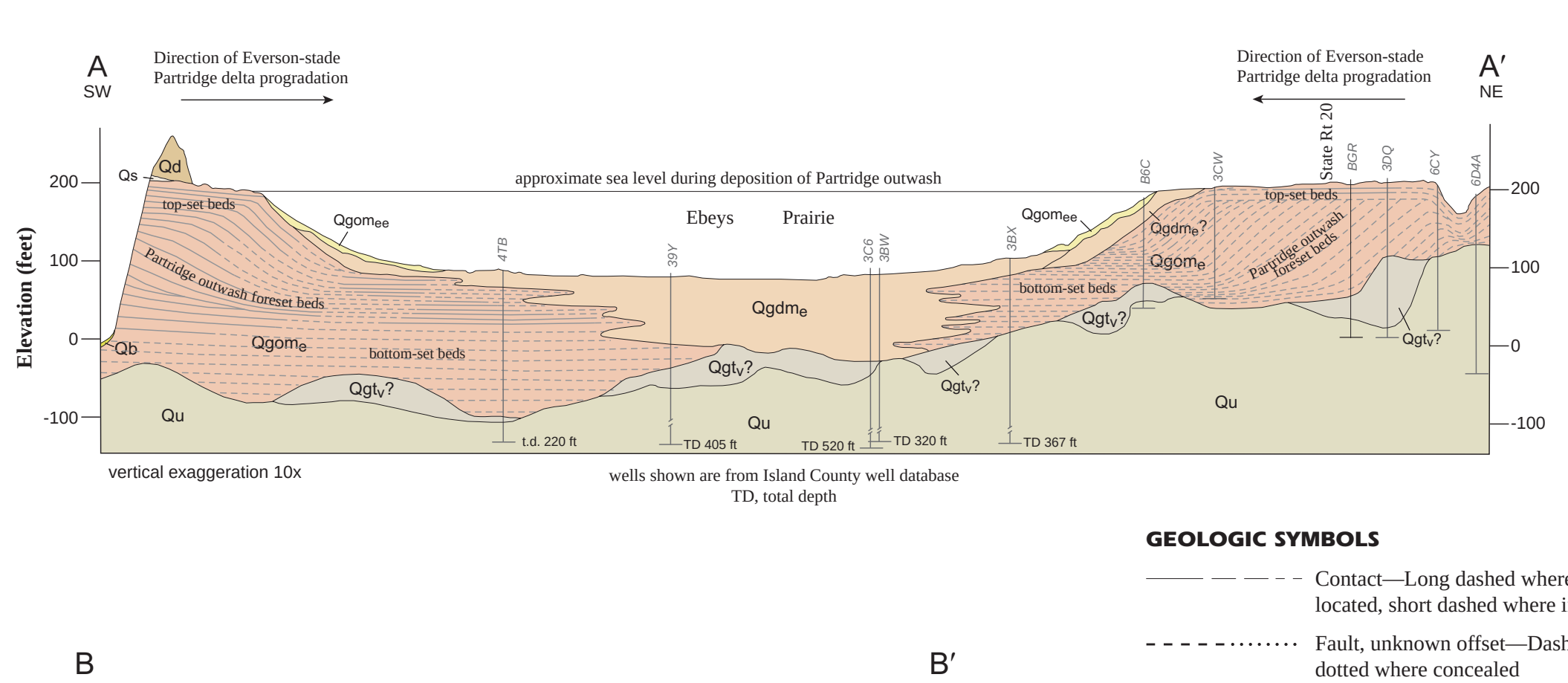
| Loc. no. | $^{14}$C yr B.P. | Cal yr B.P. (or ka) | Material dated | Geologic unit | Sample no. | Elev. (ft) | Reference | Notes |
|---|---|---|---|---|---|---|---|---|
| **WITHIN MAP AREA** | | | | | | | | |
| 1a | 140 ±40 | AD 1660–1950 | Douglas Fir (?[1]) wood | tidal estuary | Beta 199432 | ±2 | This report | AMS analysis of 7th-outermost tree ring; $^{13}C/^{12}C$ = -22.1‰ |
| 1b | 170 ±40 | AD 1650–1890; or 1910–1950 | Douglas Fir (?[1]) wood | tidal estuary | Beta 202078 | ±2 | This report | AMS analysis of 89th- to 99th-outermost tree rings; $^{13}C/^{12}C$ = -23.7‰ |
| (combination of above dates) | | AD 1740–1790; or 1810–1960 | Douglas Fir (?[1]) wood | tidal estuary | n.a. | ±2 | This report; Oxcal v3.9 (Ramsey, 1995, 2001; Ramsey and others, 2001) | Age of tree death implied by combination of Beta 199432 and 202078 (for method see Ramsey and others, 2001) |
| 2 | 935 ±110 | | marine shells | Qs | I-1093 | near "90" | Trautman and Willis (1966) | Collected by D. J. Easterbrook, 1963 |
| 3 | 8,280 ±40 | 9,420–9,130 | vole bone[2] | Qd | Beta 199434 | 50–65 | This report | AMS analysis; $^{13}C/^{12}C$ = -20.2‰ |
| 4 | 8,840 ±50 | | deer vertebra | Qd | GX-25892-AMS | ~30–40 | Mustoe and others (*in press*) | AMS analysis; $^{13}C/^{12}C$ = -21.9‰ |
| 5 | 11,850 ±240 | | marine shells | $Qgdm_e$ | I-1448 | "ca. 10" | Easterbrook (1966a,b) | Elevation from Trauman and Willis (1966) |
| 6 | 12,535 ±300 | | shells | $Qgdm_e$ | I-1079 | "0–15" | Easterbrook (1966a,b) | Elevation from Trauman and Willis (1966) |
| 7 | 12,640 ±150 | | shells in diamict | $Qgdm_e$ | USGS 1304 | "3" | Dethier and others (1995) | Collected by E.W. Domack |
| 8 | 13,010 ±170 | | shells | $Qgdm_e$ | UW-32 | 10? | Easterbrook (1966a,b) | Some references report date as 13,100 ±170 |
| 9 | 13,090 ±90 | | marine shells | $Qgdm_e$ | PC-02 | ~20 | Swanson (1994) | Swanson advocates a 400 yr reservoir correction and suggests that best age estimate is therefore 12,690 ±90 $^{14}$C yr B.P. |
| 10 | 13,230 ±90 | | marine shells | $Qgdm_e$ | PC-01 | ~10 | Swanson (1994) | Swanson advocates a 400 yr reservoir correction and suggests that best age estimate is therefore 12,830 ±90 $^{14}$C yr B.P. |
| 11 | 16,790 ±70 | 20,480–19,530 | freshwater(?) shells[3] | $Qc_o$ | Beta 199431 | 25–30 | This report | AMS analysis; $^{13}C/^{12}C$ = -10.1‰ |
| 12 | 20,890 ±70 | | freshwater shells[4] | $Qc_o$ | Beta 199429 | 9–19 | This report | AMS analysis; $^{13}C/^{12}C$ = -4.0‰ |
| 13 | 21,550 ±90 | | paleosol | $Qc_o$ | Beta 169087 | 8 | Gerald Thorsen (consulting geologist, written commun., 2004) | Date courtesy of Kurt Koger (Associated Earth Sciences, Inc.); location verified by Koger (oral commun., Feb. 2005) |
| 14 | 22,160 ±90 | | bivalve shell | $Qc_o$ | Beta 199430 | 10 | This report | AMS analysis; $^{13}C/^{12}C$ = -15.5‰ |
| 15 | 27,050 ±230 | | paleosol | $Qc_o$ | Beta 169086 | 6 | Gerald Thorsen (consulting geologist, written commun., 2004) | Date courtesy of Kurt Koger (Associated Earth Sciences, Inc.); location verified by Koger (oral commun., Feb. 2005); stratigraphically overlies West Beach silt facies |
| 16 | 34,610 ±510 | | organic sed. in peat | $Qc_o$ | Beta 199433 | 35 | This report | Conventional 14C analysis; $^{13}C/^{12}C$ = -27.8‰ |
| 17a | 11,060 ±185 | | peat bed | ? | UW 33 | "a few ft" | Trautman and Willis (1966) | Date erroneous due to lab contamination; reanalyzed as I-1446 |
| 17b | >33,200 | | peat | $Qc_w$ | I-1446 | <5? | Easterbrook (1968) | Reanalysis of UW-33 |
| **WITHIN OR NEAR MAP AREA (LOCATION INSUFFICIENTLY DOCUMENTED)** | | | | | | | | |
| | | 106 ±17 ka | clay | $Qc_w$ | BBLF-4 | <15 | Berger and Easterbrook (1993) | Thermoluminesence dating analysis from "Blowers Bluff" |
| **OUTSIDE BUT NEAR AND PERTINENT TO MAP AREA** | | | | | | | | |
| | 13,650 ±350 | | shell | $Qgdm_e$ | Beta-1319 | 79 | Dethier and others (1995) | Located at Whidbey Island Naval Air Station, Oak Harbor (lat. 48°19'25" N, lon. 122°39'9" W) |
| | 15,190 ±220 | 18,985–17,435 | organic laminae | $Qc_o$ | Beta 141690 | ? | Johnson and others (2001) | Utsalady Point, 7 mi east of Blowers Bluff (lat. 48°15'25" N, lon. 122°30'13" W); Johnson and others (2001) caution that date may be too young |
| | 37,610 ±380 | | paleosol | $Qc_o$ | Beta 154508 | 148 | Gerald Thorsen (consulting geologist, written commun., 2004) | Date courtesy of Gerald Thorsen and Kitty Reed; located on West Beach, a few hundred feet north of map area, at base of (aeolian) West Beach silt facies of unit $Qc_o$ (lat. 48°15'02" N, lon. 122°45'28" W) |
| | | 77 ±6 ka | shells | $Qc_w$ | 79-9 | ~49 | Kvenvolden and others (1980) | Amino acid, 2.8 mi south of map area (lat. 48°07'30" N, lon. 122°36'00" W) |

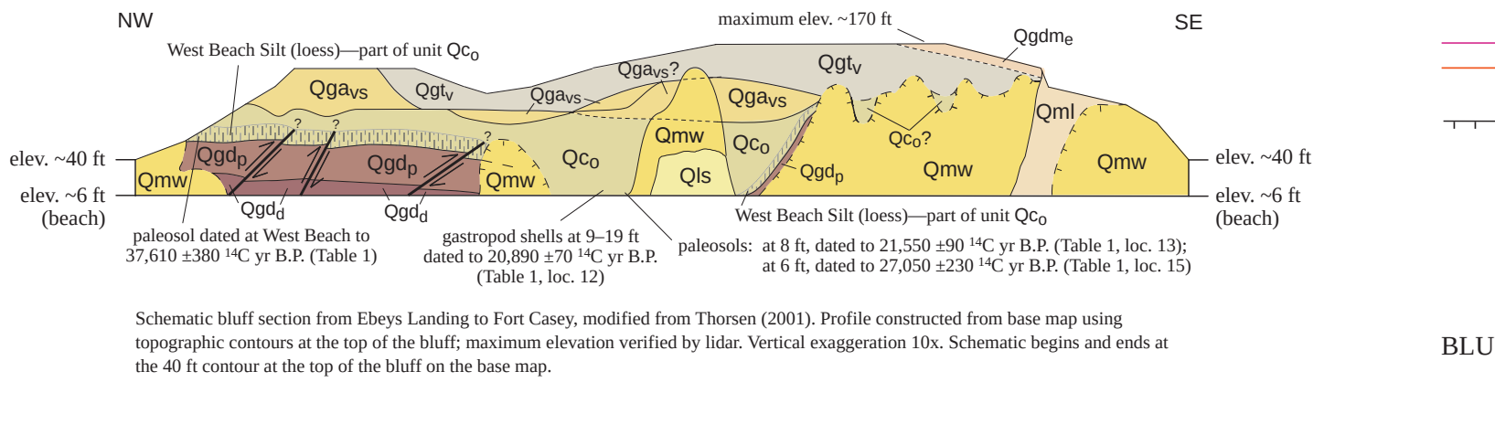
[1] Wood tentatively identified as Douglas fir (*Pseudotsuga menziezii*) by Patrick Pringle (Wash. Div. of Geology and Earth Resources, oral commun., Feb. 2005), who added that it might be pine.

[2] Based on photos, location and date, skull bones and teeth identified by Richard Johnson (Wash. State Univ., written commun., Dec. 2004) and John Fleckenstein (Wash. Dept. of Natural Resources, written and verbal communs., Nov. 2004 to Feb. 2005) as microtine rodent(s) (voles), specifically, *Microtus townsendii, Microtus oregoni, Microtus longicaudus*, or *Microtus oeconomus*, with a small chance of *Microtus miurus*.

[3] Shell fragments after extraction from sediment too small for positive identification; probably mollusks similar to those from loc. 12, implying a quiet freshwater setting.

[4] Shells identified by Liz Nesbitt (Univ. of Wash., written commun., 2005) as freshwater mollusks, including *Pisidium* pea-clams, implying a lacustrine or pond setting, and viviparid snails (*Viviparus* or *Lioplax*), implying well-oxygenated lake or stream setting.





Schematic bluff section from Ebeys Landing to Fort Casey, modified from Thorsen (2001). Profile constructed from base map using topographic contours at the top of the bluff; maximum elevation verified by lidar. Vertical exaggeration 10x. Schematic begins and ends at the 40 ft contour at the top of the bluff on the base map.

## GEOLOGIC SYMBOLS

- Contact—Long dashed where approximately located, short dashed where inferred
- Fault, unknown offset—Dashed where inferred, dotted where concealed
- Qgd / $Qc_o$ Geologic unit too narrow to show as a polygon at map scale
- Landslide scarp—Hachures on downslope side; dashed where approximately located
- 178 Geochemistry sample location
- △17 Radiocarbon date sample location
- B6R ○ Water well

BLUFF SECTION B–B′ ONLY

- Dip-slip motion on fault—Arrows show apparent relative motion

## GEOLOGIC SETTING AND DEVELOPMENT

Like most of the Puget Lowland, the map area is dominated by glacial sediment and lacks bedrock exposures. Jones (1999) inferred between 1800 ft (west of Point Partridge) and 3300 ft (east of Penn Cove) of unconsolidated deposits in the area; Mosher and others (2000) and Johnson and others (2001) used geophysical data to suggest that the top of Miocene(?) (Johnson and others, 1996) bedrock in the map area is about 1150 to 2600 ft below the surface (depending on location). The oldest sediment exposed in the map area is thought to be Double Bluff Drift, which is found at beach level south of Ebeys Landing (shoreline section B; Easterbrook, 1968; Thorsen, 2001). Based on stratigraphic position, Double Bluff Drift would likely date to marine oxygen-isotope stage (hereinafter "stage") 6, or about 185 to 125 ka (thousands of calendar years before 1950) (references to oxygen-isotope stages in this report are as defined in fig. 4 of Morrison, 1991), although direct age estimates suggest that some exposures may be older (Berger and Easterbrook, 1993; Blunt and others, 1987; Easterbrook, 1994a,b).

The oldest widely exposed unit is the interglacial Whidbey Formation, which forms the base of the section along West Beach and Blowers Bluff, where it is as much as about 120 ft thick (columnar section 5). We believe the formation to be correlative in the map area with stage 5, or about 125 to 80 ka, based on stratigraphic position and dates from within or near the map area (Table 1). Pollen within the Whidbey Formation suggests an initially cool climate that warmed later during Whidbey time (Hansen and Mackin, 1949; Easterbrook and others, 1967; Heusser and Heusser, 1981). Petrography and sedimentology suggest that a south- to west-flowing(?) ancestral Skagit (or Stillaguamish?) River extended into the map area and deposited the Whidbey Formation sediments (Dragovich and others, 2005, and petrographic studies from this project) in a low-energy setting similar to the modern lower Skagit River, flood plain, and delta, which are located about 5 to 20 mi northeast of the map area. Exposures of Whidbey deposits above sea level are rare or absent in the map area south of Penn Cove, inviting the interpretation that erosion has largely obliterated Whidbey sediments there, or that the ancestral Skagit River may have reached a lake or the sea in the vicinity of Penn Cove, so that Whidbey deposits never were deposited south of Ebey's Landing.

The Whidbey Formation is overlain by Possession Drift of stage 4 or about 80 to 60 ka. Age statements by Easterbrook (1994 a,b), Blunt and others (1987), and Easterbrook and Rutter (1981, 1982) range between 50 to 80 ka and 80 ±22 ka. However, all appear to refer to the same amino acid-based analyses, some of which were reportedly derived from samples from Blowers Bluff. Possession Drift in many locations provides the only means of distinguishing Whidbey sediment from very similar, younger "deposits of the Olympia nonglacial interval" (Pessl and others, 1989).

We believe deposits of the Olympia nonglacial interval in the map area to be correlative with stage 3 or about 60 to 20 ka (Morrison, 1991; Table 1). No direct juxtaposition of the Whidbey Formation and deposits of the Olympia nonglacial interval has been recognized in the map area, but the lower parts of some bluffs (for example, columnar sections 4 and 7) may include Whidbey Formation beneath an unrecognized disconformity. A deposit east of Long Point contains Glacier Peak volcanic pebbles (Table 2, samples 136-1 and 136-2) and strongly resembles Whidbey Formation deposits elsewhere, but was assigned to the Olympia nonglacial interval based on a 34,610 ±510 $^{14}$C yr B.P. date from a soil upsection and the lack of a recognized unconformity between that soil and the sand from which the pebbles were sampled (columnar section 7; Table 1, loc. 16).

Similarity of deposits of the Olympia nonglacial interval to the Whidbey Formation, for which a low-energy freshwater paleoenvironment is well-documented (see above; Hansen and Mackin, 1949; Heusser and Heusser, 1981; Easterbrook and others, 1967), suggests similar paleoenvironments. A similar setting in the map area during Olympia time is also favored by the freshwater, low-energy habitat requirements of clams and snails found in Olympia nonglacial sediments south of Ebey's Landing (Table 1, loc. 12) and mollusk shells from similar sediments along the north shore of Penn Cove (Table 1, loc. 11, and columnar section 4) (Liz Nesbitt, Univ. of Wash., written commun., 2005). In addition, shells from Olympia sediments in the map area have $^{13}C/^{12}C$ ratios that suggest a freshwater setting (Table 1, locs. 11, 12, 14). Because global sea level during stage 3 was lower than during Whidbey time (for example, Ludwig and others, 1996; Bloom, 1983), similar paleoenvironments suggest either that local tectonic history is complex, or that local base level was elevated during stage 3.

The Olympia nonglacial interval ended when advance outwash sand and gravel of the Vashon Stade of the Fraser Glaciation (Armstrong and others, 1965) (stage 2) buried the Puget Lowland (Booth, 1994). Porter and Swanson (1998, fig. 4) suggested that ice arrived and covered the map area approximately 18 ka. That assessment is consistent with local age control from a 20.48 to 19.53 ka date (Table 1, loc. 11) from shell material in deposits of the Olympia nonglacial interval along the north shore of Penn Cove. The shells were at least 15 to 20 ft beneath an unconformable contact with overlying Vashon Drift (columnar section 4). A separate date of 18.99 to 17.44 ka in Olympia deposits (Beta 141690, Table 1) is similarly consistent with ice arrival about 18 ka, although Johnson and others (2001) noted that sample contamination might have compromised this date.

Thorson (1980, 1981, 1989) indicated that Vashon ice thickness reached approximately 3900 to 4300 ft in the map area. In surrounding areas of the Puget Lowland, the former presence of that ice is reflected in widespread lodgment till and prominent landscape drumlinization. In contrast, our mapping and the prior work of Carlstad (1992) and Jones (1999) show that in and near Coupeville, lodgment till and drumlinization are sparse, whereas glaciomarine drift and recessional outwash dominate (Fig. 1).

The predominance in the map area of glaciomarine drift and outwash appears to reflect a period of ice-margin stabilization at Coupeville (Carlstad, 1992), which lasted long enough for proglacial meltwater to deposit the Partridge Gravel, a marine, kame-delta to seafloor-turbidite deposit (Easterbrook, 1968; Carlstad, 1992). Kettles formed within this deposit (Fig. 1) where stagnant ice was buried by outwash and are consistent with a nearby ice front (Carlstad, 1992). A west-trending moraine in Coupeville (Fig. 1) provides further evidence for a local ice front.

South of the Coupeville moraine, a distinct north-south alignment dominates drumlins (Fig. 1). To the north, this north-south drumlinization is overprinted with southwest-trending drumlinization (Fig. 1). We suggest that this difference reflects a time when the ice front stood at Coupeville, and that deposition of Partridge Gravel, the presence of the Coupeville moraine, and the southwest drumlinization favor the presence during the Everson Interstade of grounded ice north of Penn Cove, a concept that has long been debated (for example, Armstrong and Brown, 1954; Domack, 1983; Easterbrook, 1994b). The secondary drumlinization suggests that for a time, grounded ice north of the Coupeville moraine flowed southwest and was therefore subject to a stress field that never governed ice south of the map area. We speculate that this stress field resulted when the ice sheet collapsed across the eastern Strait of Juan de Fuca and Admiralty Inlet (Thorson, 1980), thus allowing the Everson Interstade (Armstrong and others, 1965) to begin as sea water entered ice-free areas below relative paleo–sea level. Prior to the collapse, the ice across the Strait of Juan de Fuca confined ice flow in the Puget Lowland to a north-south direction. The collapse removed that confining pressure in the central to northern Puget Lowland, thus triggering a reorientation to the southwest of ice flow in and north of the map area, as recorded by the overprint of southwest drumlinization north of the Coupeville moraine (Fig. 1).

The ice collapse across Admiralty Inlet that marked the onset of the Everson Interstade in the map area appears to have occurred before deposition of a shell that yielded a 13,650 ±350 $^{14}$C yr B.P. date, which is the oldest date from nearby glaciomarine drift (Table 1; Dethier and others, 1995). The sample location for this date is 5 mi north of the map area. If the hypothesis of a temporary, grounded ice margin at Coupeville and coeval formation of southwest-trending drumlinization north thereof is correct, then the ice sheet north of Coupeville persisted for some time after it had collapsed across Admiralty Inlet (Thorson, 1981; Waitt and Thorson, 1983). It follows that ice collapse across Admiralty Inlet may have occurred significantly before deposition of the shell that yielded the 13,650 $^{14}$C yr B.P. date.

The presence around Penn Cove of substantial glaciomarine drift (columnar sections 3–7), marine terraces(?) (Carlstad, 1992), and relict shorelines (Carlstad, 1992) suggests that deposition of the Partridge Gravel was completed and Penn Cove became ice-free early in the Everson Interstade, likely before deposition of the above-mentioned shell that provided the oldest known date of 13,650 ±350 $^{14}$C yr B.P. (Table 1) for the Everson Interstade. This reinforces the suggestion that the Everson Interstade locally may have begun significantly before deposition of the shell.

Southwest-directed outwash channels (Fig. 1) are apparent in Partridge Gravel on the upland surface surrounding Smith Prairie. Similar features on the upland surface northwest of Ebeys Prairie indicate south- to east-trending paleoflow (cross section A). Both cases require a vigorous sediment source to the north, where Penn Cove had to be ice-filled to permit transport of this sediment into the depositional area (Carlstad, 1992).

We suggest that this sediment source is partly documented by a high-energy outwash gravel unit (unit $Qgog_e$), which locally grades up into Partridge Gravel, and which we interpret as mostly subglacial flow deposit.

The Partridge Gravel outwash channels east and west of Ebeys Prairie terminate at a slope break, which represents the upper slope break of marine kame-delta fronts prograding into Ebeys Prairie (Carlstad, 1992) and therefore approximates paleo–sea level (Thorson, 1981). Consequently, we agree with Carlstad (1992) that Ebeys Prairie was sea floor on which glaciomarine drift was deposited while Partridge Gravel was deposited to the east and west. The two units interfinger and grade into each other beneath Ebeys Prairie (Carlstad, 1992; cross section A). Together, the two units fill irregularities in an underlying surface that may represent the subglacial topography that preceded the Everson Interstade incursion of marine water (cross section A).

Partridge outwash channels truncate some drumlins (Fig. 1), implying that a former till plain was locally obliterated by the meltwater that deposited the Partridge Gravel. However, some till plain likely remains preserved beneath Ebeys Prairie and the Partridge Gravel (cross section A). A partial underlayment of till plain is supported by well records southwest of Penn Cove, weak drumlinization(?) at relatively low elevation southeast of Ebeys Landing and around the Coupeville moraine (Fig. 1), and till exposures along the bluff south of Ebeys Landing (shoreline section B).

The maximum Everson Interstade sea level had previously been estimated at up to 196 ft (Thorson, 1980; Carlstad 1992). Regional contouring suggested that it did not exceed 230 ft (Thorson, 1981). We suggest that it rose to at least between 216 and 229 ft, based on deposits of glaciomarine drift about 220 ft above sea level (3300 ft south of Lovejoy Point).

Aside from the above-mentioned shell that suggests that the Everson Interstade began before 13,650 $^{14}$C yr B.P., the age of the Everson Interstade in the map area is further defined by six radiocarbon dates from locally collected samples (Table 1, locs. 5–10). The interstade ended locally when post-glacial crustal rebound exceeded global sea level rise, causing the land in the map area to emerge. We agree with Swanson (1994) that an age estimate of 12,690 $^{14}$C yr B.P. (Table 1, loc. 9) from the upper end of glaciomarine drift at 10 ft above sea level along the north shore of Penn Cove likely provides the best estimate for the end of the Everson Interstade in the map area, but others have favored other dates (Dethier and others, 1995; Easterbrook, 1966a,b; Blunt and others, 1987).

Since the end of the Everson Interstade, the landforms and deposits in the map area have changed little, except for dune development (Fig. 1), which must have begun by about 10 ka (shoreline section 2; Table 1; Mustoe and Carlstad, 1995; Mustoe and others, *in press*) and continues along the western shore, and shoreline erosion that began when sea level approximated modern sea level in the mid-Holocene (Kelsey and others, 2004; Mosher and Hewitt, 2004; Hutchinson, 1992).

## STRUCTURE

No demonstrably tectonic fault scarps have been mapped onshore, but the map area is tectonically active. Gower (1980) used gravity, aeromagnetic, and well data to infer a northwest-trending "Southern Whidbey Island Fault" with possible Quaternary movement; his structure crosses southern Whidbey Island near Lagoon Point (six miles southeast of Admiralty Head) and enters the Coupeville quadrangle about two miles south of Admiralty Head. Wagner and Wiley (1980) used geophysical data to extend it to west of Point Partridge as a Holocene fault and added multiple subsidiary(?) faults and folds, some of which are truncated by the Southern Whidbey Island fault. They also showed a queried Holocene(?) fault extending from the Southern Whidbey Island fault east to the shore south of Ebeys Landing, where multiple north-dipping thrusts are exposed in pre-Vashon sediment but do not appear to penetrate the Vashon deposits (shoreline section B). More recently, Johnson and others (1996) characterized the Southern Whidbey Island fault as a heterogeneous and broad (4-7 mi wide), long-lived, transpressional zone that trends northwest (310°), dips near-vertically to steeply north-northeast, and can be traced for over 43 miles. They noted that it separates two major crustal blocks, has been the source of several historic, shallow crustal earthquakes, and appears capable of generating large (surface-wave magnitude 7 or greater) earthquakes. Kelsey and others (2004) attributed 3 to 7 ft of uplift of Crocket Lake 2800 to 3200 years ago to an inferred moment-magnitude 6.5 to 7 earthquake on the Southern Whidbey Island fault zone. According to Brian Sherrod (U.S. Geological Survey, oral commun., 2005) recent trenching investigations suggest a "reasonable likelihood" of four—and a "possibility" of up to eight—postglacial earthquakes with ground deformation along the fault zone, such that it is now recognized as "one of the most active, documented shallow crustal faults in the Puget Lowland". The fault strands shown on this map are from Mosher and others (2000). The short strand that heads southeast from Admiralty Head coincides with shears in glacial deposits at Admiralty Head; however, these shears may be glaciotectonic.

Dragovich and others (2005) inferred a concealed, northwest-trending, poorly defined pre-Vashon-age(?) fault, the extension of which we show in the northeast corner of the map area. North of and parallel to that unnamed structure, they showed another fault which they named the Oak Harbor fault.

Johnson and others (2001) and Dragovich and others (2005) showed the Utsalady Point, Strawberry Point, and Devils Mountain fault (zones) a few miles north of the map area. These three fault (zones) compose a west-trending "active complex, distributed, transpressional deformation zone" (Johnson and others, 2001) that has uplifted Pleistocene strata in the Oak Harbor area relative to those in the map area (Dragovich and others, 2005). The implied north-up deformation may extend into the map area—Whidbey Formation strata at West Beach seem to dip about 0.7 degrees (apparent) to the south, which is anomalously high for the inferred low-energy paleoenvironment (see Geologic Setting and Development) and suggests post-depositional, south-down tilting. However, such down-to-south tilting appears unlikely to extend south of Penn Cove, because no consistent southerly dip is apparent in Olympia nonglacial deposits south of Penn Cove. In addition, (pre-Whidbey) Double Bluff deposits are exposed south of Ebeys Landing but have not been noted further north in the map area, and a south-down, apparent tilt slope of 0.06 degrees in the upper slope break of the kame delta front east of Ebeys Prairie matches the regional, postglacial rebound tilt in the Puget Lowland (Thorson, 1989) and therefore need not imply a Holocene, southern extension of the Pleistocene deformation seen to the north.

Trenching of the Utsalady Point fault (Johnson and others, 2003) suggested possible postglacial fault offset between AD 1550 and 1850. A submerged log sampled during this study at the northwest end of Penn Cove may have been tectonically lowered into the intertidal zone sometime between AD 1740 and 1790, or between 1810 and 1960 (Table 1, loc. 1); local history suggests it occurred prior to 1850. If so, the event would appear to require a minimum surface lowering of 4.5 ft at the site. Such deformation would be consistent with the above-mentioned down-to-south tilting of Pleistocene strata north of Penn Cove and may be consistent with Johnson and others' postulated AD 1550 to 1850 event. Further documentation and examination of the Penn Cove log would provide more information on the timing and magnitude of the surface lowering but exceeds the scope of this project.

## DESCRIPTION OF MAP UNITS

### Postglacial Deposits (Late Pleistocene to Holocene)

**Qf** **Fill**—Clay, silt, sand, gravel, organic matter, rip-rap, and debris emplaced to elevate and reshape the land surface; includes engineered and nonengineered fills; shown where fill placement is relatively extensive, readily verifiable, and appears sufficiently thick to be of geotechnical significance.

**Qml** **Modified land**—Local sediment, ranging from clay to gravel, mixed and reworked by excavation and (or) redistribution to modify topography; includes mappable sand and gravel pits excavated mostly into unit $Qgom_e$.

**Qb** **Beach deposits**—Sand and cobbles; may include boulders, silt, pebbles, and clay; pebble-sized and larger clasts typically well rounded and oblate; locally well sorted; loose; typically a mix of sediment locally derived from shoreline bluffs and underlying deposits and (or) carried in by longshore drift.

**Qd** **Dune deposits**—Hills and ridges of wind-blown sand; moderately to well sorted; deposited on upland surfaces and in kettle sidewalls along or near west-facing shoreline bluffs north of Ebeys Landing. Age estimates of 8840 ±50 and 8280 ±40 $^{14}$C yr B.P. (shoreline section 2; Table 1, loc. 3 and 4) indicate that deposition of at least some dunes began during the early Holocene. Dune morphology suggests a depositional environment free of the forests that cover most of these dunes today, but minimal soil development and location of the dunes within 0.5 mi of the present-day shoreline bluffs suggest that deposition may also be recent and ongoing.

**Qp** **Peat**—Organic and organic-matter-rich mineral sediments deposited in closed depressions; includes peat, muck, silt, and clay in and adjacent to wetlands; the freshwater equivalent of unit Qm and may locally grade down to that unit.

**Qm** **Marsh deposits**—Organic and organic-matter-rich mineral sediments deposited in a saltwater or brackish marsh (estuarine or lagoonal) environment.

**Qmw** **Mass wasting deposits**—Boulders, gravel, sand, silt, and clay; generally unsorted but may be locally stratified; typically loose; shown along mostly colluvium-covered or densely vegetated slopes that are demonstrably unstable or appear potentially unstable; contains exposures of underlying units and landslides that we either could not map with confidence or are too small to show as separate features.

**Qls** **Landslide deposits**—Gravel, sand, silt, clay, and boulders in slide body and toe, and underlying units in scarp areas; clasts are angular to rounded; unsorted; generally loose, unstratified, broken, and chaotic, but may locally retain primary bedding; may include liquefaction features; deposited by mass-wasting processes other than soil creep and frost heave; typically unconformable with surrounding units; includes active as well as inactive slides; shown where scale permits. Absence of a mapped slide does not imply absence of sliding or hazard. All shoreline bluffs in the map area are subject to episodic landsliding and resultant bluff retreat, but most slide deposits are quickly removed by beach wave action.

**Qs** **Late Pleistocene sand**—Fine sand to silt; light gray where fresh, light tan to reddish medium brown where weathered; moderately well sorted; blankets much of the map area as a 0.5 to 4 ft thick sheet that typically forms topsoil and is mapped only where thickness appears to exceed 5 ft; well to very well drained; grain size, sorting, and morphology suggest wind-blown origin for some exposures, but elsewhere, mineralogy, poor sorting, and high angularity suggest till or glaciomarine drift (units $Qgdm_e$, $Qgt_v$, and $Qgt_{va}$) or mixed sources; appears to represent a postglacial, late Pleistocene pulse of sedimentation because it is stratigraphically beneath, and typically separated by a paleosol from, Holocene dunes (unit Qd) that lack a similar degree of soil development (shoreline section 2). The paleosol may reflect a late Pleistocene to early Holocene climate conducive to more rapid soil development than modern climate.

**Table 2.** Geochemical analyses from the map area, and average geochemical values for samples from central and northern Whidbey Island and for Glacier Peak–sourced samples from elsewhere. Analyses were performed by Washington State University GeoAnalytical Laboratory (Pullman, Wash.). Major elements are normalized on a volatile-free basis, with total Fe expressed as FeO. Each analysis from this study represents a single clast of vesicular dacite or dacitic pumice; sample 04-5H is courtesy of Joe Dragovich (Wash. Div. of Geology and Earth Resources). Inductively coupled plasma mass spectrometry (ICP-MS) values for sample 124 are averages of two analytical runs. Elevations are estimated in feet above mean sea level. Differences between our chemical values for unit $Qc_w$ and those previously published by Easterbrook (1994a) likely reflect Easterbrook's use of electron microprobe as opposed to the x-ray fluorescence (XRF) and ICP-MS we employed (Joe Dragovich, Wash. Div. of Geology and Earth Resources, written commun., March 2005). "Average of 20 Whidbey Island volcanic clasts" represents the average of single-clast analyses of vesicular dacite to dacitic pumice pebbles from the Oak Harbor and Coupeville areas. Average includes 12 dacite clasts from the Whidbey Formation in the Oak Harbor area (Dragovich and others, 2005) and all samples from this table, except sample 188 (excluded as outlier that may reflect an altered clast or different source). "Average of 107 Glacier Peak dacite clasts from elsewhere" is from Dragovich and others (2005)

| Sample no. | 136-1 | 136-2 | 110 | 124 | 177 | 178 | 04-5H | 182 | 188 | Average of 20 Whidbey Island volcanic clasts | Average of 107 Glacier Peak dacite clasts from elsewhere |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Location | East of Long Point, sand with sparse volcanic pebbles | | Blowers Bluff, lower lahar run-out | | | | | Blowers Bluff, upper lahar run-out | | | |
| Elev. (ft) | 16-26 | 16-26 | 40-45 | 45-50 | 50-55 | 43-57 | ~50 | 55-70 | 70 | | |
| Geol. unit | $Qc_o$ | $Qc_o$ | $Qc_w$ | $Qc_w$ | $Qc_w$ | $Qc_w$ | $Qc_w$ | $Qc_w$ | $Qc_w$ | | |
| **MAJOR ELEMENTS NORMALIZED (XRF; in weight percent)** | | | | | | | | | | | |
| $SiO_2$ | 65.82 | 65.05 | 66.87 | 67.15 | 66.47 | 66.00 | 66.20 | 66.13 | 64.80 | 65.57 | 65.09 |
| $Al_2O_3$ | 16.64 | 16.34 | 15.94 | 16.11 | 16.39 | 16.26 | 16.23 | 16.30 | 16.55 | 16.52 | 16.62 |
| $TiO_2$ | 0.590 | 0.637 | 0.577 | 0.540 | 0.564 | 0.594 | 0.590 | 0.595 | 0.695 | 0.60 | 0.59 |
| FeO* | 3.79 | 4.33 | 3.89 | 3.48 | 3.64 | 3.88 | 3.89 | 3.91 | 3.99 | 3.96 | 4.03 |
| MnO | 0.074 | 0.087 | 0.083 | 0.074 | 0.071 | 0.077 | 0.17 | 0.075 | 0.084 | 0.08 | 0.083 |
| CaO | 4.60 | 4.85 | 4.13 | 4.18 | 4.41 | 4.56 | 4.30 | 4.50 | 5.11 | 4.66 | 4.79 |
| MgO | 1.92 | 2.40 | 1.89 | 1.74 | 1.84 | 2.09 | 1.980 | 1.98 | 2.43 | 2.12 | 2.31 |
| $Na_2O$ | 4.16 | 3.92 | 4.05 | 4.16 | 4.11 | 4.06 | 4.13 | 4.03 | 3.96 | 4.07 | 4.12 |
| $K_2O$ | 2.25 | 2.21 | 2.41 | 2.43 | 2.35 | 2.32 | 2.35 | 2.33 | 2.20 | 2.27 | 2.04 |
| $P_2O_5$ | 0.159 | 0.169 | 0.157 | 0.145 | 0.149 | 0.155 | 0.16 | 0.159 | 0.179 | 0.16 | 0.155 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 99.993 | 100.00 | 100.00 | | |
| Unnorm. Total | 99.14 | 98.67 | 98.69 | 98.70 | 98.72 | 97.80 | 98.77 | 98.69 | 98.65 | | |
| **TRACE ELEMENTS (XRF; in parts per million)** | | | | | | | | | | | |
| Ni | 16 | 17 | 18 | 15 | 14 | 17 | 22 | 15 | 20 | 19.44 | 18 |
| Cr | 16 | 20 | 17 | 14 | 16 | 18 | 16 | 19 | 29 | 19.36 | 18 |
| V | 75 | 90 | 77 | 69 | 73 | 78 | 81 | 83 | 81 | 83.57 | 81 |
| Ba | 552 | 529 | 586 | 586 | 575 | 567 | 606 | 569 | 551 | | |
| Ga | 17 | 18 | 17 | 18 | 18 | 18 | 16 | 17 | 17 | 17.42 | 17 |
| Cu | 6 | 10 | 8 | 4 | 8 | 5 | 11 | 4 | 8 | 7.94 | 10 |
| Zn | 55 | 62 | 57 | 53 | 53 | 56 | 59 | 54 | 64 | 57.42 | 57 |
| **TRACE ELEMENTS (ICP-MS; in parts per million)** | | | | | | | | | | | |
| La | 18.45 | 17.34 | 18.72 | 18.91 | 19.11 | 18.05 | 18.75 | 18.39 | 19.53 | 18.15 | 16.02 |
| Ce | 35.76 | 33.89 | 35.86 | 36.23 | 36.61 | 34.66 | 37.00 | 35.50 | 38.48 | 35.33 | 31.23 |
| Pr | 4.12 | 3.92 | 4.06 | 4.12 | 4.19 | 3.97 | 4.15 | 4.07 | 4.59 | 4.04 | 3.47 |
| Nd | 16.28 | 15.80 | 15.99 | 16.25 | 16.63 | 15.68 | 16.54 | 16.39 | 18.46 | 16.11 | 13.83 |
| Sm | 3.66 | 3.51 | 3.47 | 3.50 | 3.61 | 3.41 | 3.60 | 3.58 | 4.16 | 3.56 | 3.08 |
| Eu | 1.03 | 0.98 | 0.93 | 0.98 | 1.01 | 1.00 | 1.00 | 1.00 | 1.13 | 1.00 | 0.92 |
| Gd | 3.26 | 3.25 | 3.09 | 3.20 | 3.21 | 3.04 | 3.31 | 3.27 | 3.72 | 3.22 | 2.75 |
| Tb | 0.52 | 0.53 | 0.50 | 0.51 | 0.52 | 0.49 | 0.53 | 0.52 | 0.60 | 0.51 | 0.44 |
| Dy | 3.18 | 3.13 | 3.00 | 3.11 | 3.18 | 2.96 | 3.19 | 3.16 | 3.65 | 3.09 | 2.64 |
| Ho | 0.64 | 0.65 | 0.61 | 0.62 | 0.64 | 0.60 | 0.65 | 0.64 | 0.73 | 0.63 | 0.54 |
| Er | 1.81 | 1.77 | 1.69 | 1.77 | 1.79 | 1.68 | 1.84 | 1.77 | 2.01 | 1.76 | 1.48 |
| Tm | 0.27 | 0.27 | 0.26 | 0.27 | 0.27 | 0.25 | 0.28 | 0.27 | 0.30 | 0.26 | 0.22 |
| Yb | 1.73 | 1.75 | 1.65 | 1.73 | 1.68 | 1.64 | 1.77 | 1.74 | 1.89 | 1.69 | 1.43 |
| Lu | 0.28 | 0.27 | 0.27 | 0.28 | 0.28 | 0.27 | 0.29 | 0.28 | 0.31 | 0.28 | 0.23 |
| Ba | 548 | 511 | 562 | 576 | 571 | 534 | 606 | 548 | 537 | 544.68 | 495 |
| Th | 6.25 | 5.98 | 6.81 | 6.88 | 6.85 | 6.44 | 6.43 | 6.70 | 6.69 | 6.39 | 5.39 |

### Deposits of the Fraser Glaciation (Pleistocene)

EVERSON INTERSTADE

**$Qgom_{ee}$** **Glaciomarine drift, emergence (beach) facies**—Sand and gravel, locally silty; loose; typically only a few feet thick; underlain by glaciomarine drift (unit $Qgdm_e$) or Partridge Gravel (unit $Qgom_e$), but may rest on older sediments north and west of Penn Cove and along parts of the slope east of Ebeys Prairie; represents emergence deposits (Domack, 1983) that record a falling relative sea level at the end of the Everson Interstade. Subtle benches at varying elevations are characteristic of the unit and represent paleo–beach berms (Carlstad, 1992). This unit is partly the youngest facies of glaciomarine drift but may also include terrestrial deposits (Domack, 1983). It is mapped as outwash to maintain continuity with maps to the north (Dragovich and others, 2005).

**$Qmf_e$** **Fan deposits**—Sand, fine gravel, silt, and clay; variably sorted; loose; bedded; consists of either terrigenous nearshore marine deltaic or terrestrial alluvial fans that record a late Everson Interstade (?), onshore hydrologic regime conducive to surface runoff in loose, well-drained units like Partridge Gravel (unit $Qgom_e$); located at the foot of small, relict valleys that lack modern streams and were incised into Partridge Gravel or other easily eroded deposits. The unit may mark a climatic shift or an elevated (but dropping) relative sea level late in the Everson Interstade. If unit deposition is tied to sea level change, valley incision and fan deposition ceased when relative sea level dropped sufficiently below the head of the fan to cause the groundwater table to lower, resulting in termination of surface runoff capable of incision. Valley incision into and fan deposition on the delta front landform in Partridge Gravel indicate that Partridge deposition had locally ceased; it follows that the ice front that had supplied the water that deposited the Partridge Gravel was locally no longer supplying much meltwater, and the runoff that deposited unit $Qmf_e$ near Coupeville was likely fed by other sources. The unit is thus best viewed as neither glaciomarine drift nor outwash, even though deposition was likely coeval (and may interfinger) with nearby deposition of glaciomarine drift. This unit is assigned to the Everson Interstade on the above speculation that it is associated with Everson sea level.

**$Qgdm_e$** **Glaciomarine drift, undivided**—Most commonly clayey to silty diamicton with variable content of gravel-sized clasts, but also includes silt, clay, sand, and combinations of the above; contains marine shells; weathered color most commonly buff but ranges to olive gray, ash gray, or white; dark gray where unweathered; dry face characteristically includes vertical desiccation cracks with dark brown staining; commonly forms vertical faces prone to sudden failure along desiccation cracks; massive to rhythmically bedded, commonly with sharp upper and lower, unit-bounding unconformities (Domack, 1984); mostly loose and soft but locally hard and compact. Some exposures are very like till (Domack and Lawson, 1985), but till generally lacks fossils, and glaciomarine drift generally has a finer-grained, smoother-feeling matrix, and is more likely to be stratified, more likely to be buff-colored, and typically less compact (and less water-restrictive) than till. Till-like deposits are most prominent along elevated portions of Blowers Bluff, the north shore of Penn Cove, and the cliff between Ebeys Landing and Fort Casey. The unit consists of sea-floor sediment, and its variegated character appears to reflect initial proximity of the ice front (Domack, 1983). For detailed characterization, see Domack (1983, 1984, 1982), Domack and Lawson (1985), and Dethier and others (1995). The age of the unit spans the entire Everson Interstade (see Geologic Setting and Development). Locally divided into:

- **$Qgdm_{els}$** **Landslides**—Apparent landslides that lack evidence for recent activity. Slide surfaces are dominated by glaciomarine drift material that may be slightly looser than glaciomarine drift outside the slump area. We infer the subunit to be Everson Interstade(?) submarine(?) slumps that do not necessarily pose a slide hazard.

**$Qgim_e$** **Ice-marginal moraine—**Cobbly to bouldery, angular to rounded gravel with loose, powdery matrix, plenty of void spaces, and abundant erratics on the surface; forms a gentle, 500 to 800 ft wide ridge across Coupeville (Fig. 1); marks the ice margin during the early part of the Everson Interstade, likely before deposition of a shell in glaciomarine drift (unit $Qgdm_e$) dated at 13,650 $^{14}$C yr B.P. (Table 1, sample no. Beta 1319; see Geologic Setting and Development for field relations).

**$Qgom_e$** **Partridge Gravel** —Sand, gravel, and sand-gravel mixtures with minor interlayered silt and silty sand; at least 210 ft thick above sea level southeast of its type section at Partridge Point, with well records locally suggesting an additional 135 ft below sea level (Carlstad, 1992); forms angle-of-repose slopes, such as at Partridge Point. The unit includes three outwash facies that compose a coarsening-upward, marine, kame-delta–turbidite complex (Carlstad, 1992; cross section A): a mostly horizontally bedded, sand-dominated, bottom-set sea floor facies with common low-energy gravity flow cross-bedding, flame structures, and other soft sediment deformation features, but apparently lacking (?) dropstones; an overlying foreset-bedded sand and gravel facies; and a capping, top-set, channelized gravel and sand facies that locally coarsens to a bouldery gravel and reflects a shallow-water deltaic to subaerial, braided stream environment (outwash channels in Fig. 1) with abundant cut-and-fill cross-bedding. Many exposures of the bottom-set sand facies include sparse, randomly distributed inclusions and apparently gravity-sorted trains of sand- to fine gravel-sized, detrital fragments of peat, charred wood, charcoal, coal, pumice, and dacite. Carlstad (1992) suggested that tephra found in this unit is the Lake Tapps tephra. However, we agree with Franklin Foit (Washington State University, written commun., Feb. 2005), Dragovich and others (2005), and Joe Dragovich (Wash. Div. of Geology and Earth Resources, written commun., Feb. 2005; oral commun., Mar. 2005) that the tephra chemistry and field relations instead favor a Glacier Peak origin and suspect that the deposits are re-worked from nearby units, mostly units $Qc_o$ and $Qc_w$. The age of the unit is confined to the early Everson Interstade, sometime after initial incursion of marine water into the Puget Lowland but before deposition of a marine shell dated at 13,650 ±350 $^{14}$C yr B.P. (Table 1; see Geologic Setting and Development for field relations). Assuming an average thickness of 100 to 250 ft, we estimate that the unit holds approximately 0.2 to 0.6 mi$^3$ of sand and gravel.

**$Qgog_e$** **High-energy outwash gravel**—Variegated deposit of gravel with lenses of sand, silt, and clay and with inclusions of boulder-sized, subangular to well-rounded silt and clay rip-up clasts and channel lag gravel derived from massive to well-bedded, compact, pre-Fraser deposits of fines (columnar sections 3 and 5; Easterbrook, 1994b); crudely to well bedded, locally unbedded, and commonly including steep bedding, gravelly incisions (intrusions?) into underlying units, and other indicators of a high-energy flow regime; typically supports vertical bluff faces but locally forms angle-of-repose slopes; widely exposed beneath glaciomarine drift (unit $Qgdm_e$) along the Penn Cove shoreline between Coupeville and Blowers Bluff, where it steeply truncates at least 40 ft of pre-Fraser section (columnar section 5). The unit is interpreted herein as dominantly a subglacial flow deposit, except in upland areas between State Route 20 and Penn Cove near the northern map boundary, where the depositional and time-stratigraphic setting is unclear. Like the Partridge Gravel (unit $Qgom_e$), this unit is clearly overlain by glaciomarine drift (unit $Qgdm_e$). Based on exposures in a gravel pit southwest of Penn Cove, we believe that the unit locally grades up into and thus is a lateral facies equivalent of the Partridge Gravel. For that reason and because the unit is apparently nowhere overlain by convincing exposures of Vashon till (unit $Qgt_v$), we assign it to the Everson Interstade. We separate the unit from Partridge Gravel because Partridge Gravel is marine-deltaic and lacks the characteristics of high-energy flow that mark this unit.

VASHON STADE

**$Qgt_v$** **Till**—Mix of clay, silt, sand, and gravel deposited as diamicton directly by Vashon Stade glacier ice; gray where fresh, light yellowish brown where oxidized; unsorted and highly compacted; permeability very low where lodgment till is well developed; most commonly matrix supported, but locally clast supported; matrix more angular than water-worked sediments, resulting in a grittier feel than the matrix of unit $Qgdm_e$; cobbles and boulders commonly faceted and (or) striated; forms a patchy cover varying from less than 0.5 to more(?) than 50 ft thick, with thicknesses of 10 to 30 ft most common; may include outwash and ablation till that are too thin to substantially mask the underlying, rolling till plain; locally capped with 0.5 to 4 ft of sand that is equivalent to but too thin to be separately mapped as unit Qs; up to house-sized erratic boulders commonly signal that till is underfoot, but such boulders may also occur as dropstones, or as lag deposits where the underlying deposits have been modified by meltwater; modern soil typically caps loose surface sediment, but the underlying till is unweathered; may include flow banding; typically forms vertical faces in coastal bluffs. The unit locally resembles unit $Qgdm_e$ (Domack, 1982, 1984; Domack and Lawson, 1985). Unit $Qgt_v$ lies stratigraphically between overlying recessional glaciomarine drift (unit $Qgdm_e$) and underlying advance outwash (units $Qga_v$ and $Qga_{vs}$). Its stratigraphic position relative to unit $Qgog_e$ remains unresolved. Local and nearby age control constrains the age of the unit to between about 18 ka (~15,000 $^{14}$C yr B.P.; Swanson, 1994; Porter and Swanson, 1998; Booth, 1991) and sometime before deposition of a shell that yielded an age estimate of 13,650 ±350 $^{14}$C yr B.P. (see Geologic Setting and Development and Table 1). This unit may include local exposures of older till that are similar in stratigraphic position, lithology, and appearance. Locally divided into:

- **$Qgt_{va}$** **Ablation till—**Unsorted, unstratified melt-out deposit of loose gravel, sand, silt, and clay.

**$Qga_v$** **Advance outwash**—Sand and pebble to cobble gravel with some bouldery facies; local silt and clay; may contain till fragments; gray to grayish brown and grayish orange; clasts well rounded; typically well sorted and clean except in some ice-proximal deposits near the top of the unit; compact, but in many exposures only minimally cohesive; parallel-bedded, locally cross-bedded; less than 20 ft thick in most exposures; commonly overlain by unit $Qgt_v$ along a sharp contact and stratigraphically above unit $Qc_o$; commonly forms angle-of-repose benches within coastal bluffs. The age of this unit is bracketed to between about 18 and 20 ka by local and nearby age control from within the underlying unit $Qc_o$ (Table 1; columnar section 4) and an estimate of Vashon ice arrival by Porter and Swanson (1998) (see Geologic Setting and Development). Locally divided into:

- **$Qga_{vs}$** **Sand-dominated advance outwash**

**Qgd** **Vashon and Everson drift, undivided**—Glaciomarine drift (unit $Qgdm_e$), till (unit $Qgt_v$), and advance outwash (units $Qga_v$ and $Qga_{vs}$) combined into single unit where map scale or exposure do not permit separate presentation.

### Deposits of the Olympia Nonglacial Interval (Pleistocene)

Armstrong and others (1965) defined as "Olympia Interglaciation" the "climatic episode immediately preceding the last major glaciation" and associated with it "nonglacial strata lying beneath Vashon Drift". We avoid the label "Olympia Interglaciation" because stage 3 (60-20 ka) is not a true interglacial period (as defined in fig. 4 of Morrison, 1991).

**$Qc_o$** **Nonglacial deposits**—Silt, clay, sand, and local lenses and interbeds of fine gravel; includes the widespread "West Beach silt" facies interpreted as loess by Thorsen (1983a,b, 2001); compact; typically horizontally bedded to massive; commonly forms vertical bluffs; silt facies locally contain sparse gastropod fossils (columnar section 4 and shoreline section B; Table 1). Petrographic study (Dragovich and others, 2005, and this study) indicates that alluvial facies reflect ancestral Skagit River provenance. Sparse, local Glacier Peak dacite and pumice pebbles, such as those found to the east of Long Point (columnar section 7; Table 2, samples 136-1 and 136-2), are chemically indistinguishable from lahar runout deposits within the Whidbey Formation (unit $Qc_w$), but no lahar runout deposits were recognized in this unit. The age of the West Beach silt is constrained in the map area to between about 37,000 and 27,000 $^{14}$C yr B.P. by dates from overlying and underlying units (Table 1, sample nos. Beta 154508 and Beta 169086). The age of the entire unit may be limited to between about 37,000 and 16,800 $^{14}$C yr B.P. by six radiocarbon dates from the field area and the above-mentioned 37,000 $^{14}$C yr B.P. date from West Beach just north of the field area (Table 1). Alternatively, undated strata within the unit may include significantly older deposits of the Olympia nonglacial interval. This unit may include fine-grained early Vashon advance deposits ("Transitional beds" of Pessl and others (1989)), such as at North Penn Cove (columnar section 4), where the upper radiocarbon date and sedimentary characteristics of overlying silty sediment may be compatible with early Vashon association.

### Deposits of the Possession Glaciation (Pleistocene)

**$Qgd_p$** **Possession Drift**—Glaciomarine drift and underlying till and advance outwash sand; distinguished from equivalent Fraser Glaciation units by stratigraphic position. Glaciomarine drift facies highly variegated; typically clayey silt, silty clay, clay, and clay-rich diamicton; buff, ranging to ash gray or white; compact and commonly with vertical desiccation cracks; commonly contains shells; more compact than Everson Interstade equivalent; locally indistinguishable from till. Till facies typically sandy diamicton; ash gray to white; compact. Outwash sand gray; medium to fine grained; classified as advance based on field relations along West Beach north of map area (Dragovich and others, 2005). The unit is mostly glaciomarine drift along Blowers Bluff; it is dominantly sand at West Beach and within 1.5 mi southeast of Ebeys Landing, but glaciomarine drift overlying till further south along the same bluff. Sand at West Beach is very similar to and was distinguished from underlying channel sand of unit $Qc_w$ based on mineralogic content determined from petrography. We believe the unit age to be about 80 to 60 ky (see Geologic Setting and Development).

### Interglacial Deposits of the Whidbey Formation (Pleistocene)

**$Qc_w$** **Whidbey Formation**—Sand, silt, clay, peat layers, occasional fine gravel, and rare medium gravel; where exposed, most commonly weathered to a subtly multicolored to light-yellowish appearance; forms base of section along shoreline bluffs of West Beach and Blowers Bluff and most commonly consists of a basal flood-plain facies overlain by a channel sand facies. The flood-plain facies is typically 10 to 20 ft thick, well stratified (subhorizontally), and commonly slightly oxidized, forms prominent vertical bluffs, and contains discontinuous peat beds. Along West Beach, the flood-plain facies is at least 30 ft thick at columnar section 1, but descends below sea level 3000 ft to the south (see Structure). The flood-plain facies is overlain by a roughly 30 ft thick, clean, gray, cross-bedded to massive channel sand facies (columnar section 1) that typically forms an angle-of-repose cliff and so resembles the overlying Possession glacial sand (unit $Qgd_p$) that petrographic analysis may be needed for separation of these two units. At Blowers Bluff, the flood-plain facies reaches a maximum thickness of 25 ft and is overlain by a gravelly, cross-bedded channel sand facies that is lavender to light yellowish gray, 15 to 80 ft thick, and somewhat prone to forming angle-of-repose benches; this facies is continuous with similar deposits in the Blowers Bluff portion of the Oak Harbor 7.5-minute quadrangle north of the field area, where Dragovich and others (2005) informally named it the lahar runout of Oak Harbor and used mineralogic composition to demonstrate an ancestral Skagit River basin provenance. We agree with Dragovich and others (2005) that local concentrations of dacite and pumice pebble trains (see columnar section 5 and Easterbrook, 1994b) come from Glacier Peak lahar runout deposits (Table 2; Dragovich and others, 2005). We believe the unit age to be about 125 to 80 ka (see Geologic Setting and Development).

### Deposits of the Double Bluff Glaciation (Pleistocene)

**$Qgd_d$** **Double Bluff Drift**—Glaciomarine drift (silt, clay, and diamicton) and locally underlying till; resembles equivalent Vashon Drift units but is assigned to the Double Bluff Glaciation based on stratigraphic position; recognized in the map area only along about 1500 ft of shoreline southeast of Ebeys Landing (shoreline section B); lithology reflects British Columbian provenance (Easterbrook and others, 1967). The age of the unit appears to be 185 to 125 ky or older (see Geologic Setting and Development).

### Undivided Pre-Fraser Nonglacial Deposits (Pleistocene)

**Qc** **Pre-Fraser nonglacial deposits, undivided**—Sand, silt, clay, peat, some fine gravel, and rare medium gravel; well stratified to massive; resembles units $Qc_o$ and $Qc_w$ and is thought to be nonglacial but may locally include glacial material; mapped in a single exposure about 3000 ft west of columnar section 4; stratigraphically situated below Fraser glacial deposits but otherwise of unknown age and association; likely of Olympia or Whidbey age, but an older origin has not been ruled out.

### Undivided Pleistocene Deposits

**Qu** **Pleistocene deposits, undivided**—Sediment of unknown age and association; may include both glacial and interglacial deposits. In an exposure west of Long Point (columnar section 6), the unit consists of a 73 ft thick section of gray, medium- to fine-grained, subangular to subrounded, poorly sorted, compact to mildly compact, plane- to gently cross-bedded, lithologically diverse sand with sparsely disseminated, thin (< 1 in. thick) elongate pockets of granule-sized pumice and coal; soft-sediment deformation structures and (or) liquefaction features are exposed in the basal 20 ft of section; sand is interlayered with at least three compact, discontinuous diamictons up to 6 ft thick, with sparse to rare, subrounded to angular granule to pebble clasts; diamictons greenish to olive and dark gray; grains angular to subangular; lithologic composition mixed and not indicative of specific source area or glacial or interglacial conditions; angularity of particles in diamicton suggests till. In a separate exposure 0.3 mi southwest of the Coupeville dock, the unit consists of compact, quartz-rich sand. The unit also includes an exposure of somewhat compact cobble gravel near the top of a hill 4000 ft southeast of Lovejoy Point. This exposure is in the sideslope of a hill that rises about 10 ft above the surrounding glaciomarine drift and recessional outwash gravel, suggesting that the hill is cored with older sediment.

## ACKNOWLEDGMENTS

This report was produced in cooperation with the U.S. Geological Survey National Cooperative Geologic Mapping Program, Agreement No. 04HQAG0069, and the National Park Service, agreement for geologic mapping of the Ebey's Landing National Historical Reserve, which partially supported our mapping. We thank Pat Pringle for considerable assistance with tree ring and radiocarbon data analysis; the officials and volunteers at Ebey's Landing National Historical Reserve, the Ebey's Prairie Land Trust, and Forts Ebey and Casey of the Washington State Parks for assistance and permission to map on their land; Doug Kelly (Island Co. Health Dept.) and other Island County staff for geologic, hydrogeologic, geotechnical, and other assistance and records; Toby Rodgers and Crystal Briggs (Natural Resources Conservation Service) for soil scientific expertise and consultation; Steve Koblyk (Washington State Parks and Recreation Commission), Roger Sherman, John Harris, Chuck Arnold, and the staff and volunteers of the Coupeville Museum for historical expertise and records; Mac McKay, Yvonne Dettlaff, and Regine Polenz for assistance with field work; Pat Pringle, Eric Schuster, and Ingrid Polenz for assistance with the processing of a sub-fossil tree ring sample; Liz Nesbitt (Univ. of Wash. Burke Museum), Dick Johnson (Wash. State Univ.), and John Fleckenstein, Helen Berry, and Tom Mumford (all three Wash. Dept. of Natural Resources) for identification of fossils; George Mustoe (Western Wash. Univ.) for records, age control, and assistance pertaining to the geology of Cedar Hollow; Curt Koger (Associated Earth Sciences, Inc.) for permission to publish his radiocarbon dates; David Mosher (Geological Survey of Canada), David Dethier (Williams College), Ralph Haugerud and Brian Sherrod (both U.S. Geological Survey), and Michael Sternberg (Northwest Paleontological Association) for assistance with geologic questions; Nick Foit (Wash. State Univ.) for assistance with geochemical questions; Charles Lutrell (Eastern Wash. Univ.) for assistance with archeological and anthropological questions; and Julie Stein and Jacob Fisher (Univ. of Wash.) for sharing geoarcheological data. Thanks also to the Washington State Department of Ecology for permission to use proprietary shoreline aerial photos for our fieldwork and shoreline section 2, and to fellow Department of Natural Resources staff members Josh Logan, Tim Walsh, Hank Schasse, Joe Dragovich, Gary Petro, and Mac McKay for technical assistance and reviews. Last, but not least, thanks to the uncounted people who permitted us to study geologic exposures on their land and provided site-specific records and local knowledge.

## REFERENCES CITED

Armstrong, J. E.; Brown, W. L., 1954, Late Wisconsin marine drift and associated sediments of the lower Fraser Valley, British Columbia, Canada: Geological Society of America Bulletin, v. 65, no. 4, p. 349-364.

Armstrong, J. E.; Crandell, D. R.; Easterbrook, D. J.; Noble, J. B., 1965, Late Pleistocene stratigraphy and chronology in southwestern British Columbia and northwestern Washington: Geological Society of America Bulletin, v. 76, no. 3, p. 321-330.

Berger, G. W.; Easterbrook, D. J., 1993, Thermoluminescence dating tests for lacustrine, glaciomarine, and floodplain sediments from western Washington and British Columbia: Canadian Journal of Earth Sciences, v. 30, no. 9, p. 1815-1828.

Bloom, A. L., 1983, Sea level and coastal morphology of the United States through the late Wisconsin glacial maximum. *In* Porter, S. C., editor, The late Pleistocene; Volume 1 *of* Wright, H. E., Jr., editor, Late-Quaternary environments of the United States: University of Minnesota Press, p. 215-229.

Blunt, D. J.; Easterbrook, D. J.; Rutter, N. W., 1987, Chronology of Pleistocene sediments in the Puget Lowland, Washington. *In* Schuster, J. E., editor, Selected papers on the geology of Washington: Washington Division of Geology and Earth Resources Bulletin 77, p. 321-353.

Booth, D. B., 1991, Glacier physics of the Puget lobe, southwest Cordilleran ice sheet: Geographie physique et quaternaire, v. 45, no. 3, p. 301-315.

Booth, D. B., 1994, Glaciofluvial infilling and scour of the Puget Lowland, Washington, during ice-sheet glaciation: Geology, v. 22, no. 8, p. 695-698.

Bronk Ramsey, C.; van der Plicht, J.; Weninger, B., 2001, 'Wiggle matching' radiocarbon dates: Radiocarbon, v. 43, no. 2a, p. 381-389.

Bronk Ramsey, Christopher, 1995, Radiocarbon calibration and analysis of stratigraphy—The OxCal program: Radiocarbon, v. 37, no. 2, p. 425-430.

Bronk Ramsey, Christopher, 2001, Development of the radiocarbon calibration program: Radiocarbon, v. 43, no. 2a, p. 355-363.

Carlstad, C. A., 1992, Late Pleistocene deglaciation history at Point Partridge, central Whidbey Island, Washington: Western Washington University Master of Science thesis, 1 v.

Dethier, D. P.; Pessl, Fred, Jr.; Keuler, R. F.; Balzarini, M. A.; Pevear, D. R., 1995, Late Wisconsinan glaciomarine deposition and isostatic rebound, northern Puget Lowland, Washington: Geological Society of America Bulletin, v. 107, no. 11, p. 1288-1303.

Domack, E. W., 1982, Facies of late Pleistocene glacial marine sediments on Whidbey Island, Washington: Rice University Doctor of Philosophy thesis, 312 p., 11 plates.

Domack, E. W., 1983, Facies of late Pleistocene glacial-marine sediments on Whidbey Island, Washington—An isostatic glacial-marine sequence. *In* Molnia, B. F., editor, Glacial-marine sedimentation: Plenum Press, p. 535-570.

Domack, E. W., 1984, Rhythmically bedded glaciomarine sediments on Whidbey Island, Washington: Journal of Sedimentary Petrology, v. 54, no. 2, p. 589-602.

Domack, E. W.; Lawson, D. E., 1985, Pebble fabric in an ice-rafted diamicton: Journal of Geology, v. 93, no. 5, p. 577-591.

Dragovich, J. D.; Petro, G. T.; Thorsen, G. W.; Larson, S. L.; Foster, G. R.; Norman, D. K., 2005, Geologic map of the Oak Harbor, Crescent Harbor, and part of the Smith Island 7.5-minute quadrangles, Island County, Washington: Washington Division of Geology and Earth Resources Geologic Map GM-59, 2 sheets, scale 1:24,000.

Easterbrook, D. J., 1966a, Glaciomarine environments and the Fraser glaciation in northwest Washington—Guidebook for first Annual Field Conference, Pacific Coast Section, Friends of the Pleistocene, September 24-25, 1966: [Privately published by the author], 52 p.

Easterbrook, D. J., 1966b, Radiocarbon chronology of late Pleistocene deposits in northwest Washington: Science, v. 152, no. 3723, p. 764-767.

Easterbrook, D. J., 1968, Pleistocene stratigraphy of Island County: Washington Department of Water Resources Water-Supply Bulletin 25, part 1, 34 p., 1 plate (in 4 parts).

Easterbrook, D. J., 1994a, Chronology of pre-late Wisconsin Pleistocene sediments in the Puget Lowland, Washington. *In* Lasmanis, Raymond; Cheney, E. S., convenors, Regional geology of Washington State: Washington Division of Geology and Earth Resources Bulletin 80, p. 191-206.

Easterbrook, D. J., 1994b, Stratigraphy and chronology of early to late Pleistocene glacial and interglacial sediments in the Puget Lowland, Washington. *In* Swanson, D. A.; Haugerud, R. A., editors, Geologic field trips in the Pacific Northwest: University of Washington Department of Geological Sciences, v. 1, p. 1J 1 - 1J 38.

Easterbrook, D. J.; Crandell, D. R.; Leopold, E. B., 1967, Pre-Olympia Pleistocene stratigraphy and chronology in the central Puget Lowland, Washington: Geological Society of America Bulletin, v. 78, no. 1, p. 13-20.

Easterbrook, D. J.; Rutter, N. W., 1981, Amino acid ages of Pleistocene glacial and interglacial sediments in western Washington [abstract]: Geological Society of America Abstracts with Programs, v. 13, no. 7, p. 444.

Easterbrook, D. J.; Rutter, N. W., 1982, Amino acid analyses of wood and shells in development of chronology and correlation of Pleistocene sediments in the Puget Lowland, Washington [abstract]: Geological Society of America Abstracts with Programs, v. 14, no. 7, p. 480.

Gower, H. D., 1980, Bedrock geologic and Quaternary tectonic map of the Port Townsend area, Washington: U.S. Geological Survey Open-File Report 80-1174, 1 sheet, scale 1:100,000, with 19 p. text.

Hansen, H. P.; Mackin, J. H., 1949, A pre-Wisconsin forest succession in the Puget Lowland, Washington: American Journal of Science, v. 247, no. 12, p. 833-855.

Heusser, C. J.; Heusser, L. E., 1981, Palynology and paleotemperature analysis of the Whidbey Formation, Puget Lowland, Washington: Canadian Journal of Earth Sciences, v. 18, no. 1, p. 136-149.

Hutchinson, Ian, 1992, Holocene sea level change in the Pacific Northwest—A catalogue of radiocarbon dates and an atlas of regional sea level curves: Simon Fraser University Institute for Quaternary Research Discussion Paper 1, 99 p., 1 floppy disk.

Johnson, S. Y.; Dadisman, S. V.; Mosher, D. C.; Blakely, R. J.; Childs, J. R., 2001, Active tectonics of the Devils Mountain fault and related structures, northern Puget Lowland and eastern Strait of Juan de Fuca region, Pacific Northwest: U.S. Geological Survey Professional Paper 1643, 45 p., 2 plates.

Johnson, S. Y.; Nelson, A. R.; Personius, S. F.; Wells, R. E.; Kelsey, H. M.; Sherrod, B. L.; Okumura, Koji; Koehler, Rich; Witter, Robert; Bradley, Lee-Ann; Harding, D. J., 2003, Maps and data from a trench investigation of the Utsalady Point Fault, Whidbey Island, Washington; version 1.0: U.S. Geological Survey Miscellaneous Field Studies Map MF-2420, 1 sheet, [with 7 p. text]. [http://pubs.usgs.gov/mf/2003/mf-2420/]

Johnson, S. Y.; Potter, C. J.; Armentrout, J. M.; Miller, J. J.; Finn, C. A.; Weaver, C. S., 1996, The southern Whidbey Island fault—An active structure in the Puget Lowland, Washington: Geological Society of America Bulletin, v. 108, no. 3, p. 334-354, 1 plate.

Jones, M. A., 1999, Geologic framework for the Puget Sound aquifer system, Washington and British Columbia: U.S. Geological Survey Professional Paper 1424-C, 31 p., 18 plates.

Kelsey, H. M.; Sherrod, Brian; Johnson, S. Y.; Dadisman, S. V., 2004, Land-level changes from a late Holocene earthquake in the northern Puget Lowland, Washington: Geology, v. 32, no. 6, p. 469-472.

Kvenvolden, K. A.; Blunt, D. J.; McMenamin, M. A.; Straham, S. E., 1980, Geochemistry of amino acids in shells of the clam Saxidomus. *In* Douglas, A. G.; Maxwell, J. R., editors, Advances in organic chemistry 1979: Pergamon Press Physics and Chemistry of the Earth, v. 12, p. 321-332.

Ludwig, K. R.; Muhs, D. R.; Simmons, K. R.; Halley, R. B.; Shinn, E. A., 1996, Sea-level records at ~80ka from tectonically stable platforms—Florida and Bermuda: Geology, v. 24, no. 3, p. 211-214.

Morrison, R. B., 1991, Introduction, *In* Morrison, R. B., editor, Quaternary nonglacial geology—Conterminous U.S.: Geological Society of America DNAG Geology of North America, v. K-2, 672 p., 8 plates in accompanying case.

Mosher, D. C.; Hewitt, A. T., 2004, Late Quaternary deglaciation and sea-level history of eastern Juan de Fuca Strait, Cascadia: Quaternary International, v. 121, no. 1, p. 23-39.

Mosher, D. C.; Johnson, S. Y., editors; Rathwell, G. J.; Kung, R. B.; Rhea, S. B., compilers, 2000, Neotectonics of the eastern Juan de Fuca Strait—A digital geological and geophysical atlas: Geological Survey of Canada Open File Report 3931, 1 CD-ROM disk.

Mustoe, G. E.; Carlstad, C. A., 1995, A late Pleistocene brown bear (*Ursus arctos*) from northwest Washington: Northwest Science, v. 69, no. 2, p. 106-113.

Mustoe, G. E.; Harington, C. R.; Morlan, R. E., *in press*, Cedar Hollow, an early Holocene faunal site from Whidbey Island, Washington: Western North American Naturalist.

Pessl, Fred, Jr.; Dethier, D. P.; Booth, D. B.; Minard, J. P., 1989, Surficial geologic map of the Port Townsend 30- by 60-minute quadrangle, Puget Sound region, Washington: U.S. Geological Survey Miscellaneous Investigations Series Map I-1198-F, 1 sheet, scale 1:100,000, with 13 p. text.

Porter, S. C.; Swanson, T. W., 1998, Radiocarbon age constraints on rates of advance and retreat of the Puget lobe of the Cordilleran ice sheet during the last glaciation: Quaternary Research, v. 50, no. 3, p. 205-213.

Swanson, T. W., 1994, Determination of $^{36}$Cl production rates from the deglaciation history of Whidbey Island, Washington: University of Washington Doctor of Philosophy thesis, 121 p.

Thorsen, G. W., 1983a, West Beach silt—A late Pleistocene loess, central Puget Lowland, Washington: Washington Geologic Newsletter, v. 11, no. 2, p. 1-4.

Thorsen, G. W., 1983b, West Beach silt—A late Pleistocene loess, central Puget Lowland, Washington: Loess Letter, no. 10, p. 15-16.

Thorsen, G. W., 2001, Whidbey Island Quaternary sediments. *In* Northwest Geological Society field trip, June 2-3, 2001: Northwest Geological Society, p. 1-20.

Thorson, R. M., 1980, Ice-sheet glaciation of the Puget Lowland, Washington, during the Vashon Stade (late Pleistocene): Quaternary Research, v. 13, no. 3, p. 303-321.

Thorson, R. M., 1981, Isostatic effects of the last glaciation in the Puget Lowland, Washington: U.S. Geological Survey Open-File Report 81-370, 100 p., 1 plate.

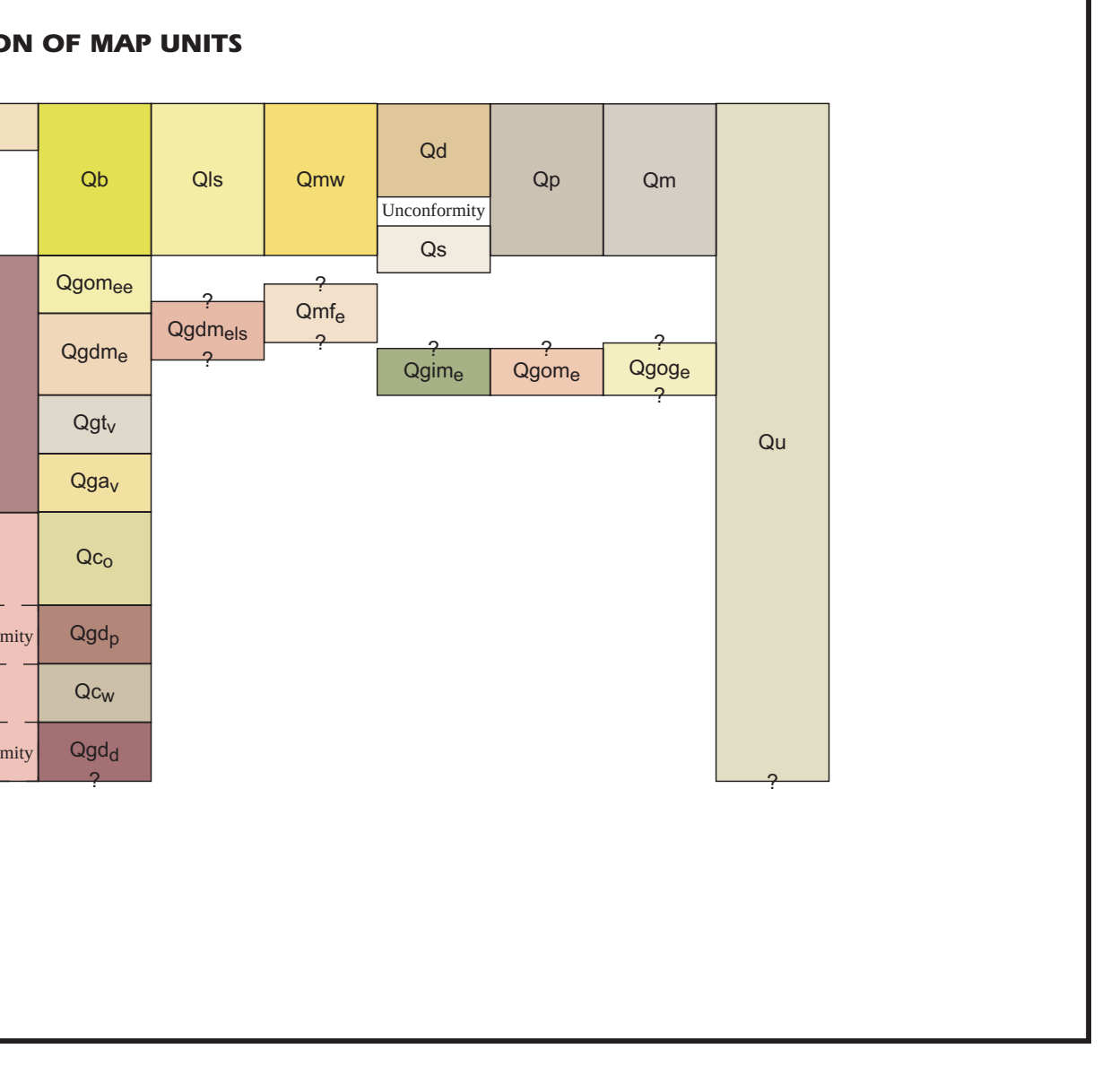
Thorson, R. M., 1989, Glacio-isostatic response of the Puget Sound area, Washington: Geological Society of America Bulletin, v. 101, no. 9, p. 1163-1174.

Trautman, M. A.; Willis, E. H., 1966, Isotopes, Inc. radiocarbon measurements V: Radiocarbon, v. 8, p. 161-203.

Wagner, H. C.; Wiley, M. C., 1980, Preliminary map of offshore geology in the Protection Island–Point Partridge area, northern Puget Sound, Washington: U.S. Geological Survey Open-File Report 80-548, 4 p., 2 plates.

Waitt, R. B., Jr.; Thorson, R. M., 1983, The Cordilleran ice sheet in Washington, Idaho, and Montana. *In* Porter, S. C., editor, The late Pleistocene; Volume 1 *of* Wright, H. E., Jr., editor, Late-Quaternary environments of the United States: University of Minnesota Press, p. 53-70.

## CORRELATION OF MAP UNITS



# Appendix B
# Standard Operating Procedures

# Water Measure Tables

## WEIGHT OF WATER

**Cubic Feet of Water =** 62.428 pounds
**Gallon =** 8.345 pounds
**1 Ounce of Water =** 28.35 grams
**Liter =** 2.205 pounds
1,000 grams
**Cubic Meter =** 2204.5 pounds
**1 pprn =** 1 lb. per million lbs.
**1 ppm =** 8.34 lbs. per million gallons of water
**1 pprn =** 1 milligram per liter of water

## WATER VOLUME EQUIVALENTS

**1 Quart =** 2 pints (pt)
.946 ml
**1 Gallon =** 4 quarts (qt)
3.785 liters (1)
3.785 liters
231 cubic inches
**1 Liter =** 1000 milliliters (ml)
.2642 gallons (gal)
61 cubic inches
**1 Quart =** 946 ml
**1 Cubic Foot =** 1728 cubic inches
7.48 gallons
28.317 liters
**1 Cubic Yard =** 202 gallons
**1 Cubic Meter =** 1000 liters
264.2 gallons

## WELL CASING VOLUME PER FOOT OF DEPTH

| Diameter Of Casing Or Hole (in.) | Gallons Per Foot Of Depth |
|---|---|
| 1 | 0.041 |
| 1.5 | 0.092 |
| 2 | 0.163 |
| 2.5 | 0.255 |
| 3 | 0.367 |
| 4 | 0.653 |
| 4.5 | 0.826 |
| 5 | 1.020 |
| 5.5 | 1.234 |
| 6 | 1.469 |
| 7 | 2.000 |
| 8 | 2.611 |
| 9 | 3.305 |
| 10 | 4.080 |
| 11 | 4.937 |
| 12 | 5.875 |
| 14 | 8.000 |
| 16 | 10.44 |
| 18 | 13.22 |
| 20 | 16.32 |
| 22 | 19.75 |
| 24 | 23.50 |
| 26 | 27.58 |
| 28 | 32.00 |
| 30 | 36.72 |
| 32 | 41.78 |
| 34 | 47.16 |
| 36 | 52.88 |

## PRESSURE

(Height x .434 lbs.)

**100 psi =** 7.03 kg/cm'
6.9 bars
689 kPa
**1 bar =** 100 kPa
14.5 psi
**1 gpm =** 378 liters/mm
**10 cfm =** 283 liters/mm

## VOLUME OF ANNULUS

(Cubic Feet/Linear Feet)

| | | Casing Diameter (inches) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Gallons Per Linear Feet** | **Hole Dia. (inches)** | **2** | **4** | **6** | **8** | **10** | **12** | **14** | **16** | **20** | **24** | **30** |
| 0.16 | 2 | | | | | | | | | | | |
| 0.65 | 4 | 0.07 | 0.00 | | | | | | | | | |
| 1.02 | 5 | 0.11 | 0.05 | | | | | | | | | |
| 1.47 | 6 | 0.17 | 0.11 | 0.00 | | | | | | | | |
| 2.00 | 7 | 0.25 | 0.18 | 0.07 | | | | | | | | |
| 2.61 | 8 | 0.33 | 0.26 | 0.15 | 0.00 | | | | | | | |
| 3.30 | 9 | 0.42 | 0.35 | 0.25 | 0.09 | | | | | | | |
| 4.08 | 10 | 0.52 | 0.46 | 0.35 | 0.20 | 0.00 | | | | | | |
| 5.87 | 12 | 0.76 | 0.70 | 0.59 | 0.44 | 0.24 | 0.00 | | | | | |
| 8.00 | 14 | 1.05 | 0.98 | 0.87 | 0.72 | 0.52 | 0.28 | 0.00 | | | | |
| 10.44 | 16 | 1.37 | 1.31 | 1.20 | 1.05 | 0.85 | 0.61 | 0.33 | 0.00 | | | |
| 13.22 | 18 | 1.75 | 1.68 | 1.57 | 1.42 | 1.22 | 0.98 | 0.70 | 0.37 | | | |
| 16.32 | 20 | 2.16 | 2.09 | 1.99 | 1.83 | 1.64 | 1.40 | 1.11 | 0.79 | 0.00 | | |
| 23.49 | 24 | 3.12 | 3.05 | 2.95 | 2.79 | 2.60 | 2.36 | 2.07 | 1.75 | 0.96 | 0.00 | |
| 36.73 | 30 | 4.89 | 4.82 | 4.71 | 4.56 | 4.36 | 4.12 | 3.84 | 3.51 | 2.73 | 1.77 | 0.00 |
| 52.88 | 36 | 7.05 | 6.98 | 6.87 | 6.72 | 6.52 | 6.28 | 6.00 | 5.67 | 4.89 | 3.93 | 2.16 |

# PLANNING FIELD SAMPLING ACTIVITIES

## 1.0 PURPOSE

This section sets forth standard operating procedures (SOPs) for planning and scheduling field sampling activities. This SOP shall also be used to determine the number and type of laboratory and field Quality Control (QC) samples required while working on U.S. Naval Facilities Engineering Command Northwest (NAVFAC NW) sites/projects, and to prepare and implement Task Order Field Sampling Plans (FSP). For information on the number and type of QC samples required for the various QC Levels, see SOPs III-A, *Laboratory QC Samples (Water and Soil),* III-B, *Field QC Samples (Water and Soil)*, III-C *Field and Laboratory QC Samples (Air)*.

## 2.0 PROCEDURES

To prepare a field sampling plan, designated personnel must identify the objectives of the sampling program, determine the number of samples to be collected for each matrix (see SOP I-A-2, *Development of Data Quality Objectives*), and select the analyses to be performed on each sample (see SOPs I-A-3, *Selection of Analytes* and I-A-4, *Analytical Methods Selection*). The duration of sampling for each matrix, the preferred sampling method, the method of shipment, and the type and quantity of supplies (such as coolers, coolant and packing material that will be needed for sample storage and transport) must also be determined. Finally, the number and type of decontamination water sources to be used for each phase of sampling must be identified. The methods of determining each of these elements are addressed below.

### 2.1 NUMBER OF SAMPLES

Designated project personnel shall determine the number of samples to be collected from each sample matrix (e.g., soil, water), and specify the type of sample analysis. SOPs I-A-2, *Development of Data Quality Objectives*, I-A-3, *Selection of Analytes*, and I-A-4, *Analytical Methods Selection*, shall be used to determine numbers and locations of samples, as well as appropriate analytical methods. These figures will be used to estimate the costs of sample analysis. They will also help determine the number and types of sample containers required; number of field duplicates, field replicates, equipment rinsates, performance evaluation (PE) samples, matrix spike/matrix spike duplicates (MS/MSD), and trip blanks to be collected, and the analyses to be performed on them for each matrix and analytical method; and the number of days required to perform sampling activities.

Sampling intervals for soil borings shall be selected on the basis of potential sources of contamination, the geologic and hydrologic complexity of the site, and the objectives of the sampling program. Areas of high contamination (for example, contamination in the capillary fringe) or complex geology or hydrogeology may require continuous sampling.

## 2.2 DURATION OF SAMPLING ACTIVITIES

The anticipated number of working days needed to complete field sampling activities shall be determined before fieldwork commences. A schedule should be developed that outlines the approximate number of samples to be collected each day, categorized by sample matrix, method of sample collection, and sample analysis (e.g., 28 soil samples collected using a hand auger and analyzed for organochlorine pesticides and chlorinated herbicides; 15 water samples collected using a bailer—7 analyzed for volatile organics and 8 analyzed for organic lead). This information will be used to determine the number of field equipment rinsate samples that will be collected (if any), the types of analyses to be performed on them, the number of MS/MSDs and field duplicates, equipment needs, and personnel.

## 2.3 NUMBER OF SAMPLES TO BE ANALYZED FOR VOLATILE ORGANICS

Prior to initiation of site sampling activities, designated personnel shall determine the number of samples to be analyzed for volatile organic compounds (VOCs). This information will be used to determine the approximate number of coolers that will contain samples to be analyzed for VOCs, which will in turn, dictate the number of VOC trip blanks needed, as specified in SOP III-B, *Field QC Samples (Water, Soil)*.

## 2.4 DECONTAMINATION WATER SOURCES

Prior to initiation of sampling activities, designated personnel shall determine the number and type of decontamination water sources. Decontamination water includes both potable water used for equipment washing, and deionized or distilled water used during the final equipment rinse. The locations of potable water supplies for field decontamination activities shall be identified and designated as the only sources to be used during site sampling activities. Similarly, the source(s) of deionized or distilled water shall be identified and designated as the only source(s) to be used during site sampling activities. The intent of this procedure is to reduce variability in equipment decontamination procedures and to make it possible to easily identify the source of contamination in the event that analysis of field blanks reveals the presence of contaminants of concern.

## 3.0 DOCUMENTATION

The number of samples to be collected, the proposed duration of sampling activities, the number of samples that will be analyzed for VOCs, and the number and type of decontamination water sources that will be used for field activities will be specified in the FSP and QAPP portions of the Work Plan prepared for each NAVFAC NW Task Order. Records of how this information is actually implemented during field activities will be maintained in field logbooks, as specified in SOP III-D, *Logbooks*.

## 4.0 REFERENCES

SOP I-A-2, *Development of Data Quality Objectives*

SOP I-A-3, *Selection of Analytes*

SOP I-A-4, *Analytical Methods Selection*

SOP II-B, *Field QC Samples (Water and Soil)*

SOP III-A, *Laboratory QC Samples (Water and Soil)*

SOP III-B, *Field QC Samples (Water, Soil)*

SOP III-C *Field and Laboratory QC Samples (Air)*

SOP III-D, *Logbooks*

## 5.0 ATTACHMENTS

None.

# IDW MANAGEMENT

## 1.0 PURPOSE

This standard operating procedure (SOP) describes the activities and responsibilities of the U.S. Naval Facilities Engineering Command Northwest (NAVFAC NW) and their subcontractors with regard to management of investigation-derived waste (IDW). The purpose of this procedure provides guidance for the minimization, handling, labeling, temporary storage, and inventory of IDW generated during site investigations and remediation projects conducted under the direction of NAVFAC NW. **Each base may have specific required procedures**. These procedures are made available to the contractor through the NAVFAC Naval Technical Representative (NTR) or other government point of contact. This SOP is also applicable to personal protective equipment (PPE), sampling equipment, decontamination fluids, non-IDW trash, non-indigenous IDW, and hazardous waste and other regulated wastes generated during implementation of site investigations and removal or remedial actions. The information presented will be used to prepare and implement Work Plans (WP), Field Sampling Plans (FSP), and Waste Management Plans (WMPs) for IDW-related field activities.

## 2.0 PROCEDURES

The procedures for IDW management in the field are described below in Sections 2.1 to 2.5. The implementation of these procedures requires Remedial Project Managers (RPMs), Field Managers, their designates and subcontractors to perform the following tasks:

- Minimize generation of IDW,
- Segregate IDW,
- Properly handle IDW containers,
- Properly label IDW containers,
- Apply good management practices in storing IDW drums and containers,
- Prepare IDW drum inventories,
- Update and Report changes to IDW drum inventories,
- Perform inspections of IDW containers and storage areas, as required,
- Prepare IDW containers for proper off-site transportation and disposition, as required.

### 2.1 IDW MINIMIZATION

Field Managers and their designates shall minimize the generation of onsite IDW to reduce the need for special storage or disposal requirements that may result in substantial additional costs and provide little or no reduction in site risks (EPA 1992). The volume of IDW shall be reduced, by applying minimization practices throughout the course of site investigation activities. These minimization strategies include: 1) material substitution; 2) using proper low-volume drilling techniques; 3) using disposable sampling and PPE; 4) using bucket and drum liners; and 5) segregating non-contaminated IDW and trash from contaminated IDW. Waste minimization strategies and types of IDW expected to be generated shall be documented in the appropriate project plans.

### 2.1.1 Material Substitution

Material substitution consists of selecting materials that degrade readily or have reduced potential for chemical impacts to the site and the environment. An example of this practice is the use of biodegradable detergents (e.g., Alconox® or non-phosphate detergents) for decontamination of non-consumable PPE and sampling equipment. In addition, field equipment decontamination can be conducted using isopropyl alcohol rather than hexane or other solvents (for most analytes of concern), to reduce the potential onsite chemical impacts of the decontamination solvent. Decontamination solvents shall be selected carefully so that solvents, and their known decomposition products, do not result in generation of RCRA hazardous waste.

### 2.1.2 Drilling Methods

Drilling methods that minimize potential IDW generation should be given priority. Sonic, Hollow stem auger and air rotary methods should be selected, where feasible, over mud rotary methods. Mud rotary drilling produces waste drilling mud, while hollow stem and air rotary drilling methods produce relatively low volumes of soil waste. Sonic drilling produces the least amount of waste. Small diameter borings and cores shall be used when soil is the only matrix to be sampled at the boring location; the installation of monitoring wells requires the use of larger diameter borings.

Soil, sludge, or sediment removed from borings, containment areas, and shallow test trenches shall not be returned to the source, unless allowed by regulation and included in the approved WP, FSP, or WMP.

### 2.1.3 Decontamination Fluids

The use of disposable sampling equipment, such as plastic bailers, trowels, and drum thieves (which do not require decontamination) minimizes the quantity of decontamination fluids generated. In general, decontamination fluids, and well development and purge water, should not be minimized because the integrity of the associated analytical data may be affected.

### 2.1.4 PPE and Disposable Sampling Equipment

Visibly soiled PPE and disposable sampling equipment shall be segregated from non-visibly soiled PPE and sampling equipment. Where investigation involves potentially hazardous waste or other regulated wastes, visibly soiled PPE and disposable sampling equipment may require decontamination. The Field Manager shall use best professional judgment to determine if decontamination is appropriate. This determination should be included in the approved WP, FSP, or WMP. If decontamination is performed, PPE and disposable sampling equipment generated in the decontamination process may be double-bagged and disposed of as non-hazardous waste.

### 2.1.5 Liners

Bucket liners can be used in the decontamination process to reduce the volume of solid IDW-generated and reduce costs on larger projects. The plastic bucket liners can be crushed into a smaller volume than the buckets, and only a small number of plastic decontamination buckets are required for the entire project. Larger, heavy-duty, 55-gallon drum liners can be used for heavily contaminated IDW to provide secondary containment, and reduce the costs of disposal and drum recycling. Drum liners may extend the containment life of the drums in severe climates and will reduce the costs of cleaning out the drums prior to recycling.

### 2.1.6 Segregation of non-IDW

All waste materials generated in the support zone are considered non-IDW trash. To minimize the total volume of IDW, all trash shall be separated from IDW, sealed in garbage bags, and properly disposed of offsite as municipal waste.

### 2.1.7 Monitoring Well Construction

Excess cement, sand, and bentonite grout prepared for monitoring well construction shall be kept to a minimum. Well construction shall be observed by Field Managers to ensure that a sufficient, but not excessive, volume of grout is prepared. Some excess grout may be produced. Unused grout that has not come in contact with potentially contaminated soil or ground water shall be considered non-hazardous trash and shall be disposed of offsite by the drilling subcontractor. Surplus materials from monitoring well installation, such as scrap PVC sections, used bentonite buckets, and cement/sand bags that do not come in contact with potentially contaminated soil, shall be considered non-IDW trash and shall be disposed of offsite by the drilling subcontractor.

### 2.1.8 Field Analytical Test Kits

IDW generated from the use of field analytical test kits consists of those parts of the kit that have been used and/or come into contact with potentially contaminated site media, or excess extracting solvents and other reagents. Potentially contaminated solid test kit IDW shall be contained in plastic bags and stored with PPE or disposable sampling equipment IDW from the same source area as soil material used for the analyses. The small volumes of waste solvents, reagents, and water samples used in field test kits should be segregated, and disposed of accordingly (based upon the characteristics of the materials, MSDS sheets, and as described in the WMP). Most other test kit materials should be considered non-IDW trash, and be disposed of as municipal waste.

## 2.2 SEGREGATION OF IDW BY MATRIX AND LOCATION

To facilitate subsequent IDW screening, sampling, classification and/or disposal, IDW shall generally be segregated by matrix and source location at the time it is generated. Each drum of solid IDW shall be completely filled, when possible. For liquid IDW, drums should be left with headspace of approximately 5% by volume to allow for expansion of the liquid and potential volatile contaminants. IDW from each distinct matrix shall be stored in a single drum (e.g., soil, water or PPE shall not be mixed in one drum). In general, IDW from separate sources should not be combined in a single drum.

It is possible that monitoring well development and purge water will contain suspended solids, which will settle to the bottom of the storage drum as sediment. Significant observations on the turbidity or sediment load of the development or purge water shall be included in the logbook and reported in attachments to the quarterly drum inventory report (see SOP III-D, *Logbooks* and Section 2.5). To avoid having mixed matrices in a single drum (i.e., sediment and water), it may be necessary to decant the liquids into a separate drum, after the sediments have settled out. This segregation may be accomplished during subsequent IDW sampling activities or during consolidation in a holding tank prior to disposal. Disposal of liquid IDW into the sanitary sewer shall only occur if approved by the appropriate regulatory agencies, municipal entities, and Naval installation. Appropriate precautions per the approved Health and Safety Plan (HASP) shall be implemented to ensure worker protection during these activities.

Potentially contaminated well construction material shall be placed in separate containers. Soil, sediment, sludge, or liquid IDW shall be segregated from potentially contaminated waste well construction materials. Potentially contaminated well construction materials from different monitoring wells shall not be commingled.

Potentially hazardous PPE and disposable sampling equipment shall be segregated from other IDW. PPE from generally clean field activities, such as water sampling, shall be segregated from visibly soiled PPE, double-bagged and disposed of offsite as municipal waste. Disposable sampling equipment from activities such as soil, sediment, and sludge sampling includes plastic sheeting used as liner material in containment areas around drilling rigs and waste storage areas; disposable sampling equipment; and soiled decontamination equipment. Where investigation involves potentially hazardous waste, visibly soiled PPE and disposable sampling equipment may require decontamination. The Field Manager shall use best professional judgment to determine if decontamination is appropriate. If decontamination is performed, PPE and disposable sampling equipment generated in the decontamination process may be double-bagged and disposed of as non-hazardous waste. PPE and disposable sampling equipment generated on separate days may be commingled.

Decontamination fluids shall be stored in drums separate from other IDW. If practical, decontamination fluids generated from different sources should not be stored in the same drum. If decontamination fluids generated over several days or from different sources are stored in a single container, information regarding dates of generation and sources shall be recorded in the field notebook, on the drum label (Section 2.3.2), and in the drum inventory (Section 2.5).

Liquid and sediment portions of the equipment decontamination fluid in the containment unit used by the drilling or excavation field crew should be separated. The contents of this unit normally consist of turbid decontamination fluid above a layer of predominantly coarse-grained sediment. When the contents of the containment unit are to be stored in IDW containers, the Field Manager shall direct the placement of as much liquid into drums as possible and transfer the remaining solids into separate drums. Observations of the turbidity and sediment load of the liquid IDW should be noted in the field notebook, on the drum label (Section 2.3.2), and in attachments to the drum inventory (see Section 2.5). It is likely that decontamination fluids will contain minor amounts of suspended solids that will settle out of suspension to become sediment at the bottom of IDW storage drums. As noted above, it may be necessary to segregate the drummed water from sediment during subsequent IDW sampling or disposal activities.

## 2.3 DRUM HANDLING AND LABELING

Drum handling consists of those actions necessary to prepare an IDW drum for labeling. Drum labeling consists of those actions required to legibly and permanently identify the contents of an IDW drum. Specific handling, storage, and labeling requirements may differ with the Naval installation or oversight entity. Specific requirements should be determined at the planning stage and documented in the WMP. General requirements are provided in the following sections.

### 2.3.1 Drum Handling

The drums used for containing IDW shall be approved by the United States Department of Transportation (DOT, 49 CFR 172). The drums shall be made of steel or plastic, have a 55-gallon capacity, be completely painted or opaque, and have removable lids (i.e., 1A1 or 1A2). New steel drums are preferred over recycled drums. For short-term storage of liquid IDW prior to discharge, double-walled bulk steel or plastic storage tanks may be used. Consideration must be given to scheduling and cost-effectiveness of bulk storage, treatment, and discharge system versus longer-term drum storage.

For long-term IDW storage, the DOT-approved drums with removable lids are recommended. The integrity of the foam or rubber sealing ring located on the underside of some drum lids shall be verified prior to sealing drums containing IDW liquids. If the ring is only partially attached to the drum lid, or if a portion of the ring is missing, a drum lid with sealing ring that is in good condition must be used. At some facilities, drums containing liquid IDW will be required to be stored in protective overpacks.

To prepare IDW drums for labeling, the outer wall surfaces and drum lids shall be wiped clean of all material that may prevent legible and permanent labeling. If potentially contaminated material adheres to the outer surface of a drum, that material shall be wiped from the drum, and the paper towel or rag used to remove the material shall be segregated with visibly soiled PPE and disposable sampling equipment.

### 2.3.2 Drum Labeling

Proper labeling of IDW drums is essential to the success and cost-effectiveness of subsequent waste screening and disposal activities. Labels shall be permanent and descriptive to facilitate correlation of field analytical data with the contents of individual IDW drums.

#### *2.3.2.1 Preprinted Labels*

A preprinted drum label as required by the appropriate Naval installation and/or regulatory agency shall be completed. The label will be affixed to the outside of the drum (or overpack if required) with the label easily readable for inspections and inventory. Label requirements may vary based on the site.

The requested information shall be printed legibly on the drum labels in black, indelible ink. Instructions for entering the required drum-specific information for each label field are provided by the Naval installation.

#### *Painted Labels*

An alternative method for labeling drums, if acceptable for the project, is to paint label information directly on the outer surface of the drum. At a minimum, the information placed on the drum shall include the contract/delivery order number, a drum number, the source identification type and number, the type of IDW, the generation date(s), and the government point of contact and telephone number. The drum surface shall be dry and free of material that could prevent legible labeling. Label information shall be confined to the upper two-thirds of the total drum height. The printing on the drum shall be large enough to be easily legible. Yellow, white, or red paint markers (oil-based enamel paint) that are non-photodegradable are recommended to provide maximum durability and contrast with the drum surface.

### *2.3.2.2 Regulatory Marking and Labeling*

Federal and State regulations may require specific labeling for IDW generated (i.e., RCRA, TSCA, NESHAPs). Pre-printed labels shall be used as appropriate and completed in accordance with the specific regulatory requirement. These requirements will be identified in the approved project plans. Once determined to be hazardous, weekly inspections must also be conducted to ensure that labels and markings are in good conditions and to ensure the integrity of containers.

In addition, prior to off-site transportation USDOT requirements for marking and labeling of regulated DOT materials must be complied with. These requirements will be identified in the approved project plans or otherwise coordinated with the Field Manager after the IDW has been characterized and off-site disposition is being planned. Note that personnel (i.e., contractors or subcontractors) who perform USDOT functions must be properly trained in accordance with 49 CFR 172, Subpart G.

## 2.4 DRUM STORAGE

Drum storage procedures shall be implemented to minimize potential human contact with the stored IDW and prevent extreme weathering of the stored drums. Waste accumulation areas will be pre-designated by NAVFAC NW prior to the start of site work. IDW drums should be placed on pallets. Good management practices should be used in storing drums which include: containers shall be in good condition and closed during storage; wastes must be compatible with containers; where liquids are stored, storage areas should have secondary containment; and spill or leaks should be removed as soon as possible. These good management practices are mandatory requirements where RCRA hazardous wastes are stored.

Waste accumulation areas shall be maintained as prescribed by local regulatory entities and the appropriate Naval installation. In general, drums of IDW shall be stored within the Area of Concern (AOC) so that the site can utilize RCRA regulatory flexibility (i.e., administrative requirements, such as 90-day storage, may not be triggered; and LDRs will not be triggered if IDW is placed back in AOC). If IDW is determined to be RCRA hazardous waste, then RCRA storage, transportation and disposal requirements must be met.

Drums shall be stored at identified waste accumulation areas. All IDW drums generated during field activities at a single AOC shall be placed together, in a secure, fenced onsite area to prevent access to the drums by unauthorized personnel. When a secure area is not available, drums shall be placed in an area of the site with the least volume of human traffic. Plastic sheeting (or individual drum covers) and yellow caution tape shall be placed around the stored drums. Drums from projects involving multiple AOCs should remain at the respective source areas where the IDW was generated. IDW should not be transferred offsite for storage elsewhere, except under rare circumstances, such as the lack of a secure storage area onsite.

Proper drum storage practices shall be implemented to minimize damage to the drums from weathering and possible exposure to humans or the environment. When possible, drums shall be stored in dry, shaded areas and covered with impervious plastic sheeting or tarpaulin material. Every effort shall be made to protect the preprinted drum labels from direct exposure to sunlight, which causes ink on the labels to fade. In addition, drums shall be stored in areas that are not prone to flooding. The impervious drum covers shall be appropriately secured to prevent dislodging by the wind. It may be possible to obtain impervious plastic covers designed to fit over individual drums; however, the labeling information shall be repeated on the outside of these opaque covers.

Drums in storage shall be placed with sufficient space between rows of drum pallets and shall not be stacked, such that authorized personnel may access all drums for inspection. Proper placement will also render subsequent IDW screening, sampling, and disposal more efficient. It is recommended that IDW drums be segregated in separate rows/areas by matrix (i.e., soil, liquid or PPE/other).

If repeated visits are made to the project site, the IDW drums shall be inspected to clear encroaching vegetation, check the condition and integrity of each drum, check and replace labels as necessary, and replace or restore protective covers.

## 2.5 DRUM INVENTORY

Accurate preparation of an IDW drum inventory is essential to all subsequent activities associated with IDW drum tracking and disposal. An inventory shall be prepared for each project in which IDW is generated, stored, and disposed of. Naval installations and local regulatory authorities may have specific requirements associated with waste inventory and these requirements should be included in the planning process and documented in the WP, FSP, and WMP.

The drum inventory information shall include 11 elements that identify drum contents and indicate their fate.

### 2.5.1 Navy Activity (Generator)/Site Name

Inventory data shall include the Navy activity and the site name where the IDW was generated (e.g., NASWI, NBK Bangor, etc.).

### 2.5.2 DO Number

Inventory data shall include the contract and delivery order number associated with each drum (e.g., 0089).

### 2.5.3 Drum Number

The drum number assigned to each drum shall be included in the inventory database.

### 2.5.4 Storage Location Prior to Disposal

The storage location of each drum prior to disposal shall be included in the inventory (e.g., Building 394 Battery Disassembly Area, or Adjacent to West end of Building 54).

### 2.5.5 Origin of Contents

The source identification of the contents of each IDW drum shall be specified in the inventory (e.g., soil boring number, monitoring well number, sediment sampling location, or the multiple sources for PPE- or rinse water-generating activities).

### 2.5.6 IDW Type

Inventory data shall include the type of IDW in each drum (e.g., soil, PPE, disposable sampling equipment, sludge, sediment, development water, steam cleaning water, decontamination rinse water).

### 2.5.7 Waste Volume

The amount of waste in each drum shall be specified in the inventory as a percentage of the total drum volume or an estimated percentage-filled level (e.g., 95% maximum for liquid IDW).

### 2.5.8 Recommended Analytical Methods and Test Results Compared with Applicable Regulatory Standards

The recommended EPA analytical methods that adequately characterize IDW contained in each drum will be summarized in a tabular format and attached to the quarterly IDW drum inventory report (see Attachment I-A-7-1). The methodology for sampling and characterizing IDW shall be specified in the appropriate project plans.

### 2.5.9 Recommended or Actual Disposition of IDW Drum Contents

The recommended means of IDW disposal for each drum shall be summarized in a tabular format (e.g., Offsite, Encapsulated Onsite, Treatment/Sewer, Offsite Incinerator) and attached to the quarterly IDW drum inventory report (see Attachment I-A-7-1). Additional narrative discussion of the rationale for the recommended disposal option shall be attached to the quarterly IDW drum inventory report as data become available.

### 2.5.10 Generation Date

Inventory data shall include the date IDW was placed in each drum. If a drum contains IDW-generated over more than one day, the start date for the period shall be specified in dd-month-yy format. This date is <u>not</u> to be confused with an RCRA hazardous waste accumulation date (40 CFR 262). The accumulation start date, if required for RCRA wastes, shall be included on the hazardous waste drum label (Section 2.3.2.2).

### 2.5.11 Expected Disposal Date

The expected date each drum is to be disposed of shall be specified as part of the inventory in month-yy format. This date is for informational purposes only for the Navy, and shall not be considered contractually binding.

### 2.5.12 Actual Disposal Date

The actual drum disposal date occurs at the time of onsite disposal, or acceptance by the offsite treatment or disposal facility. It shall only be entered in the drum inventory database when such a date is available in dd-month-yy format.

In order to provide information for all 11 of the inventory elements of the quarterly inventory report described above, the main source of information will be provided by RPMs, or their designees, and summarized in Attachment I-A-7-1.

The recommended analytical test methods and actual test results (compared to applicable regulatory standards) will be provided to the appropriate Navy groups, by the RPM, or their designees, when such data are available. Testing methods shall be documented in the associated project plans. Recommended disposal options or actual disposition of the IDW drum contents will also be provided by RPMs as data become available. The NAVFAC Northwest RPM will forward all IDW data to the appropriate Navy authority as attachments to the quarterly IDW drum inventory report. This information constitutes the results of preparing and implementing an IDW screening, sampling, classification, and disposal program for each site.

## 3.0 DOCUMENTATION

The RPM or designee is responsible for completing and updating the site-specific IDW drum inventory spreadsheet and submitting it as needed. The RPM is also responsible for submitting backup documentation to the U.S. Navy Program Management Office (PMO) about the analytical methods recommended to adequately characterize the IDW in each drum (Section 2.5.8). In addition, actual site or drum sampling results shall be forwarded to the PMO, along with a comparison to the applicable regulatory standards, for inclusion as attachments to the quarterly IDW drum inventory. As necessary, the backup documentation to the quarterly IDW drum inventory report shall also include the recommended means for IDW disposal for each drum (Section 2.5.9). After disposal, the actual means and/or location of disposal shall be indicated in tabular format with supporting narrative.

Field Managers and designates are responsible for documenting all IDW-related field activities in the field notebook, including most elements of the IDW drum inventory spreadsheet. The correct methods for developing and maintaining a field notebook are presented in SOP III-D, *Logbooks*.

Upon receipt of analytical data from the investigation, the information will be forwarded to the appropriate Naval authority for comparison to regulatory waste criteria. The Navy will designate the IDW and disposal options will be assessed based on the waste designation, approved transport/disposal facilities, and schedule for disposal. Naval installations may have additional requirements for reviewing analytical data, characterizing waste materials, transporting and off-site disposal. The RPM shall coordinate with the Naval installation early in the planning process to ensure that these requirements are properly identified, incorporated into the approved project plans, as available, and implemented in the field.

The disposal of IDW must be approved by the Navy and, in some cases, pertinent regulatory agencies. The disposal must be documented.

## 4.0 REFERENCES

Department of Transportation (DOT), Hazardous Materials Transportation Regulations, 49 CFR Parts 171 – 179.

EPA. 1998. EPA530-F-98-026, Management of Remediation Waste Under RCRA

EPA. 1991. Management of Investigative-Derived Wastes During Site Inspections. U.S. Environmental Protection Agency/540/G-91/009. May.

EPA. 1992. Guide to Management of Investigative-Derived Wastes. Quick Reference Guide. U.S. Environmental Protection Agency: 9345.3-03FS. January.

## 5.0 ATTACHMENTS

| | |
|---|---|
| Attachment IA71 | Example Format – Quarterly IDW Drum Inventory Updates |

## Attachment I-A-7-1
## Quarterly IDW Drum Inventory Updates

| Navy Activity / Site Name (Generator Site) | DO Number (0bbb) | Drum Number (xxxx-AA-Dzzz) | Drum Storage Location | Origin of Contents (Source ID #) | IDW Type | Waste Volume (Fill level %) | Waste Generation Date (dd-mm-yy) | Expected Disposal Date (mm-yy) | Actual Disposal Date (dd-mm-yy) |
|---|---|---|---|---|---|---|---|---|---|
| NSC Pearl Harbor/ Landfill | 0068 | 0068-LF-D001 | NSC, Bldg 7 | SB-1 | Soil Cuttings | 100 | 16-Dec-92 | Dec-93 | Na |
| | | 0068-LF-D002 | NA | MW-1 | Purge Water | 75 | 20-Dec-92 | Jul 93 | 26-Jul-93 |
| | | | | MW-2 | | | | | |
| | | | | MW-3 | | | | | |
| | | 0068-LF-D003 | NA | MW-1 | Decon Water | 95 | 20-Dec-92 | Jul-93 | 26-Jul-93 |
| | | | | MW-2 | | | | | |
| | | | | MW-3 | | | | | |
| | | 0068-LF-D004 | NSC, Bldg.16 | SB-1 | PPE | 50 | 16-Dec-92 | Oct-93 | NA |
| | | | | SB-2 | | | | | |
| | | | | SB-3 | | | | | |
| | | | | SB-4 | | | | | |
| | | | | MW-1 | | | | | |
| | | | | MW-2 | | | | | |
| | | | | MW-3 | | | | | |
| NAVSTA Guam/ Drum Storage | 0047 | 0047-DS-001 | Hazmat Storage Area | SB-1 | Soil Cuttings | 100 | 18-Feb-93 | Sep-93 | NA |
| | | | | SB-2 | | | | | |

NA = Not Applicable

# GENERAL FIELD OPERATION

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## 1.0 PURPOSE

This standard operating procedure (SOP) defines the general field organization and the field structure of sample collection, sample identification, record keeping, field measurements, and data collection. These SOPs are used to ensure the activities used to document sampling and field operations provide standardized background information and identities.

## 2.0 PROCEDURES

### 2.1 MOBILIZATION/DEMOBILIZATION

The SM or designee ensures that all purchase requests have been reviewed and approved by the PM. Then, the SM and PM assemble the project team in order to review the scope of work, disseminate the project plans, and complete the field equipment checklist (provided as Attachment I-A-9-1). After review by the project team, if additional items are required, additional purchase requests are prepared and approved by the PM.

The SM and project team upon arrival at the site inspects all equipment. Packing slips, bills of lading, or other documentation received with the shipment are initialed and returned to the purchasing department and a copy placed into the field file. Quantities, types, and makes of items received are checked against the original purchase requests to validate the shipment. Prior to validation of the shipping receipt, equipment is inspected to ensure all components are present and that the equipment calibrates and is fully functional. Any equipment received that is not fully functional is returned immediately and the vendor contacted to arrange a replacement.

The SM provides copies of the appropriate SOPs to the project team prior to the start of field activities. The most current versions of the SOPs are brought to the field. Any revisions to the SOPs must be approved by the PM and recorded in the field logbook.

It is imperative that rental equipment be cleaned (decontaminated), packaged, and returned immediately following the completion of a task. If any problems occurred on site with any equipment, the problems should be noted in detail in the field logbook and the SM notified. The SM will forward this information to the purchasing department and the vendor.

### 2.2 SHIPPING

If it is possible and /or practical, equipment and supplies should be shipped directly to the field site. If sensitive field equipment is to be shipped to the site, care shall be taken to ensure the equipment is not damaged en route. All original packaging material should be retained for return shipment of the equipment. Additional packing material (e.g., bubble wrap, bubble bags) may be required to provide additional protection for the shipped items. Equipment should always be shipped in its original carrying case. Each piece being shipped must have an address label on the shipping container separate from the shipping air bill.

### 2.3 CHAIN OF COMMAND

Chain of command protocols are implemented by the PM. These protocols should be strictly followed while performing field tasks. All decisions concerning priorities, project team assignments, sampling procedures, equipment management, and task approach are made by the PM, the SM, or an approved appointee. The SM or an approved designee will conduct a daily meeting prior to the start of field activities to discuss individual responsibilities. The meeting will also address potential contaminants that may be encountered, safety items (such as use of heavy equipment or protection against noise), special sampling requirements, and site control(s) to be employed to prevent injuries or exposure.

### 2.4 SAMPLING ORGANIZATION

The SM ensures the sampling design, outlined in project plans, is followed during all phases of the sampling activities at the site. For each sampling activity, field personnel record the information required by the applicable SOPs in their logbooks and on the exhibits provided in the SOPs.

### 2.5 REVIEW

The PM, SM, and, on occasion, the QAO or an approved designee checks field logbooks, daily logs, and all other documents that result from field operations for completeness and accuracy. Any discrepancies on these documents are noted and returned to the originator for correction. The reviewer acknowledges that review comments have been incorporated into the document by signing and dating the applicable reviewed documents.

## 3.0 DOCUMENTATION

Project activities shall be recorded in the field logbooks. The logbooks shall be kept current for the daily activities including documentation of all samples collected and the information relevant to the sample collection. All project required field forms shall be completed within a timely manner upon completion of the field task. All required field forms and specific logbook notations should be detailed in the field sampling plan.

## 4.0 REFERENCES

None.

## 5.0 ATTACHMENTS

| | |
|---|---|
| Attachment IA91 | Field Equipment Checklist. |

## Attachment I-A-9-1
## Field Equipment Checklist

General

___ 1. Health and Safety Plan

___ 2. Site base map

___ 3. Hand calculator

___ 4. Brunton compass

___ 5. Personal clothing and equipment

___ 6. Personal Protective Equipment (First Aid kit)

___ 7. Cell or radio telephone

Environmental Monitoring Equipment

___ 1. Shovels

___ 2. Keys to well caps

___ 3. pH meter (with calibrating solutions)

___ 4. pH paper

___ 5. Thermometer

___ 6. Conductivity meter (with calibrating solution)

___ 7. Organic vapor analyzer or photoionization detector with calibration gas

___ 8. H2S, O2, combustible gas indicator

___ 9. Draeger tubes

Shipping Supplies

___ 1. Sample preservatives (nitric, hydrochloric, sulfuric acid/sodium hydroxide)

___ 2. Heavy-duty aluminum foil

___ 3. Coolers

___ 4. Ice packs

___ 5. Large zipper locking plastic bags

___ 6. Heavy-duty garbage bags

___ 7. Duct tape

___ 8. Strapping tape

___ 9. Paper towels

___ 10. Bubble pack, foam pellets, or shredded paper

___ 11. Vermiculite

___ 12. Cooler labels (“This Side Up,” “Hazardous Material,” “Fragile”)

___ 13. Federal Express/DHL labels

### Sampling Equipment

___ 1. Tool box with assorted tools (pipe wrenches, screwdrivers, socket set and driver, open and box end wrenches, hacksaw, hammer, vice grips)

___ 2. Geologic hammer

___ 3. Trowel

___ 4. Stainless steel and/or Teflon spatula

___ 5. Hand auger

___ 6. Engineer's tape

___ 7. Steel tape

___ 8. Electric water level sounder

___ 9. Petroleum Interface Probe

___ 10. Batteries

___ 11. Bailers (Teflon, stainless steel, acrylic, PVC)

___ 12. Slug test water displacement tube

___ 13. Vacuum hand pump

___ 14. Electric vacuum pump

___ 15. Displacement hand pump

___ 16. Mechanical pump (centrifugal, submersible, bladder)

___ 17. Portable generator

___ 18. Gasoline for generator

___ 19. Hose

___ 20. Calibrated buckets

___ 21. Stop watch

___ 22. Orifice plate or equivalent flow meter

___ 23. Data logger and pressure transducers

___ 24. Strip chart recorders

___ 25. Sample bottles

___ 26. 0.45-micron filters (prepackaged in holders)

___ 27. Stainless steel bowls

___ 28. SW scoop

___ 29. Peristaltic pump/tubing

___ 30. Sample tags

___ 31. SOPs, HAZWOPER training certificates, MSDs, FSP, QAPP

### Decontamination Equipment

___ 1. Non-phosphate laboratory-grade detergent

___ 2. Selected high purity, contaminant free solvents

___ 3. Long-handled brushes

___ 4. Drop cloths (plastic sheeting)

___ 5. Trash container

___ 6. Galvanized tubs or equivalent (e.g., baby pools)

___ 7. Tap Water

___ 8. Contaminant free distilled/deionized water

___ 9. Metal/plastic container for storage and disposal of contaminated wash solutions

___ 10. Pressurized sprayers, $H_2O$

___ 11. Pressurized sprayers, solvents

___ 12. Aluminum foil

___ 13. Sample containers

___ 14. Emergency eyewash bottle

___ 15. Documentation Supplies

### Documentation Supplies

___ 1. Weatherproof, bound field logbooks with numbered pages

___ 2. Daily Drilling Report forms

___ 3. Field Borehole Log forms

___ 4. Monitoring Well Installation Log forms

___ 5. Well Development Data forms

___ 6. Groundwater Sampling Log forms

___ 7. Aquifer Test Data forms

___ 8. Sample Chain-of-Custody forms

___ 9. Custody seals

___ 10. Communication Record forms

___ 11. Documentation of Change forms

___ 12. Camera and film

___ 13. Paper

___ 14. Permanent/indelible ink pens

___ 15. Felt tip markers (indelible ink)

___ 16. Munsell Soil Color Charts

# MONITORING/SAMPLING LOCATION RECORDING

## 1.0 PURPOSE

This standard operating procedure (SOP) describes the guidelines for generating the descriptions and information to be recorded for each physical location where monitoring, or sampling is conducted.

## 2.0 PROCEDURES

### 2.1 SAMPLING LOCATION MARKING

Sampling locations are based on criteria presented in the SAP. Whenever possible, each sampling location will be marked by a wooden lathe stake, directly marking the surface with marking paint, or with surveyors flagging. Each should be labeled with the location identifier outlined in the SAP. This should be done during the site visit or as soon as is feasible during field activities. This is to give the utility locators a better idea of the specific area to be cleared. Having the locations marked will also assist the field crew gain a better perspective of the locations to be worked

### 2.2 PHOTOGRAPHIC DOCUMENTATION

Site photographs showing monitoring/sampling locations with respect to structures or the site in general are encouraged. At certain installations, photography must be approved by the Navy. Prior to commencing work, the Navy must be notified to determine if cameras are allowed at the installation. The Note that the Navy will likely inspect your camera and may purge/delete some pictures if they feel there is a security issue. When possible, a menu board included in the photograph can be used to give relative information regarding the project and location.

For each photograph, record the following information in the field logbook:

- Photo number
- Date and time of the photo
- Orientation of the photo (direction facing)
- Subject-a description of what is contained within the photo. Others may be using the photos that are unfamiliar with the site and locations.

A detailed description of field logbook entries can be found in SOP III-D, *Logbooks*.

### 2.3 MONITORING/SAMPLING LOCATION INFORMATION FORM

A Monitoring/Sampling Location Information form must be filled out to establish each new sampling location. This form must be provided to the Navy for inclusion into the NAVFAC NW NIRIS Database. Established locations should not be re-established unless new information (such as survey information) is recorded about a location. A location description may be provided about a sampling location. It should contain detailed information regarding the physical features surrounding the location, including relevant site information (i.e., obvious contamination, measurements to physical features, topographical relief, etc.). This description may be a copy of the field logbook or notes on project plan maps. These descriptions shall be attached to the field form. The PM is responsible for insuring that the project personnel have and use consistent terminology and descriptions as established in the SAP. The reverse of the field form contains a brief discussion of the form and descriptions of the information requested on the front.

## 3.0 DOCUMENTATION

None.

## 4.0 REFERENCES

SOP III-D, *Logbooks*

## 5.0 ATTACHMENTS

Attachment IA101 Example Monitoring/Sampling Location Information Form

### FORM 11-1A
### MONITORING/SAMPLING LOCATION SUMMARY

Installation ID: Establishing Contract ID: Prime Contractor Name:

Site Name: DO/CTO: Establishing Phase: Date Established:

Survey Contractor: Local System Description:

| Location Name | Location Type | Projection Specification | Coordinates | | Ground Elevation (feet msl) |
|---|---|---|---|---|---|
| | | | Northing (feet) | Easting (feet) | |
| | | | | | |
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| | | | | | |

**Location Types**

| | |
|---|---|
| ACID | Acid Pit |
| ADIT | Adit |
| AGT | Above ground tank |
| AIR | Air (not inside a building - ambient conditions) |
| AMB | Ambient drinking water aquifer monitoring well |
| AOVM | Ambient organic vapor monitor |
| ASBTS | Asbestos-Containing Area |
| BAY | Bay |
| BF | Backfill |
| BH | Borehole/Soil boring |
| BIN | Roll-off bin |
| BIOL | Biological (plant or animal) |
| BLDG | Building (includes building air and building materials) |
| BULK | Bulk sample |
| BURN | Burn pit |
| CB | Concrete boring |
| CENT | Location surveyed at the center of a UST field |
| CLGP | Canal Level Gauging Point |
| CPT | Cone penetrometer |
| CY | Cryopile |
| DCON | Decontamination pad |
| DITCH | Channel/Ditch |
| DP | Direct Push/Geoprobe |
| DRN | Drain |
| DRUM | Drum/Container contents |
| DRW | Drywell |
| DU | Decision Unit |
| DW | Domestic well |
| D_RIG_W | Drill Rig Fluid Container |
| EC | Electrode |
| ECT | Electrode |
| EF | System effluent |
| EVAP | EVAPORATION POND |
| EXCV | Excavation |
| FAGT | Former above ground tank location |
| FL | Fuel line |
| FLOOD | Flood Plain |
| FLOOD_GATE | Flood Control Gate |
| FLOOR | Floor |
| FLOOR_SCRP | Floor scrapings |
| FW | Faucet/Tap/Spigot |
| GAGE | Gaging station (not USGS) |
| GW | Geoprobe well |
| GWTH | Groundwater Test Hold |
| HA | Hand auger |
| HDPCH | Hydropunch |
| HOLE | Hole |
| HP | Holding pond/Lagoon |
| ID | Indoors |
| IMP | Import material |
| IN | System influent |
| IT | Intertidal |
| LAGOON | Lagoon |
| LENTIC | Freshwater, lentic |
| LF | Landfarm |
| LGV | Landfill Gas Vent |
| LH | Leachate (Landfill) |
| LK | Lake/pond/open reservoir |
| LOTIC | Freshwater, lotic |
| LYS | Lysimeter |
| MH | Manhole/Catch basin |
| MS | Sediment e.g., Marine Sediment |
| NQ | Quality Control sample |
| ON | Ocean, open water (not bay) |
| OTHER | Other |
| OUTFALL | Outfall |
| OW | Oil-Water Separator |
| PARK | Plantation/park/forest |
| PC | Paint chip |
| PIPE | Pipeline |
| PUBW | Public drinking water well |
| PUMP_STATN | Pumping station |
| RAIN_STATN | Rainfall station |
| REF | Reference |
| RES | Residential garden/yard |
| RV | River/stream |
| RW | Recovery well |
| SBAG | Soil bag |
| SE | Seep |
| SG | Soil Gas Probe |
| SIDEW | Side Wall |
| SLAG | Slag heap |
| SND_BLST | Sandblast material pile |
| SP | Spring/Seep |
| SPT | Septic tank |
| SR | Sewer System |
| SS | Ground surface |
| STEAM_LN | Steam Line |
| STKP | Stockpile |
| STRM_DRN | Storm drain |
| STRM_MH | Storm drain manhole |
| SUBS | Ground, sub-surface |
| SUBSLAB | Subslab |
| SUBT | Subtidal |
| SUMON | Survey monument |
| SUMP | Sump |
| SV | Soil vapor extraction system |
| SWS | Surface water body - nonspecific |
| SWSD | Surface Water/Sediment |
| SWWP | Wipe |
| SYSTEM | Treatment system air or water |
| T | Trench |
| TAA | Temporary accumulation area |
| TAIL | Mine tailings pile |
| TK | Tank |
| TMPM | Temperature Monitoring Point |
| TP | Test Pit |
| TRANS | Transformer |
| TUNNEL | Steam tunnel sampling location |
| TWP | Temporary well point |
| UGA | Geophysical anomaly |
| UNK | Unknown |
| USGS | USGS gauging station |
| UST | Underground storage tank |
| UXO | UXO |
| UXO_G | UXO grid |
| UXO_P | UXO point |
| VAULT | Vault |
| VPB | Vertical profile boring |
| WALL | Wall |
| WEEP | Weep hole |
| WF | Waste water treatment facility |
| WL | Well |
| WLAM | Alluvial Monitoring Well |
| WLBM | Bedrock Monitoring Well |
| WLE | Extraction well |
| WLEA | Alluvial Extraction Well |
| WLEB | Bedrock Extraction Well |
| WLHM | Hybrid Monitoring Well |
| WLI | Injection well |
| WLIA | Alluvial Injection Well |
| WLIM | Interface Monitoring Well |
| WLL | Leaching Well |
| WLM | Monitoring well |
| WLS | Sparge well |
| WLSG | Soil gas probe/Well |
| WRP | Waste rock pile |
| WSFI | Water system facility intake |
| WT | Wetlands |
| WW | Waste water |

Recorder: ______________________________ Date: __________

Checker: ______________________________ Date: __________

# SAMPLE NAMING

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## 1.0 PURPOSE

This standard operating procedure (SOP) describes the naming convention to be used for samples collected, analyzed, and reported for the U.S. Naval Facilities Engineering Command Northwest (NAVFAC NW) projects. Unique sample identifiers are used to facilitate tracking by laboratory and project personnel and for purposes of storing, sorting, and querying data in the NAVFAC NW NIRIS database.

## 2.0 PROCEDURES

The contractor is responsible for assigning a unique sample ID to every individual sample collected. The contractor may use his or her own designations as long as the sample ID does not already exist in the NIRIS database. The contractor must also clearly identify which samples are field duplicates. This applies to both historical and planned sampling events. The used sampling identification scheme shall be identified and outlined in the field sampling plan.

## 3.0 DOCUMENTATION

All sample collection information must be recorded within the field logbook. Each sample collected will be clearly associated with the sample location (installation, site, and well or sample point location), matrix type, sample type (i.e. environmental, field duplicate, equipment rinsate), collection date and time, sampling method, and sampling depth (if appropriate). Only data codes and location IDs associated with NIRIS and NAVFAC NW's electronic deliverables SOP (NAVFAC NW 2015) shall be used.

Any sample submitted for analysis shall be documented using a completed chain-of-custody (COC) form that must accompany the shipment and a copy retained for the project records.

Samples submitted to an EPA laboratory shall also include a completed EPA analysis request form. The COC/analytical request form must be used to track all sample IDs.

## 4.0 REFERENCES

NAVFAC NW. 2015. Navy Environmental Data Transfer, Version 5.0.

## 5.0 ATTACHMENTS

None.

# MONITORING WELL AND PIEZOMETER INSTALLATION

## 1.0 PURPOSE

The purpose of this standard operating procedure (SOP) is to outline the methods by which all U.S. Naval Facilities Engineering Command Northwest (NAVFAC NW) personnel and their contractors will conduct monitoring well and piezometer installation. This procedure establishes the protocols and necessary equipment for installation of groundwater monitoring wells and piezometers.

## 2.0 PROCEDURES

### 2.1 EQUIPMENT

The following is an equipment list:

- Drill rig capable of installing wells to the desired depth in the expected formation material and conditions
- Well casing and well screen
- Bentonite pellets
- Filter pack sand
- Bentonite Grout or Portland Type I or II cement and powdered bentonite for grouting
- Protective well casing with locking cap
- High-pressure steamer/cleaner
- Long-handled bristle brushes
- Wash/rinse tubs
- Appropriate decontamination supplies as specified in the SOP for decontamination procedures
- Location map
- Plastic bags (re-sealable)
- Self-adhesive labels
- Weighted tape measure
- Water level probe
- Deionized water
- Logbook

- Boring log sheets
- Well construction form
- Plastic sheeting
- Drums for containment of cuttings and decontamination and/or development water (if necessary)

## 2.2 DECONTAMINATION

Before drilling or well installation begins, all drilling and well installation material should be decontaminated according to the protocols in SOP III-I, *Equipment decontamination*. Drilling equipment should be decontaminated between well locations.

## 2.3 INSTRUMENT CALIBRATION

Before going into the field, the sampler should verify that field instruments are operating properly. Calibration times and readings should be recorded in a notebook to be kept by the field sampler. Specific instructions for calibrating the instruments are provided in the respective SOPs.

## 2.4 DRILLING AND WELL INSTALLATION PROCEDURES

### 2.4.1 Drilling Technique

If soil sampling is required by project plans, all soil samples should be collected according to the subsurface soil sampling procedures. The hole should be logged according to the methods specified in the project plans.

Boreholes should be advanced via conventional continuous-flight hollow-stem auger, sonic, air rotary, or mud rotary drilling methods and a drill rig capable of completing the monitor well(s) to the depth(s) specified in the project plans. Before drilling begins, well locations should be numbered and staked. The necessary permits and utility clearances shall be obtained in accordance with permits and utility clearance procedures. The permits and clearances will conform to specific Naval installation procedures or SOP 1-A-6 for utility location procedures.

During the drilling operation, the cuttings from the boring shall be placed into 55-gallon drums or roll-off container as specified in the project plans. Disposal of cuttings should be in accordance with the project plans and follow the specific Naval installation procedures or SOP l-A-7 for investigation-derived waste (IDW) management procedures.

### 2.4.2 Well Bore Drilling Operations

The procedure for well bore drilling is as follows:

- Set up drilling rig at previously staked and borehole location cleared for utilities.
- Record location, date, time, and other pertinent information in the field logbook.
- Drill hole of appropriate size using the project specified drilling method.
- Collect split-spoon samples at the predetermined intervals, if appropriate, for sample description and/or chemical analysis as specified in the project plans.
- Complete the borehole to the depth specified in the project plans.

- Document any difficult drilling conditions and ensures taken in response to such conditions (such as the addition of clean water to control heave).

### 2.4.3 Well Design Specifications

The general specifications for wells are as follows:

Boring Diameter. The boring should be of sufficient diameter to permit at least 2 inches of annular space between the boring wall and all sides of the centered riser and screen. The boring diameter should be of sufficient size to allow for the accurate placement of the screen, riser, filter pack, seal, and grout.

Well Casing. The well riser should consist of new, flush-threaded, PVC or stainless steel. The well diameter and thickness should be specified in the project plans. The risers should extend approximately 2 feet above the ground surface, except in the case of flush-mount surface casings. The tops of all well casings should be fitted with plugs or caps in locking monuments and locking caps in non-locking monuments.

Well Screens. The screen length for each well should be specified in the project plans. Well screens should consist of new threaded pipe with factory-machine slots or wrapped screen with an inside diameter equal to or greater than that of the well casing. The slot size should be indicated in the project plans and designed to be compatible with aquifer and sand pack material. The schedule thickness of PVC screen should be the same as that of the well casing. All screen bottoms should be fitted with a cap or plug of the same composition as the screen and should be within 0.5 foot of the open part of the screen. Traps may be used.

### 2.4.4 Well Installation Procedure

The following procedure should be initiated within 12 hours of well bore completion for uncased holes or partially cased holes and within 48 hours for fully cased holes. Once installation has begun, if no unusual conditions are encountered, there should be no breaks in the installation procedure until the well has been completed and the drill casing has been removed.

The procedure for monitoring well installation is as described below.

1. Decontaminate all well materials according to the SOP for decontamination procedures. After decontamination, all personnel who handle the casing should put on a clean pair of rubber or surgical gloves.
2. Measure each section of casing and screen to nearest 0.10 foot.
3. Assemble screen and casing as it is lowered into the open boring or drill casing (augers, when auger drilling is used) the hollow-stem augers.
4. Lower screen and casing to about 6 inches above the bottom of the boring.
5. Record the level of top of casing and calculate the screened interval. Adjust screen interval by raising assembly to desired interval, if necessary, and add selected filter sand to raise the bottom of the boring.
6. Begin adding filter pack sand around the annulus of the screen and casing a few feet at a time while withdrawing the drill casing or augers. Repeated depth soundings should be taken to monitor the level of the sand.

7. Allow sufficient time for the filter sand to settle through the water column outside the casing before measuring the sand level.
8. Extend the filter pack sand to at least 2 to 5 feet above the top of the well screen.
9. After placing the sand filter pack, install a seal at least 3 to 5 feet thick of bentonite pellets or chips. Add the bentonite pellets or chips slowly through the drill casing to avoid bridging. The thickness of the completed bentonite seal should be measured before the pellets have been allowed to swell. The completed bentonite seal should be allowed to hydrate before proceeding with the grouting operations.
10. Grout the remaining annulus from the top of the bentonite seal to near the ground surface as measured after the drill casing has been removed. The grout should be tremied into the borehole until the annulus is completely filled. The base of the tremie pipe should be placed approximately 5 feet above the bentonite seal. Bentonite chips or pellets may be used to backfill the well borehole.
11. After the grout sets for 24 hours it should be checked for settlement. If necessary, additional grout should be added to top off the annulus. This procedure may not be an option in high traffic or unsecured areas.
12. The steel monument, concrete pad and bollards, if required, should be installed according to the specifications in this SOP. The protective casing and posts should be painted a highly visible color.
13. Optional: Personnel should affix to the outer steel protective casing of each well a permanent, noncorrosive tag that clearly identifies the well number, the client's name, or the adjusted top of casing elevation. In some states, a state well identification number must be affixed to the monument.

### 2.4.5 Well Installation Specifications

Filter Pack. The annular space around the well screen should be backfilled with clean, washed silica sand sized to perform as a filter between the formation material and the well screen. The filter pack should extend a minimum 3 feet above the screen and may be tremied into place. The final depth to the top of the filter pack should be measured directly with the use of a weighted tape measure or rod and not by volumetric calculation methods. The grain size of the filter pack should be shown on the well construction log. The filter pack must be selected based on the grain size distribution of the native formation, and should be specified in the project plans.

Bentonite Seal and Grout. A minimum 2-foot-thick bentonite pellet/chip seal should be placed in the annulus above the filter pack. The thickness of the seal may vary slightly based on site conditions. The thickness of the seal should be measured immediately after placement, without allowance for swelling. Bentonite Grout or cement grout should then be placed from the top of the bentonite seal to the ground surface. Bentonite grout is preferred because of potential investigation derived waste issues if too much cement grout is prepared and due to heat generated from cement grout. Bentonite grout shall be "high solids" and prepared in accordance with the manufacturer's instructions. Cement grout should consist of a mixture of Portland cement (ASTM C150) and clean water, with a ratio of no more than 7 gallons of clean water per bag of cement (1 cubic foot or 94 pounds). Additionally, 3 percent by weight of bentonite powder should be added if permitted by state regulations. The grout should be prepared in a rigid aboveground container by first thoroughly mixing the cement with water, and then mixing in the bentonite powder. Grout mixtures should be placed, by pumping through a tremie pipe. The lower end of the tremie pipe should be kept within 5 feet of the top of the bentonite seal. Grout should be pumped through the tremie pipe until undiluted grout flows from the annular space at the ground surface. The tremie pipe should then be removed and more grout added to compensate for settling. After 24 hours, the drilling contractor should check the site for grout settlement and add more grout to fill any depression. This should be repeated until firm grout remains at the surface.

Protection of Well. Personnel should at all times during the progress of the work take precautions to prevent tampering with the wells or the entry of foreign material into them. Upon completion of a well, a suitable cap should be installed to prevent foreign material from entering the well. The wells should be enclosed in a protective steel casing. Steel casings should be, at a minimum, 6 inches in diameter and should be provided with locking caps and locks. All locks used at a site should be keyed alike. If the well is to be a stickup (i.e., an aboveground monument), as specified in the project plans, a 1/4-inch drainage hole should be drilled in the protective steel casing, centered approximately 1/8-inch above the internal mortar collar for drainage. The well designation should be painted on the protective casing with a brush or paint pen. Painting should be done prior to well development. If specified in the project plans, a concrete pad should be constructed around the protective casing at the final ground level elevation and sloping away from the well. The concrete pad should measure at least 2 by 2 feet, with a thickness of 6 to 8 inches. Three 3-inch-diameter or larger steel posts should be equally spaced around the well and embedded in separate concrete-filled holes just outside the concrete pad. The protective steel posts should extend approximately 1 foot above the well riser. Any well that is to be temporarily removed from service or left incomplete due to a delay in construction should be capped with a watertight cap and equipped with a “vandal-proof” cover, satisfying applicable state or local regulations or recommendations.

## 3.0 DOCUMENTATION

Observations and data acquired in the field during the drilling and installation of wells should be recorded to establish a permanent record. A boring log should be completed for each well bore.

Additional documentation of well construction in the field logbook will include the following:

- Top of Casing surveyed elevation to 0.01 feet relative to known benchmarks, control points, and coordinate systems as defined in the Survey Specifications of NAVFAC NW SOPs V5.0 (or more current)
- Date
- Time
- Personnel
- Weather
- Subcontractors
- Health and safety monitoring equipment and readings
- Description of well location and triangulation measurements from landmarks, or GPS readings.
- Quantity and composition of grout, seals, and filter pack actually used during construction

- Screen slot size (in inches), slot configuration, outside diameter, nominal inside diameter, schedule/thickness, composition, and manufacturer
- Coupling/joint design and composition
- Protective casing composition and nominal inside diameter
- Start and completion dates
- Discussion of all procedures and any problems encountered during drilling and well construction

In addition, the well installation details should be shown in a diagram drawn in the field logbook. Each well diagram should consist of the following (denoted in order of decreasing depth from the ground surface):

- Reference elevation for all depth measurements
- Project and site names
- Well number
- Date(s) of installation
- Depth at which the hole diameter changes (if appropriate)
- Depth of the static water level and date of measurement(s)
- Total depth of completed well
- Depth of any grouting or sealing
- Nominal hole diameter(s)
- Depth and type of well casing
- Description (to include length, internal diameter, slot size, and well screen material
- Any sealing off of water-bearing strata
- Static water level upon completion of the well and after development
- Drilling date(s)
- Other construction details of monitoring well including grain size of well filter pack material and location of all seals and casing joints

All entries in the field logbook should be printed in black ink and legible.

## 4.0 REFERENCES

SOP I-A-7, *IDW Management*

SOP III-I, *Equipment Decontamination*

## 5.0 ATTACHMENTS

None.

# MONITORING WELL DEVELOPMENT

## 1.0 PURPOSE

This section describes the standard operating procedures (SOP) for monitoring well development to be used by all U.S. Naval Facilities Engineering Command Northwest (NAVFAC NW) personnel and their contractors.

## 2.0 PROCEDURE

### 2.1 INTRODUCTION

Well development procedures are crucial in preparing a well for sampling. Development enhances the flow of groundwater from the formation into the well and grades the well filter pack to reduce the movement of fine (clay and silt) particles into the well. The reduction in groundwater sample turbidity achieved by development improves the representation of chemical analyses performed on groundwater samples.

The goal of well development is to restore the area adjacent to a well to its natural condition by correcting damage to the formation during the drilling process. Well development should accomplish the following tasks:

- Remove any filter cake or any drilling fluid within the borehole that affects formation permeability.
- Grade the well filter pack to reduce the intrusion of fine formation particles.

Well development should not be performed sooner than 24 hours after the completion of well installation to allow the annular seal to fully set up.

### 2.2 FACTORS AFFECTING MONITORING WELL DEVELOPMENT

#### 2.2.1 Type of Geologic Materials

Different types of geologic materials are developed more effectively by using certain development methods. Where permeability is greater, water moves more easily into and out of the formation and development is accomplished more quickly. Highly stratified deposits are effectively developed by methods that concentrate on distinct portions of the formation. If development is performed unevenly, a ground-water sample will likely be more representative of the permeable zones. In uniform deposits, development methods that apply powerful surging forces over the entire screened interval will produce satisfactory results.

### 2.2.2 Design and Completion of the Well

Because the filter pack reduces the amount of energy reaching the borehole wall, it must be as thin as possible if the development procedures are to be effective in removing fine particulate material from the interface between the filter pack and natural formation. Conversely, the filter pack must be thick enough to ensure a good distribution of the filter-pack material during emplacement and allow effective grading during development. Generally, filter pack material must be at least 2 inches thick. Variances from state agencies may be required for filter pack materials of less than 2 inches thick.

The screen slot size must be appropriate for the geologic material and filter pack material in order for development to be effective. If the slot size is too large, the filter pack and native material will enter the well, causing settlement of overlying materials and sediment accumulation in the casing. If the slot size is too small, full development may not be possible and the well yield will be below the potential of the formation. Additionally, incomplete development coupled with a narrow slot size can lead to blockage of the screen openings.

### 2.2.3 Drilling Method

The drilling method influences development procedure. Typical problems associated with specific drilling methods include the following:

- If a mud rotary method is used, a mudcake builds up on the borehole wall and must be removed during the development process.
- If drilling fluid additives have been used, the development process must attempt to remove all fluids that have infiltrated into the native formation.
- If driven casing or hollow-stem auger methods have been used, the interface between the casing or auger flights and the natural formation may have been smeared with fine particulate matter that must be removed during the development process.
- If an air rotary method has been used in rock formations, fine particulate matter is likely to build up on the borehole walls and may plug pore spaces, bedding planes, and other permeable zones. These openings must be restored during the development process.

## 2.3 PREPARATION

In preparing for monitoring well development, development logs for any other monitoring wells in the vicinity should be reviewed to determine the general permeability of the water-bearing formation, the associated likely groundwater yield from the well and the appropriate development method.

Depth to groundwater and information from the well construction log should be used in calculating of the required quantity of water to be removed. The distance between the equilibrated water level and the bottom of screen is the saturated section. The saturated section (feet) multiplied by the unit well volume per foot (gallons/linear foot) equals the gallons required to remove one total well volume of water. The unit well volume is the sum of the casing volume and the filter-pack pore volume, both of which depend upon casing and borehole diameter and the porosity of the filter pack material. Well volume for wells can be calculated using Table I-C-2-1 and Table I-C-2-2.

**Table I-C-2-1***
**Casing Volume**

| Casing Diameter (inches) | Volume (gallon/linear foot) |
|---|---|
| 2 | 0.16 |
| 4 | 0.65 |
| 6 | 1.47 |

**Table I-C-2-2***
**Filter Pack Pore Volume**

| Casing Diameter (inches) | Borehole Diameter (inches) | Volume[a] (gallon/linear foot) |
|---|---|---|
| 2 | 6 | 0.52 |
| 2 | 8 | 0.98 |
| 4 | 10 | 1.37 |
| 4 | 12 | 2.09 |
| 6 | 12 | 1.76 |

* The above two volumes must be added together to obtain one unit well volume.

[a] Assumes a porosity of 40% for filter pack.

## 2.4 DECONTAMINATION

The purpose of decontamination of development equipment is to prevent cross-contamination between monitoring wells. A steam-cleaner, if available, should be used to decontaminate development equipment. The equipment should be cleaned away from the monitoring well in such a fashion that decontamination effluent can be containerized.

A triple rinse decontamination procedure is acceptable for equipment such as bailers if access to a steam cleaner is not possible. See SOP III-I, *Equipment Decontamination*.

## 2.5 WELL DEVELOPMENT MONITORING

Throughout the well development process, a development record should be maintained in the field logbook. A well development field form presented in Attachment 1 (or similar) may be filled out in addition to the field logbook. The record should include the following information:

General

- Well name/number and location

- Date, time, and weather conditions
- Names of personnel involved

Development volume

- Initial and final water level
- Casing total depth and diameter
- Borehole diameter
- Casing volume, filter pack pore volume, total well volume
- Volume of water to be evacuated
- Method and rate of removal
- Appearance of water before and after development

Monitoring data for each sample point

- Date, time, elapsed time
- Cumulative gallons removed, removal method, removal rate
- Temperature, pH, specific conductance, turbidity, dissolved oxygen, and redox potential

Part of the well development procedure should consist of acquisition and analysis of general water quality parameters at periodic intervals, considering the total quantity of water to be removed and the removal rate. Depending on site conditions, the parameters specific conductance, pH, temperature, dissolved oxygen, turbidity, and redox potential may be measured. At a minimum the temperature, pH and turbidity should be monitored. Parameter measurements should be collected on a periodic basis during development. At a minimum, these parameters should be measured after removal of each well volume. The cumulative water volume of removed, the clock time, and the time elapsed during development should be recorded and a flow rate should be calculated. Development should continue until turbidity stabilizes at or below 10 nephelometric units or at least three well volumes have been removed. If three successive parameter measurements show stable values (values within 10% of each other) and turbidity is low, well development may cease. If stabilization has not been attained, if turbidity remains high, or if the well does not readily yield water, development should continue for a reasonable time as determined in the project plans or by the Project Manager.

The discussion of well development in special situations such as low yield formations is described in Section 2.7.

## 2.6 METHODS OF MONITORING WELL DEVELOPMENT

The methods available for the development of monitoring wells have been inherited from production well practices. Methods include (1) mechanical surging with a heavy, non-disposable bailer (stainless steel or PVC) surge block or swab, and (2) surge pumping. Development methods using air or jetting of water into the well are discouraged because of the potential for affecting water quality. In some circumstances, air or water jet development may be necessary and should be conducted under the supervision of a qualified hydrogeologist.

All development water must be containerized and appropriately labeled, unless it is permissible to discharge onsite. Development should generally utilize mechanical surging or surge pumping, followed by bailing or groundwater removal with a pump. More detailed descriptions of appropriate development methods are presented below.

### 2.6.1 Mechanical Surging and Bailing

For mechanical surging and bailing, a heavy bailer, surge block or swab is operated either manually or by a drill rig. The bailer, surge block, or swab should be of sufficient weight to free-fall through the water in the well and create a vigorous outward surge. The equipment lifting the tool must be strong enough to extract it rapidly. A bailer is then used to remove fine-grained sediment and groundwater from the well.

Methodologies:

1. Properly decontaminate all equipment entering well.
2. Record the static water level and the total well depth.
3. Lower the bailer, surge block or swab to top of the screened interval.
4. Operate in a pumping action with a typical stroke of approximately 3 feet.
5. Gradually work the surging downward through the screened interval during each cycle.
6. Surge for several minutes per cycle.
7. Remove surge block and attach bailer in its place.
8. Bail to remove fines loosened by surging until water appears clear.
9. Repeat the cycle of surging and bailing until turbidity is reduced and stabilization of water quality parameters occurs.
10. The surging should initially be gentle and the energy of the action should gradually increase during the development process.

The advantages (+) and disadvantages (–) of this method are listed below:

+ It reverses the direction of flow, reduces bridging between large particles; the inflow then moves the fine material into the well for withdrawal.
+ It affects the entire screened interval.
+ It effectively removes fines from the formation and the filter pack.
– It may cause upward movement of water in the filter pack that could disrupt the seal.
– Potential exists for damaging a screen with a tight-fitting surge block or with long surge strokes.

### 2.6.2 Surge Pumping

Methodologies:

1. Properly decontaminate all equipment entering well.
2. Record the static water level and the total well depth.
3. Lower a submersible pump or airlift pump without a check valve to a depth within 1 to 2 feet of the bottom of the screened section.
4. Start pumping and increase discharge rate causing rapid drawdown of water in the well.
5. Periodically stop and start pump, allowing the water in the drop pipe to fall back into the well and surge the formation (backwashing), thus loosening particulates.
6. The pump intake should be moved up the screened interval in increments appropriate to the total screen length.
7. At each pump position, the well should be pumped, over-pumped, and backwashed alternately until satisfactory development has been attained as demonstrated by reduction in turbidity and stabilization of water quality parameters.

The advantages (+) and disadvantages (–) of this method are listed below:

+ Reversing the direction of flow reduces bridging between large particles, and the inflow then moves the fine material into the well for withdrawal.

+ It effectively removes fines from the formation and filter pack.

– The pump position or suction line must be changed to cover the entire screen length.

– Submersible pumps suitable to perform these operations may not be available for small diameter (2 inches or less) monitoring wells.

– It is not possible to remove sediment from the well unless particle size is small enough to move through pump.

For additional information on well development, consult the references included in Section 4.0 of this SOP.

## 2.7 SPECIAL SITUATIONS

### 2.7.1 Development of Low Yield Wells

Development procedures for monitoring wells in low-yield (<0.25 gpm) water-bearing zones are somewhat limited. Due to the low hydraulic conductivity of the materials, surging of water in and out of the well casing is difficult. Also, when the well is pumped, the entry rate of water is inadequate to remove fines from the well bore and the gravel pack. Additionally, the process may be lengthy because the well can be easily pumped dry and the water level will be very slow to recover.

The procedures for mechanical surging and bailing should be followed for low yield wells. During surging and bailing, wells in low yield formations should be drawn down to total depth twice if possible.

Development can be terminated, however, if the well does not exhibit 80% recovery after 2 hours have passed.

## 3.0 DOCUMENTATION

Well development information should be documented in field logbooks in accordance with SOP III-D, *Logbooks* using indelible ink. In addition, well development monitoring forms (Attachment I-C-2-1 or similar) may be filled out in addition to the field logbook documentation. Copies of this information should be sent to the Project Manager and to the project files.

## 4.0 REFERENCES

Driscoll, F.G. 1987. Ground Water and Wells. Published by Johnson Division, St. Paul, Minnesota.

USEPA. 1992. RCRA, Ground Water Monitoring Technical Enforcement Guidance Document. U.S. Environmental Protection Agency/530/R-93/001. November.

U.S. EPA Environmental Response Team. 1988. Response Engineering and Analytical Contract Standard Operating Procedures. U.S. EPA, Research Triangle Park, NC.

SOP III-I, *Equipment Decontamination*

SOP III-D, *Logbooks*

## 5.0 ATTACHMENTS

| | |
|---|---|
| Attachment I-C-2-1 | Well Development Record |

## Attachment 1-C-2-1
## Well Development Record

| | | |
|---|---|---|
| PROJECT | | WELL NO. |
| JOB NO. | SITE | PREPARED BY |

## WELL DEVELOPMENT LOG

METHOD
OVERPUMPAGE __________
BAILER __________

SURGE
BLOCK __________
AIR LIFT __________
OTHER __________

INITIAL WATER LEVEL __________
FINAL WATER LEVEL __________

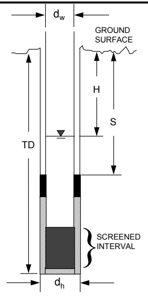
REMARKS:

CAPACITY OF CASING
(GALLONS/LINEAR FOOT)

2” = 0.16
4” = 0.65
6” = 1.47

VOLUME BETWEEN CASING AND HOLE
(GALLONS/LINEAR FOOT)
(ASSUMING 40% POROSITY)
2” CASING AND 6” HOLE - 0.52
2” CASING AND 8” HOLE - 0.98
4” CASING AND 10” HOLE = 1.37
4” CASING AND 12” HOLE - 2.09

Hole Diameter $d_h$ =_____
Well Casing:
Inside Diameter $d_w$ID =_____
Outside Diameter $d_w$OD =_____
Depth to Water: H =_____
Depth to Base of Seal: S =_____
Depth to Base of Well: TD =_____
Estimated Filter Pack Porosity: P =_____



WELL VOLUME CALCULATION :

$$\text{CASING VOLUME} = V_c = \Pi\left(\frac{d_w ID}{2}\right)^2 (TD - H) = 3.14\left(\frac{\underline{\quad\quad}}{2}\right)^2 (\underline{\quad\quad} - \underline{\quad\quad}) = \underline{\quad\quad\quad}$$

$$\text{FILTER PACK PORE VOLUME} = V_f = \Pi\left[\left(\frac{d_h}{2}\right)^2 - \left(\frac{d_w OD}{2}\right)^2\right](TD - (S \text{ or } H^*)(P) = \underline{\quad\quad\quad}$$

$$(^*\text{if } S > H, \text{use } S; \text{if } S < H, \text{use } H)$$

$$= 3.14\left[\left(\frac{\underline{\quad\quad}}{2}\right)^2 - \left(\frac{\underline{\quad\quad}}{2}\right)^2\right](\underline{\quad\quad} - \underline{\quad\quad})(\underline{\quad\quad}) = \underline{\quad\quad\quad}$$

$$\text{TOTAL WELL VOLUME} = VT = Vc + Vf = \underline{\quad\quad} + \underline{\quad\quad} = \underline{\quad\quad\quad}\ \text{ft.}^3 \times 7.48 = \underline{\quad\quad\quad}\ \text{gal.}$$

| DEVELOPMENT LOG: | | | | | CUMULATIVE WATER REMOVED | WATER QUALITY | | | | | | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DATE | TIME BEGIN/END | METHOD | ELAPSED TIME | FLOW RATE (gpm) | GALLONS | pH | TEMP | CONDUC-TIVITY | D.O.* | REDOX | TURBID-ITY | |
| | | | | | | | | | | | | |

* = Dissolved Oxygen

# LOW-FLOW GROUNDWATER PURGING AND SAMPLING

## 1.0 PURPOSE

This standard operating procedure (SOP) describes the conventional monitoring well sampling procedures to be used by all U.S. Naval Facilities Engineering Command Northwest (NAVFAC NW) personnel and contractors. Conventional monitoring well sampling procedures are provided in SOP I-C-4, *Groundwater Sampling from Temporary Wells (Piezometers)*.

## 2.0 PROCEDURE

### 2.1 PURPOSE

This procedure establishes the method for sampling groundwater monitoring wells for water-borne contaminants and general groundwater chemistry. The objective is to obtain groundwater samples with as little alteration of water chemistry as possible.

### 2.2 PREPARATION

#### 2.2.1 Site Background Information

A thorough understanding of the purposes of the sampling event should be established prior to commencing field activities. A review of available data obtained from the site and pertinent to the water sampling should also be conducted. Copies of well logs or summary tables regarding well construction information should be available on-site if possible.

Previous groundwater development and sampling logs give a good indication of well purging rates and the types of problems that may 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.

It is highly recommended that the field sampling team is familiar with the U.S. EPA recommended protocols for low-flow sampling outlined in the April 1996 Ground Water Issue *Low-Flow (Minimal Drawdown) Groundwater Sampling Procedures* (U.S. EPA 1996).

#### 2.2.2 Groundwater Analysis Selection

The requisite field and laboratory analyses should be established prior to performing water sampling. The types and numbers of quality assurance/quality control (QA/QC) samples to be collected (refer to SOP III-B, *Field QC Samples (Water, Soil)*) should be specified in the QA plan developed for the site.

### 2.3 GROUNDWATER SAMPLING PROCEDURES

Groundwater sampling procedures at a site should include: (1) measurement of depth to groundwater and total depth, (2) assessment of the presence or absence of an immiscible phase (if required by the project plan), (3) assessment of purge parameter stabilization, (4) purging of static water within the well and well bore, and (5) 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.

### 2.3.1 Measurement of Static Water Level Elevation

The depth to water and the total depth of the well should be measured 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). Dependent upon individual project requirements, synoptic water level collection may be required prior to groundwater sampling activities. In the event that synoptic water levels **are not** collected prior to sampling activities, total depth measurements should be collected **after** purging and sampling activities to prevent the suspension of fine-grained sediment that may be present at the bottom of the well. Each well should be marked with a permanent, easily identified reference point for water level measurements whose location and elevation have been surveyed.

An electronic water level meter accurate to 0.01 foot should be used to measure the water level surface and depth of the well. 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.

### 2.3.2 Decontamination of Equipment

Each piece of non-dedicated equipment should be decontaminated prior to entering the well. Decontamination should also be conducted prior to the start of sampling at a site, even if the equipment is known to be decontaminated subsequent to its last usage. This precaution is taken to minimize the potential for cross-contamination. In addition, each piece of equipment used at the site should be decontaminated prior to leaving the site. Dedicated sampling equipment need only be decontaminated prior to installation within the well. Clean sampling equipment should not be placed 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 onsite decontamination.

Further details are presented in SOP III-I, *Equipment Decontamination*.

### 2.3.3 Detection of Immiscible Phase Layers

Unless specified in the project plans, groundwater samples should not be collected from wells with detectable amounts of LNAPL and DNAPL.

### 2.3.4 Purging Equipment and Use

To help minimize the potential for cross-contamination, well sampling should proceed from the least contaminated to the most contaminated. This order may be changed in the field if conditions warrant, particularly if dedicated sampling equipment is used. If decontamination of tubing is required by the project, Teflon® tubing is recommended. All groundwater removed from potentially contaminated wells should be handled in accordance with the investigation-derived waste (IDW) handling procedures described in SOP I-A-7, *IDW Management*.

Purging should be accomplished by removing groundwater from the well at low flow rates using a pump. According to the U.S. EPA (1996), the rate at which groundwater is removed from the well during purging ideally should be between than 0.1 to 0.5 L/min. The pump intake should be placed in the middle of the calculated saturated screened interval. The purge rate should be low enough that substantial drawdown (>0.3 foot) in the well does not occur during purging. If a stabilized drawdown in the well can't be achieved and the water level is approaching the top of the screened interval, reduce the flow rate or turn the pump off (for 15 minutes) and allow for recovery. It should be noted whether or not the pump has a check valve. A check valve is required if the pump is shut off. ***Under no circumstances should the well be pumped dry or otherwise over-purged***. Begin pumping at a lower flow rate, if the water draws down to the top of the screened interval again turn pump off and allow for recovery. If two tubing volumes (including the volume of water in the pump and flow cell) have been removed during purging then sampling can proceed next time the pump is turned on. This information should be noted in the field notebook or groundwater sampling log with a recommendation for a different purging and sampling procedure (USEPA, 2012).

Water level measurements should be collected to assess the water level effects of purging. A low purge rate also will reduce the possibility of stripping VOCs from the water, and will reduce the likelihood of mobilizing colloids in the subsurface that are immobile under natural flow conditions.

Water quality parameters should be collected and recorded on a regular basis (every 3-5 minutes) during well evacuation. Field parameters to be collected may include temperature, pH, specific conductance, salinity, dissolved oxygen, Redox potential, and turbidity. At least seven readings should be taken during the purging process unless the field parameters stabilize more quickly. These parameters are measured to demonstrate that the formation water, not stale well casing water, is being evacuated. Purging should be considered complete when the high and low values between three consecutive field parameter measurements stabilize within 10%. Turbidity may be considered stable if values are less than 10 nephelometric turbidity units (NTUs). The criterion for temperature may not be applicable if a submersible pump is used during purging due to the heating of the water by the pump motor. Field personnel should refer to the project-specific Sampling and Analysis Plan (SAP) for specific measurement requirements and well stabilization criteria.

All information obtained during the purging and sampling process should be entered into the field logbook. In addition to the field logbook, the data may be logged on a groundwater sampling log (Figure I-C-5-1 or equivalent). In special situations where LNAPL has been detected in the monitoring well and a groundwater sample is determined to be necessary by the Project Manager, a stilling tube should be inserted into the well prior to well purging. The stilling tube should be composed of a material that meets the performance guidelines for sampling devices. The stilling tube should be inserted into the well to a depth that allows groundwater from the screened interval to be purged and sampled. The bottom of the tube should be set below the upper portion of the screened interval where the LNAPL is entering the well screen. The goal is to sample the aqueous phase (groundwater) while preventing the LNAPL from entering the sampling device. To achieve this goal, the stilling tube must be inserted into the well in a manner that prevents the LNAPL from entering the stilling tube.

One method of doing this is to cover the end of the stilling tube with a membrane or material that will be ruptured by the weight of the pump. A piece of aluminum foil can be placed over the end of the stilling tube. The stilling tube is lowered slowly into the well to the appropriate depth and then attached firmly to the top of the well casing. When the pump is inserted, the weight of the pump breaks the foil covering the end of the tube, and the well can be purged and sampled from below the LNAPL layer. The membrane or material that is used to cover the end of the stilling tube must be fastened firmly so that it remains attached to the stilling tube when ruptured. Moreover, the membrane or material must retain its integrity after it is ruptured. Pieces of the membrane or material must not fall off of the stilling tube into the well. Although aluminum foil is mentioned in this discussion as an example of a material that can be used to cover the end of the tube, a more chemically inert material may be required, based on the site-specific situation. Stilling tubes should be thoroughly decontaminated prior to each use. Groundwater removed during purging should be collected and stored onsite until its disposition is determined based upon laboratory analytical results. Storage should be in secured containers such as DOT-approved drums. Containers of purge water should be labeled with NAVFAC NW approved labels or paint pens.

### 2.3.5 Groundwater Sampling Methodology

The well should be sampled when groundwater within it is representative of aquifer conditions and after it has recovered sufficiently to provide enough volume for the groundwater sampling parameters. A period of no more than 2 hours should elapse between purging and sampling to prevent groundwater interaction with the casing and atmosphere. This may not be possible with a slowly recharging well. The water level should be measured and recorded prior to sampling to demonstrate the degree of recovery of the well. Sampling equipment should never be dropped into the well, because this could cause aeration of the water upon impact. In addition, the sampling methodology utilized should 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.

### 2.3.6 Sample Handling and Preservation

Many of the chemical constituents and physiochemical parameters to be measured or evaluated during groundwater monitoring programs are chemically unstable; therefore, samples must be preserved. The U.S. Environmental Protection Agency document entitled *Test Methods for Evaluating Solid Waste – Physical/Chemical Methods (SW-846)* (U.S. EPA 1995), includes a discussion of appropriate sample preservation procedures. In addition, SW-846 specifies the sample containers that should be used for each constituent or common set of parameters. In general, check with specific laboratory 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 team may add preservatives in the field.

Improper sample handling may alter the analytical results of the sample. Samples should be transferred 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 Quality Assurance Project Plan.

When sampling for VOCs, water samples should be collected in vials or containers specifically designed to prevent loss of VOCs from the sample. An analytical laboratory should provide these vials, preferably by the laboratory that will perform the analysis. Groundwater from the sampling device should be collected in vials by allowing the groundwater to slowly flow along the sides of the vial. Sampling equipment should not touch the interior of the vial. The vial should be filled above the top of the vial to form a positive meniscus with no overflow. No headspace should be present in the sample container once the container has been capped. The sample can be checked for headspace by inverting the sample bottle 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 is aerated or naturally carbonated. In these cases, the investigator should note the problem to account for possible error. Field logs and laboratory analysis reports should note any headspace in the sample container(s) at the time of receipt by the laboratory, as well as at the time the sample was first transferred to the sample container at the wellhead.

#### *2.3.6.1 Special Handling Considerations*

Samples requiring analysis for organics should not be filtered. Samples should 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.

Groundwater samples to be analyzed for total and dissolved metals should be obtained sequentially. The sample to be analyzed for total metals, should be obtained directly from the pump and be unfiltered. The second sample should be filtered through a 0.45-micron membrane in-line filter and transferred to a container to be analyzed for dissolved metals. Allow at least 500 ml of effluent to flow through the filter prior to sampling. Any difference in concentration between the total and dissolved fractions may be attributed to the original metallic ion content of the particles and adsorption of ions onto the particles.

#### *2.3.6.2 Field Sampling Preservation*

Samples should be preserved immediately upon collection. Ideally, sample jars contain preservatives of known concentration and volume during the initial filling of the jar to a predetermined final sample volume. For example, metals require storage in aqueous media at pH of 2 or less. Typically, 0.5 ml of 1:1 nitric acid added to 500 ml of groundwater will produce a pH less than 2.0. 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. It should be noted that introduction of preservatives will dilute samples, and may require normalization of results. Guidance for the preservation of environmental samples can be found in the EPA "Handbook for Sampling and Sample Preservation of Water and Wastewater:" (U.S. EPA 1982).

## 3.0 DOCUMENTATION

Information collected during groundwater sampling should be documented in the field logbook in accordance with SOP III-D, *Logbooks*. In addition, groundwater sampling purge logs may be (Figure I-C-5-1 or equivalent) may be filled out in addition to the field logbook. Copies of this information should be sent to the Project Manager and to the project files.

A groundwater sampling log should be documented in the field logbook and contain the following information:

- Identification of well
- Well depth
- Static water level depth
- Presence of immiscible layers
- Purge volume and pumping rate
- Time that the well was purged
- Collection method for immiscible layers
- Sample IDs
- Well evacuation procedure/equipment
- Date and time of collection
- Parameters requested for analysis
- Field analysis data

- Field observations on sampling event
- Name of collector

## Figure 1-C-5-1
## Groundwater Sampling Log

Project Number: ______________________ Date: ______________________

Location: ______________________ Time: ______________________

Well Number: ______________________ Climatic Conditions: ______________________

Initial Measurements: Static Water Level: ______________________
Total Depth: ______________________

Well Purging: Length of Saturated Zone: ______________________linear feet
Volume of Water to be Evacuated: ______________________gals./linear ft. x
Linear feet of Saturation x Casing Volumes* = ______________________gallons
Method of Removal: ______________________
Pumping Rate: ______________________ gallons/minute

Well Purge Data:

| DATE/ TIME | GALLONS REMOVED | pH | SP. COND. | D.O. | REDOX | TURBIDITY |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
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| | | | | | | |
| | | | | | | |

Sample Withdrawal Method: ______________________
Appearance of Sample: Color ______________________
Turbidity ______________________
Sediment ______________________
Other ______________________

Laboratory Analysis Parameters and Preservatives: ______________________

Number and Types of Sample Containers Used: ______________________

Sample ID(s): ______________________

Decontamination Procedures: ______________________

Notes: ______________________

Sampled by: ______________________
Samples delivered to: ______________________
Date/Time: ______________________
Transporters: ______________________

* Capacity of casing (gallons/linear foot): 2”-0.16, 4”-0.65, 6”-1.47, 8”-2.61, 10”-4.08, 12”-5.87

## 4.0 REFERENCES

SOP I-A-7, IDW Management

SOP *-C-4, *Groundwater Sampling from Temporary Wells (Piezometers)*

SOP III-I, Equipment Decontamination

SOP III-B, Field QC Samples

SOP III-D, Logbooks

U.S. EPA. 1982. Handbook for Sampling and Sample Preservation of Water and Wastewater. EPA-600/4-82-029. September 1982.

U.S. EPA. 1986. RCRA Ground-Water Monitoring Technical Enforcement Guidance Document.

U.S. EPA. 1996. Ground Water Issue, Low-flow (Minimal Drawdown) Groundwater Sampling Procedures. EPA/540/S-95/504. April 1996

U.S. EPA. 1995 and as revised. Test Methods for Evaluating Solid Waste–Physical/Chemical Methods (SW-846). January 1995.

U.S. EPA. 2012. Standard Operating Procedure Low-Stress (Low Flow) / Minimal Drawdown Ground-Water Sample Collection, USEPA, Region 9, Management and Technical Services Division, April 2012.

## 5.0 ATTACHMENTS

None.

# AQUIFER TESTS

## 1.0 PURPOSE

The purpose of this standard operating procedure (SOP) is to establish standard methods by which U.S. Naval Facilities Engineering Command Northwest (NAVFAC NW) personnel and contractors should conduct aquifer tests.

## 2.0 PROCEDURES

### 2.1 CONSTANT DISCHARGE AQUIFER PUMPING TESTS

Constant discharge pumping tests are commonly performed at hazardous waste sites to estimate the hydraulic conductivity, transmissivity, specific yield, and/or storativity of an aquifer. These data assist in analyzing contaminant fate and transport and site remediation options. A wide variety of aquifer test methods and aquifer conditions (e.g., confined, unconfined, leaky, etc.) exist and each test must consider both the goals of the test and site conditions.

Pumping tests that are properly designed and implemented can evaluate well efficiency and detect hydraulic boundaries, vertical leakage, or delayed yield effects, and allow assessment of hydraulic conductivity and storativity.

The proper design and implementation of a pumping test requires knowledge of the hydrogeologic setting. Information required prior to the design of the test includes:

- Objectives of the pumping test.
- Location of observation and pumping wells.
- Climatic conditions.
- Screened intervals of all wells to be used in the test.
- Installation and completion methods for wells ("As-built").
- Generalized hydrogeologic conditions.
- Regional ground-water flow direction.
- Boundary conditions.
- Existence of improperly completed or developed wells.
- Presence of pumping or irrigation.
- Potential for the capture of insoluble or dissolved contaminants.

- Hydraulic conductivity estimate for aquifer.
- Discharge flow rate estimated for test.
- Presence and location of confining layers.
- Potential well water disposal problems.
- Potential for tidal effects.
- Previous sampling results and development records.

The pumping test interpretation method is based upon an analytical solution that considers well and site conditions. The hydraulic response of the aquifer is compared to a theoretical analytical response. Different analytical solutions exist for unconfined and confined aquifers, each taking into account assumptions about test and aquifer conditions. It is important to document the assumptions applied to the interpretation of a particular test. It is beyond the scope of this procedure to provide a detailed explanation of aquifer testing analytical solutions. Several texts that address pumping test theory are included in Section 4.0, References.

Constant discharge pumping tests provide results that are more representative of aquifer characteristics than those provided by slug tests; however, pumping tests require greater effort and expense. In general, slug testing should be used only in situations where hydraulic conductivity is sufficiently low to preclude a pumping testing.

### 2.1.1 Interferences and Potential Problems

The conditions that exist at a site during the performance of a pumping test are often far from ideal. Hydrogeologic factors that may be encountered at a site include:

- Localized or regional pumping
- Barometric effects
- Tidal effects
- Aquifer compression (e.g., trains, traffic, ground shaking from seismic events)
- Boundary effects
- Recharge effects
- Leakage from underlying or overlying aquifers.
- Heterogeneous and anisotropic aquifers.

Many of these potential complications may be detected during the pre-test period, or anticipated from an examination of existing hydrogeological data.

Information about the location, completion, and development of the pumping and observation wells may be useful in evaluating potential complications. Complicating factors may include:

- Partially penetrating wells.
- Improperly completed or developed wells.

- Low-permeability conditions that may lead to well-bore storage effects, well dewatering, or slow responding observations wells.
- Wells completed within aquitards, possibly designed to evaluate the pressure response and leakage into adjacent aquifers.
- Potential skin effects caused by well bore conditions.

### 2.1.2 Pumping Test Planning

Prior to implementation of the pumping test, the following should be considered:

1. Monitoring pre-test and post-test water levels (preferably for at least 3 days). Groundwater systems are rarely static and localized conditions such as nearby pumping wells, tidal effects, barometric effects, variable recharge conditions, and other "non-ideal" conditions are likely to be present at a site.
2. The performance of a long-term, constant discharge, pumping test should consider the volume of water that will be generated during the test, storage, treatment, characterization, and disposal methods for the water generated during the test (SOP I-A-7, IDW Management). If free product is present within the vicinity of the pumping well, an oil/water separator shall be included as part of the groundwater treatment process. Permits may be required for any onsite discharge of water.
3. Observation well design, location and installation.
4. Use of subcontractors for installing and operating pumping equipment during constant discharge pumping tests.
5. Selection of pumping equipment.
6. Pump placement in well.
7. Staff scheduling, security and safety during overnight aquifer testing.
8. Traffic control and protection of pipes and cables that cross traffic flow paths.
9. Equipment decontamination (SOP III-I, *Equipment Decontamination*). Select a well containing uncontaminated groundwater for pump testing.

### 2.1.3 Field Procedures

#### *2.1.3.1 Preparation*

1. Review the site work plan, and become familiar with information about the wells to be tested, e.g., depth to water, well depth, aquifer hydraulic conductivity, distances between pumping and observation wells, and anticipated drawdown.
2. Check out the operation of all field equipment. Unless other methods are approved by the Technical Director/QA Program Manager, an electronic data logger shall be used for all aquifer testing. Ensure that the electronic data logger is fully charged. Calibrate the electronic data logger and transducers at measured depths in a container of water. Always bring additional transducers in case of malfunctions. Calibrate the flow meter at several known discharge rates.

Ensure that the calibration is linear in the anticipated test range. Have pH and conductivity meters onsite to assess water quality periodically during the pumping test.

3. Assemble a sufficient number of field pumping test forms.
4. Ensure that the pumping well has been properly developed prior to testing.
5. If a flow meter is not operating properly, calibrate an orifice weir, bucket, or other type of water measuring device to accurately measure and monitor discharge from the pumping well.
6. Have sufficient lengths of pipe on hand to transport the discharge from the pumping well to a holding tank or to a discharge point well beyond the influence of the expected cone of depression.
7. Install a flow-control valve on the discharge pipe to control the pumping rate. Ball, gate, and butterfly valves should not be used for flow control. Preferred valves for flow control are globe, diaphragm, or knife-blade with V-notch. The type of valve selected for flow control should be appropriate for the expected flow rate.
8. Install an outlet at the wellhead to obtain water quality samples during the pumping test.
9. Install a check valve on the pump so water cannot flow back into the well after the pump is shut off.
10. Install transducers in wells, making sure to secure them firmly at the wellhead and allow sufficient depth for drawdown (generally 5 to 10 feet below the water surface in the well). Measure the depth to the transducer and ensure that the transducer is not placed at a depth below the water surface beyond its range (this will ruin the transducer).
11. Arrange for treatment, special storage and handling, or a discharge permit before mobilization.

Pre-test water levels at the test site shall be monitored for at least 3 days prior to performance of the test. A continuous-recording device is recommended. The pre-test data allows researchers to make a determination of the barometric efficiency of the aquifer. When compared to barometric readings at the site, the pre-test data also helps assess experiencing variations in head with time due to tidal influences or recharge or pumping in the nearby area.

If barometric pressure is found to significantly affect water levels in the aquifer, then changes in barometric pressure should be recorded during the test (preferably using an onsite barometer) in order to correct water levels for fluctuations that may occur because of changing atmospheric conditions. Trends in pre-test water levels can then be projected for the duration of the test. Correcting water levels during the test produce results that are representative of the hydraulic response of the aquifer caused by pumping of the test well in the absence of atmospheric pressure changes.

The influence of ocean tides or localized pumping can mask the water level response to the pumping test. Water levels can be corrected for the effect of ocean tides by adding or subtracting values of tidal fluctuation from the response of the pumping. Pumping test data can be corrected for the effect of localized pumping if the pumping response prior to the test is known and predictable over the duration of the drawdown and recovery phases of the test. Non-rhythmic and "unique" water-level fluctuations may be difficult to resolve and substantial hydrologic judgment is required to properly interpret the data.

### *2.1.3.2 Step Drawdown Test*

Prior to initiating a constant-discharge pumping test, a step drawdown test shall be conducted. The purpose of the step drawdown test is to estimate the greatest flow rate that may be sustained during a constant-discharge test. The step drawdown test is typically conducted over a 4- to 8-hour period prior to commencing the constant discharge test.

To correctly assess the maximum yield of the well, the well must be pumped at discharge rates varying from relatively low to the maximum rate that the well can produce. The discharge increments for each step shall be distributed as evenly as possible through the range of well yields. Four steps should be utilized for the test. Each step shall last approximately 2 hours depending on the response of water levels to pumping. Water level recovery following the test shall be measured for approximately 8 hours.

Water levels shall be measured periodically during the step test within the pumping well and within observation wells that may be used during the constant discharge test. For each step increment, levels within the pumping well shall be measured on the same time basis as that used for the beginning of the constant discharge test (i.e., approximately on a logarithmic basis, see Section 2.1.3.3). Observation wells may be measured using a longer time scale because the primary reason for measurement is to assess whether the aquifer responds to pumpage rather than to gather data for quantitative analysis. Water levels shall also be measured during the recovery phase of the step test.

Prior to initiating the constant discharge test, the data from the step drawdown test shall be analyzed to identify the appropriate discharge rate for the long-term test. The generated drawdown versus time data shall be plotted on a semi-logarithmic graph and the sustainable discharge rate shall be determined from this graph by projecting the straight line formed by each data set for each step increment to the longer pumping times associated with the constant discharge test. Based on the projected drawdowns associated with these longer time periods and the amount of drawdown available in the pumping well, the optimum pumping rate can be determined. The step drawdown data can also be evaluated more quantitatively using methods described by Birsoy and Summers (1980) and Lohman (1982).

### *2.1.3.3 Constant-Discharge Pumping Test*

<u>Time Intervals</u>

After the pumping well has fully recovered from the step drawdown test, the constant-discharge pumping test may begin (typically 24 hours after step drawdown testing). At the beginning of the test, the discharge rate shall be set as quickly and accurately as possible. The water levels in the pumping well and observation wells shall be recorded using a data logger according to the following schedules (or an equivalent approximately logarithmic schedule):

**Table I-C-7-1**
**Pumping Well Measurements**

| Elapsed Time Since Start of Test (Minutes) | Intervals Between Measurements (Minutes) |
|---|---|
| 0-10 | .5-1 |
| 10-15 | 1 |
| 15-60 | 5 |
| 60-300 | 30 |
| 300-1440 | 60 |
| 1440-termination | 480 |

**Note:** Similar time intervals shall be used during water level recovery, with short time intervals at the start of recovery.

**Table I-C-7-2**
**Observation Well Measurements**

| Elapsed Time Since Start or Stop of Test (Minutes) | Intervals Between Measurements (Minutes) |
|---|---|
| 0-60 | 2 |
| 60-120 | 5 |
| 120-240 | 10 |
| 240-360 | 30 |
| 360-1440 | 60 |
| 1440-termination | 480 |

Available data logger measurement schedules vary by data logger manufacturer. During the early part of the test, at least one person shall be stationed at the pumping well and at least one other shall handle other pump test logistics. Readings at the wells need not be taken simultaneously. It is very important that depth to water readings be measured accurately and readings be recorded at the exact time measured. Pressure transducers and electronic data loggers must be used to record water levels in the pumping well and nearby observation wells. Manual checks of the depth to water shall be performed to verify the pressure transducer measurements. In some instances, the pressure transducer may be unstable and "drifting" may occur.

During a pumping test, the following data must be recorded on the aquifer test data form (Attachment I-C-7-1):

1. Site identification - CTO/DO number, site name, well identification number, and indication as to whether the well is an observation or pumping well.

2. Location – A description of the location of the well in which water level measurements are being taken.
3. Distance from Pumping Well - Distance the observation well is from the pumping well in feet.
4. Personnel - The company and individual conducting the pump test.
5. Test Start Date - The date when the pumping test began.
6. Test Start Time - Time, using 24-hour clock, when the pumping test began (e.g., 10:30 hours for 10:30 a.m., and 13:50 hours for 1:50 p.m.).
7. Test End Date - Same as number 5, except for the test end.
8. Test End Time - Same as number 6, except for test end.
9. Depth to water in feet and to an accuracy of 0.01 feet, in the pumping well at the beginning of the pump test and at specified intervals throughout the test.
10. Depth to water in feet and to an accuracy of 0.01 feet, in the observation well at the beginning of the pump test at specified intervals throughout the test.
11. Depth of pressure transducers.
12. Pumping Rate - Flow rate of pump measured from an orifice weir, flow meter, container, or other type of water measuring device in gallons per minute at specified intervals throughout the test.
13. Average Pumping Rate - Summation of all entries recorded in the pumping rate (gal/min) column divided by the total number of pumping rate readings.
14. Measurement Methods - Type of instrument used to measure depth-to-water (this may include steel tape, electric sounding probes, Stevens recorders, or pressure transducers).
15. Comments - Appropriate observations or information including notes on sampling
16. Measurement time – Time using a 24hour clock, at which each field measurement was taken.
17. Elapsed Time - Time elapsed since the start of pumping in minutes, calculated for each measurement from test start time and measurement time.

### Water Chemistry Measurements

During the pumping test, portable field-grade water testing equipment should be used to measure general water chemistry parameters at periodic intervals. The parameters measured should include at a minimum pH, electrical conductivity, and temperature of the water. These parameters are used to qualitatively evaluate aquifer conditions. Water testing equipment shall be recalibrated during the pump test on a predetermined schedule with known calibration standards.

### Test Duration

The duration of the test depends on the properties of the aquifer that the project seeks to characterize. The duration may be determined by plotting the drawdown data on both log-log and semi-log graphs, and performing a preliminarily evaluation during the pump test. Doing this allows possible identification of recharge boundaries or permeability barriers that might be further evaluated with a longer pump test.

Optimally, flow conditions should approach steady state where the observed drawdowns reach near-constant values prior to terminating the test.

The minimum time necessary for the test is indicated on the semi-log graph when the log-time versus drawdown for the most distant observation well plots as a straight line (assuming $u < 0.01$) (Cooper et. al. 1946). Longer tests tend to produce more reliable results. Longer tests are usually necessary for unconfined aquifers to allow evaluation of delayed yield effects. A pumping duration of 24 to 72 hours is desirable, followed by a similar period of monitoring the recovery of the water level.

Knowledge of the local hydrogeology, combined with a clear understanding of the overall project objectives should be considered in selecting duration of the test and the effect of boundary conditions. There is little need to continue the test once the increase in drawdown in all observation wells becomes insignificantly small. However, delayed yield effects and boundary effects may be observed with continued pumping.

Recovery

Once the pump has been shut down, the recovering water levels shall be recorded in the same manner and using the same time intervals as were used during the beginning of the constant discharge test (i.e., at approximately logarithmic time intervals). Recovery shall be monitored for a period corresponding to the length of the pumping portion of the test or when water levels have recovered to 95% of their original level. Any tidal and barometric monitoring shall be continued during the recovery portion of the test.

#### *2.1.3.4 Post Operation*

The following activities shall be performed after completion of water level recovery measurements:

1. Decontaminate and/or dispose of equipment as listed in SOP III-I, *Equipment Decontamination*.
2. For the electronic data logger, use the following procedures:
    a) Stop logging sequence.
    b) Print data, or
    c) Save memory at the end of the day's activities.
3. Replace testing equipment in storage containers.
4. Check sampling equipment and supplies. Repair or replace all broken or damaged equipment.
5. Replace expendable items.
6. Review field forms for completeness.
7. Interpret slug or aquifer test field results with Project Hydrogeologist and/or CTO/DO Manager. Analyze data using an appropriate analytical solution.

### 2.1.4 Pumping Test Interpretation

There are several accepted methods for determining aquifer properties such as transmissivity, storativity, and hydraulic conductivity. Kruseman and de Ridder (1990) and Freeze and Cherry (1979) present methods of interpretation. However, the appropriate method depends on the characteristics of the aquifer being tested (e.g., confined, unconfined, leaky confining layer). When reviewing pumping test data, both log-log and semi-log plots of drawdown with time shall be generated. However, log-log plots cannot be used for quantitative analysis of data obtained from the pumping well.

The interpretation of pumping test data attempts to match or duplicate the observed field response with a theoretical water level response to pumping. Aquifer parameters can be estimated on the basis of such a match, using commercially available software such as AQTESOLV©.

Ranges of aquifer parameter values are likely to occur at a site. For example, hydraulic conductivities are typically lognormally distributed. The estimate of the values may vary with the interpretation method. It is important to verify that the assumptions used to derive a particular method of solution are reasonable in view of the test conditions. For example, for a confined aquifer, storativity values should be less than 0.005.

### 2.1.5 Quality Assurance/Quality Control

All gauges, transducers, flowmeters, etc., used in conducting pumping tests shall be calibrated before and after use at the site. Copies of the documentation of instrumentation calibration should be obtained and filed with the test data records. The calibration records shall consist of laboratory measurements and, if necessary, any onsite zero adjustment and/or calibration performed. All flow and measurement meters should be checked onsite using a container of measured volume and a stopwatch. The accuracy of the meters must be verified before testing proceeds. The water levels measured by a pressure transducer-based data logger must also be verified by manual measurements before and after testing.

## 2.2 SLUG TESTS

### 2.2.1 Scope and Application

A common procedure for single-well hydraulic testing is a slug test. A slug test is restricted in application because it is a measure of the well and near-well hydrogeologic conditions only. The results of the test provide an order of magnitude estimate of the horizontal hydraulic conductivity of the aquifer, and are most useful in low-permeability materials. Storativity cannot be determined very accurately using this method.

### 2.2.2 Method Summary

A slug test involves the instantaneous injection or withdrawal of a mass (slug) of water or object displacing a known volume of water into or from a well and measuring the induced water level fluctuation.

The primary advantages of using slug tests to estimate hydraulic conductivities are that (1) estimates can be made *in situ*, thereby avoiding errors incurred in laboratory testing of disturbed soil samples; (2) tests can be performed quickly at relatively low cost because only one observation well is required; and (3) the hydraulic conductivity of small discrete portions of an aquifer can be estimated (e.g., sand layers in a clay). Estimates of storativity or specific storage cannot be reliably established from slug tests. Slug tests should be used only to evaluate water-bearing zones with relatively low hydraulic conductivities. In addition, slug testing shall always be conducted with a data logger coupled to a pressure transducer.

### 2.2.3 Interferences and Potential Problems

The zone of investigation covered by a slug test is limited to the immediate vicinity of the well bore. Thus, interpretation of the test may be strongly influenced by the hydraulic properties of the well casing, filter pack, and borehole, and may possibly reflect variations in well development. When possible, consistent methods of well construction and development shall be used at a site to minimize the potential for variation in slug test results.

A slug test may be affected by the same interferences as constant-discharge pump tests. Refer to Section 2.1.1 for further discussion.

Water levels within a borehole will often oscillate rapidly after the introduction/withdrawal of a slug volume. This does not indicate a problem with performance of the slug test. If a well is screened above and below the water table, a slug injection method will tend to store water in the filter pack and yield a higher estimate of hydraulic conductivity than would be expected. In these cases, the slug withdrawal method may yield more accurate data.

### 2.2.4 Field Procedures

#### *2.2.4.1 Preparation*

Office Procedures

1. Review the Work Plan and the procedure, including well construction, development, and sampling information on the wells to be tested.
2. Review the operator's manual provided with the electronic data logger.
3. Verify the displacement volume of the slug. This may be accomplished by accurately measuring the dimensions of a solid displacement slug or by accurately measuring the volume of water discharge from a liquid slug.
4. Check out and ensure the proper operation of all field equipment. Ensure that the electronic data logger is fully charged. Test the electronic data logger using a container of water (e.g., sink, bucket of water). Additional transducers should be brought to the site in case of malfunctions.
5. Assemble a sufficient number of field forms to complete the field assignment.
6. Assemble the appropriate testing equipment.

Equipment List

The following equipment is needed to perform slug tests. All of the equipment shall be decontaminated and tested prior to commencing field activities.

- Tape measure (subdivided into tenths of feet)
- Water pressure transducer
- Electronic water level indicator or steel tape (subdivided into hundredths of feet)
- Electronic data logger
- Solid or liquid slug of a known volume (stainless steel, PVC, and ABS plastic are appropriate construction materials)
- Watch or stopwatch with second hand (electronic stopwatch with elapsed time function and a watch with 24 hour format are recommended).

- Semi-log graph paper
- Water proof ink pen and logbook
- Temperature/pH/electrical conductivity meter (optional)
- Appropriate references and calculator
- Electrical tape and duct tape
- Health and safety equipment as required

Data Form

The slug test data form shall be used to record observations. All entries shall be made in indelible ink. The form shall include the following data:

1. Site identification - identification number assigned to the site and the well.
2. Date - the date when the test data were collected: year, month, and day.
3. Slug Volume ($ft^3$) - manufacturer's specification for the known volume or displacement of the slug device.
4. Logger - the company and person responsible for performing the field measurements.
5. Test Method - either injected (dropped) or withdrawn (pulled out) from the monitoring well.
6. Comments - Observations or information for which no other blanks are provided.
7. Depth to water (ft.) - Depth of water recorded to 0.01 feet, along with time of measurement.
8. Configuration of the data logger (e.g., sample rate, duration, transducer type, etc.).

#### *2.2.4.2 Performing the Slug Test*

The following procedures should be used to collect and report slug test data. They may be modified to reflect specific site conditions:

1. Field check and test transducers and data logger prior to testing (record field check/test results in field logbook).
2. Decontaminate the transducer and cable.
3. Collect initial water level measurements from monitoring wells in the immediate vicinity of the well to be tested.
4. Before beginning a slug test, record data logger set-up information and enter it into the electronic data logger. The type of information will vary depending on the data logger model used. Consult the operator's manual for the proper data entry sequence.
5. Test wells from least to most contaminated, if possible.
6. Determine the static water level in the test well by measuring the depth to water periodically for several minutes.
7. Cover sharp edges of the well casing with duct tape to protect the transducer cables.

8. Install the transducer and cable in the well to a depth below the target drawdown estimated for the test but at least 2 feet from the bottom of the well. Be sure this depth of submergence is within the design range stamped on the transducer and appropriate for the test method (inserting or pulling slug). Temporarily tape or clamp the transducer cable to the well to keep the transducer at constant depth.
9. Connect the transducer cable to the electronic data logger.
10. Enter the initial water level and transducer specific set-up information into the data logger according to the manufacturer's instructions (the transducer information will be stamped on the side of the transducer). Compare manual and pressure transducer measurements to check that the transducer is operational and accurate. Thermal drift may occur until the transducer equilibrates with the water in a well. Record the initial water level display by the data logger.
11. "Instantaneously" introduce or remove a known volume (slug) of water to the well. The preferred test method is to introduce a solid cylinder of known volume to displace and raise the water level. Let the water level re-stabilize and remove the cylinder. It is important to remove or add the volumes as quickly as possible because the analysis assumes an "instantaneous" change in volume is created in the well.
12. At the moment of volume addition or removal (assigned time zero), measure and record the depth to water and the time using the data logger. The number of depth-time measurements necessary to complete the test is variable, and can be estimated from previous aquifer tests or based on knowledge of the site-specific geology. It is critical to make as many measurements as possible in the early part of the test.
13. Continue measuring and recording depth-time measurements until the water level returns to equilibrium conditions or a sufficient number of readings have been made to clearly show a trend on a semi-log plot of time versus depth.
14. Retrieve the slug (if applicable) and follow appropriate decontamination procedures.

The time required for a slug test to be completed is a function of the volume of the slug, the hydraulic conductivity of the formation, and the type of well completion. The slug volume should be large enough that a sufficient number of water level measurements can be made before the water level returns to equilibrium conditions. The length of the test may range from less than a minute to several hours.

Precautions should be taken to ensure that the well is not contaminated by material introduced into the well. If water is added to the monitoring well, it should be from an uncontaminated source and transported in a clean container. Bailers, measuring devices, and solid slugs must be cleaned prior to the test. If tests are performed on more than one monitoring well, care must be taken to avoid cross-contamination of the wells.

Slug tests shall be conducted on relatively undisturbed wells. If a test is conducted on a well that has recently been pumped for water sampling purposes, the measured water level must be within 0.1 foot of the static water level prior to testing.

#### *2.2.4.3 Post Operations*

Decontaminate and/or dispose of equipment according to SOP III-I, *Equipment Decontamination*.

For the electronic data logger, implement the following procedure:

1. Stop logging sequence.
2. Print the data if possible.
3. Save the data and disconnect the battery (on some models of data logger) at the end of the day's activities.
4. Inventory sampling equipment and supplies. Repair or replace all broken or damaged equipment.
5. Replace expendable items.
6. Review field forms for completeness.
7. Interpret slug test field results with the Project Hydrogeologist and the CTO/DO Manager. Analyze the slug test using appropriate software packages or graphical solutions.

### 2.2.5 Slug Test Interpretation

The results of slug tests should be viewed as order of magnitude estimates of hydraulic conductivity and should not be performed as a substitute for constant discharge pump tests. The interpretation of the water level response usually requires a number of simplifying assumptions, and the physical properties of the well casing and filter packs are rarely included in the analysis. A limited number of test interpretation methodologies exist. The following two approaches are most commonly used:

#### *2.2.5.1 Cooper et al. Method*

A more physically-based model for the slug test was developed by the U.S. Geological Survey. It involves a curve-fitting procedure that may not always produce a unique fit and is the only method discussed herein to produce an estimate of specific storage.

#### *2.2.5.2 Bouwer and Rice Method*

This is a popular approach to the interpretation of slug test data obtained from unconfined aquifers. It is a graphical method and relatively straightforward to apply.

### 2.2.6 QA/QC

Similar to pumping test analysis. Refer to Section 2.1.5.

## 3.0 DOCUMENTATION

All data collected in the field shall be maintained onsite during field activities, and then transferred to the office project files upon completion of the aquifer test(s). Computerized data (e.g., from data loggers) shall be stored in ASCII format. The CTO/DO Manager or designee shall review all aquifer test forms upon completion of the aquifer test(s).

## 4.0 REFERENCES

Birsoy, Y.K. and W.K. Summers. 1980. Determination of Aquifer Parameters From Step Tests and Intermittent Pumping Data. Ground Water, Vol. 18, pp. 137-146.

Bouwer, H. 1989. The Bouwer and Rice Slug Test - An Update. Groundwater Vol. 27 No. 3, pp. 304-309.

Bouwer, H. and R.C. Rice. 1976. A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells, Water Resource Research, Vol. 12, No. 3.

Chirlin, G.R. 1989. A Critique of the Hvorslev Method for Slug Test Analysis: The Fully Penetrating Well. Ground Water Monitoring Review, Spring Issue, pp. 130_139.

Cooper, H.H. and C.E. Jacob, 1946. A generalized graphical method for evaluating formation constants and summarizing well field history, Am. Geophys. Union Trans., vol. 27, pp. 526-534.

Cooper, Jr., H.H., J.D. Bredenhoeft, and S.S. Papadopulos. 1967. Response of a Finite-Diameter Well to an Instantaneous Charge of Water, Water Resource Research, Vol. 13, No. 1.

Driscoll, F.G. 1986. Ground Water and Wells, Published by Johnson Division, St. Paul, Minnesota.

Freeze, R.A. and J.A. Cherry. 1979. Groundwater. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Kruseman, G.P. and N.A. de Ridder. 1990. Analysis and Evaluation of Pump Testing Data. International Institute for Land Reclamation and Development (ILRI) Publication 47. Available through the National Water Well Association.

Lohman, S.W. 1982. Ground Water Hydraulics, U.S. Geological Survey Paper 708.

NFESC. 1999. Navy Installation Restoration Chemical Data Quality Manual (IR CDQM), NFESC Special Report SP-2056-ENV.

Papadopulos, S.S., J.D. Bredehoeft, and H.H. Cooper. 1973. On the Analysis of 'slug test' data, Water Resource Research Vol. 9, pp. 1087-1089.

SOP-I-A-7, *IDW Management*

SOP III-I, *Equipment Decontamination*

U.S. Department of Interior, Bureau of Reclamation. 1977. Ground Water Manual, (Stock Number 024-003-00106-6).

U.S. EPA Environmental Response Team. 1988. Response Engineering and Analytical Contract Standard Operating Procedures. U.S. EPA, Research Triangle Park, NC.

## 5.0 ATTACHMENTS

Attachment I-C-7-1 Constant Discharge Pumping Test/Aquifer Test Data Form

## Attachment I-C-7-1
## Constant Discharge Pumping Test/Aquifer Test Data Form

### CONSTANT DISCHARGE PUMPING TEST/AQUIFER TEST DATA FORM

PROJECT NAME: ____________ PROJECT NUMBER: ____________ WELL NUMBER: ____________

LOCATION: ____________ DATE: ____________ HYDROGEOLOGIST: ____________

PUMPED WELL NO. ____ DISTANCE FROM PUMPING WELL: ______ TYPE OF TEST: ______ TEST NO. ____________

MEASURING EQUIPMENT ____________ TYPE AND DEPTH OF PUMP ____________

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time Data<br>Pump on: Date___Time ___ ( )<br>Pump off: Date___Time___ ( )<br>Duration of aquifer test:<br>Pumping___Recovery____ | | | | | Water Level Data<br>Static Water Level ______________<br>Measuring Point________________<br>Elevation of measuring point_______ | | | | Discharge Data | Water Quality Data | | | Comments on factors affecting test data |
| Date | Clock Time | Time since pump started t (min) | Time since pump stopped t (min) | V t | Depth of Water (feet) | Pressure (PSI) | Accumulated Drawdown (feet) | Corrected Drawdowns (feet) | Flow Rate (gpm) | pH | Specific Conductivity | Temp (°C) | |
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# WATER LEVEL MEASUREMENTS

## 1.0 PURPOSE

The purpose of this standard operating procedure (SOP) is to establish standard protocols for all U.S. Naval Facilities Engineering Command Northwest (NAVFAC NW) field personnel for use in making water level measurements.

## 2.0 PROCEDURE

### 2.1 EQUIPMENT

Equipment and materials used during liquid level and well-depth measurements:

- Electronic water level indicator with cable marked with 0.01-foot increments
- Electronic oil-water interface probe
- Engineers measuring tape with 0.01-foot increments may be used for water and petroleum reactive pastes as an alternative to an oil-water interface probe
- Weighted steel tape with 0.01-foot increments and chalk may be used as an alternative to a water level indicator
- Decontamination equipment
- Weatherproof, bound field logbook with numbered pages (see SOP III-D, *Logbooks*)
- Health and safety equipment appropriate for site conditions
- Keys for locked well covers
- Wire cutters if well has a security tag
- Turkey baster or hand pump in case flush-mount manhole is filled with water
- Bolt cutters for cutting “frozen” or rusted locks. HWD-40 is used to lubricate a rusted lock, but extreme care should be taken to avoid possible contamination to the well and equipment.
- Extra locks to replace cut locks

### 2.2 PRELIMINARY STEPS

Follow these steps prior to disturbing the liquid level in the well:

1. Locate the well and, confirm its label (if marked), and verify its position relative to other site features on the site map.  Gain access to the top of the well casing.

2. Locate the permanent reference mark at the top of the well casing. This reference point shall be scribed, notched, or otherwise noted on the top of the casing. If no such marks are present, measure depth relative to the top of the highest point of the well casing and note this fact in the field logbook. Determine from the records and record the elevation of the permanent reference point and record it in the logbook.
3. Record any observations and remarks regarding the characteristics and condition of the well, such as evidence of cracked casing or surface seals, security of the well (locked cap), evidence of tampering, missing well cap, surface water entering the well casing, etc.

## 2.3 OPERATION

Follow these steps when taking depth to liquid level measurements in well suspected to have NAPL present.

1. Sample the air in the wellhead for gross organic vapors if required.
2. If non-aqueous phase liquid (NAPL) contamination is suspected, use an oil-water interface probe to determine the existence and thickness of the NAPL.
3. Open interface probe housing, turn probe on, and test the alarm. Ground the probe, because the slight electric charge from the probe could set off an explosion of highly flammable vapors. Slowly lower the probe into the well until the alarm sounds. A continuous alarm indicates light non-aqueous phase liquid (LNAPL), while an intermittent alarm indicates water. If LNAPL is detected, record depth of the initial (first) alarm. Mark the spot by grasping the cable with the thumb and forefingers at the top of the casing. Determine the depth to liquid relative to the permanent reference point on the well casing. Withdraw cable sufficiently to record the depth from the scale on the interface probe cable.
4. Continue to slowly lower the probe until it passes into the water phase (intermittent alarm). Slowly retract the probe until the NAPL continuous alarm sounds and record that level in the same manner as described above.
5. Record the depth to NAPL and the depth to water readings independently in the logbook. The thickness of the LNAPL can be calculated by subtracting depth to LNAPL reading from depth to water measurement.
6. Continue to slowly lower the interface probe through the water column to check for the presence of dense non-aqueous phase liquid (DNAPL) if suspected.
7. Measure and record the depths of the DNAPL layer (if any) as described above.
8. Slowly raise the interface probe, recording the depth to each interface as the probe is withdrawn. If there is a discrepancy in depths, clean the probe sensor and recheck the depth measurements.
9. Always lower and raise the interface probe slowly to minimize mixing of media.
10. Always perform a NAPL check in wells installed in areas with suspected NAPL contamination. Always perform a NAPL check if headspace test reveals presence of volatiles. Always perform a NAPL check the first time depth to liquid is measured in a well. If a well has been measured previously, with no NAPLs present, and none of the preceding conditions are met, the NAPL check may be omitted.

11. Decontaminate interface probe as appropriate.

For wells where NAPL is not suspected to be present, an electronic water level indicator or steel tape can be used as described below:

1. Remove the water level indicator probe from the case, turn on the sounder, and test the battery and sensitivity scale by pushing the test button. Adjust the sensitivity scale until you can hear the alarm.
2. Slowly lower the probe and cable into the well, allowing the cable reel to unwind. Continue lowering the probe until the alarm sounds. Very slowly raise and lower the probe until the point is reached where the meter just beeps. Mark the spot by grasping the cable with thumb and forefingers at the top of the casing. Record the depth to water relative to the permanent reference point. If no mark is present, use the highest point on the casing as a reference point. Withdraw the cable and record the depth.
3. Alternately, use a steel tape with an attached weight if the aquifer gradients are lower than 0.05 ft./ft. Due to the possibility of adding unknown contaminants from chalk colorants, only white chalk is permitted as a level indicator.
4. Rub chalk onto the end (first 1 foot) of the steel tape and slowly lower the chalked end into the well until the weighted end is below the water surface. (A small splash can be heard when the weighted end hits the water surface.)
5. Mark the spot on the tape by grasping the tape with the thumb and forefingers at the top of the casing as described in the subsection (2) above. Record this spot on the tape in the logbook as the "HOLD". Ensure not to retract the tape from the well until after the depth measurement (HOLD) is recorded.
6. Remove the steel tape from the well. The chalk will be wet or absent where the tape was below the water surface. Locate, read, and record this length in the logbook as the "CUT". Subtract the "CUT" length from the "HOLD" length and record the difference in the logbook. This is the depth to water table.
7. Decontaminate water level indicator or steel tape as appropriate

## 2.4 PRECAUTIONS

- Depending on the device used, correction factors may be required for some measurements. For example, if the water level indicator has been shortened during its repair.
- Check instrument batteries prior to each use.
- Exercise care not to break the seals at the top of the electric water level indicator probe.
- It is important to note that when measuring total well depth (bottom of casing), using an interface probe or water level indicator, the increments of measure are ticked off from the alarm sensor on the probe. On some meters there is a portion of the probe that sticks out beyond the alarm sensor. This needs to be accounted for when reading the bottom of casing measurement (i.e., added onto the reading). A potential problem arises if it is unknown whether this has been done on previous readings or not.

## 3.0 DOCUMENTATION

This section describes the documentation necessary for depth to liquid and well-depth measurements. All information shall be recorded in the field logbook using indelible ink in accordance with SOP III-D, *Logbooks*. At a minimum, the following information must be recorded:

- Date
- Time
- Weather
- Field personnel
- Well location and label
- Well condition
- Monitoring equipment type and readings
- Depth to Liquid measurements obtained
- Any other observations

All entries in the field logbook must be printed in black ink and legible. The actual readings measured should be recorded directly in the logbook. If calculations are necessary to determine the depth to liquid or liquid elevation, they should be performed using direct readings documented in the logbook.

Water level measurements must also be submitted electronically using the appropriate Naval Electronic Data Deliverable (NEDD) format for loading into NIRIS as defined in the NAVFAC NW SOPs (V5.0 or more current).

## 4.0 REFERENCES

SOP III-D, *Logbooks*

Thornhill, Jerry T. 1989. “Accuracy of Depth to Groundwater Measurements.” In *EPA Superfund Groundwater Issue.* EPA/504/4-89/002.

## 5.0 ATTACHMENTS

None.

# FIELD PARAMETER MEASUREMENTS

## 1.0 PURPOSE

This standard operating procedure (SOP) provides instructions for the calibration, use, and checking of instruments and equipment for field measurements.

## 2.0 PROCEDURES

### 2.1 WATER QUALITY MEASUREMENTS

All field water quality meters shall be calibrated daily following the manufacturers' specifications. Calibration shall be performed prior to using the instrument for collecting parameters. In addition, the meter's calibration should be checked at mid-day and the end of the day to determine if measurements have drifted from the original calibration numbers. These checks are not intended to be a recalibration of the instrument. All calibration and measurement data shall be recorded in the project logbook. Fluids used for calibration shall be changed at regular intervals to ensure its integrity. Since different fluids have different shelf lives and tolerances, manufacturers' specifications should be checked as appropriate.

Most multi-probe water quality meters utilize a flow-through cell. If the unit being used does not have a flow-through cell, a large enough vessel (i.e. polypropylene beaker) in which the probes will be submerged shall be used. The water to be measured will be pumped continuously through the beaker from the bottom, overflowing the top. The flow-through cells will usually allow for quicker stabilization of dissolved oxygen and oxidation-reduction potential readings.

Water shall be allowed to flow continuously through the cell or beaker with water quality measurements being collected at regular intervals, every three to five minutes, until stabilization of the parameters has occurred. A minimum number of seven sets of readings should be collected or as otherwise outlined in the field sampling plan. Stabilization is considered to have occurred when three consecutive readings meet the following guidelines:

| | |
|---|---|
| pH | + 0.2 Scientific Units |
| Specific Conductance | + 3 % mS/cm |
| Turbidity | + 10% or < 10 NTUs |
| Dissolved Oxygen | + 10% mg/cm |
| Salinity | + 10% |
| Oxidation-Reduction Potential | + 10 mV |
| Temperature | + 10% °C |

In addition to recording the above listed parameters the following information shall also be documented: date, time of measurement, flow rates, purge volumes, total volume purged, and other relative information (i.e. odors, sheen, comments on turbidity, water color)

### 2.2 ORGANIC VAPORS

Various organic vapor monitors have differing requirements for equipment warm-up and operation. Ensure that all organic vapor monitors are calibrated and operated according to the manufacturer's specification.

For measuring vapors present in soils, expose the monitor to a sample of soil by collecting a sample in sealable plastic baggy and placing the probe tip into the closed bag. In cold weather, the soil may need to be warmed prior to testing.

For measuring breathing zone vapors, hold the probe tip in the area of the breathing zone while field activities are being conducted. Take representative measurements from each different work or sampling area.

For monitoring well head space, place the probe tip just inside of the monitoring well casing immediately after removing the cap.

All readings including calibration information shall be recorded in the field logbook.

## 3.0 DOCUMENTATION

Record all observations and analysis in the field logbook as defined in SOP III-D, *Logbooks*. If required by the SAP, also complete the Field Measurement Data Form.

Field measurements must also be submitted electronically using the appropriate Naval Electronic Data Deliverable (NEDD) format for loading into NIRIS as defined in the NAVFAC NW SOPs (V5.0 or more current).

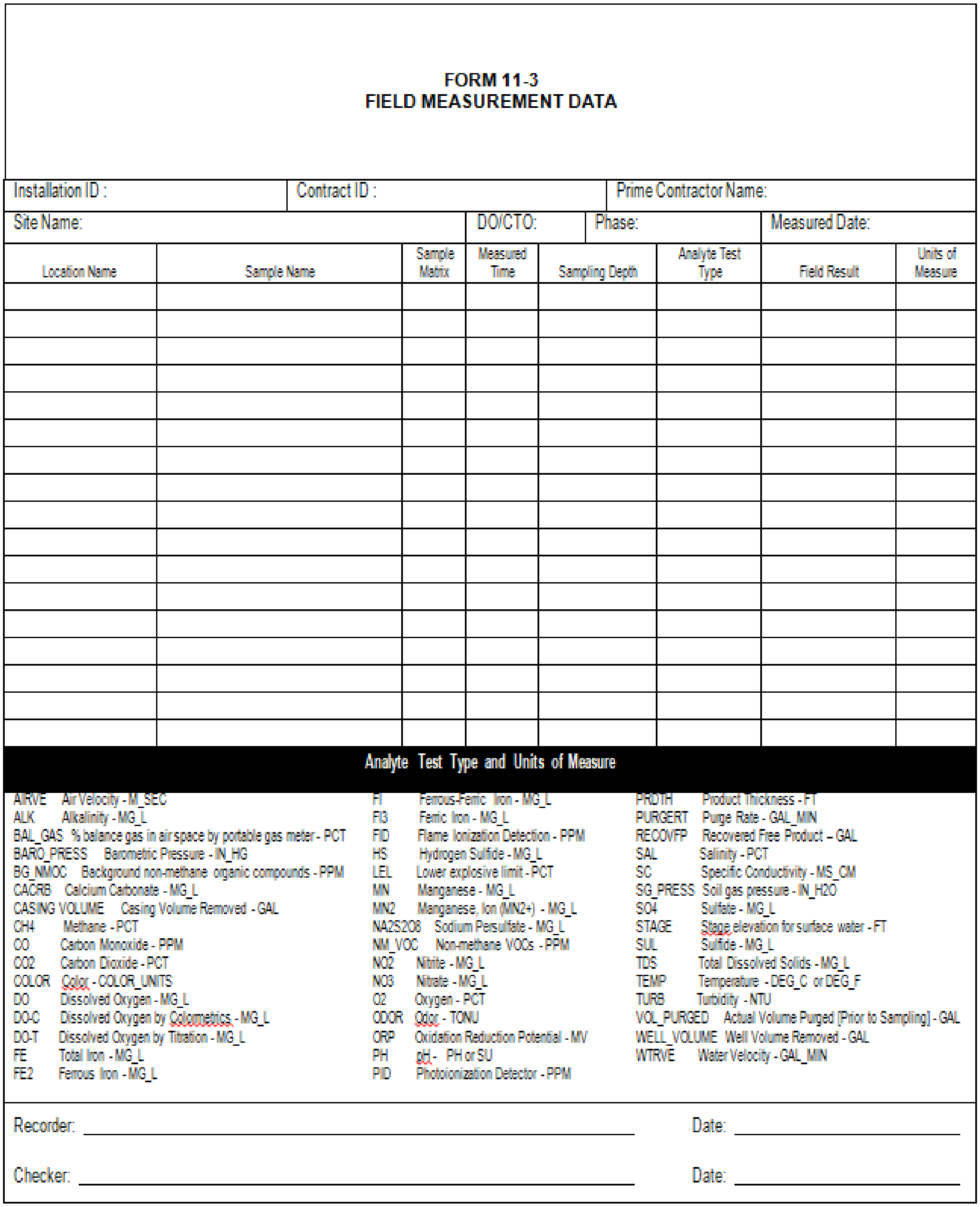
## 4.0 REFERENCES

ASTM International. 2003. D6771-02 Standard Practice for Low-flow Purging and Sampling Wells and Devices Used for Groundwater Quality Investigations

SOP III-D, *Logbooks*

## 5.0 ATTACHMENTS

Attachment I-D-7-1 Example Field Measurement Data form



## FORM 11-3
## FIELD MEASUREMENT DATA

Installation ID : Contract ID : Prime Contractor Name:

Site Name: DO/CTO: Phase: Measured Date:

| Location Name | Sample Name | Sample Matrix | Measured Time | Sampling Depth | Analyte Test Type | Field Result | Units of Measure |
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**Analyte Test Type and Units of Measure**

| | |
|---|---|
| AIRVE | Air Velocity - M_SEC |
| ALK | Alkalinity - MG_L |
| BAL_GAS | % balance gas in air space by portable gas meter - PCT |
| BARO_PRESS | Barometric Pressure - IN_HG |
| BG_NMOC | Background non-methane organic compounds - PPM |
| CACRB | Calcium Carbonate - MG_L |
| CASING VOLUME | Casing Volume Removed - GAL |
| CH4 | Methane - PCT |
| CO | Carbon Monoxide - PPM |
| CO2 | Carbon Dioxide - PCT |
| COLOR | Color - COLOR_UNITS |
| DO | Dissolved Oxygen - MG_L |
| DO-C | Dissolved Oxygen by Colometrics - MG_L |
| DO-T | Dissolved Oxygen by Titration - MG_L |
| FE | Total Iron - MG_L |
| FE2 | Ferrous Iron - MG_L |
| FI | Ferrous-Ferric Iron - MG_L |
| FI3 | Ferric Iron - MG_L |
| FID | Flame Ionization Detection - PPM |
| HS | Hydrogen Sulfide - MG_L |
| LEL | Lower explosive limit - PCT |
| MN | Manganese - MG_L |
| MN2 | Manganese, Ion (MN2+) - MG_L |
| NA2S2O8 | Sodium Persulfate - MG_L |
| NM_VOC | Non-methane VOCs - PPM |
| NO2 | Nitrite - MG_L |
| NO3 | Nitrate - MG_L |
| O2 | Oxygen - PCT |
| ODOR | Odor - TONU |
| ORP | Oxidation Reduction Potential - MV |
| PH | pH - PH or SU |
| PID | Photoionization Detector - PPM |
| PRDTH | Product Thickness - FT |
| PURGERT | Purge Rate - GAL_MIN |
| RECOVFP | Recovered Free Product – GAL |
| SAL | Salinity - PCT |
| SC | Specific Conductivity - MS_CM |
| SG_PRESS | Soil gas pressure - IN_H2O |
| SO4 | Sulfate - MG_L |
| STAGE | Stage elevation for surface water - FT |
| SUL | Sulfide - MG_L |
| TDS | Total Dissolved Solids - MG_L |
| TEMP | Temperature - DEG_C or DEG_F |
| TURB | Turbidity - NTU |
| VOL_PURGED | Actual Volume Purged [Prior to Sampling] - GAL |
| WELL_VOLUME | Well Volume Removed - GAL |
| WTRVE | Water Velocity - GAL_MIN |

Recorder: ______________________________ Date: ______________

Checker: ______________________________ Date: ______________

# LAND SURVEYING

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## 1.0 PURPOSE

This standard operating procedure (SOP) sets forth protocols 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.

## 2.0 PROCEDURES

The procedures listed below shall be followed during land surveying conducted for NAVFAC Northwest.

- All surveying work shall be performed under the direct supervision of a land surveyor registered in the state or territory in which the work is being performed (i.e. a Professional Land Surveyor, PLS).
- Survey instruments shall be calibrated in accordance with the manufacturer's specifications regarding procedures and frequencies. At a minimum, instruments shall have been calibrated no more than 6 months prior to the start of the survey work.
- Standards for all survey work shall be in accordance with National Oceanic and Atmospheric Administration (NOAA) standards and at the minimum accuracy standards set forth below. The horizontal accuracy for location of all grid intersection and planimetric features shall be (±) 0.1 feet. The horizontal accuracy for boundary surveys shall be one in ten thousand 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.
- Surveys shall be referenced to the local established coordinate systems and all elevations and benchmarks established shall be based on North American Vertical Datum of 1988.
- Surveyed points shall be referenced to Mean Sea Level (Mean Lower Low Water Level).
- Appropriate horizontal and vertical control points shall be jointly determined 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. All surveyed locations shall be mapped using a base map or other site mapping specified by the Project Manager.
- All surveys shall begin and end 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. Pins shall be driven 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. They shall be clearly marked with brightly colored weatherproof flagging and paint.
- The point on a monitoring well casing that is surveyed shall be clearly marked by filing grooves into the casing on either side of the surveyed point.

## 3.0 DOCUMENTATION

Using generally accepted practices, field notes shall be recorded daily by the surveyor in paper or electronic format. The data shall be neat, legible and easily reproducible. Copies of the surveyor's field notes and calculation forms generated during the work shall be obtained and submitted to the Navy or designee.

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
- Field book designations, including page numbers.

Drawings and calculations submitted by the surveyor shall be signed, sealed and certified by a land surveyor registered (PLS stamped) in the state or territory in which the work was done.

Dated records of land surveying equipment calibration shall be provided by the surveyor along with equipment serial numbers and calibration records.

## 4.0 REFERENCES

The detailed requirements in the Geographic Data, Survey Specifications subsection of the parent compendium (NAVFAC Northwest SOPs V5.0) also apply and are not repeated here in this field procedure. These should be consulted as part of any Land Surveying effort. In addition, NAVFAC Northwest Cadastral Team, Record of Survey or other requirements may apply to the project, an example of their requirements can be found with the Survey Specifications referenced above.

## 5.0 ATTACHMENTS

None.

# FIELD QC SAMPLES (WATER, SOIL, SEDIMENT, TISSUE)

## 1.0 PURPOSE

This standard operating procedure (SOP) describes the number and types of field Quality Control (QC) samples that will be collected during U.S. Naval Facilities Engineering Command Northwest (NAVFAC NW) site field work. Quality control samples are controlled samples introduced into the analysis stream, whose results are used to review data quality and to calculate the accuracy and precision of the chemical analysis program. The purpose of each type of QC sample collection is described in this procedure. Collection and analysis frequency for quality control samples vary by project and are found in the project QA plan. Note that project-specific or contract requirements may supersede the requirements presented in this SOP.

## 2.0 PROCEDURES

The equipment required for the collection of QC samples is identical to the equipment required for the collection of environmental samples.

Field QC checks may include submission of trip blank, equipment rinsate, field blank, duplicate, and reference samples to the laboratory. Suggested frequency and types of QC check samples are discussed in the following guidance documents: *RCRA Technical Enforcement Guidance Document*, Section 4.6.1 (EPA 1986); the use and frequency of these field QC samples should be incorporated as appropriate. Types of field QC samples are discussed in general below. The frequency at which field QC samples should be collected for each QC level is provided in Table III-B-1.

The use of performance evaluation (PE) samples is discussed in SOP III-H, *Performance Evaluation Sample Procedures.*

### 2.1 TRIP BLANK

One trip blank is prepared off site by the laboratory using ASTM Type I organic-free water and included in each shipping container with samples scheduled for analysis of VOCs, regardless of the environmental medium. Trip blanks are placed in sample coolers by the laboratory prior to transport to the site so that they accompany the samples throughout the sample collection/ handling/ transport process. Once prepared, trip blanks remain unopened throughout the transportation and storage processes and are analyzed along with the associated environmental samples. Trip blanks are analyzed for VOCs and reported as water samples, even though the associated environmental samples may be from a matrix such as soil, tissue, or product.

One set of two 40 milliliter vials will constitute a trip blank and will accompany each cooler containing samples to be analyzed for volatile organics (VOCs) by methods such as CLP VOCs, 8010/601, 8020/602, 8240/624, modified 8015 (only if purge and trap analysis is performed, e.g., for gasoline, not for extraction and analysis for diesel fuel), and equivalent state-specific methods. Trip blanks will be analyzed for VOCs only (EPA 1987).

Trip banks are not typically analyzed in association with tissue samples and are therefore not required for tissue sampling programs.

**Table III-B-1**
**Field QC Samples per Sampling Event**

| | Level C2 | | Level D2 | | Level E2 | |
|---|---|---|---|---|---|---|
| Type of Sample | Metal | Organic | Metal | Organic | Metal | Organic |
| Trip blank<br>(for volatiles only) | NA1 | 1/cooler | NA1 | 1/<br>cooler | NA[1] | 1/cooler |
| Equipment rinsate[3] | 1/day | 1/day | 1/day | 1/day | 1/day | 1/day |
| Field blank | 1/decontamination water source/event/for all QC levels and all analytes | | | | | |
| Field duplicates[4] | 10% | 10% | 10% | 10% | 5% | 5% |

Background samples at least 1/sample media/sample event[5]

Notes:

[1] NA means not applicable.

[2] QC levels are discussed in Section 2.8, Quality Control (QC) Levels.

[3] Samples are collected daily; however, only samples from every other day are analyzed. Other samples are held and analyzed only if evidence of contamination exists.

[4] The duplicate must be taken from the same sample that will become the laboratory matrix/spike duplicate for organics or for the sample used as a duplicate in inorganic analysis.

[5] Sample event is defined from the time sampling personnel arrive at the site until they leave the site for more than a period of one week; the use of controlled-lot source water makes one sample per lot rather than per event an option.

Source: NFESC. 1999. Navy Installation and Restoration Chemical Data Quality Manual.

## 2.2 EQUIPMENT RINSATE SAMPLES

Equipment rinsate samples are collected by pumping organic-free, analyte-free water over and/or through the sampling equipment (such as a bailer, sampling pump, or mixing bowl) following its final decontamination rinse. This rinse water is collected into the sample containers directly or with the use of a funnel if necessary. The rinse water may be poured by use of an electric or hand submersible pump by tipping the jug of water upside down, or by use of a stopcock.

Equipment rinsate samples are collected daily for sampling equipment used repetitively to collect environmental samples. One equipment rinsate sample shall be collected per day per sampling technique utilized that day (NFESC 1999 and EPA 1986). At least one equipment rinsate sample is analyzed for each group of 20 samples of a similar matrix type and concentration. Equipment rinsate samples are preserved, handled, and analyzed in the same manner as all environmental samples. Analytical results of equipment rinsate samples are used to access equipment cleanliness and the effectiveness of the decontamination process.

When disposable or dedicated sampling equipment is utilized, only one equipment rinsate sample will be collected per equipment lot or project phase. Disposable and/or dedicated sampling equipment may include stainless steel bowls or trowels that will be used for collection of only one soil sample, disposable bailers for ground-water sampling, dedicated submersible pumps for ground-water sampling, or other such equipment. This disposable and/or dedicated sampling equipment is typically pre-cleaned and individually wrapped by the manufacturer prior to delivery to the site. In this case, the equipment rinsate sample is used to provide verification that contaminants are not being introduced to the samples via sampling equipment.

Sampling devices (e.g., gloved hands, dip nets, or traps) for collection of tissue samples are generally non-intrusive into the organisms collected, so equipment rinsate samples will not be collected as long as the devices have been properly cleaned following SOP III-I, *Equipment Decontamination*, and the devices appear clean.

## 2.3 FIELD BLANKS

Field blanks are generally prepared on site during the sampling event by pouring American Society for Testing and Materials (ASTM) Type I organic-free water into randomly selected sample containers. Commercially available distilled water may be a satisfactory substitute for the ASTM organic-free water depending specific project requirement. At least one field blank is analyzed for each group of 20 samples of a similar matrix type and concentration.

Field blanks, consisting of samples of the source water used as the final decontamination rinse water, will be analyzed to assess whether the wash or rinse water contained contaminants that may have been carried over into the site samples.

The final decontamination rinse water source, the field blank source water, and equipment rinsate source water should all be from the same purified water source. Tap water used for steam cleaning augers or used in the initial decontamination buckets need not be collected and analyzed as a field blank, because augers typically do not touch the actual samples and because the final decontamination rinse water should be from a purified source.

Field blanks are collected at a frequency of one per sampling event per each source of water for all levels of QC. A sampling event is considered to be from the time sampling personnel arrive at a site until they leave for more than a week. Field blanks will be analyzed for the same analyses as the samples collected during the period that the water sources are being used for decontamination. If the same lot of the water source is used, a field blank needs to be collected only once per lot.

### 2.4 FIELD DUPLICATE

At least one duplicate sample is analyzed from each group of 10 samples of a similar matrix type and concentration. Field duplicate samples should be collected from areas most likely to be contaminated and are preserved, handled, and analyzed in the same manner as all environmental samples. Field duplicates have the same location identification, sampling date and time, and depth interval as the associated environmental sample, but are assigned a unique sample number that is associated with the environmental sample number by virtue of the identical timestamp and location information.

Field duplicates for groundwater and surface water samples will generally consist of replicates. Field duplicates for soil samples will consist primarily of collocates. Soil field duplicates that are to be analyzed for volatile constituents will consist only of collocates; no soil samples that are to be analyzed for volatiles will be replicated (i.e., homogenized or otherwise processed or split) in the field. A separate sample will be collected to provide duplicates for non-volatile analyses. The sample may be homogenized and split in the field to form an original and duplicate (replicate) sample, or an additional volume into a separate sample container may be collected to form a duplicate (collocate) sample. Alternatively, replicates may be formed by homogenization in the laboratory. Duplicates will be analyzed for the same analytical parameters as their associated original sample.

Field duplicates for biological tissue samples will consist of splits of the original sample. Twice the required volume of organisms for one sample will be collected and placed into one food-grade self-sealing bag. The sample will later be homogenized in the laboratory and split, producing an original and a replicate sample. Replicates will be analyzed for the same analytical parameters as their associated original samples.

### 2.5 REFERENCE SAMPLES

There are two types of background levels of chemicals:

- Naturally occurring levels, which are concentrations of chemicals present in the environment that have not been influenced by humans (e.g., iron, aluminum)
- Anthropogenic levels, which are concentrations of chemicals that are present in the environment due to human-made, non-site sources (e.g., industry, automobiles)

Reference samples are samples taken from media similar to site media, but that are collected outside the zone of contamination, usually offsite.

Reference samples will be collected for each medium sampled at a site. Site-specific conditions will dictate the number of reference samples necessary to characterize background concentrations of contaminants of concern. However, at least one reference sample from each medium will be collected during each sampling event at a site. The samples will be analyzed for all the analytes for which site samples of that medium are analyzed. Background analysis, especially for metals, should be performed to assess the typical naturally occurring levels.

At least one reference sample will be collected for each biological species collected at a site. It may be difficult to find a nearby offsite location similar enough to the project site that has the same biological species available for offsite reference sample collection. Therefore, reference sample locations may need to be more distant from the site than for soil or water offsite reference samples. Collection methods will be identical for site and reference samples.

State-specific procedures may be required to establish background conditions for the site. This SOP is not intended to address such procedures and they should be consulted as necessary.

## 2.6 TEMPERATURE BLANKS

Temperature blanks are used to measure cooler temperatures upon receipt of the coolers at the laboratory. One temperature blank will be prepared and submitted to the project laboratory with each cooler. The temperature blank will consist of a sample jar containing water, which will be packed in the cooler in the same manner as the rest of the samples and labeled “temperature blank.”

## 2.7 LABORATORY QUALITY CONTROL SAMPLES

The analytical laboratory uses a series of QC samples specified in each standard analytical method and laboratory SOP to assess laboratory performance. Analyses of laboratory QC samples are performed for samples of similar matrix type and concentration and for each sample batch. The types of laboratory QC samples are matrix spike/matrix spike duplicates, laboratory control standards, laboratory duplicates, method blanks, and surrogates. In addition, there may be other project-specific technical QC requirements.

### 2.7.1 Matrix Spike/matrix Spike Duplicate

Matrix spike/matrix spike duplicates (MS/MSDs) are used to assess sample matrix interferences and analytical errors, as well as to measure the accuracy and precision of the analysis. For MS or MSD samples, known concentrations of analytes are added to the environmental samples; the samples are then processed through the entire analytical procedure and the recovery of the analytes is calculated. Results are expressed as percent recovery of the known spiked amount for matrix spikes and the relative percent difference (RPD) for MS/MSDs. The MS/MSDs will be collected and analyzed at a rate of 5 percent of the field samples for each matrix and analytical method or at least one for each analytical batch, whichever frequency is greater.

Generally, a specific sampling location is used to collect field QC samples; however, it may not be possible to collect MS/MSD samples for all analyses at the same sampling location because of a limited volume of available material. In those instances, MS/MSD samples designated for various analyses will be collected from different locations (for example a MS/MSD for metals is collected at location X and an MS/MSD for PCBs is collected at location Y). Additionally, samples designated for MS/MSD analyses will not be collected from locations with potentially high concentrations of target analytes that may mask the added spike compounds. MS/MSD samples have the same location identification, sampling time, depth interval, and sample number as the associated environmental sample.

## 2.8 QUALITY CONTROL (QC) LEVELS

NAVFAC NW QC Levels III, IV are defined in SOP I-A-8 and Data Validation Procedure SOPs II-A through II-O. Level IV QC is appropriate to use for laboratory analysis for sites where cleanup decisions will be based on risk assessment. Sites on or eligible for the National Priorities List (NPL) will also have laboratory analyses conducted at Level IV QC. The QC level selected for laboratory analyses for many sites, therefore, will be NAVFAC NW Level IV. Other QC levels may be appropriate for certain types of samples or analyses; criteria for selection of the appropriate QC level for individual projects and field work activities are discussed in SOP I-A-8, *Data Validation Planning and Coordination*.

## 3.0 DOCUMENTATION

Records of the collection of field QC samples should be kept in the sample logbook by the methods discussed in SOPs III-E, *Record Keeping, Sample Labeling, and Chain-of-Custody* and III-D, *Logbooks*.

## 4.0 REFERENCES

EPA. 1987. Data Quality Objectives for Remedial Response Activities: Development Process

NFESC. 1999. Navy Installation and Restoration Chemical Data Quality Manual.

EPA. 1992. RCRA Technical Enforcement Guidance Document.

SOP III-I, Equipment Decontamination

SOP, III-D, *Logbooks*

## 5.0 ATTACHMENTS

None.

# LOGBOOKS

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## 1.0 PURPOSE

This standard operating procedure (SOP) describes the activities and responsibilities of U.S. Naval Facilities Engineering Command Northwest (NAVFAC NW) personnel and/or their contractors pertaining to the identification, use, and control of logbooks and associated field data records. This SOP establishes a standard format for recording field observations and describes the methods for use and maintenance of field logbooks.

## 2.0 PROCEDURE

### 2.1 EQUIPMENT

- Waterproof hardbound field logbook (typically 4-inch by 7-inch to 8-inch by 10.5-inch) with numbered pages
- Waterproof/indelible marking pen
- Ruler/straight edge
- Clipboard

### 2.2 LOGBOOK MAINTENANCE

Prior to commencement of field work, logbooks will be assigned to field personnel by the Project Manager. If personnel changes must be made during a project, the successor may use the same logbook. In this case, the logbook cover page will indicate all persons who have made entries and the dates. This may be inappropriate if there are a large number of people involved.

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 safeguard of the logbook while having custody of it.

Individuals performing specific tasks associated with a field project may keep a separate logbook; however, these logbooks must conform to this procedure and will become a permanent part of the central project file. The Project Manager is responsible for reviewing and signing all field logbooks associated with the project.

## 2.3 RECORDING FIELD ACTIVITIES

The field team provides a permanent record of daily activities, observations, and measurements through the use of a field logbook. All logbook entries will be made in indelible black or blue ink. No erasures are permitted. If an incorrect entry is made, the data will be crossed out with a single line and initialed and dated by the originator. Entries can be organized into easily understood tables if possible.

All logbook pages will be signed and dated at the bottom. Times will be recorded next to each entry. If a full page is not used during the course of a workday, a diagonal line will be drawn through the unused portion of the page and signed (in this case, it would not be necessary to sign the bottom of the page). If the project is completed and the logbook has not been completely filled, a diagonal line will be drawn across the first blank page after the last entry, and “no further entries” written before the page is signed and dated.

Daily entries will be made during field activities by, at a minimum, one field team member to provide daily records of all significant events, observations, and measurements during field operations. Notes will start at the beginning of the first blank page and extend through as many pages as necessary. All page numbers will be consecutively numbered as the logbook is filled.

The inside cover page of each logbook will contain the following information:

- Book number
- Project name
- Contract number
- Project number
- Navy Activity/Installation
- Site name
- Start date
- End date
- Person to whom the logbook is assigned
- Agency/Company name
- Agency/Company address
- Agency/Company phone number

The field logbook serves as the primary record of field activities. When possible, the field book should be dedicated to a singular Navy Activity/Installation to facilitate long-term records archiving. Entries shall be made chronologically and in sufficient detail to allow the writer or a knowledgeable reviewer to reconstruct the applicable events. 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, names of all samples collected shall be included in the logbook even if recorded elsewhere.

All field descriptions and observations are entered into the logbook, as described in Attachment III-D-1.

Typical information to be entered includes, but is not limited to, the following:

- Date and time of all onsite activities
- Site location and description
- Weather conditions
- Field work documentation
- Descriptions of and rationale for approved deviations from the Work Plan or Field Sampling Plan
- Field instrumentation readings
- Personnel present
- Photograph references
- Sample locations
- Sample identifications, as described in SOP I-A-11, Sample Naming
- Field QC sample information
- Field descriptions, equipment used, and field activities accomplished to reconstruct field operations
- Meeting information
- Daily health and safety meeting notes
- Important times and dates of telephone conversations, correspondence, or deliverables
- Field calculations
- PPE level
- Calibration records
- Subcontractors present
- Equipment decontamination procedures and effectiveness
- Procedures used for containerization of investigative-derived waste

Logbook page numbers shall appear on each page to facilitate identification of photocopies.

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

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.

A technical review of each logbook shall be performed by a knowledgeable individual such as the Project Manager.

## 3.0 DOCUMENTATION

The field logbook shall be retained as a permanent project record. If a particular Task Order requires submittal of photocopies of logbooks, this shall be performed as required.

## 4.0 REFERENCES

SOP I-A-11, *Sample Naming*

## 5.0 ATTACHMENTS

Attachment III-D-1 Description of Logbook Entries

## Attachment 1
## Description of Logbook Entries

Logbook entries shall 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 specified in the Field Sampling Plan. Record valid Navy Installation/Active and Site, at a minimum. |
| **Weather** | Indicate general weather and precipitation conditions. |
| **Level of Personal Protective Equipment** | The level of personal protective equipment (PPE), e.g., Level D, should be recorded. |
| **Methods** | Indicate method or procedure number employed for the activity. |
| **Sample IDs** | Indicate the unique identifier associated with the physical samples. Identify QC samples. Value can be numeric or alphanumeric and must not already exist in the database. |
| **Sample Type and Volume** | Indicate the medium, container type, preservative, and the volume for each sample. |
| **Sample Collection Information** | Indicate the location of sample, date and time of collection, sample matrix, sample depth interval, sample methods, sample handling, including filtration and preservation, analysis required and packaging and shipping information. |
| **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 Field Sampling Plan. |
| **Field Measurements** | Indicate measurements and field instrument readings taken during the activity. |
| **Chain of Custody and Distribution** | Indicate chain-of-custody for each sample collected and indicate to whom 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 any 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 to the work schedule, requested information, or observe team activities. Record any visual or other observations relevant to the activity, the contamination source, or the sample itself.<br>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. |

# RECORD KEEPING, SAMPLE LABELING, AND CHAIN-OF-CUSTODY PROCEDURES

## 1.0 PURPOSE

The purpose of this standard operating procedure (SOP) is to establish standard protocols for all U.S. Naval Facilities Engineering Command Northwest (NAVFAC NW) field personnel and their contractors 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/analytical request forms.

## 2.0 PROCEDURES

Standards for documenting field activities, labeling the samples, documenting sample custody, and completing chain-of-custody and analytical request forms are provided in this procedure. 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.

### 2.1 RECORD KEEPING

The field logbook serves as the primary record of field activities. Entries shall be made 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 SOP III-D, *Logbooks*.

### 2.2 SAMPLE LABELING

A sample label with adhesive backing shall be affixed to each individual sample container. Clear tape shall be placed over each label (preferably prior to sampling) to prevent the labels from tearing off, falling off, or being smeared, and to prevent loss of information on the label. The following information shall be recorded with a waterproof marker on each label:

- Project name or number (optional)
- Sample ID
- Date and time of collection
- Sampler's initials
- Matrix (optional)
- Sample preservatives (if applicable)
- Analysis to be performed on sample. This shall be identified by the method number or name identified in the subcontract with the laboratory. For water samples, a separate container is

typically used for each separate test method, whereas with soil samples, multiple analyses can be performed on the soil obtained from one sample container. In order to avoid lengthy lists on each container and confusion, soil sample containers may not list every analysis to be performed.

These labels may be obtained from the analytical laboratory or printed from a computer file onto adhesive labels. The adhesive glue used on the labels must be such that it does not contaminate the sample.

## 2.3 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. Custody of samples shall be maintained in accordance with EPA chain-of-custody guidelines as prescribed in EPA's *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.

### 2.3.1 Sample Collection Custody Procedures

According to EPA's *NEIC Policies and Procedures*, a sample is considered to be in custody if:

- 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
- It is placed in a container and secured with an official seal such that the sample cannot be reached without breaking the seal

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

- Sampler's name or initials
- 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 III-E-1.

Field personnel shall also log individual samples onto carbon copy chain-of-custody forms when a sample is collected. These forms may also serve as the request for analyses. Procedures for completing these forms are discussed in Section 2.4 indicating sample 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 III-E-2. An example of a completed COC form is provided in Attachment III-E-3 and described in Section 2.4.

### 2.3.2 Laboratory Custody Procedures

The following are custody procedures to be followed by an independent laboratory receiving samples for chemical analysis; the procedures in their Laboratory Quality Assurance Plan (LQAP) 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 samples in the coolers upon arrival. The custodian shall also 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.
- Proper preservation of samples (made by pH measurement, except VOCs and purgeable TPH). The pH of these samples will be checked by the laboratory analyst, after the sample aliquot has been removed from the vial for analysis.
- If any sample holding times have been exceeded.

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

Any discrepancy 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 III-E-4.

The custodian shall then assign a unique laboratory number to each sample and distribute the samples to secured storage areas maintained at 4°C. The unique laboratory number for each sample, contractor sample ID, client name, date and time received, analysis due date, and storage details shall also be manually logged onto a sample receipt record and later entered into the laboratory's computerized data management system. The custodian shall also 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.

## 2.4 COMPLETING CHAIN-OF-CUSTODY/ANALYTICAL REQUEST FORMS

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

Attachment III-E-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 III-E-3 is an example of a completed site-specific COC/analytical request form, with box numbers identified and discussed in text below.

Box 1 Project Manager: This name shall be the name that will appear on the report. Do not write the name of the Project Coordinator or point of contact for the project instead of the Project Manager.

Project Name: Write it, as it is to appear on the report.

Project Number: Write it as it is to appear on the report. It shall include the project number, task number, and general ledger section code. The laboratory subcontract number should also be included.

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 Basic Ordering Agreement (BOA) or each Task Order statement of work with each laboratory.

Shipment Method: State the method of shipment, e.g., hand carry; air courier via FEDEX, AIRBORNE, DHL or equivalent.

Comment: 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. For example: a specific metals list, explanation of Mod 8015, Mod 8015 + Kerosene, samples expected to contain high analyte concentrations.

Box 4 Cooler Number: This will be written somewhere 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 VOC samples. 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/QC requirements, e.g., NAVFAC NW QC Level C, D, or E.

Turnaround time (TAT): TAT for contract work will be determined by a sample delivery group (SDG), which may be formed over a 14-day period, not to exceed 20 samples. Standard turnaround time once the SDG has been completed is 35 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: 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 number: Five-character alpha-numeric identifier to be used by the laboratory to identify samples. The use of this identifier is important since the labs are restricted to the number of characters they are able to use. See SOP I-A-11, Sample Naming.

Description (sample identification): This name will be determined by the location and description of the sample, as described in SOP I-A-11, Sample Naming. 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 sample number and sample identification must be maintained separately.

Date Collected: Collection date must be recorded 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 Identification: This is for laboratory use only.

Box 7 Matrix and 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. When requesting metals that are modifications of the standard lists, define the list in the comment section. This would not be necessary when requesting standard list metals such as priority pollutant metals (PPM), target compound list from ILM03.0, and Title 22 metals which are groups of metals commonly requested and should not cause any confusion as to what metals are being analyzed. Whenever possible, list the parameters as they appear in the laboratory subcontract to maintain consistency and avoid confusion.

In the boxes below the analytical parameter, indicate the number of containers collected for each parameter by marking an "X". If more than one container is used for a sample, write a number in the desired box to indicate a request for analysis and to indicate the number of containers sent for that analysis.

Box 9 Sampler's Signature: The person who collected samples must sign here.

Relinquished By: This space shall contain the signature of the person who turned over the custody of the samples to a second party other than an express mail carrier such as FEDEX, DHL or Air Borne Express.

Received By: Typically, this is a written signature by a representative of the receiving laboratory, or a field crewmember who delivered the samples in person from the field to the laboratory. A courier such as FedEx or DHL does not sign because they do not open the coolers. It must also be used by the prime contracting laboratory when samples are sent to a subcontractor.

Relinquished By: In the case of subcontracting, the primary laboratory will sign 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).

Box 10 Lab Number 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 sample number in a cooler, or contained on a COC. This control number must be unique and never used twice. Record the date the COC is completed. It should be the same date the samples are collected.

Box 12 Total No. of Containers/row: Sum the number of containers in that row.

Box 13 Total No. of Containers/column: Sum the number of containers in that column.

Because COC forms contain different formats based upon 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.

COC forms tailored to each Task Order 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, reduce the number of trip blanks by placing all samples to be analyzed for VOA, gasoline, and BTEX compounds into one cooler. 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.

## 3.0 DOCUMENTATION

The COC/analytical request form shall be faxed daily, if possible, to the Task Order Laboratory Coordinator for accuracy verification. Following the completion of sampling activities, the sample logbook and COC forms will be transmitted to the Project Manager for storage in project files. The Project Manager shall review COC forms on a monthly basis at a minimum. The data validators shall also receive a copy. Along with the data delivered, the original COC/analytical request form shall be submitted by the laboratory. 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.

## 4.0 REFERENCES

SOP I-A-11, *Sample Naming*

SOP III-D, *Logbooks*

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

USEPA. 1986. EPA NEIC Policies and Procedures, National Enforcement Investigations Center, Denver, Colorado.

USEPA. 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (EPA OSWER Directive 9355 3-01).

USEPA. 1992. RCRA Ground Water Monitoring Technical Enforcement Guidance Document (TEGD).

USEPA. 1995 and as updated. Test Methods for Evaluating Solid Waste (SW-846), Third edition.

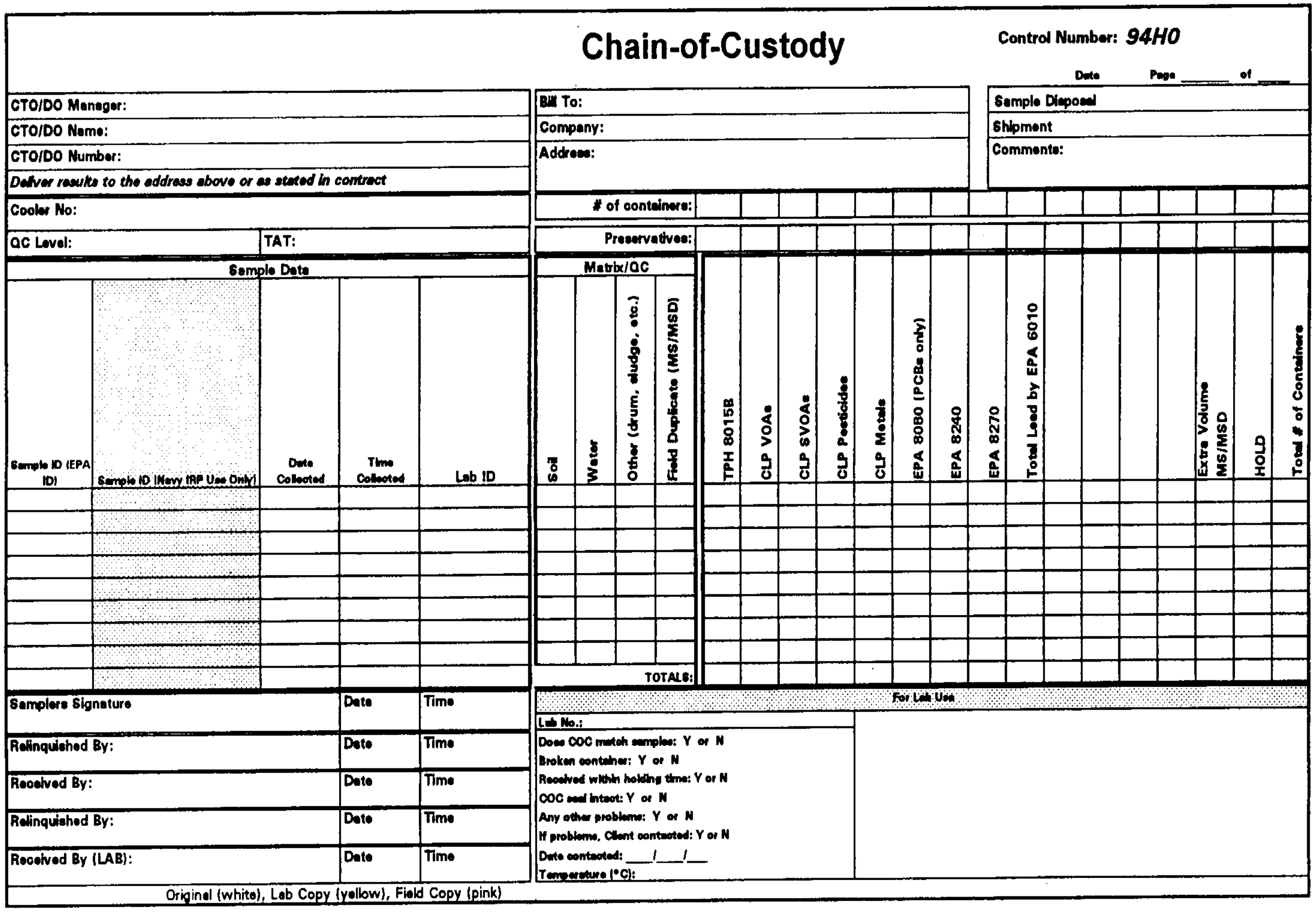
## 5.0 ATTACHMENTS

| | |
|---|---|
| Attachment III-E-1 | Chain-of-Custody Seal |
| Attachment III-E-2 | Generic Chain-of-Custody/Analytical Request Form |
| Attachment III-E-3 | Sample Completed Chain-of-Custody/Analytical Request Form |
| Attachment III-E-4 | Sample Out-of-Control Form |

## Attachment III-E-1
## Chain-of-Custody Seal

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

## Attachment III-E-2
## Generic Chain-of-Custody/Analytical Request Form



**Chain-of-Custody**

**Control Number: 94H0**

Date Page ____ of ____

CTO/DO Manager:
CTO/DO Name:
CTO/DO Number:
*Deliver results to the address above or as stated in contract*
Cooler No:
QC Level:
TAT:

Bill To:
Company:
Address:

Sample Disposal
Shipment
Comments:

| | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | **# of containers:** | | | | | | | | | | | | | | | | |
| | | | | | | | | **Preservatives:** | | | | | | | | | | | | | | | | |
| **Sample Data** | | | | | **Matrix/QC** | | | | | | | | | | | | | | | | | | | |
| Sample ID (EPA ID) | Sample ID (Navy (RP 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 |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | |
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| | | | | | | | | TOTALS: | | | | | | | | | | | | | | | | |

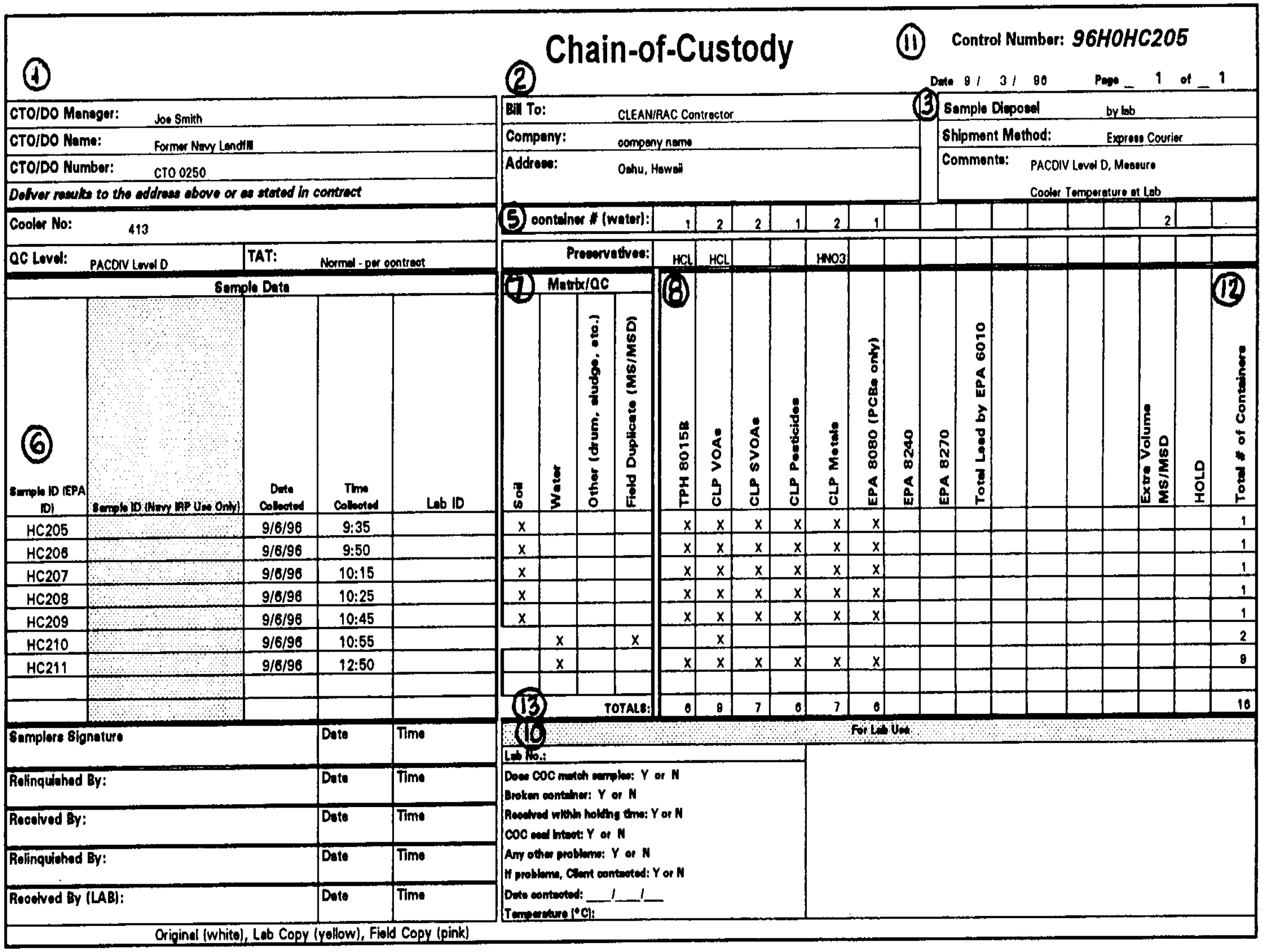
| | | |
|---|---|---|
| Samplers Signature | Date | Time |
| Relinquished By: | Date | Time |
| Received By: | Date | Time |
| Relinquished By: | Date | Time |
| Received By (LAB): | Date | Time |

For Lab Use

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

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

## Attachment III-E-3
## Sample Completed Chain-Of-Custody/ Analytical Request Form



**Chain-of-Custody**

⑪ **Control Number:** 96H0HC205

Date 9 / 3 / 96 Page 1 of 1

①
**CTO/DO Manager:** Joe Smith
**CTO/DO Name:** Former Navy Landfill
**CTO/DO Number:** CTO 0250
***Deliver results to the address above or as stated in contract***

② **Bill To:** CLEAN/RAC Contractor
**Company:** company name
**Address:** Oahu, Hawaii

③ **Sample Disposal** by lab
**Shipment Method:** Express Courier
**Comments:** PACDIV Level D, Measure Cooler Temperature at Lab

④ **Cooler No:** 413
**QC Level:** PACDIV Level D **TAT:** Normal - per contract

| | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ⑤ container # (water): | | | | | | | | | 1 | 2 | 2 | 1 | 2 | 1 | | | | | | | | 2 | | |
| Preservatives: | | | | | | | | | HCL | HCL | | | HNO3 | | | | | | | | | | | |
| Sample Data | | | | | ⑦ Matrix/QC | | | | ⑧ | | | | | | | | | | | | | | ⑫ |
| ⑥ Sample ID (EPA ID) | Sample ID (Navy IRP Use Only) | Date Collected | Time Collected | Lab ID | Soil | Water | Other (drum, sludge, etc.) | Field Duplicate (MS/MSD) | TPH 8015B | CLP VOAs | CLP SVOAs | CLP Pesticides | CLP Metals | EPA 8080 (PCBs only) | EPA 8240 | EPA 8270 | Total Lead by EPA 6010 | | | | | Extra Volume MS/MSD | HOLD | Total # of Containers |
| 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 |
| | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | ⑬ | | | TOTALS: | 6 | 8 | 7 | 6 | 7 | 6 | | | | | | | | | | 16 |

| | | |
|---|---|---|
| ⑨ Samplers Signature | Date | Time |
| Relinquished By: | Date | Time |
| Received By: | Date | Time |
| Relinquished By: | Date | Time |
| Received By (LAB): | Date | Time |

⑩ **For Lab Use**
Lab No.:
Does COC match samples: Y or N
Broken container: Y or N
Received within holding time: Y or N
COC seal intact: Y or N
Any other problems: Y or N
If problems, Client contacted: Y or N
Date contacted: ___/___/___
Temperature (°C):

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

# Attachment III-E-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<br>(List by Accession<br>AND Sample No.) |
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| 1. Type of Event<br>(Check all that apply) | | 2. Corrective Action (CA)*<br>(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: |

# SAMPLE CONTAINERS AND PRESERVATION

---

## 1.0 PURPOSE

This standard operating procedure (SOP) describes the conventional containers used for sample collection and delivery to a laboratory for analysis. Additionally it will discuss sample preservation and holding times.

## 2.0 PROCEDURES

The purpose of sample preservation is to prevent or retard the degradation and modification of chemicals or to retard biological activity in samples during transit and storage. Efforts to preserve the integrity of the samples must be initiated as soon as possible after the time of sampling and continue until analyses are performed. Preservatives must be added to the sample container as soon as possible after the time of sample collection. The recommended procedure is to request that bottles be provided by the analytical laboratory and be pre-preserved.

Complete and unequivocal preservation of samples, domestic sewage, industrial wastes, or natural waters, is impossible in practice. Regardless of the nature of the sample, complete stability for every constituent is not likely to be achieved. At best, preservation techniques can retard the chemical and biological changes that inevitably continue after the sample is removed from the parent source. Degradation of the sample ceases only if it is preserved at a temperature of absolute zero (-273°C). However, freezing of a sample to extend hold times is not permitted. Therefore, as a general rule, it is best to analyze the samples as soon as possible after collection. This is especially true when the analyte concentration is expected to be in the low microgram per liter (mg/l) range.

Methods of preservation are relatively limited and are intended generally to perform the following:

- Retard biological action
- Retard hydrolysis of chemical compounds and complexes
- Reduce volatility of constituents
- Reduce absorption effects

Preservation methods are generally:

- pH control
- Chemical addition
- Refrigeration and/or chilling using ice

The recommended preservative for various constituents is given in the Exhibits at the end of this SOP. Preservation techniques for some analyses requiring more than simple refrigeration or filtering are discussed in Section 2.2. The exhibits also provide the estimated volume of sample required for the analysis, the suggested type of container, and the maximum recommended holding times for samples to be properly preserved.

When selecting preservation techniques and sample container type, always refer to the guidance provided in the documentation of the analytical methods to be used.

## 2.1 SAMPLE CONTAINERS

Select sample containers based on the analytical parameters of interest. Use containers made of materials that are non-reactive. Glass and polyethylene containers are the most commonly accepted, and both are used when sampling many constituents. When metals are the analytes of interest, however, polyethylene containers with Teflon-lined caps are preferred. When organics are the analytes of interest, use glass containers with Teflon-lined caps.

## 2.2 SAMPLE PRESERVATION

Utilize pre-preserved sample bottles whenever possible. If this is not possible or practical, perform appropriate chemical preservation in the field for various analytical parameters as soon as possible after the time of sample collection. Cool samples after collection and during shipment. All samples should be kept out of direct sunlight as much as possible and stored in the dark (e.g., in a cooler). Regardless of the method of preservation, analyses should be performed as soon after sampling as possible.

In some instances, the optimal method for sample preservation may be inappropriate due to the restrictions placed on the transport of certain chemicals by shippers. When shipping restrictions prevent the use of some reagents for sample preservation, use the most appropriate and permissible technique. The project chemist or laboratory should be able to assist in deciding the best alternative method of preservation.

## 2.3 MAXIMUM HOLDING TIME

Complete and unequivocal preservation of a sample for an extended period of time is a practical impossibility. Regardless of the nature of the sample, complete stability for every constituent is not likely to be achieved. Maximum holding times are assigned to each analyte and are designed for quality assurance purposes to minimize degradation effects on the analysis. Therefore, as a rule, it is better to analyze the sample as soon as possible after collection. This is especially true when low contaminant concentrations are expected.

## 2.4 REVIEW

The Field Manager or an approved designee shall check all sample control documentation to ensure that the samples, transport, and analysis events have met the criteria outlined in this SOP and the field sampling plan. Any discrepancies shall be noted and the documentation will be returned to the originator for correction or explanation. The reviewer will acknowledge that corrections have been incorporated by signing and dating each reviewed document.

## 3.0 DOCUMENTATION

All sample collection information must be recorded within the field logbook. Each sample collected will be clearly associated with a sample type (i.e. normal, field duplicate, equipment blank) sample location, matrix type, collection time, collection date, analysis and sampling depth if appropriate.

With every sample submitted for analysis, a completed chain of custody (COC) must accompany the shipment and a copy retained for the project records. The COC/analytical request form must be used to track all sample identifiers.

## 4.0 REFERENCES

None.

## 5.0 ATTACHMENTS

| | |
|---|---|
| Attachment III-F-1 | Example Sample Collection Form |

## Attachment III-F-1
## Example Sample Collection Form

## FORM 11-2
## SAMPLE COLLECTION INFORMATION

Installation ID:
Establishing Contract ID:
Prime Contractor Name:

Site Name:
DO/CTO:
Establishing Phase:
Collection Date:

| Location Name | Sample Name | Depth Range (feet bgs) | | Collection Time | Sample Matrix | Sample Type | Sampling Equipment | Composite (Y/N) |
|---|---|---|---|---|---|---|---|---|
| | | Start Depth | End Depth | | | | | |
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### Sampling Equipment

| | |
|---|---|
| 2V | Double Van Veen Grab |
| AC | Air Canister |
| AP | Pump - Air Lift (bladder) |
| AS | Ashing |
| B | Bailer |
| BR | Brass (California) Ring |
| BS | Beach Seine |
| C | Continuous Flight Auger |
| CC | Continuous Core Sampler |
| CH | Charcoal Sampling Tube |
| CL | Clover Leaf Dredge Sampler |
| CN | Cone Penetrometer |
| CO | Core Sampler |
| CP | Pump - Centrifugal |
| DF | Diffusion Bag Samplers |
| DG | Drill Rig |
| DS | Dredge Sampler (brass, etc.) |
| DT | Driver Tube (geoprobe, direct push, CPT rig) |
| E2 | Pump - Electric Submersible |
| EC | Encore Soil Sampler |
| FC | Cassette Filter |
| G | Grab |
| GP | Gas-Operated, Double Acting Piston Pump |
| H | Hollow Stem Auger |
| HA | Hand Auger |
| HB | Bucket Auger |
| HC | Hand Collected |
| HD | Hand Drill - Portable Powered |
| HK | Hook and Line |
| HP | Hydropunch |
| HU | Air Sampler - High Volume w/puf Resin |
| HV | Air Sampler - High Volume |
| HX | Air Sampler - High Volume w/XAD Resin |
| IF | Isolation Flux Chamber |
| LV | Air Sampler - Low Volume Continuous |
| LY | Lysimeter |
| MPPS | Micro Push Point Sampler |
| NC | Nickel Coated Brass Bomb Sampler |
| NX | NX Rock Coring |
| PP | Pump - Peristaltic |
| PS | Passive Soil Gas Sampling Probe |
| PU | Pump - Standard, Type not Recorded |
| RS | Hollow Glass Sampling Rod |
| SC | Scoop/Trowel |
| SD | Sediment Drag or Sled |
| SK | Skimmer |
| SS | Split Spoon |
| ST | Submersible Turbine Pump |
| SY | Syringe |
| T | Shelby Tube/ASTM-D1587 |
| TB | Tedlar Bag |
| TL | Trawl |
| TR | Animal Trap |
| TS | Thief Sampler and/or Thief Type Sampler |
| UNK | Unknown |
| VC | Vacuum (gas) |
| VS | Van Dorn Sampler |
| VV | Van Veen |
| W | Swab or Wipe |
| WB | Westbay Sampling System |

Recorder: ______________________________ Date: __________

Checker______________________________ Date: __________

| **Sample Matrix** | | | | | |
|---|---|---|---|---|---|
| AA | Ambient Air | MA | Mastic | WI | Ground Water Influent (into system) |
| AC | Composite Air Sample | MO | Mortar | WL | Leachate |
| ACS | Air - Crawlspace | MR | Marine Sediment | WM | Marine Water |
| AD | Air - Drilling | MS | Metal Shavings | WN | Porewater |
| AI | Air - Indoor | NS | Near-Surface Soil | WO | Ocean Water |
| AIN | Integrated Air Sample | PA | Paper | WP | Drinking Water |
| AIR-ABS | Activity Based Sampling (ABS) Air Sample | PC | Paint Chips | WQ | Water for QC Samples |
| AO | Air - Outdoor | PP | Precipitate | WR | Ground Water Effluent (from system) |
| AQ | Air Quality Control Matrix | RE | Residue | WS | Surface Water |
| AQS | Aqueous | RK | Rock | WT | Composite Ground Water Sample |
| ASB | Asbestos | SB | Bentonite | WU | Storm Water |
| ASBF | Asbestos-Fibrous | SBS | Sub-Surface Soil (>6") | WW | Waste Water |
| ASBNF | Asbestos-Non-Fibrous | SC | Cement/Concrete | XR | XRF Data |
| AVE | Air-Vapor Extraction, Effluent | SD | Drill Cuttings - Solid Matrix | | |
| AX | Air Sample from Unknown Origin | SE | Sediment | **Sample Type** | |
| BK | Brick | SEEP | Seep | AB | Ambient Condition Blank |
| BS | Brackish Sediment | SF | Filter Sandpack | BIOCON | Bioassay Control Sample |
| CA | Cinder Ash | SJ | Sand | BS | Blank Spike |
| CK | Caulk | SK | Asphalt | BSD | Blank Spike Duplicate |
| CN | Container | SL | Sludge | EB | Equipment Blank |
| CR | Carbon (usually for a remediation system) | SM | Water Filter (solid material used to filter water) | EBD | Equipment Blank/Rinsate Duplicate |
| DF | Dust/Fallout | SN | Miscellaneous Solid Materials - Building Materials | FB | Field Blank |
| DR | Debris/Rubble | SO | Soil | FD | Field Duplicate |
| DS | Storm Drain Sediment | SP | Casing (PVC, stainless steel, cast iron, iron pipe) | FR | Field Replicate |
| DT | Trapped Debris | SQ | Soil/Solid Quality Control Matrix | FS | Field Spike |
| EF | Emissions Flux | SS | Scrapings | IDW | Purge and Rinseate Water |
| EW | Elutriate Water | SSD | Subsurface Sediment | LB | Lab Blank |
| FB | Fibers | STKG | Stack Gas | LR | Lab Replicate |
| FL | Forest Litter | STPM | Stripper Tower Packing Media | MB | Material Blank |
| GE | Soil Gas Effluent - Stack Gas (from system) | SU | Surface Soil (less than 6 inches) | MIS | Multi-Incremental Sample |
| GI | Soil Gas Influent (into system) | SW | Swab or Wipe | MS | Matrix Spike |
| GL | Headspace of Liquid Sample | SZ | Wood | N | Normal (Regular) |
| GQ | Gaseous or Headspace QC | TA | Animal Tissue | PE | Performance Evaluation |
| GR | Gravel | TP | Plant Tissue | PURGE | Purge Water Sample |
| GS | Soil Gas | TQ | Tissue QC | RD | Regulatory Duplicate |
| GSS | Soil Gas - Subslab | TX | Tissue | SB | Source Blank |
| GT | Grit | UNK | Unknown | SBD | Source Blank Duplicate |
| IC | IDW Concrete | W | Water (not groundwater, unspecified) | SCREEN | Screening Sample |
| IDD | IDW Solid | WA | Drill Cuttings - Aqueous Mix | SD | Matrix Spike Duplicate |
| IDS | IDW Soil | WB | Brackish Water | SPLIT | Sample Split |
| IDW | IDW Water | WC | Drilling Water (used for well construction) | SRM | Standard Reference Material |
| IW | Interstitial Water | WD | Well Development Water | TB | Trip Blank |
| LA | Aqueous Phase of Multiphase Liquid/Soil | WF | Freshwater (not groundwater) | TBD | Trip Blank Duplicate |
| LF | Product (floating or free) | WG | Ground Water | TBR | Trip Blank Replicate |
| LQ | Organic Liquid Quality Control Matrix | WH | Equipment Wash Water (i.e. water used for washing equipment) | | |

## Instructions
## Form 11-2 (Sample Collection Information)

The purpose of this form is to collate sample collection information for data entry to serve as a quick reference for sample information. Every sample that is collected should be recorded on one of these forms. The information recorded on this form must come from the field logbook, which is the official record. This form must be filled out in its entirety; if a value or piece of information is unknown or not applicable, a horizontal line should be drawn through that field.

The information on this form must be checked against the field logbook for accuracy and completeness by a field staff member before the form is submitted for data entry. Data from this form will not be entered without the signature of the individual who checked the form for accuracy and completeness.

**Installation ID:** Unique identifier for installation associated with the location (example: WHIDBEY)

**Establishing Contract ID:** Unique contract ID assigned by Division Contraction Office (example: D459559365800)

**Prime Contractor Name:** Name of company that established location (example: URS)

**Site Name:** Site name associated with the location (example: Site 11)

**DO/CTO:** Contract Task Order (CTO) or Delivery Order (DO) number assigned by the Navy. The format is NNNN (example: 0012)

**Establishing Phase**: Task Phase, Subtask Number or Annual Quarter (example: 1)

**Collection Date:** Date samples were collected

**Location Name:** Unique name used for the location (example: MW-2R)

**Sample Name:** Unique sample name assigned by the contractor and/or derived from historical data submittal (example: MW-1-11/02/98)

**Depth Range (feet bgs):** Start and end depth of sample collection, if applicable.

**Collection Time:** Time at which sample was collected

**Sample Matrix:** Matrix type code from options at the bottom of form (example: MR)

**Sample Type:** Sample type code from options at bottom of form (example: N)

**Sampling Equipment:** Sampling equipment code from options at bottom of form (example: G)

**Composite:** A Y/N field indicating whether or not the sample is a composite

**Recorder:** Signature of individual who completed form and date completed

**Checker:** Signature of individual who checked the data against the field logbook and date checked

# SAMPLE HANDLING, STORAGE, AND SHIPPING

## 1.0 PURPOSE

This standard operating procedure (SOP) sets forth the methods for use by U.S. Naval Facilities Engineering Command Northwest (NAVFAC NW) field personnel and their contractors engaged in handling, storing, and transporting water, soil and/or sediment samples.

## 2.0 PROCEDURE

### 2.1 HANDLING AND STORAGE

Immediately following collection, all samples will be labeled according to the procedures in SOP III-E, *Record Keeping, Sample Labeling, and Chain-of-Custody Procedures*. The lids of the containers shall not be sealed with duct tape, but may be covered with custody seals or placed directly into sealed plastic bags. The sample containers shall be placed in an insulated cooler with frozen gel packs (such as "blue ice") or ice in double, self-sealing bags. Samples should occupy the lower portion of the cooler, while the ice should occupy the upper portion. An absorbent material (e.g., proper absorbent cloth material) may be placed on the bottom of the cooler to contain liquids in case of spillage. All empty space between sample containers shall be filled with bubble wrap, Styrofoam "peanuts," or other appropriate material. Prior to shipping, glass sample containers should be wrapped on the sides, tops, and bottoms with bubble wrap or other appropriate padding and/or surrounded by packing material to prevent breakage during transport. Prior to shipment, the ice or cold packs in the coolers may require replacement to maintain samples as close to 4°C as possible during transport of the samples to the analytical laboratory. Samples shall be shipped as soon as possible to allow the laboratory to meet holding times for analyses. The procedures for maintaining sample temperatures at 4°C, pertains to all water, soil, and sediment field samples.

### 2.2 SHIPPING

All appropriate U.S. Department of Transportation (DOT) regulations (e.g., 49 Code of Federal Regulations (CFR), Parts 171-179) shall be followed in shipment of air, soil, water, and other samples.

#### 2.2.1 Hazardous Materials Shipment

Field personnel must state whether any sample is suspected to be a hazardous material. A sample should be assumed to be hazardous unless enough evidence exists to indicate it is nonhazardous. If not suspected to be hazardous, shipments may be made as described in the Section 2.2.2 for non-hazardous materials. If hazardous, the procedures summarized below must be followed.

Any substance or material that is capable of posing an unreasonable risk to life, health, or property when transported is classified as hazardous. Hazardous materials identification should be performed 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 III-G-2.

All persons offering for shipment any hazardous material must be properly trained in the appropriate regulations, as required by HM-126F, Training for Safe Transportation of Hazardous Materials. 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.

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 III-G-1 shows an example of proper package markings. A copy of 49 CFR should be referred to each time a hazardous material or potentially hazardous samples are shipped.

According to Section 2.7 of the International Air Transport Association (IATA) 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 III-G-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 III-G-3). Certain dangerous goods are not allowed on certain airlines in any quantity.

As stated in item 4 of Attachment III-G-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 percentages by weight criteria are met. These samples may be shipped as non-hazardous materials as discussed below.

### 2.2.2 Nonhazardous Materials Shipment

If the samples are suspected to be nonhazardous, based on previous site sample results, field screening results, or visual observations, if applicable, then samples may be shipped as nonhazardous.

When a cooler is ready for shipment to the laboratory, copies of the chain-of-custody form shall be placed inside a sealed plastic bag and placed inside of an insulated cooler. The coolers will then be sealed with waterproof tape and labeled "Fragile," "This-End-Up" (or directional arrows pointing up), or other appropriate notices. Custody seals will be placed on the coolers as discussed in SOP III-E, *Record Keeping, Sample Labeling, and Chain-of-Custody Procedures*.

### 2.2.3 Shipments from Outside the Continental United States

Shipment of sample coolers to the U.S. from locations outside the continental U.S. is controlled by the USDA and is subject to their inspection and regulation. Documentation is required to prove that the analytical laboratory receiving samples is certified. The laboratory must have certification by USDA to receive and properly dispose of soil; this is called a "USDA Soil Import Permit." In addition, all sample coolers must be inspected by a USDA representative, affixed with a label indicating that the coolers contain environmental samples, and shipping forms stamped by the USDA inspector prior to shipment. In addition, samples shipped from U.S. territorial possessions or foreign countries, must be cleared by the

U.S. Customs Service upon entry into the United States. As long as the commercial invoice is properly completed (see below), shipments typically pass through U.S. Customs without the need to open coolers for inspection.

Completion and use of proper paperwork will, in most cases, minimize or eliminate the need of the USDA and U.S. Customs to inspect the contents. Attachment III-G-5 shows an example of how paperwork may be placed on the outside of coolers for nonhazardous materials. For hazardous materials, refer to Section 2.2.1.

In summary, the paperwork listed below should be taped to the outside of the coolers to assist sample shipments. If a shipment is made up of multiple pieces (e.g., more than one cooler), the paperwork need be attached only to one cooler, provided that the courier agrees. All other coolers in the shipment need only be taped and have address and chain-of-custody seals affixed.

1. **Courier Shipping Form & Commercial Invoice** - See Attachments III-G-6, III-G-7, and III-G-8 for examples of the information to be included on these forms. Both forms should be placed inside a clear plastic adhesive-backed pouch, which adheres to the package (typically supplied by the courier) and placed on the cooler lid as shown in Attachment 5.
2. **Soil Import Permit and USDA Letter** (soil only) - See Attachments III-G-9 and III-G-10 for examples. The laboratory shall supply these documents prior to mobilization. The USDA in Hawaii often does stop shipments of soil without these documents. The 2" x 2" USDA label (described below), the USDA letter, and soil impact permit should be stapled together and placed inside a clear plastic pouch. Clear plastic and adhesive-backed pouches are typically supplied by the mailing courier.
3. The analytical laboratory should supply the Soil Import Permit. Although original labels are preferred, copies of this label, which are cut out to the 2" x 2" dimensions, are acceptable. Placing one label (as shown in Attachment III-G-5) covered with clear packing tape and one stapled to the actual permit is suggested.
4. The USDA does not control water samples, thus the requirements for soils listed above do not apply.
5. **Custody Seals**. Task Order personnel must sign and date custody seals. At least two seals should be placed in such a manner that they stick to both the cooler lid and body. The seals shall be placed so the cooler/container cannot be opened without breaking the seal. The custody seals are then covered with clear packing tape. This prevents the seal from coming loose and enables detection of tampering.
6. **Address Label**. A label stating the destination (the sending and laboratory, company, or location address) should be affixed to each cooler. The label should also include both telephone numbers.
7. **Special Requirements for Hazardous Materials** - see Section 2.2.1.

Upon receipt of sample coolers at the laboratory, the sample custodian shall inspect the sample containers as discussed in SOP III-E, *Record Keeping, Sample Labeling, and Chain-of-Custody Procedures*. 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.

## 3.0 DOCUMENTATION

Records shall be maintained as required by implementing these procedures.

## 4.0 REFERENCES

HM-126F, Training for Safe Transportation of Hazardous Materials

SOP III-E, Record Keeping, Sample Labeling, and Chain-of-Custody Procedures

## 5.0 ATTACHMENTS

Attachment III-G-1 Example Package Marking

Attachment III-G-2 Packing Groups

Attachment III-G-3 Label for Dangerous Goods in Excepted Quantities

Attachment III-G-4 SW-846 Preservative Exception

Attachment III-G-5 Sample Cooler Marking Figure

Attachment III-G-6 Example Courier Form

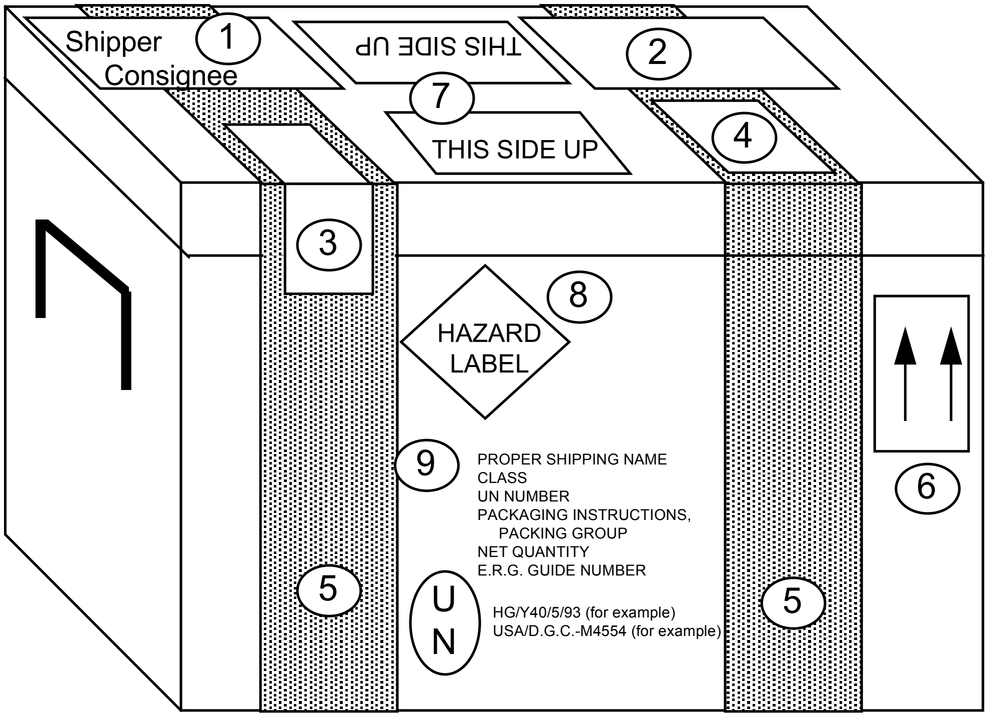
Attachment III-G-7 Commercial Invoice - Soil

Attachment III-G-8 Commercial Invoice - Water

Attachment III-G-9 Soil Import Permit

Attachment III-G-10 Soil Samples Restricted Entry Labels

## Attachment III-G-1
## Example Hazardous Material Package Marking



① **AIR BILL/COMMERCIAL INVOICE**

② **USDA PERMIT (Letter to Laboratory from USDA)**

③ **CUSTODY SEAL**

④ **USDA 2" X 2" SOIL IMPORT PERMIT**

⑤ **WATERPROOF STRAPPING TAPE**

⑥ **DIRECTION ARROWS STICKER - TWO REQUIRED**

⑦ **THIS SIDE UP STICKERS**

⑧ **HAZARD LABEL**

⑨ **HAZARDOUS MATERIAL INFORMATION**

⑩ **PACKAGE SPECIFICATIONS**

## Attachment III-G-2
## Packing Groups

| Packing Group of the Substance | | Packing Group I | | 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.

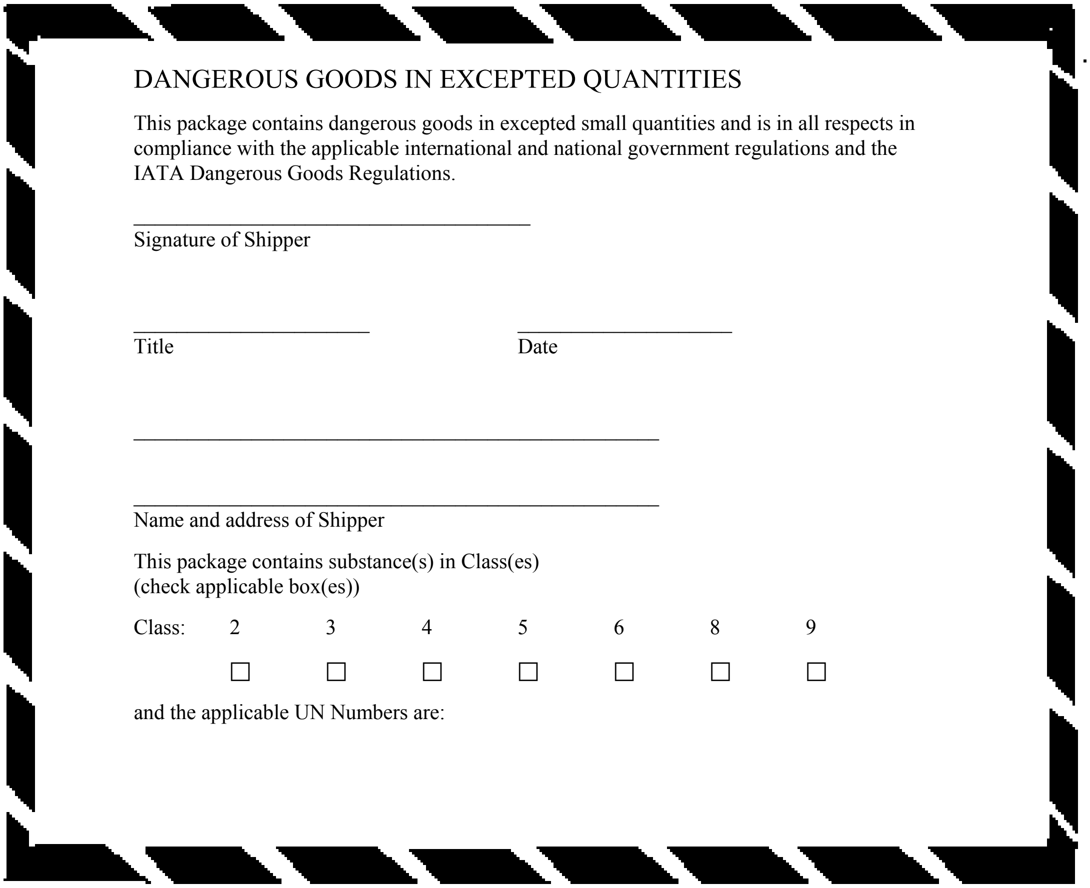
Note B: For inner packagings, the quantity contained in receptacle with a water capacity of 30 mL. For outer packagings, the sum of the water capacities of all the inner packagings contained must not exceed 1 L.

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 III-G-3
## Label For 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 |
| | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

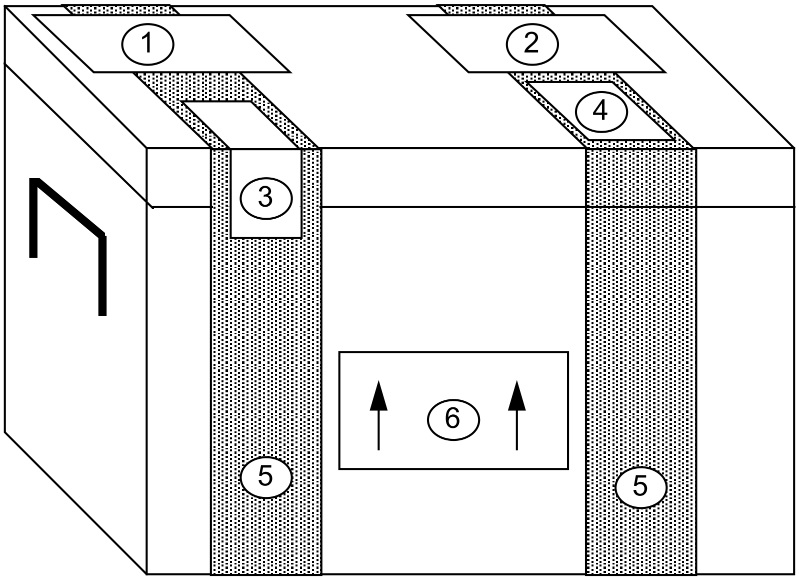
and the applicable UN Numbers are:

## ATTACHMENT III-G-4
## Preservative Exception

| Measurement | Vol. Req. (mL) | Container$^{2}$ | Preservative $^{3,4}$ | Holding Time$^{5}$ |
|---|---|---|---|---|
| MBAS | 2<br>50 | P,G | Cool, 4ºC | 48 Hours |
| NTA | 5<br>0 | 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 grater); 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 III-G-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 III-G-6
## Example Courier Form

**FedEx** USA Airbill FedEx Tracking Number 801704855619 0200 Form I.D. No.

SPL11

**Sender's Copy**

**1 From** (please print and press hard)

Date Sender's FedEx Account Number [redacted] Account Number

Sender's Name Joe Smith Phone (808) 545-2462

Company OGDEN ENVIRONMENTAL/CRC ACCT

Address 680 IWILEI RD STE 660 Dept/Floor/Suite/Room

City HONOLULU State HI ZIP 96817

**2** Your Internal Billing Reference Information
(Optional) (First 24 characters will appear on invoice)

**3 To** (please print and press hard)

Recipient's Name Sample Receipt Phone ( ) Lab Phone #

Company Lab Name

☐ Check here if residence (Extra charge applies for FedEx Express Saver)

Address Lab Address
(To "HOLD" at FedEx location, print FedEx address here) (We Cannot Deliver to P.O. Boxes or P.O. ZIP Codes) Dept/Floor/Suite/Room

City State ZIP

**For HOLD at FedEx Location check here**
☐ Hold Weekday (Not available with FedEx First Overnight)
☐ Hold Saturday (Not available at all locations) (Available for FedEx Priority Overnight and FedEx 2Day only)

**For Saturday Delivery check here**
☐ (Extra Charge. Not available to all locations) (Available for FedEx Priority Overnight and FedEx 2Day only)

**Service Conditions, Declared Value, and Limit of Liability** – By using this Airbill, you agree to the service conditions in our current Service Guide or U.S. Government Service Guide. Both are available on request. SEE BACK OF SENDER'S COPY OF THIS AIRBILL FOR INFORMATION AND ADDITIONAL TERMS. We will not be responsible for any claim in excess of $100 per package whether the result of loss, damage, or delay, non-delivery, misdelivery, or misinformation, unless you declare a higher value, pay an additional charge, and document your actual loss in a timely manner. Your right to recover from us for any loss includes intrinsic value of the package, loss of sales, interest, profit, attorney's fees, costs, and other forms of damage, whether direct, incidental, consequential, or special, and is limited to the greater of $100 or the declared value but cannot exceed actual documented loss. The maximum declared value for any FedEx Letter and FedEx Pak is $500. Federal Express may, upon your request, and with some limitations, refund all transportation charges paid. **See the FedEx Service Guide for further details.**

**Questions?**
**Call 1·800·Go·FedEx** (800)463-3339

*The World On Time*®

**4a Express Package Service** *Packages under 150 lbs.* Delivery commitment may be later in some areas.
☐ FedEx Priority Overnight (Next business morning)
☐ FedEx Standard Overnight (Next business afternoon)
☐ FedEx 2Day* (Second business day)
☐ FedEx Express Saver* (Third business day)
☐ FedEx First Overnight (Earliest next business morning delivery to select locations) (Higher rates apply)
* FedEx Letter Rate not available. Minimum charge: One pound rate.

**4b Express Freight Service** *Packages over 150 lbs.* Delivery commitment may be later in some areas.
☐ FedEx Overnight Freight (Next business day)
☐ FedEx 2Day Freight (Second business day)
☐ FedEx Express Saver Freight (Up to 3 business days)
(Call for delivery schedule. See back for detailed descriptions of freight services.)

**5 Packaging** ☐ FedEx Letter ☐ FedEx Pak (Declared value limit $500.) ☐ FedEx Box ☐ FedEx Tube ☐ Other Pkg.

**6 Special Handling**
**Does this shipment contain dangerous goods?** ☐ Yes (As per attached Shipper's Declaration) ☐ Yes (Shipper's Declaration not required)
☐ Dry Ice
Dry Ice, 9, UN 1845 III ______ x ______ kg. 904
(Dangerous Goods Shipper's Declaration not required)
CA ☐ Cargo Aircraft Only

**7 Payment**
Bill to: ☐ Sender (Account no. in section 1 will be billed) ☐ Recipient ☐ Third Party ☐ Credit Card ☐ Cash/Check
(Enter FedEx account no. or Credit Card no. below)
FedEx Account No.
Credit Card No. Exp. Date

| Total Packages | Total Weight | Total Declared Value* | Total Charges |
|---|---|---|---|
| | | $ .00 | $ |

*When declaring a value higher than $100 per shipment, you pay an additional charge. See **SERVICE CONDITIONS, DECLARED VALUE, AND LIMIT OF LIABILITY** section for further information.

**8 Release Signature** *Sign to authorize delivery without obtaining signature.*

Your signature authorizes Federal Express to deliver this shipment without obtaining a signature and agrees to indemnify and hold harmless Federal Express from any resulting claims.

287

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003520091 4

RETAIN THIS COPY FOR YOUR RECORDS

## Attachment III-G-7
## Commercial Invoice - Soil

| | |
|---|---|
| DATE OF EXPORTATION<br>1/1/94 | EXPORT REFERENCES (i.e., order no., invoice no., etc.)<br><CTO #> |
| SHIPPER/EXPORTER (complete name and address)<br>Joe Smith<br>Ogden<br>c/o <hotel name><br><hotel address> | CONSIGNEE<br>Sample Receipt<br><Lab Name><br><Lab Address> |
| COUNTRY OF EXPORT<br>Guam, USA | IMPORTER - IF OTHER THAN CONSIGNEE |
| COUNTRY OF ORIGIN OF GOODS<br>Guam, USA | |
| COUNTRY OF ULTIMATE DESTINATION<br>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<br>☐ F.O.B.<br>☐ C&F<br>☐ C.I.F. |

THESE COMMODITIES ARE LICENSED FOR THE ULTIMATE DESTINATION SHOWN.

DIVERSION CONTRARY TO UNITED STATES LAW IS PROHIBITED.

I DECLARE ALL THE INFORMATION CONTAINED IN THIS INVOICE TO BE TRUE AND CORRECT

SIGNATURE OF SHIPPER/EXPORTER (Type name and title and sign)

| Name/Title | Signature | Date |
|---|---|---|
| Joe Smith, Ogden | Joe Smith | 1/1/94 |

## ATTACHMENT III-G-8

## Commercial Invoice - Water

| | |
|---|---|
| DATE OF EXPORTATION<br>1/1/94 | EXPORT REFERENCES (i.e., order no., invoice no., etc.)<br><CTO #> |
| SHIPPER/EXPORTER (complete name and address)<br>Joe Smith<br>Ogden<br>c/o <hotel name><br><hotel address> | CONSIGNEE<br>Sample Receipt<br><Lab Name><br><Lab Address> |
| COUNTRY OF EXPORT<br>Guam, USA | IMPORTER - IF OTHER THAN CONSIGNEE |
| COUNTRY OF ORIGIN OF GOODS<br>Guam, USA | |
| COUNTRY OF ULTIMATE DESTINATION<br>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<br>☐ F.O.B.<br>☐ C&F<br>☐ C.I.F. |

THESE COMMODITIES ARE LICENSED FOR THE ULTIMATE DESTINATION SHOWN.

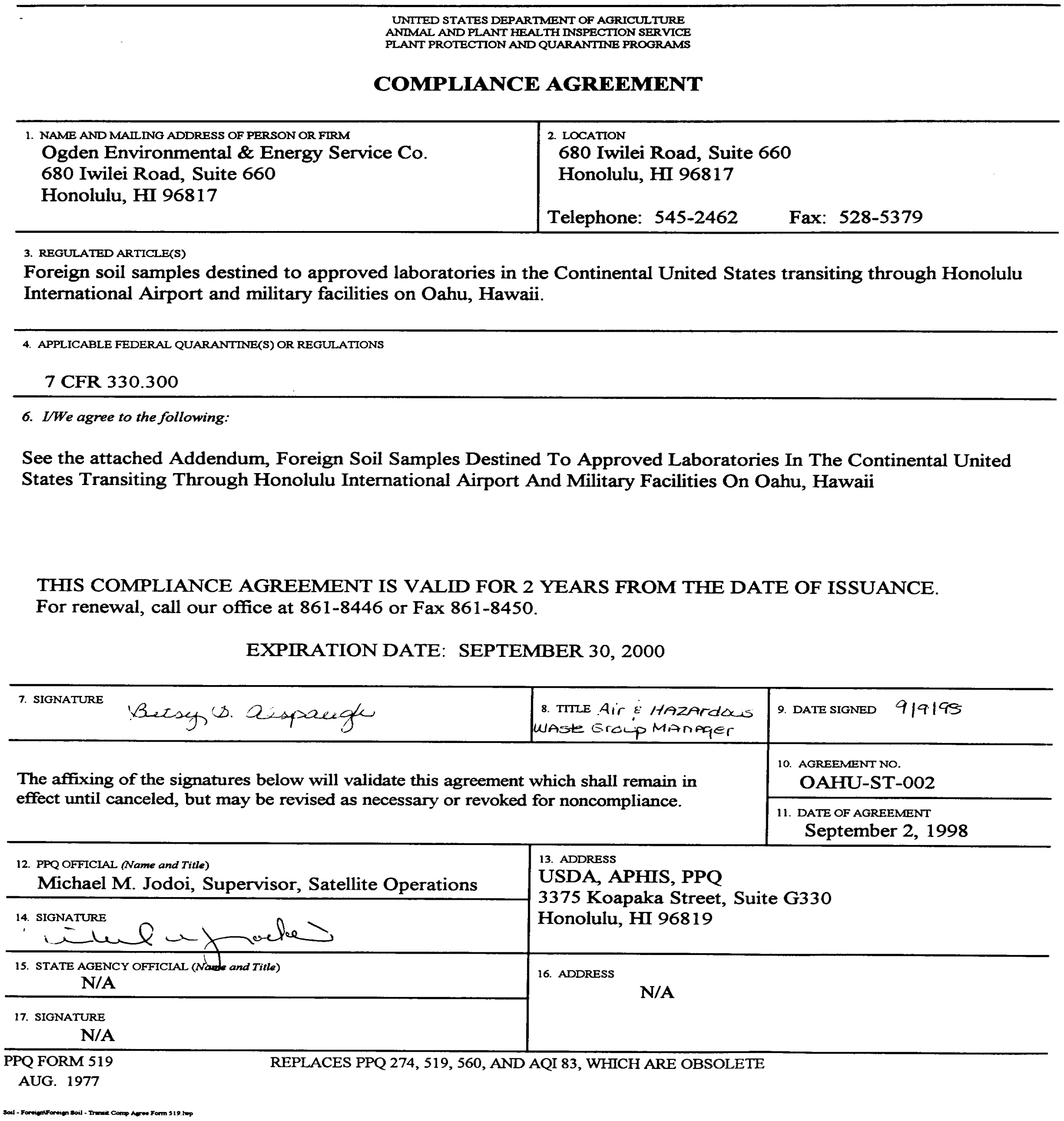
DIVERSION CONTRARY TO UNITED STATES LAW IS PROHIBITED.

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 III-G-9
## Soil Import Permit



UNITED STATES DEPARTMENT OF AGRICULTURE
ANIMAL AND PLANT HEALTH INSPECTION SERVICE
PLANT PROTECTION AND QUARANTINE PROGRAMS

### COMPLIANCE AGREEMENT

1. NAME AND MAILING ADDRESS OF PERSON OR FIRM
Ogden Environmental & Energy Service Co.
680 Iwilei Road, Suite 660
Honolulu, HI 96817

2. LOCATION
680 Iwilei Road, Suite 660
Honolulu, HI 96817
Telephone: 545-2462 Fax: 528-5379

3. REGULATED ARTICLE(S)
Foreign soil samples destined to approved laboratories in the Continental United States transiting through Honolulu International Airport and military facilities on Oahu, Hawaii.

4. APPLICABLE FEDERAL QUARANTINE(S) OR REGULATIONS
7 CFR 330.300

6. *I/We agree to the following:*

See the attached Addendum, Foreign Soil Samples Destined To Approved Laboratories In The Continental United States Transiting Through Honolulu International Airport And Military Facilities On Oahu, Hawaii

THIS COMPLIANCE AGREEMENT IS VALID FOR 2 YEARS FROM THE DATE OF ISSUANCE.
For renewal, call our office at 861-8446 or Fax 861-8450.

EXPIRATION DATE: SEPTEMBER 30, 2000

7. SIGNATURE Betsy D. Aispaugh
8. TITLE Air & Hazardous Waste Group Manager
9. DATE SIGNED 9/9/98

The affixing of the signatures below will validate this agreement which shall remain in effect until canceled, but may be revised as necessary or revoked for noncompliance.

10. AGREEMENT NO. OAHU-ST-002
11. DATE OF AGREEMENT September 2, 1998

12. PPQ OFFICIAL (*Name and Title*)
Michael M. Jodoi, Supervisor, Satellite Operations

13. ADDRESS
USDA, APHIS, PPQ
3375 Koapaka Street, Suite G330
Honolulu, HI 96819

14. SIGNATURE

15. STATE AGENCY OFFICIAL (*Name and Title*)
N/A

16. ADDRESS
N/A

17. SIGNATURE
N/A

PPQ FORM 519
AUG. 1977

REPLACES PPQ 274, 519, 560, AND AQI 83, WHICH ARE OBSOLETE

Soil - Foreign\Foreign Soil - Transit Comp Agree Form 519.lwp

## Attachment III-G-10
## 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)

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.

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PPQ FORM 550 Edition of 12/77 may be used
(JAN 83)

U.S. DEPARTMENT OF AGRICULTURE
ANIMAL AND PLANT HEALTH INSPECTION SERVICE
PLANT PROTECTION AND QUARANTINE
HYATTSVILLE, MARYLAND 20782
soil samples
restricted entry

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The material contained in this package is imported under authority of the Federal Plant Pest Act of May 23, 1957.

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For release without treatment if addressee is currently listed as approved by Plant Protection and Quarantine.

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PPQ FORM 550 Edition of 12/77 may be used
(JAN 83)

# EQUIPMENT DECONTAMINATION

## 1.0 PURPOSE

The standard operating procedure (SOP) describes general methods of equipment decontamination (decon) for use by U.S. Naval Facilities Engineering Command Northwest (NAVFAC NW) field personnel and their contractors during field sampling activities. Some sites may require additional steps (e.g. nitric rinses for metals, hexane for chlorinated pesticides) to insure equipment is properly deconned. These should be identified and addressed in the Work Plans and/or the Quality Assurance Project Plans (QAPPs)

## 2.0 PROCEDURES

Decontamination of equipment is necessary to prevent cross-contamination and to maintain the highest integrity possible in collected samples. Planning a decontamination program should include consideration of the following factors:

- The location where the decon procedures will be conducted
- The types of equipment requiring decon
- The frequency of equipment decontamination
- The cleaning technique and types of cleaning solutions appropriate to the contaminants of concern
- The method for containing the residual contaminants and wash water from the deconning process
- The use of a quality control measure to determine the effectiveness of the decontamination procedure (e.g. equipment rinsate samples)

This subsection describes standards for decontamination, including the techniques to be used, frequency of decontamination, cleaning solutions, and effectiveness.

### 2.1 DECONTAMINATION AREA

An appropriate location for the decontamination area at a site shall be selected on the basis of the ability to control access to the area, control residual material removed from equipment, the need to store dirty and clean equipment, and the ability to restrict access to the area being investigated. The decontamination area shall be located an adequate distance away and upwind from potential contaminant sources to avoid contamination of clean equipment.

### 2.2 TYPES OF EQUIPMENT

Examples of drilling equipment that must be deconned includes drill bits, auger sections, split spoon samplers, and hand tools. Decontamination of monitoring well development and ground-water sampling equipment includes submersible pumps, non-disposable bailers, interface probes, water level meters, bladder pumps, airlift pumps, and lysimeters. Other sampling equipment that may require 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, COLIWASA samplers, and dippers. Equipment with a porous surface, such as rope, cloth hoses, and wooden blocks, cannot be thoroughly decontaminated and should be properly disposed of after one use.

### 2.3 FREQUENCY OF EQUIPMENT DECONTAMINATION

Down-hole drilling equipment and equipment used in monitoring well development and purging shall be decontaminated prior to initial use and between each borehole or well. However, down hole drilling equipment 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, the drilling tools shall be decontaminated prior to drilling deeper. Groundwater sampling should be initiated by sampling ground water from the monitoring well where the least contamination is suspected. This is more important when not using disposable equipment. All groundwater, surface water, and soil sampling devices shall be decontaminated prior to initial use and between collection of each sample to prevent the possible introduction of contaminants into successive samples.

### 2.4 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, pump drop-pipe, etc., is steam cleaning. Steam cleaning is accomplished using a portable, high-pressure steam cleaner equipped with a pressure hose and fittings. For this method, equipment shall be thoroughly steam washed and rinsed 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 non-phosphate detergent (Citrinox®, Liquinox®, or other suitable phosphate free detergent) and potable water solution, (2) rinse with potable water, and (3) rinses with deionized or distilled water. Equipment shall be disassembled as much as is practical, prior to cleaning. An initial gross wash scrub down and quick rinse should be completed at the beginning of the process if equipment is heavily soiled. After decontamination, care needs to be taken that the cleaned equipment does not become contaminated. This may require wrapping items in foil or plastic and storing the equipment in a specified “clean” area.

Decontaminating submersible pumps requires additional effort because internal surfaces become contaminated during usage. The pumps shall be decontaminated by circulating fluids through the pump while it is operating. This circulation can be done using a clean 4-inch or greater diameter pipe equipped with an end cap. The pipe shall be filled with enough decon fluid to submerge the pump, the pump placed within the capped pipe, and the pump operated while circulating the fluids within the pipe. The decontamination sequence shall include (1) detergent and potable water, (2) potable water rinse, and (3) deionized or distilled water rinse. The decontamination fluids shall be changed after each cycle. Changing of the fluids may include dumping of the detergent water, mixing detergent in the potable water rinse, using the deionized water as the potable rinse and renewing the distilled/deionized water. All decon water shall be disposed of as outlined in the field work plans.

Decontamination solvent(s) to be used during field activities will be specified in Project Work Plans or QAPPs. If solvents are used, sufficient time must be allowed to insure the solvent has evaporated from the equipment prior to reuse.

Equipment used for measuring field parameters such as pH, temperature, specific conductivity, and turbidity shall be rinsed with deionized or distilled water. New, unused soil sample liners and caps will be cleaned using the three step process, outlined above, to remove any dirt or cutting oils that may be on them prior to use.

### 2.5 CONTAINMENT OF RESIDUAL CONTAMINANTS AND CLEANING SOLUTIONS

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. This may require setting up a containment area with a system for pumping the water generated decontamination water into proper containers.

Clean equipment should be stored in a separate location to prevent recontamination. Decontamination fluids contained within the bermed area shall be collected and disposed of as outlined in the field sampling plan.

Containment of fluids from the decontamination of lighter-weight drilling equipment and hand-held sampling devices shall be accomplished using wash buckets or tubs. The decontamination fluids shall be collected and disposed of as outlined in the field sampling plan.

### 2.6 EFFECTIVENESS OF DECONTAMINATION PROCEDURES

A decontamination program must incorporate quality control measures to determine the effectiveness of cleaning methods. Quality control measures typically include collection of equipment rinsate samples or wipe testing. Equipment rinsates consist of analyte-free water that has been poured over or through the sample collection equipment after its final decontamination rinse. Wipe testing is performed by wiping a cloth over the surface of the equipment after cleaning. Further descriptions of these samples and their required frequency of collection are provided in SOP III-B, *Field QC Samples (Water, Soil)*. 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.

## 3.0 DOCUMENTATION

The decontamination process shall be recorded in the field logbook.

## 4.0 REFERENCES

SOP III-B, *Field QC Samples (Water, Soil).*

## 5.0 ATTACHMENTS

None.

# EQUIPMENT CALIBRATION, OPERATION, AND MAINTENANCE

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## 1.0 PURPOSE

This standard operating procedure (SOP) describes the activities and responsibilities of the U.S. Naval Facilities Engineering Command Northwest (NAVFAC NW) personnel pertaining to the operating, calibration, and maintenance of equipment used to collect environmental data. Reliable measurements of data required by the field sampling plan are necessary because the information recorded may be the basis for development of remedial action and responses.

## 2.0 PROCEDURES

### 2.1 EQUIPMENT CALIBRATION

All water quality monitoring equipment will be calibrated and adjusted to operate within the manufacturers' specifications. Water quality instruments and equipment that require calibration are to be calibrated to specifications prior to field use. In addition, a one-point calibration check is made at midday and at intervals outlined in the field sampling plan. A final check is conducted at the end of each field day. This is not a recalibration of the meter but a check of the calibration to ensure the continued accuracy of the meter. All calibration information shall be recorded in the project logbook.

Special attention shall be paid to instruments that may be affected by the change in the ambient temperature or humidity. Calibration checks should also be performed when sampling conditions change significantly, a change of sample matrix, and/or readings are unstable or there is a change of parameter measurements that appear unusual.

### 2.2 EQUIPMENT MAINTENANCE

All field monitoring equipment, field sampling equipment, and accessories are to be maintained in accordance with the manufacturer's recommendations and specifications and/or established field practices. All maintenance will be performed by qualified personnel and documented in the field logbook.

Equipment requiring battery charging shall be charged as recommended by the manufacturer. Backup batteries for meters requiring them shall be included as part of the meters accessories. Care must be taken to protect meters from adverse elements. This may involve placing the meter in a large plastic bag to shield it from the weather.

## 3.0 DOCUMENTATION

All field equipment calibration, maintenance, and operation information shall be recorded within the field logbook. This is to document that appropriate procedures have been followed and to track the equipment operation. All entries in the field logbook must be written accurately and legibly as outlined in the SOP III-D, *Logbooks*.

Logbook entries shall contain, but are not necessarily limited to, the following:

- Equipment model and serial numbers
- Date and time of calibration or maintenance performed
- Calibration standard used
- Calibration lot number and expiration date if listed on bottle
- Calibration procedure used if there are multiple options
- Calibration and calibration check readings including units used
- Problems and solutions regarding use, calibration or maintenance of the equipment
- And other pertinent information

## 4.0 REFERENCES

SOP III-D, *Logbooks*

## 5.0 ATTACHMENTS

None.

STANDARD OPERATING PROCEDURE

# Continuous Water Level Measurements

## I. Purpose and Scope

The purpose of this procedure is to provide a guideline for the measurement of the depth to groundwater using continuously recording data loggers and pressure transducers.

## II. Equipment and Materials

- Pressure transducers and data loggers (pressure transducers with built-in data loggers are also acceptable). The pressure rating should be appropriate for the anticipated range of submergence depths of each transducer.
- Portable computers and/or external data storage devices.

## III. Procedures and Guidelines

- Synchronize time recording devices to the computer that will be used to program the data-logging pressure transducers before each aquifer test.
- Deploy transducers below the static water level in a given well. Depth of deployment will be determined by the FTL.
- Data-logging pressure transducers will be equipped with direct read cable so that the transducer functionality and data quality can be verified during the aquifer testing program.
- Secure transducers to the wells (e.g. using a slip mesh wire loop) such that the deployment depths do not shift during the aquifer test.
- Record automatic water level readings via data-logging pressure transducers using a linear or logarithmic time scale. A logarithmic time-scale is preferred for locations in which rapid initial changes in water levels are expected, such as pumping wells. A linear scale is generally sufficient for observation wells, unless pre-test activities indicate that rapid water level changes are expected at the observation wells. Follow the instruction manual for transducer setup.
- During the first hour of any test, monitor data loggers frequently. After the first hour, monitoring shall continue at least hourly.
- Reset pumping well transducer to begin logging logarithmically after pumping ceases.
- Download data from the transducers at the groundwater level monitoring period such as at the end of the aquifer test. Do not stop and restart tests during data

downloads. Collect manual water level measurements during transducer download.

- Remove pressure transducers and data loggers from the wells and decontaminate equipment after aquifer test is complete.

# IV. Data Analysis

Depending on the type of aquifer and local setting, a variety of analysis techniques are available for data interpretation.

# V. Attachments

None.

# VI. Key Checks

- Equipment must be decontaminated and inspected before and after each use to ensure it is in good condition.
- Transducers and data loggers must be calibrated and tested before aquifer testing begins.
- Prior to deployment, verify that transducers have sufficient memory and battery capacity to store the anticipated number of measurements.

STANDARD OPERATING PROCEDURE

# Multi RAE Photoionization Detector (PID)

## I. Purpose

The purpose of this SOP is to provide general reference information for using the Multi RAE PID in the field. Calibration and operation, along with field maintenance, will be included in this SOP.

## II. Scope

This procedure provides information on the field operation and general maintenance of the Multi RAE PID. Review of the information contained herein will ensure that this type of field monitoring equipment will be properly utilized. Review of the owner's instruction manuals is a necessity for more detailed descriptions.

## III. Definitions

Carbon Monoxide Sensor (CO) - Carbon Monoxide concentration in ppm.

Volatile Organic Compound (VOC) – VOC concentration in ppm

Lower Explosive Limit (LEL) - Combustible gas is expressed as a percent of the lower explosive limit.

Hydrogen Sulfide Sensor ($H_2S$) - Hydrogen Sulfide concentration in ppm.

Oxygen Sensor (OXY) - Oxygen concentration as a percentage.

ppm - parts per million: parts of vapor or gas per million parts of air by volume.

## IV. Procedures

The PID operates on the principle that most organic compounds and some inorganic compounds are ionized when they are bombarded by high-energy ultraviolet light. The air sample is drawn across a UV lamp using a pump or a fan. The energy of the lamp determines whether a particular chemical will be ionized. Each chemical compound has a unique photoionization potential (PIP). When the UV light energy is greater than the ionization potential of the chemical, ionization will occur. All PID readings are relative to the calibration gas, usually isobutylene.

It is important to calibrate the PID in the same temperature and elevation that the equipment will be used, and to determine the background concentrations in the field before taking measurements. For environments where background readings are high, factory zero calibration gas should be used.

Note: For volatile and semi-volatile compounds, knowing the PIP is critical in determining the appropriate instrument to use when organic vapor screening. Consult the QAPP and manufacturer's manual to determine that the proper instrument has been selected for the contaminate vapors of interest. If an expected compound at a site has a PIP less than 11.7 eV, it is possible to use a PID. If the ionization potential is greater than 11.7eV, a flame-ionization detector is required.

The following subsections will discuss Mini RAE calibration, operation, and maintenance. These sections, however, do not take the place of the instruction manual.

## A. Calibration

For Multi RAE configured with $O_2$, LEL, $H_2S$, CO, sensors and a 10.6 eV PID Lamp.

**Start up Instrument**

- Press **Mode** button
- Observe displays:

On!……..

Multi RAE
Version X.XX

Model Number
SN XXXX

Date Time
Temp

Checking Sensor
Ids….

VOC Installed

CO Installed

$H_2S$ Installed

OXY Installed

LEL Installed

$H_2S$ VOC CO
LEL OXY

```
Alarm Limits=
```

```
XX XX.X XX
XX High XX.X
```

```
XX XX.X XX
XX Low XX.X
```

```
XX XX.X XX
 STEL
```

```
XX XX.X XX
 TWA
```

```
Battery = X.XV
Shut off at 4.2V
```

```
User Mode=
```

```
Alarm Mode=
```

```
Datalog Time Left
```

```
Datalog Mode
```

```
Datalog Period
```

```
Unit ready in…..
10 Seconds
```

- The pump will start, the seconds will count down to zero, and the instrument will be ready for use

### Calibration Check and Adjustment

Allow instrument to warm up for 15 minutes.

- Depress the **[N/-]** key first, then while depressing the **[N/-]**, depress the **[Mode]** key also and depress both keys for 5 seconds.
- Display will read:

```
Calibrate
Monitor?
```

- Press the **[Y/+]** key
- Display will read:

Fresh Air
Calibration?

- If "Zero Air" is necessary, attach the calibration adapter over the inlet port of the Multi RAE Monitor and connect the other end of the tube to the gas regulator (HAZCO loaner regulator LREG.5, RAE Systems P/N 008-3011 or suitable .5 LPM regulator) on the Zero Air bottle (HAZCO P/N SGZA, RAE P/N 600-0024). If no Zero Air is available, perform the Fresh Air Calibration in an area free of any detectable vapor.
- Press the **[Y/+]** key
- Display will read:

Zero….
In progress…

CO Zeroed!
Reading = X

VOC Zeroed!
Reading = X

LEL Zeroed!
Reading = X

OXY Zeroed!
Reading = X

Zero Cal done!
$H_2S$ Zeroed!
Reading = X

In each of the above screens, "X" is equal to the reading of the sensor before it was zeroed.

- Display will then read:

Multiple Sensor
Calibration?

- Press the **[Y/+]** key
- The display shows all of the pre-selected sensors and the "OK?" question:

CO $H_2S$
LEL OK? OXY

- Apply calibration gas – use either HAZCO Services Part Number R-SGRAE4 or Rae Systems Part Number 008-3002 – using a .5 LPM regulator and direct tubing.
- Press the **[Y/+]** key. Display will read:

Apply Mixed gas

Calibration
In progress …

- The display will count down showing the number of remaining seconds:

CO cal'ed
Reading=50

$H_2S$ cal'ed
Reading=25

LEL cal'ed
Reading=50

OXY cal'ed
Reading=20.9

Calibration done
Turn off gas!

- Display will read:

Single Sensor
Calibration?

- Press the **[Y/+]**.
- Display will read:

CO VOC $H_2S$
LEL pick? OXY

- Attach 100 ppm Isobutylene (HAZCO P/N r-SGISO or Rae P/N 600-0002) using a 1.0 LPM regulator (HAZCO P/N LR10HS or Rae P/N 008-3021). Open regulator.
- Press the **[Mode]** key once, the V of VOC will be highlighted.
- Press the **[Y/+]**. The display will read:

Apply VOC Gas

Calibration
In progress…

- The display will count down showing the number of remaining seconds:, then display:

VOC cal'd
Reading=100

Calibration done
Turn off gas!

Single Sensor
Calibration?

- Press **[Mode]** key twice to return to main screen.

- **CALIBRATION IS COMPLETE!**

### B. Operation

Due to the Multi RAE having many functions in terms of operation, it is recommended that you follow the operational procedures as outlined in the instruction manual from pages 9 to 14.

### C. Site Maintenance

After each use, the meter should be recharged and the outside of the instruments should be wiped clean with a soft cloth.

### D. Scheduled Maintenance

| Function | Frequency |
|---|---|
| Check alarm and settings | Monthly/before each use |
| Clean screens and gaskets around sensors | Monthly |
| Replace sensors | Biannually or when calibration is unsuccessful |

## V. Quality Assurance Records

Quality assurance records will be maintained for each air monitoring event. The following information shall be recorded in the field logbook.

- Identification - Site name, date, location, CTO number, activity monitored, (surface water sampling, soil sampling, etc), serial number, time, resulting concentration, comments and identity of air monitoring personnel.
- Field observations - Appearance of sampled media (if definable).
- Additional remarks (e.g, Multi RAE had wide range fluctuations during air monitoring activities.)

## VI. References

Multi RAE Plus Multiple Gas Monitor User Manual, RAE Systems, Revision B1, November 2003.

**DRAFT FINAL STANDARD OPERATING PROCEDURE – Navy CLEAN PROGRAM**

# Groundwater Sampling for Per- and Polyfluoroalkyl Substances (PFAS)

## I. Purpose and Scope

This SOP provides guidelines for groundwater sample collection for samples that will be analyzed for per- and polyfluoroalklyl substances (PFAS) via LC/MS/MS Compliant with QSM 5.1 Table B-15. This SOP should be used in conjunction with approved region-specific groundwater sampling SOPs which provide methods for general and low-flow groundwater sampling. In cases in which information in this SOP conflicts with region-specific groundwater sampling SOPs, this SOP will supersede the information in the general SOPs.

Standard techniques for collecting representative samples are summarized. These procedures are specific to the Navy Comprehensive Long-term Environmental Action Navy (CLEAN) Program under Contract N62470-16-D-9000. Materials, equipment, and procedures may vary; refer to the Sampling and Analysis Plan and operator's manuals for specific details.

## II. Equipment and Materials

### Equipment and Materials Required

- If installing wells, ensure driller does not use polytetrafluoroethylene (PFTE)-containing drill lube or other drilling lubes containing PFAS. Biolube has been determined to be an acceptable drilling lube for installing wells where PFAS may be of concern. Additionally, Waterra surge blocks have been confirmed to not contain PFAS and may be used for development.
- Groundwater sampling equipment
  - PFAS-free tubing (avoid Teflon, Viton, PTFE and other fluorinated compounds)
    - High density polyethylene tubing (unlined)
    - If Masterflex tubing is needed for peristaltic pumps, Cole Parmer C-Flex (06424 series) and Tygon E-3603 (06509 series) are suitable options
  - PFAS-free Bailer (if using a bailer[1])
  - PFAS-free Pump such as:
    - Geotech PFAS-free Portable Bladder Pump (note, most bladder pumps include a Teflon-lined bladder, but Geotech currently has one model which is Teflon-free).
    - Panacea P120 or P125. The P200 Stainless Steel Pump may also be used, but the standard model contains Teflon at the tube connection. If you are using this Panacea model, you must request one with the "PTFE-free thread sealant option."
    - Waterra stainless foot-valve
    - QED Sample Pro

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[1] Geotech and Waterra offer PFAS free bailer options

    - Monsoon or Mega Monsoon submersible pump
    - Grundfos Rediflo2 (this pump contains small Teflon components, but has not been shown to leach, it is less preferable than the other options)
    - Peristaltic pump (may be suitable for shallow locations)
- Groundwater sample containers (high density polyethylene [HDPE] bottle with HDPE screwcap), sample bottles should not be glass as glass may sorb PFAS. Sample bottle caps should not contain Teflon. Notify your project manager (PM) if bottles provided by the lab are glass or contain Teflon parts.
- Laboratory prepared deionized, certified PFAS-free water for field blank collection
- PFAS-free shipping supplies (labels [if available][2], coolers, and ice)
- Loose leaf paper without waterproof coating or a spiralbound notebook (not waterproof)
- Metal clip board (if using loose-leaf paper)
- Pen (not Sharpie)
- Nitrile or latex gloves

## Equipment and Materials to Avoid During Sampling

Equipment and materials used to collect groundwater samples should not contain any fluorinated compounds, Teflon, or synthetic rubber with fluoropolymer elastomers (e.g., Viton).

Specifically, the following material should be avoided during sampling:

- Gore-Tex brand or similar high-performance outdoor clothing, clothing treated with ScotchGuard brand or similar water repellent, fluoropolymer-coated Tyvek, wrinkle-resistant fabrics, and fire-resistant clothing with fluorochemical treatment or anything advertised as water repellant.
- Weather-proof log books with fluorochemical coatings
- New clothing that has been washed fewer than six times

The sample collection area should be clear of the following items:

- Pre-packaged food wrappers (e.g., fast food sandwich wrappers, pizza boxes, etc.)
- Microwave popcorn bags
- Blue ice containers
- Aluminum foil
- Kim-Wipes
- Sunscreen, insect repellant and other personal hygiene products that may contain PFAS

Research which has not yet been published has allowed us to generate a list of sunscreens and insect repellents which do not contain fluorine. Check with Bill Diguiseppi or Laura Cook on recommendations (because the research is not ours, it cannot be released externally at this time).

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[2] Efforts will be made to obtain PFAS-free labels; however, information on labels is scarce and labels are frequently mounted on PFAS-coated paper to allow for easy removal.

# III. Procedures and Guidelines

Wash hands with dish detergent before sampling and don nitrile gloves. Do not use Kleen Guard powder free nitrile gloves which were shown in research to contain fluorine

Follow Navy CLEAN SOPs for low-flow or conventional groundwater sample collection, depending on site requirements.

## Sample Collection

Once water quality parameters have stabilized for low-flow purging, samples can be collected. For conventional purging, if water quality parameters do not stabilize, a minimum of 3 well volumes must be purged prior to sample collection.

The steps to be followed for sample collection are as follows:

1. Ensure that the end of the tubing does not touch the ground or equipment. Remove the cap from the sample bottle. Position the sample bottle under the end of the tubing.
2. Fill the bottle. Samples do not need to be collected headspace free.
3. Affix labels after bottles have been closed; collect only one sample at a time to avoid mislabeling. Pack the sample on ice immediately for shipment to the offsite laboratory. Avoid packing materials that may contain fluorine. Unpublished research has allowed us to generate a list of packing materials which do not contain fluorine. Please contact Bill Diguiseppi or Laura Cook for recommendations (because the research is not ours, it cannot be released externally at this time).

## Equipment Decontamination

Whenever possible, use disposable equipment when collecting groundwater samples. If reusable equipment must be used, the equipment must be cleaned/decontaminated between uses. Alconox and Liquinox soap are acceptable for cleaning/decontaminating reusable equipment at PFAS sites. Any water used for cleaning/decontamination must be certified PFAS-free by a laboratory. Consider triple-rinsing. Once decontaminated, wrap equipment in plastic bags (such as Ziploc), and store away from potential PFAS sources.

### *Use of Water Quality Equipment and Water Level Indicators*

Water quality meters typically do not contain PFAS. However, consistent with general sampling SOPs, disconnect the water quality meter prior to sampling. Some water level indicators do contain small polyvinylidene fluoride (a PFAS constituent for which we do not currently monitor) or less frequently, Teflon, components, but we have not noted cross contamination from water level indicators at any sites. The Durham Geoslope Water Level Indicators have been shown to be fluorine free.

# V. References

United States Environmental Protection Agency (USEPA), 2009. *Determination of Selected Perfluorinated Alkyl Acids in Drinking Water by Solid Phase Extraction and Liquid Chromatography/ Tandem Mass Spectrometry (LC/MS/MS).* September.

United States Navy, 2017. *Interim Per- and Polyfluoroalkyl Substances (PFAS) Site Guidance for NAVFAC Remedial Project Managers (RPMs).* September

United States Navy, 2015. *Navy Drinking Water Sampling Policy for Perfluorochemicals: Perfluorooctane Sulfonate and Perfluorooctanoic acid.* September.

DRAFT FINAL STANDARD OPERATING PROCEDURE – Navy CLEAN PROGRAM

# Rotosonic Groundwater Sample Collection for Per- and Polyfluoroalkyl Substances

## I. Purpose and Scope

This SOP provides guidelines for groundwater sample collection using rotosonic drilling technology for samples that will be analyzed for per- and polyfluoroalklyl substances (PFAS) via LC/MS/MS Compliant with QSM 5.1 Table B-15.

Standard techniques for collecting representative samples are summarized. These procedures are specific to the Navy Comprehensive Long-term Environmental Action Navy (CLEAN) Program under Contract N62470-16-D-9000. Materials, equipment, and procedures may vary; refer to the Sampling and Analysis Plan and operator’s manuals for specific details.

## II. Equipment and Materials

### Equipment and Materials Required

- Sonic drill sampling rods and retractable stainless-steel screen without PFAS-containing components (Avoid Teflon, Viton, PTFE and all other fluorinated compounds)
- PFAS-free tubing (avoid Teflon, Viton, PTFE and other fluorinated compounds)
    - High density polyethylene tubing (unlined)
    - Masterflex tubing, Cole Parmer C-Flex (06424 series) and Tygon E-3603 (06509 series) are suitable options
- Water quality meter (Horiba® or YSI®)
- PFAS-free bladder pump
- Pre-cleaned sample containers
- Air monitoring and water quality instruments (as needed)
- Personal protective equipment
- Groundwater sample containers (high density polyethylene [HDPE] with HDPE screw cap [no Teflon caps])
- PFAS-free shipping labels (if available[1]) materials
- Loose leaf paper or a wire-bound notebook without waterproof coating
- Metal clipboard
- Pen (not Sharpie)
- Nitrile or Latex gloves
- Laboratory prepared deionized, certified PFAS-free water for field blank collection
- PVC casing and screen for temporary well

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[1] Efforts will be made to obtain PFAS-free labels; however, information on labels is scarce and labels are frequently mounted on PFAS-coated paper to allow for easy removal.

Ensure the driller has not used and will not use drilling lube containing polytetrafluoroethylene (PFTE) or any other fluorine-containing substance. Biolube has been determined to be an acceptable substitute.

## Equipment and Materials to Avoid During Sampling

Equipment and materials used to collect groundwater samples should not contain any fluorinated compounds, Teflon, or synthetic rubber with fluoropolymer elastomers (e.g., Viton).

Specifically, the following material should be avoided during sampling:

- Gore-Tex brand or similar high-performance outdoor clothing, clothing treated with ScotchGuard brand or similar water repellent, fluoropolymer-coated Tyvek, wrinkle-resistant fabrics, and fire-resistant clothing with fluorochemical treatment or anything advertised as water repellant.
- Weather-proof log books with fluorochemical coatings
- New clothing that has been washed fewer than six times

The sample collection area should be clear of the following items:

- Pre-packaged food wrappers (e.g., fast food sandwich wrappers, pizza boxes, etc.)
- Microwave popcorn bags
- Blue ice containers
- Aluminum foil
- Kim-Wipes
- Sunscreen, insect repellant and other personal hygiene products that may contain PFAS

Research which has not yet been published has allowed us to generate a list of sunscreens and insect repellents which do not contain fluorine. Check with Bill Diguiseppi or Laura Cook on recommendations (because the research is not ours, it cannot be released externally at this time).

# III. Procedures and Guidelines

Wash hands with dish detergent before sampling and don nitrile gloves. Do not use Kleen Guard powder free nitrile gloves which were shown in research to contain fluorine.

Once the area has been determined to be free of materials potentially containing PFAS, these steps can be followed to collect the sonic groundwater sample:

1) Decontaminate slotted lead rod and other downhole equipment in accordance with SOP *Decontamination of Personnel and Equipment* and this SOP.
2) Advance the drive-ahead sampler to the desired sampling depth and withdraw the rods 2 to 3 feet to expose the retractable screen to the aquifer formation. Ensure that the screened lead rod has been inserted to the desired sampling depth. If using temporary well casing, deploy PVC screen and casing to desired sampling depth.
3) Deploy your sampling pump to mid-screen.
4) Purge the volume of water added to the well during drilling. If no water has been used, purge three well volumes from the casing. When using the drive-ahead sampler, calculate

the well volume as the volume of water in the drill rod (bullet a). When using a temporary well, calculate the well volume as the volume of water in the casing plus the volume of water in the sand pack (bullet b).

a) To calculate the volume of water in the drill rod, use the appropriate coefficient for the rod diameter given under “Well Casing Volume per Foot of Depth” on the attached reference sheet (Geotech, 2019). Then use the following formula:

   V (gallons) = coefficient * *h* (where *h* is the height of the water column in feet)

b) To calculate the volume of the temporary well casing and sand pack, first calculate the volume of the casing as above. Then calculate the volume of the annulus using the coefficients given under “Volume of Annulus” on the reference sheet (Geotech, 2019). The volume of the annulus is then multiplied by the porosity of the sand pack (a porosity of 0.35 can be assumed for this case). This is summarized in the following formula:

   V (gallons) = V_casing + (0.35 * V_annulus)

c) Note: If the sample interval / well is unable to produce enough water to generate three well volumes or if it goes dry, then the volume purge method will not be used. In this case, the casing will be pumped dry and allowed to recharge to 90% of the static water level (time permitting) before sampling.

5) Collect and record one set of water quality parameters prior to sampling.

6) Fill all sample containers. Samples should be collected in accordance with SOP *Groundwater Sampling when Analyzing for Per- and Polyfluoroalkyl Substances (PFAS)***.** Affix labels after bottles have been closed; collect only one sample at a time to avoid mislabeling.

7) Remove and discard polyethylene sampling tubing from the rods. Withdraw PVC temporary PVC screen and casing.

### Equipment Decontamination

Ensure that the sonic rig operator thoroughly completes the decontamination process between sampling locations. Do not use water from the facility (e.g. fire hydrants) if there is a possibility that the water available is contaminated with PFAS.

Whenever possible, use disposable equipment when collecting groundwater samples. If reusable equipment must be used, the equipment must be cleaned/decontaminated between uses. Alconox and Liquinox soap are acceptable for cleaning/decontaminating reusable equipment at PFAS sites. Any water used for cleaning/decontamination must be certified PFAS-free by a laboratory. Consider triple-rinsing. Once decontaminated, wrap equipment in plastic bags (such as Ziploc), and store away from potential PFAS sources.

### *Use of Water Quality Equipment*

Water quality meters typically do not contain PFAS. However, consistent with general sampling SOPs, disconnect the water quality meter prior to sampling.

# References

Geotech, 2019. *Water Measure Tables*. Web. 28 March 2019.

United States Environmental Protection Agency (USEPA), 2009. *Determination of Selected Perfluorinated Alkyl Acids in Drinking Water by Solid Phase Extraction and Liquid Chromatography/Tandem Mass Spectrometry (LC/MS/MS)*. September.

United States Navy, 2015. *Navy Drinking Water Sampling Policy for Perfluorochemicals: Perfluorooctane Sulfonate and Perfluorooctanoic acid.* September.

DRAFT FINAL STANDARD OPERATING PROCEDURE – Navy CLEAN PROGRAM

# Rotosonic Groundwater Sample Collection for Per- and Polyfluoroalkyl Substances

## I. Purpose and Scope

This SOP provides guidelines for groundwater sample collection using rotosonic drilling technology for samples that will be analyzed for per- and polyfluoroalklyl substances (PFAS) via LC/MS/MS Compliant with QSM 5.1 Table B-15.

Standard techniques for collecting representative samples are summarized. These procedures are specific to the Navy Comprehensive Long-term Environmental Action Navy (CLEAN) Program under Contract N62470-16-D-9000. Materials, equipment, and procedures may vary; refer to the Sampling and Analysis Plan and operator's manuals for specific details.

## II. Equipment and Materials

### Equipment and Materials Required

- Sonic drill sampling rods and retractable stainless-steel screen without PFAS-containing components (Avoid Teflon, Viton, PTFE and all other fluorinated compounds)
- PFAS-free tubing (avoid Teflon, Viton, PTFE and other fluorinated compounds)
  - High density polyethylene tubing (unlined)
  - Masterflex tubing, Cole Parmer C-Flex (06424 series) and Tygon E-3603 (06509 series) are suitable options
- Water quality meter (Horiba® or YSI®)
- PFAS-free bladder pump
- Pre-cleaned sample containers
- Air monitoring and water quality instruments (as needed)
- Personal protective equipment
- Groundwater sample containers (high density polyethylene [HDPE] with HDPE screw cap [no Teflon caps])
- PFAS-free shipping labels (if available[1]) materials
- Loose leaf paper or a wire-bound notebook without waterproof coating
- Metal clipboard
- Pen (not Sharpie)
- Nitrile or Latex gloves
- Laboratory prepared deionized, certified PFAS-free water for field blank collection
- PVC casing and screen for temporary well

Ensure the driller has not used and will not use drilling lube containing polytetrafluoroethylene (PFTE) or any other fluorine-containing substance. Biolube has been determined to be an acceptable substitute.

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[1] Efforts will be made to obtain PFAS-free labels; however, information on labels is scarce and labels are frequently mounted on PFAS-coated paper to allow for easy removal.

### Equipment and Materials to Avoid During Sampling

Equipment and materials used to collect groundwater samples should not contain any fluorinated compounds, Teflon, or synthetic rubber with fluoropolymer elastomers (e.g., Viton).

Specifically, the following material should be avoided during sampling:

- Gore-Tex brand or similar high-performance outdoor clothing, clothing treated with ScotchGuard brand or similar water repellent, fluoropolymer-coated Tyvek, wrinkle-resistant fabrics, and fire-resistant clothing with fluorochemical treatment or anything advertised as water repellant.
- Weather-proof log books with fluorochemical coatings
- New clothing that has been washed fewer than six times

The sample collection area should be clear of the following items:

- Pre-packaged food wrappers (e.g., fast food sandwich wrappers, pizza boxes, etc.)
- Microwave popcorn bags
- Blue ice containers
- Aluminum foil
- Kim-Wipes
- Sunscreen, insect repellant and other personal hygiene products that may contain PFAS

Research which has not yet been published has allowed us to generate a list of sunscreens and insect repellents which do not contain fluorine. Check with Bill Diguiseppi or Laura Cook on recommendations (because the research is not ours, it cannot be released externally at this time).

# III. Procedures and Guidelines

Wash hands with dish detergent before sampling and don nitrile gloves. Do not use Kleen Guard powder free nitrile gloves which were shown in research to contain fluorine.

Once the area has been determined to be free of materials potentially containing PFAS, these steps can be followed to collect the sonic groundwater sample:

1. Decontaminate slotted lead rod and other downhole equipment in accordance with SOP *Decontamination of Personnel and Equipment* and this SOP.
2. Drive lead probe rod to the desired sampling depth, and withdraw rods 2 to 3 feet to expose the retractable screen to the aquifer formation. Ensure that the screened lead rod has been inserted to the desired sampling depth. If using temporary well casing, deploy PVC screen and casing to desired sampling depth.
3. Insert the stainless-steel foot valve into the end of the polyethylene sampling tubing and insert tubing through the rods or insert peristaltic pump tubing through rods, depending on which method is used.
4. Collect and record one set of water quality parameters prior to sampling.

5. Fill all sample containers. Samples should be collected in accordance with SOP *Groundwater Sampling when Analyzing for Per- and Polyfluoroalkyl Substances (PFAS)***.** Affix labels after bottles have been closed; collect only one sample at a time to avoid mislabeling.
6. Remove and discard polyethylene sampling tubing from the rods. Withdraw PVC temporary PVC screen and casing.

**Equipment Decontamination**

Ensure that the sonic rig operator thoroughly completes the decontamination process between sampling locations. Do not use water from the facility (e.g. fire hydrants) if there is a possibility that the water available is contaminated with PFAS.

Whenever possible, use disposable equipment when collecting groundwater samples. If reusable equipment must be used, the equipment must be cleaned/decontaminated between uses. Alconox and Liquinox soap are acceptable for cleaning/decontaminating reusable equipment at PFAS sites. Any water used for cleaning/decontamination must be certified PFAS-free by a laboratory. Consider triple-rinsing. Once decontaminated, wrap equipment in plastic bags (such as Ziploc), and store away from potential PFAS sources.

***Use of Water Quality Equipment***

Water quality meters typically do not contain PFAS. However, consistent with general sampling SOPs, disconnect the water quality meter prior to sampling.

# References

United States Environmental Protection Agency (USEPA), 2009. *Determination of Selected Perfluorinated Alkyl Acids in Drinking Water by Solid Phase Extraction and Liquid Chromatography/Tandem Mass Spectrometry (LC/MS/MS)*. September.

United States Navy, 2015. *Navy Drinking Water Sampling Policy for Perfluorochemicals: Perfluorooctane Sulfonate and Perfluorooctanoic acid.* September*.*

DRAFT FINAL STANDARD OPERATING PROCEDURE – NAVY CLEAN PROGRAM

# Soil Sampling for Per- and Polyfluoroalkyl Substances

## I. Purpose

This SOP provides guidelines for soil sample collection and handling for samples that will be analyzed for per- and polyfluoroalkyl substances (PFAS) via LC/MS/MS Compliant with QSM 5.1 Table B-15. Standard techniques for collecting representative samples are summarized. These procedures are specific to the Navy Comprehensive Long-term Environmental Action Navy (CLEAN) Program under Contract N62470-16-D-9000. Materials, equipment, and procedures may vary; refer to the Sampling and Analysis Plan and operator's manuals for specific details.

## II. Equipment and Materials

### Equipment and Materials Required

- A hand auger or other device that can be used to remove the soil from the ground. Stainless steel tools, carbon steel tools, or steel DPT tooling with acetate sleeves are preferred for PFAS sampling. Avoid any sampling materials containing PFAS (such as Teflon, Viton, PTFE, or other fluorinated compounds). Any plastic sampling materials should be evaluated thoroughly before selection to ensure they are fluorine-free.
- A stainless steel spatula or fluorine-free disposable plastic scoop should be used to remove material from the sampling device.
- Unpainted wooden stakes or pin flags
- Fiberglass measuring tape (at least 200 feet in length)
- GPS Unit
- PFAS-free labels (if available[1]) shipping materials
- Loose leaf paper or a wire-bound notebook without waterproof coating
- Metal clipboard (if using loose-leaf paper)
- Pen (not Sharpie)
- Personal protection equipment (rubber or latex gloves, boots, etc.). Check with your SME prior to selecting PPE to ensure there are no fluorine-containing components.
- Sample jars (sample jars should be made of high density polyethylene (HDPE) as glass jars may sorb PFAS, please notify the project manager [PM] if glass jars are provided by the lab). Sample containers should not contain Teflon lids.
- Laboratory-prepared deionized, certified PFAS-free water for field blank collection

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[1] Efforts will be made to obtain PFAS-free labels; however, information on labels is scarce and labels are frequently mounted on PFAS-coated paper to allow for easy removal.

## Equipment and Materials to Avoid During Sampling

Equipment and materials used to collect soil samples should not contain any fluorinated compounds including Teflon or synthetic rubber with fluoropolymer elastomers (e.g. Viton).

If a driller is supporting collection of soil samples in split spoons or acetate DPT sleeves, ensure the driller has not used and will not use drilling lube containing polytetrafluoroethylene (PTFE) or any other fluorine-containing substance. Biolube has been determined to be an acceptable substitute.

Specifically, the following material should be avoided during sampling:

- Gore-Tex brand or similar high-performance outdoor clothing, clothing treated with ScotchGuard brand or similar water repellent, fluoropolymer-coated Tyvek, wrinkle-resistant fabrics, and fire-resistant clothing with fluorochemical treatment or anything advertised as water repellant.
- Weather-proof log books with fluorochemical coatings
- New clothing that has been washed fewer than six times

The sample collection area should be clear of the following items:

- Pre-packaged food wrappers (e.g., fast food sandwich wrappers, pizza boxes, etc.)
- Microwave popcorn bags
- Blue ice containers
- Aluminum foil
- Kim-Wipes
- Sunscreen, insect repellant and other personal hygiene products that may contain PFAS

Research which has not yet been published has allowed us to generate a list of sunscreens and insect repellents which do not contain fluorine. Check with Bill Diguiseppi or Laura Cook on recommendations (because the research is not ours, it cannot be released externally at this time).

# III. Procedures and Guidelines

Once the area has been determined to be free of materials potentially containing PFAS, these steps can be followed to collect the soil samples:

A. Wear protective gear, as specified in the Health and Safety Plan.

B. To locate samples, identify the correct location using the pin flags or stakes. Proceed to collect a sample from the undisturbed soil adjacent to the marker following steps C and D. If markers are not present, the following procedures will be used.

   1. For samples on a grid:

      a. Use measuring tape to locate each sampling point on the first grid line as prescribed in the sampling plan. As each point is located, drive a numbered stake in the ground and record its location on the site map and in the field notebook/clipboard.

      b. Proceed to sample the points on the grid line.

      c. Measure to location where next grid line is to start and stake first sample. For subsequent samples on the line take two orthogonal measurements: one to the previous grid line, and one to the previous sample on the same grid line.

d. Proceed to sample the points on the grid line as described in Section C below.

e. Make sure to stake location after sample collection in case professional surveying is to be completed.

f. Repeat 1c and 1e above until all samples are collected from the area.

g. Or, a GPS unit can be used to identify each location based on map coordinates, if available.

2. For non-grid samples:

a. Use measuring tape to position sampling point at location described in the sampling plan by taking two measurements from fixed landmarks (e.g., corner of house and fence post).

b. Note measurements, landmarks, and sampling point on a sketch in the field notebook, and on a site location map.

c. Proceed to sample as described in Section C below.

d. Make sure to stake location after sample collection in case professional surveying is to be completed.

e. Repeat 2a through 2d above until all samples are collected from the area.

f. Or, a GPS unit can be used to identify each location based on map coordinated, if available.

C. To the extent possible, differentiate between fill and natural soil. If both are encountered at a boring location, sample both as prescribed in the field sampling plan. Do not locate samples in debris, tree roots, or standing water. In residential areas, do not sample in areas where residents' activities may impact the sample (e.g., barbecue areas, beneath eaves of roofs, driveways, garbage areas). If an obstacle prevents sampling at a measured grid point, move as close as possible, but up to a distance of one half the grid spacing in any direction to locate an appropriate sample. If an appropriate location cannot be found, consult with the Field Team Leader (FTL). If the FTL concurs, the sampling point may be deleted from the program. The FTL will contact the CH2M HILL PM immediately. The PM and Navy Technical Representative (NTR) will discuss whether the point should be deleted from the program. If it is deleted, the PM will follow-up with the NTR in writing.

D. To collect samples using hand tools:

1. Use a decontaminated stainless steel scoop/trowel or disposable plastic scoop to scrape away surficial organic material (grass, leaves, etc.) adjacent to the stake. New disposable scoops or trowels may also be used to reduce the need for equipment blanks if the disposable scoops have been confirmed by your project PFAS subject matter expert (SME) to be PFAS free.

2. If sampling:

a. Surface soil: Obtain soil sample by scooping soil using the augering scoop/trowel, starting from the surface and digging down to a depth of about 6 inches, or the depth specified in the workplan.

b. Subsurface soil: Obtain the subsurface soil sample using an auger down to the depths prescribed in the field sampling plan.

3. Record lithologic description and any pertinent observations (such as discoloration) in the field notebook/clipboard.
4. Empty the contents of the scoop/trowel into a decontaminated stainless steel pan or dedicated sealable bag.
5. Repeat this procedure until sufficient soil is collected to meet volume requirements.
6. Homogenize cuttings in the pan using a decontaminated stainless steel utensil.
7. Transfer sample for analysis into appropriate containers with a decontaminated utensil. Affix labels after bottles have been closed; collect only one sample at a time to avoid mislabeling.
8. Immediately upon collection, all samples for chemical analysis are to be placed in a closed container on ice unless it is not possible to do so. Although unusual and uncommon, there may be instances where it is not possible to have containers with ice at the sample location. In these instances, the samples should be placed on ice as soon as practical and during the time between collection and placing the samples on ice, the samples should be kept as cool as possible.
9. Backfill the hole with soil removed from the borehole. To the extent possible, replace topsoil and grass and attempt to return appearance of sampling area to its pre-sampled condition. For samples in non-residential, unmowed areas, mark the sample number on the stake and leave stake in place. In mowed areas, remove stake.

E. To collect Samples Using DPT Methods

1. Decontaminate sampling tubes and other non-dedicated downhole equipment in accordance with SOP *Decontamination of Personnel and Equipment*. Ensure that decontamination water used is PFAS free (do not use water from fire hydrants on-base for steam cleaning unless the water has been demonstrated to be free of PFAS).
2. Drive sampling tube to the desired sampling depth using the truck-mounted hydraulic percussion hammer. If soil above the desired depth is not to be sampled, first drive the lead rod, without a sampling tube, to the top of the desired depth.
3. Remove the rods and sampling tube from the borehole and remove the sampling tube from the lead rod.
4. Cut open the acetate liner using a specific knife designed to slice the acetate liners (see below).

5. Fill all sample containers, using a decontaminated or dedicated sampling implement. Label the containers and immediately place samples on ice for shipment to the laboratory.

6. Decontaminate all non-dedicated downhole equipment (rods, sampling tubes, etc.) in accordance with SOP Decontamination of Personnel and Equipment and ensure decontamination water is from a PFAS-free water source.

7. Backfill borehole at each sampling location with grout or bentonite and repair the surface with like material (bentonite, asphalt patch, concrete, etc.), as required.

# Equipment Decontamination

Whenever possible, use disposable equipment when collecting sediment samples. If reusable equipment must be used, the equipment must be cleaned/decontaminated between uses. Alconox and Liquinox soap are acceptable for cleaning/decontaminating reusable equipment at PFAS sites. Any water used for cleaning/decontamination must be certified PFAS-free by a laboratory. Consider triple-rinsing. Once decontaminated, wrap equipment in plastic bags (such as Ziploc), and store away from potential PFAS sources.

# References

United States Environmental Protection Agency (USEPA), 2009. *Determination of Selected Perfluorinated Alkyl Acids in Drinking Water by Solid Phase Extraction and Liquid Chromatography/Tandem Mass Spectrometry (LC/MS/MS)*. September.

United States Navy, 2017. Interim Per- and Polyfluoroalkyl Substances (PFAS) Site Guidance for NAVFAC Remedial Project Managers (RPMs). September.

United States Navy, 2015. *Navy Drinking Water Sampling Policy for Perfluorochemicals: Perfluorooctane Sulfonate and Perfluorooctanoic acid.* September

STANDARD OPERATING PROCEDURE – Navy CLEAN PROGRAM

# Management of Liquid Waste Containing Per- and Polyfluoroalkyl Substances (PFAS)

## I. Purpose and Scope

This SOP provides guidelines for managing waste containing per- and polyfluoalklyl substances (PFAS) in accordance with the *Interim Per- and Polyfluoralkyl Substances (PFAS) Site Guidance for NAVFAC Remedial Project Managers (RPMs)/September 2017 Update* (guidance). This SOP should be used in conjunction with an Environmental and/or Waste Management Plan (EMP and/or WMP) approved by your Environmental Manager (EM). If you do not have a site-specific EMP, please contact your EM.

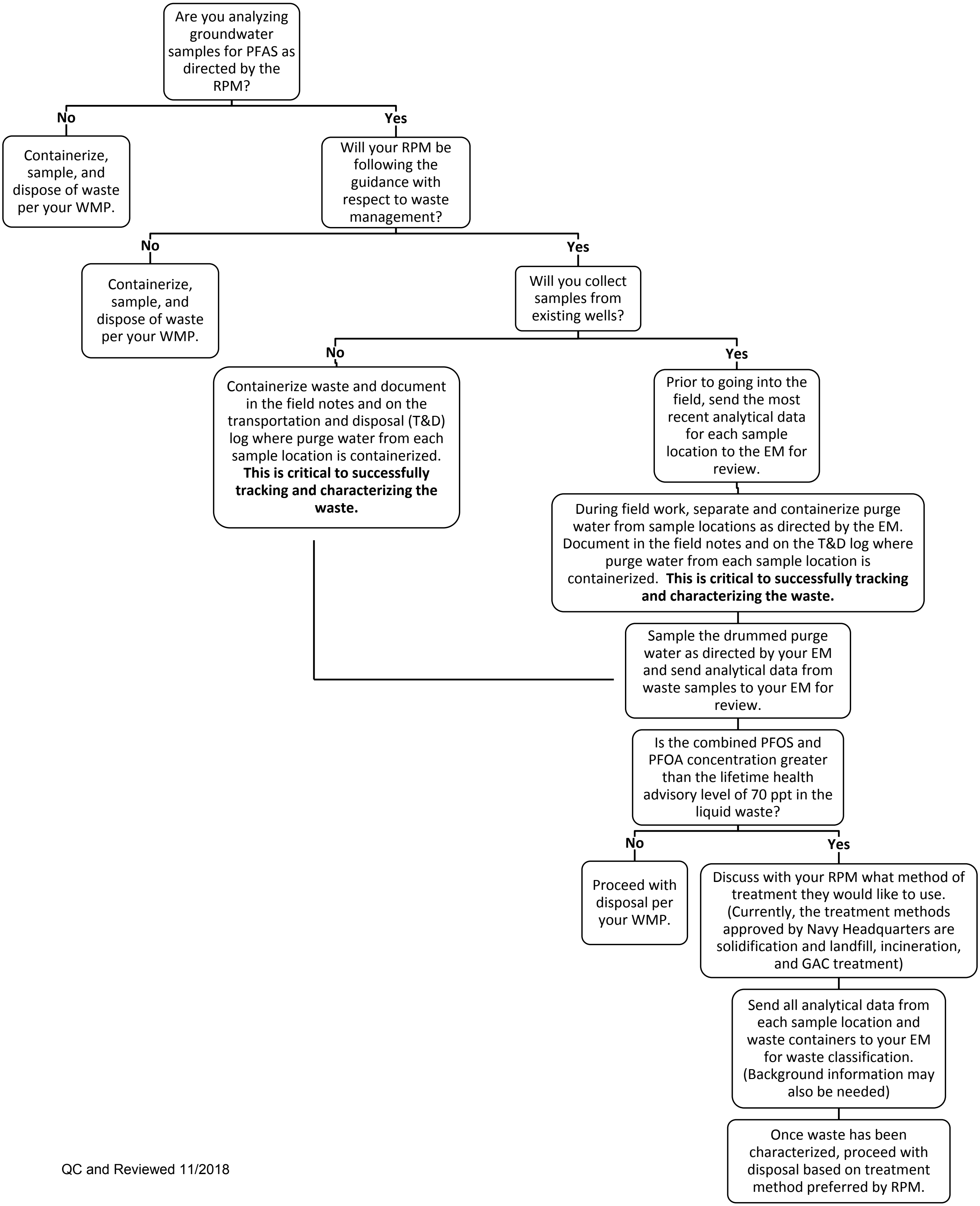
Standard procedures for managing liquid waste during PFAS investigation are summarized. These procedures are specific to the Navy Comprehensive Long-term Environmental Action Navy (CLEAN) Program under Contract N62470-16-D-9000.

Currently, PFAS are not regulated as a hazardous waste in US EPA regulations (state and territory rules may vary). Treatment of liquid waste containing PFAS, as recommended by the guidance, is a client directed action. When and how it is implemented will be left to the discretion of the individual RPMs. These project specific actions will be communicated with the Project Manager (PM) and/or Activity Manager (AM).

# II. Procedures and Guidelines

The following flowchart outlines the procedures required to manage liquid waste during PFAS investigations. Any deviations from this procedure must be approved by the EM.

ch2m



QC and Reviewed 11/2018

# Appendix C
# Department of Defense Environmental Laboratory Accreditation Program Accreditation Letters

# PERRY JOHNSON LABORATORY ACCREDITATION, INC.

# *Certificate of Accreditation*

*Perry Johnson Laboratory Accreditation, Inc. has assessed the Laboratory of:*

## ***Battelle***

***141 Longwater Drive, Suite 202, Norwell, MA 02061***

*(Hereinafter called the Organization) and hereby declares that Organization has met the requirements of ISO/IEC 17025:2005 "General Requirements for the competence of Testing and Calibration Laboratories" and the DoD Quality Systems Manual for Environmental Laboratories Version 5.1.1 February 2018 and is accredited is accordance with the:*

## **United States Department of Defense Environmental Laboratory Accreditation Program (DoD-ELAP)**

***This accreditation demonstrates technical competence for the defined scope:***

***Environmental Testing***

***(As detailed in the supplement)***

Accreditation claims for such testing and/or calibration services shall only be made from addresses referenced within this certificate. This Accreditation is granted subject to the system rules governing the Accreditation referred to above, and the Organization hereby covenants with the Accreditation body's duty to observe and comply with the said rules.

For PJLA:

Tracy Szerszen

Tracy Szerszen
President/Operations Manager

| *Initial Accreditation Date:* | *Issue Date:* | *Expiration Date:* |
|---|---|---|
| November 17, 2016 | December 20, 2018 | February 28, 2021 |
| *Revision Date:* | *Accreditation No.:* | *Certificate No.:* |
| March 27, 2019 | 91667 | L18-588-R2 |

Perry Johnson Laboratory
Accreditation, Inc. (PJLA)
755 W. Big Beaver, Suite 1325
Troy, Michigan 48084

*The validity of this certificate is maintained through ongoing assessments based on a continuous accreditation cycle. The validity of this certificate should be confirmed through the PJLA website: www.pjlabs.com*

# *Certificate of Accreditation: Supplement*

ISO/IEC 17025:2005 and DoD-ELAP

## Battelle

141 Longwater Drive, Suite 202, Norwell, MA 02061
Contact Name: Jonathan Thorn Phone: 781-681-5565

*Accreditation is granted to the facility to perform the following testing:*

| Matrix | Standard/Method | Technology | Analyte |
|---|---|---|---|
| Drinking Water | EPA 537.1 | LC/MS/MS | 4,8-dioxa-3H-perfluorononanoic acid (ADONA) |
| Drinking Water | EPA 537.1 | LC/MS/MS | 9-chlorohexadecafluoro-3-oxanone-1-sulfonic acid (9Cl-PF3ONS) |
| Drinking Water | EPA 537.1 | LC/MS/MS | 11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (11Cl-PF3OUdS) |
| Drinking Water | EPA 537.1 | LC/MS/MS | Hexafluoropropylene oxide dimer acid (HFPO-DA) |
| Drinking Water | EPA 537.1 | LC/MS/MS | Perfluoro-n-hexanoic acid (PFHxA) |
| Drinking Water | EPA 537.1 | LC/MS/MS | Perfluoro-n-heptanoic Acid (PFHpA) |
| Drinking Water | EPA 537.1 | LC/MS/MS | Perfluoro-n-octanoic Acid (PFOA) |
| Drinking Water | EPA 537.1 | LC/MS/MS | Perfluorononanoic acid (PFNA) |
| Drinking Water | EPA 537.1 | LC/MS/MS | Perfluoro-n-decanoic Acid (PFDA) |
| Drinking Water | EPA 537.1 | LC/MS/MS | Perfluoro-n-undecanoic acid (PFUnA) |
| Drinking Water | EPA 537.1 | LC/MS/MS | Perfluoro-n-dodecanoic acid (PFDoA) |
| Drinking Water | EPA 537.1 | LC/MS/MS | Perfluoro-n-tridecanoic acid (PFTrDA) |
| Drinking Water | EPA 537.1 | LC/MS/MS | Perfluoro-n-tetradecanoic acid (PFTeDA) |
| Drinking Water | EPA 537.1 | LC/MS/MS | N-methylperfluoro-1-octanesulfonamidoacetic acid (NMeFOSAA) |
| Drinking Water | EPA 537.1 | LC/MS/MS | N-ethylperfluoro-octanesulfonamidoacetic acid (NEtFOSAA) |
| Drinking Water | EPA 537.1 | LC/MS/MS | Perfluoro-1-butanesulfonic Acid (PFBS) |
| Drinking Water | EPA 537.1 | LC/MS/MS | Perfluoro-1-hexanesulfonic Acid (PFHxS) |
| Drinking Water | EPA 537.1 | LC/MS/MS | Perfluoro-1-octanesulphonic Acid (PFOS) |
| Solids/Tissues | PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 | LC/MS/MS | 3-Perfluoropropyl propanoic Acid (3:3 FTCA) |
| Solids/Tissues | PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 | LC/MS/MS | 3-Perfluoropropyl propanoic acid (5:3 FTCA) |
| Solids/Tissues | PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 | LC/MS/MS | 3-Perfluoropropyl propanoic acid (7:3 FTCA) |
| Solids/Tissues | PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 | LC/MS/MS | Perfluoro-1-octanesulfonamide (PFOSA) |
| Aqueous/Solids/Tissues | PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 | LC/MS/MS | 4,8-dioxa-3H-perfluorononanoic acid (Adona) |
| Aqueous/Solids/Tissues | PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 | LC/MS/MS | 9-chlorohexadecafluoro-3-oxanonane-1-sulfonic acid (9CI-PF3ONS) |

# *Certificate of Accreditation: Supplement*

ISO/IEC 17025:2005 and DoD-ELAP

## Battelle

141 Longwater Drive, Suite 202, Norwell, MA 02061
Contact Name: Jonathan Thorn Phone: 781-681-5565

*Accreditation is granted to the facility to perform the following testing:*

| Matrix | Standard/Method | Technology | Analyte |
|---|---|---|---|
| Aqueous/Solids/Tissues | PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 | LC/MS/MS | 11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (11CI-PF3OUdS) |
| Aqueous/Solids/Tissues | PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 | LC/MS/MS | Hexafluoropropylene oxide dimer acid (HFPO-DA) |
| Aqueous/Solids/Tissues | PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 | LC/MS/MS | Sodium perfluoro-1-pentanesulfonate (PFPeS) |
| Aqueous/Solids/Tissues | PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 | LC/MS/MS | Perfluoro-1-nonanesulfonate (PFNS) |
| Aqueous/Solids/Tissues | PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 | LC/MS/MS | Perfluoro-1-heptanesulfonate (PFHpS) |
| Aqueous/Solids/Tissues | PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 | LC/MS/MS | N-ethylperfluoro-octanesulfonamidoacetic acid (NEtFOSAA) |
| Aqueous/Solids/Tissues | PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 | LC/MS/MS | 1H,1H,2H,2H-Perfluorohexane sulfonate (4:2FTS) |
| Aqueous/Solids/Tissues | PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 | LC/MS/MS | 1H,1H,2H,2H-Perfluorooctane sulfonate (6:2FTS) |
| Aqueous/Solids/Tissues | PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 | LC/MS/MS | 1H,1H,2H,2H-Perfluorodecane sulfonate (8:2FTS) |
| Aqueous/Solids/Tissues | PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 | LC/MS/MS | Perfluoro-n-butanoic Acid (PFBA) |
| Aqueous/Solids/Tissues | PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 | LC/MS/MS | Perfluoro-n-pentanoic acid (PFPeA) |
| Aqueous/Solids/Tissues | PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 | LC/MS/MS | Perfluoro-n-hexanoic acid (PFHxA) |
| Aqueous/Solids/Tissues | PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 | LC/MS/MS | Perfluoro-n-heptanoic Acid (PFHpA) |
| Aqueous/Solids/Tissues | PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 | LC/MS/MS | Perfluoro-n-octanoic Acid (PFOA) |
| Aqueous/Solids/Tissues | PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 | LC/MS/MS | Perfluorononanoic acid (PFNA) |

# *Certificate of Accreditation: Supplement*

ISO/IEC 17025:2005 and DoD-ELAP

## Battelle

141 Longwater Drive, Suite 202, Norwell, MA 02061
Contact Name: Jonathan Thorn Phone: 781-681-5565

*Accreditation is granted to the facility to perform the following testing:*

| Matrix | Standard/Method | Technology | Analyte |
|---|---|---|---|
| Aqueous/Solids/Tissues | PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 | LC/MS/MS | Perfluoro-n-decanoic Acid (PFDA) |
| Aqueous/Solids/Tissues | PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 | LC/MS/MS | Perfluoro-n-undecanoic acid (PFUnA) |
| Aqueous/Solids/Tissues | PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 | LC/MS/MS | Perfluoro-n-dodecanoic acid (PFDoA) |
| Aqueous/Solids/Tissues | PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 | LC/MS/MS | Perfluoro-n-tridecanoic acid (PFTrDA) |
| Aqueous/Solids/Tissues | PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 | LC/MS/MS | Perfluoro-n-tetradecanoic acid (PFTeDA) |
| Aqueous/Solids/Tissues | PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 | LC/MS/MS | N-methylperfluoro-1-octanesulfonamidoacetic acid (NMeFOSAA) |
| Aqueous/Solids/Tissues | PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 | LC/MS/MS | Perfluoro-1-butanesulfonic Acid (PFBS) |
| Aqueous/Solids/Tissues | PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 | LC/MS/MS | Perfluoro-1-hexanesulfonic Acid (PFHxS) |
| Aqueous/Solids/Tissues | PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 | LC/MS/MS | Perfluoro-1-octanesulphonic Acid (PFOS) |
| Aqueous/Solids/Tissues | PFAS by LCMSMS Compliant with QSM 5.1 Table B-15 | LC/MS/MS | Perfluoro-1-decanesulfonate (PFDS) |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | 2,2',3,3',4,4'-Hexachlorobiphenyl (BZ 128) |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | 2,2',3,3',4,5-Hexachlorobiphenyl (BZ 129) |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | 2,2',3,4,4',5,5'-Heptachlorobiphenyl (BZ 180) |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | 2,2',3,4,4',5',6-Heptachlorobiphenyl (BZ 183) |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | 2,2',3,4,4',5'-Hexachlorobiphenyl (BZ 138) |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | 2,2',3,4,4',6,6'-Heptachlorobiphen yl (BZ 184) |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | 2,2',3,4',5,5',6-Heptachlorobiphenyl (BZ 187) |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | 2,2',3,4,5'-Pentachlorobiphenyl (BZ 87) |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | 2,2',3,5'-Tetrachlorobiphenyl (BZ 44) |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | 2,2',4,4',5,5'-Hexachlorobiphenyl (BZ 153) |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | 2,2',4,5,5'-Pentachlorobiphenyl (BZ 101) |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | 2,2',4,5'-Tetrachlorobiphenyl (BZ 49) |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | 2,2',5,5'-Tetrachlorobiphenyl (BZ 52) |

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*Accreditation is granted to the facility to perform the following testing:*

| Matrix | Standard/Method | Technology | Analyte |
|---|---|---|---|
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | 2,2',5-Trichlorobiphenyl (BZ 18) |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | 2,3,3',4,4'-Pentachlorobiphenyl (BZ 105) |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | 2,3,3',4',6-Pentachlorobiphenyl (BZ 110) |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | 2,3',4,4',5-Pentachlorobiphenyl (BZ 118) |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | 2,3',4,4'-Tetrachlorobiphenyl (BZ 66) |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | 2,4,4'-Trichlorobiphenyl (BZ 28) |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | 2,4'-DDD |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | 2,4'-DDE |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | 2,4'-DDT |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | 2,4'-Dichlorobiphenyl (BZ 8) |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | 3,3',4,4',5,5'-Hexachlorobiphenyl (BZ 169) |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | 3,3',4,4',5-Pentachlorobiphenyl (BZ 126) |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | 3,3',4,4'-Tetrachlorobiphenyl (BZ 77) |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | 4,4'-DDD |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | 4,4'-DDE |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | 4,4'-DDT |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | Aldrin |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | alpha-BHC (alpha-Hexachlorocyclohexane) |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | alpha-Chlordane |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | beta-BHC (beta-Hexachlorocyclohexane) |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | Chlorpyrifos |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | cis-Nonachlor |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | Decachlorobiphenyl (BZ 209) |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | delta-BHC |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | Dieldrin |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | Endosulfan II |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | Endosulfan I |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | Endosulfan sulfate |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | Endrin |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | Endrin aldehyde |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | Endrin ketone |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | gamma-BHC<br>(Lindane, gamma-Hexachlorocyclohexane) |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | gamma-Chlordane |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | Heptachlor |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | Heptachlor epoxide |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | Hexachlorobenzene |

*Accreditation is granted to the facility to perform the following testing:*

| Matrix | Standard/Method | Technology | Analyte |
|---|---|---|---|
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | Methoxychlor |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | Mirex |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | Oxychlordane |
| Aqueous/Solid/Tissue | EPA 8081 MOD | GC-ECD | trans-Nonachlor |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 1,4-Dichlorobenzene |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 1-Methylnaphthalene |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 1-Methylphenanthrene |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl (BZ 206) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,3',4,4',5,5'-Octachlorobiphenyl (BZ 194) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,3',4,4',5,6,6'-Nonachlorobiphenyl (BZ 207) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,3',4,4',5,6-Octachlorobiphenyl (BZ 195) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,3',4,4',5-Heptachlorobiphenyl (BZ 170) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,3',4,4',6,6'-Octachlorobiphenyl (BZ 197) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,3',4,4',6-Heptachlorobiphenyl (BZ 171) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,3',4,4'-Hexachlorobiphenyl (BZ 128) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,3',4,5,5',6,6'-Nonachlorobiphenyl (BZ 208) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,3',4,5,5',6-Octachlorobiphenyl (BZ 198) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,3',4,5,5',6'-Octachlorobiphenyl (BZ 199) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,3',4,5,5'-Heptachlorobiphenyl (BZ 172) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,3',4,5,6,6'-Octachlorobiphenyl (BZ 200) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,3',4,5',6,6'-Octachlorobiphenyl (BZ 201) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,3',4,5,6-Heptachlorobiphenyl (BZ 173) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,3',4,5,6'-Heptachlorobiphenyl (BZ 174) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,3',4,5',6-Heptachlorobiphenyl (BZ 175) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,3',4,5',6'-Heptachlorobiphenyl (BZ 177) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,3',4,5'-Hexachlorobiphenyl (BZ 130) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,3',4,6,6'-Heptachlorobiphenyl (BZ 176) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,3',4,6-Hexachlorobiphenyl (BZ 131) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,3',4-Pentachlorobiphenyl (BZ 82) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,3',5,5',6,6'-Octachlorobiphenyl (BZ 202) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,3',5,5',6-Heptachlorobiphenyl (BZ 178) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,3',5,6,6'-Heptachlorobiphenyl (BZ 179) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,3',5,6-Hexachlorobiphenyl (BZ 134) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,3',5,6'-Hexachlorobiphenyl (BZ 135) |

# *Certificate of Accreditation: Supplement*

ISO/IEC 17025:2005 and DoD-ELAP

## Battelle

141 Longwater Drive, Suite 202, Norwell, MA 02061
Contact Name: Jonathan Thorn Phone: 781-681-5565

*Accreditation is granted to the facility to perform the following testing:*

| Matrix | Standard/Method | Technology | Analyte |
|---|---|---|---|
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,3',5-Pentachlorobiphenyl (BZ 83) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,3',6,6'-Hexachlorobiphenyl (BZ 136) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,3',6-Pentachlorobiphenyl (BZ 84) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,3'-Tetrachlorobiphenyl (BZ 40) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,4,4',5,5',6-Octachlorobiphenyl (BZ 203) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,4,4',5,5'-Heptachlorobiphenyl (BZ 180) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,4,4',5',6-Heptachlorobiphenyl (BZ 183) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,4,4',5-Hexachlorobiphenyl (BZ 137) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,4,4',5'-Hexachlorobiphenyl (BZ 138) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,4,4',6,6'-Heptachlorobiphenyl (BZ 184) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,4,4',6-Hexachlorobiphenyl (BZ 139) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,4,4',6'-Hexachlorobiphenyl (BZ 140) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,4,4'-Pentachlorobiphenyl (BZ 85) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,4,5,5',6-Heptachlorobiphenyl (BZ 185) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,4',5,5',6-Heptachlorobiphenyl (BZ 187) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,4,5,5'-Hexachlorobiphenyl (BZ 141) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,4',5,5'-Hexachlorobiphenyl (BZ 146) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,4',5,6,6'-Heptachlorobiphenyl (BZ 188) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,4',5',6-Hexachlorobiphenyl (BZ 149) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,4,5',6-Hexachlorobiphenyl (BZ 144) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,4,5'-Pentachlorobiphenyl (BZ 87) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,4',5'-Pentachlorobiphenyl (BZ 97) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,4',6-Pentachlorobiphenyl (BZ 91) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,4-Tetrachlorobiphenyl (BZ 41) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,4'-Tetrachlorobiphenyl (BZ 42) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,5,5',6-Hexachlorobiphenyl (BZ 151) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,5,5'-Pentachlorobiphenyl (BZ 92) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,5',6-Pentachlorobiphenyl (BZ 95) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,5-Tetrachlorobiphenyl (BZ 43) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,5'-Tetrachlorobiphenyl (BZ 44) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,6'-Tetrachlorobiphenyl (BZ 46) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3,6-Tetrachlorobiphenyl (BZ 45) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',3-Trichlorobiphenyl (BZ 16) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',4,4',5,5'-Hexachlorobiphenyl (BZ 153) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',4,4',5,6'-Hexachlorobiphenyl (BZ 154) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',4,4',5-Pentachlorobiphenyl (BZ 99) |

# *Certificate of Accreditation: Supplement*

ISO/IEC 17025:2005 and DoD-ELAP

## Battelle

141 Longwater Drive, Suite 202, Norwell, MA 02061
Contact Name: Jonathan Thorn Phone: 781-681-5565

*Accreditation is granted to the facility to perform the following testing:*

| Matrix | Standard/Method | Technology | Analyte |
|---|---|---|---|
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',4,4',6,6'-Hexachlorobiphenyl (BZ 155) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',4,4',6-Pentachlorobiphenyl (BZ 100) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',4,4'-Tetrachlorobiphenyl (BZ 47) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',4,5,5'-Pentachlorobiphenyl (BZ 101) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',4,5-Tetrachlorobiphenyl (BZ 48) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',4,5'-Tetrachlorobiphenyl (BZ 49) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',4,6,6'-Pentachlorobiphenyl (BZ 104) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',4,6'-Tetrachlorobiphenyl (BZ 51) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',4,6-Tetrachlorobiphenyl (BZ 50) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',4-Trichlorobiphenyl (BZ 17) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',5,5'-Tetrachlorobiphenyl (BZ 52) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',5,6'-Tetrachlorobiphenyl (BZ 53) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',5-Trichlorobiphenyl (BZ 18) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',6,6'-Tetrachlorobiphenyl (BZ 54) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2',6-Trichlorobiphenyl (BZ 19) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,2'-Dichlorobiphenyl (BZ 4) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3,3',4,4',5,5',6-Octachlorobiphenyl (BZ 205) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3,3',4,4',5,5'-Heptachlorobiphenyl (BZ 189) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3,3',4,4',5,6-Heptachlorobiphenyl (BZ 190) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3,3',4,4',5',6-Heptachlorobiphenyl (BZ 191) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3,3',4,4',5-Hexachlorobiphenyl (BZ 156) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3,3',4,4',5'-Hexachlorobiphenyl (BZ 157) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3,3',4,4',6-Hexachlorobiphenyl (BZ 158) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3,3',4,4'-Pentachlorobiphenyl (BZ 105) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3,3',4',5,5',6-Heptachlorobiphenyl (BZ 193) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3,3',4',5,6-Hexachlorobiphenyl (BZ 163) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3,3',4',5',6-Hexachlorobiphenyl (BZ 164) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3,3',4',6-Pentachlorobiphenyl (BZ 110) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3,3',4'-Tetrachlorobiphenyl (BZ 56) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3',4,4',5,5'-Hexachlorobiphenyl (BZ 167) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3,4,4',5,6-Hexachlorobiphenyl (BZ 166) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3,4,4',5-Pentachlorobiphenyl (BZ 114) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3',4,4',5-Pentachlorobiphenyl (BZ 118) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3',4,4',5'-Pentachlorobiphenyl (BZ 123) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3,4,4',6-Pentachlorobiphenyl (BZ 115) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3,4,4'-Tetrachlorobiphenyl (BZ 60) |

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## Battelle

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Contact Name: Jonathan Thorn Phone: 781-681-5565

*Accreditation is granted to the facility to perform the following testing:*

| Matrix | Standard/Method | Technology | Analyte |
|---|---|---|---|
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3',4,4'-Tetrachlorobiphenyl (BZ 66) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3',4',5,5'-Pentachlorobiphenyl (BZ 124) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3',4',5',6-Pentachlorobiphenyl (BZ 125) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3,4',5-Tetrachlorobiphenyl (BZ 63) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3',4,5-Tetrachlorobiphenyl (BZ 67) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3',4',5-Tetrachlorobiphenyl (BZ 70) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3,4',6-Tetrachlorobiphenyl (BZ 64) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3',4',6-Tetrachlorobiphenyl (BZ 71) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3,4'-Trichlorobiphenyl (BZ 22) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3',4-Trichlorobiphenyl (BZ 25) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3',4'-Trichlorobiphenyl (BZ 33) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3',5-Trichlorobiphenyl (BZ 26) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3,5-Trimethylnaphthalene |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3,6-Trichlorobiphenyl (BZ 24) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3',6-Trichlorobiphenyl (BZ 27) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3-Dichlorobiphenyl (BZ 5) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,3'-Dichlorobiphenyl (BZ 6) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,4,4',5-Tetrachlorobiphenyl (BZ 74) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,4,4',6-Tetrachlorobiphenyl (BZ 75) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,4,4'-Trichlorobiphenyl (BZ 28) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,4,5-Trichlorobiphenyl (BZ 29) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,4',5-Trichlorobiphenyl (BZ 31) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,4,6-Trichlorobiphenyl (BZ 30) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,4',6-Trichlorobiphenyl (BZ 32) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,4'-DDD |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,4'-DDE |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,4'-DDT |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,4-Dichlorobiphenyl (BZ 7) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,4'-Dichlorobiphenyl (BZ 8) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,5-Dichlorobiphenyl (BZ 9) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2,6-Dimethylnaphthalene |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2-Chlorobiphenyl (BZ 1) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2-Chloronaphthalene |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2-Methylnaphthalene |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 2-Methylphenanthrene |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 3,3',4,4',5,5'-Hexachlorobiphenyl (BZ 169) |

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## Battelle

141 Longwater Drive, Suite 202, Norwell, MA 02061
Contact Name: Jonathan Thorn Phone: 781-681-5565

*Accreditation is granted to the facility to perform the following testing:*

| Matrix | Standard/Method | Technology | Analyte |
|---|---|---|---|
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 3,3',4,4',5-Pentachlorobiphenyl (BZ 126) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 3,3',4,4'-Tetrachlorobiphenyl (BZ 77) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 3,3',4,5,5'-Pentachlorobiphenyl (BZ 127) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 3,3',5,5'-Tetrachlorobiphenyl (BZ 80) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 3,3'-Dichlorobiphenyl (BZ 11) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 3,4,4',5-Tetrachlorobiphenyl (BZ 81) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 3,4,4'-Trichlorobiphenyl (BZ 37) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 3,4-Dichlorobiphenyl (BZ 12) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 3,4'-Dichlorobiphenyl (BZ 13) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 3,6-Dimethylphenanthrene |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 4,4'-Dichlorobiphenyl (BZ 15) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | 4-Chlorobiphenyl (BZ 3) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | Acenaphthene |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | Acenaphthylene |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | Anthracene |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | Benzo(a)anthracene |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | Benzo(a)pyrene |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | Benzo(b)fluoranthene |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | Benzo(b)thiophene |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | Benzo(e)pyrene |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | Benzo(g,h,i)perylene |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | Benzo(k)fluoranthene |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | Biphenyl |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | Chrysene |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | cis-Decalin |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | Decachlorobiphenyl (BZ 209) |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | Dibenz(a,h)anthracene |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | Dibenzofuran |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | Dibenzothiophene |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | Fluoranthene |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | Fluorene |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | lndeno(l,2,3-cd)pyrene |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | Naphthalene |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | Perylene |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | Phenanthrene |
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | Pyrene |

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*Accreditation is granted to the facility to perform the following testing:*

| Matrix | Standard/Method | Technology | Analyte |
|---|---|---|---|
| Aqueous/Solid/Tissue | EPA 8270D MOD | GC-MS | trans-Decalin |

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## Battelle

141 Longwater Drive, Suite 202, Norwell, MA 02061
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*Accreditation is granted to the facility to perform the following testing:*

| Matrix | Standard/Method | Technology | Analyte |
|---|---|---|---|
| Aqueous | EPA 3510 C | Separatory Funnel | Prep |
| Aqueous | EPA 3640A MOD | Gel-permeation chromatography (GPC) | Cleanup |
| Aqueous | EPA 3660B MOD | Sulfur Cleanup | Cleanup |
| Solid | EPA 3640A MOD | Gel-permeation chromatography (GPC) | Cleanup |
| Solid | EPA 3660B MOD | Sulfur Cleanup | Cleanup |
| Solid | NOAA NOS ORCA 71 | Orbital Shaker | Prep |
| Tissue | EPA 3640A MOD | Gel-permeation chromatography (GPC) | Cleanup |
| Tissue | EPA 3660B MOD | Sulfur Cleanup | Cleanup |
| Tissue | NOAA NOS ORCA 71 | Tissuemizer | Prep |

# Appendix D
# Laboratory Standard Operating Procedures

# *Sampling and Analysis Plan*
# *Supplemental Site Inspection*
# *Outlying Landing Field Coupeville*
# *Naval Air Station Whidbey Island*
# *Oak Harbor, Washington*

**NOTIFICATION: APPENDIX D CONTAINS**
**SENSITIVE BUT UNCLASSIFIED INFORMATION**
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