SAP Worksheet #1—Title and Signature Page

Final

Sampling and Analysis Plan
Monitoring Well Installation, Aquifer Testing, Drinking Water Sampling, and Groundwater Sampling
Outlying Landing Field Coupeville

Naval Air Station Whidbey Island
Oak Harbor, Washington

Contract Task Order 4041

December 2017

Prepared for

Department of the Navy
Naval Facilities Engineering Command
Northwest

Under the

NAVFAC CLEAN 9000 Program
Contract N62470-16-D-9000

Prepared by

ch2m℠

1100 112th Avenue NE, Suite 500
Bellevue, WA 98004

This page intentionally left blank.

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

Approval Signatures:

Naval Facilities Engineering Command Atlantic
Quality Assurance Officer

Other Approval Signatures:

Kendra Leibman
Naval Facilities Engineering Command Northwest
Remedial Project Manager

David Einan
United States Environmental Protection Agency Region 10
Remedial Project Manager

This page intentionally left blank.

Executive Summary

The Department of the Navy (Navy), Naval Facilities Engineering Command (NAVFAC) Northwest has contracted CH2M HILL, Inc. (CH2M) to conduct an aquifer test and drinking water sampling at the Keystone Hill well and area located on the west side of Outlying Landing Field (OLF) Coupeville, Washington in Island County. This Uniform Federal Policy-Sampling and Analysis Plan/Quality Assurance Project Plan (SAP) describes the aquifer testing and groundwater and drinking water sampling activities to be conducted at the Keystone Hill well and area located on the west side of the OLF Coupeville property. CH2M prepared this document under the NAVFAC Comprehensive Long-term Environmental Action – Navy (CLEAN) 9000 Contract N62470-16-D-9000, Contract Task Order 4041, for submittal to NAVFAC Northwest.

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 (FCLP) 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, three per- and polyfluorinated substances (PFAS): perfluorooctanoic acid [PFOA], perflouorooctane sulfonate [PFOS], and perfluorobutane sulfonate [PFBS]) have been detected in groundwater samples collected from on-Base wells. 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 was likely used and released at the site.

The Keystone Hill well is a drinking water well operated by the Town of Coupeville, just west of OLF Coupeville. To satisfy anticipated increased demand, the Town of Coupeville completed a water system plan in which the pumping rate of the Keystone Hill well will be increased from 150 gallons per minute (gpm) to 300 gpm. However, PFOA was detected in groundwater at three on-Base wells at OLF Coupeville at concentrations above the United States Environmental Protection Agency (USEPA) lifetime health advisory (LHA) of 0.07 micrograms per liter (µg/L), and PFOA was detected in drinking water samples collected from the Keystone Hill well at concentrations near the USEPA lifetime health advisory level. The Town of Coupeville is concerned that increasing extraction rates may result in higher PFAS concentrations in water produced by the Keystone Hill well. Information regarding the impact of pumping rate at the Keystone Hill well on groundwater flow directions and quality at the OLF Coupeville is necessary to evaluate the feasibility of expanding the Town of Coupeville’s drinking water system. This information is also necessary for the Navy’s evaluation of new drinking water sources for homes that have drinking water above the USEPA’s LHA.

The objectives of the aquifer test and groundwater/drinking water sampling are to:

- Determine the radius of influence (ROI) and extent of hydraulic capture of the Keystone Hill well when operating under normal (150 gpm) pumping conditions.
- Determine the ROI and extent of hydraulic capture through numerical modeling of the Keystone Hill well when production is increased to the Town of Coupeville’s proposed 300 gpm.
- Determine the current PFAS concentrations in the Keystone Hill well and determine current PFOA/PFOS concentrations in the surrounding monitoring wells.

The aquifer test objectives will be accomplished via the following activities:

- Install two observation-well pairs.
- Collect lithologic data from the newly-installed observation well soil borings to determine where semi-confining aquitards and aquifers are present.
- Complete transducer deployment at the Keystone Hill well, the newly-installed observation well pairs, and seven existing monitoring wells on the OLF before initiation of the aquifer test and during a 7-day period during, which multiple pumping cycles will be measured.
- Complete synoptic monitoring events prior to the test and during the test.
- Install a flow meter on the Keystone Hill well discharge piping to obtain accurate flow rate information from the well during the course of the aquifer test.
- Collect a drinking water sample from the Keystone Hill well during the aquifer test, and submit to an offsite laboratory for PFAS analysis. Field measurements of drinking water quality (pH, dissolved oxygen [DO], temperature, conductivity, oxidation-reduction potential [ORP], and turbidity) will be completed during drinking water sampling.
- Collect groundwater samples from the two new monitoring well pairs and seven existing monitoring wells, and submit to an offsite laboratory for PFAS analysis. Field measurements of groundwater quality (pH, dissolved oxygen [DO], temperature, conductivity, oxidation-reduction potential [ORP], and turbidity) will be completed during groundwater sampling.
- Complete numerical 2-dimensional or 3-dimensional (3D) groundwater flow modeling to determine the ROI and extent of hydraulic capture for the current and elevated pumping rates from the Keystone Hill 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.* September. *(Navy, 2017a)*

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 investigation. All tables are embedded within the worksheets. All figures are included at the end of the document. Data from the Keystone Hill well including a well log and previous pumping test data are included in **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 Vista Analytical, the laboratory that has 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. All laboratories employed under this SAP will be DoD-ELAP-accredited.

SAP Worksheets

Appendixes

Tables

Figures

Acronyms and Abbreviations

±	plus or minus
%	percent
>	more than
≤	less than or equal to
°C	degree Celsius
µg/L	micrograms per liter
3D	3-dimensional
AM	Activity Manager
amsl	above mean sea level
AFFF	aqueous film-forming foam
amu	atomic mass unit
bgs	below ground surface
CA	corrective action
CCV	continuing calibration verification
CH2M	CH2M HILL, Inc.
CLEAN	Comprehensive Long-term Environmental Action—Navy
DO	dissolved oxygen
DL	detection limit
DoD	Department of Defense
DQI	data quality indicator
DV	data validation
EDD	electronic data deliverable
ELAP	Environmental Laboratory Accreditation Program
FD	field duplicate
FCLP	Field Carrier Landing Practice
FTL	Field Team Leader
gpm	gallons per minute
H&S	health and safety
HQ	hazard quotient
HSM	Health and Safety Manager
HSP	Health and Safety Plan
ICAL	initial calibration
ID	identification
IDW	investigation-derived waste
IS	internal standards
LCS	laboratory control sample
LCL	lower confidence limit
LHA	Lifetime Health Advisory
LOD	limit of detection
LOQ	limit of quantitation
mL	milliliter(s)
MLU	multi-layer

MPC	measurement performance criteria
MS	matrix spike
MSD	matrix spike duplicate
N/A	not applicable
NAS	Naval Air Station
NAVFAC	Naval Facilities Engineering Command
Navy	Department of the Navy
NTR	Navy Technical Representative
OLF	Outlying Landing Field
ORP	oxidation-reduction potential
PA/SI	Preliminary Assessment/Site Inspection
PAL	project action limit
PC	Project Chemist
PFAS	per- and polyfluoroalkyl substances
PFOA	perfluorooctanoic acid
PFOS	perfluorooctane sulfonate
PFBS	perfluorobutane sulfonate
PID	Photoionization Detector
PM	Project Manager
POC	point of contact
PQL	project quantitation limit
PQO	Project Quality Objective
QA	quality assurance
QAO	Quality Assurance Officer
QC	quality control
QM	Quality Manager
QSM	Quality Systems Manual
RL	reporting limit
ROI	radius of influence
RPD	relative percent difference
RPM	Remedial Project Manager
RSL	regional screening level
SAP	Sampling and Analysis Plan
SBO	safe behavior observation
SI	site investigation
SME	Subject Matter Expert
SOP	standard operating procedure
SSC	Site Safety Coordinator
STC	Senior Technical Consultant
TBD	to be determined
TM	Task Manager
UCL	upper confidence limit
UCMR	Unregulated Contaminant Monitoring Rule
UPLC/MS/MS	ultra performance liquid chromatography - tandem mass spectrometer
USEPA	United States Environmental Protection Agency

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
Contractor Name:	CH2M HILL, Inc. (CH2M)
Contract Number:	N62470-16-D-9000, Contract Task Order 4041
Contract Title:	Comprehensive Long-term Environmental Action – Navy (CLEAN) Program 9000
Work Assignment:	Aquifer Testing at the well designated by the Department of Energy as Well 1-09 APR989, also designated as Source #18 by the Island County Department of Health, and heretofore known as the 'Keystone Hill well'

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)
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 Naval Facilities Engineering Command (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 Scoping Session with NAVFAC Northwest RPM	August 23, 2017
Project Scoping Session with NAVFAC Northwest RPM and Town of Coupeville Water District	August 30 2017

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

Document	Date
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)	August, 2017
Site Inspection for Perfluorinated Compounds in Groundwater, Outlying Landing Field Coupeville, NAS Whidbey Island, Coupeville, Washington (Navy, 2017c)	January, 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
OLF Coupeville – NAVFAC Atlantic	Project Chemist (PC)	2016–present
Town of Coupeville – Joe Grogan	Keystone Hill Well Operator	2016-present
United States Environmental Protection Agency (USEPA) Region 10 – David Einan	Technical Representative/Base Stakeholder	2016-present
Island County, Washington – Doug Kelly	Technical Representative/Base Stakeholder	2016-present

7. Lead organization: Department of Navy (Navy) – NAVFAC Northwest

8. If any required SAP elements and required information are not applicable (N/A) 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	Navy Technical Representative (NTR)	NAVFAC Northwest	(253) 279-0212	Steve.skeehan@navy.mil
TBD	NAVFAC QAO	NAVFAC Atlantic	TBD	TBD
Dave Einan	Project Manager (PM)	USEPA Region 10	(509) 376-3883	Einan.David@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
Rebecca Maco	PM/Activity Manager (AM)	CH2M	(425) 233-3392	rebecca.maco@ch2m.com
Peter Lawson	Senior Technical Consultant (STC)	CH2M	(530) 229-3383	peter.lawson@ch2m.com
Susan Moore	Quality Manager (QM)	CH2M	(425) 233-3223	susan.moore@ch2m.com
Laura Cook	Subject Matter Expert (SME)	CH2M	(757) 671-6214	Laura.cook@ch2m.com
Joe Hauser	Project Task Manager (TM)	CH2M	(425) 233-3108	joe.hauser@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	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
Martha Maier	Laboratory PM	Vista Analytical	(916) 673-1520	mmaier@vista-analytical.com

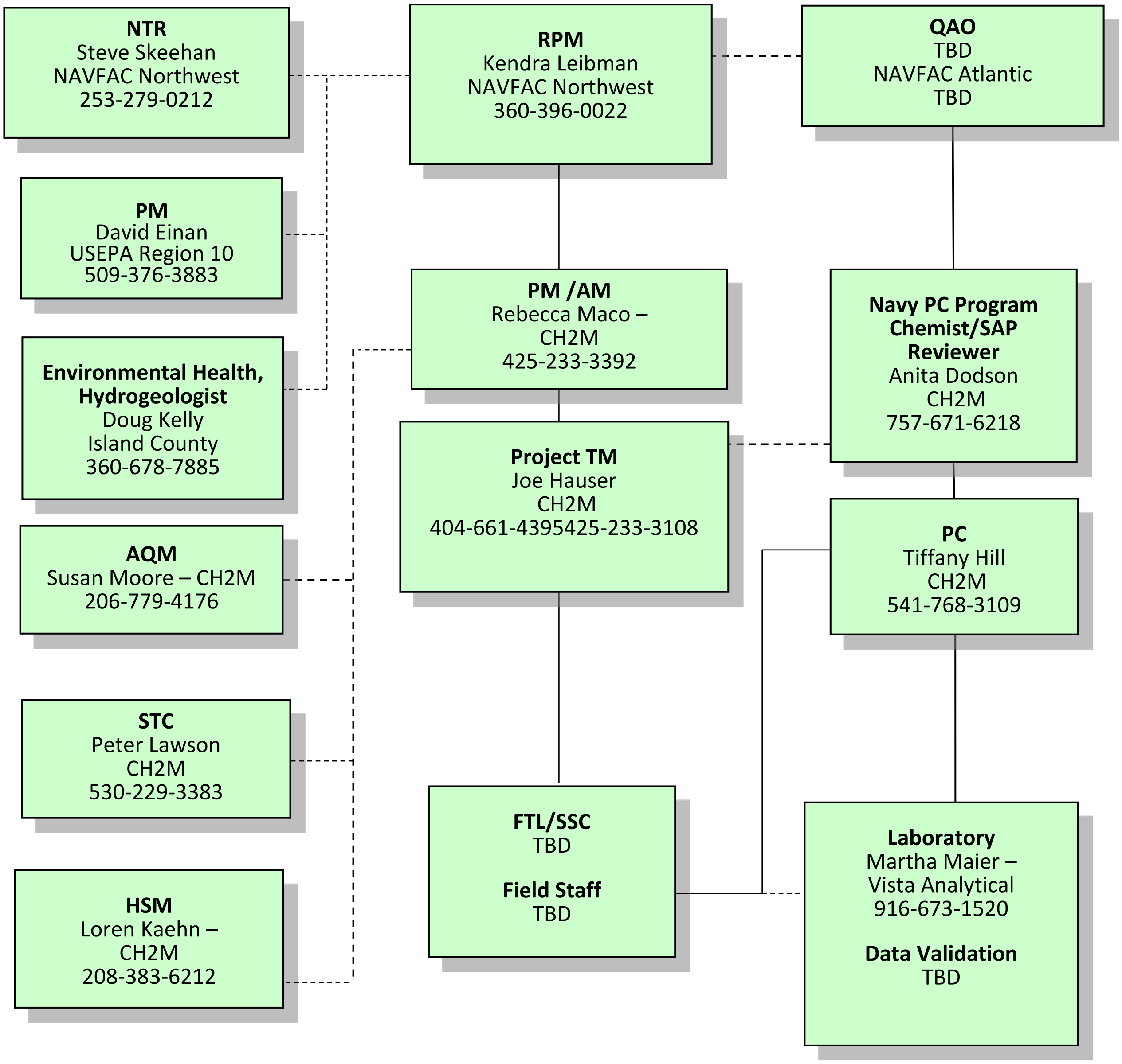
This page intentionally left blank.

SAP Worksheet #4—Project Personnel Sign-Off Sheet

Name	Organization/Title/Role	Telephone Number	Signature/Email Receipt	SAP Section Reviewed	Date SAP Read
Rebecca Maco	CH2M/PM and AM	(425) 233-3392		09/22/2017	09/22/2017
Peter Lawson	CH2M/STC	(530) 229-3383		09/13/2017	09/13/2017
Susan Moore	CH2M/QM	(425) 233-3223		09/18/2017	09/18/2017
Laura Cook	CH2M/SME	(757) 671-6214		09/28/2017	09/28/2017
Joe Hauser	CH2M/Project TM	(425) 233-3108		09/08/2017	09/08/2017
Janna Staszak	CH2M/SAP Reviewer	(757) 518-9666		09/25/2017	09/25/2017
Anita Dodson	CH2M/Navy PC/ SAP Reviewer	(757) 671-6218		10/03/2017	10/04/2017
Tiffany Hill	CH2M/PC	(541) 768-3109		09/05/2017	09/05/2017
TBD	Data Validator	TBD			
Loren Kaehn	CH2M/Health and Safety Manager (HSM)	(208) 383-6212		09/29/2017	09/29/2017
TBD	FTL	CH2M			
TBD	SSC	CH2M			
Martha Maier	Vista Analytical Laboratory PM	(916) 673-1520		09/05/2017	09/05/2017

This page intentionally left blank.

SAP Worksheet #5—Project Organizational Chart



This page intentionally left blank.

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 (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 (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 (360) 396-0022	Primary POC for the Navy; can delegate communication to other internal or external POCs. CH2M PM will notify the Technical Representative 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 and implementation and primary POC with RPMs and project team	CH2M PM	Rebecca Maco	rebecca.maco@ch2m.com (425) 233-3392	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 a field change request (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 (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 QM	Susan Moore	susan.moore@ch2m.com (425) 233-3223	Contact QM regarding quality issues during project implementation. The QM will report to the PM, the Technical Representative, and the RPM.
Technical communications for project implementation, and data interpretation	CH2M SME	Laura Cook	laura.cook@ch2m.com (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.

SAP Worksheet #6—Communication Pathways (continued)

Communication Drivers	Responsible Entity	Name	Phone Number	Procedure
Communication regarding items specific to OLF tasks and primary POC for field team	CH2M TM	Joe Hauser	joe.hauser@ch2m.com (425) 233-3108	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 (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/AM CH2M TM CH2M FTL/SSC Field Team Members	Rebecca Maco Joe Hauser TBD TBD	rebecca.maco@ch2m.com (425) 233-3392 joe.hauser@ch2m.com (425) 233-3108 TBD 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 Technical Representative, the 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 logbook, 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 logbooks; provide daily progress reports to PM.
Reporting laboratory data quality issues	Vista Analytical	Martha Maier	mmaier@vista-analytical.com (916) 673-1520	All quality assurance (QA)/quality control (QC) issues with project field samples will be reported within 2 days to the PC by the laboratory.

SAP Worksheet #6—Communication Pathways (continued)

Communication Drivers	Responsible Entity	Name	Phone Number	Procedure
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 Release of analytical data	PC	Tiffany Hill	tiffany.hill@ch2m.com (541) 768-3109	Tracks data from sample collection through database upload daily. 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 project schedule.
Reporting data quality issues	Data Validation (DV)	TBD	TBD	The data validator 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, PM, and Project TM	TBD Rebecca Maco Joe Hauser	TBD rebecca.maco@ch2m.com (425) 233-3392 joe.hauser@ch2m.com (425) 233-3108	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 Technical Representative and RPM of any field issues that would negatively affect schedule or the ability to meet project data quality objectives.

This page intentionally left blank.

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.
TBD	NAVFAC QAO/Chemist	NAVFAC Atlantic	Provides QA oversight and reviews SAPs.
Rebecca Maco	PM/AM	CH2M	Oversees and manages project activities.
Peter Lawson	STC	CH2M	Provides senior technical support for project approach and execution.
Susan Moore	QM	CH2M	Provides QA oversight.
Laura Cook	SME	CH2M	Provides senior technical support for project approach and execution.
Joe Hauser	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.
Martha Maier	Laboratory PM	Vista Analytical	Manages samples tracking and maintains good communication with PC.
Anne Helak	Laboratory QAO	Vista Analytical	Responsible for audits, CA, and checks of QA performance within the laboratory.

This page intentionally left blank.

SAP Worksheet #8—Special Personnel Training Requirements Table

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

This page intentionally left blank.

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

Project Name: Aquifer Testing and Groundwater/Drinking Water Sampling at Keystone Hill Well **Projected Date(s) of Sampling:** November-December 2017 **PM:** Rebecca Maco		**Site Name:** OLF Coupeville **Site Location:** Coupeville, Washington		
Date of Session: Wednesday, August 23, 2017 **Scoping Session Purpose:** To obtain consensus on overall objectives of the investigation at OLF Coupeville.				
Name	**Title/Project Role**	**Affiliation**	**Phone #**	**E-mail Address**
Kendra Leibman	Lead RPM	NAVFAC Northwest	(360) 396-0022	kendra.leibman@navy.mil
Christopher Generous	RPM	NAVFAC Northwest	(360) 396-0014	christopher.generous@navy.mil
Laura Himes	RPM	NAVFAC Northwest	(360) 396-0031	laura.himes@navy.mil
Leslie Yuenger	Public Affairs Officer	NAVFAC Northwest	360-396-6387	leslie.yuenger@navy.mil
Rebecca Maco	PM	CH2M	(425) 233-3392	rebecca.maco@ch2m.com

Comments

The purpose of the scoping session was to obtain consensus on the path forward and schedule for the investigation work at OLF Coupeville. A site investigation (SI) for per- and polyfluoroalkyl substance (PFAS) in groundwater at OLF Coupeville was initially discussed as PFAS were recently detected in groundwater. Specifically, sampling of on-Base wells yielded detection of perfluorooctanoic acid (PFOA) at concentration above the United States Environmental Protection Agency (USEPA) lifetime health advisory (LHA) of 0.07 micrograms per liter (µg/L). Perfluorobutane sulfonate (PFBS) and perfluorooctane sulfonate (PFOS) were also detected in samples collected from on-base wells, but the result was below the Regional Screening Level (RSL) (USEPA, 2017) of 400 µg/L for PFBS (based on a hazard quotient [HQ] of 1.0) and LHA of 0.07 µg/L for PFOS, respectively. PFOA was also detected in samples collected from an off-base well, the Keystone Hill well, at concentrations below the LHA.

Field work is expected to begin in November 2017.

Action Items

- Obtain information from the Town of Coupeville Water District to support site investigation work at OLF associated with the Keystone Hill well and to obtain information to better evaluate if residences with PFAS contamination in their private wells could be connected to the Town of Coupeville water system.
- Define scope to support evaluation of the impact of Keystone Hill well pumping on OLF hydraulics and PFAS concentrations in selected wells, and feasibility of expanding the Town of Coupeville's water distribution system.
- Prepare SAP.

Consensus Decisions

The stakeholders on the call agree that the SAP will focus only on impact of Keystone Hill well pumping on OLF hydraulics and PFAS concentrations in selected wells, and feasibility of expanding the Town of Coupeville's water distribution system. Detailed objectives for the investigation will be discussed at a separate scoping meeting. Characterization of the nature and extent of PFAS in groundwater at OLF will be included in a subsequent SAP.

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

Project Name: Aquifer Testing at Keystone Hill Well **Projected Date(s) of Sampling:** November-December 2017 **PM:** Rebecca Maco/CH2M	**Site Name:** OLF Coupeville **Site Location:** Coupeville, Washington

Date of Session: Wednesday, August 30, 2017

Scoping Session Purpose: To obtain information from the Town of Coupeville to support evaluation of impact of Keystone Hill well pumping on OLF and feasibility of expanding the Town of Coupeville’s water distribution system.

Name	Title/Project Role	Affiliation	Phone #	E-mail Address
Kendra Leibman	Lead RPM	NAS Northwest	(360) 396-0022	kendra.leibman@navy.mil
Doug Kelly	County Hydrogeologist	Island County Environmental Health	(360) 678-7885	D.Kelly@co.island.wa.us
Molly Hughes	Mayor	Town of Coupeville	(360) 678-4461, ext. 2	Mayor@townofcoupeville.org
Kim Hinds	Town Engineer	Town of Coupeville	(360) 678-4461, ext 4	engineer@townofcoupeville.org
Joe Grogan	Water District Manager	Town of Coupeville	(360) 914-0314	utilities1@townofcoupeville.org
Brain Shuck	Water Resource Engineer	CH2M	(425) 233-3131	brain.shuck@ch2m.com
Doug Holsten	Deputy OLF Task Lead; Geology SME	CH2M	(425) 233-3211	doug.holsten@ch2m.com
Kat Brown	Long-term Solutions Task Lead	CH2M	(530) 299-3416	kathryn.brown@ch2m.com

Comments

To satisfy anticipated increased demand, the Town of Coupeville is planning to increase the Keystone Hill well’s extraction rate. The following is a summary of the information obtained from the Town of Coupeville during the scoping session:

- The Keystone Hill well is the primary well in Town’s system and currently operating 21 to 23 hours per day at approximately 150 gallons per minute (gpm). Because of anticipated increased demand, the Town is planning to increase the pumping rate of the Keystone Hill well to 300 gpm.
- Water level and pump on and off times are not recorded; no records are available to coordinate with March 2017 MW-14 transducer data.
- Water level and specific capacity checked approximately two times per month to monitor potential screen clogging.
- Town of Coupeville open to using Keystone Hill well as aquifer test pumping well, with the following constraints
  - The Town relies on this well heavily, so turning the well off for a pretest static period (for more than the usual 1 to 3 hours) is problematic. Taking the well offline presents significant challenges. Bringing on other ‘backup’ wells to fill the gap is also problematic.

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

  - The Town has two concerns with pumping the Keystone Hill well at a higher rate than 150 gpm:
    - The possibility of pulling in contaminants from OLF (especially since PFAS are present at levels already close to LHA at this well).
    - The downstream treatment system is limited; system might be able to treat another approximately 50 gpm from the Keystone well, but no more.
  - The Town has some concern about the length of test (the length of time Town would be inconvenienced), which is likely a minimum of 24 hours and up to 48 hours. Test plan is still being formulated.
  - NAVFAC Northwest agreed to consider these constraints in developing aquifer test plan, as well as to share the preliminary plan with the Town for discussion.
  - Because of the Town's constraints, the following actions should be taken:
    - Limit the pumping rate during the test to 150 gpm.
    - Minimize the length of test; there will be concern if more than 48 hours is proposed.
    - Instead of starting test after a prolonged rest period, limit the pretest rest period to 4 hours, and conduct the test while the Keystone Hill well is under normal operation.
- The Town is open to installing 1 or 2 observation-well pairs near Keystone well. Note that the property surrounding the well is owned by Island County, so their buy-in would be necessary. Doug Kelly (County Hydrogeologist) was on the call and inferred County could be agreeable.

Field work is expected to begin in November 2017.

Action Items

- CH2M will develop a preliminary testing plan for Keystone Hill well to present to Town of Coupeville.
- Kim Hinds will track down GIS locations for lines.
- Kendra Leibman will send the Town of Coupeville water pipeline information to CH2M.

Consensus Decisions

CH2M agrees to consider the constraints herein listed in developing a preliminary aquifer test plan and will share the preliminary plan with Town of Coupeville and the Navy for discussion.

SAP Worksheet #9-3—Project Scoping Session Participants Sheet

Project Name: Aquifer Testing at Keystone Hill well **Projected Date(s) of Sampling:** November-December 2017 **PM:** Rebecca Maco/CH2M	**Site Name:** OLF Coupeville **Site Location:** Coupeville, Washington
Date of Session: Tuesday, September 26, 2017 **Scoping Session Purpose:** To obtain buyoff from the Town of Coupeville and Island County on the revised Aquifer Test Plan for the Keystone Hill Well.	

Name	Title/Project Role	Affiliation	Phone #	E-mail Address
Kendra Leibman	RPM	NAS Northwest	(360) 396-0022	kendra.leibman@navy.mil
Doug Kelly	County Hydrogeologist	Island County Environmental Health	(360) 678-7885	D.Kelly@co.island.wa.us
Jill Wood	Environmental Health and Natural Resources	Island County Environmental Health	(360) 678-7888	JillW@co.island.wa.us
Molly Hughes	Mayor	Town of Coupeville	(360) 678-4461, ext. 2	Mayor@townofcoupeville.org
Kim Hinds	Town Engineer	Town of Coupeville	(360) 678-4461, ext 4	engineer@townofcoupeville.org
Joe Grogan	Water District Manager	Town of Coupeville	(360) 914-0314	utilities1@townofcoupeville.org
Rebecca Maco	Project Manager	CH2M	(425) 233-3392	rebecca.maco@ch2m.com
Joe Hauser	OLF Task Lead	CH2M	(425) 233-3108	joe.hauser@ch2m.com
Doug Holsten	Geology SME	CH2M	(425) 233-3211	doug.holsten@ch2m.com
Peter Lawson	STC	CH2M	(530) 949-0870	Peter.lawson@ch2m.com

Comments

The meeting included brief Introductions, a health and safety topic (exhaust from generators), and a thank you to Joe Grogan for assisting in the site visit conducted by CH2M at the Keystone Hill well on Wednesday, September 20. The team discussed the following topics included in the draft testing plan that was provided electronically to all attendees:

- Both observation well pairs to be installed on OLF property
- A single 4-hour shutdown period prior to aquifer test is requested (to be conducted at standard pumping rate for Keystone Hill well [known to the Town as well 108])
- Aquifer test to be run over a 7-day period utilizing the normal pumping rate and pumping cycle for the Keystone Hill well (approximately 150 gpm for 21-23 hours per day.)
- A non-intrusive ultrasonic flowmeter and data logger will be temporarily installed at the Keystone Hill well during the test so that accurate measurements of flow rates and drawdown can be recorded

SAP Worksheet #9-3—Project Scoping Session Participants Sheet (continued)

- Groundwater sampling will be conducted before, during, and at the conclusion of the test at the Keystone Hill well, the two new well pairs, and the five existing monitoring wells.
- Tentative fieldwork schedule – late November, 2017 for well install, development, and aquifer testing
- The Department of Transportation well (also known as the Patmore Well) on adjacent property just north of the Keystone Hill well may be available for observation and sampling during the aquifer test
- The results from the aquifer test can be used to simulate what the results of an increased pumping rate at the Keystone Hill well
- The Town Mayor indicated that the seven residents who have exceedances in drinking water wells on their property intend to file a class action lawsuit
- The Town Mayor voiced concern to the Navy about the usage of funding for more testing versus treatment

Action Items

- Island County will search for records regarding past pump testing at the Department of Transportation well
- CH2M will determine whether the Department of Transportation well can be used for observation and sampling during the aquifer test

Consensus Decisions

The Navy, CH2M, the Town of Coupeville, and Island County agreed to move forward with the aquifer test in accordance with the draft plan presented at this meeting.

This page intentionally left blank.

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 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 (FCLP) 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. The area to be investigated includes a community drinking water well (Keystone Hill well), located west of Keystone Hill Road, approximately 200 feet west of the western boundary of OLF Coupeville and its surrounding environs (**Figure 10-3**).
Potential Sources	Potential source areas for off-Base drinking water PFAS impacts are on-Base locations of suspected releases of AFFF, including a potential previous release of AFFF near Building 2807 (the Trainer Building). Groundwater data collected during the 2016-2017 SI are consistent with this hypothesis. The runway and storage buildings located east of the runway are also suspected source areas. Well construction records for the water supply well at Building 2807 show that the well casing was not grouted below 18 feet below ground surface (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 for migration of PFAS in shallower perched groundwater into the well annular space and potentially into deeper aquifer units. In addition, the primary drinking water aquifer, (known as the Sea Level Aquifer) contains PFAS at concentrations above the USEPA lifetime health advisory level, and is semiconfined, which would allow migration of PFAS.
Study Area Investigation History	The investigation area includes both off-Base area adjoining and in the vicinity of OLF Coupeville and on-Base areas within the OLF Coupeville (**Figure 10-3**). There are no reports of on-Base source areas at OLF Coupeville as documented in *Final Sampling and Analysis Plan Investigation of Perfluorinated Compounds in Drinking Water, Outlying Landing Field Coupeville* (CH2M, 2017b). There is no available documentation that aqueous film-forming foam (AFFF) was used at the site. However, three PFAS(PFOA, PFOS, and PFBS) have been detected in groundwater samples collected from on-Base wells. 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 was likely used/released at the site. The Navy conducted on-Base drinking water sampling at OLF Coupeville in September 2016. PFOA was detected in one on-Base drinking water well below the USEPA health advisory, which indicates a potential previous release of AFFF near Building 2807 (**Figure 10-2**). 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 the USEPA's Unregulated Contaminant Monitoring Rule (UCMR) 3. The PFAS detection prompted initiation of groundwater investigation at OLF Coupeville (CH2M, 2017a). 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 bgs (ranging from 95.88 to -38.51 feet above mean sea level), to provide data on the piezometric surface in each well and vertical distribution of PFAS at each well pair location. The monitoring wells were typically screened at three general elevation intervals (two of the three elevation intervals represented at each well pair): 'shallow' wells were screened above 50 feet above mean sea level (amsl); 'intermediate' wells were screened 0 to 50 feet amsl; and 'deep 'wells were screened near or below 0 foot amsl. Note that the shallow, intermediate, and deep screen intervals do not indicate three discrete aquifers or water-bearing zones and the 'middle' and 'deep' screen intervals are located within the source aquifer of drinking water on Whidbey Island (known locally as the Sea Level Aquifer [USGS, 1982]). Further characterization of the nature and extent of PFAS in groundwater at OLF Coupeville will be included in a subsequent expanded PA/SI SAP.

SAP Worksheet #10—Conceptual Site Model (continued)

Table 10-1. OLF Coupeville Conceptual Site Model

Study Area Investigation History (continued)	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 due to the PFOA detection identified during the Navy's UCMR 3 sampling. Off-Base sampling included evaluation of off-Base site history including drinking water well construction and installation information. The Navy sampled 120 drinking water wells near OLF Coupeville, of which one was the Town of Coupeville's Keystone Hill well. The Keystone Hill 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 gpm for 21 to 23 hours per day. Water from the Keystone Hill well 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 (Birm), and post-chlorination with sodium hypochlorite.	
Site Conditions	**Physical Characteristics**	Both OLF Coupeville and the Keystone Hill well are located on a broad plateau of Smith Prairie in central Whidbey Island at an elevation of approximately 195 feet amsl. 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. The Keystone Hill well is located in a forested area within the Ebey's Landing National Historic Reserve and is accessed by Keystone Hill Road to the east (**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. (**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. The potentiometric surface for the Cross sections have been developed to evaluate the comprehensive site hydrogeology and are shown on **Figures 10-3** through **10-7**. Boring logs from the initial construction of the Keystone Hill well in 2008 are similar to neighboring OLF Coupeville with silty sand and gravel from the surface to 133 ft bgs (**Appendix B**). A seven-foot thick confining layer of silty clay from 133-140 ft 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 ft bgs.

SAP Worksheet #10—Conceptual Site Model (continued)

Table 10-1. OLF Coupeville Conceptual Site Model

Site Conditions	**Geology and Hydrogeology (continued)**	The Keystone Hill well is screened from 142-182 ft bgs or 8-48 ft amsl within the fine sand comprising the Sea Level Aquifer (intermediate 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 Keystone Hill well had a yield of 302 gallons-per-minute (gpm) with approximately 20 ft of drawdown over a 24-hour period and a transmissivity of 79,000 gallons-per-day-per-foot (gpd/ft) (Robinson and Noble, 2008). The current yield of the Keystone Hill well as operated by the Town of Coupeville is approximately 150 gpm over a 21-23-hour period each day. The groundwater elevation study conducted in March 2017 indicated groundwater elevation fluctuations in each of the 27 wells during a 48-hour monitoring period ranged up to 0.6 ft. Deep-screened wells (WI-CV-MW01-D, WI-CV-MW03-D, WI-CV-MW10-D, and WI-CV-MW12-D) show a clear semidiurnal tidal influence. Two intermediate-screened wells (WI-CV-MW06-M and WI-CV-MW08-M) show a weaker semidiurnal tidal influence. WI-CV-MW14-M appears to show a response to nearby pumping, possibly related to operation of the Town of Coupeville Keystone Hill well. Pumping records have not been obtained for the Town of Coupeville well. Most other wells show small water level variations that appear to correlate with barometric pressure fluctuations (CH2M, 2017a). Groundwater contour maps have been generated for intermediate-and-deep-screened monitoring well networks, included as **Figures 10-8** and **10-9**, 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. The dominant flow direction in the intermediate-screened wells is to the southwest in the northern portion of the site, shifting to the south-southeast in the southern portion of the site (**Figure 10-8**). Groundwater flow in the deep-screened wells is to the south (**Figure 10-9**). Vertical gradients are not currently understood but are suspected to be downward. The Island County Water Resource Management Plan (Island County, 2005) suggests that OLF is located on a hydrogeologic divide, and groundwater flow is likely to be radial away from OLF Coupeville. The impact of off-Base water supply wells (pumping conditions) on localized groundwater flow is unknown and will be studied during a Site Inspection and/or Remedial Investigation for OLF Coupeville currently planned for 2018. In general, the overall groundwater flow direction appears to be consistent over time regardless of tidal influence (CH2M, 2017a). The fine sands representing outwash are transmissive and is locally known as the Sea Level Aquifer (USGS, 1982). Cross sections have been developed to evaluate the comprehensive site hydrogeology and are shown on **Figures 10-3** through **10-7**. These mixed deposits are distributed in beds of inconsistent thickness across the site, which complicates identification of distinct hydrogeologic units. Boring logs from the initial construction of the Keystone Hill well in 2008 are similar to neighboring OLF Coupeville with silty sand and gravel from the surface to 133 feet bgs (**Appendix B**). A 7-foot thick confining layer of silty clay from 133 to 140 feet bgs separates the overlying sands and gravels from the underlying fine sand with trace gravel. Total depth of the boring was to 200 feet bgs. The Keystone Hill well is screened from 142-182 feet bgs or 8 to 48 feet amsl within the fine sand comprising the Sea Level Aquifer (intermediate 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 Keystone Hill well 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 and Noble, 2008). The current yield of the Keystone Hill well as operated by the Town of Coupeville is approximately 150 gpm over a 21- to 23-hour period each day.

SAP Worksheet #10—Conceptual Site Model (continued)

Table 10-1. OLF Coupeville Conceptual Site Model

Contaminants of Potential Concern	14 PFAS compounds (listed in **Worksheet #15**)
Nature and Extent	<u>Drinking Water</u> Keystone Hill well: Two drinking water samples collected from the Keystone Hill well in December 2016 were analyzed for PFOA and PFOS. PFOA was detected in both samples at concentrations of 0.0555 and 0.0611 μg/L, or below the USEPA lifetime health advisory of 0.07 μg/L. PFOS was not detected in either of the two drinking water samples (Navy, 2017d). These results are consistent with the independent testing results conducted by the Town of Coupeville in November 2016, where PFOA was detected at concentrations below the USEPA lifetime health advisory and PFOS was not detected. <u>Groundwater</u> OLF Coupeville: PFOA, PFOS and PFBS were analyzed for groundwater samples collected from 27 wells located within OLF Coupeville in February and March 2017 (CH2M, 2017a). Groundwater sample results are shown on **Figure 10-10**. PFBS and PFOS were both detected at selected wells at concentrations below the RSL (USEPA, 2017) of 400 µg/L (based on a HQ of 1.0) and USEPA LHA of 0.07 µg/L for PFOS, respectively. PFOA concentrations at three wells (WI-CV-MW02-S, WI-CV-MW05-M, and WI-CV-MW14-M) exceeded the LHA of 0.07 μg/L for PFOA. The highest-combined PFOA and PFOS concentration in the intermittent shallow/perched aquifer was 0.626 μg/L, in the sample from WI-CV-MW02-S. This was the only detection in shallow/perched interval that exceeded the LHA for the total concentration of PFOA plus PFOS (0.07 µg/L). This location may represent a source area. The highest detection was of PFOA at a concentration of 1.19 μg/L in the sample collected from WI-CV-MW05-M. PFAS concentrations in WI-CV-MW05-S, the shallow well for this well pair, were significantly lower with no exceedances of the LHA, indicating a possible upgradient source and potential transport pathway between the shallow/perched and intermediate -screened intervals (which could not be positively confirmed with the existing well network) (CH2M, 2017a).

SAP Worksheet #10—Conceptual Site Model (continued)

Table 10-1. OLF Coupeville Conceptual Site Model

Migration Pathways	PFAS contamination was most widespread in intermediately-screened monitoring wells, compared to the shallow/perched and deep-screened wells. In addition to the elevated concentration in the sample from WI-CV-MW05-M, the combined PFOA and PFOS concentration in the sample from WI-CV-MW14-M also exceeded the LHA at 0.167 μg/L. Detections of one or more PFAS were noted in WI-CV-MW09-M, WI-CV-MW10-M, and WI-CV-MW13-M. With the exception of a PFOS detection of 0.000914 J μg/L at WI-CV-MW03-D, there were no detections of PFAS in the deep-screened wells. PFBS was not detected in wells located north or south of the runway. West of the runway, PFBS was detected in the intermediate interval. East of the runway, PFBS was only detected in the shallow/perched wells. <u>Soil (Keystone Hill well and OLF Coupeville):</u> • No environmental investigations have been conducted for soil at the site. • A Site Inspection and/or Remedial Investigation for OLF Coupeville is currently planned for 2018. • Horizontal and vertical transport via advection with groundwater flow. • 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. • Leaching of PFAS currently and/or historically present from soil to groundwater may be a potential pathway. Investigation of this pathway will be included in a future SAP.
Potential Receptors / Exposures Routes	Current and future off base residents: Ingestion of PFAS in groundwater. Current and future drinking water users at OLF Coupeville: Ingestion of PFAS in groundwater. Ecological receptors: Not applicable

Data Needs

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

- Information regarding the impact of pumping rate at the Keystone Hill well on groundwater conditions at the OLF Coupeville is necessary to evaluate the feasibility of expanding the Town of Coupeville’s drinking water distribution system from the current extraction rate of 150 gpm to the Town of Coupeville’s proposed extraction rate of 300 gpm.
- PFAS concentration at the Keystone Hill well is necessary to evaluate whether PFAS concentration changes during the pumping cycle of the Keystone Hill well, and PFAS concentrations at the surrounding monitoring wells are necessary to determine whether PFAS LHA exceedances are present in wells within the capture zone of the Keystone Hill well at current and proposed extraction rates.

This page intentionally left blank.

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

Problem Definition, Environmental Questions, and Project Quality Objectives

The Town of Coupeville operates a community drinking water well, Keystone Hill well, approximately 200 feet west of OLF Coupeville. To satisfy anticipated increased demand, the Town of Coupeville completed a water system plan in which the pumping rate of the Keystone Hill well will be increased from 150 gallons per minute (gpm) to 300 gpm. However, PFOA was detected in groundwater at three on-base wells at concentrations above the LHA and PFOA has recently been detected in drinking water samples collected from the Keystone Hill well at concentrations near the EPA lifetime health advisory level. The Town of Coupeville is concerned that increasing extraction rates may result in higher PFAS concentrations in water produced by the Keystone Hill well. Information regarding the impact of pumping rate at the Keystone Hill well on groundwater conditions at the OLF Coupeville is necessary to evaluate the feasibility of expanding the Town of Coupeville's drinking water distribution system. This information is also necessary for the Navy's evaluation of new drinking water sources for homes that have drinking water above the USEPA's LHA.

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**. Characterization of the nature and extent of PFAS in groundwater at OLF Coupeville will be included in a future SAP.

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

Table 11-1. Problem Quality Objectives

Problem Definition Objectives	Environmental Question(s)	General Investigation Approach	PQOs
Determine the radius of influence (ROI) and extent of hydraulic capture of the Keystone Hill well when operating under normal pumping conditions.	What is the ROI and extent of hydraulic capture of the Keystone Hill well under normal operational conditions of 150 gpm and run between 21 and 23 hours per day?	A review of historical data from the Keystone Hill well including an aquifer test conducted when the well was first constructed in 2008 (Robinson and Noble, 2008) was evaluated using the multi-layer (MLU) analytical modeling software. Results from the document review in conjunction with modeling results were used to determine placement of the proposed observation wells for the proposed aquifer testing of the Keystone Hill well (see **Figure 11-1**). Two observation-well pairs will be installed for the test. To determine if a vertical hydraulic gradient is present, each pair will consist of a shallow well for any perched aquifers present and a deeper well screened within the Sea Level Aquifer and similar to the screened interval of the Keystone Hill well (142 to 182 feet bgs). It is expected that one well pair will be located approximately 190 feet east of the Keystone Hill well and the other well pair will be located approximately 260 feet northeast of the Keystone Hill well; both well pairs will be located just inside the OLF boundary (see **Figure 11-1**). Groundwater levels will be monitored in the two new well pairs and seven existing monitoring well pairs during the aquifer test. The aquifer test at the Keystone Hill well will be run by CH2M personnel with permission from the Town of Coupeville. Transducers will be deployed in the Keystone Hill well, newly-installed observation wells, and selected monitoring wells located on the OLF for a 7-day period. A new flowmeter on the Keystone Hill well discharge piping will be installed for the test, and the test will not interfere with routine pumping well operations. Results from the aquifer test will be simulated in the same software as the historical review, and the ROI and extent of hydraulic capture will be estimated using three-dimensional groundwater flow modeling software.	If the extent of hydraulic capture produced by operation of the Keystone Hill well at current pumping rates does not encompass enough monitoring wells with known PFOA/PFOS LHA exceedances to drive the Keystone Hill well to an LHA exceedance, then current pumping operations will continue with periodic sampling as determined by the project team (**Worksheet #4**) in consultation with the NAVFAC Northwest RPM. If the extent of hydraulic capture produced by operation of the Keystone Hill well operating at the current pumping rate encompasses enough wells with PFOA/PFOS LHA exceedances to drive the Keystone Hill well to an LHA exceedance, the pumping rate recommended by the project team (**Worksheet #4**) will be adjusted accordingly to reduce the number of exceeding wells within capture zones.

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

Table 11-1. Problem Quality Objectives (continued)

Problem Definition Objectives	Environmental Question	General Investigation Approach	PQO
Determine the ROI and extent of hydraulic capture through numerical modeling of the Keystone Hill well when production is increased to the Town of Coupeville's proposed 300 gpm during expansion.	What is the area of the modeled, expanded ROI and extent of hydraulic capture when the pumping rate is increased to 300 gpm and does it extend to onsite monitoring wells with known PFAS LHA exceedances?	Using data collected from the aquifer test at the Keystone Hill well during normal pumping conditions, modeling software will be used extrapolate the drawdown and extent of hydraulic capture produced when the Keystone Hill well operates at 300 gpm to meet anticipated increased demand from the Town of Coupeville.	If the modeled extent of hydraulic capture from the increased rate of 300 gpm extends to additional wells with PFOA/PFOS LHA exceedances that will drive the Keystone Hill well to LHA exceedance, then the project team (**Worksheet #4**) will recommend to NAVFAC Northwest RPM that the Town of Coupeville do not increase the pumping rate at the Keystone Hill well.
Determine current PFOA/PFOS concentrations in the Keystone Hill and in the surrounding monitoring wells.	Do the PFOA/PFOS concentrations in the Keystone Hill well and other wells within the hydraulic capture zone of the Keystone Hill well at current and proposed extraction rates exceed the PFOA/PFOS LHA?	For the Keystone Hill well, a single sample will be collected during the pumping cycle at the half-way point of a cycle (i.e. mid-afternoon). For the eleven monitoring wells surrounding the Keystone Hill well (two new well pairs, two existing well pairs, and three additional existing wells), a single sampling event will be conducted after the conclusion of the aquifer test during the middle portion of the day. The purpose of the surrounding monitoring well sampling is to investigate the PFAS concentrations in wells that may be within the current and/or future capture zone of the Keystone Hill well.	If the concentrations of the wells within the current and/or future capture zones and the Keystone Hill well itself are found to exceed the PFOA/PFOS LHA, then the concentrations in the exceeding wells will be considered in conjunction with groundwater flow modeling results to aid the Town of Coupeville in the evaluating potential impacts on water quality resulting from increasing the production flow rate from the Keystone Hill well.

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

What are the Project Action Limits?

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 groundwater monitoring wells (at OLF Coupeville) and the Keystone Hill drinking water well.

- USEPA LHA for PFOA and PFOS: 0.07 µg/L, unless both chemicals are detected, then 0.07 µg/L is the LHA for the cumulative concentration of the two chemicals
- USEPA RSL for perfluorobutane sulfonates (PFBS): 400 µg/L (based on a HQ = 1.0)
- PALs currently do not exist for the remaining 11 PFAS compounds. At the time of drafting this SAP, there are no USEPA RSLs or any state regulatory screening levels available. Per Navy policy, data need to be collected for all 14 analytes listed in USEPA Method 537 rev. 1.1

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.
- Synoptic water level surveys at the Keystone Hill well and transducer deployment at the pumping well, the newly-installed observation well pairs, and existing monitoring wells on the OLF before the aquifer test and a 7-day period during which multiple pumping cycles will be measured.
- Field measurements of drinking water quality and groundwater quality (pH, dissolved oxygen [DO], temperature, conductivity, oxidation-reduction potential [ORP], and turbidity) will be completed during drinking water sampling of the Keystone Hill well and surrounding monitoring wells.
- Groundwater and drinking water samples will be submitted to an offsite laboratory (Vista Analytical) for PFAS analysis.
- Numerical 2-dimensional or 3-dimensional (3D) groundwater flow modeling to determine ROI and extent of hydraulic capture for current and elevated pumping rates at the Keystone Hill well.

Samples to be collected and analyzed to meet each of 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)

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

- On-Base at OLF Coupeville: Install four new observation wells, log soil borings from the new well locations, collect groundwater samples from four new and seven existing monitoring wells.
- Keystone Hill well: Collect drinking water samples and field measurements.
- Collect samples and conduct aquifer testing and numerical modeling as outlined in **Worksheets #14, #17, and #18**, and in accordance with the project schedule outlined in **Worksheet #16**. The data will be collected following the standard operating procedures (SOPs) presented in **Worksheet #21**.

This page intentionally left blank.

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

Matrix: Groundwater
Analytical Group: PFAS
Concentration Level: Low

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 Reagent Blank		One per site per day of sampling	Bias/Contamination	No analytes detected > ½ LOQ or >1/10 sample concentration, whichever is greater
Cooler Temperature Indicator		One per cooler	Accuracy/Representativeness	Temperature ≤ 6 degrees Celsius (°C), not frozen

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

Matrix: Drinking Water
Analytical Group: PFAS
Concentration Level: Low

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 20%
Field Reagent Blank		One per property, or per well where drinking water sampled	Bias/Contamination	No analytes detected more than (>) 1/3 limit of quantitation (LOQ). Concentrations greater than 1/3 will require all associated samples to be re-sampled and re-analyzed; however, decision making and/or action (i.e., providing an alternate drinking water source) may proceed in advance of the resampling and re-analysis
Cooler Temperature Indicator		One per cooler	Accuracy/Representativeness	Temperature less than or equal to (≤) 10 degrees Celsius (°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.	CH2M. 2017b. Draft Technical Memorandum, *Evaluation of Per- and Polyfluoroalkyl Substances in Groundwater Outlying Landing Field Coupeville*. Naval Air Station Whidbey Island Coupeville, Washington. July 2017.	Navy. Groundwater and geology. February and March 2017.	Data will be used to assist the placement of observation wells.	None
Well construction and historical well testing data (pumping test results and water quality testing results) from the Keystone Hill well	Robinson and Noble. 2008. *Town of Coupeville Keystone Hill well Construction and Testing Report*. Tacoma, Washington. April 2008.	Robinson and Noble. 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
Off-Base Drinking Water Results	CH2M. Report in Progress. *Results of the Investigation of Per- and Polyfluoroalkyl Substances in Drinking Water Ault Field and Outlying Landing Field Coupeville Naval Air Station Whidbey Island Coupeville, Washington*	Navy. Groundwater. October and November 2017.	Data will be used to assist in the selection of existing monitoring wells to be included in this investigation.	None
Drinking water data from Keystone Hill well	Navy. 2017d. Final Phase 2 Naval Air Station Whidbey Island Per- and Polyfluoroalkyl Substances Drinking Water Investigation Open House Posters. February. https://www.navfac.navy.mil/content/dam/navfac/NAVFAC%20Atlantic/NAVFAC%20Northwest/PDFs/About%20Us/PFAS%20Groundwater%20and%20Drinking%20Water%20Investigation/nw_Final_Poster_ALL_NASWI.pdf	Town of Coupeville. Groundwater. November 2016.	Data will be used to determine if PFAS concentrations at the Keystone Hill well are changing over time.	None

This page intentionally left blank.

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 C**.

Premobilization Tasks

- 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 validator
  - 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 the Town of Coupeville for site access.

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. Prior to 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 HSP.

Utility Clearance

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.

Observation Well Installation

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

Soil Logging

Soil borings from the observation wells 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 C**.

Well Development

Following well installation, each well will be developed by the drilling subcontractor and CH2M field crew in accordance with the SOPs listed in **Worksheet #21** and provided in **Appendix C**.

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

Surveying

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

Sampling Tasks

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

- Groundwater and Drinking Water Level Measurements
  - Synoptic water level survey at the Keystone Hill well and monitoring wells once prior to transducer installation. Wells included in the initial synoptic are CV-MW01M, CV-MW01D, CV-MW02S, CV-MW02M, CV-MW03S, CV-MW03M, CV-MW04S, CV-MW04M, CV-MW05S, CV-MW05M, CV-MW06S, CV-MW06M, CV-MW07S, CV-MW07M, CV-MW08S, CV-MW08M, CV-MW09S, CV-MW09M, CV-MW11S, CV-MW11M, CV-MW13S, CV-MW13M, CV-MW14M, WI-CV-WL01, and WI-CV-WL02. Additional wells including the Patmore well to the north and the Youderian well to the south may be monitored if access can be obtained.
  - Transducer deployment at the Keystone Hill well, the newly-installed observation well pairs, and existing monitoring wells MW02S, MW04S, MW04M, MW05M, MW07S, MW07M, and MW14M before the aquifer test and a 7-day period during which multiple pumping cycles will be measured in accordance with the SOPs listed in **Worksheet #21** and provided in **Appendix C**.
  - Synoptic water level surveys will be conducted daily during transducer deployment at CV-MW01M, CV-MW01D, CV-MW02M, CV-MW03S, CV-MW03M, CV-MW05S, CV-MW08S, CV-MW08M, CV-MW09S, CV-MW09M, CV-MW11S, CV-MW11M, CV-MW13S, CV-MW13M, WI-CV-WL01, and WI-CV-WL02.
- Other Groundwater and Drinking Water Field Measurements
  - Field measurements of drinking water and groundwater quality (pH, DO, temperature, conductivity, ORP, and turbidity) will be completed during drinking water and groundwater sampling of the Keystone Hill well and surrounding monitoring wells in accordance with the SOPs listed in **Worksheet #21** and provided in **Appendix C.**
- Groundwater and Drinking Water Samples
  - Groundwater and drinking water samples will be collected in accordance with **Worksheet #17 and #18** and with the SOPs listed in **Worksheet #21** and provided in **Appendix C.**

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.* September. *(Navy, 2017a)* and in accordance with SOPs listed in **Worksheet #21** and provided in **Appendix C**.

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

Analyses and Testing Tasks

- Vista Analytical will process, prepare samples for analyses, and analyze samples in accordance with Worksheet #18 and #19.
- Groundwater samples will be analyzed for fourteen the analytes from the USEPA Method 537 Modified (in accordance with QSM v5.1 Table B-15, reporting branched and linear PFAS isomers (PFOA, PFOS, and PFBS) that are commercially available in accordance with **Worksheets #18** and **#19**.
- Drinking water samples will be analyzed for fourteen the analytes from the drinking water method (USEPA Method 537), reporting branched and linear PFAS isomers (PFOA, PFOS, and PFBS) that are commercially available in accordance with **Worksheets #18** and **#19**.

Aquifer Testing

An aquifer test will be conducted at the Keystone Hill well to better quantify aquifer hydraulic properties and address the following objectives:

- Provide improved delineation of the current and potential future hydraulic capture zone of the Keystone Hill well.
- Provide insight as to whether increased pumping at the Keystone Hill well could potentially result in increased PFAS concentrations (i.e. if wells with LHA exceedances are within the current of future capture zone of the Keystone Hill well.

For a period of 7 days, electronic pressure transducers will be placed in the pumping well (Keystone Hill), the newly installed observation wells, and current on-base monitoring wells MW-02S, MW-04S, MW-04M, MW-05M, MW-07S, MW-07M, and MW-14M to record water level fluctuations prior to testing. The transducers will be programmed to record water level data on a logarithmic time scale with the maximum time interval of 1 minute and will have a minimum accuracy of +/-0.01 ft. The Keystone Hill well will be requested to be shut down for 4 hours before testing, to allow the aquifer to rebound to non-pumping conditions. A new or temporary high-accuracy flowmeter will be installed onto the Keystone Hill well for the duration of the aquifer test for better precision on pumping rates. Upon installation of the flowmeter, it will be calibrated with the existing totalizing flowmeter being employed by the Town of Coupeville by measuring flow in 10 minute increments and comparing the results of each device.

Because of the high current demand on the Keystone Hill well to supply drinking water for surrounding residences, it is infeasible to impede operations by performing step-rate testing before a constant-rate test. Instead, the existing pump cycle of 150 gpm for 21 to 23 hours/day will be used as a proxy for the constant-rate test and the 300 gpm proposed by the Town of Coupeville will be extrapolated from the results of this test using modeling software.

The constant-rate portion of the aquifer test will be initiated by the beginning of the regular pump cycle of the Keystone Hill well following the 4-hour shutdown. Manual groundwater measurements and totalizer readings will be measured at the Keystone Hill well and observation wells at least once before the testing, twice during the testing and once after the testing is complete. An ultra-sonic flowmeter will be placed on the water main inside the Keystone Hill well building during the duration of the test to measure flow from the well to the Town water system. Transducers will remain in the wells for a minimum of 72 hours after the constant-rate test to determine any trends from several pump cycles. Vented transducers will be used to eliminate the need for barometric pressure corrections. Additionally, Island County Department of Health will provide access to data from barometers operating in Coupeville to provide a method to correct for confined aquifer barometric influences, if necessary.

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

Modeling

Drawdown data measured at the instrumented wells will be used to evaluate aquifer hydraulic properties in the vicinity of the Keystone Hill well. The MLU software is a quasi-numerical modeling tool that will be used to analyze the drawdown data. MLU is a powerful yet efficient tool for evaluating aquifer responses to pumping. However, in some instances, MLU can struggle to replicate observed drawdowns, particularly for aquifer systems with considerable heterogeneity. As an alternative, a simple 3D groundwater flow model may also be constructed. The method of analysis will be determined once data from the test have been reviewed.

Once the hydraulic properties have been determined, the selected model (i.e., MLU or 3D groundwater flow model) will be used to estimate the hydraulic capture zone for the Keystone Hill well under two different pumping scenarios. The first scenario will represent current conditions, where the Keystone Hill well pumps at 150 gpm. The second scenario will represent the increased pumping condition, where the Keystone Hill well pumps at 300 gpm. This analysis could provide insight as to whether increased extraction rates could potentially result in higher PFAS concentrations in water produced by the Keystone Hill well.

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 technical memorandum 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 (USEPA 537 Modified in accordance with QSM v5.1 Table B-15)

Analyte	Chemical Abstract Service Number	USEPA Lifetime Health Advisory (µg/L)	RSLs Tap water HQ = 1.0 (June 2017) (µg/L)	PQL Goal[1] (µg/L)	Laboratory Limits (µg/L)			LCS and MS/MSD Recovery Limits and RPD[2] (%)		
					LOQs (µg/L)	LODs (µg/L)	DLs (µg/L)	LCL	UCL	RPD
Perfluorooctanoic acid (PFOA)	335-67-1	0.07	--	0.008	0.008	0.005	0.00218	70	130	30
Perfluorooctane Sulfonate (PFOS)	1763-23-1	0.07	--	0.008	0.008	0.005	0.00218	70	130	30
Perfluorobutanesulfonic acid (PFBS)	375-73-5	--	400	0.008	0.008	0.005	0.00218	70	130	30
Perfluorohexanoic acid (PFHxA)	307-24-4	--	--	0.008	0.008	0.005	0.00218	70	130	30
Perfluoroheptanoic acid (PFHpA)	375-85-9	--	--	0.008	0.008	0.005	0.00218	70	130	30
Perfluorohexane sulfonate (PFHxS)	355-46-4	--	--	0.008	0.008	0.005	0.00218	70	130	30
Perfluorononanoic acid (PFNA)	375-95-1	--	--	0.008	0.008	0.005	0.00218	70	130	30
Perfluorodecanoic acid (PFDA)	335-76-2	--	--	0.008	0.008	0.005	0.00218	70	130	30
Perfluoroundecanoic acid (PFUnA)	2058-94-8	--	--	0.008	0.008	0.005	0.00218	70	130	30
Perfluorododecanoic acid (PFDoA)	307-55-1	--	--	0.008	0.008	0.005	0.00218	70	130	30
Perfluorotridecanoic acid (PFTrDA)	72629-94-8	--	--	0.008	0.008	0.005	0.00218	70	130	30
Perfluorotetradecanoic acid (PFTeDA)	376-06-7	--	--	0.008	0.008	0.005	0.00218	70	130	30

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

Matrix: Groundwater
Analytical Group: PFAS (USEPA 537 Modified in accordance with QSM v5.1 Table B-15)

Analyte	Chemical Abstract Service Number	USEPA Lifetime Health Advisory (µg/L)	RSLs Tap water HQ = 1.0 (June 2017) (µg/L)	PQL Goal[1] (µg/L)	Laboratory Limits (µg/L)			LCS and MS/MSD Recovery Limits and RPD[2] (%)		
					LOQs (µg/L)	LODs (µg/L)	DLs (µg/L)	LCL	UCL	RPD
N-Ethylperfluoro-1-octanesulfonamidoacetic acid (EtFOSAA)	2991-50-6	--	--	0.008	0.008	0.005	0.00218	70	130	30
N-Methylperfluoro-1-octanesulfonamidoacetic acid (MeFOSAA)	2355-31-9	--	--	0.008	0.008	0.005	0.00218	70	130	30
PFOA + PFOS (calculated)[4]	--	0.07	--	--	--	--	--	--	--	--

Notes:

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

[2] Accuracy and precision limits follow laboratory in-house limits per Quality Systems Manual (QSM) v5.1, Table B-15.

[3] PALs are available for PFOS, PFOA, and PFBS. No other criteria are available or applicable to the remaining analytes. The analytes have been included to follow Navy policy.

[4] If both PFOS and PFOA are detected, the combined concentration must be less than 0.07 µg/L. Otherwise, the chemicals will be compared to the USEPA LHA of 0.07 µg/L individually.

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 in advance of sample testing.

DL = detection limit
LCL = lower confidence limit
LCS = laboratory control sample
LOD = limit of detection
RPD = relative percent difference
UCL = upper confidence limit

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

Matrix: Drinking Water

Analytical Group: PFAS (USEPA Method 537)

Analyte	Chemical Abstract Service (CAS) Number	USEPA Lifetime Health Advisory (µg/L)	RSLs Tapwater HQ = 1.0 (June 2017) (µg/L)	PQL Goal[1] (µg/L)	Laboratory Limits (µg/L)			LCS and MS/MSD Recovery Limits and RPD[2] (%)		
					LOQs (µg/L)	LODs (µg/L)	DLs (µg/L)	LCL[3]	UCL[3]	RPD
Perflurooctane Sulfonate (PFOS)	1763-23-1	0.07	--	0.01	0.01	0.005	0.00104	70	130	30
Perfluoro-n-octanoic acid (PFOA)	335-67-1	0.07	--	0.01	0.01	0.005	0.00108	70	130	30
Perfluorobutane sulfonate (PFBS)	375-73-5	--	400	0.01	0.01	0.005	0.000443	70	130	30
Perfluorohexanoic acid (PFHxA)	307-24-4	--	--	0.01	0.01	0.005	0.000663	70	130	30
Perfluoroheptanoic acid (PFHpA)	375-85-9	--	--	0.01	0.01	0.005	0.000533	70	130	30
Perfluorohexane sulfonate (PFHxS)	355-46-4	--	--	0.01	0.01	0.005	0.000415	70	130	30
Perfluorononanoic acid (PFNA)	375-95-1	--	--	0.01	0.01	0.005	0.00144	70	130	30
Perfluorodecanoic acid (PFDA)	335-76-2	--	--	0.01	0.01	0.005	0.00128	70	130	30
Perfluoroundecanoic acid (PFUnA)	2058-94-8	--	--	0.01	0.01	0.005	0.000255	70	130	30
Perfluorododecanoic acid (PFDoA)	307-55-1	--	--	0.01	0.01	0.005	0.000952	70	130	30
Per(fluorotridecanoic acid (PFTrDA)	72629-94-8	--	--	0.01	0.01	0.005	0.000943	70	130	30
Perfluorotetradecanoic acid (PFTeDA)	376-06-7	--	--	0.01	0.01	0.005	0.000777	70	130	30
N-Ethylperfluoro-1-octancesulfonamidoacetic acid (EtFOSAA)	2991-50-6	--	--	0.01	0.01	0.005	0.00193	70	130	30
N-Methylperfluoro-1-octanesulfonamidoacetic acid (MeFOSAA)	2355-31-9	--	--	0.01	0.01	0.005	0.00304	70	130	30
PFOA + PFOS (calculated)[4]	--	0.07	--	--	--	--	--	--	--	--

Notes:

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

[2] Accuracy and precision limits follow USEPA Method 537 Revision 1.1 per Navy policy.

[3] PALs are available for PFOS, PFOA, and PFBS. No other criteria are available or applicable to the remaining analytes. The analytes have been included to follow Navy policy.

[4] If both PFOS and PFOA are detected, the combined concentration must be less than 0.07ug/L. Otherwise, the chemicals will be compated to the USEPA Lifetime Health Advisory of 0.07 ug/L individually.

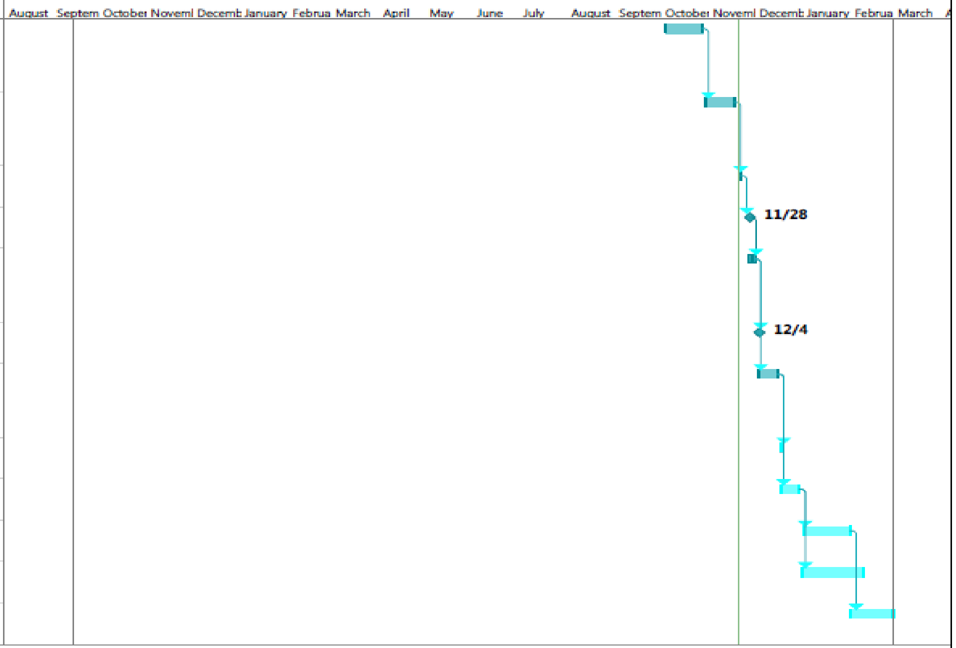
DL = detection limit; LCL = lower confidence limit; LCS = laboratory control sample; LOD = limit of detection; LOQ = limit of quantitation; RPD = relative percent difference; UCL = upper confidence limitLimits are verified on a quarterly basis per DoD QSM and may be subject to change. Any changes to these limits which impact the project SAP objectives, must be approved by the NAVFAC RPM in advance of sample testing.

This page intentionally left blank.

SAP Worksheet #16—Project Schedule/Timeline Table

Delivery Order 4041 - Expedited SAP for Outlying Landing Field - NAS Whidbey Island

ID	ℹ	Task Mode	Task Name	Duration	Start	Finish
1		📌	NAVFAC Northwest Expedited Draft SAP Review	18 days	Wed 10/4/17	Fri 10/27/17
2		📌	Resolve NAVFAC Northwest Expedited SAP comments	15 days	Mon 10/30/17	Fri 11/17/17
3		📌	Submit Final SAP, APP/SSHP, EPP, IDW	1 day	Tue 11/21/17	Tue 11/21/17
4		📌	Pre-Mobilization Kickoff Meeting	0 days	Tue 11/28/17	Tue 11/28/17
5		📌	Pre-mobilization activities (place roll off boxes, utility locate)	3 edays	Tue 11/28/17	Fri 12/1/17
6		📌	Field Kickoff Meeting	0 days	Mon 12/4/17	Mon 12/4/17
7		📌	Well Installation (Includes Development)	10 days	Mon 12/4/17	Fri 12/15/17
8		📌	Survey Well Locations	1 day	Mon 12/18/17	Mon 12/18/17
9		📌	Aquifer Testing and Sampling	10 days	Mon 12/18/17	Fri 12/29/17
10		📌	Laboratory Analysis	30 edays	Mon 1/1/18	Wed 1/31/18
11		📌	Groundwater Modeling	30 days	Mon 1/1/18	Fri 2/9/18
12		📌	Data Validation	28 edays	Wed 1/31/18	Wed 2/28/18



Project: Delivery Order 4041
Outlying Landing Field - NAS W
Date: Tue 11/21/17

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	◇		

Page 1

This page intentionally left blank.

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 drinking water collected from the Keystone Hill well and groundwater from the monitoring wells on-Base. The sampling strategy and rationale are detailed in **Table 17-1.**

Table 17-1. Sampling Strategy Table

Location	Matrix	Depth of Samples (feet bgs)	Analysis	Laboratory Method	Number of Samples	Sampling Strategy	Rationale
WI-CV-MW02S	GW	Surface Port – Well screened from 91.5 to 101.5 feet bgs	PFAS	USEPA Method 537 Modified in accordance with QSM v5.1, Table B-15 / SOP 49[1]	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. The sample will be collected during the aquifer testing in middle of a typical pumping cycle (i.e. mid-day).	Groundwater sampling of the monitoring wells during pumping conditions will assess the PFAS concentrations during the pump cycle. Increased or decreased PFAS concentrations from previous sampling events, depending on the well, may be indicative that drawdown at current rates is capturing a currently undelineated PFAS source. The PFAS concentrations will also determine whether LHA exceedances are present within the capture zone of the Keystone Hill well at current or proposed extraction rates.
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-MW05M		Surface Port – Well screened from 160 to 170 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-MW14M		Surface Port – Well screened from 161 to 171 feet bgs			1		
WI-CV-MW15S		Surface Port – Well expected to be constructed with 10 feet of screen located between 91-139 feet bgs			1		
WI-CV-MW15M		Surface Port – Well expected to be constructed with 10 feet of screen located between 148-193 feet bgs			1		
WI-CV-MW16S		Surface Port – Well expected to be constructed with 10 feet of screen located between 91-139 feet bgs			1		
WI-CV-MW16M		Surface Port – Well expected to be constructed with 10 feet of screen located between 148-193 feet bgs			1		
WI-CV-1RW23[3]	DW	Surface Port – Well Screened from 142-182 feet bgs	PFAS	USEPA Method 537/ SOP 64[1,2]	1	Drinking water will be collected for in-field water quality parameters and laboratory analysis of PFAS from a sample port at the Keystone Hill well wellhead. One sample will be collected during the middle of the pump cycle.	Drinking water sampling of the Keystone Hill well during pumping conditions will assess if there is any change in PFAS concentrations during from previous sampling events. Increased PFAS concentrations may be indicative that drawdown at current rates is capturing a currently undelineated PFAS source.

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] USEPA Method 537 is being used on the WI-CV-1RW23. Water removed from this well is pumped to the Town's pretreatment system which includes chlorination and Birm filtration.

[3] WI-CV-1RW23 is also known as the Keystone Hill well.

GW = groundwater
bgs = below ground surface.
RPM = Remedial Project Manager
PM = Project Manager
PFAS= per- and polyfluoroalkyl substances

This page intentionally left blank.

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

Station Identification (ID)	Sample ID[1]	Matrix	Depth (ft bgs)	Analytical Group	Number of Samples (identify field duplicates)	Sampling SOP Reference
WI-CV-MW02S	WI-CV-GW02S-MMYY	Groundwater	Middle of well screen	PFAS (Method 537 Modified in accordance with QSM v5.1, Table B-15)	1-1	**Worksheet #21**
WI-CV-MW04S	WI-CV-GW04S-MMYY				1 - 2 (FD)	
	WI-CV-GW04SP-MMYY					
WI-CV-MW04M	WI-CV-GW04M-MMYY				1- 1	
WI-CV-MW05M	WI-CV-GW05M-MMYY				1-2 (FD)	
	WI-CV-GW05MP-MMYY					
WI-CV-MW07S	WI-CV-GW07S-MMYY				1- 1	
WI-CV-MW07M	WI-CV-GW07M-MMYY				1- 1	
WI-CV-MW14M	WI-CV-GW14M-MMYY				1- 1	
WI-CV-MW15S	WI-CV-GW15S-MMYY				1 - 3 (MS/MSD)	
	WI-CV-GW15S-MMYY-MS					
	WI-CV-GW15S-MMYY-MSD					
WI-CV-MW15M	WI-CV-GW15M-MMYY				1- 1	
WI-CV-MW16S	WI-CV-GW16S-MMYY				1- 1	
WI-CV-MW16M	WI-CV-GW16M-MMYY				1- 1	
WI-CV-1RW23[2]	WI-CV-1RW23-MMYY	Drinking water		PFAS (Method 537)	1- 4 (FD and MS/MSD)	
	WI-CV-1RW23P-MMYY					
	WI-CV-1RW23-MMYY-MS					
	WI-CV-1RW23-MMYY-MSD					
WI-CV-MWXX[3]	WI-CV-MWXX-MMYY	Groundwater		PFAS (Method 537 Modified)	TBD	

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

Station Identification (ID)	Sample ID[1]	Matrix	Depth (ft bgs)	Analytical Group	Number of Samples (identify field duplicates)	Sampling SOP Reference
Field QC Samples						
WI-CV-QC[4]	WI-CV-FB01-MMDDYY	QC	N/A	PFAS	1	**Worksheet #21**
	WI-CV-FB02-MMDDYY				1	
	WI-CV-FBXX-MMYY[3]				TBD	

Notes:

[1] Sample locations will be sampled on three occasions. If they are collected within the same calendar month, letter designations “A” and “B” will be added to the end of the well identifying segment (1RW23 or FB23 segment for example).

[2] 1RW23 is also known as the Keystone Hill Well.

[3] Placeholder for contingency samples

[4] With site in consideration being OLF Coupeville, one field reagent blank should be collected daily with samples. QC will also be collected separately for groundwater and drinking water samples.

SAP Worksheet #19—Analytical SOP Requirement Table

Matrix	Analytical Group	Analytical and Preparation Method/SOP Reference	Containers	Sample Volume	Preservation Requirements	Maximum Holding Time[a] (preparation/analysis)
Groundwater	PFAS	USEPA Method 537 Modified in accordance with QSM v5.1, Table B-15) / SOP 49	2 x 125 milliliters (mL) polypropylene	125 mL	Cool to ≤6 °C	14 days/ 28 days
Drinking Water	PFAS	USEPA Method 537/ SOP 64	2 x 250 milliliters (mL) polypropylene	250 mL	≤10°C but not frozen, Trizma (5.0 grams per liter)	14 days/ 28 days

Notes:

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

mL = milliliter

This page intentionally left blank.

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 Equip. Blanks[1]	No. of Trip Blanks[1]	Total No. of Samples to Lab[1]
GW	PFAS	Up to 11	2	1/1	3	3	N/A	21
DW	PFAS	1	1	1/1	1	N/A	N/A	5

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**.

This page intentionally left blank.

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	Navy CLEAN Program Drinking Water Sampling when Analyzing for Per and Polyfluoroalkyl Substances (PFASs),	CH2M	All field equipment within the sample collection area	N	Provides guidance for drinking water sample collection for samples that will be analyzed for PFASs via EPA Method 537 (not modified) for Navy CLEAN projects under Contract N62470-16-D-9000.
SOP I-A-1	Planning Field Sampling Activities, Rev. Sept. 2006	NAVFAC Northwest	None	N	Establishes SOPs for planning and scheduling field sampling activities.
SOP I-A-7	IDW Management, Rev. Sept. 2006	NAVFAC Northwest	None	N	Describes activities and responsibilities of NAVFAC Northwest and its subcontractors regarding management of IDW.
SOP I-A-9	General Field Operation, Rev. Aug. 2006	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. Sept. 2006	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. Apr. 2007	NAVFAC Northwest	None	N	Describes the naming convention to be used for samples collected, analyzed, and reported for NAVFAC Northwest projects.
SOP I-C-1	Monitoring Well / Piezometer Installation, Rev. Sept. 2006	NAVFAC Northwest	Drilling equipment	N	Describes the methods by which NAVFAC Northwest field personnel and their contractors will conduct monitoring well installation.
SOP I-C-2	Monitoring Well Development, Rev. Sept. 2006	NAVFAC Northwest	Drilling equipment	N	Describes the methods by which NAVFAC Northwest field personnel and their contractors will conduct monitoring well development.
SOP-I-C-5	Low-Flow Groundwater Purging and Sampling, Rev. Sept. 2006	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 I-C-7	Aquifer Tests, Rev. Sept. 2006	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 I-D-5	Water Level Measurements, Rev. Sept. 2006	NAVFAC Northwest	Water level meters	N	Establishes standard protocols for all NAVFAC Northwest field personnel for use in making water level measurements.
SOP I-D-7	Field Parameter Measurements, Rev. Sept. 2006	NAVFAC Northwest	Water quality meters	N	Provides instructions for the calibration, use, and checking of instruments and equipment for field measurements.
SOP-I-E	Soil and Rock Classification, Rev. Sept 2006	NAVFAC Northwest	Drilling equipment, camera, and field logbooks	N	Establishes standard protocols for all NAVFAC Northwest field personnel for use in making soil and rock classification decisions.
SOP I-G-1	Land Surveying, Rev. Sept. 2006	NAVFAC Northwest	Surveying equipment	N	Describes the methods by which NAVFAC Northwest field personnel and their contractors will conduct land surveying.
SOP III-F	Sample Containers and Preservation, Rev. Aug. 2006	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. Aug. 2006	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
SOP III-I	Equipment Decontamination, Rev. Aug. 2006	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
SOP III-J	Equipment Calibration, Operation, and Maintenance, Rev. Aug. 2006	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

This page intentionally left blank.

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 pH probe	Calibration	Daily, before use	pH reads 4.0 +/- 3%	Clean probe with deionized water and calibrate again. Do not use instrument if not able to calibrate properly	FTL	SOP-007	**Appendix C**
Horiba U-22 Specific conductance probe	Calibration	Daily, before use	Conductivity reads 4.49 +/- 3%	Clean probe with deionized water and calibrate again. Do not use instrument if not able to calibrate properly.	FTL	SOP-007	**Appendix C**
Horiba U-22 Turbidity probe	Calibration	Daily, before use	Turbidity reads 0 +/- 3%	Clean probe with deionized water and calibrate again. Do not use instrument if not able to calibrate properly.	FTL	SOP-007	**Appendix C**
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. Do not use instrument if not able to calibrate properly.	FTL	SOP-007	**Appendix C**
Horiba U-22	Maintenance- Check mechanical and electronic parts, verify system continuity, check battery, and clean probes. Calibration check	Daily before use, at the end of the day, and when unstable readings occur.	Stable readings after 3 minutes. pH reads 4.0 +/- 3% conductivity reads 4.49 +/- 3% turbidity reads 0 +/- 3%	Clean probe with deionized water and calibrate again. Do not use instrument if not able to calibrate properly.	FTL	SOP-007	**Appendix C**
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 C**
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 C**
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 C**

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**).

This page intentionally left blank.

SAP Worksheet #23—Analytical SOP References Table

Lab SOP Number	Title, Revision Date, and/or Number	Date Reviewed if not Revised	Definitive or Screening Data	Matrix and Analytical Group	Instrument	Organization Performing Analysis	Variance to QSM	Modified for Project Work (Y/N)
12	*Sample Receiving and Sample Control Procedures; rev. 12; 11/08/16*		N/A	Drinking water/Groundwater/PFAS	N/A	Vista Analytical	N	N
14	*Bottle Order Preparation; rev. 4; 9/03/14*		N/A	Drinking water/Groundwater/PFAS	N/A	Vista Analytical	N	N
49	Preparation and Analysis for the Determination of Per and Poly-Fluorinated Compounds; Rev. 10; 6/14/17		Definitive	Groundwater/PFAS	UPLC/MS/MS	Vista Analytical	N	N
64	*Preparation and Analysis for the Determination of Per and Polyfluorinated Compounds in Drinking Water; 12/8/16; rev. 1*		Definitive	Drinking Water/ PFAS	UPLC/MS/MS	Vista Analytical Laboratory	N	N

Notes:

[a] Nonanalytical SOPs do not require an annual review cycle.

[b] Vista Analytical’s Department of Defense (DoD) Environmental Laboratory Accreditation Program (ELAP) accreditation through A2LA is granted through September 30, 2019.

UPLC/MS/MS = ultra performance liquid chromatography - tandem mass spectrometer

This page intentionally left blank.

SAP Worksheet #24—Analytical Instrument Calibration Table

Instrument	Calibration Procedure	Frequency of Calibration	Acceptance Criteria	CA	Person Responsible for CA	SOP Reference
UPLC/MS/MS (PFAS, modified EPA 537 in accordance with QSM v5.1, Table B-15)	Initial calibration (ICAL) for all analytes	At instrument set-up and after ICV or 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) 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) S/N Ratio: ≥ 10:1 for all ions used for quantitation. 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. The %RSD of the RFs for all analytes must be <20%. Linear or non-linear calibrations must have r^2 ≥0.99 for each analyte. Analytes must be within 70-130% of their true value for each calibration standard.	Correct problem, then repeat ICAL.	Analyst / Supervisor	SOP 49 DoD QSM v5.1 Table B-15
	ICV	Once after each ICAL, analysis of a second source standard prior to sample analysis.	All reported analytes within ± 30% of true value.	Correct problem and verify second source standard. Rerun ICV. If that fails, correct problem and repeat ICAL.		
	Continuing Calibration Verification (CCV)	Analysis of mid-level standard after every 10 field samples. 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. Analyte concentrations must be within ±30% of their true value.	Immediately analyze two additional consecutive CCVs. If both pass, samples may be reported without reanalysis. If either fails, or if two consecutive CCVS cannot be run, perform corrective action(s) and repeat CCV and all associated samples since last successful CCV. Alternatively, recalibrate if necessary; then reanalyze all associated samples since the last acceptable CCV.		
	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.	NA		
	Mass Spectral Acquisition Rate	Each analyte and extracted internal standard analyte.	A minimum of 10 spectra scans are acquired across each chromatographic peak.	NA		

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

Instrument	Calibration Procedure	Frequency of Calibration	Acceptance Criteria	CA	Person Responsible for CA	SOP Reference
UPLC/MS/MS (PFAS, modified EPA 537 in accordance with QSM v5.1, Table B-15)	Calibration, Calibration Verification, and 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).	**NA**	Analyst / Supervisor	SOP 49 DoD QSM v5.1 Table B-15
	Ion Transitions (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: PFOA: 413 —› 369 PFOS: 499 —› 80 PFHxS: 399 —› 80 PFBS: 299 —› 80 4:2 FTS: 327 —› 307 6:2 FTS: 427 —› 407 8:2 FTS: 527 —› 507 NEtFOSAA: 584 —› 419 NMeFOSAA: 570 —› 419 If these transitions are not used, the reason must be technically justified and documented (e.g., alternate transition was used due to observed interferences).	NA		
	Instrument Sensitivity Check (ISC)	Prior to analysis and at least once every 12 hours.	Analyte concentrations must be at LOQ; concentrations must be within ±30% of their true values.	Correct problem, rerun. ISC. If problem persists, repeat ICAL. No samples shall be analyzed until ISC has met acceptance criteria. ISC can serve as the initial daily CCV.		
UPLC/MS/MS (PFAS, unmodified EPA 537)	Tune Check	Prior to ICAL and after any mass calibration or maintenance is performed.	Tuning standard must contain analytes of interest or appropriate substitute. Mass assignments of tuning standard within 0.5 amu of true value.	Retune instrument. If the tuning will not meet acceptance criteria, an instrument mass calibration must be performed and the tuning redone.	Lab Manager/ Analyst	64
	Minimum five-point initial calibration for target analytes, lowest concentration standard at or below the RL	Initial calibration prior to sample analysis	Each calibration point for each analyte (natives and surrogates) must calculate to be within 70-130 percent, except the lowest cal point, which must calculate to within 50 to 150 percent for natives.	Evaluate standards, chromatography, and mass spectrometer response. If problem found with above, correct as appropriate, then repeat initial calibration.		
	Peak Asymmetry Verification	With initial calibration	Calculated factor in the range of 0.8 to 1.5.	Change instrument conditions to correct, then repeat initial calibration.		
	Second-source calibration verification	Once per initial calibration, following initial calibration.	All reported analytes and labeled compounds within ± 30 percent of true value.	Evaluate data. If problem (e.g., concentrated standard, plugged transfer line) found, correct, then repeat second source verification. If it still fails, then repeat initial calibration.		

Instrument	Calibration Procedure	Frequency of Calibration	Acceptance Criteria	CA	Person Responsible for CA	SOP Reference
UPLC/MS/MS (PFAS, unmodified EPA 537)	Daily calibration verification	Analysis of mid-level standard after every 10 field samples. All samples must be bracketed by the analysis of a standard.	All CV analytes must be within ± 30 percent of true value. For all continuing calibration verifications (CCVs), internal standards must be within ± 50 percent of true value and 70 to 140 percent of the most recent prior CCV.	Recalibrate, and reanalyze all affected samples since the last acceptable CCV. OR Immediately analyze two additional consecutive CCVs. If both pass, samples may be reported without reanalysis. If either fails, take corrective action(s) and re-calibrate; then reanalyze all affected samples since the last acceptable CCV. If reanalysis cannot be performed, data must be qualified and explained in the case narrative.	Lab Manager/ Analyst	64

This page intentionally left blank.

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

Instrument/ Equipment	Maintenance Activity	Testing Activity	Inspection Activity	Frequency	Acceptance Criteria	CA	Responsible Person	SOP Reference
UPLC/MS/MS	Clean sample and gas cones. Change the column. Clean the T-Wave.	USEPA 537 Mod / USEPA 537	Check the sample and gas cones.	T-Wave cleaning is performed when the instrument response deteriorates. Other instrument maintenance is done as needed to keep the instrument performing at peak performance.	ICAL within acceptance criteria on WS#24 and IS recovery within acceptance criteria on WS#28	Recalibrate and/or perform the necessary equipment maintenance. Check the calibration standards. Reanalyze the affected data.	Vista Analyst/ Supervisor	SOP 49 / SOP 64

This page intentionally left blank.

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 C of this SAP.
Sample Packaging (Personnel/Organization): Project Field Team, FTL/CH2M. Field SOPs are in Appendix C of this SAP.
Coordination of Shipment (Personnel/Organization): FTL/CH2M.
Type of Shipment/Carrier: FedEx Priority Overnight
SAMPLE RECEIPT AND ANALYSIS
Sample Receipt (Personnel/Organization): Sample Receiving –Vista Analytical, El Dorado Hills, California
Sample Custody and Storage (Personnel/Organization): Sample Receiving –Vista Analytical, El Dorado Hills, California
Sample Preparation (Personnel/Organization): Vista Analytical, El Dorado Hills, California
Sample Determinative Analysis (Personnel/Organization): Vista Analytical, El Dorado Hills, California
SAMPLE ARCHIVING
Field Sample Storage (No. of days from sample collection): 45 days
Sample Extract/Digestate Storage (No. of days from extraction/digestion): 90 days
Biological Sample Storage (No. of days from sample collection): N/A
SAMPLE DISPOSAL
Personnel/Organization): Sample Disposal – Vista Analytical, El Dorado Hills, California
Number of Days from Analysis: 45 days

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^{o}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 Vista Analytical in El Dorado Hills, California.

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 logbook 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 logbook 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.

This page intentionally left blank.

SAP Worksheet #28-1—Laboratory QC Sample Table

Matrix: Groundwater
Analytical Group: PFAS
Analytical Method/SOP Reference: USEPA Method 537 Modified in accordance with QSM v5.1, Table B-15 /SOP 49

QC Sample	Frequency/Number	Method/ SOP QC Acceptance Limits	CA	Person(s) Responsible for CA	DQI	Measurement Performance Criteria (MPC)
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 sample concentration or >1/10 regulatory limit, whichever is greater. For common laboratory contaminants, no analytes detected >LOQ.	Correct problem. Reprep and reanalyze method blank and all samples processed with the contaminated blank. If reanalysis cannot be performed, the data must be qualified and explained in the case narrative.	Analyst/ Supervisor	Bias/ Contamination	Same as Method/ SOP QC Acceptance Limits
LCS	One per prep batch of 20 or fewer samples of similar matrix; or one per day, whichever comes first	See **Worksheet #15**	Correct problem. Reprep and reanalyze the LCS and all samples in the associated preparatory batch, if sufficient sample material is available. If reanalysis cannot be performed, the data must be qualified and explained in the case narrative.		Accuracy/Bias/Precision	
MS/MSD	One per prep batch of 20 or fewer samples of similar matrix; or one per day, whichever comes first	See **Worksheet #15.** Sample spiked with all analytes at a concentration ≥ LOQ and ≤ the mid-level calibration concentration.	Examine the project specific requirements. Contact the client as to additional measures to be taken. For the specific analyte(s) in the parent sample, apply J-flag if acceptance criteria are not met and explain in the Case Narrative. RPD ≤ 30%		Precision/ Accuracy/Bias	
Internal Standards (IS)	Every sample, spiked sample, standard, and method blank	Added to sample prior to extraction. For aqueous samples prepared by serial dilution instead of SPE, added to samples prior to analysis. 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).		Accuracy	
Instrument Blanks	Immediately following the highest standard analyzed and daily prior to sample analysis.	Concentration of each analyte must be ≤ 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. 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. 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.		Bias/Contamination	

SAP Worksheet #28-2—Laboratory QC Samples Table

Matrix: Drinking Water

Analytical Group: PFAS

Analytical Method/SOP Reference: USEPA Method 537/SOP 64

QC Sample	Frequency/Number	Method/ SOP QC Acceptance Limits	CA	Person(s) Responsible for CA	DQI	Measurement Performance Criteria (MPC)
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 sample concentration or >1/10 regulatory limit, whichever is greater. For common laboratory contaminants, no analytes detected >LOQ.	Correct problem. Reprep and reanalyze method blank and all samples processed with the contaminated blank. If reanalysis cannot be performed, the data must be qualified and explained in the case narrative.	Analyst/ Supervisor	Bias/ Contamination	Same as Method/ SOP QC Acceptance Limits
LCS	One per prep batch of 20 or fewer samples of similar matrix; or one per day, whichever comes first	See **Worksheet #15-1**	Reanalyze LCS once. If acceptable, report. Evaluate samples for detections, and LCS for high bias. If LCS has high bias, and samples non-detect, report with case narrative comment. If LCS has low bias, or if there are detections for critical compounds of concern, evaluate and reprep and reanalyze the LCS and all samples in the associated prep batch for failed analytes, if sufficient sample material is available. If reanalysis cannot be performed, data must be qualified and narrated.		Accuracy/Bias	
MS/MSD	One per prep batch of 20 or fewer samples of similar matrix; or one per day, whichever comes first	Method Limits of 70 to 130 percent for spikes > LOQ, and 50 to 150 percent for spikes at or below the LOQ.	Evaluate the data, and re-prepare /reanalyze the native sample and MS/MSD pair if laboratory error is indicated.		Precision/ Accuracy/Bias	
Internal Standards (IS)	Every sample, spiked sample, standard, and method blank	13C-PFOA 50-150% 13C-PFOS 50-150%	For failed QC samples, correct problem and rerun all associated failed field samples. If reanalysis cannot be performed, the data must be qualified and explained in the case narrative.		Accuracy	
Surrogates	Every samples, spiked sample, and method blank	13C2-PFHxA 70-130% 13C2-PFDA 70-130%	Identify and correct the problem. Re-prep and reanalyze all samples with failed surrogates in the associated preparatory batch. If obvious chromatographic interference with surrogate is present, re-analysis may not be necessary. Qualify all applicable data if acceptance criteria are not met, and explain in case narrative.		Accuracy/Bias	

SAP Worksheet #29—Project Documents and Records Table

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

This page intentionally left blank.

SAP Worksheet #30—Analytical Services Table

Matrix	Analytical Group	Sample Locations/ID	Analytical Method	Data Package Turnaround Time	Laboratory/ Organization	Backup Laboratory/ Organization[a]
Groundwater	PFAS	Refer to **Worksheets #18** and **#20**	USEPA Method 537 Modified in accordance with QSM v5.1, Table B-15	10 calendar days	Vista Analytical Laboratory 1104 Windfield Way, El Dorado Hills, CA 95762 Contact: Martha Maier (916)-673-1520	TBD
Drinking water	PFAS		USEPA Method 537			

Notes:

[a] backup lab will be determined if necessary.

This page intentionally left blank.

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 CH2M	FTL CH2M	PM CH2M	PM CH2M
Safe Work Observation	One during sampling event	Internal	CH2M	SSC CH2M	Field Team Member observed CH2M	HSM CH2M	SSC CH2M
Field Document Review	Daily during sampling event	Internal	CH2M	PM or Task Manager CH2M	FTL CH2M	PM CH2M	PM CH2M

This page intentionally left blank.

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 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 CH2M	Immediately
Field Document Review	Markup copy of field documentation	TBD, FTL, CH2M	Within 1 day of review	Verbal and Memorandum	FTL CH2M	Within 1 day of receipt of markup
Offsite Laboratory Technical Systems Audit	TBD by Laboratory Accreditation Bureau	Martha Maier, Laboratory PM, Vista Analytical	Within 2 months of audit	Memorandum	TBD by Laboratory Accreditation Bureau	Within 2 months of receipt of initial notification.

This page intentionally left blank.

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

____
____
____
____

This page intentionally left blank.

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			

This page intentionally left blank.

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 CH2M	Included in project files
QA Management Report/Technical Memorandum	Once results have been assessed for data usability	To be submitted with Final PA/SI Report	CH2M Project Chemist	NAVFAC Northwest RPM, and will be posted in project file.

This page intentionally left blank.

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 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 data validator 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 PC/CH2M	Step I	Internal
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 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 IIa	Internal
Sample Chronology	Holding times from collection to extraction or analysis and from extraction to analysis will be considered during the DV process.	DV	Step IIa and IIb	External
Raw Data	Ten percent review of raw data to confirm laboratory calculations. For a recalculated result, the data validator 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 data validator 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% of the raw data will be checked to confirm calculations. Any discrepancies will be addressed in the DV 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 PFAS analyzed for in 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. The data qualifiers used are those presented in National Functional Guidelines for Superfund Organic Data Review (USEPA, 2017). The specific qualifiers listed therein may be applied to data should non-conformances against the QA/QC criteria as presented in this SAP be identified..	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.

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. 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

CH2M HILL, Inc. (CH2M). 2017b. *Draft Technical Memorandum Evaluation of Per- and Polyfluoroalkyl Substances in Groundwater Outlying Landing Field Coupeville*, Naval Air Station Whidbey Island Coupeville, Washington. July.

CH2M. 2017c. *Final Sampling and Analysis Plan Investigation of Per- and Polyfluoroalkyl Substances in Drinking Water Ault Field and Outlying Landing Field Coupeville*, Naval Air Station Whidbey Island Oak Harbor and Coupeville, Washington. August.

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 11/4/2016.

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. Investigation of Perfluorinated Compounds in Drinking Water, Ault Field and Outlying Landing Field Coupeville, Naval Air Station Whidbey Island, Oak Harbor and Coupeville, Washington. August.

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

Navy. 2017d. Final Phase 2 Naval Air Station Whidbey Island Per- and Polyfluoroalkyl Substances Drinking Water Investigation Open House Posters. February. https://www.navfac.navy.mil/content/dam/navfac/NAVFAC%20Atlantic/NAVFAC%20Northwest/PDFs/About%20Us/PFAS%20Groundwater%20and%20Drinking%20Water%20Investigation/nw_Final_Poster_ALL_NASWI.pdf

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

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

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

This page intentionally left blank.

Figures

R:\N\Navy\CLEAN\MULTI_REGION\PFC_679580\MapFiles\NW\Whidbey_NAS\CTO4041\Whidbey\ESAP\Figure_10_1_Coupeville_Base_Location.mxd9/20/2017bmailhes

Basemap Data and Imagery Source: Esri

Legend

- ● City
- ▬ Secondary Road
- — Local Connecting Road
- ⬚ Base Boundary

N

0 1 2 Miles

1 inch = 2 miles

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

For Official Use Only

\\brookside\GIS_SHARE\ENBG\00_Proj\N\Navy\CLEAN\MULTI_REGION\PFC_679580\MapFiles\NW\Whidbey_NAS\CTO4041\Whidbey\ESAP\Figure_10_2_Coupeville_Site_Layout.mxd11/14/2017AM038876

Legend

- ● Monitoring Well Location
- ▲ Keystone Hill Well Location
- ☒ OLF Coupeville Supply Well
- — Elevation Contour (25 ft Interval)
- ⌗ Base Boundary

N

0 0.25 0.5 Mile

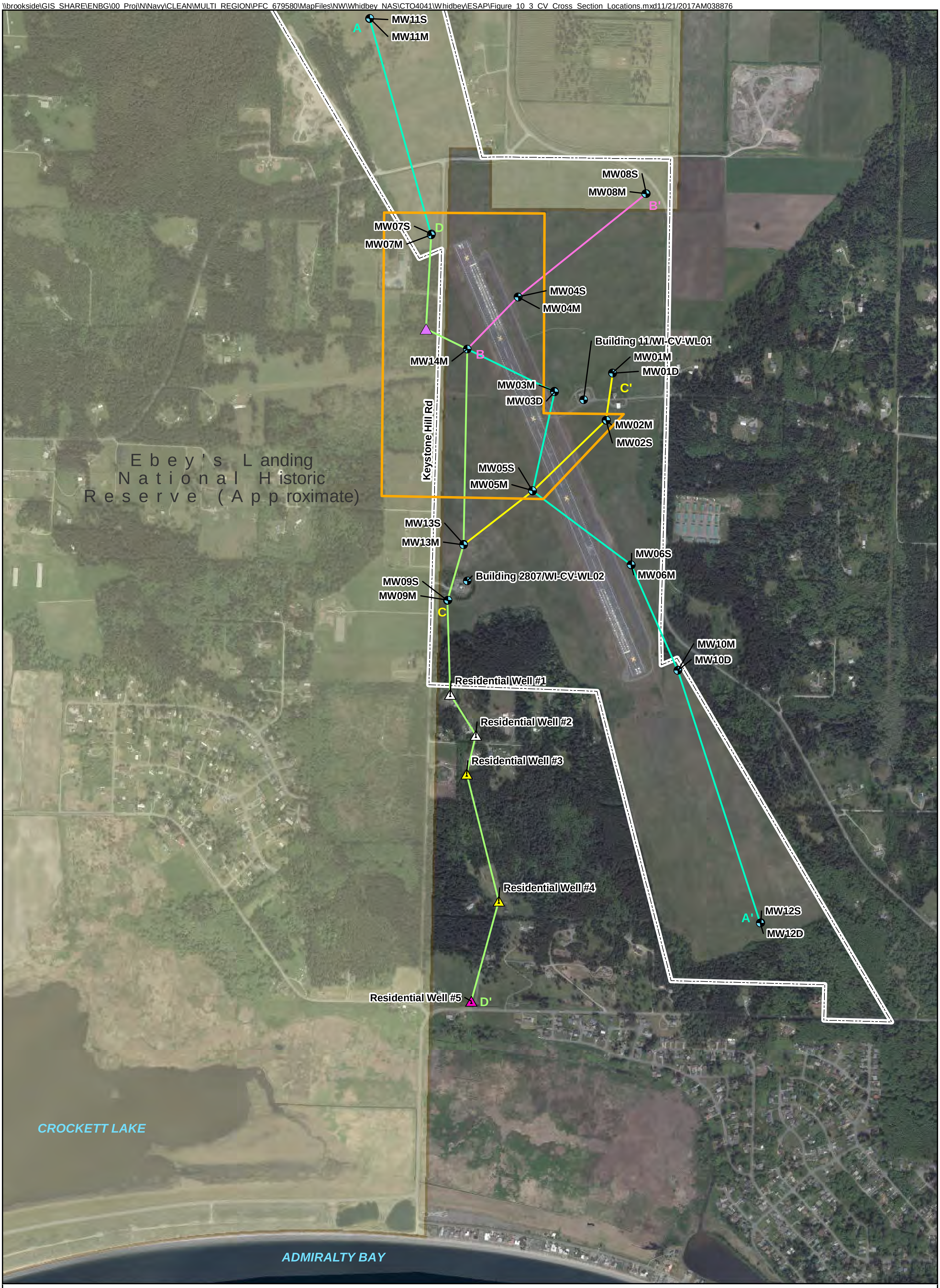
1 inch = 0.5 mile

Imagery Source: Esri

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

For Official Use Only

\\brookside\GIS_SHARE\ENBG\00_Proj\N\Navy\CLEAN\MULTI_REGION\PFC_679580\MapFiles\NW\Whidbey_NAS\CTO4041\Whidbey\ESAP\Figure_10_3_CV_Cross_Section_Locations.mxd11/21/2017AM038876



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)

▭ Investigation Area

N

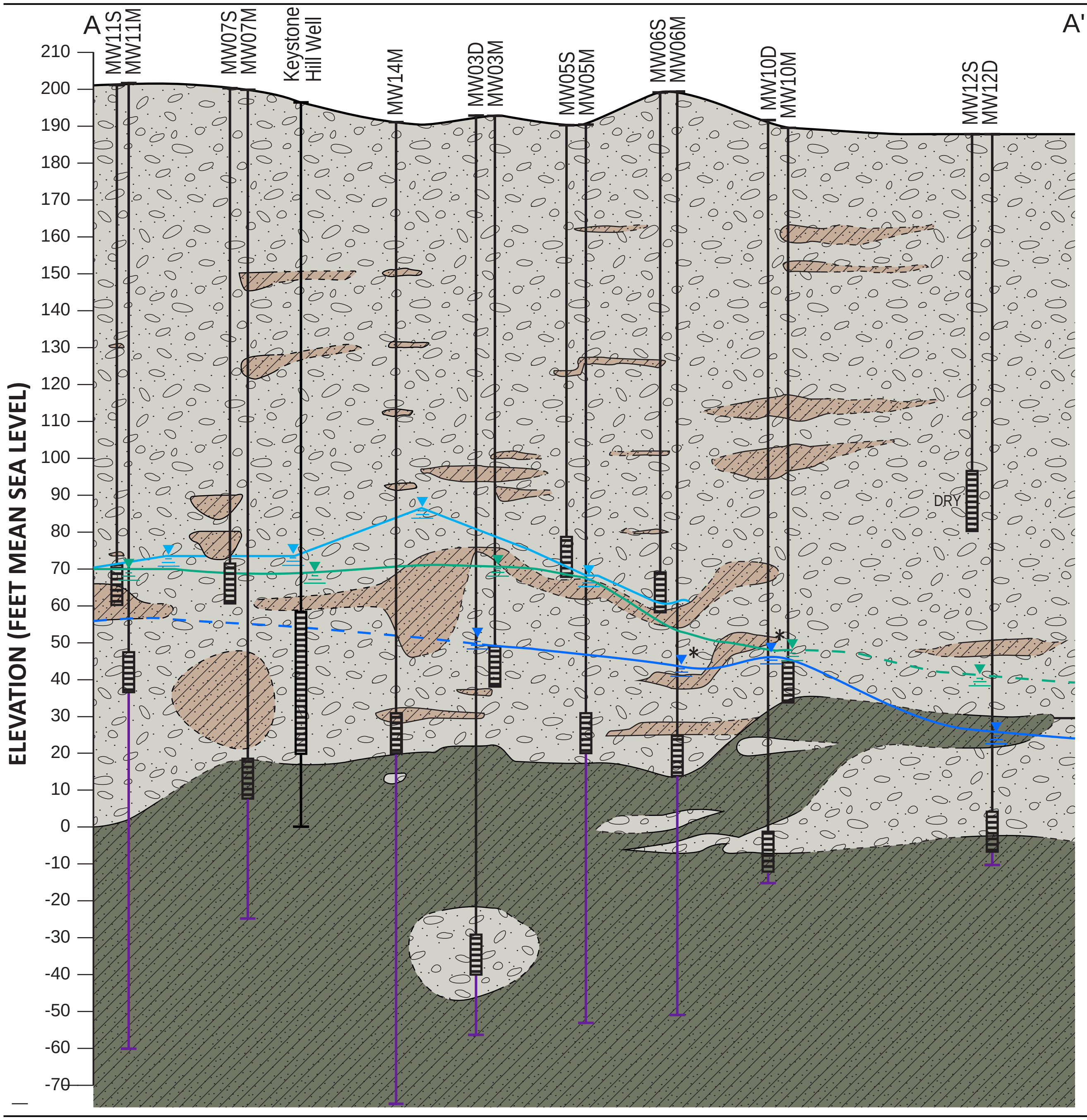
0 0.1 0.2 Miles

1 inch = 0.2 mile

Imagery Source: Esri

Figure 10-3
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.

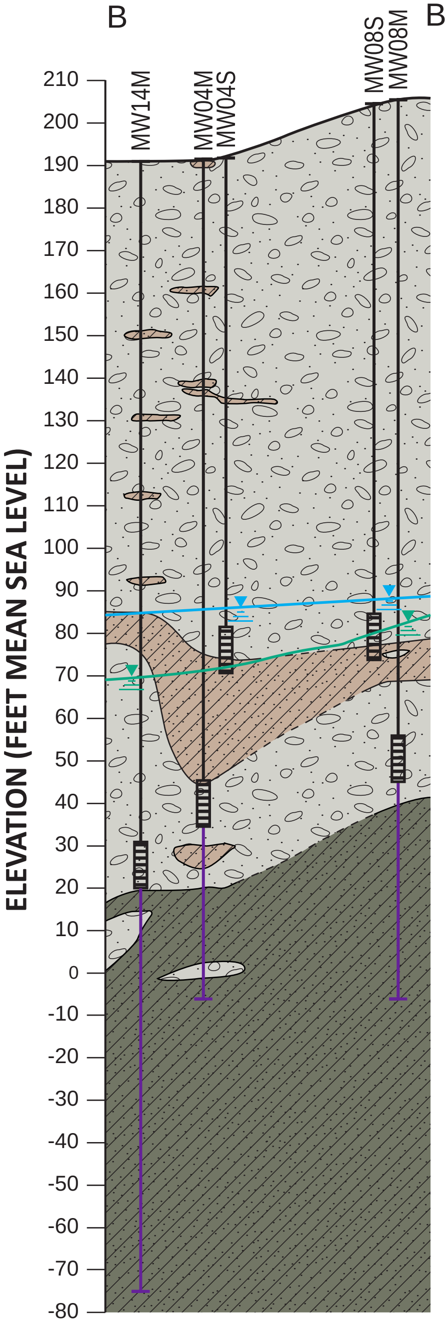
Cross section is conceptual in nature; predominant soil type was generally used for stratigraphic interpretation, however, in some cases similar units were combined for the purpose of simplification.

Geologic contacts are dashed where inferred.

0 .25 .5

Approximate horizontal scale in miles

Figure 10-4
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.

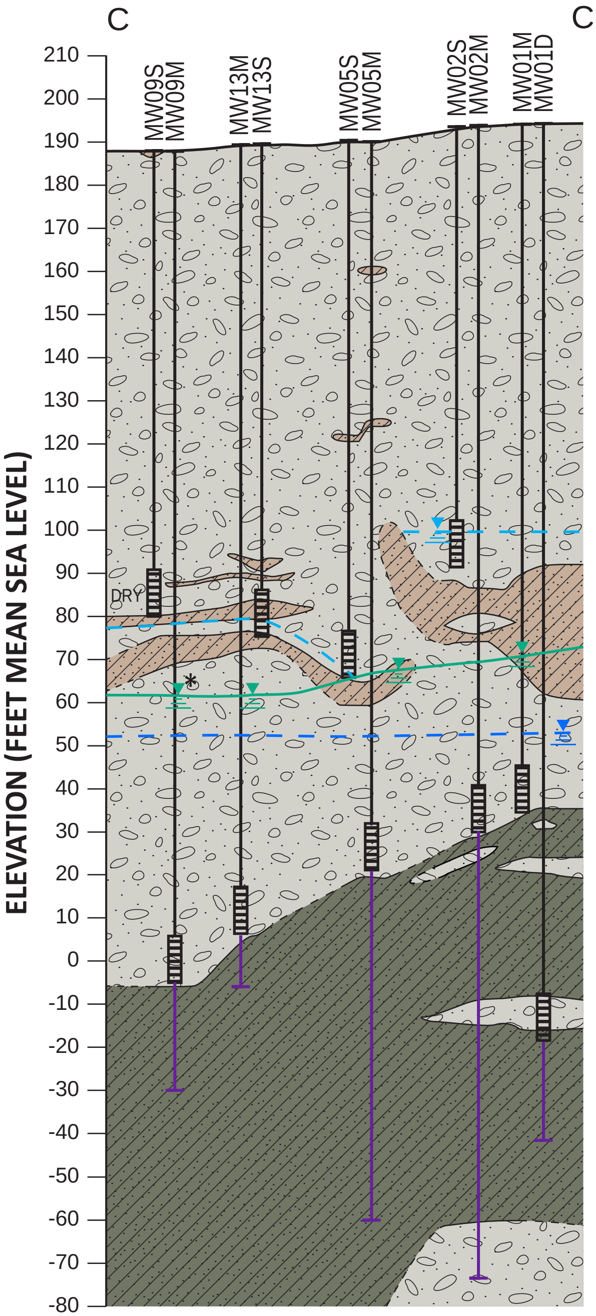
Cross section is conceptual in nature; predominant soil type was generally used for stratigraphic interpretation, however, in some cases similar units were combined for the purpose of simplification.

Geologic contacts are dashed where inferred.

0 .25 .5

Approximate horizontal scale in miles

Figure 10-5
Cross Section B-B'
Outlying Landing Field Coupeville
Naval Air Station Whidbey Island
Coupeville, Washington



Notes:

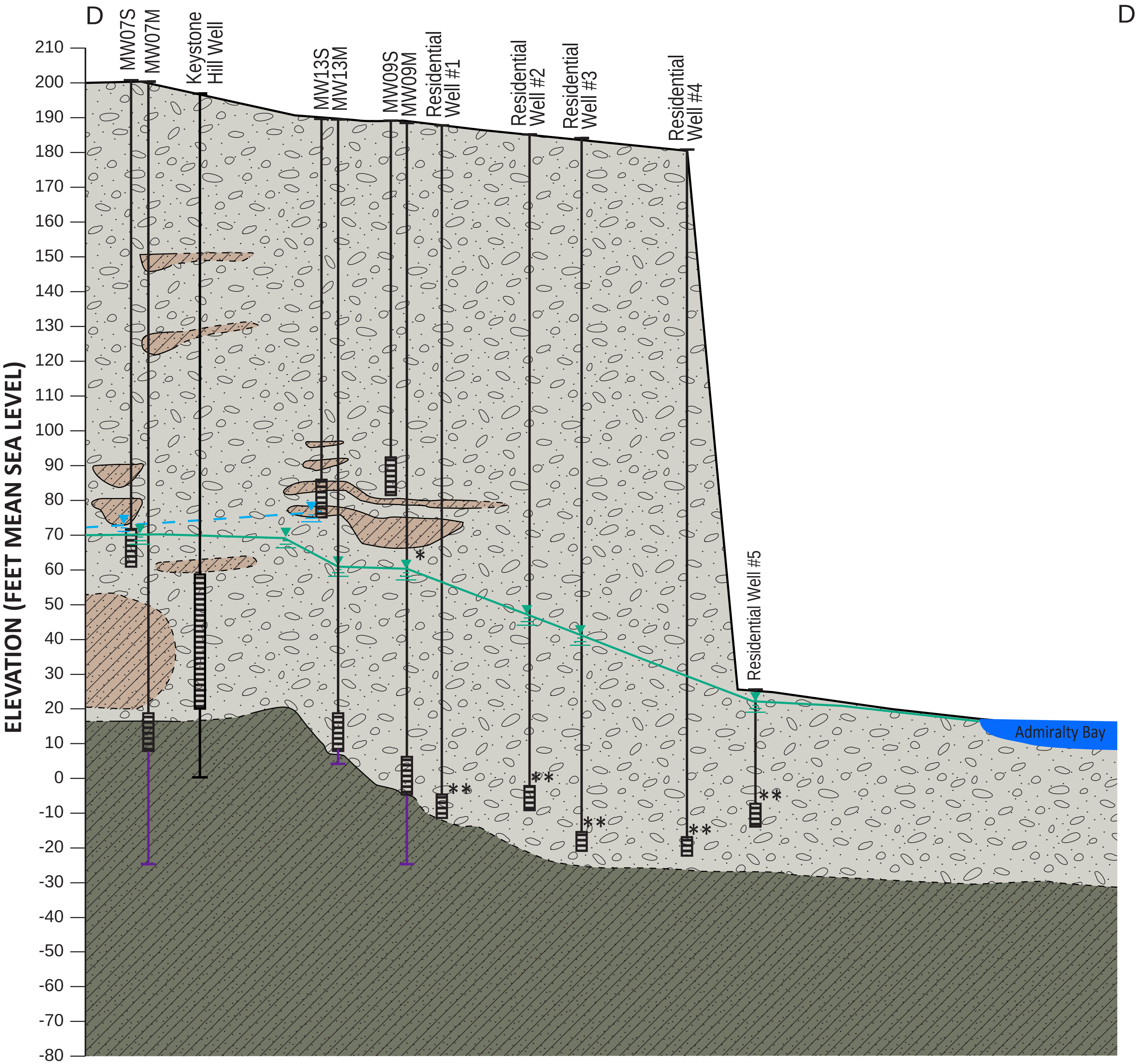
*Water level anomalous data estimated from March 18, 2017 round.

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.

Figure 10-6
Cross Section C-C'
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:

*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.

0 .25 .5

Approximate horizontal scale in miles

Figure 10-7

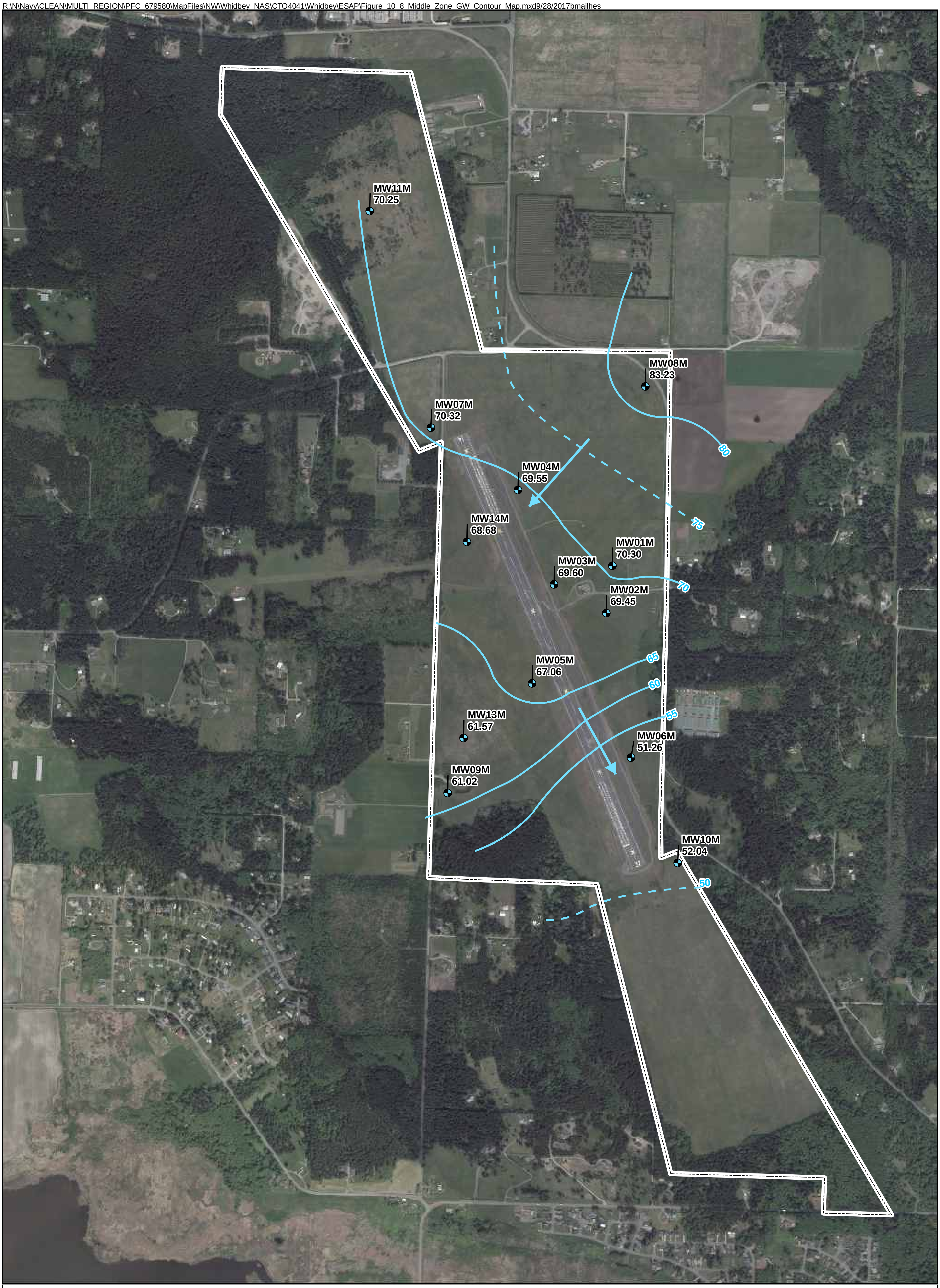
Cross Section D-D'

Outlying Landing Field Coupeville

Naval Air Station Whidbey Island

Coupeville, Washington

R:\N\Navy\CLEAN\MULTI_REGION\PFC_679580\MapFiles\NW\Whidbey_NAS\CTO4041\Whidbey\ESAP\Figure_10_8_Middle_Zone_GW_Contour_Map.mxd9/28/2017bmailhes



Legend

● Monitoring Well Location

— 5-foot Contour Interval (dashed where inferred)

➡ Direction of Intermediate-Screened Interval Groundwater Flow

⬚ Base Boundary

N

0 0.1 0.2 Miles

1 inch = 0.2 mile

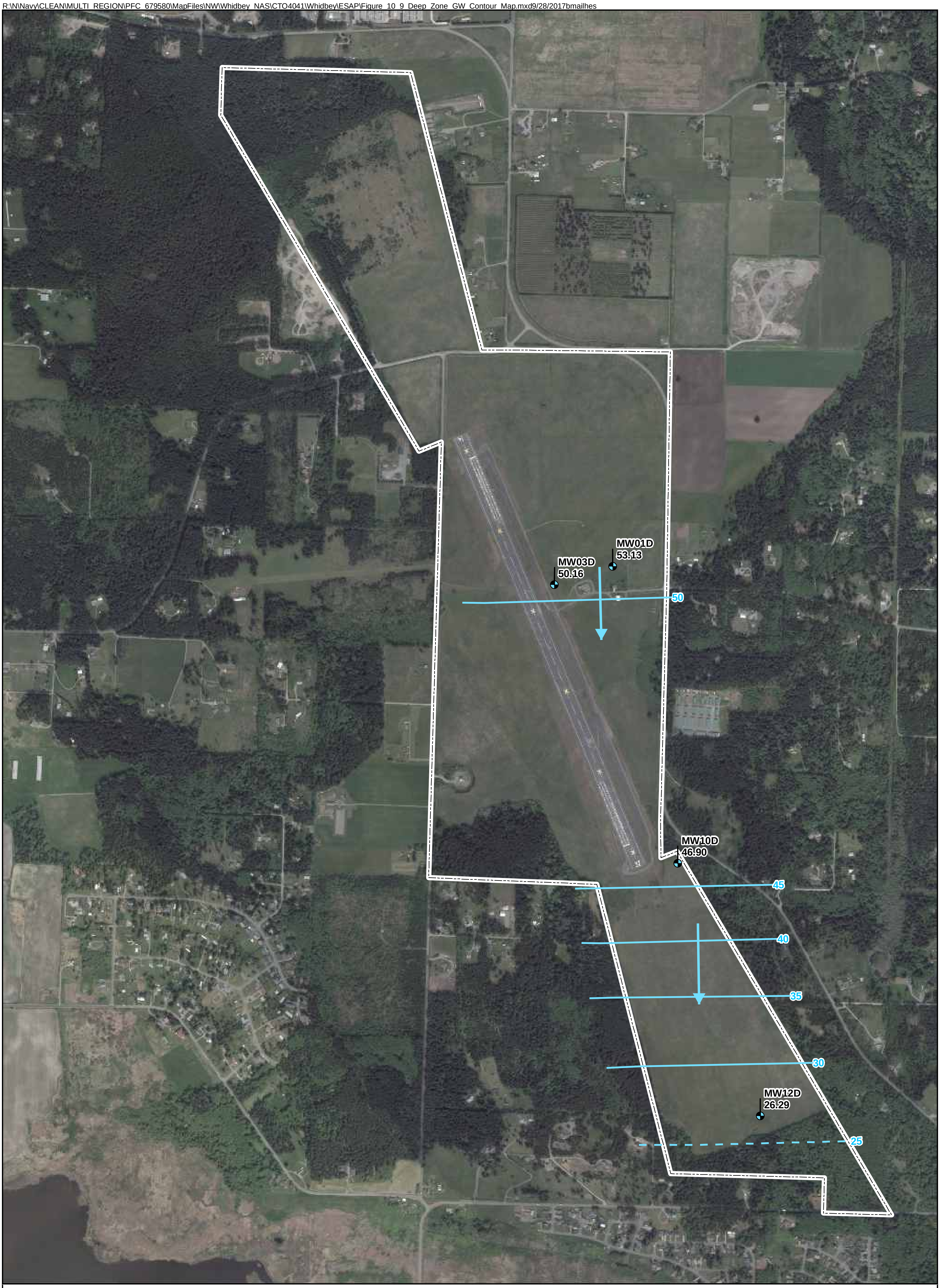
Imagery Source: Esri

Note:
Groundwater Elevation (feet above MSL)
Groundwater level measurements used to generate
this contour map were collected 3/3/2017 and 3/18/2017.

Figure 10-8
Intermediate-Screened Interval Groundwater Contours
Outlying Landing Field Coupeville
Naval Air Station Whidbey Island
Coupeville, Washington

For Official Use Only

R:\N\Navy\CLEAN\MULTI REGION\PFC 679580\MapFiles\NW\Whidbey NAS\CTO4041\Whidbey\ESAP\Figure 10 9 Deep Zone GW Contour Map.mxd9/28/2017bmailhes



Legend

- ● Monitoring Well Location
- — 5-foot Contour Interval (dashed where inferred)
- ➜ Direction of Deep-Screened Interval Groundwater Flow
- ⬚ Base Boundary

Note:
Groundwater Elevation (feet above MSL)
Groundwater level measurements used to generate
this contour map were collected 3/3/2017 and 3/18/2017.

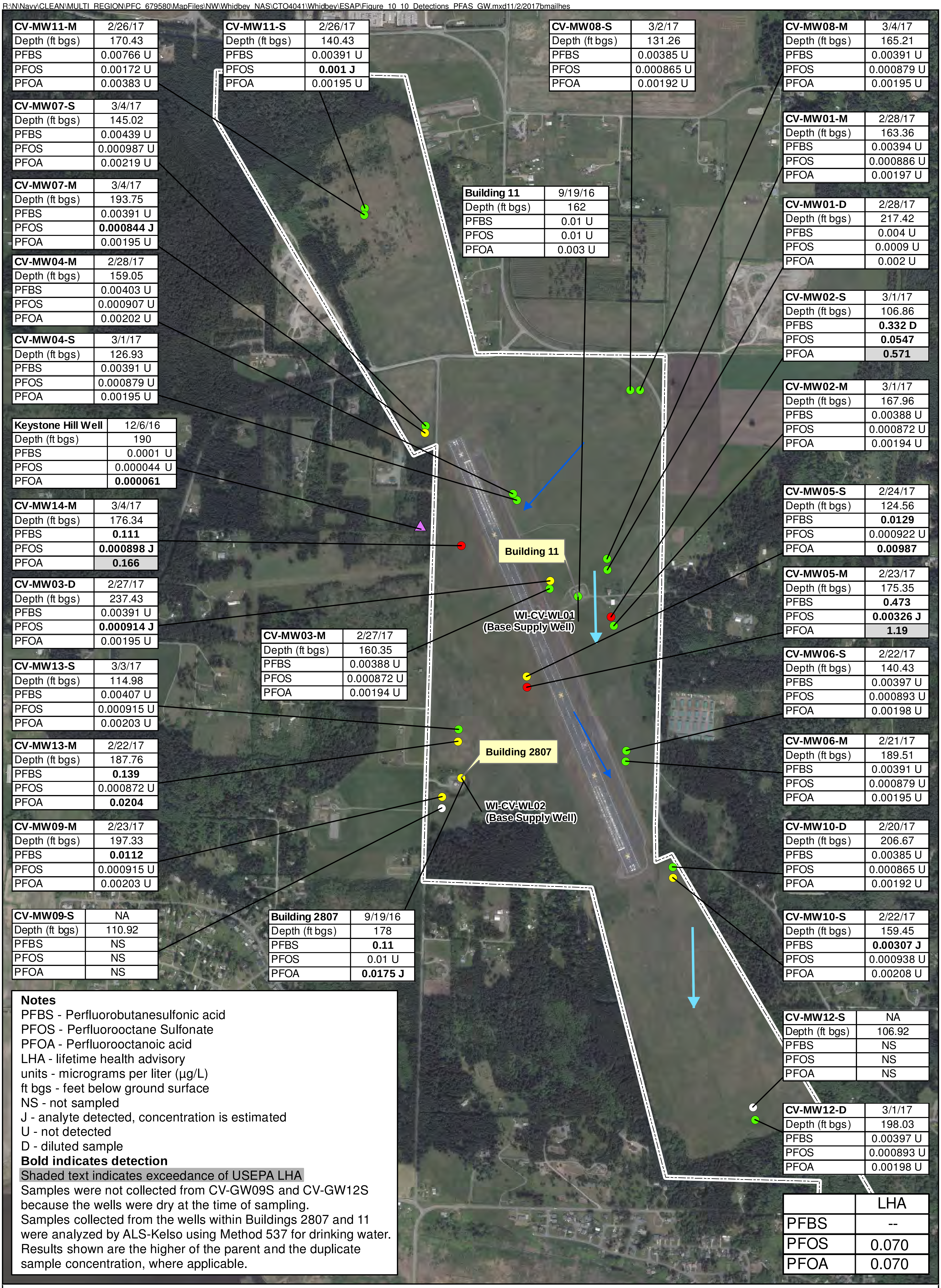
N

0 0.1 0.2
Miles

1 inch = 0.2 mile
Imagery Source: Esri

Figure 10-9
Deep-Screened Interval Groundwater Contour Map
Outlying Landing Field Coupeville
Coupeville, Washington

For Official Use Only



CV-MW11-M	2/26/17
Depth (ft bgs)	170.43
PFBS	0.00766 U
PFOS	0.00172 U
PFOA	0.00383 U

CV-MW11-S	2/26/17
Depth (ft bgs)	140.43
PFBS	0.00391 U
PFOS	**0.001 J**
PFOA	0.00195 U

CV-MW08-S	3/2/17
Depth (ft bgs)	131.26
PFBS	0.00385 U
PFOS	0.000865 U
PFOA	0.00192 U

CV-MW08-M	3/4/17
Depth (ft bgs)	165.21
PFBS	0.00391 U
PFOS	0.000879 U
PFOA	0.00195 U

CV-MW07-S	3/4/17
Depth (ft bgs)	145.02
PFBS	0.00439 U
PFOS	0.000987 U
PFOA	0.00219 U

CV-MW01-M	2/28/17
Depth (ft bgs)	163.36
PFBS	0.00394 U
PFOS	0.000886 U
PFOA	0.00197 U

Building 11	9/19/16
Depth (ft bgs)	162
PFBS	0.01 U
PFOS	0.01 U
PFOA	0.003 U

CV-MW07-M	3/4/17
Depth (ft bgs)	193.75
PFBS	0.00391 U
PFOS	**0.000844 J**
PFOA	0.00195 U

CV-MW01-D	2/28/17
Depth (ft bgs)	217.42
PFBS	0.004 U
PFOS	0.0009 U
PFOA	0.002 U

CV-MW04-M	2/28/17
Depth (ft bgs)	159.05
PFBS	0.00403 U
PFOS	0.000907 U
PFOA	0.00202 U

CV-MW02-S	3/1/17
Depth (ft bgs)	106.86
PFBS	**0.332 D**
PFOS	**0.0547**
PFOA	**0.571**

CV-MW04-S	3/1/17
Depth (ft bgs)	126.93
PFBS	0.00391 U
PFOS	0.000879 U
PFOA	0.00195 U

CV-MW02-M	3/1/17
Depth (ft bgs)	167.96
PFBS	0.00388 U
PFOS	0.000872 U
PFOA	0.00194 U

Keystone Hill Well	12/6/16
Depth (ft bgs)	190
PFBS	0.0001 U
PFOS	0.000044 U
PFOA	**0.000061**

CV-MW14-M	3/4/17
Depth (ft bgs)	176.34
PFBS	**0.111**
PFOS	**0.000898 J**
PFOA	**0.166**

CV-MW05-S	2/24/17
Depth (ft bgs)	124.56
PFBS	**0.0129**
PFOS	0.000922 U
PFOA	**0.00987**

CV-MW03-D	2/27/17
Depth (ft bgs)	237.43
PFBS	0.00391 U
PFOS	**0.000914 J**
PFOA	0.00195 U

CV-MW05-M	2/23/17
Depth (ft bgs)	175.35
PFBS	**0.473**
PFOS	**0.00326 J**
PFOA	**1.19**

CV-MW03-M	2/27/17
Depth (ft bgs)	160.35
PFBS	0.00388 U
PFOS	0.000872 U
PFOA	0.00194 U

CV-MW06-S	2/22/17
Depth (ft bgs)	140.43
PFBS	0.00397 U
PFOS	0.000893 U
PFOA	0.00198 U

CV-MW13-S	3/3/17
Depth (ft bgs)	114.98
PFBS	0.00407 U
PFOS	0.000915 U
PFOA	0.00203 U

CV-MW13-M	2/22/17
Depth (ft bgs)	187.76
PFBS	**0.139**
PFOS	0.000872 U
PFOA	**0.0204**

CV-MW06-M	2/21/17
Depth (ft bgs)	189.51
PFBS	0.00391 U
PFOS	0.000879 U
PFOA	0.00195 U

CV-MW09-M	2/23/17
Depth (ft bgs)	197.33
PFBS	**0.0112**
PFOS	0.000915 U
PFOA	0.00203 U

CV-MW10-D	2/20/17
Depth (ft bgs)	206.67
PFBS	0.00385 U
PFOS	0.000865 U
PFOA	0.00192 U

CV-MW09-S	NA
Depth (ft bgs)	110.92
PFBS	NS
PFOS	NS
PFOA	NS

Building 2807	9/19/16
Depth (ft bgs)	178
PFBS	**0.11**
PFOS	0.01 U
PFOA	**0.0175 J**

CV-MW10-S	2/22/17
Depth (ft bgs)	159.45
PFBS	**0.00307 J**
PFOS	0.000938 U
PFOA	0.00208 U

CV-MW12-S	NA
Depth (ft bgs)	106.92
PFBS	NS
PFOS	NS
PFOA	NS

CV-MW12-D	3/1/17
Depth (ft bgs)	198.03
PFBS	0.00397 U
PFOS	0.000893 U
PFOA	0.00198 U

Notes

PFBS - Perfluorobutanesulfonic acid
PFOS - Perfluorooctane Sulfonate
PFOA - Perfluorooctanoic acid
LHA - lifetime health advisory
units - micrograms per liter (µg/L)
ft bgs - feet below ground surface
NS - not sampled
J - analyte detected, concentration is estimated
U - not detected
D - diluted sample
Bold indicates detection
Shaded text indicates exceedance of USEPA LHA
Samples were not collected from CV-GW09S and CV-GW12S because the wells were dry at the time of sampling.
Samples collected from the wells within Buildings 2807 and 11 were analyzed by ALS-Kelso using Method 537 for drinking water.
Results shown are the higher of the parent and the duplicate sample concentration, where applicable.

	LHA
PFBS	--
PFOS	0.070
PFOA	0.070

Legend

- ● Monitoring well with no exceedance of LHA
- ● Monitoring well with LHA exceedance
- ● No detections of PFAS
- ○ Not Sampled
- ▲ Keystone Hill Well Location
- → Direction of Intermediate-Screened Interval Groundwater Flow
- → Direction of Deep-Screened Interval Groundwater Flow
- ⬚ Base Boundary

N

0 0.1 0.2
Miles

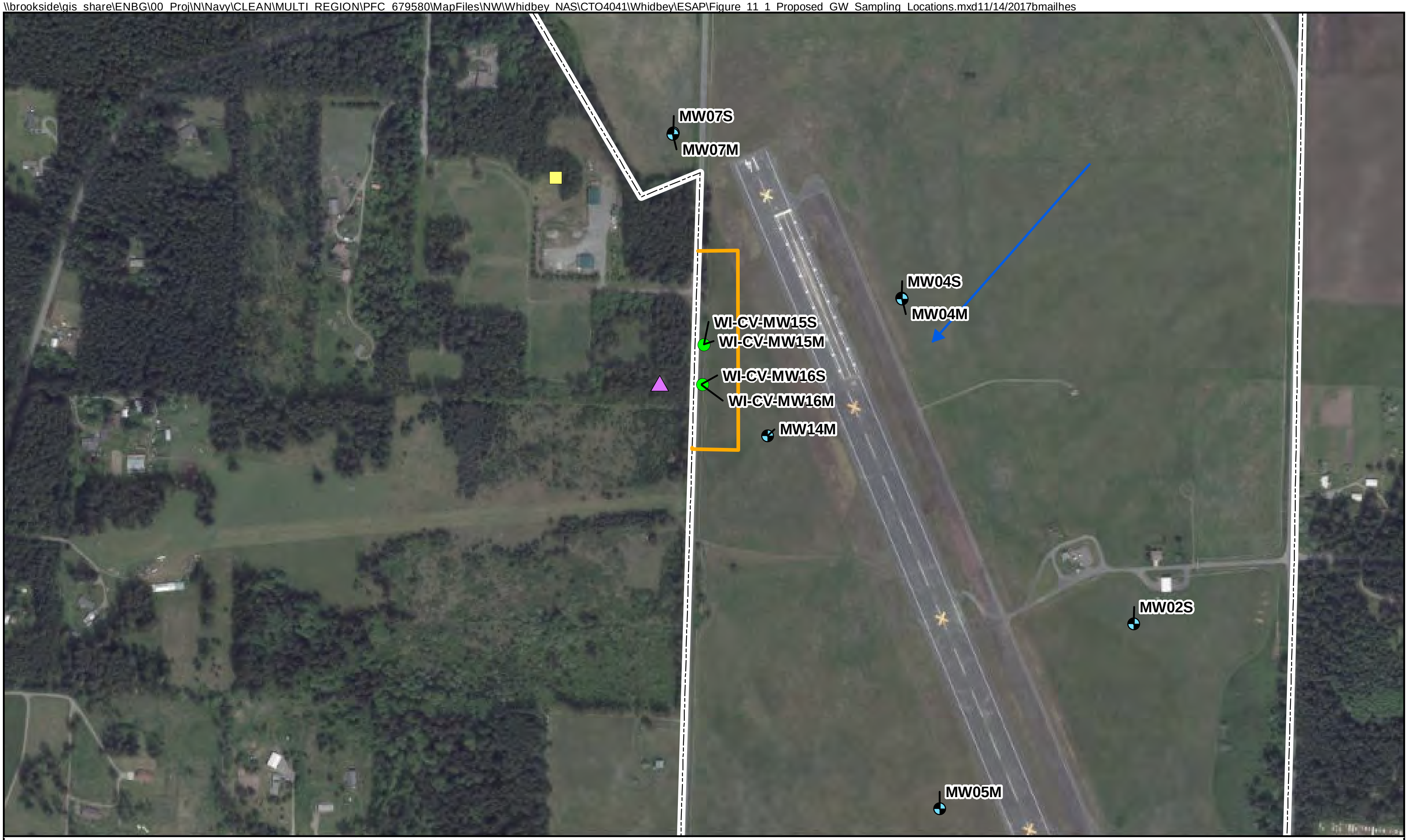
1 inch = 0.2 mile

Imagery Source: Esri

Figure 10-10
Detections of PFAS in Groundwater
Outlying Landing Field Coupeville
Coupeville, Washington

For Official Use Only

\\brookside\gis_share\ENBG\00_Proj\N\Navy\CLEAN\MULTI_REGION\PFC_679580\MapFiles\NW\Whidbey_NAS\CTO4041\Whidbey\ESAP\Figure_11_1_Proposed_GW_Sampling_Locations.mxd11/14/2017bmailhes



Legend

- ● Proposed Observation Well
- ⊕ Existing Monitoring Well
- ☐ DOT Well Location
- △ Keystone Hill Well Location
- ― Proposed Section 106 Clearance Area
- → Direction of Intermediate-Screened Interval Groundwater Flow
- ⬚ Base Boundary

N

0 300 600 Feet

1 inch = 600 feet

Imagery Source: Esri

Figure 11-1
Proposed Groundwater Sampling Locations
Outlying Landing Field Coupeville
Naval Air Station Whidbey Island
Coupeville, Washington

For Official Use Only

Appendix A

Geologic Map of Coupeville

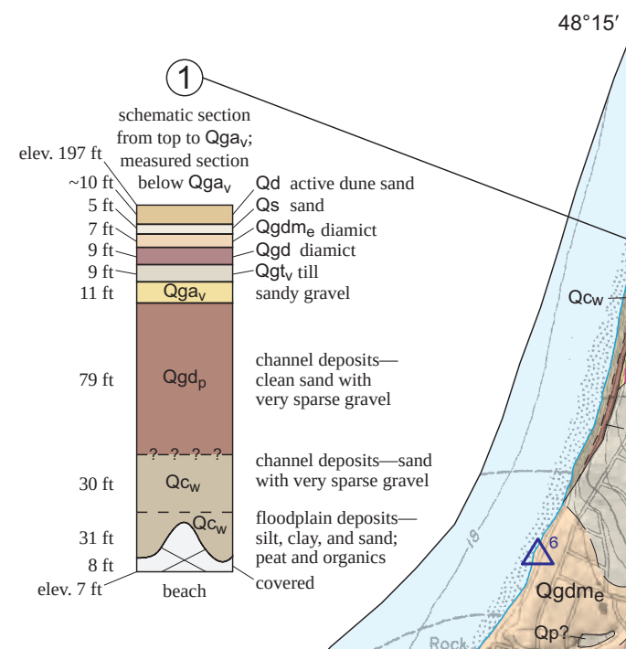
WASHINGTON STATE DEPARTMENT OF
Natural Resources
Doug Sutherland - Commissioner of Public Lands
Division of Geology and Earth Resources
Ron Teissere - State Geologist

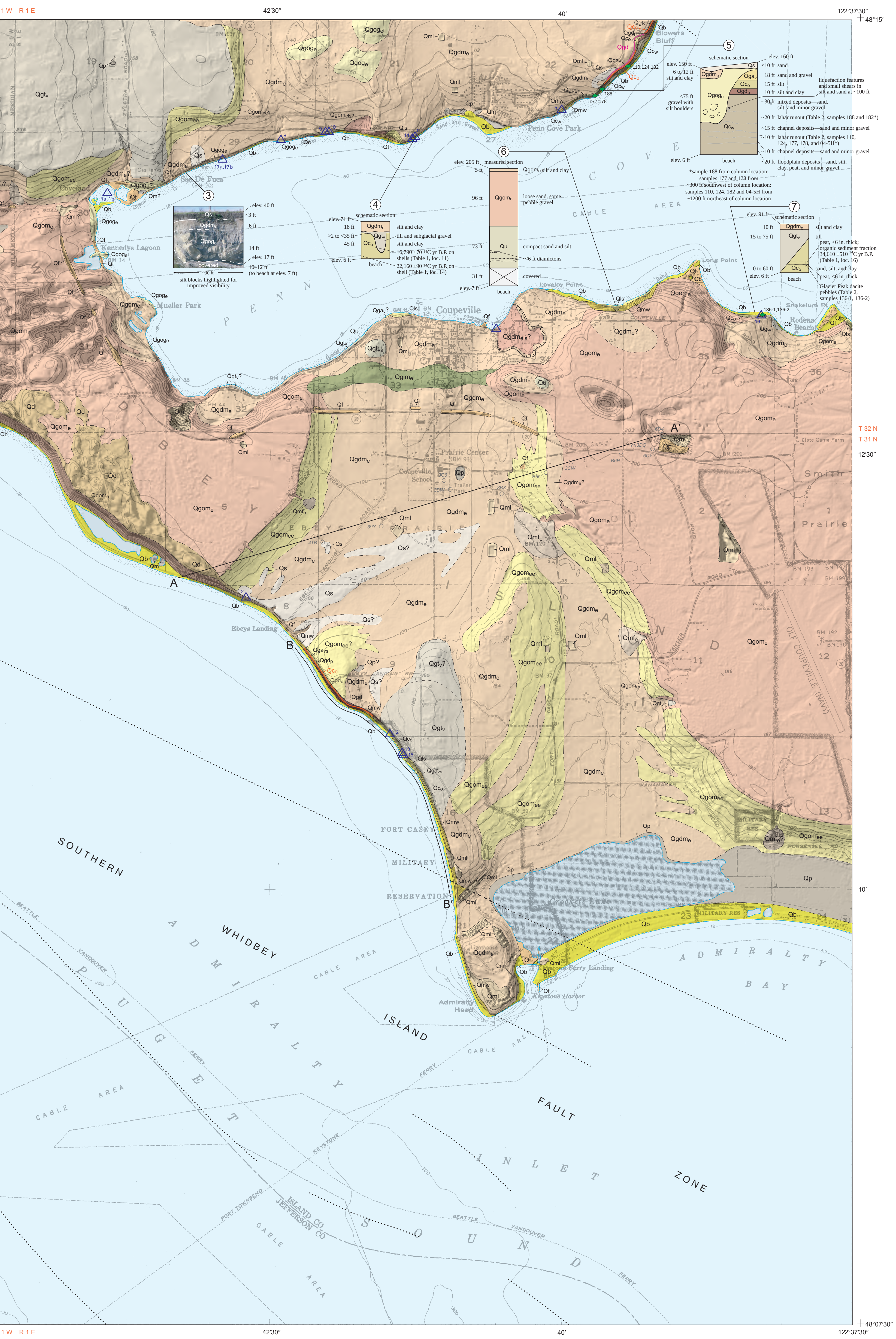
WASHINGTON DIVISION OF GEOLOGY AND EARTH RESOURCES
GEOLOGIC MAP GM-58

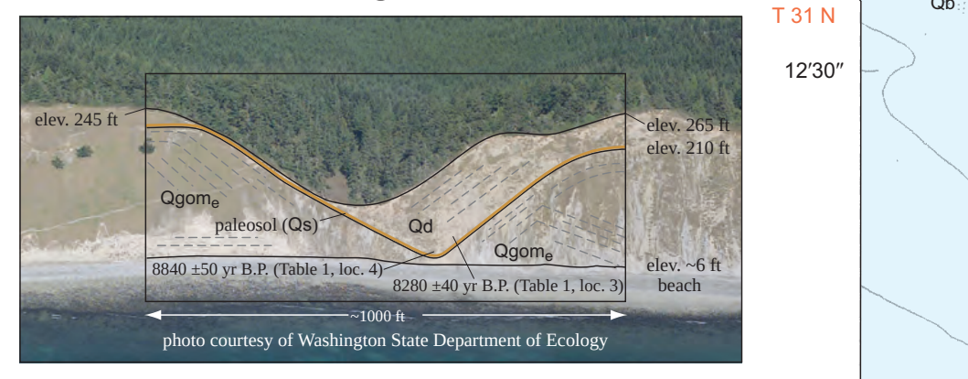
Geologic Map of the Coupeville and Part of the Port Townsend North 7.5-minute Quadrangles, Island County, Washington

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

June 2005







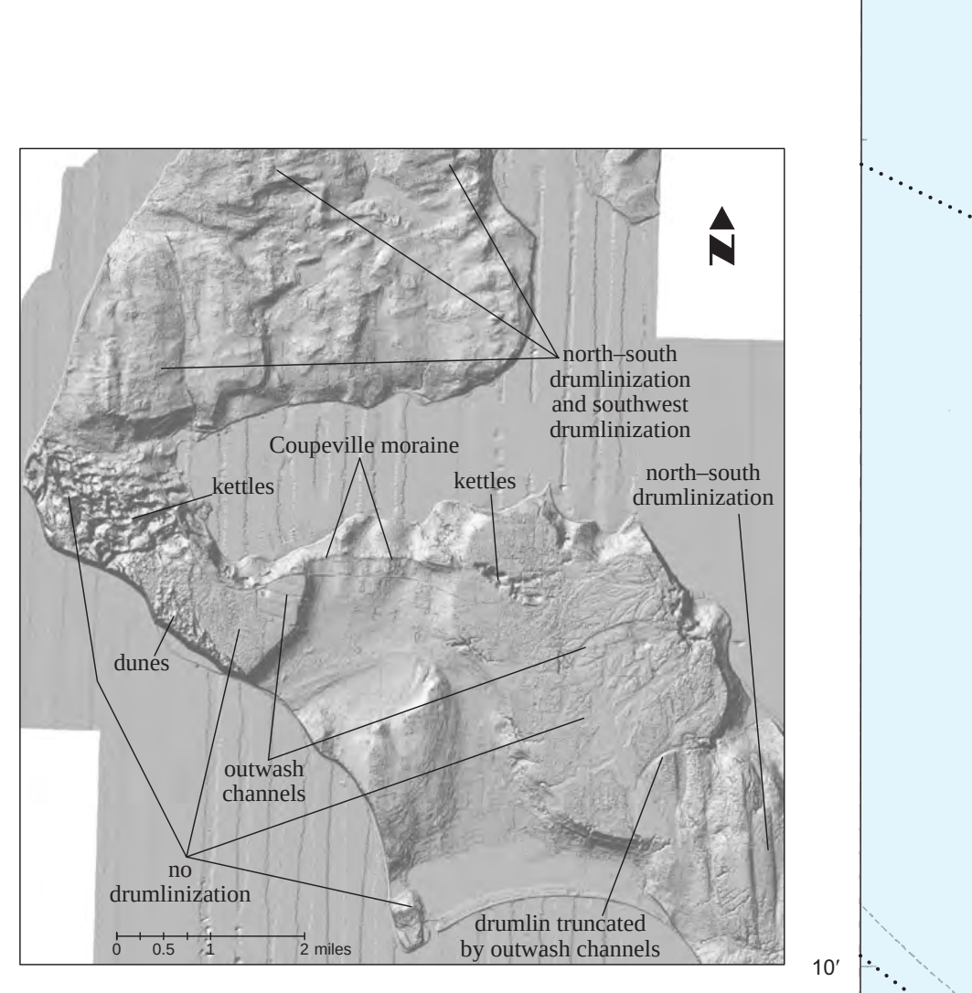
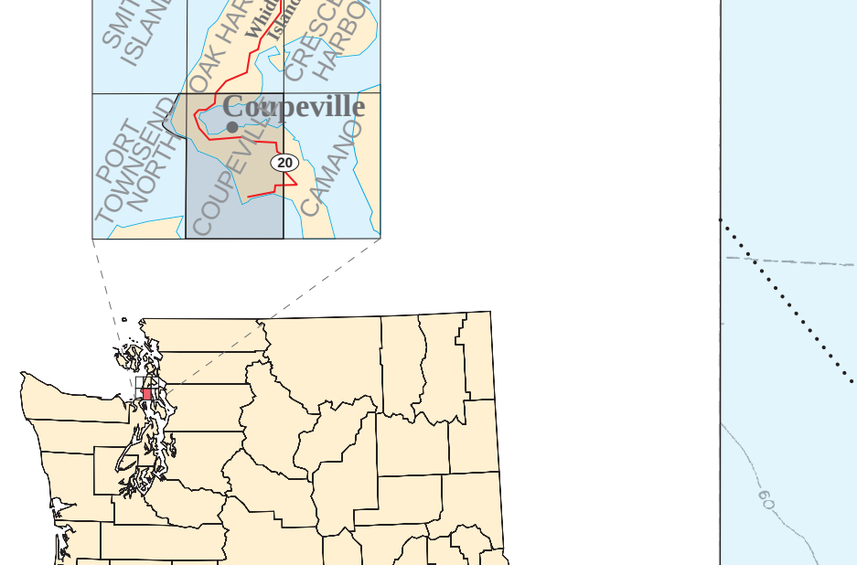


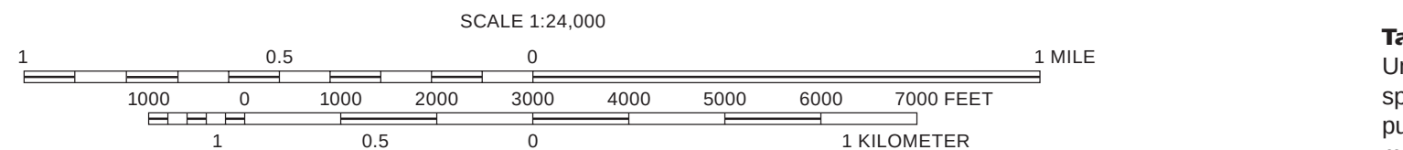
Figure 1. Lidar-based hillshade image of central Whidbey Island. Vertical exaggeration is 6 times. Simulated sun angle is 45 degrees; sun azimuth, 315 degrees. The image illustrates the systematic distribution of landforms in the area. Strong north-south drumlinization in the southeast reflects south-directed 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.

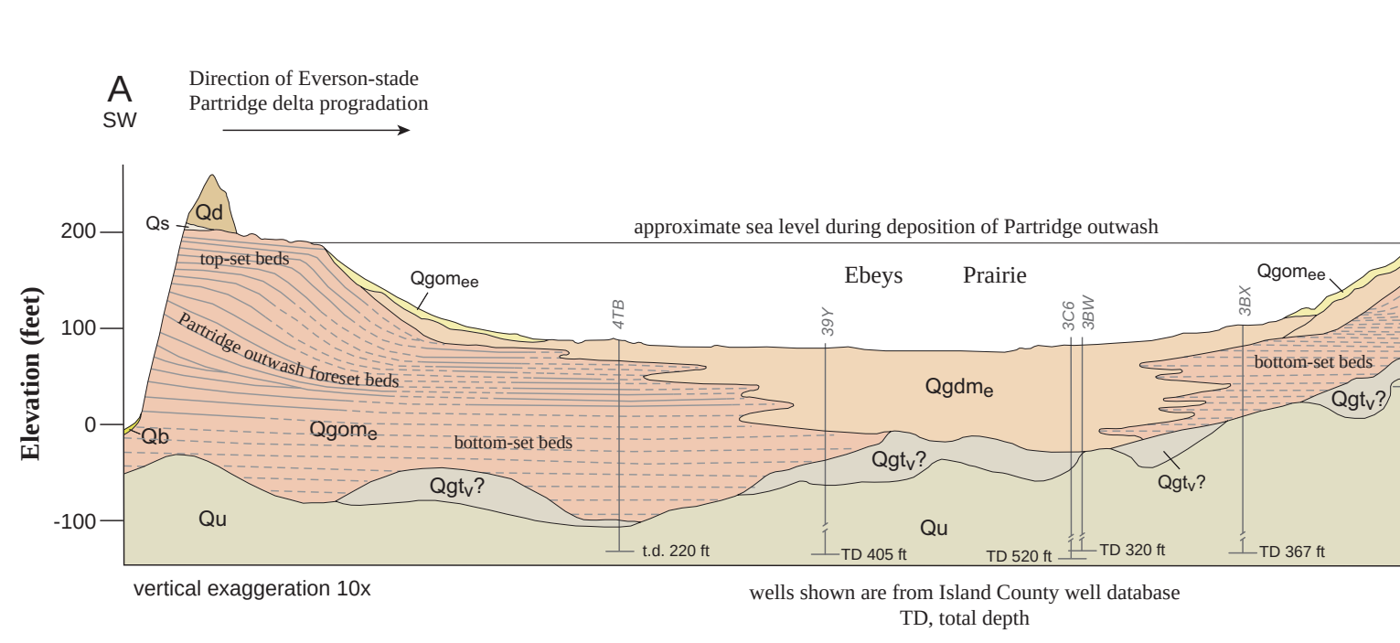


Lambert conformal conic projection
North American Datum of 1927; to place on North American
Datum of 1983, move the projection lines 70 feet north
and 300 feet east as shown by crosshair corner ticks
Base map from scanned and rectified U.S. Geological Survey
7.5-minute Coupeville and Port Townsend North 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

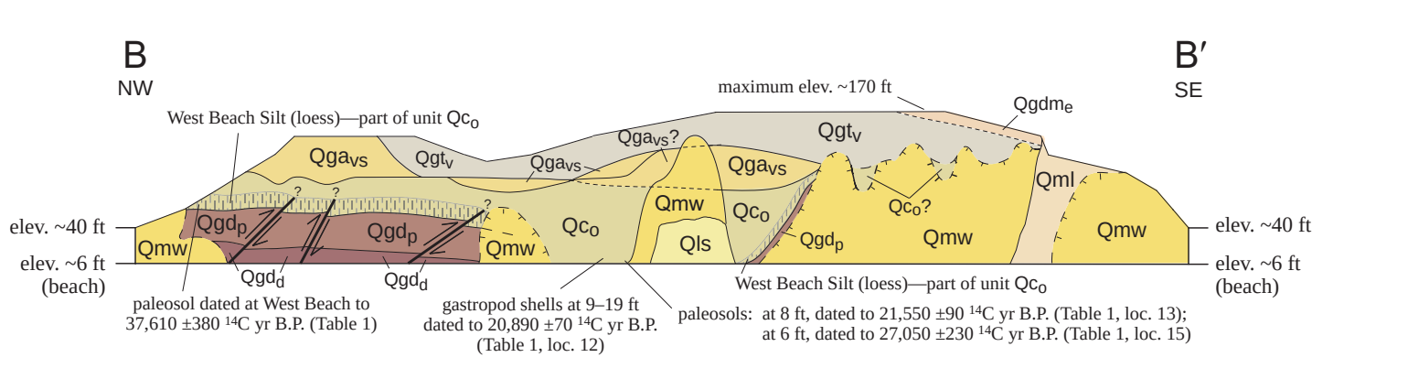
contour interval 20 feet





vertical exaggeration 10x

wells shown are from Island County well database
TD, total depth



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
- Geologic unit too narrow to show as a polygon at map scale
- Landslide scarp—Hachures on downslope side; dashed where approximately located
- Geochemistry sample location
- Radiocarbon date sample location
- 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.

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.

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.

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

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)

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.

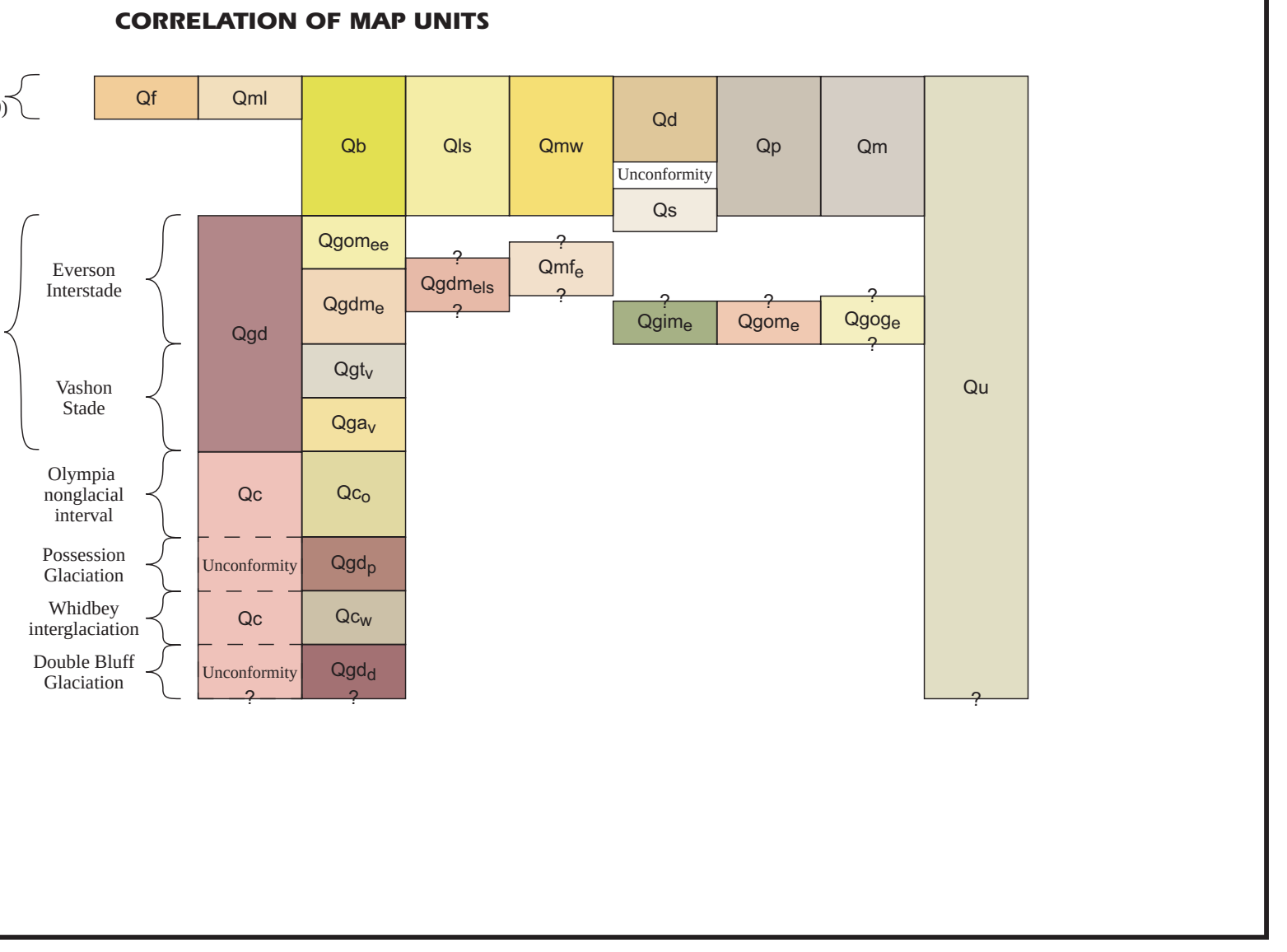
Thorson, R. M., 1989, Glacio-isostatic response of the Puget Sound area, Washington: Geological Society of America Bulletin, v. 101, no. 9, p. 1163-1174.

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
Keystone Hill Well Log and Pumping Test Report

ROBINSON
NOBLE SALTBUSH INC. Established 1947
GROUNDWATER & ENVIRONMENTAL SCIENTISTS
1947 60 Years 2007

TOWN OF COUPEVILLE
KEYSTONE HILL
WELL CONSTRUCTION AND TESTING REPORT

APRIL 2008

by

Douglas C Dow

Douglas C. Dow, L.HG.
Senior Associate Hydrogeologist

State of Washington
Hydrogeologist
258
Licensed Geologist
DOUGLAS C. DOW

3011 South Huson Street, Suite A Tacoma, Washington 98409 ▪ (253) 475-7711 ▪ Fax: (253) 472-5846
e-mail: mail@robinson-noble.com

TOWN OF COUPEVILLE
KEYSTONE HILL WELL
CONSTRUCTION AND TESTING REPORT
APRIL 2008

Table of Contents

FIGURES

Tables

APPENDIX

TOWN OF COUPEVILLE
KEYSTONE HILL WELL
CONSTRUCTION AND TESTING REPORT
APRIL 2008

Introduction

This report presents Robinson, Noble & Saltbush's findings and recommendations based on observation of construction, well screen design and development, and conducting a pumping test of Keystone Hill Well 1 for the Town of Coupeville (Town) on Whidbey Island, Washington. The Washington State Department of Health (Health) requires hydrogeologic evaluation of 24-hour, constant-rate, individual well tests prior to source approval. A Robinson, Noble & Saltbush hydrogeologist prepared a test plan, assisted with testing, and evaluated the test results. The Town's drilling contractor, Hokkaido Drilling and Development Co. of Graham, Washington, conducted the test. Water samples were collected and analyzed by Avocet Environmental Testing for all Group A parameters.

Background

The Town has water rights totaling 970 gallons per minute (gpm) and 606 acre-feet per year (afy) for their new well-field complex that includes the Fort Casey, Keystone, and in Town well fields. Because of the risk of seawater intrusion into the in Town well field, the Town decided to explore the potential of the aquifer identified by the Patmore Well on Keystone Hill Road west of the Navy Auxiliary Airfield. The new well is located in the southeast corner of parcel number R13111-432-4450 about 1.25 miles north of the Town's Fort Casey Wellfield, in Township 31 North, Range 1 East, NE4, NE4, Section 11 on Whidbey Island (**Figure 1**).

Well Construction

The 12-inch Keystone Hill Well was drilled to a depth of 200 feet by Hokkaido Drilling and Development Corp. with cable-tool equipment. The hydrogeologic log and completion details are shown on **Figure 2** and on the well's Water Well Report form in the **Appendix**. Aquifer sand samples were collected by the driller during construction and sieved in Robinson, Noble & Saltbush's soils laboratory. The grain-size analyses are included in the **Appendix** and indicated that an efficient well screen design could include a 0.040-inch slot, Type 304 stainless-steel, wire wrap well screen surrounded by Colorado Silica sand size 8-12. The well screen assembly details are listed in **Table 1**. The well screens were installed between 142 and 182 feet below ground surface (bgs) in the predominately gray sand aquifer. A sand pack was placed in the annulus between the 12-inch casing and 8-inch well screen from 122 to 190 feet. The 12-inch casing was pulled back to 144 feet. The 12-inch casing shoe remnant was left in the hole between 190 and 200 feet. The open hole was backfilled with washed and chlorinated pea gravel to provide a solid base for the well screen assembly.

Table 1: Well Screen Assembly Details

Item	Top (feet BGS)	Bottom (feet BGS)	Comments
Riser	122	142	8-inch mild steel pipe
0.040-slot screen	142	182	Type 304 stainless steel
Tailpipe	182	190	Plate bottom

Notes: All screens are 7.88-inch inside diameter.
All screens are Type 304 stainless steel, v-wire construction and standard strength.
All measurements are referenced to ground surface at the time of well construction.
Filter sand is Colorado Silica Sand size 8-12.

The sediments penetrated by the drill are predominately dry, gray, silty sand with gravel layers from land surface to a depth of 133 feet. Gray silty clay and siltbound gravel found between 133 and 143 feet comprise the confining layer overlying the aquifer. The static water level was measured at a depth of 122 feet bgs and stayed at about that depth while drilling continued through the water-bearing sand and gravel to the bottom of the aquifer at 182 feet bgs.

Well Testing

Hokkaido installed a 40-horsepower submersible pump into the well screen with the intake at a depth of 152 feet. A step pumping test was conducted on March 3rd followed by the 24-hour test on March 4th, which was started at 10:30 a.m. The test was monitored with a transducer/data logger set to measure the water level in the well every minute. Manual measurements included in the **Appendix**, were measured and recorded by the driller at selected intervals. A recording barometer was secured to a tree next to the well for the duration of the test period.

Pumping Test Results

Test results are shown on **Table 2** and in **Figures 3, 4** and **5**. The Keystone Hill Well was pumped for 24 hours at an average rate of 302 gpm. At the end of the 24 hours, the water level drawdown below the static water level of 125.08 feet was 20.12 feet, indicating a specific capacity of about 15 gpm/ft of drawdown. As shown on **Figures 3** and **4**, the pumping water level at the end of the 24-hour test was approximately 145 feet and had reached stabilization. Stabilization is defined by Health as less than 0.10 feet of drawdown per hour during the last four hours of testing. The manual water level data is included in the **Appendix**. The aquifer was not impacted by tidal changes.

Table 2: Pumping Test Results

Date	Discharge Rate (gpm)	Elapsed Time (hrs)	Drawdown (feet)	Specific Capacity (gpm/ft)
3/3	145	0.5	8.59	16.8
	200	0.5	11.57	17.2
	261	0.5	15.52	16.8
	302	0.5	18.58	16.2
	332	0.5	20.94	15.8
3/4-5	302	24	20.12	15.0

The pumping water level after 24 hours was within two feet of the top of the well screen. The pumping water level in a high production well should never be allowed to draw down inside the well screen. This practice can cause cascading water, air entrainment, reduced well efficiency, increased encrustation potential, and shorter well life.

Youderian Observation Well

The property to the south is owned by Ernest Youderian. He had a new well (APR989) drilled to a depth of 168 feet into the same aquifer. A copy of the well's Water Well Report Form is included in the **Appendix**. The measured distance of the Youderian Well south of the Keystone Hill Well is about 700 feet. As shown on **Figures 6**, **7**, and **8**, it was also monitored with a transducer/data logger measuring water levels at one-minute intervals. The 24-hour test produced about one half foot of interference as shown on **Figure 6**. This small amount of interference will not impair the use of the Youderian well. **Figure 6** also shows that the static water level in the aquifer appears to have declined about one-tenth of a foot during the week long monitoring period. This apparent seasonal decline is also shown on the Keystone Hill Well 1 hydrograph, **Figure 3**.

Transmissivity

Transmissivity (T) represents the permeability for the full-aquifer thickness and is equivalent to the amount of water flowing through a vertical, one-foot wide strip of the aquifer in one day (under unit gradient). It is calculated from drawdown and recovery patterns, such as those illustrated in **Figures 4** and **5**. The transmissivity was calculated using the Jacob/Theis, modified, non-equilibrium formula from the pumping rate and the slope of the drawdown and recovery graphs. The average transmissivity calculated for the Keystone Hill Well is about 79,000 gpd/ft.

Water Quality Testing

Water samples were collected at 24 hours and sent to Avocet Environmental Testing for Group A drinking water analysis. Laboratory reports are included in the **Appendix**.

Inorganic Test Results

Water pumped during the test was sand free and had a slight odor of hydrogen sulfide. Water temperature was 51.5 degree Fahrenheit. The results of inorganic water quality analyses from the Keystone Hill Well performed by Avocet, showed all measured parameters to be below Health's maximum contaminant levels (MCL) required for safe drinking water.

Volatile Organic Test Results

Analysis performed by Anatek Labs, Inc shows all measured parameters to be below the detection level for each compound.

Synthetic Organic Test Results

Analysis performed by Anatek Labs, Inc shows all measured parameters to be below the MCL for each compound. However, di(ethylhexyl)phthalate was detected at 2.91 ug/L which is below the MCL of 6 ug/L but exceeds the State reporting level of 1.3 ug/L. This compound was most likely introduced through the well construction or testing process and is probably does not originate in the aquifer. We recommend the Town resample the water for this compound after the well is put into service.

Radionuclide Test Results

Analysis performed by Energy Laboratories, Inc shows measured parameters to be below the MCL for gross alpha, gross beta, and radium 228.

Bacteriological Test Results

Bacteriological analysis results showed no coliform bacteria present.

Findings

The Keystone Hill Well

- produced 302 gpm for 24 hours; however, the pumping water level was within two feet of the top of the well screen.
- had a stabilized pumping water level for the last six hours of the test.
- is completed in a confined sand and gravel aquifer between 142 and 182 feet below ground surface.
- shows an aquifer transmissivity of about 79,000 gpd/ft.
- produces water of acceptable quality, which has a slight odor of hydrogen sulfide and a temperature of 51.5 degrees Fahrenheit.

Conclusions and Recommendations

Keystone Hill Well 1 fully penetrates a confined sand and gravel aquifer found between 143 and 182 feet below ground surface. This aquifer is positioned above sea level and receives recharge from precipitation falling on the surface of the ground, which then infiltrates through the confining layers into the aquifer. The aquifer recharge area consists of several square miles of Smith Prairie and likely discharges south toward the Town's Fort Casey Well Field and Crockett Lake.

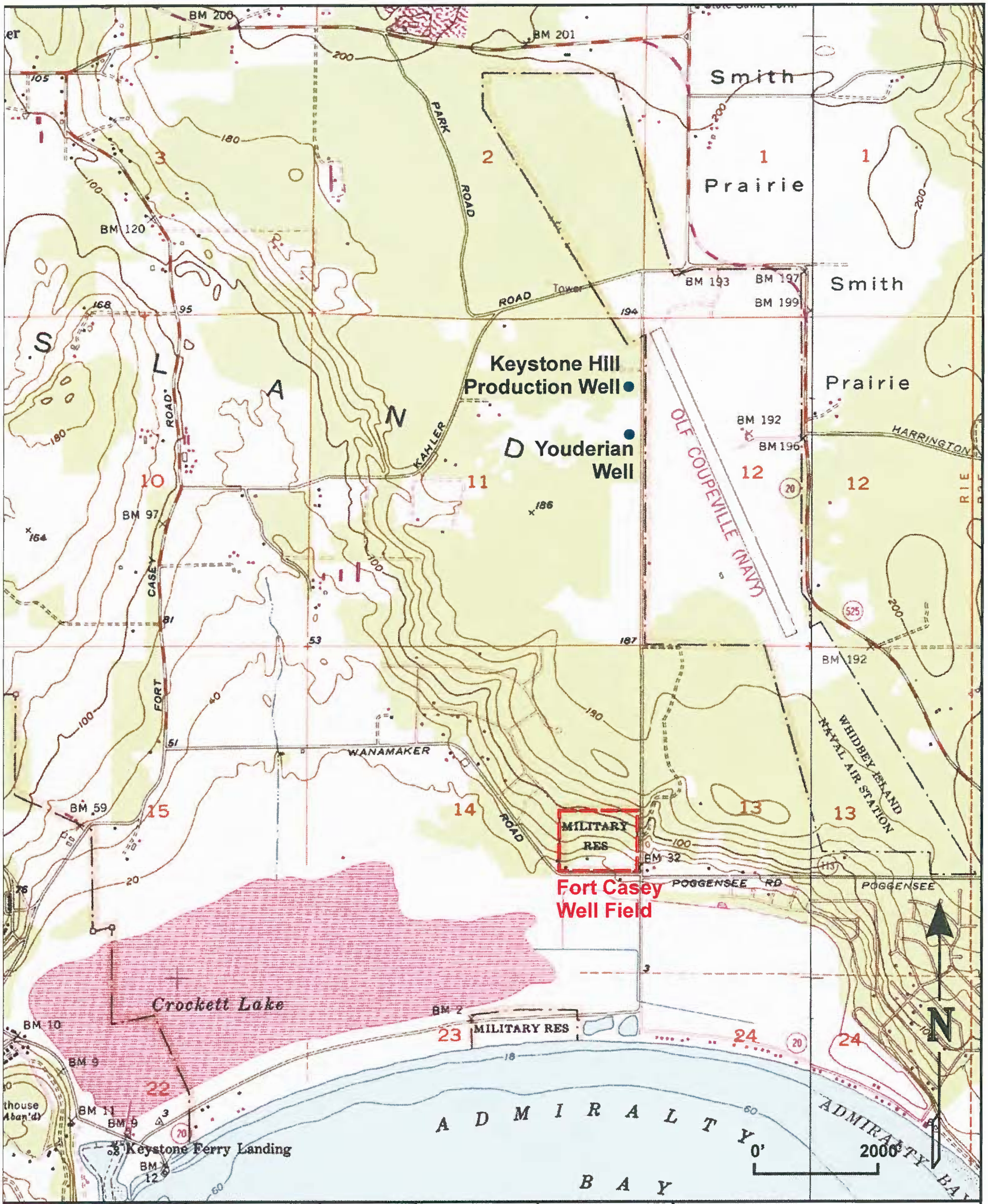
Robinson, Noble & Saltbush recommends the Town install a production pump into the 8-inch riser pipe with the pump intake at a depth of about 150 feet below ground surface. The pump could be either a line shaft turbine or submersible turbine with a maximum discharge rate of 250 gpm with a pumping lift of 140 feet. If a submersible turbine is specified, the pump manufacturer should be contacted to determine if a shroud will be required to provide sufficient cooling for the submersible motor.

Water levels must be closely monitored until the well's operational characteristics are fully understood by the Town's operator. We recommend the Town measure the well's static water level monthly, starting as soon as possible, in order to determine the amount of seasonal water level fluctuation in the aquifer. Once the well is in operation, the Town should also record the instantaneous pumping rate and total volume pumped each time a pumping water level is measured. The Town should plot this water level data at least annually to monitor the health of the aquifer and the wells efficiency.

Robinson, Noble & Saltbush recommends drilling additional wells, as needed, south from Well 1 along Keystone Hill Road with spacing no closer that 500 feet between wells. At that distance, interference between wells will be less than one foot.

The statements, conclusions, and recommendations provided in this report are to be exclusively used within the context of this document. They are based upon generally accepted hydrogeologic practices and are the result of analysis by Robinson, Noble & Saltbush, Inc. staff. This report, including any attachments to it, is for the exclusive use of the Town of Coupeville. Unless specifically stated in the document, no warranty, expressed or implied, is made.

FIGURES



ROBINSON NOBLE SALTBUSH INC.
GROUNDWATER & ENVIRONMENTAL SCIENTISTS
1947 60 Years 2007

Note:
Basemap taken from
USGS Coupeville
Quadrange

PM: DCD
April 2008

1205-005A
Scale 1" = 2000'

Island County
T 31 N/R 01 E - 11

Figure 1
Well Location Map

Town of Coupeville: Keystone Hill Production Well

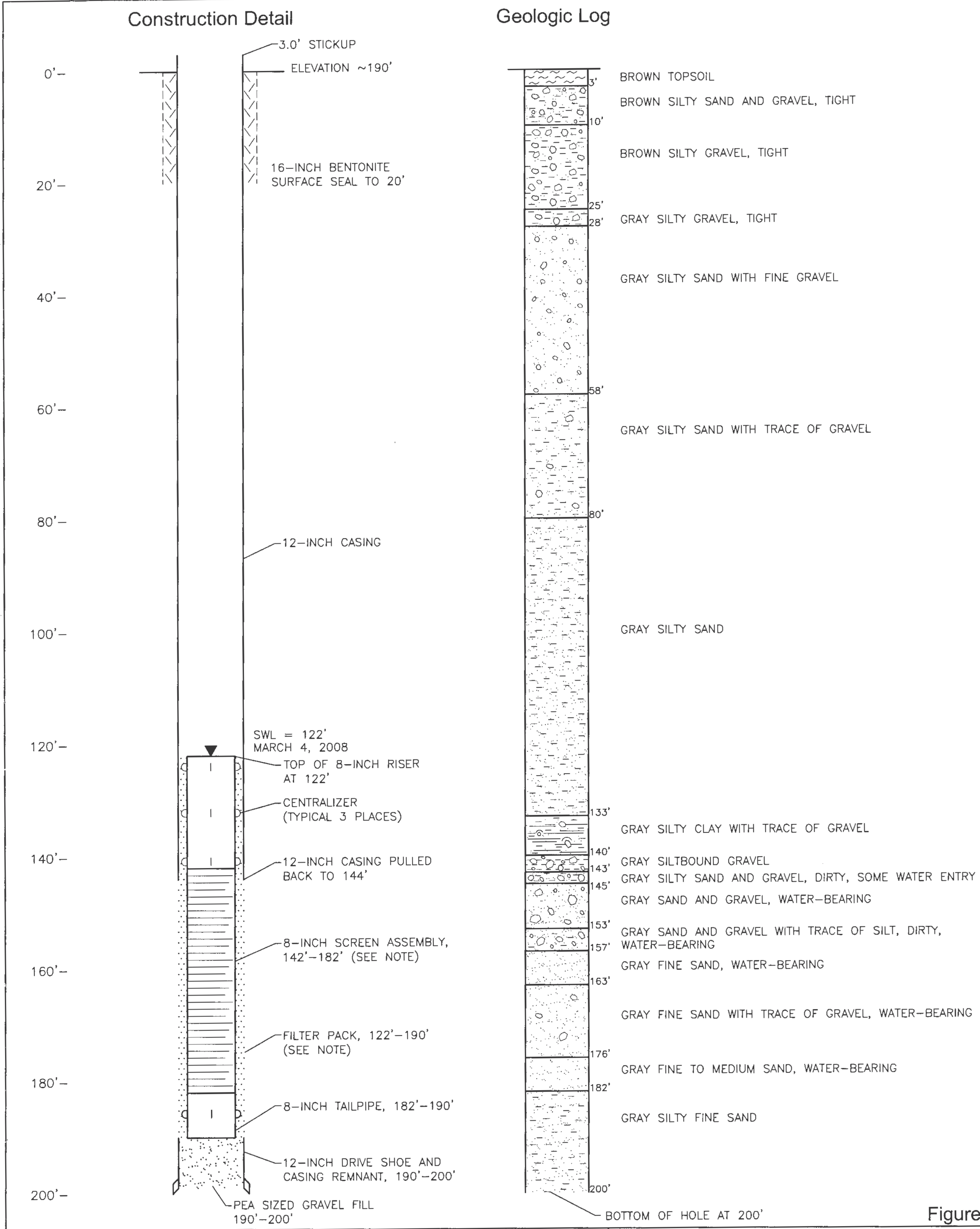


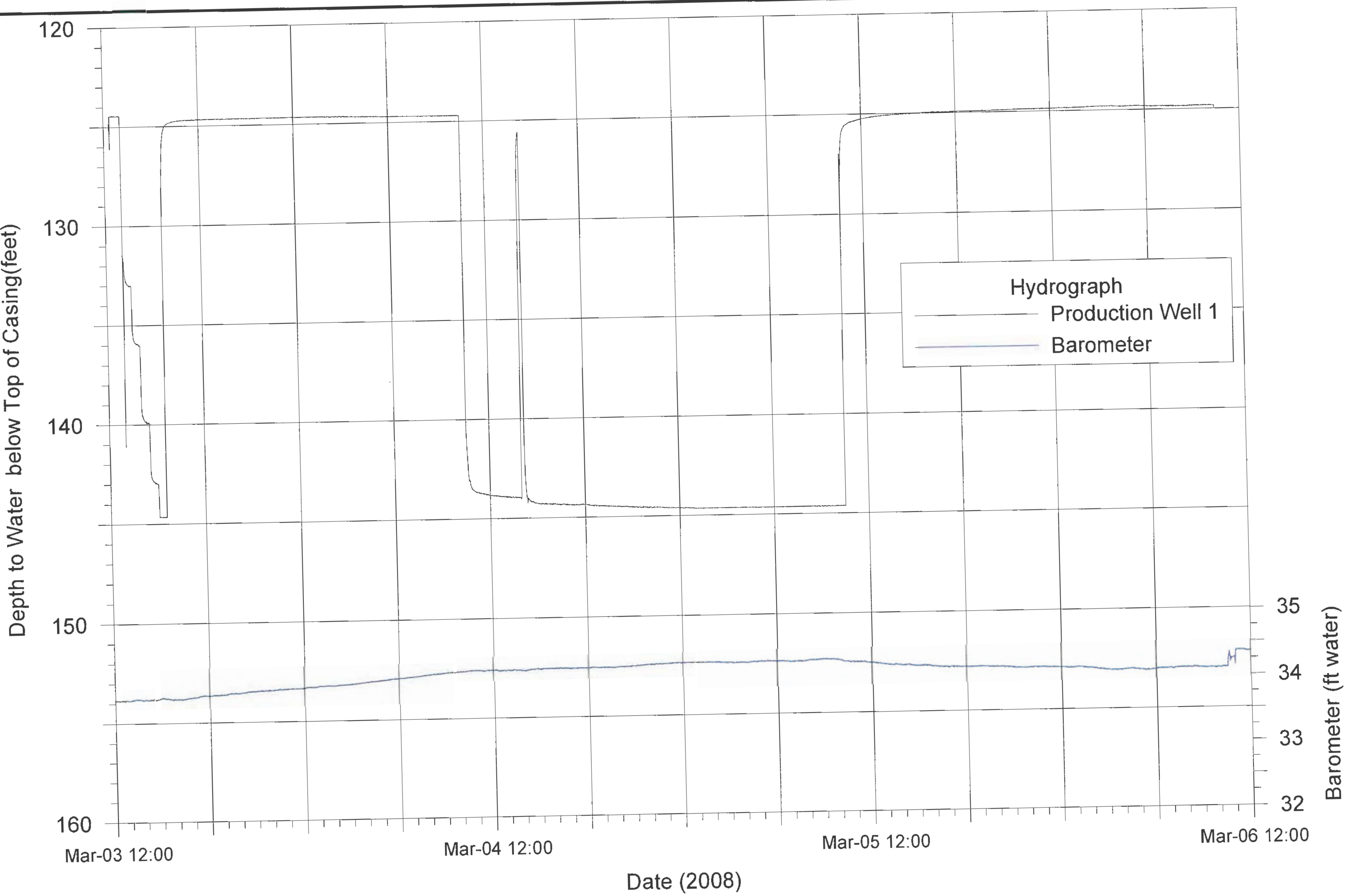
Figure 2

ROBINSON NOBLE SALTBUSH INC.
GROUNDWATER & ENVIRONMENTAL SCIENTISTS
1947 60 Years 2007

PM: DCD
April 2008
Island County
T 31 N/R 01 E - 11

Note: Well screen is 8-inch diameter pipe size, 40-slot (0.040-inch opening), type 304 stainless steel. Filter pack is 8x12 Colorado Silica Sand product.

Construction Detail and Geologic Log for Keystone Hill Production Well
Town of Coupeville

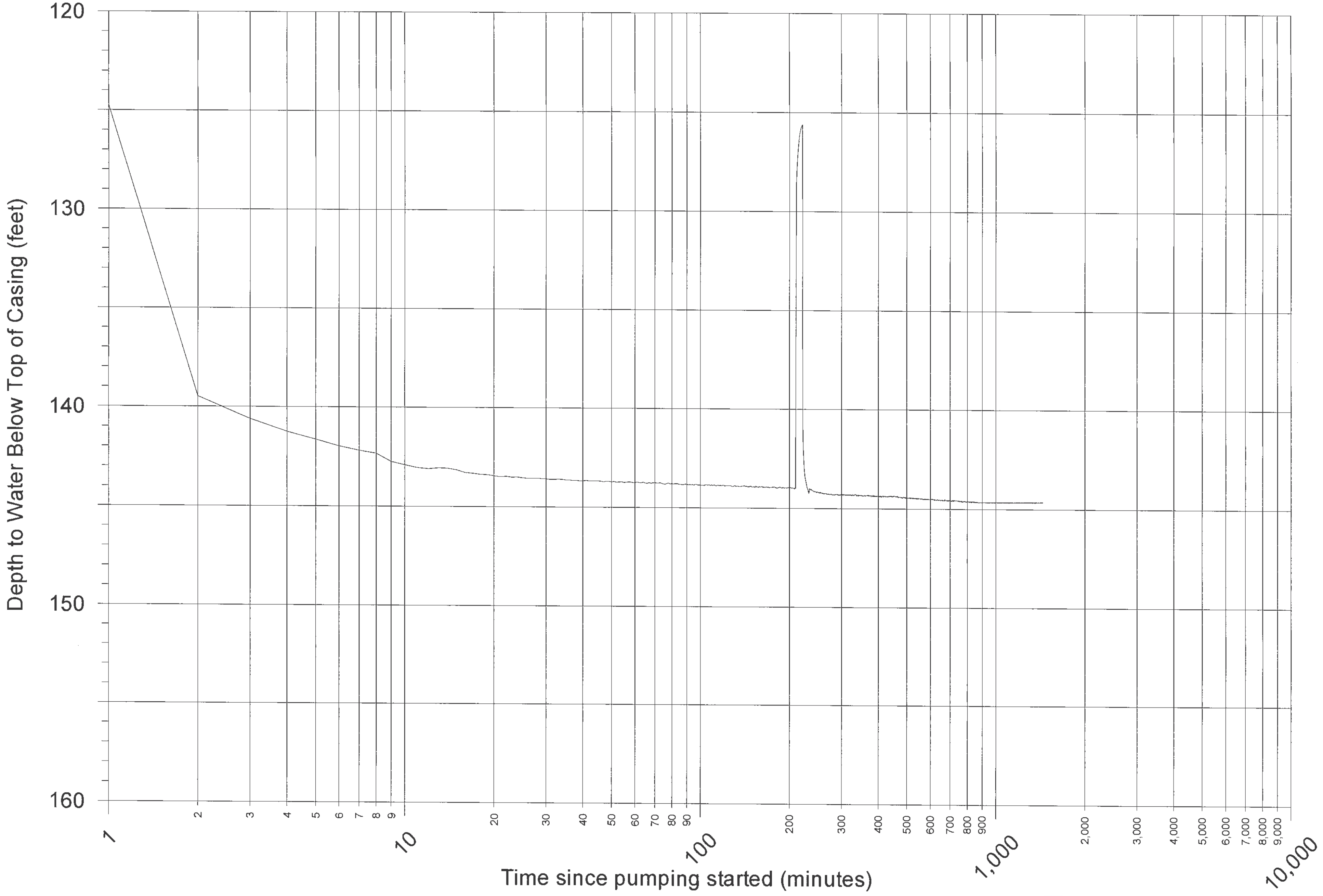


ROBINSON NOBLE SALTBUSH INC.
GROUNDWATER & ENVIRONMENTAL SCIENTISTS
1947 60 Years 2007

Date: 03/08
Job#: 1205-005A
PM: DCD

Pressure Transducer
Hydrograph (03/03/08-03/06/08)
One minute intervals

Figure 3
Coupeville: Keystone Hill Well 1 Hydrograph

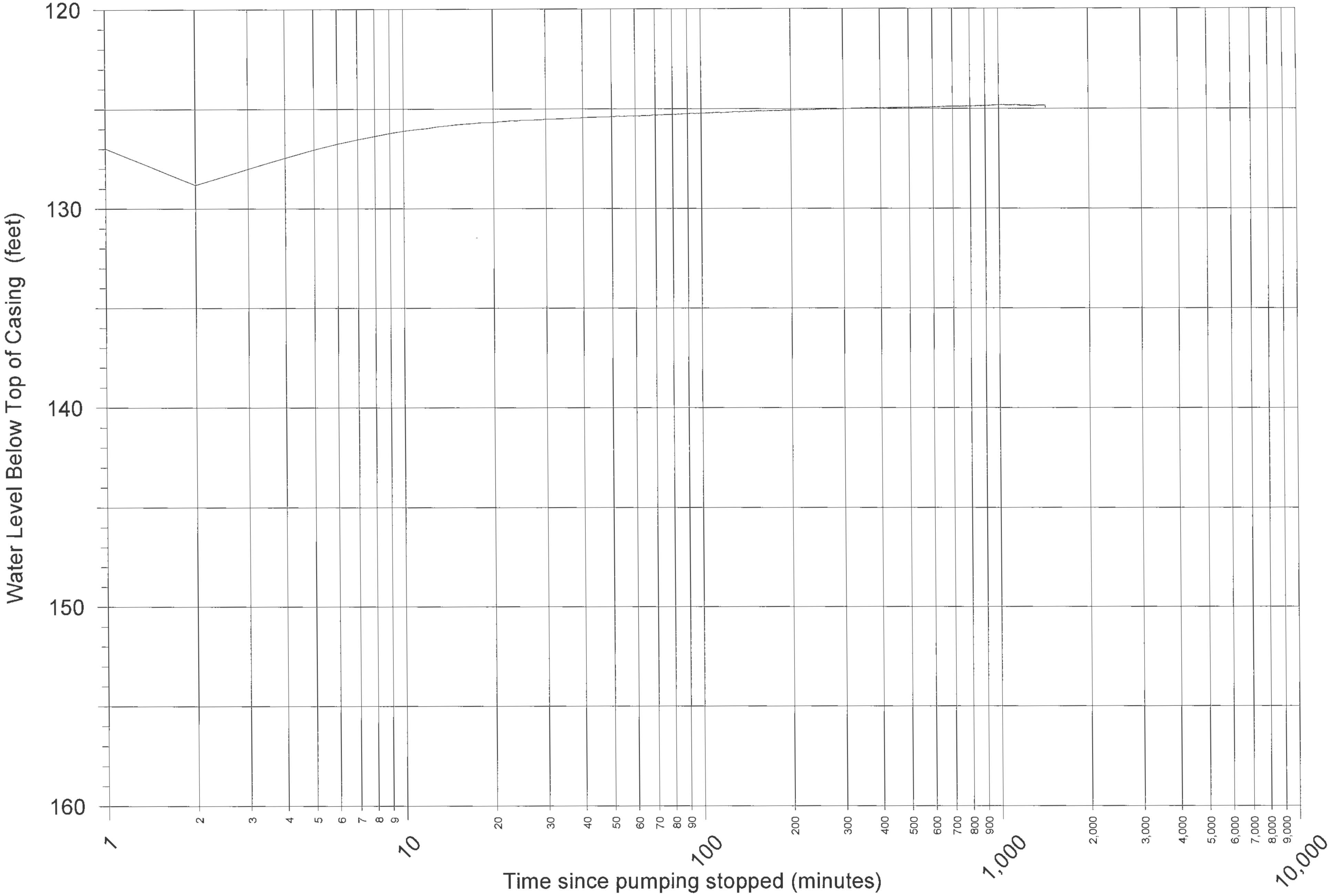


ROBINSON
NOBLE SALTBUSH INC.
GROUNDWATER & ENVIRONMENTAL SCIENTISTS
1947 60 Years 2007

Date: 03/08
Job#: 1205-005A
PM: DCD

Coupeville: Keystone Hill Production Well 1
Drawdown Plot (03/04/08-03/05/08)
Average pumping rate: 302 gpm, SWL= 125.08 ft btc

Figure 4

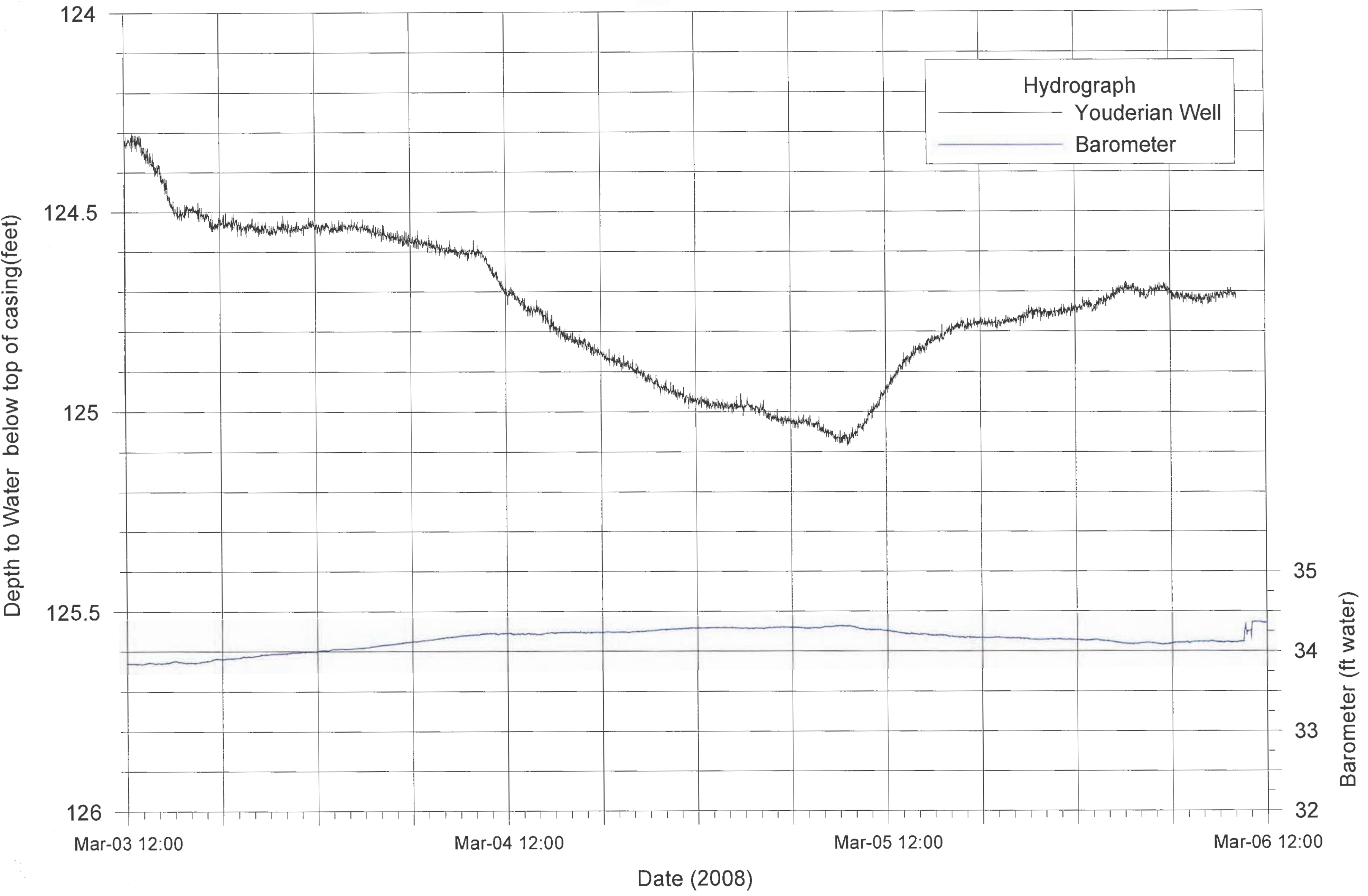


ROBINSON NOBLE SALTBUSH INC.
GROUNDWATER & ENVIRONMENTAL SCIENTISTS
1947 60 Years 2007

Date: 03/08
Job#: 1205-005A
PM: DCD

Coupeville: Keystone Hill Production Well 1
Recovery Plot (03/05/08-3/06/08)
Pre-Test SWL + 125.08 ft. btc

Figure 5

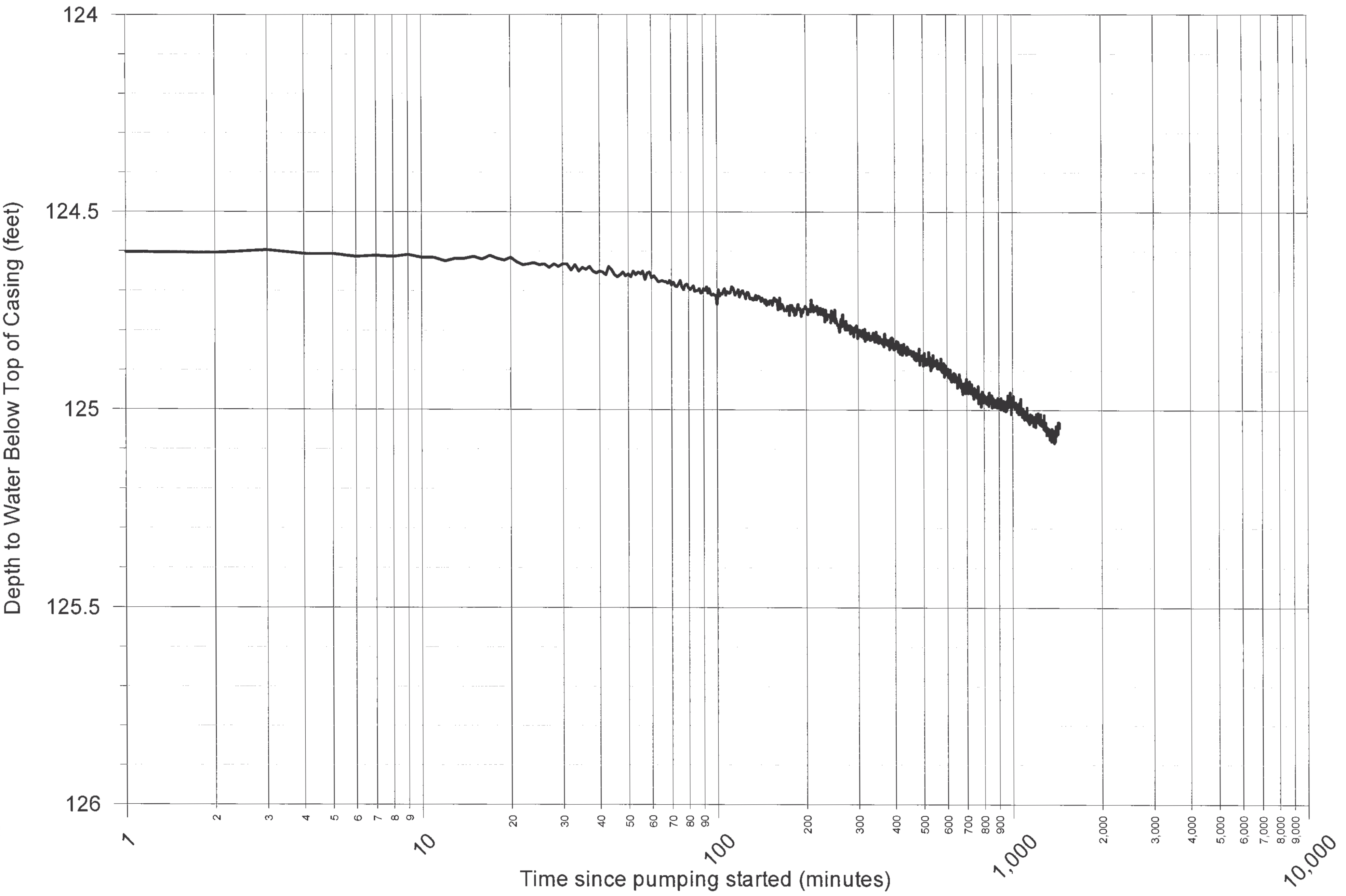


ROBINSON NOBLE SALTBUSH INC.
GROUNDWATER & ENVIRONMENTAL SCIENTISTS
1947 60 Years 2007

Date: 03/08
Job#: 1205-005A
PM: DCD

Pressure Transducer
Hydrograph (03/03/08-03/06/08)
One minute intervals
SWL= 124.6 ft btc

Figure 6
Coupeville: Youderian Observation Well
Hydrograph

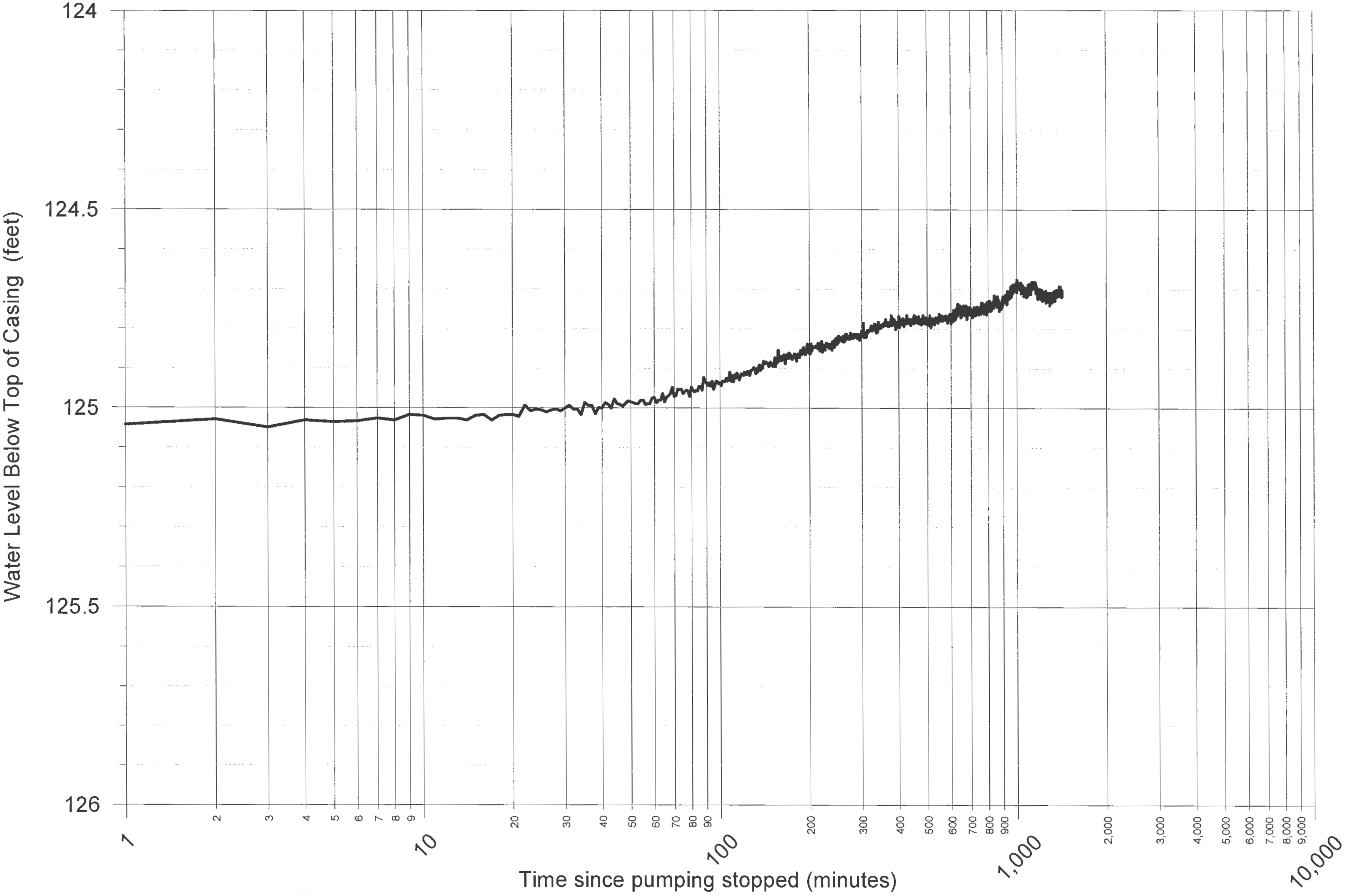


ROBINSON NOBLE SALTBUSH INC.
GROUNDWATER & ENVIRONMENTAL SCIENTISTS
1947 60 Years 2007

Date: 03/08
Job#: 1205-005A
PM: DCD

Coupeville: Youderian Observation Well
Drawdown Plot (03/04/08-03/05/08)
SWL= 124.6 ft btc

Figure 7



ROBINSON NOBLE SALTBUSH INC.
GROUNDWATER & ENVIRONMENTAL SCIENTISTS
1947 60 Years 2007

Date: 03/08
Job#: 1205-005A
PM: DCD

Coupeville: Youderian Observation Well
Recovery Plot (03/05/08-3/06/08)
SWL= 124.6 ft btc

Figure 8

WATER WELL REPORT FORM

WASHINGTON STATE DEPARTMENT OF ECOLOGY

WATER WELL REPORT

Original & 1st copy – Ecology, 2nd copy – owner, 3rd copy – driller

Construction/Decommission *("x" in circle)*

☒ Construction

☐ Decommission *ORIGINAL INSTALLATION*

Notice of Intent Number ____

PROPOSED USE: ☐ Domestic ☐ Industrial ☒ Municipal ☐ DeWater ☐ Irrigation ☐ Test Well ☐ Other ______

TYPE OF WORK: Owner's number of well (if more than one) Keyst

☒ New well ☐ Reconditioned *Method :* ☐ Dug ☐ Bored ☐ Driven

☐ Deepened ☒ Cable ☐ Rotary ☐ Jetted

DIMENSIONS: Diameter of well 12 inches, drilled 200 ft.

Depth of completed well 190 ft.

CONSTRUCTION DETAILS

Casing Installed: ☒ Welded 12" Diam. from +3 ft. to 144 ft.

☐ Liner installed ____" Diam. from ____ ft. to ____ ft.

☐ Threaded ____" Diam. From ____ ft. to ____ ft.

Perforations: ☐ Yes ☒ No

Type of perforator used ______

SIZE of perfs ____ in. by ____ in. and no. of perfs ____ from ____ ft. to ____ ft.

Screens: ☒ Yes ☐ No ☐ K-Pac Location ______

Manufacturer's Name Johnson

Type SS Model No. PS

Diam. 8 Slot size 0.040 from 142 ft. to 182 ft.

Diam. ____ Slot size ____ from ____ ft. to ____ ft.

Gravel/Filter packed: ☒ Yes ☐ No Size of gravel/sand 8 x 12

Materials placed from 122 ft. to 190 ft.

Surface Seal: ☒ Yes ☐ No To what depth? 20 ft.

Material used in seal bentonite

Did any strata contain unusable water? ☐ Yes ☒ No

Type of water? ______ Depth of strata ______

Method of sealing strata off ______

PUMP: Manufacturer's Name ______

Type: ______ H.P. ______

WATER LEVELS: Land-surface elevation above mean sea level 200 ft.

Static level 125.0 ft. below top of well Date 3/4/08

Artesian pressure ______ lbs. per square inch Date ______

Artesian water is controlled by ______ cap, valve, etc.)

WELL TESTS: Drawdown is amount water level is lowered below static level

Was a pump test made? ☒ Yes ☐ No If yes, by whom? R,N&S

Yield: 302 gal./min. with 20.1 ft. drawdown after 24 hrs.

Yield: ______ gal./min. with ____ ft. drawdown after ______ hrs.

Yield: ______ gal./min. with ____ ft. drawdown after ______ hrs.

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level
1	129.3	5	128	30	125.9
2	128.4	10	126.4	45	125.8
3	127.8	15	126.1		

Date of test Bailer test ______ gal./min. with ____ ft. drawdown after __ hrs.

Airtest gal./min. with stem set at ______ ft. for ______ hrs.

Artesian flow ______ g.p.m. Date ______

Temperature of water 51.5 Was a chemical analysis made? ☒ Yes ☐ No

CURRENT

Notice of Intent No. WE07945

Unique Ecology Well ID Tag No. AFT 338

Water Right Permit No. CG1-*00845S

Property Owner Name Town of Coupeville

Well Street Address Keystone Hill Road

City Coupeville County Island

Location NE1/4-1/4 NE1/4 Sec 11 Twn 31N R 1E

EWM ☒ Or WWM ☐

Lat/Long (s, t, r Still REQUIRED) Lat Deg 48 Min 192 Sec 33

Long Deg 122 Min 637 Sec 99

CONSTRUCTION OR DECOMMISSION PROCEDURE

Formation: Describe by color, character, size of material and structure, and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information. (USE ADDITIONAL SHEETS IF NECESSARY.)

MATERIAL	FROM	TO
Top soil, brown	0	3
Silty sand, gravel, tight, br	3	10
Silty gravel tight brown	10	25
Silty gravel tight gray	25	28
Silty sand w/fine gravel gray	28	58
Silty sand w/trace gravel gra	58	80
Silty sand, gray	80	133
Silty clay w/trace gvl gray	133	140
Siltbound gravel gray	140	143
Silty sand gvl gray some wate	143	145
Sand gravel gray water	145	153
Dirty sand & gvl w/trc silt	153	157
sand, fine gray	157	163
Sand, fine gray w/Trc gvl	163	176
Sand fine-med gray	176	182
Sand fine silty gray	182	200

Start Date 1/23/08 Completed Date 3/7/08

Tax Parcel No. R131114324450

WELL CONSTRUCTION CERTIFICATION: I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

☒ Driller ☐ Engineer ☐ Trainee Driller or trainee License No. 1146

Name (Print Last, First) Dodge , Biily A

Driller/Engineer/Trainee Signature

IF TRAINEE: Driller's License No:

Driller's Signature:

Drilling Company Hokkaido Drilling, Inc.

Address P.O. Box 100

City, State, Zip Graham , WA, 98338

Contractor's Registration No. HOKKAD1017M8 Date 3/25/08

289953

31-1E-11h

WASHINGTON STATE DEPARTMENT OF ECOLOGY

WATER WELL REPORT

Original & 1st copy – Ecology, 2nd copy – owner, 3rd copy – driller

Construction/Decommission *("x" in circle)*

☒ Construction

○ Decommission *ORIGINAL INSTALLATION Notice of Intent Number* ____

CURRENT
Notice of Intent No. W257512

Unique Ecology Well ID Tag No. APR989

Water Right Permit No. ____

Property Owner Name ERNEST H. YOUDERIAN

Well Street Address xx Keystone HILL Rd

City Coupeville County ISLand

Location SE 1/4-1/4 NE 1/4 Sec 11 Twn 31 R 1 [✓ EWM] or WWM circle one

Lat/Long (s, t, r Still **REQUIRED**) Lat Deg ____ Lat Min/Sec ____ Long Deg ____ Long Min/Sec ____

Tax Parcel No. R13130-330-4620

PROPOSED USE: ☒ Domestic ☐ Industrial ☐ Municipal ☐ DeWater ☐ Irrigation ☐ Test Well ☐ Other ____

TYPE OF WORK: Owner's number of well (if more than one) ____

☒ New well ☐ Reconditioned ☐ Deepened *Method:* ☐ Dug ☐ Bored ☐ Driven ☒ Cable ☐ Rotary ☐ Jetted

DIMENSIONS: Diameter of well 6 inches, drilled 168 ft.
Depth of completed well 168 ft.

CONSTRUCTION DETAILS

Casing Installed: ☒ Welded 6" Diam. from +1.5 ft. to 158 ft.
☐ Liner installed ____" Diam. from ____ ft. to ____ ft.
☐ Threaded ____" Diam. from ____ ft. to ____ ft.

Perforations: ☐ Yes ☒ No
Type of perforator used ____
SIZE of perfs ____ in. by ____ in. and no. of perfs ____ from ____ ft. to ____ ft.

Screens: ☒ Yes ☐ No ☒ K-Pac Location 157
Manufacturer's Name Johnson
Type StainLess Model No. Tele
Diam. 5 Slot size 12 from 158 ft. to 163 ft.
Diam. 5 Slot size 10 from 163 ft. to 168 ft.

Gravel/Filter packed: ☐ Yes ☒ No ☐ Size of gravel/sand ____
Materials placed from ____ ft. to ____ ft.

Surface Seal: ☒ Yes ☐ No To what depth? 18 ft.
Material used in seal Bentonite
Did any strata contain unusable water? ☐ Yes ☐ No
Type of water? ____ Depth of strata ____
Method of sealing strata off ____

PUMP: Manufacturer's Name ____
Type: ____ H.P. ____

WATER LEVELS: Land-surface elevation above mean sea level 200 ft.
Static level 125'6" ft. below top of well Date 1/21/08
Artesian pressure ____ lbs. per square inch Date ____
Artesian water is controlled by ____ (cap, valve, etc.)

WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? ☐ Yes ☒ No If yes, by whom? ____
Yield: ____ gal./min. with ____ ft. drawdown after ____ hrs.
Yield: ____ gal./min. with ____ ft. drawdown after ____ hrs.
Yield: ____ gal./min. with ____ ft. drawdown after ____ hrs.

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test ____
Bailer test 10 gal./min. with 1 ft. drawdown after 1 hrs.
Airtest ____ gal./min. with stem set at ____ ft. for ____ hrs.
Artesian flow ____ g.p.m. Date ____
Temperature of water ____ Was a chemical analysis made? ☐ Yes ☒ No

CONSTRUCTION OR DECOMMISSION PROCEDURE

Formation: Describe by color, character, size of material and structure, and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information. (USE ADDITIONAL SHEETS IF NECESSARY.)

MATERIAL	FROM	TO
Brown Topsoil	0	2
Silty Sand & Gravel	2	22
Gravel	22	47
Silty Sand	47	54
Sandy Clay	54	63
Silty Sand	63	80
Clean sand	80	95
Silty Sand	95	101
Sandy Clay	101	115
Brown Clay	115	120
Gravel	120	132
Sand & Gravel	132	140
Water sand	140	164
Finer Watersand	164	168
more sand	168	
Well Site meets all	set	backs
under ICC 8.09.		

RECEIVED
FEB 19 2008
DEPT. OF ECOLOGY

Start Date 1/15/08 Completed Date 1/21/08

WELL CONSTRUCTION CERTIFICATION: I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

☒ Driller ☐ Engineer ☐ Trainee Name (Print) G Boonstra
Driller/Engineer/Trainee Signature Gerlof Boonstra
Driller or trainee License No. 0038

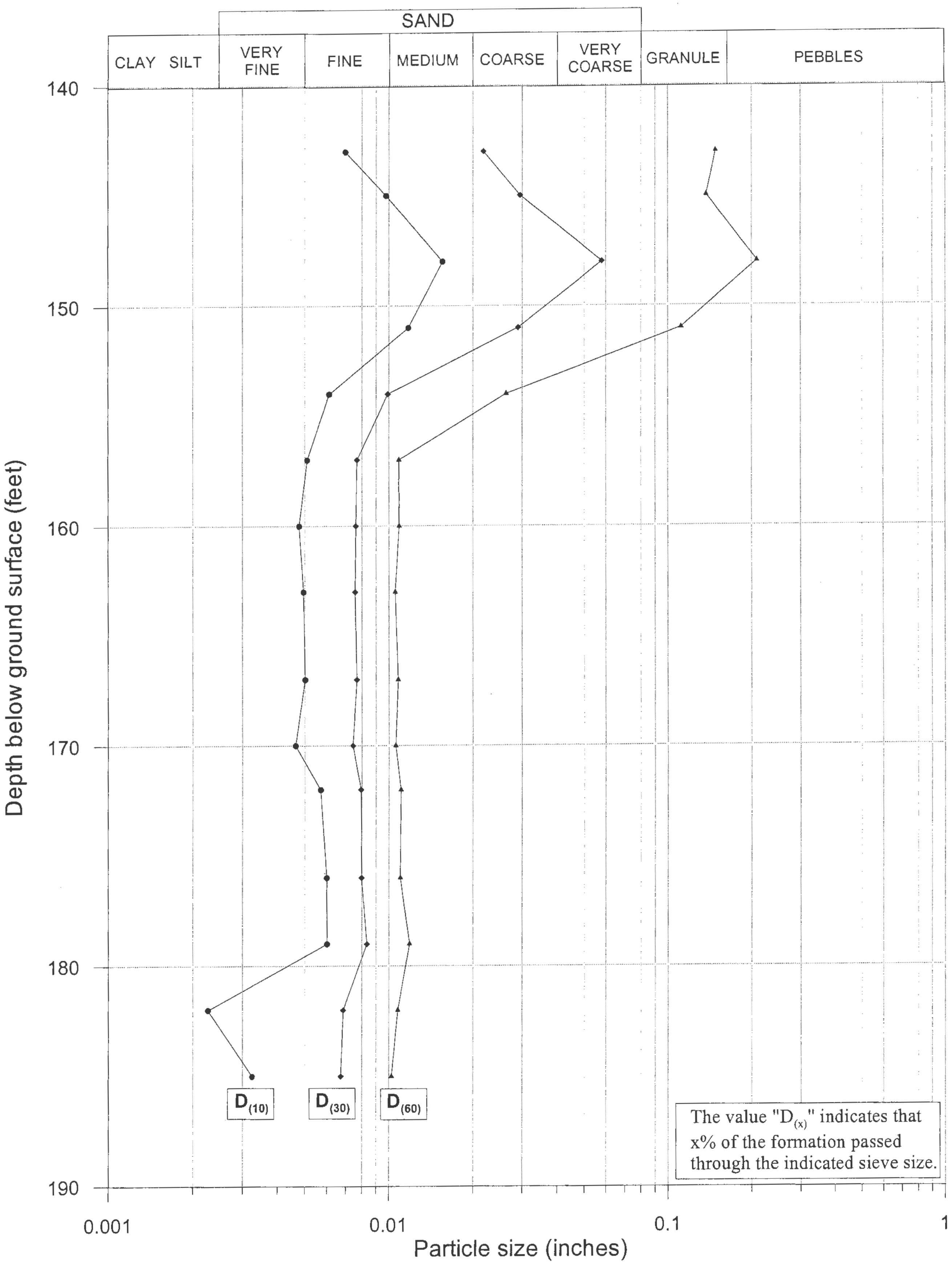
If TRAINEE,
Driller's Licensed No. ____
Driller's Signature ____

Drilling Company WHIDBEY DRILLERS
Address 716 Holbrook Rd
City, State, Zip Coupeville WA 98239
Contractor's Registration No. WHIDBWD944Q9 Date 1-22-08

Ecology is an Equal Opportunity Employer.

ECY 050-1-20 (Rev 3/05)

GRAIN SIZE ANALYSES



The value "$D_{(x)}$" indicates that x% of the formation passed through the indicated sieve size.

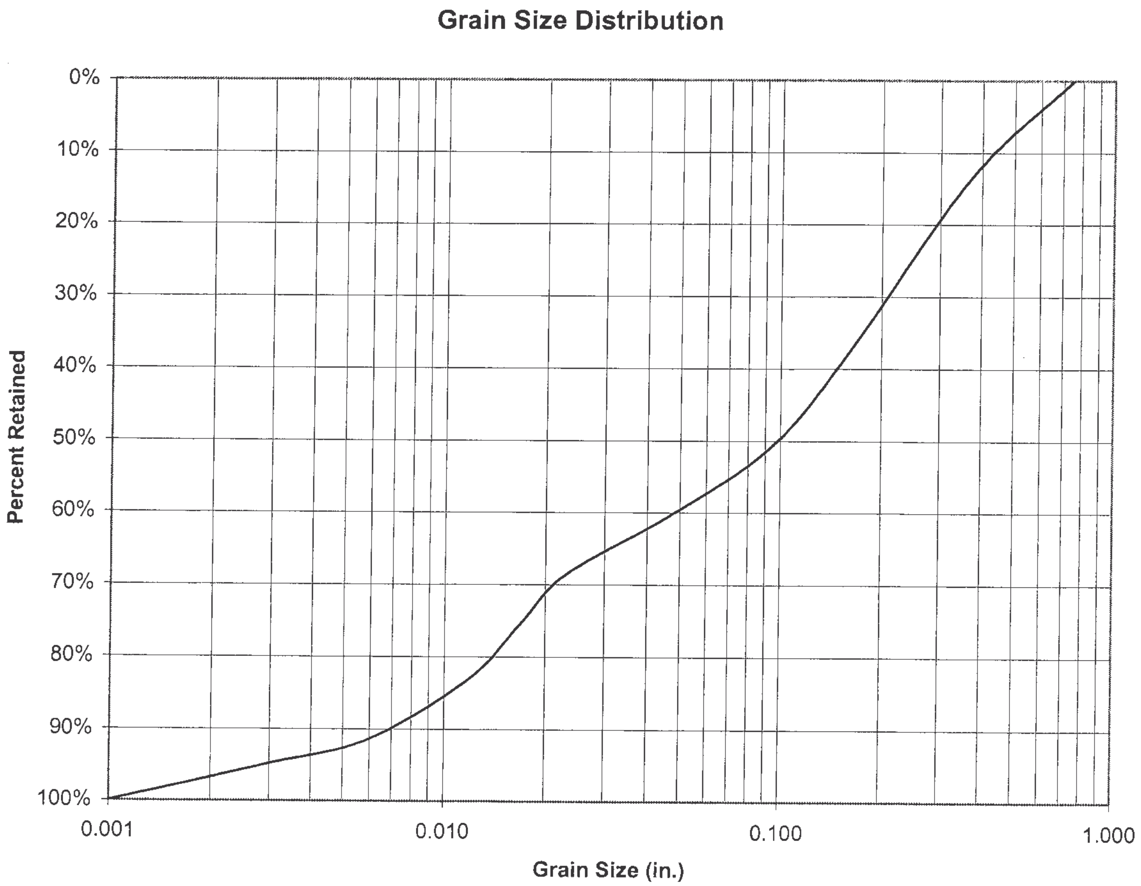
ROBINSON NOBLE SALTBUSH INC. Established 1947
GROUNDWATER & ENVIRONMENTAL SCIENTISTS
1947 *60 Years* 2007

Date: February 2008
Job No. 1205-001A
PM: DCD

Figure X
Vertical Grain Size Distribution
Coupeville: Keystone Hill Well

Grain Size Calculations

Job	Coupeville:Keystone Hill							
Job #	1205-005A							
Depth	143							
					Calculations			
		Weights	Percentage		0.9	0.7	0.4	
Sieve Sizes (Assumes Max. Size of 3/4")	0.750	0	0%		0	0	0	
	0.375	126.1	13%		0	0	0	
	0.157	362.2	38%		0	0	0.148488	
	0.093	482.2	51%		0	0	0	
	0.047	570.4	60%		0	0	0	
	0.023	649.2	69%		0	0.021806	0	
	0.017	712.4	75%		0	0	0	
	0.012	783.5	83%		0.006992	0	0	
	0.006	864.2	91%		0	0	0	
	0.003	896.7	95%		0	0	0	
	0.001	945.4	100%		0	0	0	
			Depth	D10	D30	D60		
			143	0.007	0.022	0.148		

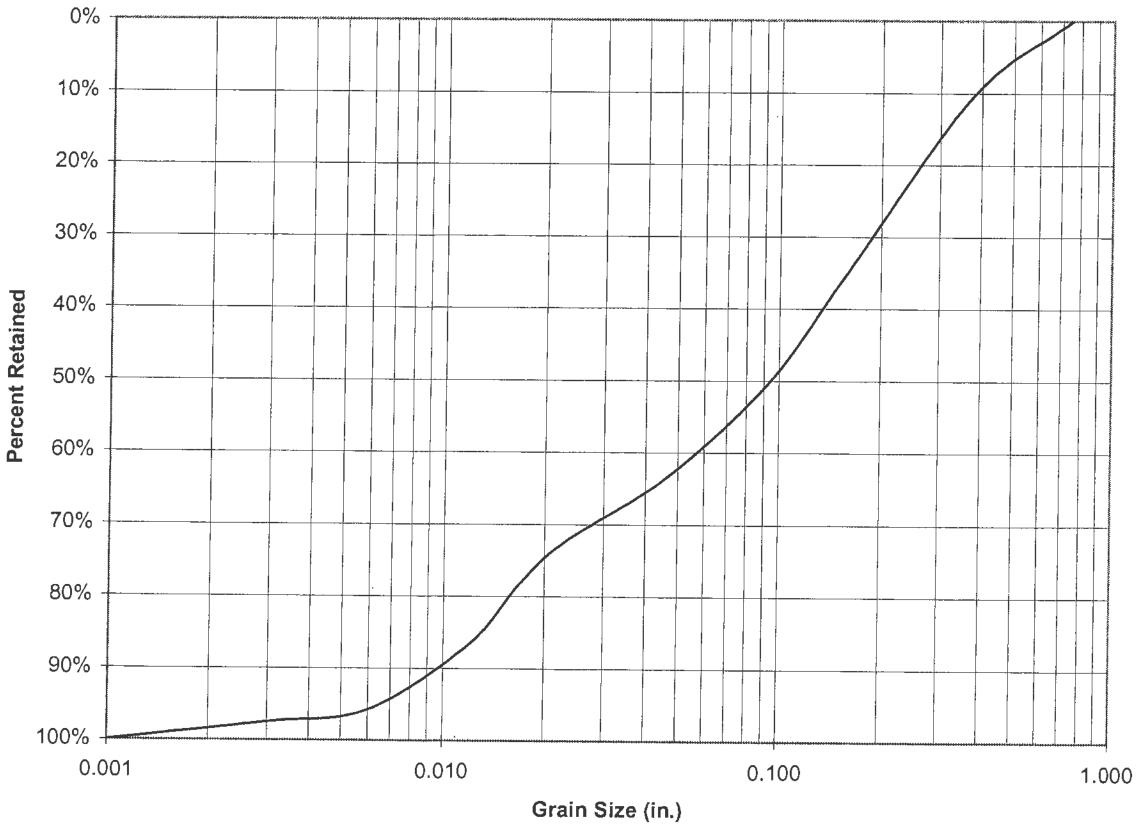


Grain Size Calculations

Job	Coupeville:Keystone Hill						
Job #	1205-005A						
Depth	145						
				Calculations			
		Weights	Percentage		0.9	0.7	0.4
Sieve Sizes (Assumes Max.Size of 3/4")	0.750	0	0%		0	0	0
	0.375	103.9	11%		0	0	0
	0.157	350.2	35%		0	0	0.137391
	0.093	497.2	50%		0	0	0
	0.047	624.7	63%		0	0.029434	0
	0.023	716.2	72%		0	0	0
	0.017	772.2	78%		0	0	0
	0.012	855.7	87%		0.009775	0	0
	0.006	946.3	96%		0	0	0
	0.003	963.7	98%		0	0	0
	0.001	988.1	100%		0	0	0

Depth	D10	D30	D60
145	0.010	0.029	0.137

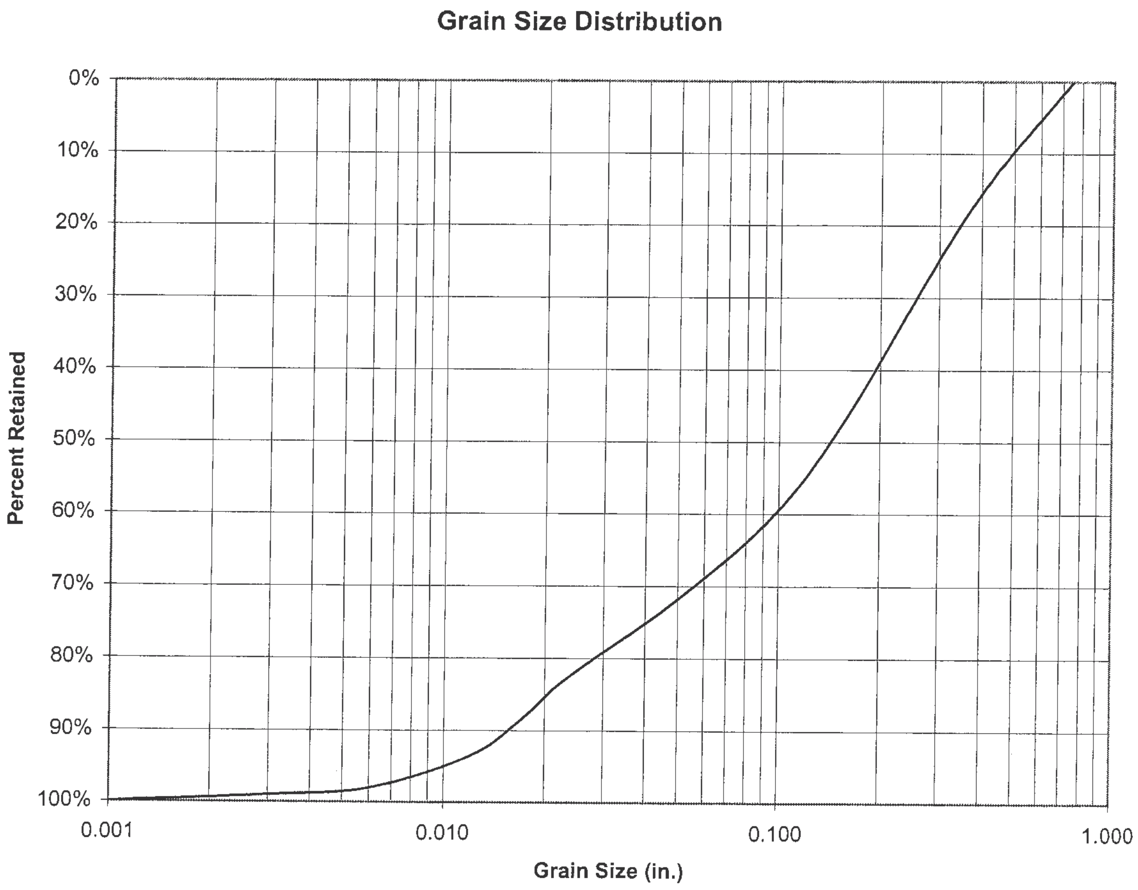
Grain Size Distribution



Grain Size Calculations

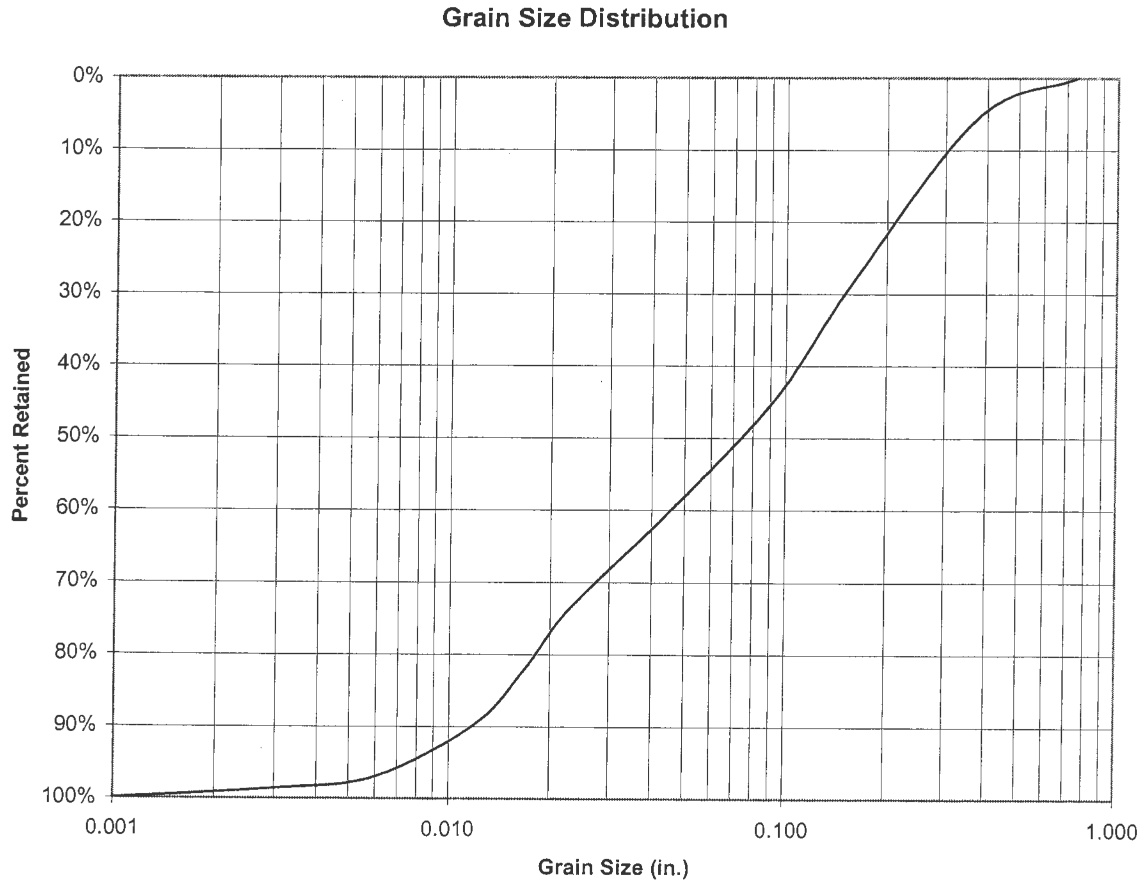
Job	Coupeville:Keystone Hill					
Job #	1205-005A					
Depth	148					
				Calculations		
		Weights	Percentage	0.9	0.7	0.4
Sieve Sizes (Assumes Max.Size of 3/4")	0.750	0	0%	0	0	0
	0.375	177.7	17%	0	0	0.208847
	0.157	478.5	47%	0	0	0
	0.093	620.8	61%	0	0.058	0
	0.047	740.9	73%	0	0	0
	0.023	844.3	83%	0	0	0
	0.017	900.9	89%	0.015561	0	0
	0.012	952.2	94%	0	0	0
	0.006	997.4	98%	0	0	0
	0.003	1007.4	99%	0	0	0
	0.001	1017.4	100%	0	0	0

Depth	D10	D30	D60
148	0.016	0.058	0.209



Grain Size Calculations

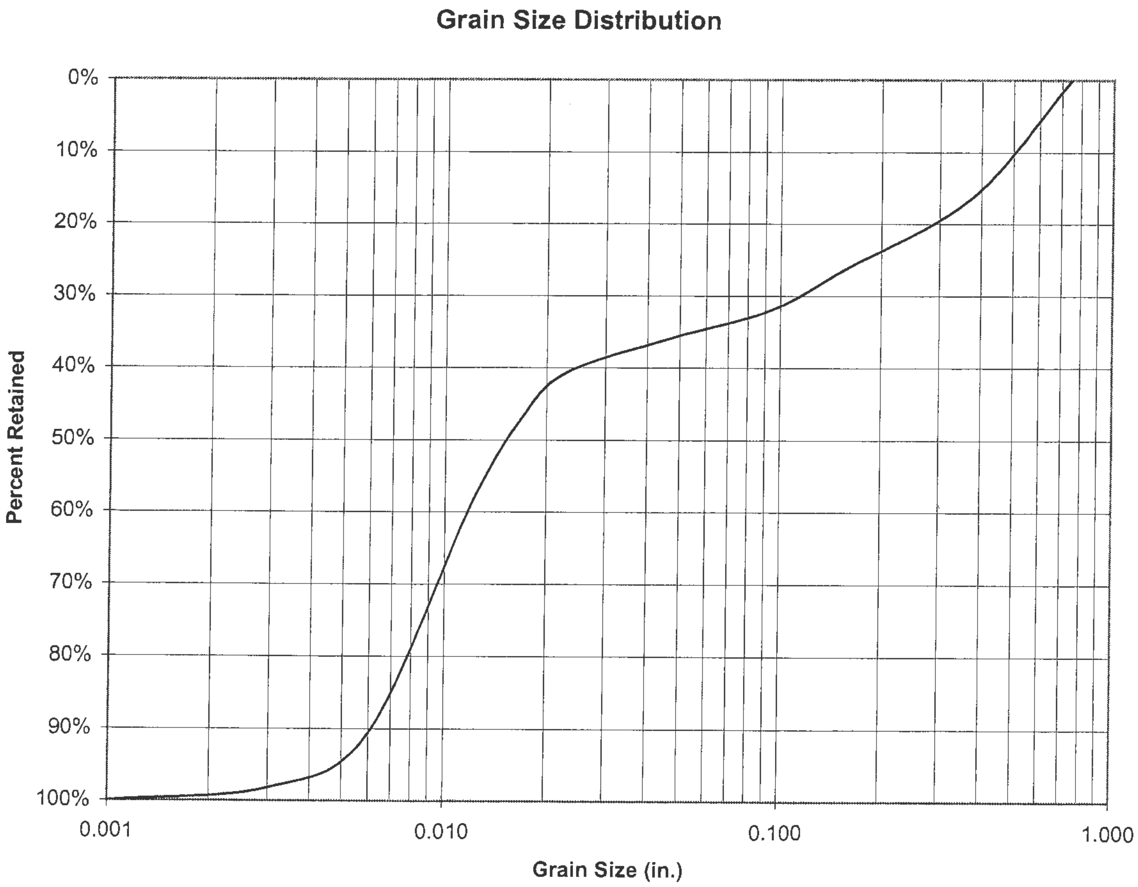
Job	Coupeville:Keystone Hill						
Job #	1205-005A						
Depth	151						
					Calculations		
		Weights	Percentage		0.9	0.7	0.4
Sieve Sizes (Assumes Max.Size of 3/4")	0.750	0	0%		0	0	0
	0.375	57	6%		0	0	0
	0.157	294.6	29%		0	0	0.111548
	0.093	458.5	45%		0	0	0
	0.047	610.8	59%		0	0.02905	0
	0.023	755.8	74%		0	0	0
	0.017	840.5	82%		0	0	0
	0.012	921.5	90%		0.01174	0	0
	0.006	996.5	97%		0	0	0
	0.003	1013.6	99%		0	0	0
	0.001	1027.5	100%		0	0	0
			Depth	D10	D30	D60	
			151	0.012	0.029	0.112	



Grain Size Calculations

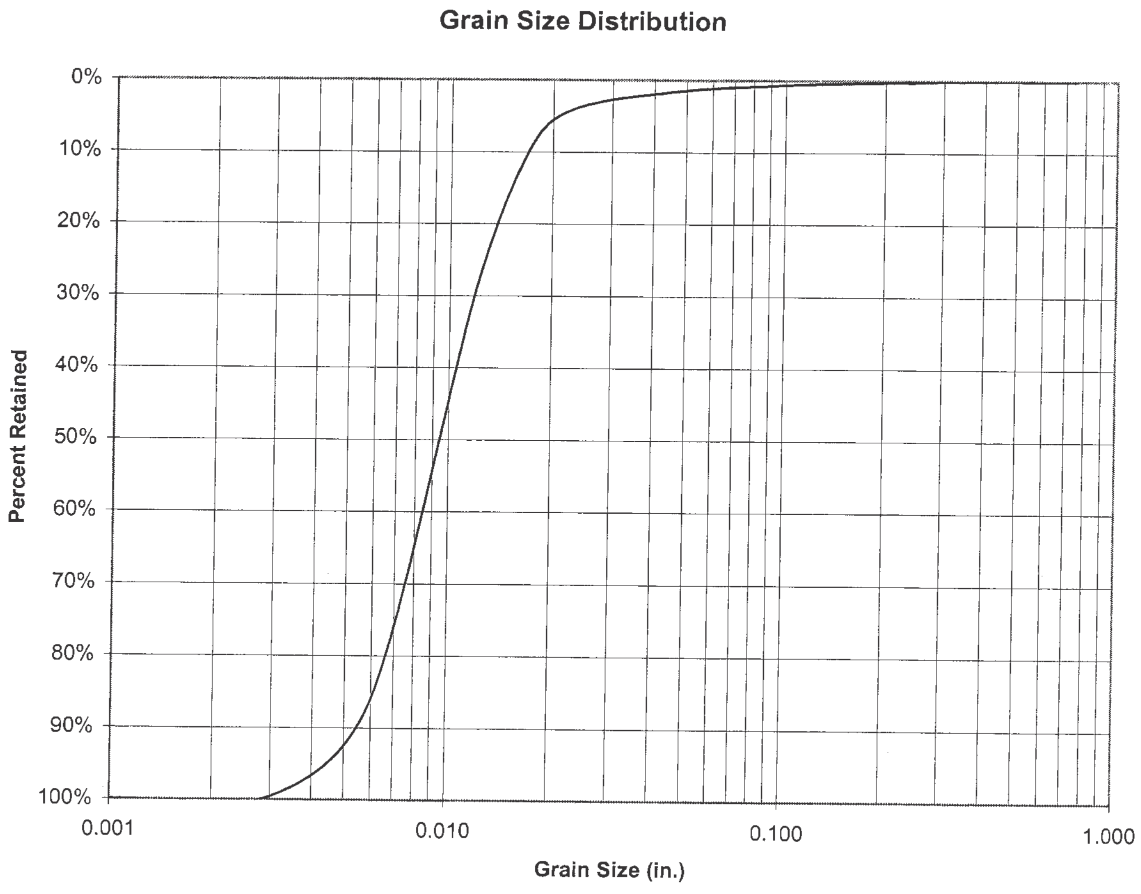
Job	Coupeville:Keystone Hill						
Job #	1205-005A						
Depth	154						
					Calculations		
		Weights	Percentage		0.9	0.7	0.4
Sieve Sizes (Assumes Max.Size of 3/4")	0.750	0	0%		0	0	0
	0.375	176.2	16%		0	0	0
	0.157	283.5	26%		0	0	0
	0.093	345.4	32%		0	0	0
	0.047	387.2	36%		0	0	0.026329
	0.023	438.1	41%		0	0	0
	0.017	504.3	47%		0	0	0
	0.012	634.2	59%		0.00612	0.009896	0
	0.006	976.7	91%		0	0	0
	0.003	1058.6	98%		0	0	0
	0.001	1077.6	100%		0	0	0

Depth	D10	D30	D60
154	0.006	0.010	0.026



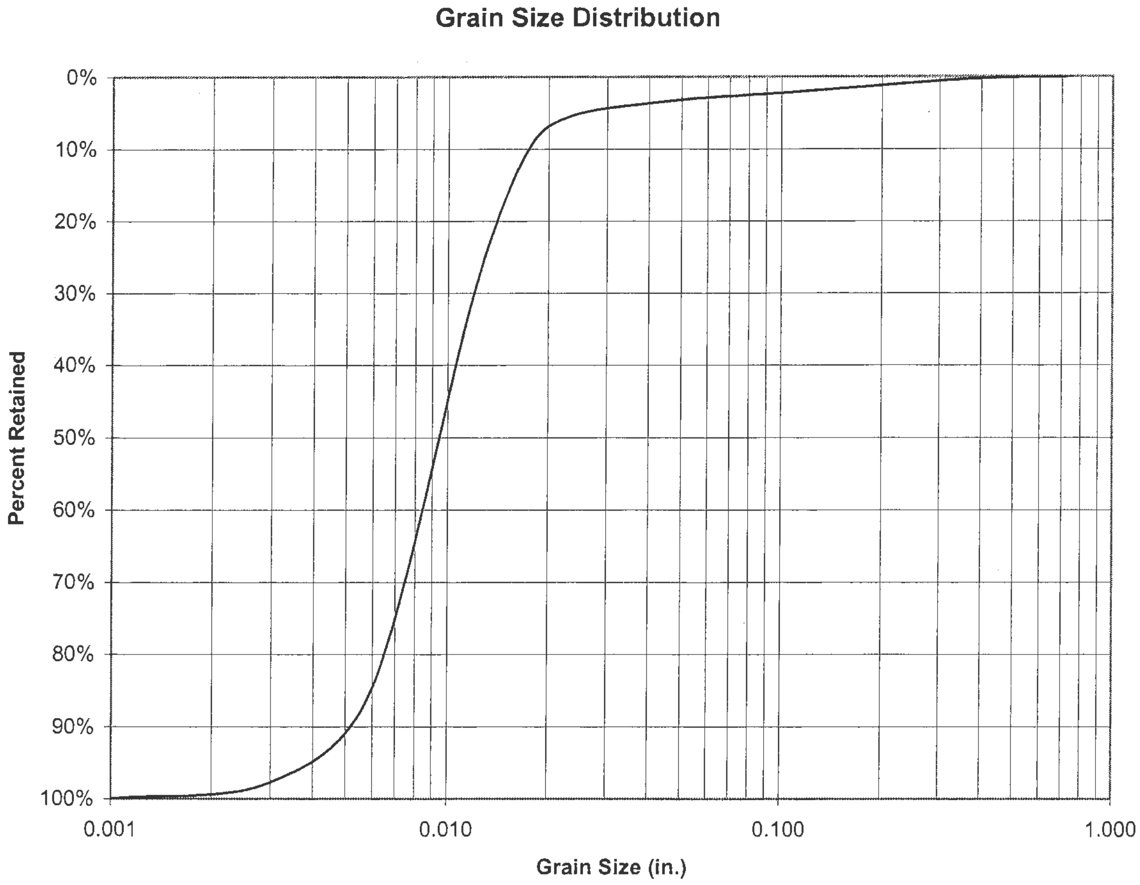
Grain Size Calculations

Job	Coupeville:Keystone Hill							
Job #	1205-005A							
Depth	157							
					Calculations			
		Weights	Percentage		0.9	0.7	0.4	
Sieve Sizes (Assumes Max.Size of 3/4")	0.750	0	0%		0	0	0	
	0.375	0	0%		0	0	0	
	0.157	3	0%		0	0	0	
	0.093	6.1	1%		0	0	0	
	0.047	13.3	2%		0	0	0	
	0.023	34.6	4%		0	0	0	
	0.017	84.9	10%		0	0	0	
	0.012	247.1	29%		0	0.007684	0.010846	
	0.006	731.4	86%		0.005113	0	0	
	0.003	847.2	100%		0	0	0	
	0.001	850.7	100%		0	0	0	
			Depth	D10	D30	D60		
			157	0.005	0.008	0.011		


Grain Size Distribution

Grain Size Calculations

Job	Coupeville:Keystone Hill							
Job #	1205-005A							
Depth	160							
					Calculations			
		Weights	Percentage		0.9	0.7	0.4	
Sieve Sizes (Assumes Max.Size of 3/4")	0.750	0	0%		0	0	0	
	0.375	3.2	0%		0	0	0	
	0.157	16.9	2%		0	0	0	
	0.093	24.5	2%		0	0	0	
	0.047	34.9	3%		0	0	0	
	0.023	57.9	6%		0	0	0	
	0.017	114.9	11%		0	0	0	
	0.012	313	30%		0	0.007609	0.010891	
	0.006	887.9	85%		0.004782	0	0	
	0.003	1024.6	98%		0	0	0	
	0.001	1048.2	100%		0	0	0	
			Depth	D10	D30	D60		
			160	0.005	0.008	0.011		

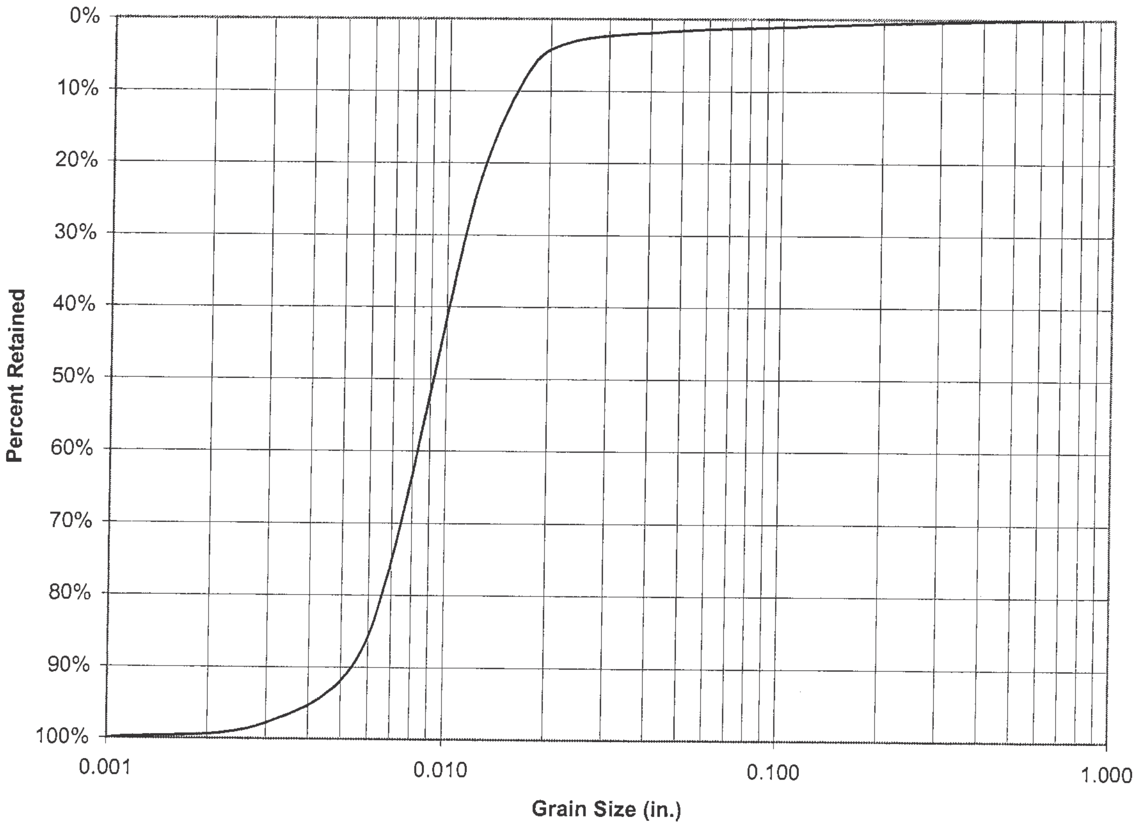


Grain Size Calculations

Job	Coupeville:Keystone Hill						
Job #	1205-005A						
Depth	163						
				Calculations			
		Weights	Percentage		0.9	0.7	0.4
Sieve Sizes (Assumes Max.Size of 3/4")	0.750	0	0%		0	0	0
	0.375	2.4	0%		0	0	0
	0.157	7.8	1%		0	0	0
	0.093	12.4	1%		0	0	0
	0.047	17.9	2%		0	0	0
	0.023	34.4	3%		0	0	0
	0.017	83.5	8%		0	0	0
	0.012	268.5	25%		0	0.007565	0.010536
	0.006	913.6	86%		0.004954	0	0
	0.003	1041.6	98%		0	0	0
	0.001	1064.7	100%		0	0	0

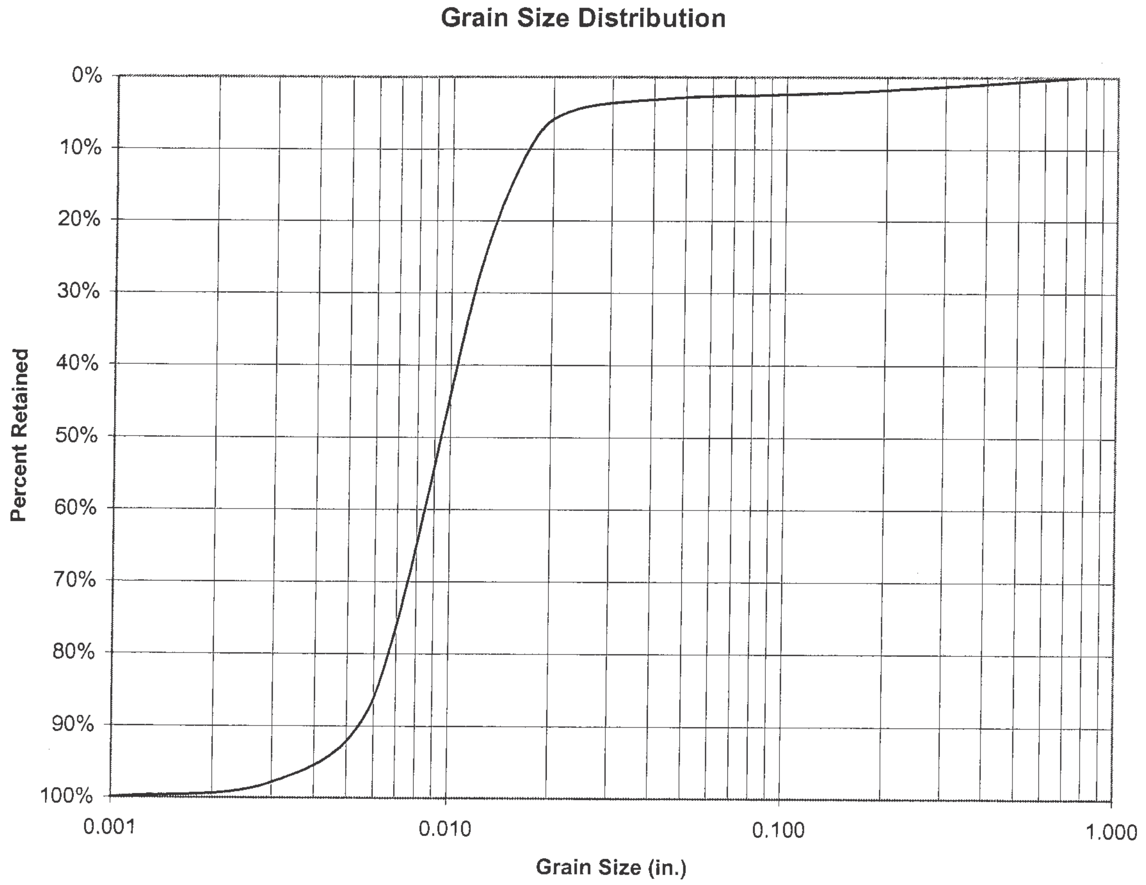
Depth	D10	D30	D60
163	0.005	0.008	0.011

Grain Size Distribution



Grain Size Calculations

Job	Coupeville:Keystone Hill						
Job #	1205-005A						
Depth	167						
					Calculations		
		Weights	Percentage		0.9	0.7	0.4
Sieve Sizes (Assumes Max.Size of 3/4")	0.750	0	0%		0	0	0
	0.375	9.8	1%		0	0	0
	0.157	19.5	2%		0	0	0
	0.093	23.4	2%		0	0	0
	0.047	27.5	3%		0	0	0
	0.023	44.3	5%		0	0	0
	0.017	95.5	10%		0	0	0
	0.012	272.4	28%		0	0.007683	0.010797
	0.006	826.7	86%		0.005025	0	0
	0.003	938.4	98%		0	0	0
	0.001	958.9	100%		0	0	0
			Depth	D10	D30	D60	
			167	0.005	0.008	0.011	

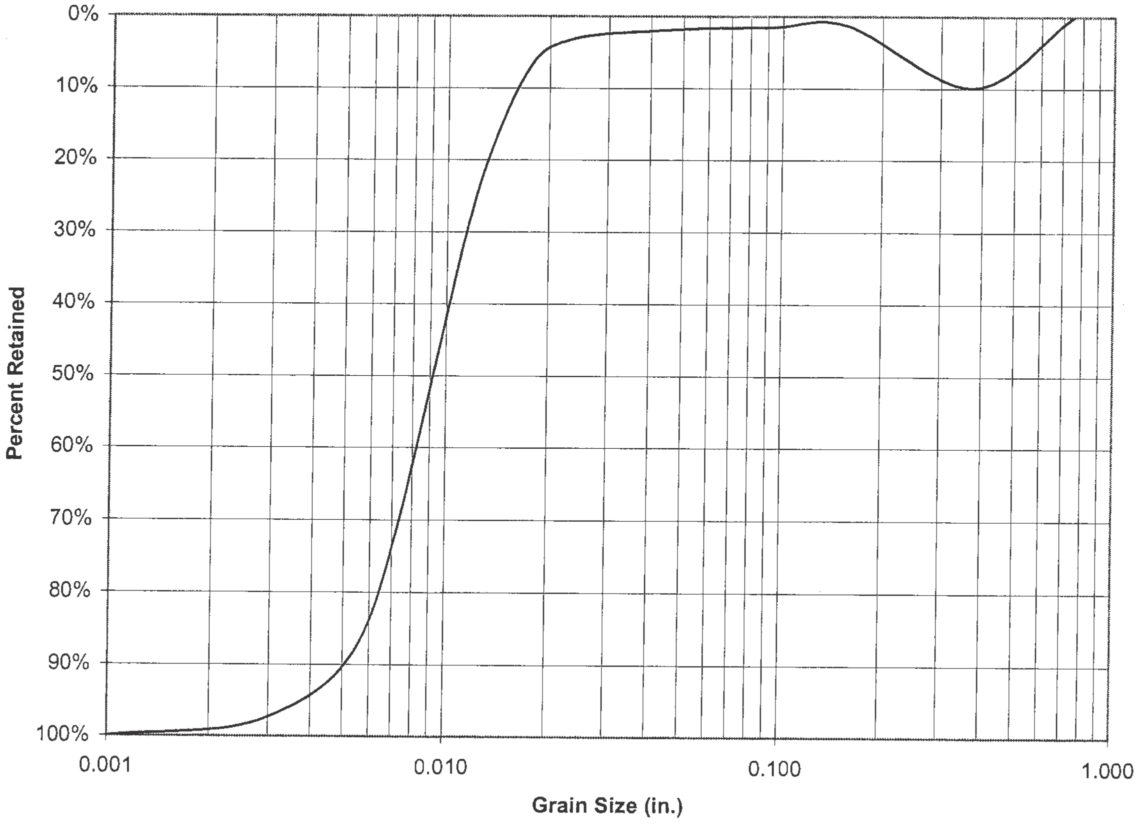


Grain Size Calculations

Job	**Coupeville:Keystone Hill**						
Job #	**1205-005A**						
Depth	**170**						
					Calculations		
		Weights	**Percentage**		0.9	0.7	0.4
Sieve Sizes (Assumes Max.Size of 3/4")	0.750	0	0%		0	0	0
	0.375	94	10%		0	0	0
	0.157	12.1	1%		0	0	0
	0.093	14.3	2%		0	0	0
	0.047	17.4	2%		0	0	0
	0.023	31.2	3%		0	0	0
	0.017	76.3	8%		0	0	0
	0.012	247.6	26%		0	0.007447	0.010565
	0.006	793	84%		0.004642	0	0
	0.003	920	97%		0	0	0
	0.001	945	100%		0	0	0

Depth	**D10**	**D30**	**D60**
170	0.005	0.007	0.011

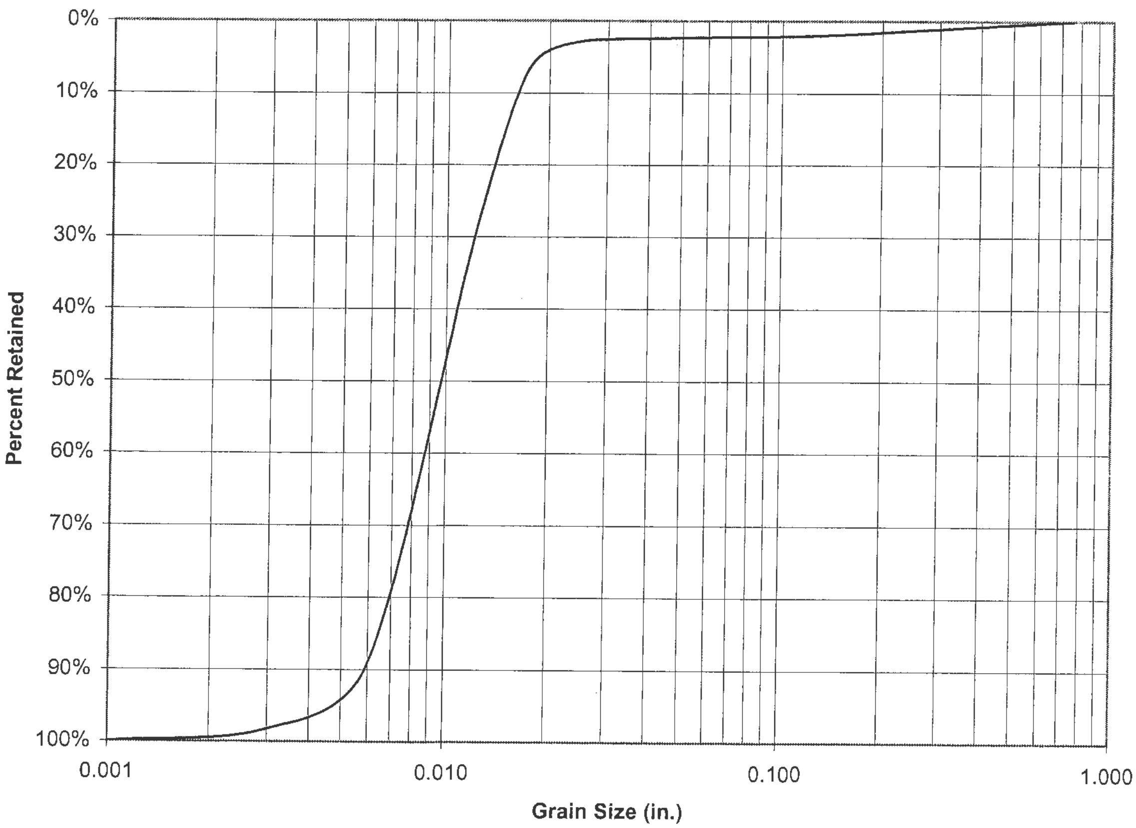
Grain Size Distribution



Grain Size Calculations

Job	**Coupeville:Keystone Hill**							
Job #	**1205-005A**							
Depth	**172**							
					Calculations			
		Weights	**Percentage**		0.9	0.7	0.4	
Sieve Sizes (Assumes Max.Size of 3/4")	0.750	0	0%		0	0	0	
	0.375	7.3	1%		0	0	0	
	0.157	16.6	2%		0	0	0	
	0.093	19.8	2%		0	0	0	
	0.047	21.8	2%		0	0	0	
	0.023	29	3%		0	0	0	
	0.017	69.7	8%		0	0	0	
	0.012	282.3	31%		0	0.007962	0.011042	
	0.006	820	89%		0.005706	0	0	
	0.003	904.5	98%		0	0	0	
	0.001	920.3	100%		0	0	0	
			Depth	**D10**	**D30**	**D60**		
			172	0.006	0.008	0.011		

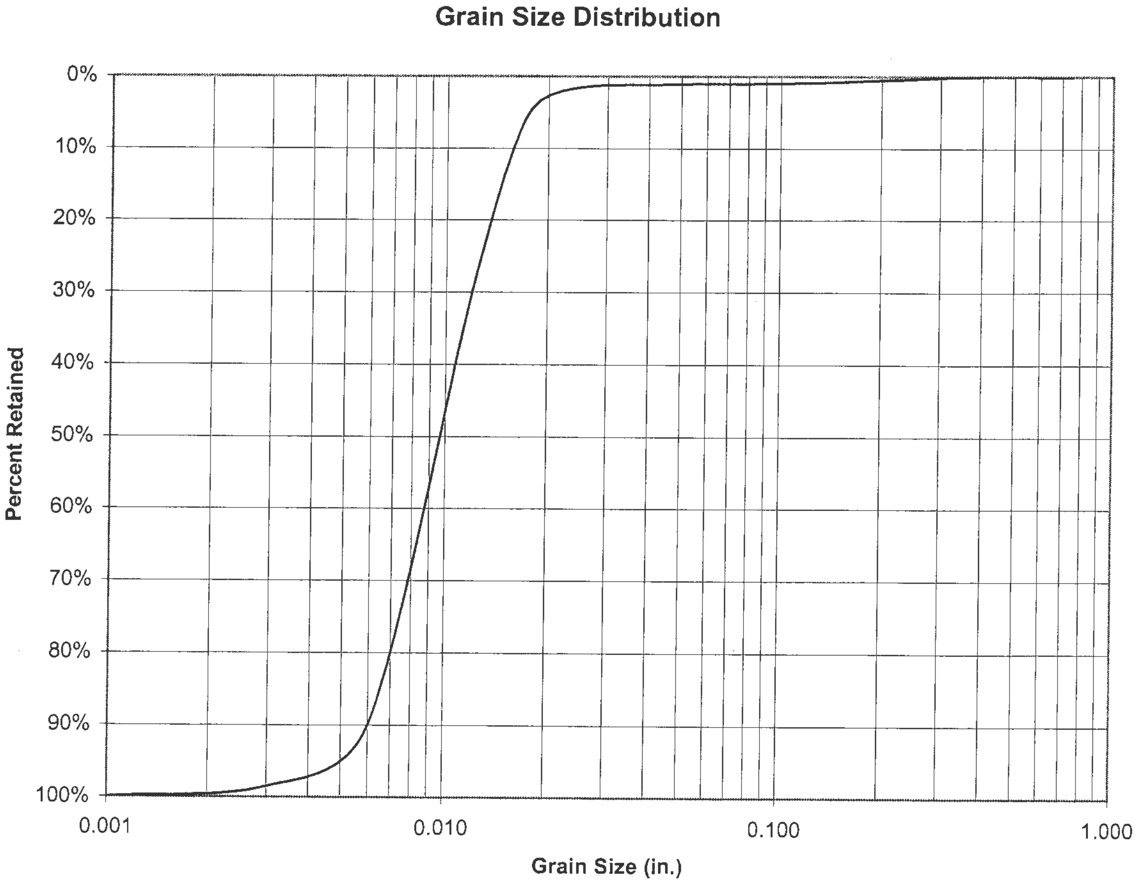
Grain Size Distribution



Grain Size Calculations

Job	Coupeville:Keystone Hill					
Job #	1205-005A					
Depth	176					
				Calculations		
		Weights	Percentage	0.9	0.7	0.4
Sieve Sizes (Assumes Max.Size of 3/4")	0.750	0	0%	0	0	0
	0.375	0	0%	0	0	0
	0.157	5.8	1%	0	0	0
	0.093	7.8	1%	0	0	0
	0.047	8.8	1%	0	0	0
	0.023	14.6	2%	0	0	0
	0.017	49.9	6%	0	0	0
	0.012	235.9	30%	0.006006	0.007992	0.010972
	0.006	716.6	90%	0	0	0
	0.003	784.1	99%	0	0	0
	0.001	795.7	100%	0	0	0

Depth	D10	D30	D60
176	0.006	0.008	0.011



Robinson & Noble, Inc.

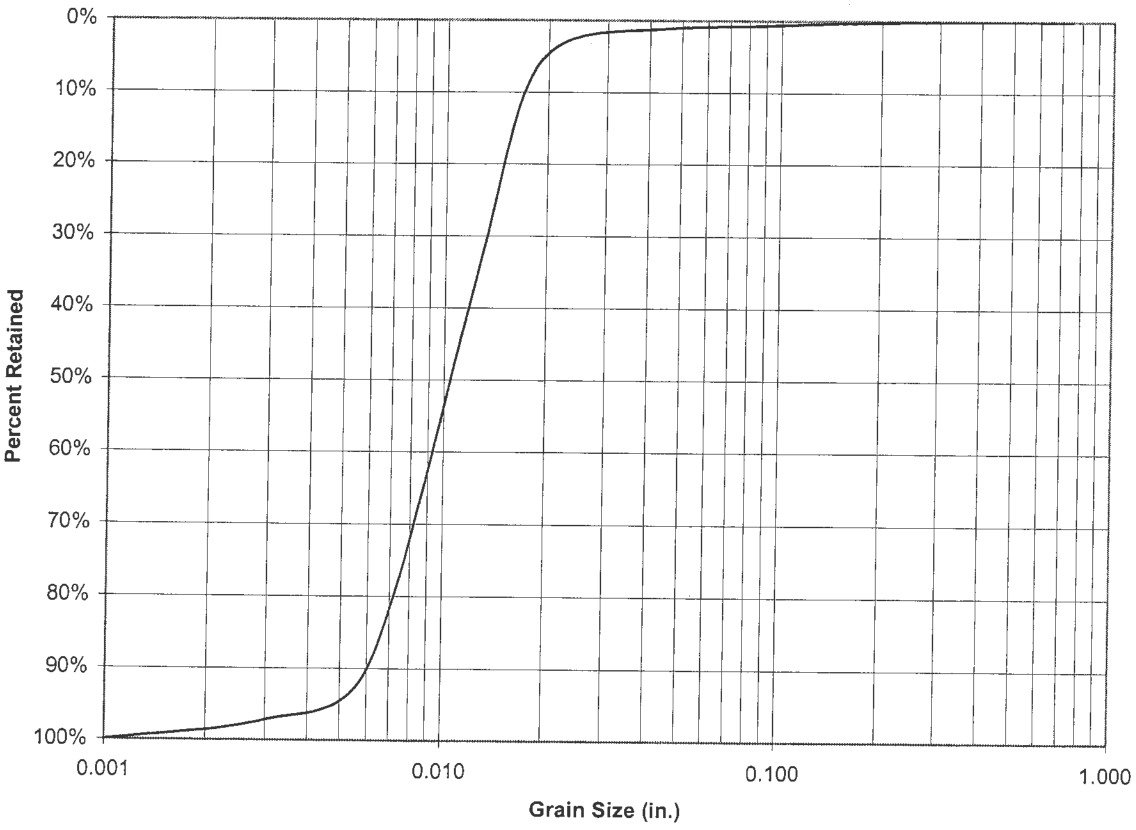
Grain Size Calculations

Job	**Coupeville:Keystone Hill**					
Job #	**1205-005A**					
Depth	**179**					

				Calculations		
		Weights	**Percentage**	0.9	0.7	0.4
Sieve Sizes (Assumes Max.Size of 3/4")	0.750	0	0%	0	0	0
	0.375	0	0%	0	0	0
	0.157	2.6	0%	0	0	0
	0.093	6.3	1%	0	0	0
	0.047	10.1	1%	0	0	0
	0.023	26.7	3%	0	0	0
	0.017	96.4	10%	0	0	0
	0.012	368.5	39%	0.006022	0.008353	0.01185
	0.006	858.4	90%	0	0	0
	0.003	925	97%	0	0	0
	0.001	951.8	100%	0	0	0

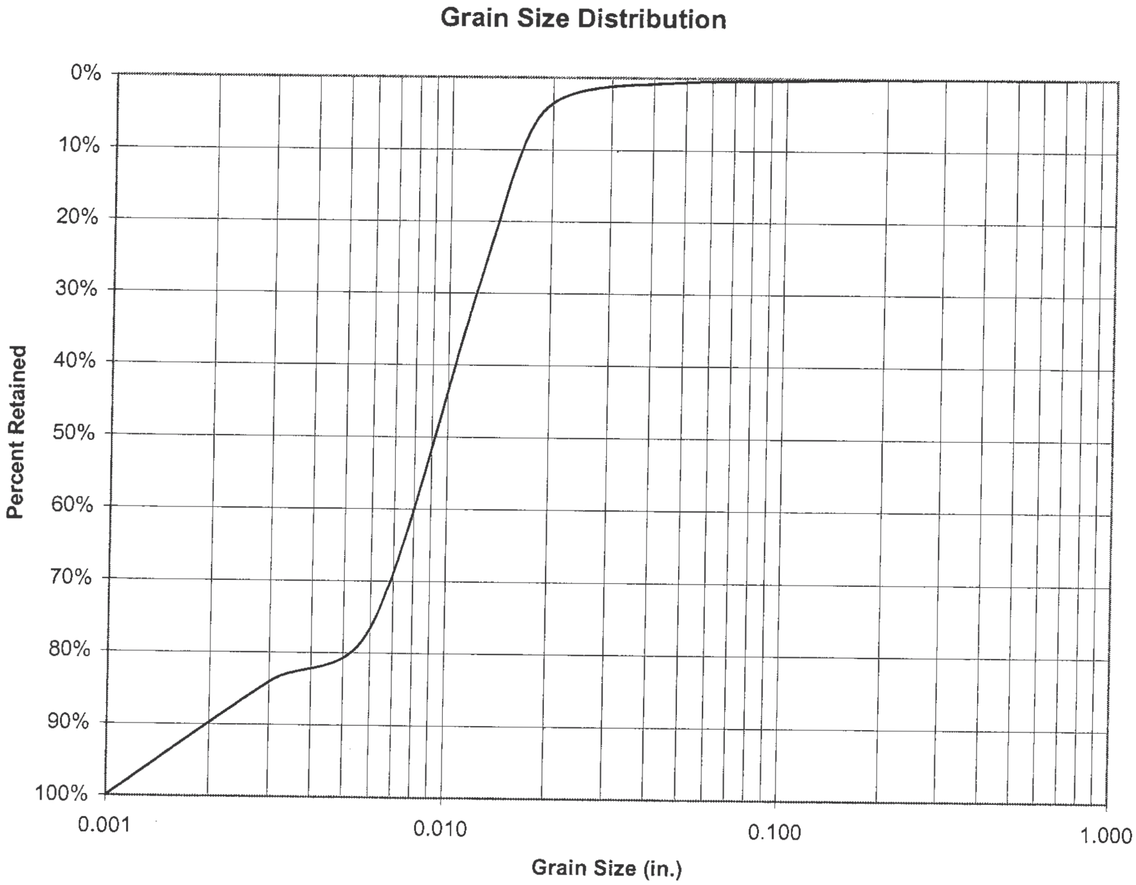
Depth	**D10**	**D30**	**D60**
179	0.006	0.008	0.012

Grain Size Distribution



Grain Size Calculations

Job	**Coupeville:Keystone Hill**						
Job #	**1205-005A**						
Depth	**182**						
					Calculations		
		Weights	**Percentage**		0.9	0.7	0.4
Sieve Sizes (Assumes Max.Size of 3/4")	0.750	0	0%		0	0	0
	0.375	0	0%		0	0	0
	0.157	0.8	0%		0	0	0
	0.093	2.5	0%		0	0	0
	0.047	5.4	1%		0	0	0
	0.023	18.9	2%		0	0	0
	0.017	68.3	8%		0	0	0
	0.012	261.5	30%		0	0.006862	0.01076
	0.006	657.9	77%		0	0	0
	0.003	722.1	84%		0.002259	0	0
	0.001	858.5	100%		0	0	0
			Depth	**D10**	**D30**	**D60**	
			182	0.002	0.007	0.011	



Robinson & Noble, Inc.

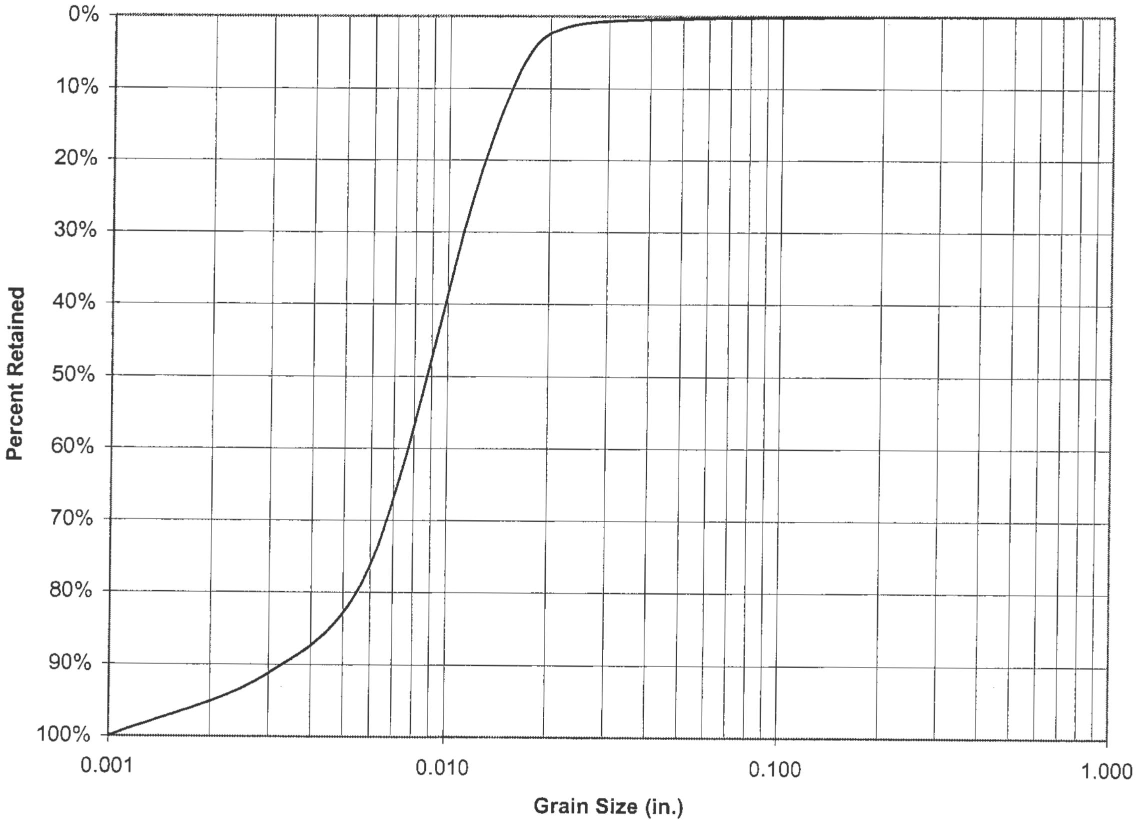
Grain Size Calculations

Job	**Coupeville:Keystone Hill**
Job #	**1205-005A**
Depth	**185**

				Calculations			
		Weights	**Percentage**		0.9	0.7	0.4
Sieve Sizes (Assumes Max.Size of 3/4")	0.750	0	0%		0	0	0
	0.375	0	0%		0	0	0
	0.157	0.7	0%		0	0	0
	0.093	1.6	0%		0	0	0
	0.047	3.2	0%		0	0	0
	0.023	12.3	1%		0	0	0
	0.017	53.4	6%		0	0	0
	0.012	217.6	25%		0	0.006727	0.010216
	0.006	673	76%		0.003251	0	0
	0.003	805.4	91%		0	0	0
	0.001	882.6	100%		0	0	0

Depth	**D10**	**D30**	**D60**
185	0.003	0.007	0.010

Grain Size Distribution



MANUAL WATER LEVEL MEASUREMENTS

Robinson & Noble, Inc.
3011 South Huson Street, Suite A
Tacoma, WA 98409
253-475-7711

PUMPING TEST DATA

STEP TEST

Page: 1 of 3
Date: 3-3-08

Project: Town of Coupeville
Well: Keystone Hill Well 1
Static Water Level: 124.85
Stick Up: 3.3'
Reference Point: Top 1" Tube.
Measurement Device: Sounder

Project Number: 1205-005 A
Weather Conditions:
Measured By: DCD
Contractor: Hokkaido
Pump Type: Sub
Flow Meas. Method: 6 x 4 Orifice

Time	Elapsed Time	Depth to Water	Drawdown	Flow Meas. Reading	Q gpm	Comments
1300	0	124.85	0			
	1	132.00		~145		Dirty Brown
	2	132.30				
	3	132.56				
	4	132.73				
	5	132.90				
	15	133.33				Clearing
	20	133.38				Some VF SAND
1330	30	133.44	8.59		145	Q/S = 16.8
	31	135.65		9.5"	200	
	32	135.87				
	35	136.10				
	40	136.28				
	46	136.34				
	50	136.37				
	55	136.40				Clear some VF SAND
1400	60	136.42	11.57		200	Q/S = 17.2
	61	139.50		16.5"	261	
	62	139.71				
	63	139.85				

Robinson & Noble, Inc.
3011 South Huson Street, Suite A
Tacoma, WA 98409
253-475-7711

PUMPING TEST DATA

STEP TEST

Page: 2 of 3
Date: 3-3-08

Project: Town of Coupeville
Well: Keystone Hill Well 1
Static Water Level: 124.85
Stick Up:
Reference Point:
Measurement Device:
Project Number: 1205-005A
Weather Conditions:
Measured By: DCD
Contractor: Hokkaido
Pump Type:
Flow Meas. Method:

Time	Elapsed Time	Depth to Water	Drawdown	Flow Meas. Reading	Q (gpm)	Comments
1404	64	139.95			261	
	65	140,00				
	71	140.22				
	75	140.27				
	80	140.32				
	85	140.34				
1430	90	140.37	15.52		261	Q/s = 16.8
	91	142.70		22.5"	302	
	92	142.88				
	93	142.98				
	94	143.06				
	95	143.13				
	100	143.27				Some VF Sand
	105	143.33				
	110	143.37				
	116	143.40				
1500	120	143.43	18.58		302	Q/s = 16.25
	121	145.20		27"	332	
	122	145.32				
	123	145.41				

Robinson & Noble, Inc.
3011 South Huson Street, Suite A
Tacoma, WA 98409
253-475-7711

PUMPING TEST DATA

Step Test

Page: 3 of 3
Date: 3-3-08

Project: Town of Coupeville
Well: Keystone Hill Well 1
Static Water Level: 124.85
Stick Up:
Reference Point:
Measurement Device:

Project Number: 1205-005A
Weather Conditions:
Measured By: DCD
Contractor: Hokkaido
Pump Type:
Flow Meas. Method:

Time	Elapsed Time	Depth to Water	Drawdown	Flow Meas. Reading	Q ( )	Comments
1504	124	145.49				
	125	145.52				
	131	145.64				
	135	145.68				
	140	145.72				
	145	145.75				
1530	150	145.79	20.94		332	Q/S = 15.8
		Recovery				
	1	129.00				
	2	128.00				
	5	126.67				
	10	125.86				
	15	125.55				
	20	125.40				
1600	30	125.30				

Robinson & Noble, Inc.
3011 South Huson Street, Suite A
Tacoma, WA 98409
253-475-7711

PUMPING TEST DATA

24 hr. Test

Page: 1 of 2
Date: 3-4-08

Project: Town of Coupeville
Well: Keystone Hill WELL 1
Static Water Level: 125.08
Stick Up: 3.3
Reference Point: TOP of 1"
Measurement Device: Sounder

Project Number: 1205-005A
Weather Conditions:
Measured By: DCD & Hokkaido
Contractor: Hokkaido
Pump Type: Sub
Flow Meas. Method: 6 x 4 Orifice

Time	Elapsed Time	Depth to Water	Drawdown	Flow Meas. Reading	Q (gpm)	Comments
1030	0	125.08	0			
	.5	139.20				
	1	140.10		22.5"	302	
	2	141.12				
	3	141.67				
	4	142.09				Clear
	5	142.37				
	7	142.77				SAND Free
	8	143.20				
	9	143.35				
	10	143.50				
	15	143.67				
	20	143.88				
	26	144.00				
1100	30	144.04				
	40	144.11				
	50	144.15				
1130	60	144.19				
	90	144.28				
1230	120	144.31				

Robinson & Noble, Inc.
3011 South Huson Street, Suite A
Tacoma, WA 98409
253-475-7711

PUMPING TEST DATA

24 hr. TesT

Page: 2 of 2
Date: 3-4 to 5-08

Project: Town of Coupeville
Well: Keystone H-21 Well 1
Static Water Level: 125.08
Stick Up:
Reference Point:
Measurement Device:

Project Number: 1250-005 A
Weather Conditions:
Measured By: DCD - Hokkaido
Contractor: Hokkaido
Pump Type:
Flow Meas. Method:

Time	Elapsed Time	Depth to Water	Drawdown	Flow Meas. Reading	Q (gpm)	Comments
1340	190	144.40				
1400	—	—				7 mins Shutdown
1420	230	144.45		22.5"	302	
1500	270	144.73				
1600	330	144.77				
1700	390	144.82				
1800	450	144.82				
2000	570	144.95				
2200	690	145.00				
2400	810	145.07				
3/5 0200	930	145.11				
0400	1050	145.18				
0700	1230	145.22				clear Sand Free
0900	1350	145.26				Slight H2S
1000	1410	145.22				Temp 51.5 °F
1030	1440	145.20	20.12		302	Q/s = 15
		Recovery				
	1	129.33				
	2	128.45				
	3	127.80				

10 126.46
15 126.18
30 125.94
45 125.84
3/6 1020 1430 125.26

Robinson & Noble, Inc.
3011 South Huson Street, Suite A
Tacoma, WA 98409
253-475-7711

OBSERVATION WELL DATA

Page: 1 of 1
Date: 3-3-08

Project: Town of Coupeville
Well No.: Youderian APR 989 Piezo No.:
Owner: "
Location: ~ 700' South of Keystone Hill Well 1
Measuring Point: TOC 6" - Top 1" coupling Stickup: 1.6'
Static Water Level:
Other Information: 6" Well Reported 168' Deep SWL = 125.5 50gpm

Date	Time	Elapsed Time	DTW	Drawdown	Remarks
3/3	1200		125.55		
3/4	1021		125.86		
	1200		125.97		
3/5	0915		126.30		
	1124	54	126.22		After 54 minutes of Recovery
3/6	1007	1417	125.94		

LABORATORY WATER QUALITY RESULTS

Avocet Environmental Testing
1500 North State Street, Suite 200
Bellingham, WA 98225
(360) 734-9033

AVOCET
ENVIRONMENTAL TESTING

DRINKING WATER INORGANIC CHEMICALS (IOC) REPORT

Date Collected:	03/05/08	System Group Type:	[✓ A] B Private
Water System ID #:	**155509**	**System Name:**	**Town of Coupeville**
Lab/Sample #:	05763404	County:	Island
Sample Location:	Keystone Hill Well	Source Number(s):	Unknown
		Date Received:	03/05/08
Sample Purpose:	New Well	Date Analyzed:	03/06/08
Sample Composition:	Single Source	Date Reported:	03/20/08
Supervisor:	Mark Lorenz	Sample Type:	Pre-treatment
		Sample Collected by:	Jack Robinson
		Phone Number:	(360) 914-1162
Send Report To:	Town of Coupeville P.O. Box 725 Coupeville, WA 98239	Bill To:	Same

DOH#	Analyte	RESULT	Units	SRL	Trigger	MCL	Above MCL	Method	Analyst
				EPA Regulated					
4	Arsenic	**0.009**	mg/L	0.002	0.01	0.01		sm3113B	ML
5	Barium	**0.022**	mg/L	0.1	2	2		sm3113B	ML
6	Cadmium	**<0.0005**	mg/L	0.002	0.005	0.005		sm3113B	ML
7	Chromium	**<0.005**	mg/L	0.01	0.1	0.1		sm3113B	ML
11	Mercury	**<0.0005**	mg/L	0.0005	0.002	0.002		EPA245.1	ML
12	Selenium	**<0.005**	mg/L	0.005	0.05	0.05		sm3113B	ML
110	Beryllium	**<0.002**	mg/L	0.003	0.004	0.004		sm3113B	ML
111	Nickel	**<0.01**	mg/L	0.04	0.1	0.1		sm3113B	ML
112	Antimony	**<0.005**	mg/L	0.005	0.006	0.006		sm3113B	ML
113	Thallium	**<0.001**	mg/L	0.002	0.002	0.002		EPA200.9	ML
116	Cyanide	**<0.05**	mg/L	0.05	0.2	0.2		sm4500CN-F	JK
19	Fluoride	**0.4**	mg/L	0.2	2	4		EPA300.0	ML
114	Nitrite-N	**<0.05**	mg/L	0.5	0.5	1		EPA300.0	ML
20	Nitrate-N	**1.0**	mg/L	0.5	5	10		EPA300.0	ML
161	Total Nitrate/Nitrite	**1.0**	mg/L	0.5	5	10		EPA300.0	ML
				EPA Regulated (Secondary)					
8	Iron	**0.022**	mg/L	0.1	0.3	0.3		sm3113B	ML
10	Manganese	**0.037**	mg/L	0.01	0.05	0.05		sm3113B	ML
13	Silver	**<0.002**	mg/L	0.01	0.05	0.05		sm3113B	ML
21	Chloride	**11**	mg/L	20	250	250		EPA300.0	ML
22	Sulfate	**24**	mg/L	10	250	250		EPA300.0	ML
24	Zinc	**<0.025**	mg/L	0.2	5	5		sm3111B	ML
				State Regulated					
14	Sodium	**12**	mg/L	5	-----	-----		sm3111B	ML
15	Hardness	**210**	mg/L	10	-----	-----		sm2340C	DC
16	Conductivity	**450**	μmhos	10	700	700		sm2510B	JK
17	Turbidity	**0.3**	NTU	0.1	1	1		EPA180.1	JK
18	Color	**<5**	color units	5	15	15		sm2120B	JK
26	TDS	**NA**	mg/L	150	500	500		sm2540C	
				State Unregulated					
9	Lead	**<0.001**	mg/L	0.002	0.015	0.015		sm3113B	ML
23	Copper	**0.009**	mg/L	0.2	1.3	1.3		sm3113B	ML

Comments:

Trigger Level = DOH drinking water response level. Systems w/results exceeding this level must contact regional DOH for further information.

MCL (Maximum Contaminant Level) = If the contaminant amount exceeds the MCL, immediately contact your regional DOH office.

< = Indicates the compound was not detected in sample; also, Method Detection Level (lab MDL) is lower than the SRL.

SRL (State Reporting Levels) = minimum reporting levels required by Washington DOH

TDS = Total Dissolved Solids NTU = Nephelometric Turbidity Units

NA = Not Applicable ND = Not Detected Copies: A - Client

Anatek Labs, Inc.

1282 Alturas Drive • Moscow, ID 83843 • (208) 883-2839 • Fax (208) 882-9246 • email moscow@anateklabs.com
504 E Sprague Ste. D • Spokane WA 99202 • (509) 838-3999 • Fax (509) 838-4433 • email spokane@anateklabs.com

Volatile Organic Chemicals (VOC's) Analysis Report
EPA Test Method - EPA 524.2

System ID#: 155509
System Name: CITY OF COUPEVILLE
Lab/Sample Number: 125 14337
Collect Date: 3/5/2008
DOH Source #:
Multiple Source Nos:
Sample Type: B
Sample Purpose: B
Date Received: 3/12/2008
Date Reported: 3/24/2008
Supervisor: JWC
Date Analyzed: 3/17/2008
County: ISLAND
Sample Location: 63405 / KEYSTONE HILL WELL
Report To:
Address: 1500 N. STATE ST. STE. 200
City, State, ZIP BELLINGHAM, WA 98225
Phone Number: 360-734-9033

EPA Regulated

DOH #	Analytes	Results	Units	SRL	Trigger	MCL	Method	Analyst
45	Vinyl Chloride	ND	ug/L	0.5	0.5	2	EPA 524.2	TGT
46	1,1-Dichloroethylene	ND	ug/L	0.5	0.5	7	EPA 524.2	TGT
47	1,1,1-Trichloroethane	ND	ug/L	0.5	0.5	200	EPA 524.2	TGT
48	Carbon Tetrachloride	ND	ug/L	0.5	0.5	5	EPA 524.2	TGT
49	Benzene	ND	ug/L	0.5	0.5	5	EPA 524.2	TGT
50	1,2-Dichloroethane	ND	ug/L	0.5	0.5	5	EPA 524.2	TGT
51	Trichloroethylene	ND	ug/L	0.5	0.5	5	EPA 524.2	TGT
52	1,4-Dichlorobenzene	ND	ug/L	0.5	0.5	75	EPA 524.2	TGT
56	Dichloromethane	ND	ug/L	0.5	0.5	5	EPA 524.2	TGT
57	trans-1,2-Dichloroethylene	ND	ug/L	0.5	0.5	100	EPA 524.2	TGT
60	cis-1,2-dichloroethylene	ND	ug/L	0.5	0.5	70	EPA 524.2	TGT
63	1,2-Dichloropropane	ND	ug/L	0.5	0.5	5	EPA 524.2	TGT
66	Toluene	ND	ug/L	0.5	0.5	1000	EPA 524.2	TGT
67	1,1,2-Trichloroethane	ND	ug/L	0.5	0.5	5	EPA 524.2	TGT
68	Tetrachloroethylene	ND	ug/L	0.5	0.5	5	EPA 524.2	TGT
71	Chlorobenzene	ND	ug/L	0.5	0.5	100	EPA 524.2	TGT
73	Ethylbenzene	ND	ug/L	0.5	0.5	700	EPA 524.2	TGT
76	Styrene	ND	ug/L	0.5	0.5	100	EPA 524.2	TGT
84	1,2-Dichlorobenzene	ND	ug/L	0.5	0.5	600	EPA 524.2	TGT
95	1,2,4-Trichlorobenzene	ND	ug/L	0.5	0.5	70	EPA 524.2	TGT
160	Total Xylene	ND	ug/L	0.5	0.5	10000	EPA 524.2	TGT
74	m/p-Xylene (MCL for Total)	ND	ug/L	0.5	0.5		EPA 524.2	TGT
75	o-Xylene (MCL for Total)	ND	ug/L	0.5	0.5		EPA 524.2	TGT

EPA Unregulated

DOH #	Analytes	Results	Units	SRL	Trigger	MCL	Method	Analyst
27	Chloroform	ND	ug/L	0.5	0.5		EPA 524.2	TGT
28	Bromodichloromethane	ND	ug/L	0.5	0.5		EPA 524.2	TGT
29	Chlorodibromomethane	ND	ug/L	0.5	0.5		EPA 524.2	TGT
30	Bromoform	ND	ug/L	0.5	0.5		EPA 524.2	TGT
53	Chloromethane	ND	ug/L	0.5	0.5		EPA 524.2	TGT
54	Bromomethane	ND	ug/L	0.5	0.5		EPA 524.2	TGT
55	Chloroethane	ND	ug/L	0.5	0.5		EPA 524.2	TGT

58	1,1-Dichloroethane	ND	ug/L	0.5	0.5		EPA 524.2	TGT
59	2,2-Dichloropropane	ND	ug/L	0.5	0.5		EPA 524.2	TGT
62	1,1-Dichloropropylene	ND	ug/L	0.5	0.5		EPA 524.2	TGT
64	Dibromomethane	ND	ug/L	0.5	0.5		EPA 524.2	TGT
70	1,3-Dichloropropane	ND	ug/L	0.5	0.5		EPA 524.2	TGT
72	1,1,1,2-Tetrachloroethane	ND	ug/L	0.5	0.5		EPA 524.2	TGT
78	Bromobenzene	ND	ug/L	0.5	0.5		EPA 524.2	TGT
79	1,2,3-Trichloropropane	ND	ug/L	0.5	0.5		EPA 524.2	TGT
80	1,1,2,2-Tetrachloroethane	ND	ug/L	0.5	0.5		EPA 524.2	TGT
81	o-Chlorotoluene	ND	ug/L	0.5	0.5		EPA 524.2	TGT
82	p-Chlorotoluene	ND	ug/L	0.5	0.5		EPA 524.2	TGT
83	m-Dichlorobenzene	ND	ug/L	0.5	0.5		EPA 524.2	TGT
154	1,3-Dichloropropene	ND	ug/L	0.5	0.5		EPA 524.2	TGT

State Unregulated

DOH #	Analytes	Results	Units	SRL	Trigger	MCL	Method	Analyst
65	cis-1,3-Dichloropropene	ND	ug/L	0.5	0.5		EPA 524.2	TGT
69	trans-1,3-Dichloropropene	ND	ug/L	0.5	0.5		EPA 524.2	TGT
85	Flourotrichloromethane	ND	ug/L	0.5	0.5		EPA 524.2	TGT
86	Bromochloromethane	ND	ug/L	0.5	0.5		EPA 524.2	TGT
87	Isopropylbenzene	ND	ug/L	0.5	0.5		EPA 524.2	TGT
88	n-Propylbenzene	ND	ug/L	0.5	0.5		EPA 524.2	TGT
89	1,3,5-Trimethylbenzene	ND	ug/L	0.5	0.5		EPA 524.2	TGT
90	tert-Butylbenzene	ND	ug/L	0.5	0.5		EPA 524.2	TGT
91	1,2,4-Trimethylbenzene	ND	ug/L	0.5	0.5		EPA 524.2	TGT
92	sec-Butylbenzene	ND	ug/L	0.5	0.5		EPA 524.2	TGT
93	p-Isopropyltoluene	ND	ug/L	0.5	0.5		EPA 524.2	TGT
94	n-Butylbenzene	ND	ug/L	0.5	0.5		EPA 524.2	TGT
96	Naphthalene	ND	ug/L	0.5	0.5		EPA 524.2	TGT
97	Hexachlorobutadiene	ND	ug/L	0.5	0.5		EPA 524.2	TGT
98	1,2,3-Trichlorobenzene	ND	ug/L	0.5	0.5		EPA 524.2	TGT
102	EDB (Scan Confirm 504.1)	ND	ug/L	0.5	0.5		EPA 524.2	TGT
103	DBCP(Scan Confirm 504.1)	ND	ug/L	0.5	0.5		EPA 524.2	TGT
162	Dichlorodifluoromethane	ND	ug/L	0.5	0.5		EPA 524.2	TGT

ND = Not Detected within the sensitivity of the instrument
Numerical Entry = Detection at level indicated
SRL - Minimum reporting level for Washington DOH
MCL - EPA maximum contaminant level
Trigger - Washington DOH response level. If results exceed this level, contact the DOH

Lab Supervisor: ______________________ **Date:** 3/24/2008

Anatek Labs, Inc.
1282 Alturas Drive • Moscow, ID 83843 • (208) 883-2839 • Fax (208) 882-9246 • email moscow@anateklabs.com
504 E Sprague Ste. D • Spokane WA 99202 • (509) 838-3999 • Fax (509) 838-4433 • email spokane@anateklabs.com

Synthetic Organic Chemicals (SOC's) Analysis Report
EPA Test Method - EPA 525.2, 505

System ID#: 155509
System Name: CITY OF COUPEVILLE
Lab/Sample Number: 125 14338
Collect Date: 3/5/2008
DOH Source #:
Multiple Source Nos:
Sample Type: B
Sample Purpose: B
Date Received: 3/12/2008
Date Reported: 3/24/2008
Supervisor: JWC

County: ISLAND
Sample Location: 63405 / KEYSTONE HILL WELL
Report To:
Address: 1500 N. STATE ST. STE. 200
City, State, ZIP BELLINGHAM, WA 98225
Phone Number: 360-734-9033

EPA Regulated

DOH #	Analyte	Result	Units	SRL	Trigger	MCL	Method	Analysis Date	Analyst	Qualifier
33	Endrin	ND	ug/L	0.02	0.02	2	EPA 505	3/18/2008	SAT	
34	Lindane (HCH gamma)	ND	ug/L	0.04	0.04	0.2	EPA 505	3/18/2008	SAT	
35	Methoxychlor	ND	ug/L	0.2	0.2	40	EPA 505	3/18/2008	SAT	
36	Toxaphene	ND	ug/L	2	2	3	EPA 505	3/18/2008	SAT	
117	Alachlor	ND	ug/L	0.4	0.4	2	EPA 525.2	3/14/2008	EMP	
119	Atrazine	ND	ug/L	0.2	0.2	3	EPA 525.2	3/14/2008	EMP	
120	Benzo(a)pyrene	ND	ug/L	0.04	0.04	0.2	EPA 525.2	3/14/2008	EMP	
122	Chlordane (Total)	ND	ug/L	0.4	0.4	2	EPA 505	3/18/2008	SAT	
124	di(ethylhexyl)adipate	ND	ug/L	1.3	1.3	400	EPA 525.2	3/14/2008	EMP	
125	di(ethylhexyl)phthalate	2.91	ug/L	1.3	1.3	6	EPA 525.2	3/14/2008	EMP	
126	Heptachlor	ND	ug/L	0.08	0.08	0.4	EPA 505	3/18/2008	SAT	
127	Heptachlor Epoxide	ND	ug/L	0.04	0.04	0.2	EPA 505	3/18/2008	SAT	
128	Hexachlorobenzene	ND	ug/L	0.2	0.2	1	EPA 525.2	3/14/2008	EMP	
129	Hexachlorocyclopentadiene	ND	ug/L	0.2	0.2	50	EPA 525.2	3/14/2008	EMP	
133	Simazine	ND	ug/L	0.15	0.15	4	EPA 525.2	3/14/2008	EMP	
153	PCB (As Total Arochlors)	ND	µg/L	0.2	0.2	0.5	EPA 505	3/18/2008	SAT	

EPA Unregulated

DOH #	Analyte	Result	Units	SRL	Trigger	MCL	Method	Analysis Date	Analyst	Qualifier
118	Aldrin	ND	ug/L	0.2	0.2		EPA 505	3/18/2008	SAT	
121	Butachlor	ND	ug/L	0.4	0.4		EPA 525.2	3/14/2008	EMP	
123	Dieldrin	ND	ug/L	0.2	0.2		EPA 505	3/18/2008	SAT	
130	Metolachlor	ND	ug/L	1	1		EPA 525.2	3/14/2008	EMP	
131	Metribuzin	ND	ug/L	0.2	0.2		EPA 525.2	3/14/2008	EMP	
132	Propachlor	ND	ug/L	0.2	0.2		EPA 525.2	3/14/2008	EMP	
254	Fluorene	ND	ug/L	0.2	0.2		EPA 525.2	3/14/2008	EMP	
173	Aroclor 1221	ND	ug/L	0.5	0.5		EPA 505	3/18/2008	SAT	
174	Aroclor 1232	ND	ug/L	0.1	0.5		EPA 505	3/18/2008	SAT	
175	Aroclor 1242	ND	ug/L	0.1	0.3		EPA 505	3/18/2008	SAT	
176	Aroclor 1248	ND	ug/L	0.1	0.1		EPA 505	3/18/2008	SAT	
177	Aroclor 1254	ND	ug/L	0.1	0.1		EPA 505	3/18/2008	SAT	
178	Aroclor 1260	ND	ug/L	0.1	0.2		EPA 505	3/18/2008	SAT	
180	Aroclor 1016	ND	ug/L	0.2	0.2		EPA 505	3/18/2008	SAT	

State Unregulated

DOH #	Analyte	Result	Units	SRL	Trigger	MCL	Method	Analysis Date	Analyst	Qualifier
179	Bromacil	ND	ug/L	0.2	0.2		EPA 525.2	3/14/2008	EMP	
183	Prometon	ND	ug/L	0.2	0.2		EPA 525.2	3/14/2008	EMP	
190	Terbacil	ND	ug/L	0.2	0.2		EPA 525.2	3/14/2008	EMP	
202	Diazinon	ND	ug/L	0.2	0.2		EPA 525.2	3/14/2008	EMP	
208	EPTC	ND	ug/L	0.3	0.3		EPA 525.2	3/14/2008	EMP	
232	4,4'-DDD	ND	ug/L	0.1	0.1		EPA 505	3/18/2008	SAT	
233	4,4'-DDE	ND	ug/L	0.1	0.1		EPA 505	3/18/2008	SAT	
234	4,4'-DDT	ND	ug/L	0.1	0.1		EPA 505	3/18/2008	SAT	
236	Cyanizine	ND	ug/L	0.2	0.2		EPA 525.2	3/14/2008	EMP	
239	Malathion	ND	ug/L	0.2	0.2		EPA 525.2	3/14/2008	EMP	
243	Trifluralin	ND	ug/L	0.2	0.2		EPA 525.2	3/14/2008	EMP	
244	Acenaphthylene	ND	ug/L	0.2	0.2		EPA 525.2	3/14/2008	EMP	
245	Acenaphthene	ND	ug/L	0.2	0.2		EPA 525.2	3/14/2008	EMP	
246	Anthracene	ND	ug/L	0.2	0.2		EPA 525.2	3/14/2008	EMP	
247	Benzo(a)anthracene	ND	ug/L	0.2	0.2		EPA 525.2	3/14/2008	EMP	
248	Benzo(b)fluoranthene	ND	ug/L	0.2	0.2		EPA 525.2	3/14/2008	EMP	
249	Benzo(g,h,i)perylene	ND	ug/L	0.2	0.2		EPA 525.2	3/14/2008	EMP	
250	Benzo(k)fluoranthene	ND	ug/L	0.2	0.2		EPA 525.2	3/14/2008	EMP	
251	Chrysene	ND	ug/L	0.2	0.2		EPA 525.2	3/14/2008	EMP	
252	Dibenz(a,h)anthracene	ND	ug/L	0.2	0.2		EPA 525.2	3/14/2008	EMP	
253	Fluoranthene	ND	ug/L	0.2	0.2		EPA 525.2	3/14/2008	EMP	
255	Indeno(1,2,3-cd)pyrene	ND	ug/L	0.2	0.2		EPA 525.2	3/14/2008	EMP	
256	Phenanthrene	ND	ug/L	0.2	0.2		EPA 525.2	3/14/2008	EMP	
257	Pyrene	ND	ug/L	0.2	0.2		EPA 525.2	3/14/2008	EMP	
258	Butylbenzylphthalate	ND	ug/L	0.4	0.4		EPA 525.2	3/14/2008	EMP	
259	Di-n-butylphthalate	ND	ug/L	0.4	0.4		EPA 525.2	3/14/2008	EMP	
260	Diethylphthalate	ND	ug/L	0.4	0.4		EPA 525.2	3/14/2008	EMP	
261	Dimethylphthalate	ND	ug/L	0.4	0.4		EPA 525.2	3/14/2008	EMP	

ND = Not Detected within the sensitivity of the instrument
Numerical Entry = Detection at level indicated
SRL - Minimum reporting level for Washington DOH
MCL - EPA maximum contaminant level
Trigger - Washington DOH response level. If results exceed this level, contact the DOH

Lab Supervisor: ______________________ **Date:** 3/24/2008

Anatek Labs, Inc.

1282 Alturas Drive • Moscow, ID 83843 • (208) 883-2839 • Fax (208) 882-9246 • email moscow@anateklabs.com
504 E Sprague Ste. D • Spokane WA 99202 • (509) 838-3999 • Fax (509) 838-4433 • email spokane@anateklabs.com

Synthetic Organic Chemicals (SOC's) Analysis Report
EPA Test Method - EPA 515.3

System ID#: 155509
System Name: CITY OF COUPEVILLE
Lab/Sample Number: 125 14338
Collect Date: 3/5/2008
DOH Source #:
Multiple Source Nos:
Sample Type: B
Sample Purpose: B
Date Received: 3/12/2008
Date Reported: 3/24/2008
Supervisor: JWC
Date Analyzed: 3/15/2008
County: ISLAND
Sample Location: 63405 / KEYSTONE HILL WELL
Report To:
Address: 1500 N. STATE ST. STE. 200
City, State, ZIP BELLINGHAM, WA 98225
Phone Number: 360-734-9033

EPA Regulated

DOH #	Analytes	Result	Units	SRL	Trigger	MCL	Method	Analyst
37	2,4-D	ND	ug/L	0.2	0.2	70	EPA 515.3	SAT
38	2,4,5-TP (Silvex)	ND	ug/L	0.4	0.4	50	EPA 515.3	SAT
134	Pentachlorophenol	ND	ug/L	0.08	0.08	1	EPA 515.3	SAT
137	Dalapon	ND	ug/L	2.0	2.0	200	EPA 515.3	SAT
139	Dinoseb	ND	ug/L	0.4	0.4	7	EPA 515.3	SAT
140	Picloram	ND	ug/L	0.2	0.2	500	EPA 515.3	SAT

EPA Unregulated

DOH #	Analytes	Result	Units	SRL	Trigger	MCL	Method	Analyst
138	Dicamba	ND	ug/L	0.2	0.2		EPA 515.3	SAT

State Unregulated

DOH #	Analytes	Result	Units	SRL	Trigger	MCL	Method	Analyst
135	2,4-DB	ND	ug/L	1.0	1.0		EPA 515.3	SAT
136	2,4,5-T	ND	ug/L	0.4	0.4		EPA 515.3	SAT
220	Bentazon	ND	ug/L	0.5	0.5		EPA 515.3	SAT
221	Dichloroprop	ND	ug/L	0.5	0.5		EPA 515.3	SAT
223	Acifluorofen	ND	ug/L	2.0	2.0		EPA 515.3	SAT
225	Dacthal (DCPA Acid Metabolites (A))	ND	ug/L	0.1	0.1		EPA 515.3	SAT
226	3,5-Dichlorobenzoic Acid	ND	ug/L	0.5	0.5		EPA 515.3	SAT

Other

DOH #	Analytes	Result	Units	SRL	Trigger	MCL	Method	Analyst
224	Chloramben	ND	ug/L	0.2			EPA 515.3	SAT
228	4-Nitrophenol	ND	ug/L	0.2			EPA 515.3	SAT

Notes:
ND = Not Detected within the sensitivity of the instrument
Numerical Entry = Detection at level indicated
SRL - Minimum reporting level for Washington DOH
MCL - EPA maximum contaminant level
Trigger - Washington DOH response level. If results exceed this level, contact the DOH

Lab Supervisor: ____________________ **Date:** 3/24/2008

Anatek Labs, Inc.

1282 Alturas Drive • Moscow, ID 83843 • (208) 883-2839 • Fax (208) 882-9246 • email moscow@anateklabs.com
504 E Sprague Ste. D • Spokane WA 99202 • (509) 838-3999 • Fax (509) 838-4433 • email spokane@anateklabs.com

Synthetic Organic Chemicals (SOC's) Analysis Report
EPA Test Method - EPA 531.1

System ID#: 155509
System Name: CITY OF COUPEVILLE
Lab/Sample Number: 125 14338
Collect Date: 3/5/2008
DOH Source #:
Multiple Source Nos:
Sample Type: B
Sample Purpose: B
Date Received: 3/12/2008
Date Reported: 3/24/2008
Supervisor: JWC
Date Analyzed: 3/21/2008
County: ISLAND
Sample Location: 63405 / KEYSTONE HILL WELL
Report To:
Address: 1500 N. STATE ST. STE. 200
City, State, ZIP: BELLINGHAM, WA 98225
Phone Number: 360-734-9033

EPA Regulated

DOH #	Analytes	Result	Units	SRL	Trigger	MCL	Method	Analyst
146	Carbofuran	ND	ug/L	2.0	2.0	40	EPA 531.1	JWC
148	Oxamyl	ND	ug/L	4.0	4.0	200	EPA 531.1	JWC

EPA Unregulated

DOH #	Analytes	Result	Units	SRL	Trigger	MCL	Method	Analyst
141	3-Hydroxycarbofuran	ND	ug/L	2.0	2.0		EPA 531.1	JWC
142	Aldicarb	ND	ug/L	1.0	1.0		EPA 531.1	JWC
143	Aldicarb Sulfone	ND	ug/L	0.7	0.7		EPA 531.1	JWC
144	Aldicarb Sulfoxide	ND	ug/L	1.8	1.8		EPA 531.1	JWC
145	Carbaryl	ND	ug/L	2.0	2.0		EPA 531.1	JWC
147	Methomyl	ND	ug/L	1.0	4.0		EPA 531.1	JWC

Other

DOH #	Analytes	Result	Units	SRL	Trigger	MCL	Method	Analyst
326	Baygon	ND	ug/L	1.0			EPA 531.1	JWC
327	Methiocarb	ND	ug/L	4.0			EPA 531.1	JWC

Notes:
ND = Not Detected within the sensitivity of the instrument
Numerical Entry = Detection at level indicated
SRL - Minimum reporting level for Washington DOH
MCL - EPA maximum contaminant level
Trigger - Washington DOH response level. If results exceed this level, contact the DOH

Lab Supervisor:

Date: 3/24/2008

Volatile Organic Chemicals (VOC's) Analysis Report
EPA Test Method - EPA 524.2

System ID#: 155509
System Name: CITY OF COUPEVILLE
Lab/Sample Number: 125 14339
Collect Date: 3/5/2008
DOH Source #:
Multiple Source Nos:
Sample Type:
Sample Purpose:
Date Received: 3/12/2008
Date Reported: 3/24/2008
Supervisor: JWC
Date Analyzed: 3/17/2008
County: ISLAND
Sample Location: Trip Blank
Report To:
Address: 1500 N. STATE ST. STE. 200
City, State, ZIP BELLINGHAM, WA 98225
Phone Number: 360-734-9033

EPA Regulated

DOH #	Analytes	Results	Units	SRL	Trigger	MCL	Method	Analyst
45	Vinyl Chloride	ND	ug/L	0.5	0.5	2	EPA 524.2	TGT
46	1,1-Dichloroethylene	ND	ug/L	0.5	0.5	7	EPA 524.2	TGT
47	1,1,1-Trichloroethane	ND	ug/L	0.5	0.5	200	EPA 524.2	TGT
48	Carbon Tetrachloride	ND	ug/L	0.5	0.5	5	EPA 524.2	TGT
49	Benzene	ND	ug/L	0.5	0.5	5	EPA 524.2	TGT
50	1,2-Dichloroethane	ND	ug/L	0.5	0.5	5	EPA 524.2	TGT
51	Trichloroethylene	ND	ug/L	0.5	0.5	5	EPA 524.2	TGT
52	1,4-Dichlorobenzene	ND	ug/L	0.5	0.5	75	EPA 524.2	TGT
56	Dichloromethane	ND	ug/L	0.5	0.5	5	EPA 524.2	TGT
57	trans-1,2-Dichloroethylene	ND	ug/L	0.5	0.5	100	EPA 524.2	TGT
60	cis-1,2-dichloroethylene	ND	ug/L	0.5	0.5	70	EPA 524.2	TGT
63	1,2-Dichloropropane	ND	ug/L	0.5	0.5	5	EPA 524.2	TGT
66	Toluene	ND	ug/L	0.5	0.5	1000	EPA 524.2	TGT
67	1,1,2-Trichloroethane	ND	ug/L	0.5	0.5	5	EPA 524.2	TGT
68	Tetrachloroethylene	ND	ug/L	0.5	0.5	5	EPA 524.2	TGT
71	Chlorobenzene	ND	ug/L	0.5	0.5	100	EPA 524.2	TGT
73	Ethylbenzene	ND	ug/L	0.5	0.5	700	EPA 524.2	TGT
76	Styrene	ND	ug/L	0.5	0.5	100	EPA 524.2	TGT
84	1,2-Dichlorobenzene	ND	ug/L	0.5	0.5	600	EPA 524.2	TGT
95	1,2,4-Trichlorobenzene	ND	ug/L	0.5	0.5	70	EPA 524.2	TGT
160	Total Xylene	ND	ug/L	0.5	0.5	10000	EPA 524.2	TGT
74	m/p-Xylene (MCL for Total)	ND	ug/L	0.5	0.5		EPA 524.2	TGT
75	o-Xylene (MCL for Total)	ND	ug/L	0.5	0.5		EPA 524.2	TGT

EPA Unregulated

DOH #	Analytes	Results	Units	SRL	Trigger	MCL	Method	Analyst
27	Chloroform	ND	ug/L	0.5	0.5		EPA 524.2	TGT
28	Bromodichloromethane	ND	ug/L	0.5	0.5		EPA 524.2	TGT
29	Chlorodibromomethane	ND	ug/L	0.5	0.5		EPA 524.2	TGT
30	Bromoform	ND	ug/L	0.5	0.5		EPA 524.2	TGT
53	Chloromethane	ND	ug/L	0.5	0.5		EPA 524.2	TGT
54	Bromomethane	ND	ug/L	0.5	0.5		EPA 524.2	TGT
55	Chloroethane	ND	ug/L	0.5	0.5		EPA 524.2	TGT
58	1,1-Dichloroethane	ND	ug/L	0.5	0.5		EPA 524.2	TGT
59	2,2-Dichloropropane	ND	ug/L	0.5	0.5		EPA 524.2	TGT

62	1,1-Dichloropropylene	ND	ug/L	0.5	0.5		EPA 524.2	TGT
64	Dibromomethane	ND	ug/L	0.5	0.5		EPA 524.2	TGT
70	1,3-Dichloropropane	ND	ug/L	0.5	0.5		EPA 524.2	TGT
72	1,1,1,2-Tetrachloroethane	ND	ug/L	0.5	0.5		EPA 524.2	TGT
78	Bromobenzene	ND	ug/L	0.5	0.5		EPA 524.2	TGT
79	1,2,3-Trichloropropane	ND	ug/L	0.5	0.5		EPA 524.2	TGT
80	1,1,2,2-Tetrachloroethane	ND	ug/L	0.5	0.5		EPA 524.2	TGT
81	o-Chlorotoluene	ND	ug/L	0.5	0.5		EPA 524.2	TGT
82	p-Chlorotoluene	ND	ug/L	0.5	0.5		EPA 524.2	TGT
83	m-Dichlorobenzene	ND	ug/L	0.5	0.5		EPA 524.2	TGT
154	1,3-Dichloropropene	ND	ug/L	0.5	0.5		EPA 524.2	TGT

State Unregulated

DOH #	Analytes	Results	Units	SRL	Trigger	MCL	Method	Analyst
65	cis-1,3-Dichloropropene	ND	ug/L	0.5	0.5		EPA 524.2	TGT
69	trans-1,3-Dichloropropene	ND	ug/L	0.5	0.5		EPA 524.2	TGT
85	Flourotrichloromethane	ND	ug/L	0.5	0.5		EPA 524.2	TGT
86	Bromochloromethane	ND	ug/L	0.5	0.5		EPA 524.2	TGT
87	Isopropylbenzene	ND	ug/L	0.5	0.5		EPA 524.2	TGT
88	n-Propylbenzene	ND	ug/L	0.5	0.5		EPA 524.2	TGT
89	1,3,5-Trimethylbenzene	ND	ug/L	0.5	0.5		EPA 524.2	TGT
90	tert-Butylbenzene	ND	ug/L	0.5	0.5		EPA 524.2	TGT
91	1,2,4-Trimethylbenzene	ND	ug/L	0.5	0.5		EPA 524.2	TGT
92	sec-Butylbenzene	ND	ug/L	0.5	0.5		EPA 524.2	TGT
93	p-Isopropyltoluene	ND	ug/L	0.5	0.5		EPA 524.2	TGT
94	n-Butylbenzene	ND	ug/L	0.5	0.5		EPA 524.2	TGT
96	Naphthalene	ND	ug/L	0.5	0.5		EPA 524.2	TGT
97	Hexachlorobutadiene	ND	ug/L	0.5	0.5		EPA 524.2	TGT
98	1,2,3-Trichlorobenzene	ND	ug/L	0.5	0.5		EPA 524.2	TGT
102	EDB (Scan Confirm 504.1)	ND	ug/L	0.5	0.5		EPA 524.2	TGT
103	DBCP(Scan Confirm 504.1)	ND	ug/L	0.5	0.5		EPA 524.2	TGT
162	Dichlorodifluoromethane	ND	ug/L	0.5	0.5		EPA 524.2	TGT

ND = Not Detected within the sensitivity of the instrument
Numerical Entry = Detection at level indicated
SRL - Minimum reporting level for Washington DOH
MCL - EPA maximum contaminant level
Trigger - Washington DOH response level. If results exceed this level, contact the DOH

Lab Supervisor: ______________________ **Date:** 3/24/2008

ENERGY LABORATORIES

ENERGY LABORATORIES, INC. • 2393 Salt Creek Highway (82601) • P.O. Box 3258 • Casper, WY 82602
Toll Free 888.235.0515 • 307.235.0515 • Fax 307.234.1639 • casper@energylab.com • www.energylab.com

RADIONUCLIDE ANALYSIS REPORT

System ID No.: **155509**
System Name: **Town of Coupeville**
Lab/Sample No: **142-94001**
Date Collected: **03/05/2008**
DOH Source No:
Multiple Source Nos:
Sample Type: **Before Treatment**
Sample Purpose: **New Well**
Date Received: **03/11/2008**
Date Reported: **03/31/2008**
Supervisor: **Jim Yocum, QC Officer**
Date Analyzed: **See Below**
Analyst: **See Below**
County: **Island**
Group :
Sample Location: **Reystone Hill Well**

Send Report To: **Avocet Environmental Testing, Inc**
1500 North State Street, Suite 200
Bellingham, WA 98225

Bill To: **Avocet Environmental Testing, Inc**
1500 North State Street, Suite 200
Bellingham, WA 98225

DOH #	ANALYTES	LAB MDA	RESULTS	UNITS	DATE ANALYZED	MCL	(ANALYST'S INITIALS) & METHOD USED
EPA/STATE REGULATED (These analyses should be performed in order as listed)							
165	Gross Alpha	**1.0**	**4.7**	pCi/L	**03/21/2008**	**15**	**CRW / E900.0**
166	Radium 228	**1.0**	**0.46**	pCi/L	**03/19/2008**	**5**	**PLJ / RA-05**
*Determine Radium 226 activity if Gross Alpha is greater than 5.0 pCi/L**							
39	Radium 226*			pCi/L			
*Determine Uranium activity if Gross Alpha is greater than 15.0 pCi/L ***							
105	Uranium** (mass)			µg/L		30	
105	Uranium** (activity)			pCi/L		20**	
Depending on the foregoing data determine the following (must be completed if data is available):							
40	Radium 226 + 228			pCi/L			
40	Gross Alpha*** + Radium 228			pCi/L		5	
41	Gross Alpha minus Uranium			pCi/L		15	
Do the following only if specifically requested by the client or the state							
42	Gross Beta****	**2.0**	**1.2**	pCi/L	**03/21/2008**	**50**	**CRW / E900.0**
43	Tritium****			pCi/L		20,000	
44	Strontium 90****			pCi/L		8	
107	Cesium 134****			pCi/L		***	
108	Iodine 131****			pCi/L		***	

MCL (Maximum Contaminant Level): If the contaminant amount exceeds the MCL, immediately contact your regional DOH office.
MDA: Minimum Detectable Amount.
NA (Not Analyzed): use in the results column for compounds not included in the current analysis.
ND (Not Detected): use in the results column for compounds analyzed and not detected at a level greater than or equal to the MDA.
*** If Gross Alpha is less than , or equal to, 5 pCi/L,** it may be assumed that the Alpha activity is entirely due to Radium 226 (i.e., Radium 226 would not need to be run). The Alpha activity is then added to the Radium 228 activity (i.e., Beta activity) for MCL determinations. If the sum of the Alpha activity plus the Radium 228 activity is greater than 5 pCi/L, Radium 226 activity must then be determined for water system compliance purposes (i.e., Radium 226 + Radium 228 activity)
****Uranium's MCL is given in mass terms (µg/L).** When Uranium is determined by mass methods, it must be converted to activity levels (pCi/L) for calculation of the MCL (Gross Alpha less Uranium). A conversion factor of 0.67 pCi/l per µg/L should be used. Uranium needs to be determined only when the Gross Alpha exceeds 15 pCi/L.
*** Use Gross Alpha in lieu of Radium 226 when the Gross Alpha is less than, or equal to, 5.0 pCi/L
****** The MCL for beta particle and photon radioactivity from man-made radionuclides** is the average annual concentration which shall not produce an annual dose equivalent to the total body or any internal organ greater than four millirem/yr.
Comments: Use back of page for comments

Appendix C
Standard Operating Procedures

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

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)	

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

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

WELL DEVELOPMENT LOG

PROJECT		WELL NO.
JOB NO.	SITE	PREPARED BY

METHOD
OVERPUMPAGE __________
BAILER __________

SURGE
BLOCK __________
AIR LIFT __________
OTHER __________

INITIAL WATER LEVEL __________
FINAL WATER LEVEL __________

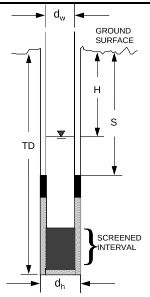
REMARKS:

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_wID =_____
Outside Diameter d_wOD =_____
Depth to Water: H =_____
Depth to Base of Seal: S =_____
Depth to Base of Well: TD =_____
Estimated Filter Pack Porosity: P =_____



WELL VOLUME CALCULATION :

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

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

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

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

TOTAL WELL VOLUME = VT = Vc + Vf = ____ + ____ = ______ $ft.^3$ x 7.48 = ______ 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

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

Time Intervals

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 <u>not</u> 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

<u>Office Procedures</u>

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.

<u>Equipment List</u>

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 Pump on: Date___Time ___ ( ) Pump off: Date___Time___ ( ) Duration of aquifer test: Pumping___Recovery____					Water Level Data Static Water Level _______________ Measuring Point_________________ 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)	

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).

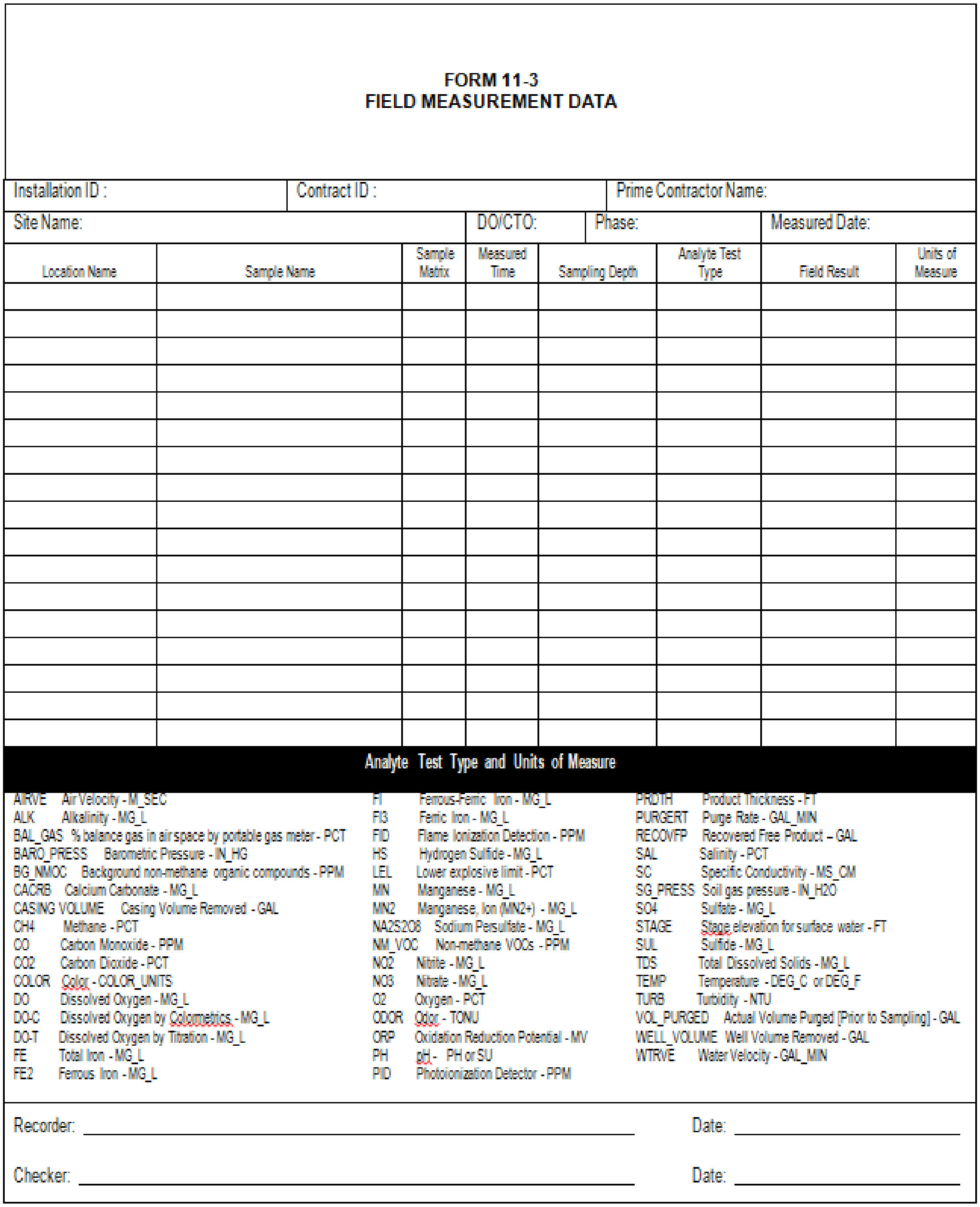
4.0 REFERENCES

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

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: ______________

SOIL AND ROCK CLASSIFICATION

1.0 PURPOSE

This section sets forth standard operating procedures (SOPs) for soil and rock classification to be used by U.S. Naval Facilities Engineering Command Northwest (NAVFAC NW) personnel and their contractors.

2.0 PROCEDURES

2.1 SOIL CLASSIFICATION

The basic purpose of the classification of soils is to thoroughly describe the physical characteristics of the sample and to classify it according to an appropriate soil classification system for the NAVFAC NW. The Unified Soil Classification System (USCS) was developed so that soils could be described on a common basis by different investigators and serves as a "shorthand" description of soil. A classification of a soil in accordance with the USCS includes not only a group symbol and name, but also a complete word description.

Describing soils on a common basis is essential so that soils described by different site qualified personnel are comparable. Site individuals describing soils, as part of NAVFAC NW site activities, must use the classification system described herein to provide the most useful geologic database for all present and future subsurface investigations and remedial activities at NAVFAC NW sites.

The site geologist or other qualified individual shall describe the soil and record the description in a boring log or logbook. The essential items in any written soil description are as follows:

- Classification group name (e.g., silty sand)
- Color, moisture, and odor
- Range of particle sizes and maximum particle size
- Approximate percentage of boulders, cobbles, gravel, sand, and fines
- Plasticity characteristics of the fines
- In-place conditions such as consistency, density, structure, etc.
- USCS classification symbol

The USCS serves as a "shorthand" for classifying soil into 15 basic groups:

GW[1]	Well graded (poorly sorted) gravel (>50% gravel, <5% fines)
GP[1]	Poorly graded (well sorted) gravel (>50% gravel, <5% fines)
GM1	Silty gravel (>50% gravel, >15% silt)

GC1	Clayey gravel (>50% gravel, >15% clay)
SW1	Well graded (poorly sorted) sand (>50% sand, <5% fines)
SP1	Poorly graded (well sorted) sand (>50% sand, <5% fines)
SM1	Silty sand (>50% sand, >15% silt)
SC1	Clayey sand (>50% sand, >15% clay)
ML2	Inorganic, low plasticity silt (slow to rapid dilatancy, low toughness and plasticity)
L2	Inorganic, low plasticity (lean) clay (no or slow dilatancy, medium toughness and plasticity)
MH2	Inorganic elastic silt (no to slow dilatancy, low to medium toughness and plasticity)
CH2	Inorganic, high plasticity (fat) clay (no dilatancy, high toughness and plasticity)
OL	Organic low plasticity silt or organic silty clay
OH	Organic high plasticity clay or silt
PT	Peat and other highly organic soils

1 If percentage of fines is 5% to 15%, a dual identification shall be given (e.g., a soil with more than 50% poorly sorted gravel and 10% clay is designated GW-GC.

2 If the soil is estimated to have 15% to 25% sand or gravel, or both, the words "with sand" or "with gravel" (whichever predominates) shall be added to the group name (e.g., clay with sand, CL; or silt with gravel, ML). If the soil is estimated to have 30% or more sand or gravel, or both, the words "sandy" or "gravelly" (whichever predominates) shall be added to the group name (e.g., sandy clay, CL). If the percentage of sand is equal to the percent gravel, use "sandy."

Figure I-E-1 defines the terminology of the USCS. Flowcharts presented in Figures I-E-2 and I-E-3 indicate the process for describing soils. The particle size distribution and the plasticity of the fines are the two properties of soil used for classification. In some cases, it may be appropriate to use a borderline classification, e.g., SC/CL, if the soil has been identified as having properties that do not distinctly place the soil into one group.

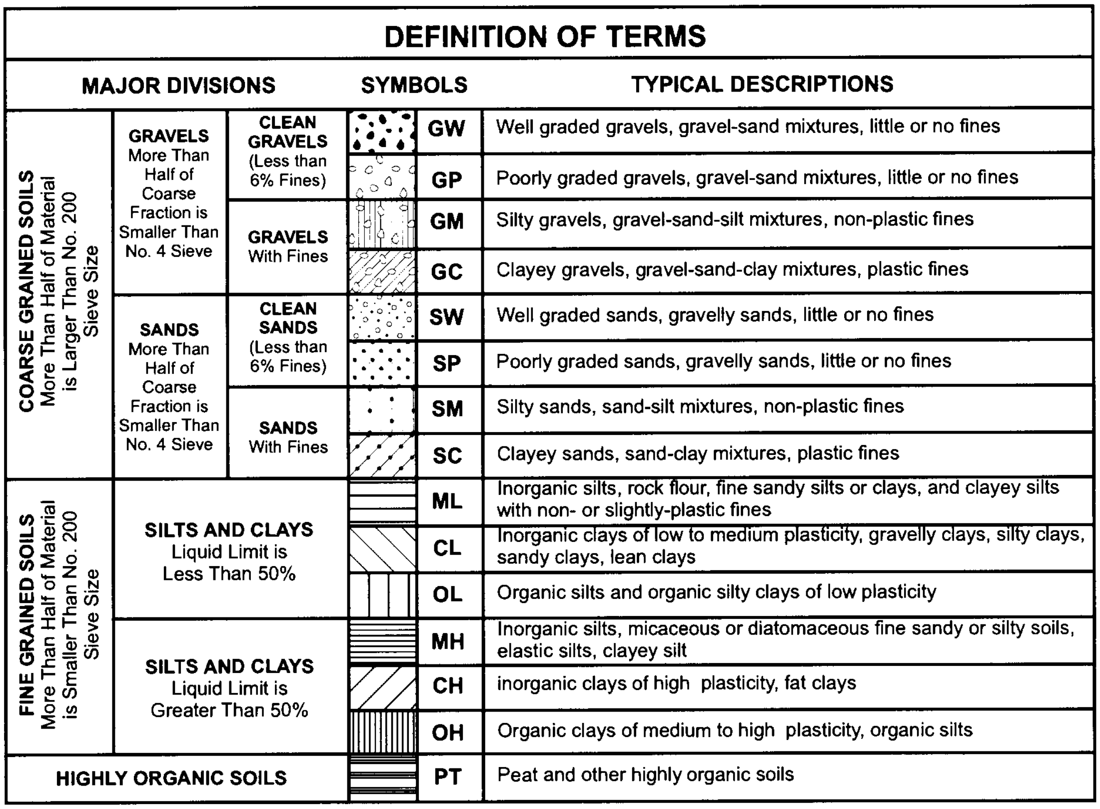
2.1.1 Estimation of Particle Size Distribution

One of the most important factors in classifying a soil is the estimated percentage of soil constituents in each particle size range. To become proficient in estimating this factor requires extensive practice and frequent checking. The steps involved in determining particle size distribution are listed below.

1. Select a representative sample (approximately 1/2 of a 6-inch long by 2.5 inch diameter sample liner.)
2. Remove all particles larger than 3 inches from the sample. Estimate and record the percent by volume of these particles. Only the fraction of the sample smaller than 3 inches is classified.
3. Estimate and record the percentage of dry mass of gravel (less than 3 inches and greater than 1/4 inch.

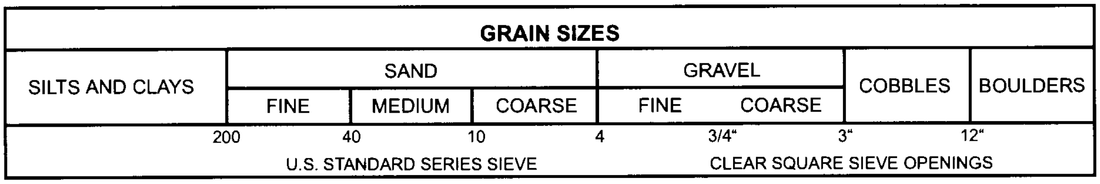
4. Considering the rest of the sample, estimate and record the percentage of dry mass of sand particles (about the smallest particle visible to the unaided eye).
5. Estimate and record the percentage of dry mass of fines in the sample (do not attempt to separate silts from clays).
6. Estimate percentages to the nearest 5%. If one of the components is present in a quantity considered less than 5%, indicate its presence by the term "trace".
7. The percentages of gravel, sand, and fines must add up to 100%. "Trace" is not included in the 100% total.

Figure I-E-1
Unified Soil Classification System (USCS)



DEFINITION OF TERMS

MAJOR DIVISIONS			SYMBOLS	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS More Than Half of Material is Larger Than No. 200 Sieve Size	**GRAVELS** More Than Half of Coarse Fraction is Smaller Than No. 4 Sieve	**CLEAN GRAVELS** (Less than 6% Fines)	**GW**	Well graded gravels, gravel-sand mixtures, little or no fines
			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines
		GRAVELS With Fines	**GM**	Silty gravels, gravel-sand-silt mixtures, non-plastic fines
			GC	Clayey gravels, gravel-sand-clay mixtures, plastic fines
	SANDS More Than Half of Coarse Fraction is Smaller Than No. 4 Sieve	**CLEAN SANDS** (Less than 6% Fines)	**SW**	Well graded sands, gravelly sands, little or no fines
			SP	Poorly graded sands, gravelly sands, little or no fines
		SANDS With Fines	**SM**	Silty sands, sand-silt mixtures, non-plastic fines
			SC	Clayey sands, sand-clay mixtures, plastic fines
FINE GRAINED SOILS More Than Half of Material is Smaller Than No. 200 Sieve Size	**SILTS AND CLAYS** Liquid Limit is Less Than 50%		**ML**	Inorganic silts, rock flour, fine sandy silts or clays, and clayey silts with non- or slightly-plastic fines
			CL	Inorganic clays of low to medium plasticity, gravelly clays, silty clays, sandy clays, lean clays
			OL	Organic silts and organic silty clays of low plasticity
	SILTS AND CLAYS Liquid Limit is Greater Than 50%		**MH**	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts, clayey silt
			CH	inorganic clays of high plasticity, fat clays
			OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS			**PT**	Peat and other highly organic soils



GRAIN SIZES

SILTS AND CLAYS	SAND			GRAVEL		COBBLES	BOULDERS
	FINE	MEDIUM	COARSE	FINE	COARSE		

200 40 10 4 3/4" 3" 12"

U.S. STANDARD SERIES SIEVE CLEAR SQUARE SIEVE OPENINGS

Figure I-E-2
Flow Chart for Fine Grain Soils Classification

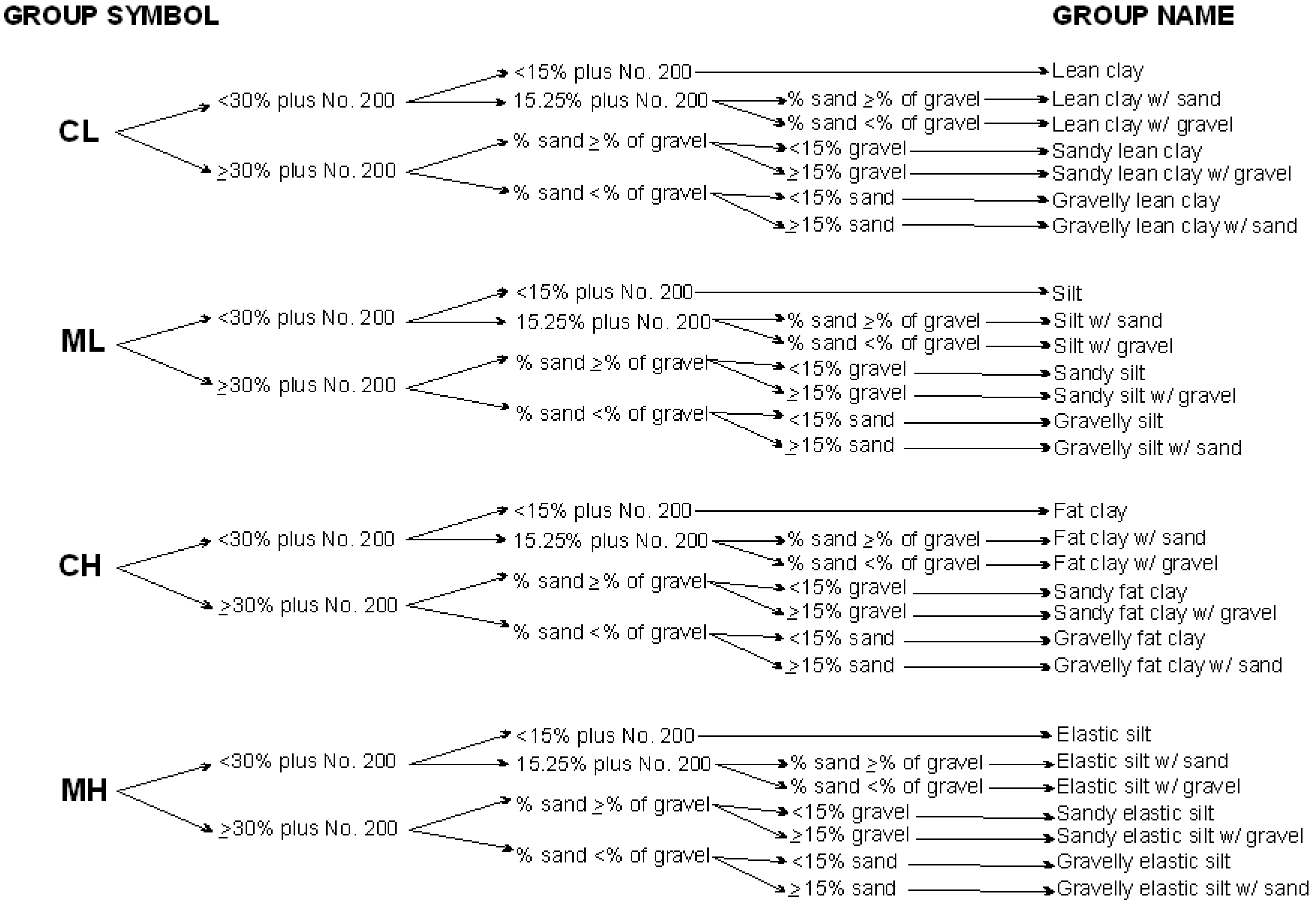
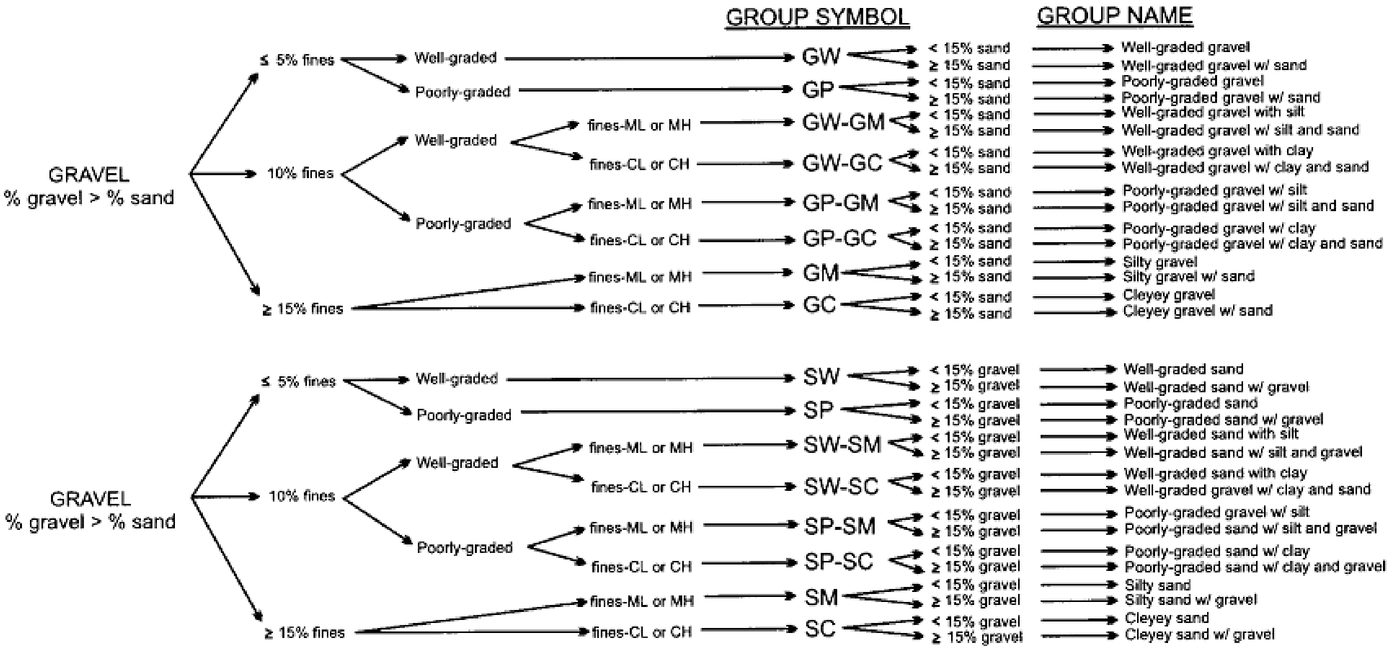


Figure I-E-3
Flow Chart for Soils with Gravel



2.1.2 Soil Dilatancy, Toughness, and Plasticity

2.1.2.1 Dilatancy

To evaluate dilatancy, the following procedures shall be followed:

1. From the specimen, select enough material to mold into a ball about 1/2 inch (12 mm) in diameter. Mold the material, adding water if necessary, until it has a soft, but not sticky, consistency.
2. Smooth the soil ball in the palm of one hand with the blade of a knife or small spatula. Shake horizontally, striking the side of the hand vigorously against the other hand several times. Note the reaction of water appearing on the surface of the soil. Squeeze the sample by closing the hand or pinching the soil between the fingers, and note the reaction as none, slow, or rapid in accordance with the criteria in Table I-E-1. The reaction is the speed with which water appears while shaking, and disappears while squeezing.

Table I-E-1
Criteria for Describing Dilatancy

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

2.1.2.2 Toughness

Following the completion of the dilatancy test, the test specimen is shaped into an elongated pat and rolled by hand on a smooth surface or between the palms into a thread about 1/8 inch (3 mm) in diameter. (If the sample is too wet to roll easily, it should be spread into a thin layer and allowed to lose some water by evaporation.) Fold the sample threads and re-roll repeatedly until the thread crumbles at a diameter of about 1/8 inch. The thread will crumble at a diameter of 1/8 inch when the soil is near the plastic limit. Note the pressure required to roll the thread near the plastic limit. Also, note the strength of the thread. After the thread crumbles, the pieces should be lumped together and kneaded until the lump crumbles. Note the toughness of the material during kneading. Describe the toughness of the thread and lump as low, medium, or high in accordance with the criteria in Table I-E-2.

Table I-E-2
Criteria for Describing Toughness

Description	Criteria
Low	Only slight pressure is required to roll the thread near the plastic limit. The thread and the lump are weak and soft.
Medium	Medium pressure is required to roll the thread to near the plastic limit. The thread and the lump have medium stiffness.
High	Considerable pressure is required to roll the thread to near the plastic limit. The thread and the lump have very high stiffness.

2.1.2.3 Plasticity

The plasticity of a soil is defined by the ability of the soil to deform without cracking, the range of moisture content over which the soil remains in a plastic state, and the degree of cohesiveness at the plastic limit. The plasticity characteristic of clays and other cohesive materials are defined by the liquid limit and plastic limit. The liquid limit is defined as the soil moisture content at which soil passes from the liquid to the plastic state as moisture is removed. The test for the liquid limit is a laboratory, not a field, analysis.

The plastic limit is the soil moisture content at which a soil passes from the plastic to the semi-solid state as moisture is removed. The plastic limit test can be performed in the field and is indicated by the ability to roll a 1/8-inch (0.125-inch) diameter thread of fines, the time required to roll the thread, and the number of times the thread can be re-rolled when approaching the plastic limit.

The plasticity tests are not based on natural soil moisture content but on soil that has been thoroughly mixed with water. If a soil sample is too dry in the field, water should be added prior to performing classification. If a soil sample is too sticky, the sample should be spread thin and allowed to lose some soil moisture.

The criteria for describing plasticity in the field, using the rolled thread method, are presented in Table I-E-3.

Table I-E-3
Criteria for Describing Plasticity

Description	Criteria
Non-Plastic	A 1/8-inch thread cannot be rolled.
Low plasticity	The thread can barely be rolled.
Medium plasticity	The thread is easy to roll and not much time is required to reach the plastic limit.
High plasticity	It takes considerable time rolling the thread to reach the plastic limit

2.1.3 Angularity

The angularity of the coarse sand and gravel particles is described according to the following criteria:

- Rounded—particles have smoothly-curved sides and no edges;

- Subrounded-particles have nearly plane sides, but have well-rounded corners and edges;
- Subangular—particles are similar to angular, but have somewhat rounded or smooth edges; and
- Angular—particles have sharp edges and relatively plane sides with unpolished surfaces. Freshly broken or crushed rock would be described as angular.

2.1.4 Color, Moisture, and Odor

The natural moisture content of soils is very important information. The terms for describing the moisture condition and the criteria for each are shown in Table I-E-4.

Table I-E-4
Soil Moisture Content Qualifiers

Qualifier	Criteria
Dry	Absence of moisture, dry to the touch
Moist	Damp but no visible water.
Wet	Visible water, usually soil is below water table

Color is described by hue and chroma using the Munsell Soil Color Chart. For the sake of uniformity, all site geologists shall utilize this chart for soil classification. Doing so will facilitate correlation of geologic units between boreholes logged by different geologists The Munsell color chart is a small booklet of numbered color chips with names like "5YR 5/6, yellowish-red". Mottling or banding of colors should be noted. It is particularly important to note and describe staining because it may indicate contamination.

If odors are noted, they should be described if they are unusual or suspected to result from contamination. An organic odor may have the distinctive smell of decaying vegetation. Unusual odors may be related to hydrocarbons, solvents, or other chemicals in the subsurface. An organic vapor analyzer (OVA) may be used to detect the presence of volatile organic contaminants. In general, respirators should be worn if strong organic odors are present.

2.1.5 In-place Conditions

The conditions of undisturbed soil samples shall be described in terms of their density/consistency (i.e., compactness), cementation, and structure utilizing the following guidelines:

2.1.5.1 Density/Consistency

Density and consistency describe a physical property that reflects the relative resistance of a soil to penetration. The term "density" is commonly applied to coarse to medium-grained sediments (i.e., gravels, sands), whereas the term "consistency" is normally applied to fine-grained sediments (i.e., silts, clays). There are separate standards of measure for both density and consistency that are used to describe the properties of a soil.

The density or consistency of a soil is determined by observing the number of blows required to drive a 1 3/8-inch (35 mm) diameter split barrel sampler 18 inches using a drive hammer weighing 140 lbs. (63.5

kg) dropped over a distance of 30 inches (0.76 m). The number of blows required to penetrate each 6 inches of soil is recorded in the field boring log during sampling. The first 6 inches of penetration is considered to be a seating drive; therefore, the blow count associated with this seating drive is recorded but not used in determining the soil density/consistency. The sum of the number of blows required for the second and third 6 inches of penetration is termed the "standard penetration resistance," or the "N-value." The observed number of blow counts must be corrected by an appropriate factor if a different type of sampling device (e.g., Modified California Sampler with liners) is used. For a 2 3/8-inch I.D. Modified California Sampler equipped with brass or stainless steel liners and penetrating a cohesionless soil (sand/gravel), the N-value from the Modified California Sampler must be divided by 1.43 to provide data that can be compared to the 1 3/8-inch diameter sampler data.

For a cohesive soil (silt/clay), the N-value for the Modified California Sampler should be divided by a factor of 1.13 for comparison with 1 3/8-inch diameter sampler data.

The sampler should be driven and blow counts recorded for each 6-inch increment of penetration until one of the following occurs:

- A total of 50 blows have been applied during any one of the three 6-inch increments; a 50-blow count occurrence shall be termed "refusal" and noted as such on the boring log.
- A total of 150 blows have been applied.
- The sampler is advanced the complete 18 inches without the limiting blow counts occurring, as described above.

If the sampler is driven less than 18 inches, the number of blows per partial increment shall be recorded on the boring log. If refusal occurs during the first 6 inches of penetration, the number of blows will represent the N-value for this sampling interval. Representative descriptions of soil density/consistency vs. N-values are presented in Table I-E-5.

Table I-E-5a
Measuring Soil Density with A California Sampler Relative Density (Sands, Gravels)

	Field Criteria (N-Value)	
Description	**1 3/8" I.D. Sampler**	**2" I.D. Sampler using 1.43 factor**
Very loose	0-4	0-6
Loose	4-10	6-14
Medium dense	10-30	14-43
Dense	30-50	43-71
Very Dense	>50	>71

Table I-E-5b
Measuring Soil Density with a California Sampler Consistency: Fine-Grained Cohesive Soils

	Field Criteria (N-Value)	
Description	**1 3/8" I.D. Sampler**	**2" I.D. Sampler using 1.13 factor**
Very soft	0-2	0-2
Soft	2-4	2-4
Medium Stiff	4-8	4-9
Stiff	8-16	9-18
Very Stiff	16-32	18-36
Hard	>32	>36

For undisturbed fine-grained soil samples, it is also possible to measure consistency with a hand-held penetrometer. The measurement is made by placing the tip of the penetrometer against the surface of the soil contained within the sampling liner or shelby tube, pushing the penetrometer into the soil a distance specified by the penetrometer manufacturer, and recording the pressure resistance reading in pounds per square foot (PSF). The values are as follows:

Table I-E-6
Measuring Soil Consistency with a Hand-held Penetrometer

Description	Pocket Penetrometer Reading (PSF)
Very Soft	0 to 250
Soft	250 to 500
Medium Stiff	500 to 1000
Stiff	1000 to 2000
Very Stiff	2000 to 4000
Hard	>4000

Consistency can also be estimated using thumb pressure using the following table:

Table I-E-7
Measuring Soil Consistency Using Thumb Pressure

Description	Criteria
Very soft	Thumb will penetrate soil more than 1 inch (25 mm)
Soft	Thumb will penetrate soil about 1 inch (25 mm)
Firm	Thumb will penetrate soil about 1/4 inch (6 mm)
Hard	Thumb will not indent soil but readily indented with thumbnail
Very hard	Thumbnail will not indent soil

2.1.5.2 Cementation

Cementation is used to describe the friability of a soil. Cements are chemical precipitates that provide important information as to conditions that prevailed at the time of deposition, or conversely, diagenetic effects that occurred following deposition. Seven types of chemical cements are recognized by Folk (1980). They are as follows:

Quartz - siliceous;

Chert - chert-cemented or chalcedonic;

Opal - opaline;

Carbonate - calcitic, dolomitic, sideritic (if in doubt, calcareous should be used);

Iron oxides - hematitic, limonitic (if in doubt, ferruginous should be used);

Clay minerals - if the clay minerals are detrital or have formed by recrystallization of a previous clay matrix, they are not considered to be a cement. Only if they are chemical precipitates, filling previous pore space (usually in the form of accordion-like stacks or fringing radial crusts) should they be included as "kaolin-cemented," "chlorite-cemented," etc.

Miscellaneous minerals - pyritic, collophane-cemented, glauconite-cemented, gypsiferous, anhydrite-cemented, baritic, feldspar-cemented, etc.

The degree of cementation of a soil is determined qualitatively by utilizing finger pressure on the soil in one of the sample liners to disrupt the gross soil fabric. The three cementation descriptors are as follows:

Weak - friable, crumbles or breaks with handling or slight finger pressure;

Moderate - friable, crumbles or breaks with considerable finger pressure;

Strong - not friable, will not crumble or break with finger pressure.

2.1.5.3 Structure

This variable is used to qualitatively describe physical characteristics of soils that are important to incorporate into hydrogeological or geotechnical descriptions of soils at a site. Appropriate soil structure descriptors are as follows:

Granular - spherically-shaped aggregates with faces that do not accommodate adjoining faces.

Stratified - alternating layers of varying material or color with layers at least 6 mm (1/4 inch) thick; note thickness.

Laminated - alternating layers of varying material or color with layers less than 6 mm (1/4 inch) thick; note thickness.

Blocky - cohesive soil that can be broken down into small angular or subangular lumps that resist further breakdown.

Lensed - inclusion of a small pocket of different soils, such as small lenses of sand, should be described as homogeneous if it is not stratified, laminated, fissured, or blocky. If lenses of different soils are present, the soil being described can be termed homogeneous if the description of the lenses is included.

Prismatic or Columnar - particles arranged about a vertical line, ped is bounded by planar, vertical faces that accommodate adjoining faces; prismatic has a flat top; columnar has a rounded top.

Platy - particles are arranged about a horizontal plane.

2.1.5.4 Other Features

Mottled - soil that appears to consist of material of two or more colors in blotchy distribution.

Fissured - breaks along definite planes of fracture with little resistance to fracturing (determined by applying moderate pressure to sample using thumb and index finger)

Slickensided - fracture planes appear polished or glossy, sometimes striated (parallel grooves or scratches)

2.1.6 Development of Soil Description

Standard soil descriptions will be developed according to the following examples. There are three principal categories under which all soils can be classified. They are described below.

2.1.6.1 Coarse-grained Soils

Coarse-grained soils are divided into sands and gravels. A soil is classified as a sand if over 50% of the coarse fraction is "sand-sized." It is classified as a gravel if over 50% of the coarse fraction is composed of "gravel-sized" particles. The written description of a coarse-grained soil shall contain, in order of appearance:

Typical name including the second highest percentage constituent as an adjective, if applicable (underlined), grain size of coarse fraction, Munsell color and color number, moisture content, relative density, sorting, angularity, other features such as stratification (sedimentary structures) and cementation, possible formational name, primary USCS classification, secondary USCS classification (when necessary), and approximate percentages of minor constituents (i.e., sand, gravel, shell fragments, rip-up clasts, etc.) in parentheses.

Example: Poorly-sorted SAND with SILT, medium- to coarse-grained, light olive gray, 5Y 6/2, saturated, loose, poorly sorted, subrounded clasts, SW/SM (minor silt with approximately

20% coarse-grained sand-sized shell fragments, and 80% medium-grained quartz sand, and 5% to 15% ML).

2.1.6.2 *Fine-grained Soils*

Fine-grained soils are further subdivided into clays and silts according to their plasticity. Clays are rather plastic, while silts have little or no plasticity. The written description of a fine-grained soil should contain, in order of appearance:

Typical name including the second highest percentage constituent as an adjective, if applicable (underlined), Munsell color, moisture content, consistency, plasticity, other features such as stratification, possible formation name, primary USCS classification, secondary USCS classification (when necessary), and the percentage of minor constituents in parentheses.

Example: SANDY Lean CLAY, dusky red, 2.5 YR 3/2, moist, firm, moderately plastic, thinly laminated, CL (70% fines, 30% sand, with minor amounts of disarticulated bivalves (about 5%)).

2.1.6.3 *Organic Soils*

For highly organic soils, the types of organic materials present will be described as well as the type of soil constituents present using the methods described above. Identify the soil as an organic soil, OL/OH, if the soil contains enough organic particles to influence the soil properties. Organic soils usually have a dark brown to black color and may have an organic odor. Often, organic soils will change color, for example, from black to brown, when exposed to air. Some organic soils will lighten in color significantly when air-dried. Organic soils normally will not have a high toughness or plasticity. The thread for the toughness test will be spongy.

Example: ORGANIC CLAY, black, 2.5Y, 2.5/1, wet, soft, low plasticity, organic odor, OL (100% fines), weak reaction to HCl.

2.2 ROCK CLASSIFICATION

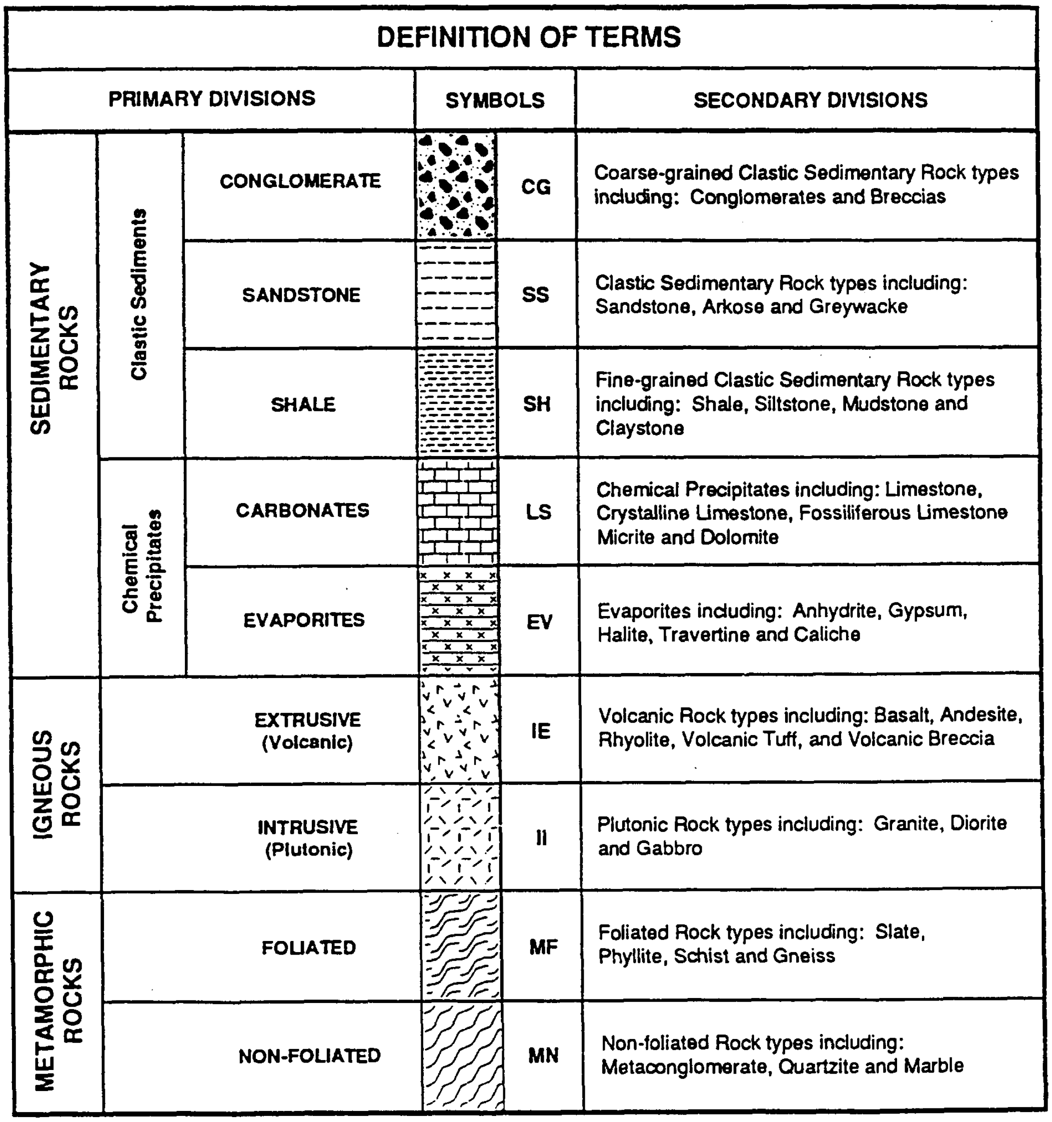
The purpose of rock classification is to thoroughly describe the physical and mineralogical characteristics of a specimen and to classify it according to an established system. The generalized rock classification system described below was developed for NAVFAC NW because, unlike the USCS for soils, there is no universally accepted rock classification system. In some instances, a more detailed and thorough rock classification system may be appropriate. Any modifications to this classification system, or the use of an alternate classification system should be considered during preparation of the site Work Plan and Field Sampling Plan. Both the Project Manager and the Technical Director/QA Program Manager must approve modifications to this classification system, or the use of another classification system.

Describing rock specimens on a common basis is essential so that rocks described by different site geologists are comparable. Site geologists describing rock specimens as a part of NAVFAC NW activities must use the classification system described herein, or if necessary, another more detailed classification system. Use of a common classification system provides the most useful geologic database for all present and future subsurface investigations and remedial activities at NAVFAC NW sites.

In order to provide a more consistent rock classification between geologists, a rock classification template has been designated as shown in Figure I-E-4. The template includes classification of rocks by origin and mineralogical composition. All site geologists when classifying rocks shall use this template.

The site geologist shall describe the rock specimen and record the description in a borehole log or logbook. The items essential in any written rock description are as a Classification group (i.e., metamorphic foliated).

Figure I-E-4
Rock Classification System



DEFINITION OF TERMS					
PRIMARY DIVISIONS			SYMBOLS		SECONDARY DIVISIONS
SEDIMENTARY ROCKS	Clastic Sediments	CONGLOMERATE		CG	Coarse-grained Clastic Sedimentary Rock types including: Conglomerates and Breccias
		SANDSTONE		SS	Clastic Sedimentary Rock types including: Sandstone, Arkose and Greywacke
		SHALE		SH	Fine-grained Clastic Sedimentary Rock types including: Shale, Siltstone, Mudstone and Claystone
	Chemical Precipitates	CARBONATES		LS	Chemical Precipitates including: Limestone, Crystalline Limestone, Fossiliferous Limestone Micrite and Dolomite
		EVAPORITES		EV	Evaporites including: Anhydrite, Gypsum, Halite, Travertine and Caliche
IGNEOUS ROCKS		EXTRUSIVE (Volcanic)		IE	Volcanic Rock types including: Basalt, Andesite, Rhyolite, Volcanic Tuff, and Volcanic Breccia
		INTRUSIVE (Plutonic)		II	Plutonic Rock types including: Granite, Diorite and Gabbro
METAMORPHIC ROCKS		FOLIATED		MF	Foliated Rock types including: Slate, Phyllite, Schist and Gneiss
		NON-FOLIATED		MN	Non-foliated Rock types including: Metaconglomerate, Quartzite and Marble

- Classification Name (i.e., schist)
- Color
- Mineralogical composition and percent
- Texture/Grain size (i.e., fine-grained, pegmatitic, aphlitic, glassy, etc.)
- Structure (i.e., foliated, fractured, lenticular, etc.)
- Rock Quality Designation (sum of all core pieces greater than two times the diameter of the core divided by the total length of the core run, expressed as a percentage) and
- Classification symbol (i.e., MF).

Example: Metamorphic foliated schist: Olive gray, 5Y, 3/2, Garnet 25%, Quartz 45%, Chlorite 15%, Tourmaline 15%, Fine-grained with Pegmatite garnet, highly foliated, slightly wavy, MF

3.0 DOCUMENTATION

Soil classification information collected during soil sampling should be documented onto the field boring logs, field trench logs, and into the field notebook. Copies of the field boring log form are presented in SOP I-B-1, *Soil Sampling*. Copies of this information shall be placed in the project files and reviewed by the Project Manager on a monthly basis at a minimum. If specified in the project SAP, lithologic data should also be submitted electronically in the appropriate Naval Environmental Data Deliverable (NEDD) format as defined in the NAVFAC NW SOPs (V5.0 or more current).

4.0 REFERENCES

ASTM, 1990. Standard Practice for Description and Identification of Soils (Visual, Manual Procedure) Designation D 2488-90.

Birkeland, Peter W. 1984. Soils and Geomorphology. Oxford University Press.

Compton, Robert R. 1985. Geology in the Field. John Wiley & Sons, Inc.

Folk, Robert L. 1980. Petrology of Sedimentary Rocks.

Huang, Walter T. 1962. Petrology. McGraw-Hill Book Company.

McCarthy, David F. 1988. Essentials of Soil Mechanics and Foundations: Basic Geotechnics. Prentice Hall.

Munsell Soil Color Chart, 1990 Edition (Revised).

Pettijohn, F.J. 1957. Sedimentary Rocks. Harper, New York.

Rahn, Perry H. 1986. Engineering Geology. Elsevier Science Publishing Company, Inc.

SOP I-B1, *Soil Sampling*

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

None.

LAND SURVEYING

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 (for volatiles only)	NA1	1/cooler	NA1	1/ 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

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. 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.

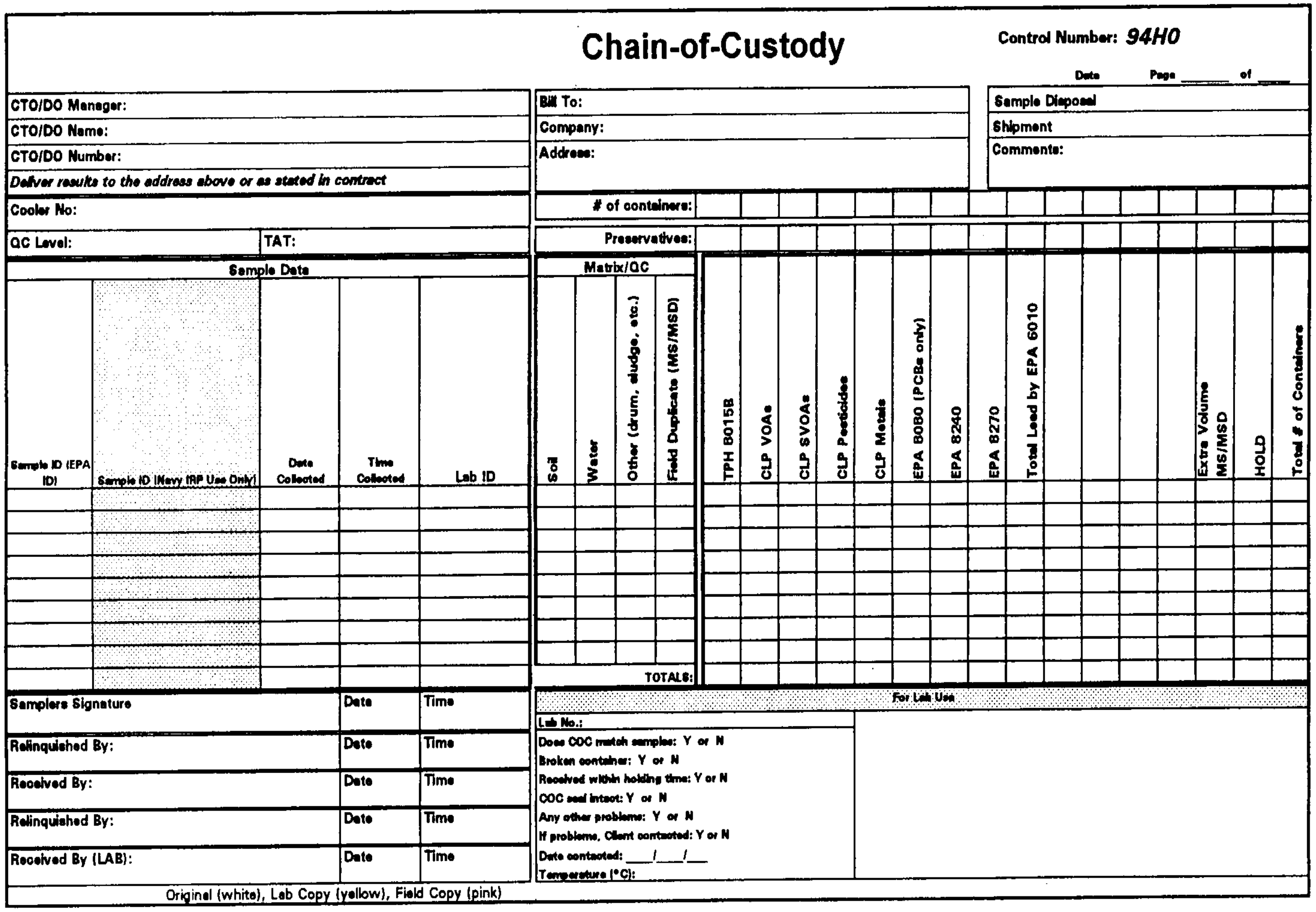
5.0 ATTACHMENTS

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:

Sample Data

Sample ID (EPA ID)	Sample ID (Navy IRP Use Only)	Date Collected	Time Collected	Lab ID

	Matrix/QC																		
# of containers:																			
Preservatives:																			
	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
TOTALS:																			

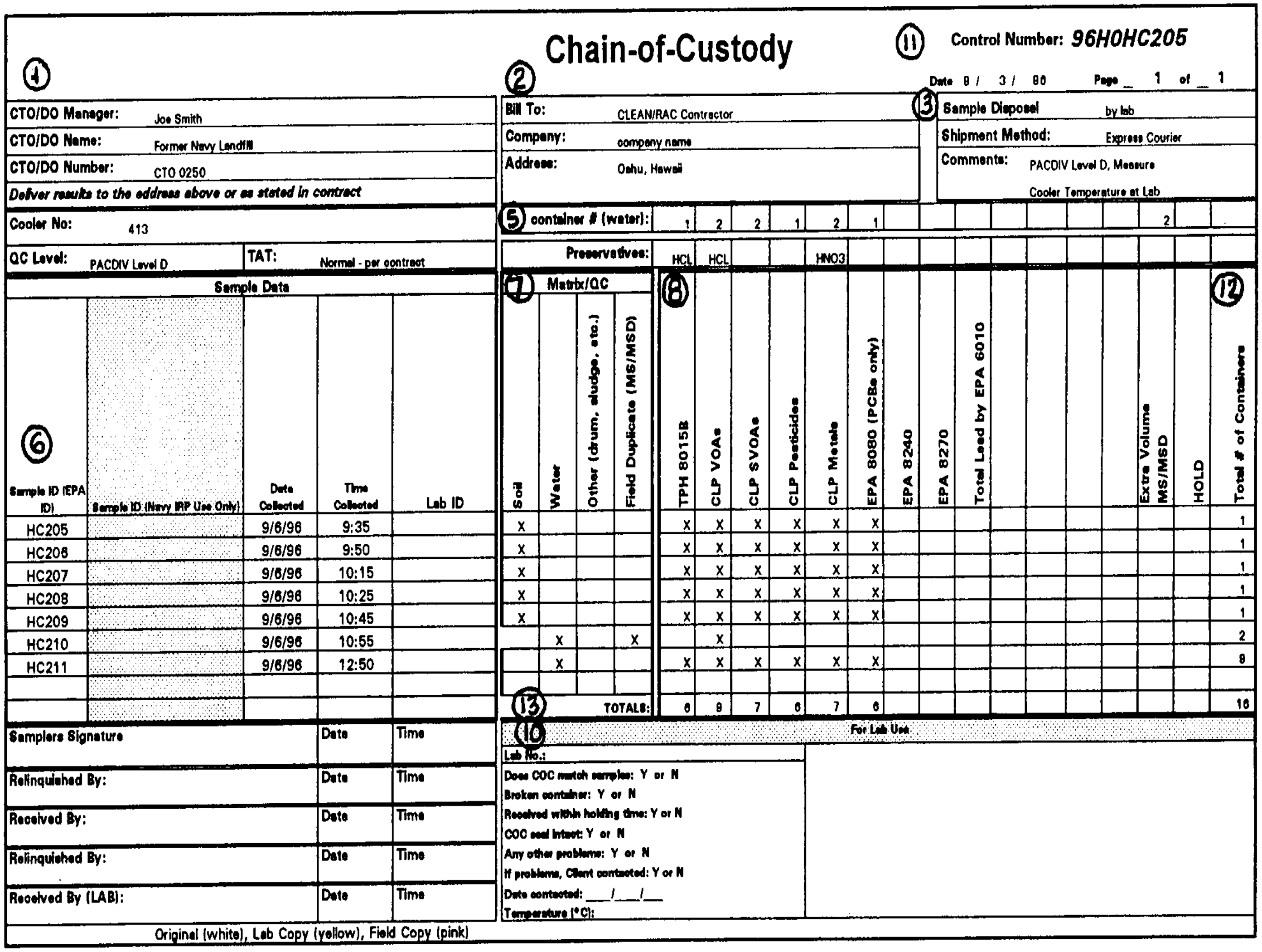
Samplers Signature	**Date**	**Time**
Relinquished By:	**Date**	**Time**
Received By:	**Date**	**Time**
Relinquished By:	**Date**	**Time**
Received By (LAB):	**Date**	**Time**

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 8 / 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

Sample Data ⑥ · ⑦ **Matrix/QC** · ⑧ · ⑫

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
⑤ container # (water):									1	2	2	1	2	1								2		
Preservatives:									HCL	HCL			HNO3											
HC205		9/6/96	9:35		X				X	X	X	X	X	X										1
HC206		9/6/96	9:50		X				X	X	X	X	X	X										1
HC207		9/6/96	10:15		X				X	X	X	X	X	X										1
HC208		9/6/96	10:25		X				X	X	X	X	X	X										1
HC209		9/6/96	10:45		X				X	X	X	X	X	X										1
HC210		9/6/96	10:55			X		X		X														2
HC211		9/6/96	12:50			X			X	X	X	X	X	X										9
					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 (List by Accession AND Sample No.)

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

3. Results of Corrective Action

☐ Return to Control (indicated with)

☐ Corrective Actions Not Successful - DATA IS TO BE FLAGGED with _____________.

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

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					

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 <u>does</u> 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

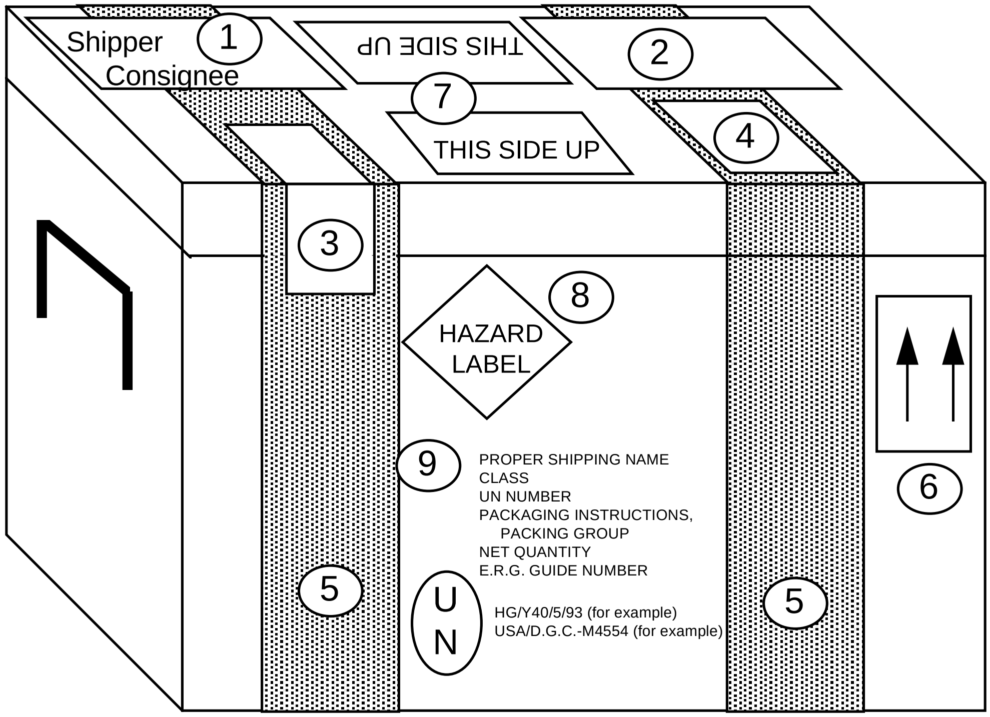
HM-126F, Training for Safe Transportation of Hazardous Materials

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.

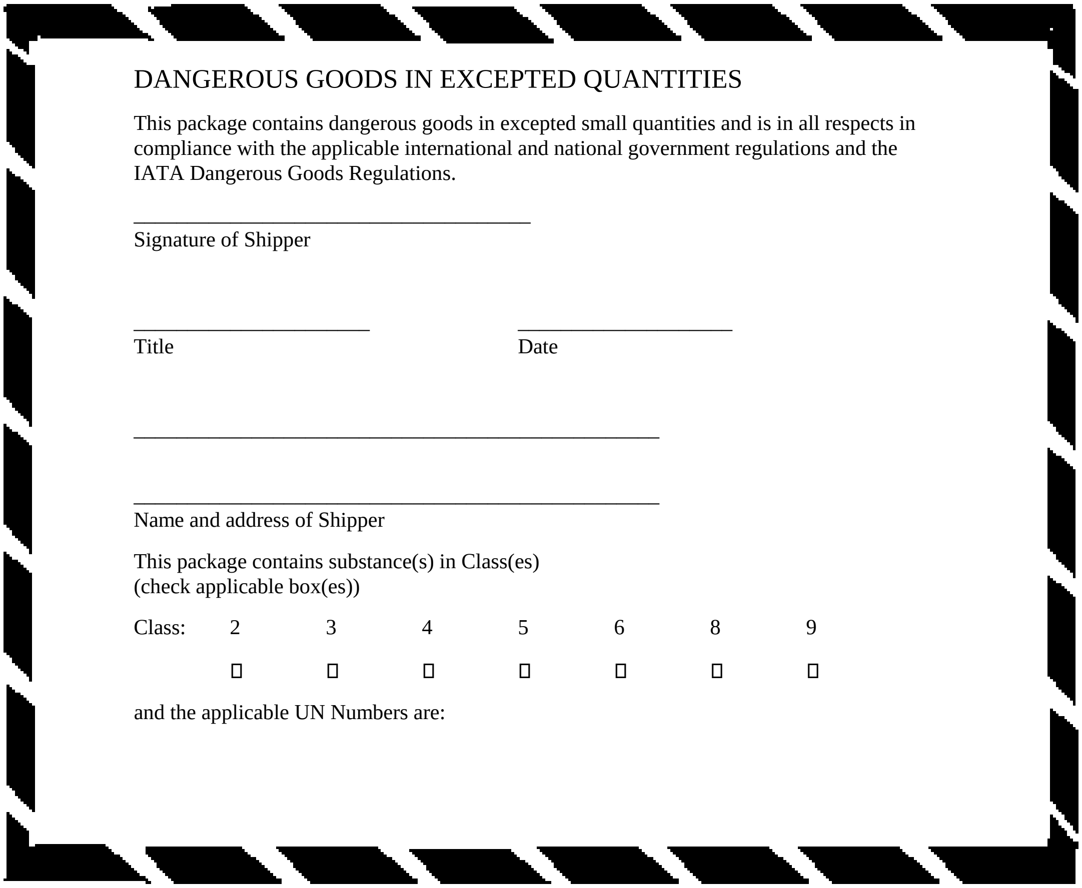
Note B: For inner packagings, the quantity contained in receptacle with a water capacity of 30 mL. For outer packagings, the sum of the water capacities of all the inner packagings contained must not exceed 1 L.

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	250	P,G	Cool, 4ºC	48 Hours
NTA	50	P,G	Cool, 4ºC	24 Hours

1. More specific instructions for preservation and sampling are found with each procedure as detailed in this manual. A general discussion on sampling water and industrial wastewater may be found in ASTM, Part 31, p. 72-82 (1976) Method D-3370.

2. Plastic (P) or Glass (G). For metals, polyethylene with a polypropylene cap (no liner) is preferred.

3. Sample preservation should be performed immediately upon sample collection. For composite samples each aliquot should be preserved at the time of collection. When use of an automated sampler makes it impossible to preserve each aliquot, then samples may be preserved by maintaining at 4ºC until compositing and sample splitting is completed.

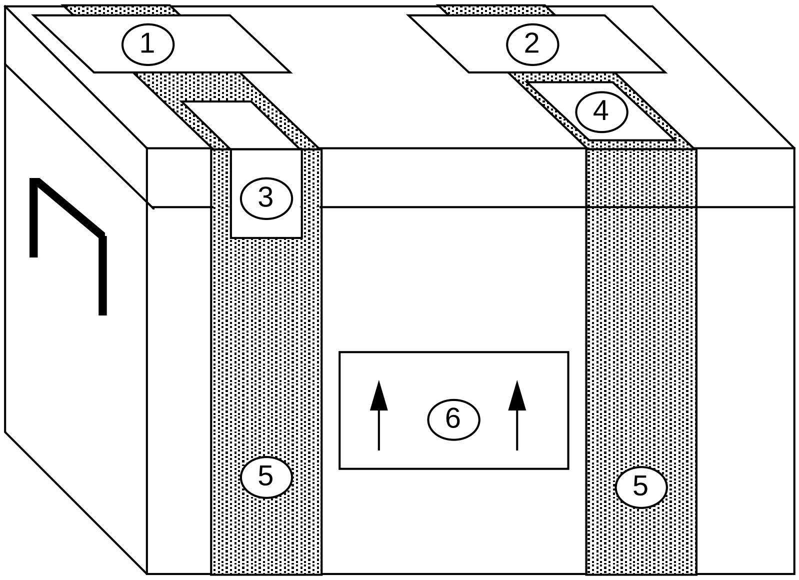
4. When any sample is to be shipped by common carrier or sent through the United States Mail, it must comply with the Department of Transportation Hazardous Materials Regulations (49 CFR Part 172). The person offering such material for transportation is responsible for ensuring such compliance. for the preservation requirements of Table 1, the Office of Hazardous Materials, Materials Transportation Bureau, Department of Transportation has determined that the Hazardous Materials regulations do not apply to the following materials: Hydrochloric acid (HCl) in water solutions at concentration of 0.04% by weight or less (pH about 1.96 or greater); Nitric acid (HNO_3) in water solutions at concentrations of 0.15% by weight or less (pH about 1.62 or greater); Sulfuric acid (H_2SO_4) in water solutions at concentrations of 0.35% by weight or less (pH about 1.15 or 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 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

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

☐ Check here if residence (Extra charge applies for FedEx Express Saver)

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 (Enter FedEx account no. or Credit Card no. below) ☐ Cash/Check

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

WCSL 0997
Rev. Date 5/97
Part #150364
©1994-97 FedEx
PRINTED IN U.S.A.

003520091 4

RETAIN THIS COPY FOR YOUR RECORDS

Attachment III-G-7
Commercial Invoice - Soil

DATE OF EXPORTATION 1/1/94	EXPORT REFERENCES (i.e., order no., invoice no., etc.) <CTO #>
SHIPPER/EXPORTER (complete name and address) Joe Smith Ogden c/o <hotel name> <hotel address>	CONSIGNEE Sample Receipt <Lab Name> <Lab Address>
COUNTRY OF EXPORT Guam, USA	IMPORTER - IF OTHER THAN CONSIGNEE
COUNTRY OF ORIGIN OF GOODS Guam, USA	
COUNTRY OF ULTIMATE DESTINATION USA	

INTERNATIONAL AIR WAYBILL NO. ☐

(NOTE: All shipments must be accompanied by a Federal Express International Air Waybill)

MARKS/ NOS	NO. OF PKGS	TYPE OF PACKAGING	FULL DESCRIPTION OF GOODS	QTY	UNIT OF MEASURE	WEIGHT	UNIT VALUE	TOTAL VALUE
	3	coolers	Soil samples for laboratory analysis only				$1.00	$3.00
	TOTAL NO. OF PKGS.					TOTAL WEIGHT		TOTAL INVOICE VALUE
	3							$3.00
								Check one ☐ F.O.B. ☐ C&F ☐ C.I.F.

THESE COMMODITIES ARE LICENSED FOR THE ULTIMATE DESTINATION SHOWN.

DIVERSION CONTRARY TO UNITED STATES LAW IS PROHIBITED.

I DECLARE ALL THE INFORMATION CONTAINED IN THIS INVOICE TO BE TRUE AND CORRECT

SIGNATURE OF SHIPPER/EXPORTER (Type name and title and sign)

Joe Smith, Ogden	Joe Smith	1/1/94
Name/Title	Signature	Date

ATTACHMENT III-G-8
Commercial Invoice - Water

DATE OF EXPORTATION 1/1/94	EXPORT REFERENCES (i.e., order no., invoice no., etc.) <CTO #>
SHIPPER/EXPORTER (complete name and address) Joe Smith Ogden c/o <hotel name> <hotel address>	CONSIGNEE Sample Receipt <Lab Name> <Lab Address>
COUNTRY OF EXPORT Guam, USA	IMPORTER - IF OTHER THAN CONSIGNEE
COUNTRY OF ORIGIN OF GOODS Guam, USA	
COUNTRY OF ULTIMATE DESTINATION USA	

INTERNATIONAL AIR WAYBILL NO.

(NOTE: All shipments must be accompanied by a Federal Express International Air Waybill)

MARKS/ NOS	NO. OF PKGS	TYPE OF PACKAGING	FULL DESCRIPTION OF GOODS	QTY	UNIT OF MEASURE	WEIGHT	UNIT VALUE	TOTAL VALUE
	3	coolers	Water samples for laboratory analysis only				$1.00	$3.00
	TOTAL NO. OF PKGS.					TOTAL WEIGHT		TOTAL INVOICE VALUE
	3							$3.00
								Check one ☐ F.O.B. ☐ C&F ☐ C.I.F.

THESE COMMODITIES ARE LICENSED FOR THE ULTIMATE DESTINATION SHOWN.

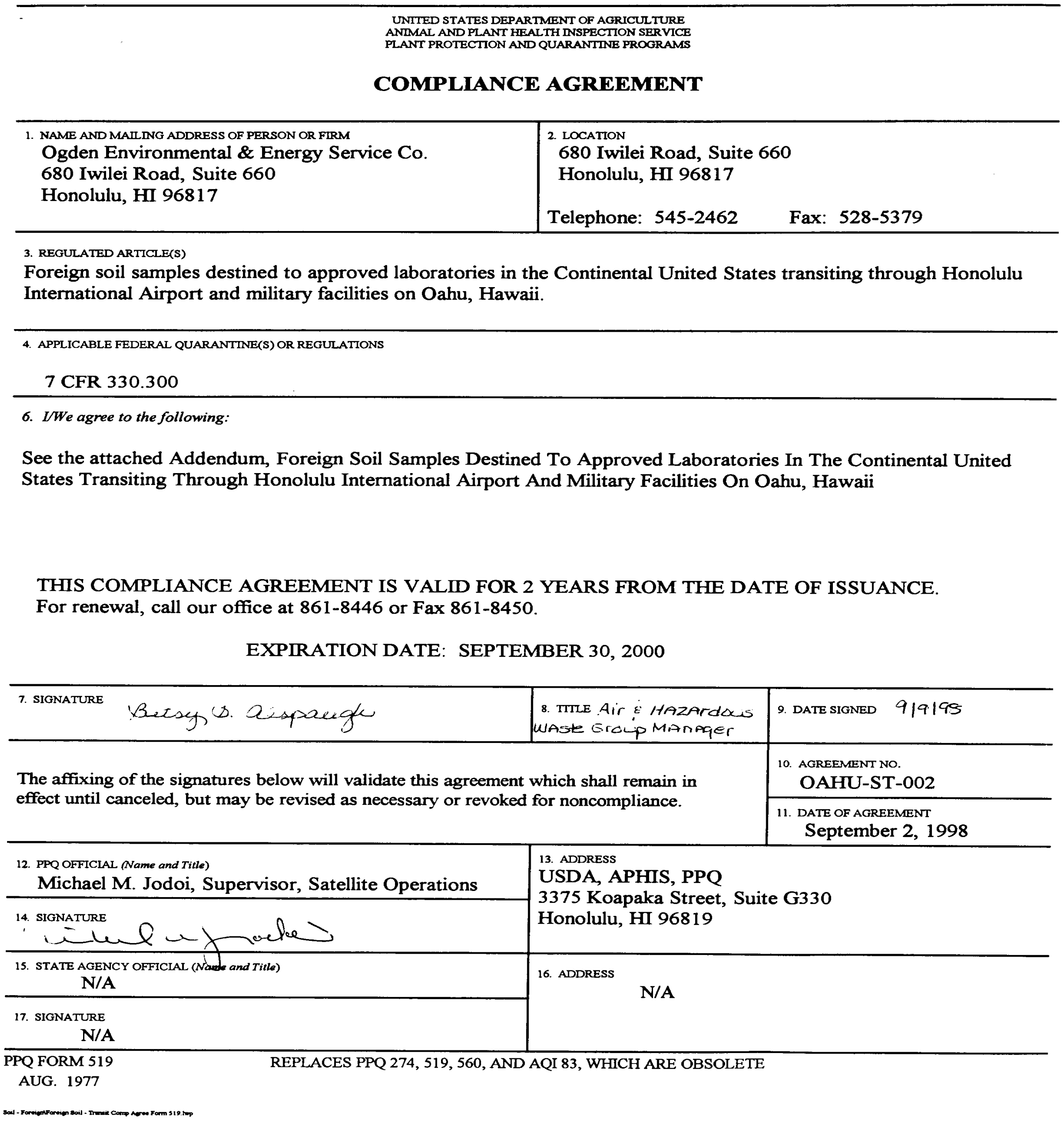
DIVERSION CONTRARY TO UNITED STATES LAW IS PROHIBITED.

I DECLARE ALL THE INFORMATION CONTAINED IN THIS INVOICE TO BE TRUE AND CORRECT

SIGNATURE OF SHIPPER/EXPORTER (Type name and title and sign)

Joe Smith, Ogden	Joe Smith	1/1/94
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.hwp

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.

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.

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)

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

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.

Guidelines for Logging Soil Borings

Tunnels and Earth Engineering Practice

September 2015

Contents

Tables

Figures

Appendixes

Guidelines for Logging Soil Borings

1. Introduction

The purpose of this document is to guide CH2M HILL staff in accurately and consistently recording the field data necessary to characterize soil borings and recovered soil samples. Adherence to a standard format for recording data will help streamline project efforts and lead to a consistent presentation of subsurface data.

2. Policy

The guidelines presented herein are recommended for CH2M HILL projects where soil borings are conducted as part of a subsurface exploration program. These guidelines establish the minimum information that should be recorded in the field to sufficiently describe information gathered during drilling, as well as characterize soil samples collected during the exploration program. Additional information may need to be collected based on project-specific requirements. This document does not address abandonment of boreholes, installations (e.g., piezometer, monitoring wells, thermistors or similar) or final presentation of the data (e.g., gINT logs). Guidelines for these activities will be presented in separate standalone documents.

For projects where environmental contamination is possible or expected, additional planning and procedures will be required that are not included in these guidelines. CH2M health and safety personnel, as well as other experience project staff should be consulted to establish procedures for drilling, sampling, storing, and testing of samples with environmental contamination. For projects where contamination was not expected, but is encountered during the field program, the work should be stopped and the geotechnical task lead contacted before any further work occurs.

The geotechnical task lead should review these guidelines and determine if additional data requirements are needed for the project. Certain project stakeholders (clients or regulators) may require the use of different forms and/or logging requirements. In such cases, the guidelines presented herein should still be referenced to supplement those requirements to meet the overall project goals, as determined by the geotechnical task lead.

The typical CH2M HILL Standard Soil Boring Log Form should be used on all projects for field logging of soil borings (Figure 1). The form provides a template to document information recommended by ASTM D5434, *Standard Guide for Field Logging of Subsurface Explorations of Soil and Rock*, and ASTM D2488, *Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)*. This document provides direction to meet the general requirements of these standards, as well as other relevant ASTM standards discussed subsequently. It should be stressed that the logger should be familiar with the ASTM standards; these guidelines are not a substitute for the ASTM (or other) standards.

CH2M HILL staff members are encouraged to provide suggestions for clarification or improvements to this document.

3. Borings with Soil and Rock

Most exploratory boreholes that involve rock coring are advanced using soil boring techniques until rock is encountered. Because the contact between soil/highly weathered rock and sound rock can be gradual, it is not always clear when to begin rock coring. A separate document, “CH2M HILL Guidelines for Logging of Rock Cores” provides direction on determining how and when to switch to rock coring.

In some cases, both soil drilling and rock coring may be used in a single borehole. For example, where the transition to rock is gradual, coring may be performed through harder rock zones, and Standard Penetration Test (SPT) samples may be taken intermittently where softer material or soil infilling is encountered. Switching back and forth between methodologies requires advance planning with the drilling firm to ensure that the correct equipment is available on-site. Field logs should clearly describe procedures and drilling techniques used to advance the full depth of exploration.

4. Soil Boring Log Form

A typical CH2M HILL Standard Soil Boring Log Form is shown in Figure 1; it is recommended that the form be printed on weatherproof paper (e.g., all-weather *Rite-in-the-Rain* brand paper), which is available from office reprographics departments and from all regional warehouses. See Appendix C for a full-page printable version of the log. Following are instructions for completing the log forms. Appendix A contains examples of completed field soil boring logs.

All heading information on the form should be filled out completely on each log page, and all technical items in each column addressed or otherwise marked "N/A" as appropriate. The logger should review completed logs for accuracy, clarity, consistency, and completeness. On large projects with multiple loggers, it is recommended that logs be frequently reviewed for consistency by a single person (i.e., the geotechnical task lead or designee).

4.1 Soil Boring Log Standard Information

4.1.1 Project Number

Fill in the CH2M HILL project number, including appropriate task and function numbers.

4.1.2 Boring and Sheet Number

Enter the complete boring number, including prefix or suffix. If the boring consists of both soil drilling and rock coring, the soil boring log and the rock core log must have the same boring number. Boring names and numbers should be as required by the client and to meet project requirements. Boring naming convention should be established before the field program commences, and may be as simple as the boring name and number (e.g., B-01) for small projects, or more complex where multiple programs have been conducted over time, or when it is advantageous to indicate installations in the name. An example for the latter case is CH-B-05vwp-15, where CH stands for CH2M HILL, B stands for boring, 05 stands for the boring number, vwp indicates a vibrating wire piezometer, and 15 indicates the last two digits of the year.

Enter the number of the log sheet (i.e., page number). The sheets for a single boring should be sequentially numbered; do not begin a new numbering sequence for any rock core logs that follow soil boring logs. Where rock coring follows soil drilling, appropriate notes should be added to the last soil boring log form used to indicate that the borehole log is continued on the rock core log that follows, beginning at the depth at which soil sampling was ended. These notes should be entered into the Comments column of the log.

4.1.3 Project

Fill in the name of the project or client.

4.1.4 Location and Elevation

For all borings, regardless of whether or not post-survey is planned, record the approximate location of the boring such that the boring can be relocated in the field with the recorded information.

If the boring location was staked or otherwise marked by survey before boring, indicate the distance and direction from the location, using modifiers such as "approximate" or "estimated," as appropriate (e.g., estimate 5 feet NW of staked location). The reason for moving a staked boring may be helpful to note in the Comments section (e.g., gas line interference). When possible, also include stationing, coordinates, mileposts, or similar information (e.g., MP 242+15; 12 feet behind guardrail). If the boring is conducted at the staked location, a notation of "at staked location" should be made.

If a pre-exploration survey location was not provided or is not available, measure to recoverable reference points (e.g., stationary objects such as guardrails, buildings, fire hydrants), with enough measurements to either recover the location for a post-exploration survey or to document the location if a post-survey is not conducted. Where available and informative, identify the client facility, distance from nearest intersection, town and state, or similar descriptive location information. If available, a hand-held GPS unit may also be used to record the boring locations in the field, however, field measurements should still be made to provide a check on the GPS measurements.

Enter the elevation of the ground surface at the boring location. If the boring is offset from a surveyed or staked location with an elevation, provide an approximate elevation difference relative to the ground surface between the staked or surveyed location and the actual boring location. If it is estimated from a topographic map or is roughly determined using a hand level, use the modifier "approximate." As with the boring location, it is important to tie the boring elevation to a recoverable reference point (fire hydrant, floor slab) if no other elevation data are available. Such points can be picked up later in a site survey, from which boring elevations can be determined.

4.1.5 Drilling Contractor

Enter the name of the drilling company and the city and state where the company or the drill crew is based, along with the first initial and full last name of the lead driller.

4.1.6 Drilling Method and Equipment

Identify the drilling method and equipment, including the following:

- Make, model and serial number of the drill rig(s) used in the exploration;
- Method of drilling: e.g., mud rotary, hollow-stem auger, air rotary, sonic, overburden drilling with eccentric big ("ODEX"), etc.;
- Drill tool types and sizes: e.g., rod size for both drilling and sampling, bit type and size, casing size;
- Fluids type: e.g., air, mud, water;
- SPT hammer type (if used) and efficiency (if known): e.g., automatic hammer (eff=78%), safety hammer (no efficiency for safety hammer); and,
- Core barrel type, length, and diameter.

4.1.7 Water Levels

Water levels should be measured at the completion of each boring and recorded in the Comments column with a date and time. For multi-day borings, the water level should be measured each morning before resuming drilling. If possible, obtain a water level reading approximately 24 hours after completion of drilling. Water levels should also be noted during drilling activities, such as when first encountered.

Water levels observed in boreholes that use drilling methods with introduced fluids, such as mud rotary drilling or rock coring, may not be representative of the static water level. For such boreholes, the point at which fluids are added should be noted in the Comments column, e.g., switching from hollow-stem auger to mud rotary techniques.

Water level measurements observed in boreholes with casing still in place to maintain borehole stability may also not be representative of groundwater conditions. Regardless, water level measurements in these instances may be useful and should be recorded with the appropriate notations (e.g., may not be representative due to fluids, amount of casing left in place, etc.).

Water level measurements that are considered representative of static water levels should be entered in the header of the form.

If there are nearby bodies of water, it may be helpful to approximate the water levels in the vicinity of the boring. The information can be helpful in approximating long-term water levels in the exploration area.

If water levels will be taken after completion of drilling using a piezometer, whether an open standpipe, a monitoring well, or installed instrument, the log should include relevant information on the installation of the measurement system in the Comments column. For example, the top and bottom of the sand pack and screened interval, the depth of the instrument installation (e.g., vibrating wire piezometer), initial calibration readings, etc.

4.1.8 Start and Finish

Enter the times and dates the boring was started and completed. These times are intended to document drilling time, not including abandonment or installations. The Comments column can be used to clarify start and finish as required, such as for starting and ending dates and times for abandonment and installations if there are no other forms available to record this information.

4.1.9 Logger

Enter the logger’s first initial and full last name.

4.2 Boring Log Technical Data

4.2.1 Depth Below Surface

Use a scale that is adequate for the needs of the project and does not crowd the field notations. Logging ten to twenty feet per page is often suitable for most projects, depending on the complexity of the subsurface materials. To the extent possible, use the same scale on all sheets for a log; if different scales are required, the scale change should be clearly identified on the log.

4.2.2 Sample Interval, Number, Type and Recovery

For discrete sampling, a solid horizontal line should be drawn across the log in the Sample columns (number, type, recovery) through the SPT column at the top and bottom of each sample attempted, whether SPT, thin-walled (e.g. Shelby tube), or other type. For continuous soil recovery methods such as sonic drilling, a system similar to rock coring may be used where a horizontal line is drawn through the same columns at the top and bottom of each sonic run. For drilling methods such as air rotary where only cuttings are collected, the geotechnical task lead should determine the appropriate means to record the required information. Additional notes and examples are provided below.

- For discrete sampling, the sample number and type should be recorded in the appropriate columns. For example, 1-SS = first sample, split spoon. Number samples consecutively, regardless of type. For example, if a thin-walled tube sample such as a Shelby tube (ST) or a Pitcher tube (PT) sample was taken following the 1-SS sample, their designation should read 2-ST or 2-PT. Enter a sample number for all discrete sample attempts even if no material was recovered in the sampler. Where more than one soil type is recovered in a single SPT and the soils are preserved separately for laboratory testing or other purposes, the sample may be designated with an “A” and “B”, e.g., 2A-SS and 2B-SS.

- For continuous recovery drilling, the run number and type (e.g., 1-SN for sonic) should be entered as the sample number/type. Further sample notions should be determined by the task lead, depending on how much of the soil is collected for preservation and/or laboratory testing. See subsection 7 of these guidelines for additional notes.

- For projects where soil and rock coring is conducted in the same boring, the numerical sequence for the core runs should start with new numbering; e.g., if the last soil sample was 10-SS, the first rock core would be designated 1-HQ. Certain projects may dictate that a continuous numbering system be used from soil sampling to rock core logging. If alternating soil samples and rock core are taken, the sample numbering should remain consecutive (e.g., 8-SS, 9-NQ, 10-SS, 11-NQ, etc.).

- For both discrete and continuous sampling, record the total length of the soil recovered to the nearest tenth of a foot. Slough at the top of the sample should be discarded and not included in recovery measurements.

- For grab or bag samples taken from cuttings (or other recovered materials) during drilling, such as from hollow-stem auger, ODEX or air rotary, recording of the sample information should be determined by the task lead. At a minimum, the sample should be numbered or otherwise appropriately labeled with the estimated depth range (e.g., 6-B or 4-GB, bag sample of ODEX cuttings from 10-15 feet). The numbering may be a separate numbering scheme or continuous with other sampling as appropriate for the project.

4.2.3 Standard Penetration Results

In this column, enter the number of blows required for each 6 inches of sampler penetration and the "N" value, which is the sum of the blows in the last two 6-inch penetration intervals for 18-inch samples and the second and third 6-inch penetration intervals for 24-inch samples. A typical 18-inch SPT involving successive blow counts of 2, 3, and 4 is recorded as 2-3-4 (7); a typical 24-inch SPT involving successive blow counts of 4, 8, 9, and 20 is recorded as 4-8-9-20 (17).

Where an SPT sampler advances or sinks under the weight of rods (WOR) or weight of the hammer (WOH) for part or all of the sample length, the length of travel to the nearest 0.1 foot or inch along with the blow counts required to drive through the remainder of the sample interval should be recorded as the N-value, such as WOH/12”-2. If the sampler sinks the entire sample interval, terminate the sample at the required sampling depth, and record the N-value as WOH, WOR or both as appropriate. Where possible, WOH and WOR samples be drilled out and re-sampled beneath the original sample interval. For this type of re-sampling, and in other similar cases, a 6-inch gap between the bottom of the previous interval and the top of the next interval can help minimize disturbance in the top of the deeper sample.

When there is no soil recovery in an SPT, the soil description column should state “No Recovery” and any notes regarding the sample should be included in the Comments column. As with the case of WOH and WOR samples, no recovery samples should be drilled out and resampled at an appropriate interval beneath the original sample interval where possible and practicable.

A SPT can be terminated prematurely in hard materials if the sampler encounters refusal, where refusal is defined as one of the following:

- A penetration of more than 6 inches but less than 12 inches with a blow count of 100
- A penetration of less than 6 inches with a blow count of 50
- No movement of the sampler after 10 successive hammer blows

Partial penetrations (less than 18”) should be recorded as shown in the following examples:

- An example blow count of 50 blows for 4 inches is recorded as 50/4"
- An example blow count of 27 blows for 6 inches and 50 blows for 3 inches is recorded as 27-50/3”
- An example blow count of 14, 32 and 50 blows in 2 inches is recorded as 14-32-50/2”

See the Standard Penetration Test Procedures subsection of these guidelines for additional discussion.

4.2.4 Soil Description

This section presents the format for the field classification of soil. In general, the approach and format for classifying soils should conform to the latest revision of ASTM D2488, *Visual-Manual Procedure for Description and Identification of Soils*. The Unified Soil Classification System (USCS) Group Symbol is based on numerical values of certain soil properties that are measured by laboratory tests (per ASTM D2487). Also, some elements of a complete soil description, such as the presence of cobbles or boulders, changes in strata, and the relative proportions of soil types in a bedded deposit, can be obtained only in the field. Corrections and additions to the field classification can be made through laboratory testing.

Soil descriptions should be precise and comprehensive without being verbose. The overall character of the soil should not be distorted by excessive emphasis on relatively insignificant details. In general, similarities between consecutive samples should be stressed rather than differences. When samples appear to be of the same material, the description may be recorded as “same as SS-17.” Report the specific sample that is referred to rather than just “same as above.” For minor differences, the description may record the similar sample and the difference such as: “same as SS-19 except very dense” or “same as SS-5 except wet and trace organics.”

The logger should be as consistent as possible in describing samples throughout the field program. By being consistent, final reduction of the field data is more efficient. For example, if a laboratory test shows that a material field-classified consistently as a silt is actually a lean clay, the logs can be updated appropriately. The final boring logs should show the USCS group name in parenthesis, e.g., (ML), when the ASTM D2488 procedures are used, and should show the group name without a parenthesis, e.g., ML, when ASTM D2477 procedures are used (as is done with laboratory testing).

Soil descriptions should be applied as follows:

- For discrete sampling, the soil descriptions should be applied to the samples recovered. For changes in lithology within the soil sample, indicate the length of the materials as measured from either the top of the sample or from the top of the borehole as directed by the geotechnical task lead. For example, SS-5A: 0-5” *describe soil*; SS-5B: 5-13” *describe soil* or SS-3A: 15.0-15.4’ *describe soil*; SS-3B: 15.4-16.2’ *describe soil*
- For thin-wall tube samples, the materials visible at the top and bottom of the tube should be described on the log in the soil description column.
- For continuous soil recovery (e.g., sonic) the soil should be described in a manner similar to rock cores, where the depths are indicated with the appropriate soil descriptors. For example:

  10.0-10.2’: *describe soil*

  10.2-13.4’: *describe soil*

  13.4-15.0’: *describe soil*

  Zones of no recovery should be logged similar to that done for rock core logging (e.g., 17-17.3’ no recovery). See the CH2M HILL Guidelines for Logging of Rock Cores for other guidance that may be helpful.
- For drilling methods where only cuttings are returned (e.g., air rotary), the geotechnical task lead should determine the level of description required to meet the project requirements. As an example, the cuttings can be described for each interval drilled in the Comments column, as the cuttings are not likely to represent the true soil conditions due to alterations in size of the grains and mixing of soils. Any grab samples collected can also be described in the Comments column.

The format and order for soil descriptions should usually be as follows, unless otherwise specified for the project by the task lead:

1. Soil name (synonymous with ASTM D2488 Group Name) with appropriate modifiers
2. USCS Group Symbol
3. Color, preferably using a Munsell soil color chart
4. Moisture content
5. Relative density (sands and gravels) or consistency (silts and clays)
6. Estimate of soil particle percentages and sizes
7. Estimate of plasticity and dilatancy for fine grained soils; estimate of plasticity for fines in coarse grained soils
8. Soil structure, mineralogy, cementation, presence of organics, reaction to HCl, presence of cobbles, or other descriptors such as appropriate to the project

9. Inference of fill versus native material (e.g., “FILL” is stated at the end of the soil description; additional information can be presented in the Comments column)

This order follows, in general, the format described in ASTM D2488. Details on these items are provided in the following sections, and examples of soil descriptions are provided in Table 1.

Soil Name

The basic name of a soil should be consistent with the ASTM D2488 Group Name based on visual estimates of gradation and plasticity. The ASTM D2488 flow charts are presented in Appendix C. Group Symbol application is discussed in the next subsection.

The following are example descriptions; note that percentages are based on weight, not volume:

- A soil sample is visually estimated to contain 15 percent gravel, 55 percent sand, and 30 percent fines (passing No. 200 sieve). The fines are estimated as either low or highly plastic silt. This visual classification is SILTY SAND WITH GRAVEL, with a Group Symbol of (SM).
- Another soil sample has the following visual estimate: 10 percent gravel, 30 percent sand, and 60 percent fines (passing the No. 200 sieve). The fines are estimated as low plastic silt. This visual classification is SILT WITH SAND. The gravel portion is not included in the soil name because the gravel portion was estimated as less than 15 percent. The Group Symbol is (ML).

The gradation of coarse-grained soil (i.e., more than 50 percent retained on No. 200 sieve) is included in the specific soil name in accordance with ASTM D2488. The maximum size and angularity or roundedness of gravel and sand-sized particles should also be recorded. For fine-grained soil (i.e., 50 percent or more passing the No. 200 sieve), the name is modified by the appropriate plasticity/elasticity term in accordance with ASTM D2488.

The presence of large sized materials, such as cobbles and boulders, is often critical information for design and construction considerations. Where there is evidence of cobbles or boulders in the formation such as glacial tills, the soil name should include the modifier “with cobbles” or “with cobbles or boulders,” e.g., Silty Sand with Gravel and Cobbles (SM). Cobbles and large materials may only appear in samples as fragments (e.g., fractured segments where on portion is rounded and the rest is fresh and angular), and the logger should note the presence of the larger materials based on visual observation, as well as drilling action, poor sample recovery due to large materials plugging the sample, or other indirect means which should be noted in the Comments column as appropriate. Because the small sampling size of standard split-spoon samples do not allow for collection of intact large granular materials like cobbles, estimates of percentages of cobbles and boulders are difficult to make with soil borings alone. For projects where obtaining percentages of these materials is desired with a high degree of accuracy, test pits are recommended.

Interlayered or interbedded soil should each be described starting with the predominant type. An introductory name, such as Interlayered (or Interbedded) Silty Sand (SM) and Silt (ML), should be used. Also, the relative proportion of each soil type should be indicated (see Table 1 for example).

Group Symbol

The appropriate group symbol from ASTM D2488 should be given after each soil name. The group symbol should be placed in parentheses to indicate that the classification has been estimated. When laboratory testing is conducted, the final log description should reflect group symbol names with no parenthesis to indicate that ASTM D2487 applies.

In accordance with ASTM D2488, dual symbols (e.g., GP-GM or SW-SC) can be used to indicate that a soil is estimated to have about 10 percent fines. Borderline symbols (e.g., GM/SM or SW/SP) can be used to indicate that a soil sample has been identified as having properties that do not distinctly place the soil into a specific group. Generally, the group name assigned to a soil with a borderline symbol should be the group name for the first symbol. The use of a borderline symbol should not be used indiscriminately. Every effort should be made to first place the soil into a single group.

Color

The predominant color of the soil should be recorded, ideally using the Munsell® soil color chart (Munsell Color, 2009b). The name of the color chip along with the Munsell notation should be recorded on the boring log. In addition to the predominant color, gradual or abrupt color changes, such as mottling or staining, should be recorded. These additional colors can be described using Munsell notations or alternative descriptions at the discretion of the task lead. Review the instructions in the Munsell publications for proper use of the Munsell chart and preservation of the color chips.

Moisture Content

The degree of moisture present in a soil sample should be defined as dry, moist, or wet. Moisture content can be estimated from the criteria listed in Table 2.

Relative Density or Consistency

Relative density of a coarse-grained (cohesionless) soil is based on field N-values (ASTM D1586). If the presence of large gravel or disturbance of the sample (e.g., heave) makes determination of the *in situ* relative density or consistency difficult, then this item should be left out of the description and explained in the Comments column of the soil boring log.

Consistency of fine-grained (cohesive) soil should be estimated from N-values for disturbed samples such as SPTs, and on the results of pocket penetrometer or torvane results for saturated, undisturbed samples (e.g., the bottom of thin tube samples). Pocket penetrometer results may also be useful for disturbed samples, however, however they may not be representative (see Section 8).

Relationships for determining relative density or consistency of soil samples are shown in Tables 3 and 4.

Soil Particle Descriptions, Soil Structure, Mineralogy, Plasticity and Other Descriptors

Other important information to record includes descriptions of the soil mass and discontinuities such as inclusions, joints or fissures, slickensides, bedding or laminations, root holes, organic materials, and wood debris, or other debris materials. Significant mineralogical information should be noted. Cementation, abundant mica, or unusual mineralogy should be described, as well as other information such as organic debris or odor. Estimated percentages may be useful for some items, such as estimate 15% organic particles.

Estimates of particle sizes should be included when possible for each main group of particles (gravel, sand and fines). “Fines” refers to all particles passing the No. 200 sieve; silt-size and clay-size particles should not be estimated separately. The descriptors of plasticity and dilatancy will give an indication of the relative percentage of each. Note that percentages are estimated based on weight, not volume. Percentages should be provided numerically (e.g., estimated 20-25% fines); percentages that are less than five percent may be labeled as “trace” (e.g., trace fine sand).

The particle shapes should be included for at least coarse sands and gravels, and for other sand-size particles as the project requires. This information may be helpful in determining the origin of the materials (e.g., alluvium) and friction angle values. The descriptors should be as shown in Table 6; ASTM D2488 provides photographs of applicable particles for additional reference.

An estimate of plasticity should be provided for the fine-grained fraction of soils classified as silts and clays and for the fines contained within coarse grained soils. The procedures given in ASTM D2488 provide a means to estimate plasticity, which should be reported as shown in Table 7.

Dilatancy should be reported for the fine-grained fraction of soils classified as silts and clays. Dilatancy does not need to be reported for the fines present in coarse grained materials. Dilatancy should be reported as shown in Table 8.

Reaction to hydrochloric acid (HCl) should be recorded for all materials suspected of carbonate derivation or where required for other purposes such as for acid forming potential. HCl reactions should be reported as shown in Table 9. HCl dilution for carbonate material determination is outlined in ASTM D2488, and is generally 1 part concentrated HCl (10 N) and 3 parts distilled water. The HCl (both undiluted and diluted) could cause burns, and care should be taken when handling.

Other relevant descriptors include cementation, dry strength, toughness, structure (e.g., criteria given in Table 7 of ASTM D2488) and other items as determined relevant for the project. Appropriate reporting of these items should be determined by the geotechnical task lead.

Examples of reporting of the items described in this subsection are shown in Table 1.

4.2.5 Relative Drilling Resistance

The relative drilling resistance (RDR) between sample intervals should be assessed and documented. The criteria and typical ground conditions for RDR values ranging from 1 to 5 are summarized in Table 10. The logger should determine a RDR value for each drilling interval between samples, based on the observations and input the driller.

4.2.6 Comments

This column should contain pertinent information not addressed elsewhere on the log form. Types of information to record include pertinent observations (e.g., changes in drilling fluid color, rod drops, drilling chatter, rod bounce as in driving on a cobble, damaged Shelby tubes, and equipment malfunctions). Also note if casing was used, the sizes and depths installed, and if drilling fluid was added or changed.

The driller’s observations and perceptions of the materials encountered can provide valuable information to the logger. A good relationship with the driller should be established at the beginning of the field program, as well as a clear understanding for the driller to alert the field staff to any significant changes in drilling throughout the program. Changes in material, occurrence of boulders, pockets of harder or softer materials, color changes, and loss of drilling fluid can all be invaluable data to record for future interpretation of subsurface conditions. Such information should be attributed to the driller and recorded in this column with the appropriate depth. The abbreviation “DR” for “driller reports” or “driller remark” may be used, e.g., 10’ - DR 50% circulation loss; 25’ – DR material change.

Some projects may require that times be recorded for various items such as sample attempts, start and end of continuous drilling runs, equipment downtime, or similar items.

Specific information to record in the Comment column includes the following:

- The date and time drilling began and ended each day for multi-day borings
- The depth and size of casing and the method of installation
- The date, time, and depth of water level measurements
- Depth of rod chatter or other related drilling information; this information may help to determine the presence of larger diameter material than can be sampled.
- RDR values, with brief description of drilling condition (e.g., constant chattering, no chattering, fast advancing, etc.) and depth
- Depth and percentage of drilling fluid loss
- Use of drilling fluids, changes in drilling fluids

- Notes on cuttings materials (e.g., changes in color, consistency)
- Depth of hole caving or heaving
- Start/end time for continuous drilling runs
- Sample times
- Depth of change in material; this is especially important where discrete samples are collected as it may provide information for interpreting the soil strata between samples
- Presence of large materials such as cobbles, boulders, wood, logs, debris or similar
- Presence and thickness of suspected fill materials
- Sampling information for thin-walled samples (e.g., pressure used, issues, etc.)
- If appropriate for the material sampled, the results of pocket penetrometer or torvane test, eg., PP = _____ TSF or TV = ____TSF.
- Information and/or results of *in situ* testing, as appropriate (e.g., Packer test performed at 17 feet, see separate log)
- Piezometer or other installation information such as unique well number (required by some states), screen and sand pack depths, casing diameter and depth, installation depth of instruments, initial calibration values, etc.
- Abandonment information such as bentonite chips or grout, number of bags used, difficulties in abandonment, surface finish
- Samples pulled for laboratory testing
- Additional samples collected from cuttings
- Description of early boring termination such as drilling refusal, obstacles, or similar; for refusal conditions, record the time to advance the bit (e.g., 5 minutes to advance 2 inches)
- Description of unusual odors or the presence of suspicious materials indicating contamination
- Abbreviations used in the log (e.g., f = fine grained, c = coarse grained, np = non-plastic, etc.)

Depending on project requirements, information on abandonment of the hole (e.g., bentonite chips, grout) and on installations such as monitoring wells, piezometers, and thermistors may also be recorded in this column as directed by the task lead. Examples include the type and number of bags of chips, the time to complete abandonment, well installation details, etc. Abandonment procedures for borings will vary based on state requirements, environmental considerations (e.g., aquifer penetration, contamination, etc.) and future planned facilities (e.g., borings drilled in dam foundations, etc.). Proper abandonment techniques should be established before drilling commences.

5. Standard Penetration Test Procedures

SPTs are conducted to obtain a measure of the resistance of the soil to penetration of the sampler and to recover a disturbed soil sample. Unless project requirements specify otherwise, SPTs should be conducted in accordance with ASTM D1586, *Standard Test Procedure for Penetration Test and Split-Barrel Sampling of Soils*. The information contained in this section provides additional guidance.

McGregor and Duncan (1998) provides a detailed survey and summary of research findings regarding the effects of various practices and equipment on SPT results (e.g., overstating or understating field N-values). While beyond the scope of these guidelines, McGregor and Duncan (1998) also provide a summary of corrections and correlations available for interpreting SPT results, as well as interpreting Becker Penetration Tests.

5.1 Equipment

Before starting the testing, the necessary equipment should be inspected for compliance with the requirements of ASTM D1586. The split-barrel sampler should measure 2-inch outside diameter (O.D.), with 1-3/8-inch inner diameter (I.D.), and should have a split tube at least 18 inches long. The minimum size drilling rod for sampling allowed is "A" rod (1-5/8-inch O.D.). If available, a stiffer rod, such as "N" rod (2-5/8-inch O.D.), should be used for depths greater than 50 feet. The drive weight assembly should consist of a 140-pound hammer weight, a drive head, and a hammer guide that permits a free fall of 30 inches.

Items that should be recorded related to SPT include the information noted below. This information is used to interpret and correct the field SPT results to appropriate engineering values for use in design.

- Sampler size(s)
- Rod size(s)
- Hammer type (e.g., donut, safety, automatic); if the hammer is powered by a cathead, the operator’s first initial and last name should be recorded along with the number of rope wraps.
- Type and use of liners in the sampler
- Significant deviations from the ASTM procedures

For projects where it is critical, the efficiency (energy transfer) of an automatic hammer should be requested from the driller. Energy transfer measurements are performed by a specialized testing firm and are done in accordance with ASTM D4633. Such testing is typically independent of the specific exploration and the readings are considered acceptable if they were obtained within a year of the project, unless significant maintenance or other changes to the hammer have occurred. Some projects may required project-site-specific energy testing.

For project with seismic design elements, see Subsection 5.3 notes.

5.2 Procedures

SPTs should generally be conducted at intervals not exceeding 5 to 10 feet, and at least in every change of strata. Smaller spacing (e.g., 2.5-foot spacing) is often used at the top of the borehole (e.g., first 10 feet) or in specific areas of interest. Larger spacing is permissible when the sampling depth exceeds 100 feet or when the purpose of the hole is to collect information only at specific elevations. Sample spacing should be determined as part of the project planning. SPTs are often also be taken immediately following collection of thin-walled tube samples.

Before driving the split-barrel sampler, loose and foreign material should be removed from the bottom of the borehole. The driller may elect to tag the bottom of the hole with a weighted tape before the tools are lowered into the hole. Alternatively, the rod stickup should be observed and measured when necessary to ensure that the sampler is being driven from the bottom of the borehole. The SPT should be performed by driving a standard split-barrel sampler 18 inches into undisturbed soil at the bottom of the borehole by a 140-pound guided hammer or ram, falling freely from a height of 30 inches. If appropriate or desired for the project, 24-inch samples may also be taken in the same manner.

As noted in subsection 4.2.3, the SPT N-value is the number of blows required to drive the sampler for three 6-inch intervals, for a total of 18 inches (or four 6-inch intervals for a total of 24 inches) and should be recorded on the soil boring log.

5.3 General Considerations

The following comments and suggestions should be considered when performing SPTs:

- Before the start of drilling, it is important to establish a clear protocol for collecting SPT blowcount data. It is important to understand whether the driller, helper or the engineer will measure the blowcounts. Although generally preferable for the engineer to do this, the engineer may be distracted by logging of the previous sample, and the drilling operation may be more efficient and more accurate if it benefits from the undistracted attention of the driller or helper during sampling. If the driller or helper measures the blowcounts, the engineer should spot check blowcounts as a consistency measure.
- The borehole should be cleaned out before every sample attempt. Because a minor amount of caving can be expected, the borehole can be considered to be adequately cleaned if no more than 4 inches of loose or foreign material has collected at the bottom of the borehole. A greater amount of caving is sufficient cause to require the hole to be cleaned again.
- At times “continuous” sampling using SPTs may be employed for additional samples or to adequately characterize the subsurface conditions. This generally consists of using a 24-inch drive for the SPTs and taking samples at 2-foot intervals. Note that the depth accuracy in drilling is generally within 0.5 to 1 foot depending on driller skill and equipment, and no matter how well a borehole is cleaned before a sample, there is always some material left in the borehole. As a result, samples taken in this manner often contain a portion of drilling disturbed soils and/or slough. It may be more advantageous to obtain, 18-inch or 24-inch samples on a 2.5-foot interval to allow for some margin to obtain quality samples. This method of sampling is labor intensive, especially for deeper depths, and should be considered when budgeting projects.
- Where heaving conditions are expected (e.g., loose sands beneath the water table or artesian conditions), drilling methods should be selected to minimize heave, as it generally results in erroneous SPT values. Borings with potential for heave should be carefully monitored and any heave should be recorded on the boring log in the Comments column. Drilling methods such as mud rotary or casing with casing advancer are preferred for expected heaving conditions, however, careful work with hollow-stem augers (HSA), such as an experienced driller using drilling fluids with the HSA and slow withdrawal of the auger plug can also minimize heave. Hollow-stem auger drilling is generally not appropriate for drilling loose sands below the water table unless rigorous heave control measures are implemented.
- The ball check valve in the split-barrel sampler should be cleaned and working properly for each sample. Bent, chipped, or damaged shoes should be replaced. The split-barrel halves should not be warped. In case of zero sample recovery (i.e., if the sample is lost during first attempt), a catcher can be used during subsequent attempts to facilitate recovery.
- During SPT sampling, it is important that rod connections be tight and that the hammer guide be connected securely to the drill rods. If the hammer guide connection becomes loose, much of the hammer energy may be lost because of deflection of the hammer coupling. If a lifting rope is used, it should not rub against the mast.
- During SPT sampling, it is important that the drill rods be positioned at the center of the drill hole. This is necessary to preclude the development of friction between drill rods and the walls of the borehole or casing, and provide consistent and reproducible energy transfer to the sampler.
- If the hammer weight is raised by means of a rope and cathead, generally 2-1/2 wraps on the cathead should be used. The operator should exercise care to prevent friction of the rope on the cathead during the fall of the hammer. The logger should carefully observe sampling procedure for consistency, noting any changes or deviations to the testing in the Comments section of the borehole log.
- Occasionally, non-standard procedures or equipment are used for obtaining samples (such as 3-inch O.D. split-barrel samplers, or 300-pound hammers). Any nonstandard practice should be described in

the Comments section of the borehole log and the blow counts should be clearly marked as not conforming to SPT procedures.

- For projects where the potential for earthquake-induced liquefaction will be determined using the empirical SPT procedure or projects with rigorous quality requirements, additional SPT requirements will be necessary. These include use of a SPT hammer that has a recent efficiency measurement, sometimes referred to as a “calibrated” hammer, and careful recording of all SPT sampling equipment. For consistency of SPT measurements, it is usually necessary to use an automatic hammer. Regardless of the type of hammer, it is critical that the energy delivered by the hammer be established. Hammer efficiency measurements should be conducted for the specific equipment being used, and if the rope-cathead procedure is being used, for the specific operators who will conduct the SPTs in the field. The geotechnical task lead should determine the appropriate calibration period, e.g., if an efficiency measurement within the past year is acceptable or if a project specific efficiency measurement should be conducted for the project.

6. Thin-walled Samples

Thin-walled tube samples are often taken on projects with fine-grained materials where specialty testing such as strength and consolidation are desired. Thin-walled samples are often referred to as “undisturbed” samples, but it is more accurate to describe them as “relatively undisturbed, “especially as compared SPT samples. Thin-walled samples should be obtained in accordance with ASTM D1587 *Thin-Walled Tube Sampling of Soils for Geotechnical Purposes*. Specific field sampling procedures followed should be noted on the logs.

As with SPT samples, the ASTM D1587 provides information on the appropriate dimensions for samplers. This information and any deviations should be recorded on the boring log in the Comments section. Tubes used for samples should be inspected and observed for wall thickness, end taper or cutting edge, coatings, presence of rust, etc.

During testing, pertinent information that should be recorded is outlined below:

- Information on the sampler type: e.g., direct push Shelby Tube, Osterberg type sampler, Pitcher barrel type sampler;
- Pressure applied during the test for soft materials, e.g., down pressure or hydraulic pressure from the rig (per rig gauges) or if the material is soft enough, weight of the rods, etc.;
- Drilling times or related information for hard materials recovered through a pitcher tube type sampler;
- Issues with recovery of the sampler such as excessive handling or disturbance;
- Notation of any damage to the tube;
- Recovery of the sample collected in the tube;
- Results of field strength testing such as pocket penetrometer results and/or torvane results;
- SPT samples may be desirable immediately below thin-walled samples (e.g., taken in the same hole as the thin-walled sample was extracted)
- Specific field procedures, such as allowing the sample to sit for a period of time before retrieving the sample.

Samples obtained from thin-walled techniques are generally used for higher-order, more expensive laboratory testing and care should be taken to achieve as high a quality of sample as possible.

7. Sonic Drilling

Recording information from sonic drilling or a similar continuous sampling process has been noted in other sections of this report. The information collected from sonic drilling will depend on the project goals. If the goal of the project is for the entirety of the recovered soil materials (referred to as a soil core) is to be logged and preserved, procedures similar to those used for rock coring are applicable (e.g., logging of the entire recovered soil core by depth, notation of strata changes, zones of no recovery). Discrete samples pulled for laboratory testing should be recorded on the log in the Comments column (e.g., 7-B, bag sample from 10.4 to 10.8 feet).

8. Field Strength Testing

Routine field strength testing includes pocket penetrometer and torvane testing. The instructions included with these tools should be followed for proper use. Additional guidance is included below. Other field strength testing such as field vane shear are not covered in these guidelines (see ASTM and other agencies).

- Pocket penetrometer and torvane testing are intended to measure undrained strength, and therefore are only applicable to saturated, fine-grained materials, e.g., silts and clays. Fine grained materials with sizeable coarse grained fractions, e.g. Silt with Gravel, should not be tested with these tools. If unsaturated materials are tested, appropriate notes should be recorded in the Comments column and the collected data should be carefully considered for applicability and accuracy.

- Pocket penetrometer testing should be implemented on recovered SPT samples and at the bottom of thin-walled tube samples, where possible. Pocket penetrometer testing may also be useful on sonic cores. The depth and results should be recorded in the Comments column.

- Torvane testing should be implemented at the bottom of thin-walled tube samples, where possible. The depth and results should be recorded in the Comments column.

9. Labeling, Handling and Photographing of Soil Samples

9.1 Sample Labeling and Handling

The samples recovered from the borehole are an important part of the boring record and should be properly packaged and labeled. Samples that are improperly or inadequately labeled are not useful. The following description outlines the typical requirements for packaging and labeling of samples; additional or more specific labeling may be required for certain projects.

- Disturbed (SPT) samples should be placed in glass jars or in sturdy plastic bags that are appropriately labeled. At a minimum, the project name, project number, boring number, sample number, sample depth, and date should be recorded. The choice of storage container should be based on planned laboratory tests and time frames. For example, if moisture contents are critical, sturdy plastic bags are appropriate if laboratory testing will take place shortly after collection. Otherwise, glass jars may be a better choice. Minimum sample sizes should be considered based on planned laboratory testing; in general, it is advisable to collect as much of each sample as possible to provide options for the laboratory. As noted previously, samples which encounter 2 separate material types should be split into multiple samples (e.g., A and B). SPT samples collected while mud-rotary drilling should take care to remove excess drilling fluid prior to placing in bags or jars.

- Thin-walled tubes should be cleaned of mud and moisture. When dry, use an indelible marker to label the sides with the following information: an arrow indicating the top of the sample, project name, project number, boring number, sample number, sample depth, amount of recovery, and date. The top and bottom of the sample should be circumscribed on the outside of the tube with a marker. The top lid of the tube should be labeled with the boring number, sample number, and depth, e.g.: A-12, 4-ST, 5-7’. Plastic lids should be placed on the ends and taped with airtight tape, such as electrical tape. Make certain that the holes in the top of the tube are sealed. The open portion of the tube above the sample should be packed to prevent shifting of the soil with a non-absorbent material. Dampened newspaper is a convenient packing material, but can be problematic for a long-term storage and should be separated from the soil sample by a wax seal or an inverted cap. Waxing of Shelby tubes is essential if sample testing will not occur within a few days. Shelby tubes should be transported and stored vertically (top end up) with as little disturbance as possible.

- For sonic samples, if the entirety of the sonic core is planned to be kept for a period of time, appropriately sized boxes should be used to store the core. The boxes should be labeled similar to rock cores with the project name, project number, boring number, depths contained in the box, date, and where required, the recovery for each run. If only individual samples are pulled for preservation, the containers should be labeled with the project name, project number, boring number, depth range, and date.

Handling and storage of samples is dependent on the planned laboratory testing program and other project requirements. On large or remote projects where laboratory testing might be staged and samples may need to be stored for a long period of time, special storage conditions may be required, such as maintaining certain temperature and humidity levels. Samples of any type should not be allowed to freeze. Thin-walled samples have special considerations to keep them as “undisturbed” as possible. Samples that are contaminated or are expected to be contaminated should be handled in accordance with the health and safety plan for the project. ASTM D4220 *Standard Practices for Preserving and Transporting of Soil Samples* provides guidance on preserving and transporting samples.

9.2 Photographing of Soil Samples

As directed by the task lead, photographs of split-spoon and sonic samples should be collected in the field. Guidance is provided below and examples are provided in Appendix B.

- For SPTs, the sample should be photographed while still in the split-spoon with a whiteboard or other method indicating the sample information listed in subsection 9.1. The split-spoon should be photographed with the top of the sample on the left hand side of the photograph. A legible scale and a Munsell color chart (where used on the project) should be included in the photograph.
- For sonic cores, the samples should be photographed similar to rock cores. One sonic run or core box should be photographed at a time, and depending on the size of the box, several photographs may be required to adequately show the soil core. For example, an overall picture to show the entire core box should be included, along with close-ups of the box (e.g., right, middle, left hand sides of the box) so that the details of the core are visible. Special features or samples selected for laboratory testing can also be photographed separately. The inner box lid or a white board with the same information should be framed in the picture to include pertinent information. Photos should not be oblique and should include a legible scale, such as a folding ruler; if used on the project, the Munsell color chart should be included in a photograph. Photographs can be most easily and efficiently taken in the field while the soil core is fresh, and with natural light.

10. Field Equipment and Field Reference Guides

A suggested field equipment list of tools and supplies that are useful or necessary in various phases of soil logging is provided in Appendix C, along with a field reference guide that provides quick access to the many of the key logging items discussed in this procedure. Appendix C also contains a full page version of the soil log suitable for copying, as well as the ASTM flow charts for determining Group Symbol and Group Name.

11. References

11.1 Cited References

ASTM D1586. *Standard Test Method for Penetration Resistance and Split Barrel Sampling of Soils*. American Society for Testing and Materials. 1999.

ASTM D1587. *Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes*. American Society for Testing and Materials. 2000.

ASTM D2487. *Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System).* American Society for Testing and Materials. 2000.

ASTM D2488. *Standard Practice for Description and Identification of Soils (Visual – Manual Procedure)*.American Society for Testing and Materials. 2000.

ASTM D4220. *Standard Practice for Preserving and Transporting Soil Samples*. American Society for Testing and Materials. 2000.

ASTM D4633. *Standard Test Method for Energy Measurement for Dynamic Penetrometers*. American Society for Testing and Materials. 2010.

ASTM D5434: *Standard Guide for Field Logging of Subsurface Explorations of Soil and Rock.* American Society for Testing and Materials.

Hunt, S.W. (2014). Tunneling in Cobbles and Boulders. Breakthroughs in Tunneling Short Course, Colorado School of Mines.

McGregor, J.A. and Duncan, J.M. (1998). Performance and Use of Standard Penetration Test in Geotechnical Engineering Practice. Center for Geotechnical Practice and Research, Charles E. Via, Jr. Department of Civil Engineeering, Virginia Tech. October.

Munsell Color. 2009a. *Munsell Soil Color Book*. Munsell Color, 4300 44th Street, Grand Rapids, MI.

Sowers, G. F. Introductory Soil Mechanics and Foundations: Geotechnical Engineering. MacMillan Publishing Co., New York, 4th edition. 621 pp. 1979.

11.2 Non-Cited References

Bell, F. G. Engineering Properties of Soils and Rocks. Butterworth Publishers, Inc., London, 1981.

Burmister, D. M. "Principles and Techniques of Soil Identification," Proceedings of the Highway Research Board, pp. 402-433, 1949.

Casagrande, A. "Classification and Identification of Soils", American Society of Civil Engineers Transactions, pp. 901-991, 1947.

Kovacs, W. D., L. A. Salomone, and F. Y. Yokel. Energy Measurement in the Standard Penetration Test. U.S. Dept. of Commerce, National Bureau of Standards, Building Science Series 135, 1981.

Matula, M. "Rock and Soil Description and Classification for Engineering Geological Mapping", Report by the IAEG Commission on Engineering Geological Mapping. Bulletin of the International Association of Engineering Geology, No. 24, pp. 235-274, 1981.

Federal Highway Administration (FHWA). 2002. Geotechnical Engineering Circular No. 5 - Evaluation of Soil and Rock Properties. FHWA-IF-02-034. April.

U.S. Bureau of Reclamation. Earth Manual. 2nd ed., Washington, D.C. U.S. Government Printing Office, 1974.

Tables

TABLE 1

Example Soil Descriptions

Group Name and Symbol	Description
Poorly Graded Sand (SP)	light brown (7.5YR 6/3), moist, loose, fine silica sand, trace non-plastic fines
Fat Clay (CH)	dark gray (7.5YR 4/1), moist, stiff, high plasticity, no dilatancy
Silt (ML)	light greenish gray (GLEY 1 7/1), wet, very loose, non-plastic, very rapid dilatancy, some mica, moderate HCL reaction, carbonate derived.
Well-Graded Sand With Gravel and Cobbles (SM)	reddish brown (2.5 YR 5/4), moist, dense, fine to coarse sand, est. 20% subangular gravel to 0.6 inch maximum, cobbles to est. 8”, est. 10% non-plastic fines, trace organic particles
Poorly Graded Sand With Silt (SP-SM)	white (5YR 8/1), wet, medium dense, fine to medium sand, est. 10-15% non-plastic fines, no HCL reaction
Organic Soil With Sand (OH)	dark brown to black (7.5YR 3/2 t0 2.5/1), wet, firm to stiff, est. 20% fine sand, trace of mica, fine roots, no HCL reaction
Silty Gravel With Sand (GM)	light red (2.5 YR 6/8), moist, very dense, fine to medium sand, est. 25% subrounded gravel to 1.2 inches maximum, est. 30% non-plastic fines, strongly cemented
Interlayered Silt (ML) and Silty Sand (SM)	60% ML and 40% SM; layers 1.5 to 3 inches thick; olive gray (5Y 5/4), ML is nonplastic, very rapid dilatancy; SM is fine sand with est. 35% non-plastic fines
Lean Clay (CL)	dark greenish gray (GLEY 1 4/1), moist, firm, low to medium plasticity, slow dilatancy, trace very fine sand, interbedded CL layers 0.2 to 1.2 inches thick, no HCL reaction
Silty Sand With Gravel (SM)	light yellowish brown (10YR 6/4), moist, medium dense, well-graded sand, est. 25% gravel to 1.0 inch maximum, est. 15-20% fines, trace small particles of coal, fill
Sandy Elastic Silt (MH)	light gray to white (5YR 7/1 to 8/1), wet, stiff, non-plastic, very rapid dilatancy, est. 35% fine carbonate sand, moderately cemented, mild HCl reaction
Lean Clay With Sand (CL)	very dark grayish brown (10YR 3/2), moist, stiff, low plasticity, slow dilatancy, est. 30% fine sand
Well-Graded Gravel With Silt and Sand (GW-GM)	Brown (7.5YR 4/3), moist, very dense, rounded gravel to 3.0 inch maximum, est. 10% fine to coarse sand, est. 20% non-plastic fines.

TABLE 2

Criteria for Describing Moisture Content

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

Source: ASTM D2488

TABLE 3

Relative Density of Coarse-Grained Soil

Blows/Ft	Relative Density
0-4	Very loose
5-10	Loose
11-30	Medium
31-50	Dense
50	Very Dense

Source: Sowers, 1979

TABLE 4

Consistency of Fine-Grained Soil

Blows/Ft	Consistency	Pocket Penetrometer (TSF)	Torvane (TSF)	Field Test
<2	Very soft	<0.25	<0.12	Easily penetrated several inches by fist
2-4	Soft	0.25-0.50	<0.12-0.25	Easily penetrated several inches by thumb
5-8	Firm	0.50-1.0	0.25-0.5	Can be penetrated several inches by thumb with moderate effort
9-15	Stiff	1.0-2.0	0.5-1.0	Readily indented by thumb, but penetrated only with great effort
16-30	Very stiff	2.0-4.0	1.0-2.0	Readily indented by thumbnail
30	Hard	>4.0	>2.0	Indented with difficulty by thumbnail

Source: Sowers, 1979

TABLE 5
Particle Size Guidance

Description	Sieve Size	Examples
Boulder	Greater than 12 inches	> Basketball
Cobble	3 to 12 inches	Fist to basketball
Coarse Gravel	3/4 to 3 inches	Thumb to fist
Fine Gravel	No. 4 to 3/4 inches (4.75mm to 3/4 inches)	Pea to thumb
Coarse Sand	No. 10 to No. 4 (2.0 to 4.75 mm)	Rock salt to pea
Medium Sand	No. 40 to No. 10 (0.425 to 2.0 mm)	Sugar to rock salt
Fine Sand	No. 200 to No. 40 (0.075 to 0.425 mm)	Flour to sugar
Silt and Clay	Passing No. 200 (< 0.075mm)	Grains not visible

TABLE 6
Criteria for Describing Angularity of Coarse-Grained Particles

Description	Criteria
Angular	Particles have sharp edges and relatively plane sides with unpolished surfaces
Subangular	Particles are similar to angular, but have rounded edges
Subrounded	Particles have nearly plane sides, but have well-rounded corners and edges
Rounded	Particles have smoothly curved sides and no edges

Source: ASTM D2488

TABLE 7
Criteria for Describing Plasticity

Description	Criteria
Nonplastic	A 1/8-inch (3-mm) thread cannot be rolled at any water content
Low	The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit
Medium	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. The lump crumbles when dried than the plastic limit.
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rerolled several times after reach the plastic limit. The lump can be formed without crumbing when drier than the plastic limit.

Source: ASTM D2488

TABLE 8
Criteria for Describing Dilatancy

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

Source: ASTM D2488

TABLE 9
Criteria for Describing Reaction with Hydrochloric Acid (HCl)

Description	Criteria
None	No visible reaction
Weak	Some reaction, with bubbles forming slowly
Strong	Violent reaction, with bubbles forming immediately

Source: ASTM D2488

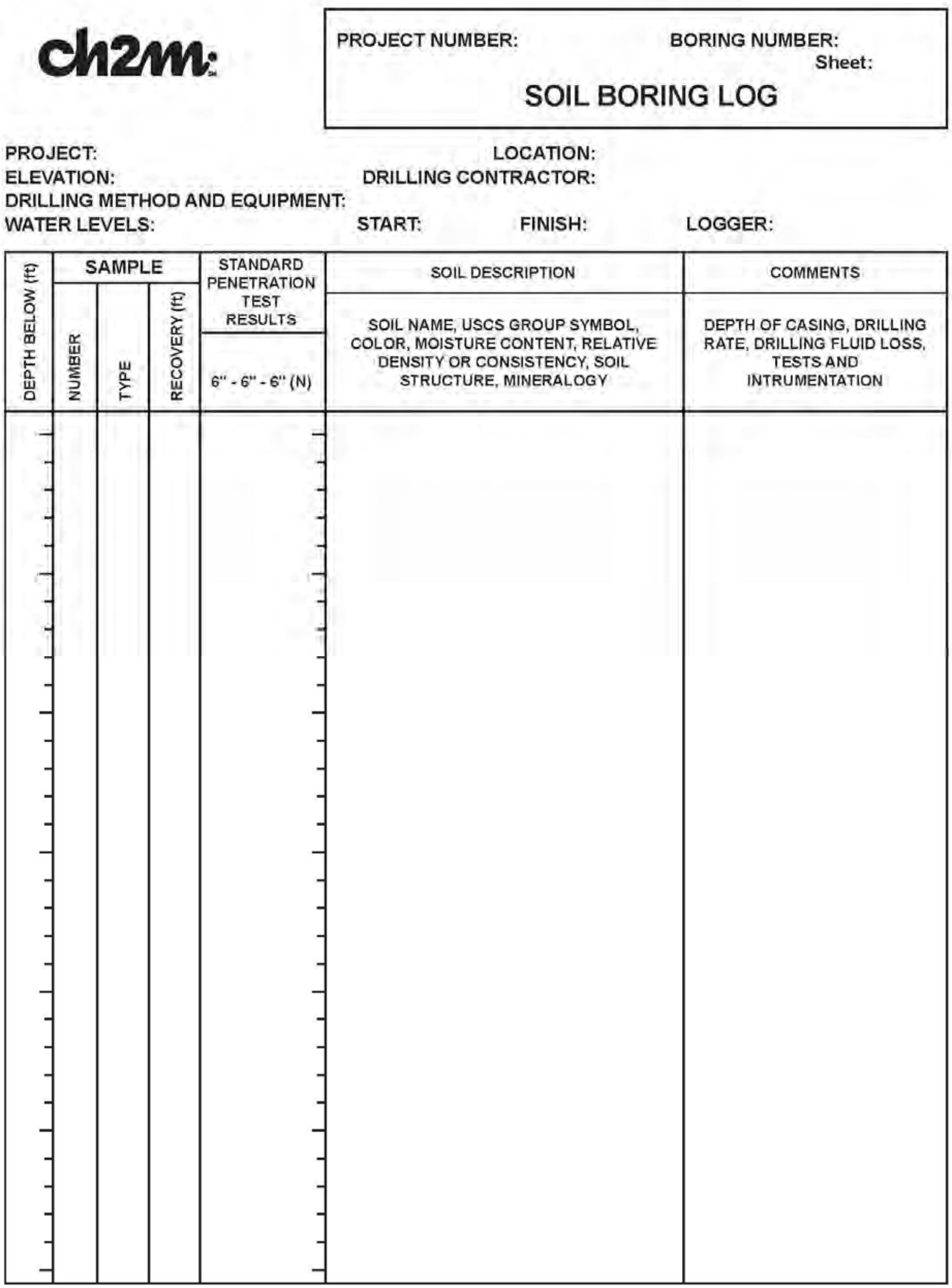
TABLE 10
Relative Drilling Resistance Criteria

RDR	Term	Criteria	Typical Ground Conditions
1	Very easy	No chatter, very little resistance, very fast and steady drill advance rate	Very soft to soft silts and clays; very loose to loose silts and sands; no gravel, cobbles, boulders or rubble
2	Easy	No chatter, some resistance, fast and steady drill advance rate	Firm to stiff silts and clays; loose to medium dense silts and sands; little or no gravel, no to very few cobbles, boulders or pieces of rubble
3	Moderate	Some chatter, firm drill resistance with moderate advance rate	Stiff to very stiff silts and clays; dense silts and sands; medium dense sands and gravel; occasional cobbles or rubble pieces (2 to 3 occurrences per 10 feet)
4	Hard	Frequent chatter and variable drill resistance, slow advance rate	Very stiff to hard silts and clays with some gravel and cobbles; very dense to extremely dense silts and sands with some gravel; dense to very dense sands and gravel; very weathered, soft bedrock; frequent cobbles and boulders or rubble pieces (3 to 4 occurrences per 10 feet)
5	Very hard	Constant chatter, variable and very slow drill advance, nearly refusal	Hard to very hard silts and clays with some gravel; very dense to extremely dense gravelly sand or sandy gravel; very frequent cobbles and boulders (at least 5 occurrences per 10 feet); weathered, very jointed bedrock

Source: Hunt, 2014

Figures

FIGURE 1
Blank Soil Boring Log (Typical) [See Appendix C for a full page copy]



ch2m

PROJECT NUMBER: **BORING NUMBER:**
Sheet:

SOIL BORING LOG

PROJECT: **LOCATION:**
ELEVATION: **DRILLING CONTRACTOR:**
DRILLING METHOD AND EQUIPMENT:
WATER LEVELS: **START:** **FINISH:** **LOGGER:**

DEPTH BELOW (ft)	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	COMMENTS
	NUMBER	TYPE	RECOVERY (ft)	6" - 6" - 6" (N)	SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INTRUMENTATION

Appendix A
Examples of Completed Soil Boring Logs

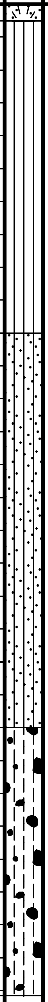
CH2MHILL

PROJECT NUMBER: 462759

BORING NUMBER: B-3A SHEET 1 OF 1

SOIL BORING LOG

PROJECT : Rocky Hill Interceptor, Rocky Hill/ Wethersfield, CT
LOCATION : Wethersfield, CT
ELEVATION : 28.0 ft
DRILLING CONTRACTOR : O. Cone/ New England Boring
DRILLING EQUIPMENT AND METHOD : Mobile Drill B-53, 2-1/4" SSA, 3-1/4" HSA
ORIENTATION : Vertical
WATER LEVELS : ▼ dry during and after drilling
START : 5/29/2013
END : 5/29/2013
LOGGER : Y. L. Chou



DEPTH BELOW EXISTING GRADE (ft)	INTERVAL (ft)	RECOVERY (in)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
28.0	5.0				**3" Top Soil** 0-0.25' **Gravelly Silt With Sand (stratum 1) (ML)** 0.25' - brown to red brown, dry, stiff, nonplastic, coarse to fine gravel, coarse to fine sand, contains brick fragments	140 lbs Safety Hammer, 30" drop, NWJ rod, 2" OD & 24 " long Split Spoon Sampler, Off set 3' south east from B-3; Solid Stem Auger drilling to 5'. GW is dry during drilling and at completion. RDR = 2-3 (occcasional chattering and grinding)
5 23.0	7.0	20.0	SS-1	10-12-17-30 (29)	**Silty Sand With Gravel (stratum 1) (SM)** 5' - brown to red brown, moist, medium dense, coarse to fine sand and gravel	Switched to Hollow Stem Auger drilling RDR = 3 (chattering near 6')
	9.0	13.0	SS-2	40-28-22-17 (50)	7' - Same as above except dense, contains 1" cobble fragment	RDR = 2-3
10 18.0	11.0	17.0	SS-3	13-22-37-28 (59)	9' - Same as above except very dense	Wc=9.5% 41% fines RDR = 3-4 (grinding at 10')
	11.8	6.0	SS-4	22-50/4 (50/4")	**Poorly Graded Gravel With Sand And Silt (stratum 3) (GP-GM)** 11' - brown to red brown, dry, very dense, coarse to fine gravel and sand, cobble at 11'	RDR = 2-3 DRD = 4-5 (grinding at 11.5')
	13.0 13.1	0.0	SS-5	50/1 (50/1")		RDR = 4 (resistance; slow advancement)
15 13.0	15.0 15.1	1.0	SS-6	50/1 (50/1")	15' - 1" light gray rock fragment Bottom of Boring at 15.1 ft bgs on 5/29/2013	RDR = 4-5 (constant, slow advancement and grinding) Auger refusal at 15'
20						

PROJECT NUMBER:	BORING NUMBER:
338884	BCA-7 SHEET 1 OF 2

SOIL BORING LOG

PROJECT : PEC COLA, New Hill, NC
LOCATION : (NAD 27) (687127.9 N, 2013818.7 E)
ELEVATION : 263.2 ft MSL (NGVD 29)
DRILLING CONTRACTOR : K. Canuel, S&ME
DRILLING EQUIPMENT AND METHOD : CME-750, Tricone Bit, 24 Split Spoon, 140 lb. Automatic Hammer
ORIENTATION :
WATER LEVELS : ---
START : 8/9/06 11:17
END : 8/9/06 16:07
LOGGER : LH

DEPTH BELOW EXISTING GRADE (ft)	INTERVAL (ft)	RECOVERY (in)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	SYMBOLIC LOG	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
263.2	0.0 2.0	14.0	SS1SS	5-8-9-11 (17)	**Clay (CL)** 0.0-1.2' - reddish brown, light greenish gray mottling, dry, very stiff, trace roots	▨	
	2.5 4.5	15.0	SS2SS	6-5-11-14 (16)	**Clay (CL)** 2.5-3.8' - reddish brown, trace brown mottling, dry, very stiff, gray sand pockets very fine to medium grained 3.5-3.8' - trace gravel laminated beds	▨	
5 258.2	5.0 7.0	12.0	SS3SS	8-9-11-13 (20)	**Clay (CL)** 5.0-6.0' - reddish brown, trace brown mottling, dry, very stiff, gray and yellowish brown sand pockets very fine to medium grained	▨	
	7.5 9.5	15.0	SS4SS	7-8-10-16 (18)	**Clay (CL)** 7.5-8.8' - reddish brown, trace brown mottling, dry, very stiff, brown clay pockets mottled light gray	▨	
10 253.2	10.0 12.0	7.0	SS5SS	34-50/6 (50/6")	**Clay (CL)** 10.0-10.6' - reddish brown, moist, hard, low plasticity, laminated	▨	Install NW surface casing to 10' bgs.
	12.5 14.5	5.0	SS6SS	50/5 (50/5")	**Clay (CL)** 12.5-13.0' - reddish brown, moist, hard, low plasticity, reddish black linear mottles	▨	
15 248.2	15.0 17.0	11.0	SS7SS	39-50/6 (50/6")	**Clay (CL)** 15.0-16.0' - reddish brown, mottled reddish black and light greenish gray, moist, hard, low plasticity	▨	
	17.5 19.5	10.0	SS8SS	15-17-50/5 (67/11")	**Clay (CL)** 17.5-18.4' - reddish brown, mottled reddish black and light greenish gray, moist, hard, low plasticity	▨	
20							

PROJECT NUMBER:	BORING NUMBER:
338884	BCA-7 SHEET 2 OF 2

SOIL BORING LOG

PROJECT : PEC COLA, New Hill, NC
LOCATION : (NAD 27) (687127.9 N, 2013818.7 E)
ELEVATION : 263.2 ft MSL (NGVD 29)
DRILLING CONTRACTOR : K. Canuel, S&ME
DRILLING EQUIPMENT AND METHOD : CME-750, Tricone Bit, 24 Split Spoon, 140 lb. Automatic Hammer
ORIENTATION :
WATER LEVELS : ---
START : 8/9/06 11:17
END : 8/9/06 16:07
LOGGER : LH

DEPTH BELOW EXISTING GRADE (ft)	INTERVAL (ft)	RECOVERY (in)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	SYMBOLIC LOG	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
243.2	20.0 22.0	5.0	SS9SS	50/5 (50/5")	**Clay (CL)** 20.0-20.5' - reddish brown, mottled reddish black and light greenish gray, moist, hard, low plasticity	▨	
25 238.2	25.0 27.0	6.0	SS10SS	50/6 (50/6")	**Silt (ML)** 25.0-25.3' - light gray and pale red, moist, very dense **Clay (CL)** 25.3-25.5' - reddish brown, mottled reddish black and light greenish gray, moist, hard, low plasticity	▥ ▨	
							First water level = 7.4' bgs taken 8/10/06 at 20:02
30 233.2	30.0 30.2	2.0	SS11SS	50/2 (50/2")	**Sand With Silt (SP-SM)** 30.0-30.2' - light gray and pale red, moist, very dense, very fine to fine grained, subangular to subrounded, poorly sorted, 20% silt Bottom of Boring at 30.2 ft bgs on 8/9/06 16:07	⋯	
35 228.2							
40							

CH2MHILL

PROJECT NUMBER: 338884.FL

BORING NUMBER: A-01 SHEET 1 OF 9

SOIL BORING LOG

PROJECT : Progress Energy Florida - COLA Investigation, Levy County Site LOCATION : 1723879.2 N, 457603.8 E (NAD83)

ELEVATION : 41.6 ft (NAVD88) DRILLING CONTRACTOR : Universal Engineering Sciences, Jacksonville, FL; Driller: B. Truitt; Cathead Operator: B. Crews

DRILLING METHOD AND EQUIPMENT : Dietrich D-50 S/N 232, mud rotary, cathead, NWJ rods, 6 tri-cone bit ORIENTATION : Vertical

WATER LEVELS : 2 ft bgs on 03/15/07 START : 3/14/2007 END : 3/21/2007 LOGGER : R. Bitely

DEPTH BELOW SURFACE AND ELEVATION (ft)	SAMPLE INTERVAL (ft)	RECOVERY (ft)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	SYMBOLIC LOG	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
41.6							"Water level is based on Ground Water Monitoring at LNP site (FSAR Table 2.4.12.08)" Water at 6' below ground surface
5 36.6	3.5 5.0	1.0	SS-1	5-4-3 (7)	**Poorly Graded Sand With Silt (SP-SM)** 3.5-4.5' - very pale orange to moderate yellowish brown, (10YR 8/2 to 10YR 5/4), wet, loose, very fine to fine grained, 10-15% fines, nonplastic, <10% root matter and organic material, trace concretions up to 1/4", very fine silica sand and silt in an iron matrix		Few dense lenses from 5.0-8.5', thin, relatively consistent drilling rate (moderately rapid)
10 31.6	8.5 9.4	0.5	SS-2	9-50/5 (59/11")	**Limestone Fragments** 8.5-8.75' - very pale orange, (10YR 8/2), strong HCl reaction, gravel-sized, subrounded to angular, up to 1"x1-1/2" **Silt (ML)** 8.75-9.0' - grayish orange, (10YR 7/4), moist to wet, hard, nonplastic, rapid dilatancy, mild to moderate HCl reaction, 10-15% very fine to medium grained sand, all carbonate derived		Very hard from 9.0-12.5', possible limestone lenses, light chatter, extremely slow advancement rate Relatively consistent from 12.5-28.5', moderately rapid drilling rate
15 26.6	13.5 15.0	0.8	SS-3	27-17-4 (21)	**Silt With Limestone Fragments (ML)** 13.5-14.3' - very pale orange, (10YR 8/2), wet, very stiff, nonplastic, mild to moderate HCl reaction, 10-15% very fine to fine grained sand, 3 limestone lenses (<1/2") at 13.5', 13.7' and 14.0', all carbonate derived		
20	18.5 20.0	1.3	SS-4	40-54-50 (104)			SS-4 actual sample depth is 18.5-20.0'

PROJECT NUMBER:	BORING NUMBER:	
338884.FL	A-01	SHEET 2 OF 9

SOIL BORING LOG

PROJECT : Progress Energy Florida - COLA Investigation, Levy County Site LOCATION : 1723879.2 N, 457603.8 E (NAD83)

ELEVATION : 41.6 ft (NAVD88) DRILLING CONTRACTOR : Universal Engineering Sciences, Jacksonville, FL; Driller: B. Truitt; Cathead Operator: B. Crews

DRILLING METHOD AND EQUIPMENT : Dietrich D-50 S/N 232, mud rotary, cathead, NWJ rods, 6 tri-cone bit ORIENTATION : Vertical

WATER LEVELS : 2 ft bgs on 03/15/07 START : 3/14/2007 END : 3/21/2007 LOGGER : R. Bitely

DEPTH BELOW SURFACE AND ELEVATION (ft)	SAMPLE INTERVAL (ft)	RECOVERY (ft)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	SYMBOLIC LOG	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
21.6					**Sandy Silt (ML)** 18.5-19.75' - very pale orange, (10YR 8/2), moist, hard, nonplastic, rapid dilatancy, mild to moderate HCl reaction, 35-40% very fine to fine grained sand, all carbonate derived		
	23.5 25.0	1.5	SS-5	17-24-31 (55)	**Sandy Silt With Limestone Fragments (ML)** 23.5-25.0' - grayish orange, (10YR 7/4), wet, hard, nonplastic, rapid dilatancy, moderate to strong HCl reaction, 20% fine to coarse gravel, limestone fragments are extremely weak rock (R0); similar to 18.5-19.75'		
25 16.6							
	28.5 29.3	0.8	SS-6	34-50/3.5 (84/9.5")	**Silty Sand With Limestone Fragments (SM)** 28.5-29.25' - Same as 23.5-25.0' except 72% fine to medium grained sand, interbedded with limestone lenses (<1/2") at 28.5-28.8' and intermittent throughout		Slow advancement rate from 28.5-33.5' with several dense lenses <0.5' thick, associated with light chatter
30 11.6							
	33.5 33.7	0.2	SS-7	50/2.5 (50/2.5")	**Limestone Fragments** 33.5-33.7' - grayish orange to dusky yellowish brown, (10YR 7/4 to 10YR 2/2), mild to moderate HCl reaction, gravel-sized limestone fragments up 1-1/2" diameter, sample includes 1/2" thick iron cemented lenses that have no HCl reaction		
35 6.6							
	38.5 39.6	1.1	SS-8	28-35-50/1 (85/7")			Extremely dense from 39.0-46.0', slow drilling with light to heavy rig chatter
40							

CH2MHILL

PROJECT NUMBER: 338884.FL

BORING NUMBER: A-01 SHEET 2 OF 9

SOIL BORING LOG

PROJECT : Progress Energy Florida - COLA Investigation, Levy County Site LOCATION : 1723879.2 N, 457603.8 E (NAD83)

ELEVATION : 41.6 ft (NAVD88) DRILLING CONTRACTOR : Universal Engineering Sciences, Jacksonville, FL; Driller: B. Truitt; Cathead Operator: B. Crews

DRILLING METHOD AND EQUIPMENT : Dietrich D-50 S/N 232, mud rotary, cathead, NWJ rods, 6 tri-cone bit ORIENTATION : Vertical

WATER LEVELS : 2 ft bgs on 03/15/07 START : 3/14/2007 END : 3/21/2007 LOGGER : R. Bitely

DEPTH BELOW SURFACE AND ELEVATION (ft)	SAMPLE INTERVAL (ft)	RECOVERY (ft)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	SYMBOLIC LOG	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
21.6					**Sandy Silt (ML)** 18.5-19.75' - very pale orange, (10YR 8/2), moist, hard, nonplastic, rapid dilatancy, mild to moderate HCl reaction, 35-40% very fine to fine grained sand, all carbonate derived		
	23.5 25.0	1.5	SS-5	17-24-31 (55)	**Sandy Silt With Limestone Fragments (ML)** 23.5-25.0' - grayish orange, (10YR 7/4), wet, hard, nonplastic, rapid dilatancy, moderate to strong HCl reaction, 20% fine to coarse gravel, limestone fragments are extremely weak rock (R0); similar to 18.5-19.75'		
25 16.6							
	28.5 29.3	0.8	SS-6	34-50/3.5 (84/9.5")	**Sandy Silt With Limestone Fragments (ML)** 28.5-29.25' - Same as 23.5-25.0' except 40% fine to medium grained sand, interbedded with limestone lenses (<1/2") at 28.5-28.8' and intermittent throughout		Slow advancement rate from 28.5-33.5' with several dense lenses <0.5' thick, associated with light chatter
30 11.6							
	33.5 33.7	0.2	SS-7	50/2.5 (50/2.5")	**Limestone Fragments** 33.5-33.7' - grayish orange to dusky yellowish brown, (10YR 7/4 to 10YR 2/2), mild to moderate HCl reaction, gravel-sized limestone fragments up 1-1/2" diameter, sample includes 1/2" thick iron cemented lenses that have no HCl reaction		
35 6.6							
	38.5 39.6	1.1	SS-8	28-35-50/1 (85/7")			Extremely dense from 39.0-46.0', slow drilling with light to heavy rig chatter
40							

PROJECT NUMBER: 338884.FL

BORING NUMBER: A-01 **SHEET** 3 **OF** 9

SOIL BORING LOG

PROJECT : Progress Energy Florida - COLA Investigation, Levy County Site LOCATION : 1723879.2 N, 457603.8 E (NAD83)

ELEVATION : 41.6 ft (NAVD88) DRILLING CONTRACTOR : Universal Engineering Sciences, Jacksonville, FL; Driller: B. Truitt; Cathead Operator: B. Crews

DRILLING METHOD AND EQUIPMENT : Dietrich D-50 S/N 232, mud rotary, cathead, NWJ rods, 6 tri-cone bit ORIENTATION : Vertical

WATER LEVELS : 2 ft bgs on 03/15/07 START : 3/14/2007 END : 3/21/2007 LOGGER : R. Bitely

DEPTH BELOW SURFACE AND ELEVATION (ft)	SAMPLE INTERVAL (ft)	RECOVERY (ft)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	SYMBOLIC LOG	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
1.6					**Sandy Silt With Limestone Fragments (ML)** 38.5-39.58' - olive gray to light olive gray, (5Y 3/2 to 5Y 5/2), wet, hard, low to medium plasticity, slow to rapid dilatancy, moderate to strong HCl reaction, 35% fine to coarse grain sand, trace organic content, limestone interbeds at 38.5-38.7' and intermittently throughout		
	43.5 43.8	0.3	SS-9	50/3 (50/3")	**Limestone Fragments** 43.5-43.75' - light olive gray, (5Y 6/1), mild HCl reaction, very fine to fine gravel, up to 3/4"x1/2"		
45 -3.4							
	48.5	0.3	SS-10	28-50/2 (78/8")	**Silty Sand (SM)** 48.5-48.8' - yellowish gray, (5Y 8/1), wet, very dense, 30% fines, nonplastic, mild to moderate HCl reaction, fine to medium grained sand, 10% gravel-sized limestone fragments		Split spoon sample SS-10 actually advanced 48.5-49.2
50 -8.4					Begin Rock Coring at 49.0 ft bgs See the next sheet for the rock core log		
55 -13.4							
60							

PROJECT NUMBER:	BORING NUMBER:
338884.FL	A-01 SHEET 4 OF 9

ROCK CORE LOG

PROJECT : Progress Energy Florida - COLA Investigation, Levy County Site LOCATION : 1723879.2 N, 457603.8 E (NAD83)

ELEVATION : 41.6 ft (NAVD88) DRILLING CONTRACTOR : Universal Engineering Sciences, Jacksonville, FL; Driller: B. Truitt; Cathead Operator: B. Crews

CORING METHOD AND EQUIPMENT : Dietrich D-50 S/N 232, mud rotary, NQ tools, NW/HW casing ORIENTATION : Vertical

WATER LEVELS : 2 ft bgs on 03/15/07 START : 3/14/2007 END : 3/21/2007 LOGGER : R. Bitely

DEPTH BELOW SURFACE AND ELEVATION (ft)	CORE RUN, LENGTH, AND RECOVERY (%)	DISCONTINUITIES			SYMBOLIC LOG	LITHOLOGY	COMMENTS
		R Q D (%)	FRACTURES PER FOOT	DESCRIPTION DEPTH, TYPE, ORIENTATION, ROUGHNESS, PLANARITY, INFILLING MATERIAL AND THICKNESS, SURFACE STAINING, AND TIGHTNESS		ROCK TYPE, COLOR, MINERALOGY, TEXTURE, WEATHERING, HARDNESS, AND ROCK MASS CHARACTERISTICS	SIZE AND DEPTH OF CASING, FLUID LOSS, CORING RATE AND SMOOTHNESS, CAVING ROD DROPS, TEST RESULTS, ETC.
50 -8.4	49.0 R1-NQ 2.5 ft 88% 51.5	42	0 >10 2 NR	49.55-49.65, 50.2-50.3' - Fracture zone (2), rough, undulating, with 1" openings 50.45' - Mechanical break or fracture, 40 deg, rough, undulating, open <3/4" 50.75, 50.9' - Bedding plane or mechanical break (2), <10 deg, rough, undulating, open <1/2"		**Limestone** 49.0-51.2' - dark yellowish brown, (10YR 4/2), fine grained, extremely weak to very weak (R0 to R1), voids (<3/16") over 70% of surface except from 49.65-50.2' where voids (<1/16") cover <20% of surface, fossiliferous, cavities <1/2"x1/4" over <15% of surface, trace organics **No Recovery 51.2-51.5'**	Switch to NQ rock coring tooling at 49.0', drive HW casing to 49', seat casing in <6" rock, flush casing with 3-7/8" tricone bit R1: 5 minutes
55 -13.4	R2-NQ 5 ft 98% 56.5	82	0 2 0 2 3 NR	53.0' - Mechanical break or fracture, <10 deg, rough, stepped to undulating, tight 53.8' - Mechanical break or fracture, <10 deg, rough, undulating, tight at fracture with associated cavity 54.4' - Mechanical break 55.0, 55.1' - Fractures, 35 deg, rough, undulating, tight 56.0, 56.2' - Mechanical break or fractures, <10 deg, rough, undulating, open <1/2"		**Limestone** 51.5-56.4' - moderate yellowish brown, (10YR 5/4), fine grained, moderate to strong HCl reaction, very weak to weak (R1 to R2), voids (<3/16") over 60-80% of surface, few cavities <1-1/2"x1" concentrated at 53.8', fossiliferous **No Recovery 56.4-56.5'**	R2: 10 minutes
60 -18.4	R3-NQ 5 ft 78% 61.5	48	>10 2 3 >10 NR	56.5-56.8' - Fracture zone, rough, undulating, gravel-sized (<1-1/2"x1"), open 57.0, 57.3, 57.5' - Fractures (3), 50-90 deg, smooth, undulating, intersecting fractures, tight 58.7, 58.85, 59.5' - Bedding plane or mechanical break (3), smooth, undulating, tight 58.95' - Mechanical break 59.75-60.0' - Fracture zone, rough, undulating, gravel-sized fragments <1"diameter, open		**Limestone** 56.5-60.4' - pale yellowish brown, (10YR 6/2), fine grained, very weak to medium strong (R1 to R3), voids (<3/16") over 85% of surface, fossiliferous, trace organics, extremely weak rock (R0) zones at 56.5-56.8', 58.7', 58.85', 59.5', 59.75-60.0' **No Recovery 60.4-61.5'**	Water level at 1' below ground surface at 17:30, end drilling on 03/14/07 Water level at 2' below ground surface on 03/15/07 07:30 R3: 16 minutes
65 -23.4	R4-NQ 5 ft 99% 66.5	98	0 1 0 0 1 NR	61.3' - Bedding plane or mechanical break, rough, undulating, broken along weak bedding planes, tight 63.15' - Bedding plane, horizontal, rough, undulating, tight 63.5, 63.7, 63.95, 64.0, 64.05, 64.4, 64.45, 65.2' - Mechanical break (8)		**Limestone** 61.5-66.45' - pale yellowish brown, (10YR 6/2), very fine to fine grained, weak to medium strong (R2 to R3), voids (<3/16") over 60-80% of surface at 61.5-61.9', 62.5-62.8', 63.5-65.1' and 65.4-66.3', organic material as <1/4" thick laminations at 63.0-65.2' over 20% of surface; very weak rock (R1) at 62.7-63.1', 65.0-65.5' and 66.3', bioturbated with some secondary infilling at 65.5-66.3' **No Recovery 66.45-66.5'**	R4: 8 minutes
	R5-NQ		3 2	66.7, 67.5, 68.2, 68.5, 70.2, 70.3, 70.55' - Mechanical break or bedding plane (7), <10 deg, rough, undulating, <1/4" openings 67.3' - Fracture, 70 deg and vertical, rough, stepped to undulating, tight			Driller's Remark: Slight fluid loss in zone

PROJECT NUMBER: 338884.FL

BORING NUMBER: A-01 SHEET 5 OF 9

ROCK CORE LOG

PROJECT : Progress Energy Florida - COLA Investigation, Levy County Site LOCATION : 1723879.2 N, 457603.8 E (NAD83)

ELEVATION : 41.6 ft (NAVD88) DRILLING CONTRACTOR : Universal Engineering Sciences, Jacksonville, FL; Driller: B. Truitt; Cathead Operator: B. Crews

CORING METHOD AND EQUIPMENT : Dietrich D-50 S/N 232, mud rotary, NQ tools, NW/HW casing ORIENTATION : Vertical

WATER LEVELS : 2 ft bgs on 03/15/07 START : 3/14/2007 END : 3/21/2007 LOGGER : R. Bitely

DEPTH BELOW SURFACE AND ELEVATION (ft)	CORE RUN, LENGTH, AND RECOVERY (%)	DISCONTINUITIES R Q D (%)	DISCONTINUITIES FRACTURES PER FOOT	DISCONTINUITIES DESCRIPTION: DEPTH, TYPE, ORIENTATION, ROUGHNESS, PLANARITY, INFILLING MATERIAL AND THICKNESS, SURFACE STAINING, AND TIGHTNESS	SYMBOLIC LOG	LITHOLOGY: ROCK TYPE, COLOR, MINERALOGY, TEXTURE, WEATHERING, HARDNESS, AND ROCK MASS CHARACTERISTICS	COMMENTS: SIZE AND DEPTH OF CASING, FLUID LOSS, CORING RATE AND SMOOTHNESS, CAVING ROD DROPS, TEST RESULTS, ETC.
70 -28.4	5 ft 92% 71.5	62	0 3 1 NR	69.45' - Fracture, 60 deg, smooth, undulating, tight		**Limestone** 66.5-71.1' - pale yellowish brown, (10YR 6/2), very fine to fine grained, very weak to weak (R1 to R2), voids up to 3/16" over 80% of surface, fossiliferous, trace laminated organics, very weak rock to weak rock at 66.5-67.0' and 70.0-71.1', medium strong rock (R3) at 69.0-70.0' **No Recovery 71.1-71.5'**	R5: 7 minutes
75 -33.4	R6-NQ 5 ft 96% 76.5	50	1 5 2 3 5 NR	72.35' - Bedding plane, <10 deg, rough, undulating, 1/4" soil seam infill, open 1/2" 72.6, 72.85, 72.95' - Bedding plane or mechanical break (3), <10 deg, rough, undulating, tight 73.7' - Mechanical break or bedding plane, 15 deg, rough, undulating, open 1/4" 74.1' - Mechanical break or bedding plane, horizontal, smooth, undulating, 1/4" infill, open 1/4" 74.8-75.2 and 75.5-76.0' - Clay seams (2), smooth, undulating, extremely weak rock (R0) zones		**Limestone** 71.5-76.3' - pale yellowish brown, (10YR 6/2), very fine to fine grained, weak (R2) to medium strong (R3) at 71.5-72.3', 72.7-73.7', and 74.2-74.7' with voids (<3/16") over 80% of surface; extremely weak (R0) to very weak (R1) at 72.3-72.7' and 73.7-74.2' with voids (<3/16") over 30% of surface; extremely weak (R0) to very weak (R1) interbeds from 74.7-76.0'; all fossiliferous **No Recovery 76.3-76.5'**	R6: 7 minutes
80 -38.4	R7-NQ 5 ft 77% 81.5	28	2 3 >10 10 NR	77.0, 77.3' - Fractures (2), 60 deg and 50-90 deg, rough, stepped to undulating, tight 77.95, 78.15, 78.3' - Fractures (3), <10 deg, rough, stepped to undulating, tight 78.65-79.0' - Fracture zone, rough, stepped to undulating, dissolution zone, angular to subangular gravel-sized fragments <1" diameter 79.2' - Fracture, vertical, smooth, undulating, tight 79.35, 79.5' - Fractures (2), rough, undulating, silt and/or clay sized infilling, tight 79.5-79.65' - Clay seam, 4-1/2" silt and/or clay sized infilling, Elastic Silt (MH) to Lean Clay (CL), moderate plasticity, low dilatancy, strong HCl reaction 79.85' - Bedding plane, smooth, undulating, tight		**Limestone** 76.5-79.5' - moderate yellowish brown to very light gray, (10YR 5/4 to N8), very fine to fine grained, weak to medium strong (R2 to R3), except extremely weak (R0) to very weak (R1) rock at 78.1-78.3' and 79.5-79.85'; 76.5-78.3' and 79.85-80.35' - 80% voids <3/16", fossiliferous (molds, casts); 78.3-79.0' - >90% voids <3/16", 30-40% cavities up to 1/2"x1/4", highly fractured zone; 79.0-79.5' - <20% voids <3/16", medium strong rock (R3) **Lean Clay - Elastic Silt (CL-ML)** 79.5-79.85' - medium plasticity, slow dilatancy, strong HCl reaction **No Recovery 80.35-81.5'**	03/20/2007 set NW casing to 80' to free NQ tooling 03/21/2007 continue rock coring from 81.5' below ground surface, 100% circulation with NW casing at 80' below ground surface R7: 10 minutes
85 -43.4	R8-NQ 5 ft 90% 86.5	76	>10 0 1 >10 0 NR	81.5-81.7' - Fracture zone, rough, undulating, gravel sized fragments <1/2" diameter, angular to subangular 82.25' - Fracture, 0-40 deg, rough, undulating, open <1" 83.6' - Bedding plane, <10 deg, rough, undulating, tight 84.0' - Mechanical break 84.65-84.8' - Fracture zone, horizontal and 20 deg, rough, undulating, fragmented rock, angular gravel sized fragments <1"diameter, open <2" 84.95' - Mechanical break, rough, undulating, open <1/2"		**Limestone** 81.5-86.0' - pale yellowish brown to moderate yellowish brown, (10YR 6/2 to 10YR 5/4), very fine to fine grained, mild to moderate HCl reaction, weak to medium strong (R2 to R3), voids (<3/16") over 60-80% of surface at 81.5-83.0' and 84.5-86.0', fossiliferous (molds <1/2"x1/4"), dissolution cavities up to 2"x1/2" at 82.3', 84.65-84.8', 84.9-85.15' and 85.6-86.65'	SC-1 collected at 84.95-86.0' R8: 9 minutes
	R9-NQ		>10 0	86.75-86.95' - Fracture zone, rough, undulating, angular gravel sized fragments <1-1/2" diameter, 2-1/2" open			

PROJECT NUMBER:	BORING NUMBER:
338884.FL	A-01 SHEET 6 OF 9

ROCK CORE LOG

PROJECT : Progress Energy Florida - COLA Investigation, Levy County Site LOCATION : 1723879.2 N, 457603.8 E (NAD83)

ELEVATION : 41.6 ft (NAVD88) DRILLING CONTRACTOR : Universal Engineering Sciences, Jacksonville, FL; Driller: B. Truitt; Cathead Operator: B. Crews

CORING METHOD AND EQUIPMENT : Dietrich D-50 S/N 232, mud rotary, NQ tools, NW/HW casing ORIENTATION : Vertical

WATER LEVELS : 2 ft bgs on 03/15/07 START : 3/14/2007 END : 3/21/2007 LOGGER : R. Bitely

DEPTH BELOW SURFACE AND ELEVATION (ft)	CORE RUN, LENGTH, AND RECOVERY (%)	DISCONTINUITIES			SYMBOLIC LOG	LITHOLOGY	COMMENTS
		R Q D (%)	FRACTURES PER FOOT	DESCRIPTION DEPTH, TYPE, ORIENTATION, ROUGHNESS, PLANARITY, INFILLING MATERIAL AND THICKNESS, SURFACE STAINING, AND TIGHTNESS		ROCK TYPE, COLOR, MINERALOGY, TEXTURE, WEATHERING, HARDNESS, AND ROCK MASS CHARACTERISTICS	SIZE AND DEPTH OF CASING, FLUID LOSS, CORING RATE AND SMOOTHNESS, CAVING ROD DROPS, TEST RESULTS, ETC.
	5 ft 98%	80	1	89.0' - Bedding plane, <10 deg, rough, undulating, open 1/4"		**Limestone** 83.0-84.5' - mild to moderate HCl reaction, mottled with zones of bioturbation having a secondary infill of a very fine, medium strong rock (R3) matrix, voids (<3/16") over 30% of surface, secondary infilling of bioturbated zone consisting of 20-30% of surface, trace fossil molds **No Recovery 86.0-86.5'** **Limestone** 86.5-87.05' - moderate yellowish brown to very light gray, (10YR 4/2 to N8), very fine to fine grained, extremely weak to very weak (R0 to R1), grayish blue mottling (5PB 5/2), voids (3/16") over 60-80% of surface from 84.5-86.0' and fossiliferous with trace organics 87.05-89.15' - Same as 86.5-87.05' except very light gray (N8) and grayish blue (5PB 5/2) mottling, voids (3/16") over 50-60% of surface, fossiliferous (microfossils) 89.15-90.7' - fine grained, very weak (R1), voids (<3/16") over 30-50% of surface, moderately fossiliferous 90.7-91.4' - Same as 86.5-87.05' except no mottling **No Recovery 91.4-91.5'** **Limestone** 91.5-96.4' - moderate yellowish brown to yellowish gray, (10YR 5/4 to 5Y 7/2), very fine to fine grained, extremely weak to weak (R0 to R2) 91.55-91.85' - fine grained, very weak (R1), voids (<3/16") over 30-50% of surface, fossiliferous 91.85-94.6' - moderate HCl reaction, voids (<3/16") over 60-80% of surface, moderately fossiliferous (molds up to 1/2" x 1/4"), few cavities <1/2" diameter, trace organics 94.6-96.4' - strong HCl reaction, gradual transition to >30% voids up to 1/16", 1/4" diameter cavity with medium light gray (N6) clay infill **No Recovery 96.4-96.5'** **Limestone** 96.5-101.5' - yellowish gray, (5Y 7/2), very fine to fine grained, strong HCl reaction, extremely weak to very weak (R0 to R1), voids (<3/16") over 70-80% of surface, moderately fossiliferous (molds <1/2"x1/4"), trace organics; 1/2" silt seam at 98.0', slow to fast dilatancy, low plasticity, carbonate material	
90 -48.4			0				
			2	90.95' - Bedding plane, horizontal, smooth, undulating, open <1/4"			R9: 11 minutes
	91.5		NR				
			1	91.25' - Mechanical break or bedding plane, 15 deg, rough, undulating, tight 91.6' - Bedding plane, horizontal, smooth, undulating, tight			
			0	92.9' - Mechanical break			
	R10-NQ 5 ft 98%	82	3	93.85-93.95' - Fracture zone, rough, undulating, 3 fractures, open <1-1/2"			
95 -53.4			1				
			4	95.3' - Fracture, 75 deg, smooth, undulating, tight 95.85-95.9' - Clay seam, horizontal, smooth, undulating, 3/4" clay infilling, Fat Clay (CH), medium gray (N5), moist, soft, high plasticity			R10: 16 minutes
	96.5		NR				
			1	96.05, 96.35' - Mechanical break or bedding plane (2), <10 deg, rough, undulating, tight			
			2	96.85, 97.55' - Bedding plane, <10 deg, rough, undulating, tight			SC-2 collected at 98.05-99.0'
	R11-NQ 5 ft 100%	98	0	97.05, 99.0, 99.75, 101.05, 101.4' - Mechanical break (5) 98.0' - smooth, undulating, <1/2" silt and/or clay sized infilling			
100 -58.4			0				
			0				R11: 8 minutes
	101.5		1	101.55, 102.65, 103.75' - Bedding plane or fractures (3), horizontal, smooth, undulating, tight			
			1				
	R12-NQ 5 ft 96%	86	1	104.0, 104.85' - Mechanical break			
105 -63.4			0				
			>10	105.5-105.6' - Fracture zone, rough, undulating, gravel sized fragments, <1" diameter			R12: 3 minutes
	106.5		NR				
			0				
			1				
	R13-NQ						

PROJECT NUMBER: 338884.FL

BORING NUMBER: A-01 SHEET 7 OF 9

ROCK CORE LOG

PROJECT : Progress Energy Florida - COLA Investigation, Levy County Site LOCATION : 1723879.2 N, 457603.8 E (NAD83)

ELEVATION : 41.6 ft (NAVD88) DRILLING CONTRACTOR : Universal Engineering Sciences, Jacksonville, FL; Driller: B. Truitt; Cathead Operator: B. Crews

CORING METHOD AND EQUIPMENT : Dietrich D-50 S/N 232, mud rotary, NQ tools, NW/HW casing ORIENTATION : Vertical

WATER LEVELS : 2 ft bgs on 03/15/07 START : 3/14/2007 END : 3/21/2007 LOGGER : R. Bitely

DEPTH BELOW SURFACE AND ELEVATION (ft)	CORE RUN, LENGTH, AND RECOVERY (%)	DISCONTINUITIES			SYMBOLIC LOG	LITHOLOGY	COMMENTS
		R Q D (%)	FRACTURES PER FOOT	DESCRIPTION DEPTH, TYPE, ORIENTATION, ROUGHNESS, PLANARITY, INFILLING MATERIAL AND THICKNESS, SURFACE STAINING, AND TIGHTNESS		ROCK TYPE, COLOR, MINERALOGY, TEXTURE, WEATHERING, HARDNESS, AND ROCK MASS CHARACTERISTICS	SIZE AND DEPTH OF CASING, FLUID LOSS, CORING RATE AND SMOOTHNESS, CAVING ROD DROPS, TEST RESULTS, ETC.
	5 ft 100%	70	4	108.65' - Fracture, 75 deg, smooth, undulating, tight		**Limestone** 101.5-106.3' - yellowish gray, (5Y 7/2), very fine to fine grained, strong HCl reaction, extremely weak to very weak (R0 to R1), voids (<1/16") over 50% of surface, few cavities up to 1/2"x1/4", poorly to moderately fossiliferous; 105.6-106.05' weak rock (R2) zone, voids (<3/16") over 70% of surface, moderately fossiliferous, moderate HCl reaction at 105.6-106.05' **No Recovery 106.3-106.5'** **Limestone** 106.5-111.5' - moderate yellowish brown to yellowish gray, (10YR 5/4 to 5Y 7/2), very fine to fine grained, strong HCl reaction, very weak (R1), voids (<3/16") over 60-80% of surface, moderately to highly fossiliferous (molds <1/4" diameter) concentrated at 106.5-107.7' and 110.0-110.3', surface iron staining at 106.8', 107.8' and 109.5' 111.5-116.5' - yellowish gray, (5Y 7/2), very fine to fine grained, strong HCl reaction, very weak (R1), 40% voids to <1/16", poorly to moderately fossiliferous (molds <1/16"), iron staining at 113.8', 114.6' and 115.7' 116.5-119.0' - yellowish gray, (5Y 7/2), very fine to fine grained, strong HCl reaction, very weak to weak (R1 to R2), voids (<3/16") over 60% of surface, poorly to moderately fossiliferous (molds <1/2"x1/4") 119.0-121.35' - Same as 116.5-119.0' except 80% voids up to 3/16", few cavities up to 1/2" diameter, highly fossiliferous (molds <1/2") **No Recovery 121.35-121.5'** **Limestone** 121.5-122.65' - Same as 119.0-121.35' 122.65-124.0' - pale yellowish brown, (10YR 6/2), very fine to fine grained, very weak (R1), voids (<1/16") over >50% of surface, poorly fossiliferous (molds up to 1/4" diameter), few cavities up to 1/2"x1/4" 124.0-126.5' - Same as 122.65-124.0' except voids up to 3/16" over 60-80% of surface, extremely weak rock (R0), highly fossiliferous below 125.75', friable	
110 -68.4			4	109.1, 109.15, 109.25' - Fractures (3), 90, 30, 50 deg, smooth to rough, undulating, intersecting fractures from 108.7-109.5'			
	111.5		3	109.65' - Fractures, 65 deg and 70 deg, rough, undulating, tight			R13: 10 minutes
			0	110' - Fracture, 75-85 deg, rough, undulating, tight, intersecting 110.5-110.65' - Fracture zone, 50 deg and 70 deg, rough, undulating, open <1-1/2"			
			0				
	R14-NQ 5 ft 100%	100	0	113.35, 114.0, 114.2, 115.2, 116.25, 116.5' - Mechanical break (6)			SC-3 collected at 114.2-115.2'
115 -73.4			0				
	116.5		0				R14: 7 minutes
			1	116.6' - Bedding plane, horizontal, smooth, undulating, tight			
			0				
	R15-NQ 5 ft 97%	92	0	118.85, 119.85' - Mechanical break (2)			
120 -78.4			0				
	121.5		2	120.5-120.6' - Fracture zone, 25 deg and horizontal, rough, undulating, intersecting, open <1"			R15: 9 minutes
			NR				
			1	121.9' - Bedding plane, horizontal, smooth, undulating, tight			
			0				
	R16-NQ 5 ft 100%	84	0				
125 -83.4			0				
	126.5		>10	125.75-126.5' - Fracture zone, rough, undulating, gravel sized fragments <3"x1-1/2"			R16: 6 minutes
			2				
			1	127.25, 127.45, 127.7, 131.3' - Bedding plane, horizontal, smooth, undulating, tight			
	R17-NQ			128.7, 129.0' - Mechanical break (2)			

ROCK CORE LOG

PROJECT : Progress Energy Florida - COLA Investigation, Levy County Site LOCATION : 1723879.2 N, 457603.8 E (NAD83)

ELEVATION : 41.6 ft (NAVD88) DRILLING CONTRACTOR : Universal Engineering Sciences, Jacksonville, FL; Driller: B. Truitt; Cathead Operator: B. Crews

CORING METHOD AND EQUIPMENT : Dietrich D-50 S/N 232, mud rotary, NQ tools, NW/HW casing ORIENTATION : Vertical

WATER LEVELS : 2 ft bgs on 03/15/07 START : 3/14/2007 END : 3/21/2007 LOGGER : R. Bitely

DEPTH BELOW SURFACE AND ELEVATION (ft)	CORE RUN, LENGTH, AND RECOVERY (%)	DISCONTINUITIES R Q D (%)	DISCONTINUITIES FRACTURES PER FOOT	DISCONTINUITIES DESCRIPTION DEPTH, TYPE, ORIENTATION, ROUGHNESS, PLANARITY, INFILLING MATERIAL AND THICKNESS, SURFACE STAINING, AND TIGHTNESS	SYMBOLIC LOG	LITHOLOGY ROCK TYPE, COLOR, MINERALOGY, TEXTURE, WEATHERING, HARDNESS, AND ROCK MASS CHARACTERISTICS	COMMENTS SIZE AND DEPTH OF CASING, FLUID LOSS, CORING RATE AND SMOOTHNESS, CAVING ROD DROPS, TEST RESULTS, ETC.
130 -88.4	5 ft 100% 131.5	87	0 0 1			**Limestone** 126.5-131.5' - yellowish gray, (5Y 7/2), very fine to fine grained, strong HCl reaction, very weak to weak (R1 to R2), voids (<3/16") over 60% of surface, poorly to moderately fossiliferous, few cavities <1/2" diameter, trace secondary infill of cavities, laminated bedding at 127.2', 127.85' and 128.95'	R17: 5 minutes
135 -93.4	R18-NQ 5 ft 100% 136.5	100	0 0 0 0 0	133.05, 134.0, 135.2' - Mechanical break (3)		131.5-136.5' - yellowish gray, (5Y 7/2), very fine to fine grained, very weak to medium strong (R1 to R3), 131.5-132.95' - voids <3/16" over 40% of surface, poorly fossiliferous (molds <1/2" diameter); 132.95-136.5' - voids up to 3/16" over 70% of surface, highly fossiliferous (molds <1/2"), molds over 30-50% surface	SC-4 collected at 133.05-134.0' R18: 10 minutes
140 -98.4	R19-NQ 5 ft 94% 141.5	86	1 2 1 0 >10 NR	137.5' - Bedding plane, horizontal, smooth, undulating, tight 138.05, 138.45, 138.6' - Bedding plane, <10 deg, rough, undulating, tight 140.9-141.2' - Fracture zone, rough, undulating, gravel sized fragments <2" diameter		136.5-141.2' - yellowish gray to light olive gray, (5Y 7/2 to 5Y 5/2), very fine to fine grained, strong HCl reaction, very weak to medium strong (R1 to R3), laminated bedding, 30-60% voids up to 3/16", poorly to moderately fossiliferous (molds <1/2"x1/4"), surface iron staining at 136.7', 137.7', 138.2', 139.1' and 140.5', laminated throughout **No Recovery 141.2-141.5'**	R19: 8 minutes
145 -103.4	R20-NQ 5 ft 70% 146.5	23	>10 >10 4 >10 NR	141.6-142.0' - Bedding plane (>10), <10 deg, smooth to rough, undulating, open <1/4" 142.0-142.65' - Fracture zone, rough, undulating, angular gravel-sized fragments <1-1/2" diameter 142.9, 143.3, 143.65, 144.15, 144.25, 144.5, 144.7' - Fractures (8), <10 deg, rough, undulating, <1/2" openings 144.7-145.0' - Fracture zone, rough, undulating		**Limestone** 141.5-145.0' - moderate yellowish brown to yellowish gray, (10YR 5/4 to 5Y 7/2), very fine to fine grained, 141.5-142.0' - moderate yellowish brown, very weak to weak rock (R1-R2), voids (<3/16") over 70% of surface, moderately fossiliferous, trace organics, trace laminated bedding; 142.0-145.0' - voids up to 3/16" over 50% of surface, medium strong rock (R3), highly fossiliferous (molds <1"x1/2"), cavities <1.5"x1", several cavities with secondary mineral infill, heavily bioturbated **No Recovery 145.0-146.5'**	Core barrel malfunction from 144.7-145.0' due to rock fragments wedged in bit R20: 10 minutes
	R21-NQ		2 1	146.6' - Bedding plane, <10 deg, rough, undulating, open <1/4" 146.8, 147.8' - Bedding plane (2), horizontal, smooth, undulating, tight			

PROJECT NUMBER:	BORING NUMBER:
338884.FL	A-01 SHEET 9 OF 9

ROCK CORE LOG

PROJECT : Progress Energy Florida - COLA Investigation, Levy County Site LOCATION : 1723879.2 N, 457603.8 E (NAD83)

ELEVATION : 41.6 ft (NAVD88) DRILLING CONTRACTOR : Universal Engineering Sciences, Jacksonville, FL; Driller: B. Truitt; Cathead Operator: B. Crews

CORING METHOD AND EQUIPMENT : Dietrich D-50 S/N 232, mud rotary, NQ tools, NW/HW casing ORIENTATION : Vertical

WATER LEVELS : 2 ft bgs on 03/15/07 START : 3/14/2007 END : 3/21/2007 LOGGER : R. Bitely

DEPTH BELOW SURFACE AND ELEVATION (ft)	CORE RUN, LENGTH, AND RECOVERY (%)	DISCONTINUITIES R Q D (%)	FRACTURES PER FOOT	DESCRIPTION: DEPTH, TYPE, ORIENTATION, ROUGHNESS, PLANARITY, INFILLING MATERIAL AND THICKNESS, SURFACE STAINING, AND TIGHTNESS	SYMBOLIC LOG	LITHOLOGY: ROCK TYPE, COLOR, MINERALOGY, TEXTURE, WEATHERING, HARDNESS, AND ROCK MASS CHARACTERISTICS	COMMENTS: SIZE AND DEPTH OF CASING, FLUID LOSS, CORING RATE AND SMOOTHNESS, CAVING ROD DROPS, TEST RESULTS, ETC.
150 -108.4	5 ft 86% 151.5	80	1 0 0 NR	148.95' - Bedding plane, horizontal, rough, undulating, open <1/4"		**Limestone** 146.5-150.8' - moderate yellowish brown to yellowish gray, (10YR 5/4 to 5Y 7/2), very fine to fine grained, mild to moderate HCl reaction, laminated bedding, 146.5-148.9' - weak to medium strong rock (R2-R3), voids (<3/16") over 30% of surface, voids increase to 80% from 148.3-148.9' 148.9-150.8' - very weak rock (R1), voids (up to 3/16") over 60% of surface, moderately fossiliferous (casts) concentrated at 148.9-150.0 **No Recovery 150.8-151.5'**	R21: 13 minutes
155 -113.4	R22-NQ 5 ft 100% 156.5	92	1 1 0 0 2	151.85' - Bedding plane, horizontal, rough, undulating, tight 153.45-153.55' - Clay seam or bedding plane, horizontal, smooth, undulating, 5/8" silt and/or clay sized infilling, tight 155.65, 156.35' - Bedding plane (2), <10 deg, smooth, undulating, tight		**Limestone** 151.5-153.45' - Same as 148.9-150.8' except very weak (R1) **Silty Sand (SM)** 153.45-153.55' - wet, loose, silt has rapid dilatancy, 50% fine to medium grained sand, calcareous, 1/4" thick lense **Limestone** 153.55-156.5' - pale yellowish brown to yellowish gray, (10YR 6/2 to 5Y 7/2), very fine to fine grained, moderate to strong HCl reaction, medium strong (R3), 50-70% voids up to 3/16", poorly to moderately fossiliferous, laminated bedding concentrated at 155.0-156.5', few cavities <1/2"x1/4", 1 large (3/4"x1/2") cavity at 156.4'	SC-5 collected 151.85-152.8' R22: 14 minutes
160 -118.4	R23-NQ 5 ft 100% 161.5	92	3 0 0 0 1	156.7, 156.8, 156.9' - Bedding plane (3), <10 deg, smooth, undulating, tight 158.35, 158.6, 159.7' - Mechanical break (3) 160.65' - Bedding plane, <10 deg, smooth, undulating, tight		156.5-161.5' - pale yellowish brown, (10YR 6/2), very fine to fine grained, moderate to strong HCl reaction, weak to very weak (R2 to R1), 60% voids up to 3/16", moderately fossiliferous (molds 3/4"x1/2" diameter), trace organics, trace secondary infill and silt-sized carbonate material at 158.35-158.5' and 160.5', medium strong rock (R3) lense at 158.7-159.7', laminated bedding at 156.5-156.9' and 160.5-160.9' Bottom of Boring at 161.5 ft bgs on 3/21/2007	R23: 7 minutes Water level at 5' below ground surface on 3/21/2007 at 18:30

Appendix B
Example Photographs of Soil Samples

Examples of SPT sample photographs and white boards.

PE Florida COLA Site

Borehole I.D. : CT-1
Sample I.D. : SS-1
Depth (ft. bgs) : 0'
Recovery : 1.2'
Blow Count : 1-1-2
Date : 12/02/07

PE Florida COLA Site

Borehole I.D. : IT-2
Sample I.D. : SS-12
Depth (ft. bgs) : 55'
Recovery : 1.3'
Blow Count : 12-19-13 (32)
Date : 7/1/07

Example of sonic soil cores - overall box photograph with box close ups (left and right sides).

PE Florida COLA Site
Borehole I.D. : I-1
Run I.D. : R5-S
Depth (ft. bgs) : 36' - 46'
Recovery : 75%
RQD : 20"/120" = 16%
Date : 2/20/07

PE Florida COLA Site

Borehole I.D. : I-1
Run I.D. : R5-S
Depth (ft. bgs) : 36' - 46'
Recovery : 75%
RQD : 20"/120" = 16%
Date : 2/20/07

Appendix C

Field Equipment Checklist and Field Reference Guide

Suggested Field Equipment Checklist for Soil Sampling and Logging

- ☐ Project workplan, site investigation plans, and other planning information such as boring location map, boring summary tables, utility plans, etc.
- ☐ Permits: encroachment, environmental, etc.
- ☐ Copy of utility clearance
- ☐ Copy of the drilling contract or subcontract
- ☐ Previous site exploration data, geology maps, etc.
- ☐ Underground service alert ticket
- ☐ Site contact information
- ☐ Field Safety Instructions (FSI)/Health and Safety Plan (signed and dated by all field personnel); Pre-drilling safety checklist and other H&S Plan forms to be field out.
- ☐ Personal Protective Equipment and safety equipment per the FSI/HSP. Typical items include:
  - ○ Hard hat
  - ○ Safety glasses
  - ○ Safety vest
  - ○ Steel-toed boots
  - ○ Ear protection (earplugs and/or ear muffs)
  - ○ Work (outer) gloves and inner (latex or nitrile) gloves
  - ○ Rain gear if appropriate
  - ○ Cold weather gear if appropriate
  - ○ Rubber boots if appropriate
  - ○ Safety equipment (per FSI, e.g., fire extinguisher, first aid kit, environmental monitoring equipment such as a PID, snake chaps, bear spray, rubber boots, etc.)
  - ○ Additional equipment as required for environmental contamination
- ☐ Logging and sampling supplies
  - ○ Pens, pencils, erasers, and Sharpie-style permanent markers (thick and thin)
  - ○ Chalk, soapstone, and/or lumber crayons for marking rock core samples
  - ○ Field clipboard
  - ○ Straight ruler including millimeters
  - ○ Measuring tape / 6-foot folding rule in tenths and inches
  - ○ Blank log sheets (and for rock if needed) on weatherproof paper
  - ○ Munsell soil color charts (and rock if needed)
  - ○ Notebook for daily documentation (field “yellow book”)
  - ○ White board with dry erase markers (or disposable note cards)

  - ○ HD digital camera with extra batteries and memory
  - ○ Wire straining for evaluating cuttings
  - ○ Protractor
  - ○ Core boxes (verify drillers to supply for proposed methods – sonic, rock coring, etc.)
  - ○ Electric and duct tape
  - ○ Bulk sample bags
  - ○ Ziploc-style heavy duty/freeze bags (quart and gallon size) and/or glass jars
  - ○ Plastic wrap
  - ○ Materials for sealing thin-tube samples (parafin wax, stove, fuel, lighter, pot, etc. or confirm if drilling is providing)
  - ○ Putty knife or spatula with rounded end for scraping samples out of spoons
  - ○ Labels (carry extra for backup)
  - ○ Buckets for large samples or carrying samples
- ☐ 3-ft step ladder (to photograph whole sonic core runs)
- ☐ 100-foot cloth or fiberglass tape
- ☐ Flagging and spray paint
- ☐ Sturdy folding tables and chairs
- ☐ Screwdriver – flat-head and phillips head
- ☐ Rock hammer
- ☐ Small sledge hammer
- ☐ Hand level and/or handheld inclinometer
- ☐ Approved utility knife
- ☐ Water depth meter
- ☐ Sunscreen, insect repellant, hand sanitizer, hand wash
- ☐ Paper towels/cloth rags
- ☐ Drinking water, food
- ☐ Spray bottles or hand sprayers and appropriate water (e.g., de-ionized may be required for environmental reasons)
- ☐ Hand-held GPS
- ☐ Laptop
- ☐ Cell phone or other site specific communication device
- ☐ Awning for high rainfall or sun protection
- ☐ Wooden stakes for marking borehole locations
- ☐ Trash bags

- ☐ Means of transporting Shelby tube samples
- ☐ Wrist watch
- ☐ Other project specific items
    - ○ Understand access requirements and limitations.
    - ○ Understand support vehicle requirements (e.g., car, truck, SUV, etc.).
    - ○ Understand how drillers will get water if needed for drilling method (pump from stream with appropriate fish screens and permits, get from hydrant, client supplied, bring from offsite, how to dispose, fill with air-gap on water tank, etc.).
    - ○ Potential limitations from fire danger (restricted work hours, post-work standby, spark arrestors on all equipment, etc.).
    - ○ Be prepared to repair landscaping, or advise client that landscaping will be damaged by drill rig.
    - ○ Understand if sidewalks patched, asphalt patched, concrete cored, air-knifing to expose utilities in upper portion of borehole.
    - ○ Understand cuttings disposal (drum, scatter onsite, relocate to onsite disposal, etc.).
    - ○ Traffic control subcontractor if needed, coordinate traffic control with drilling schedule.
    - ○ Traffic cones or signage if needed.

ch2m℠

PROJECT NUMBER

BORING NUMBER

Sheet: of

SOIL BORING LOG

PROJECT :

LOCATION :

ELEVATION :

DRILLING CONTRACTOR :

DRILLING METHOD AND EQUIPMENT USED :

WATER LEVEL :

START :

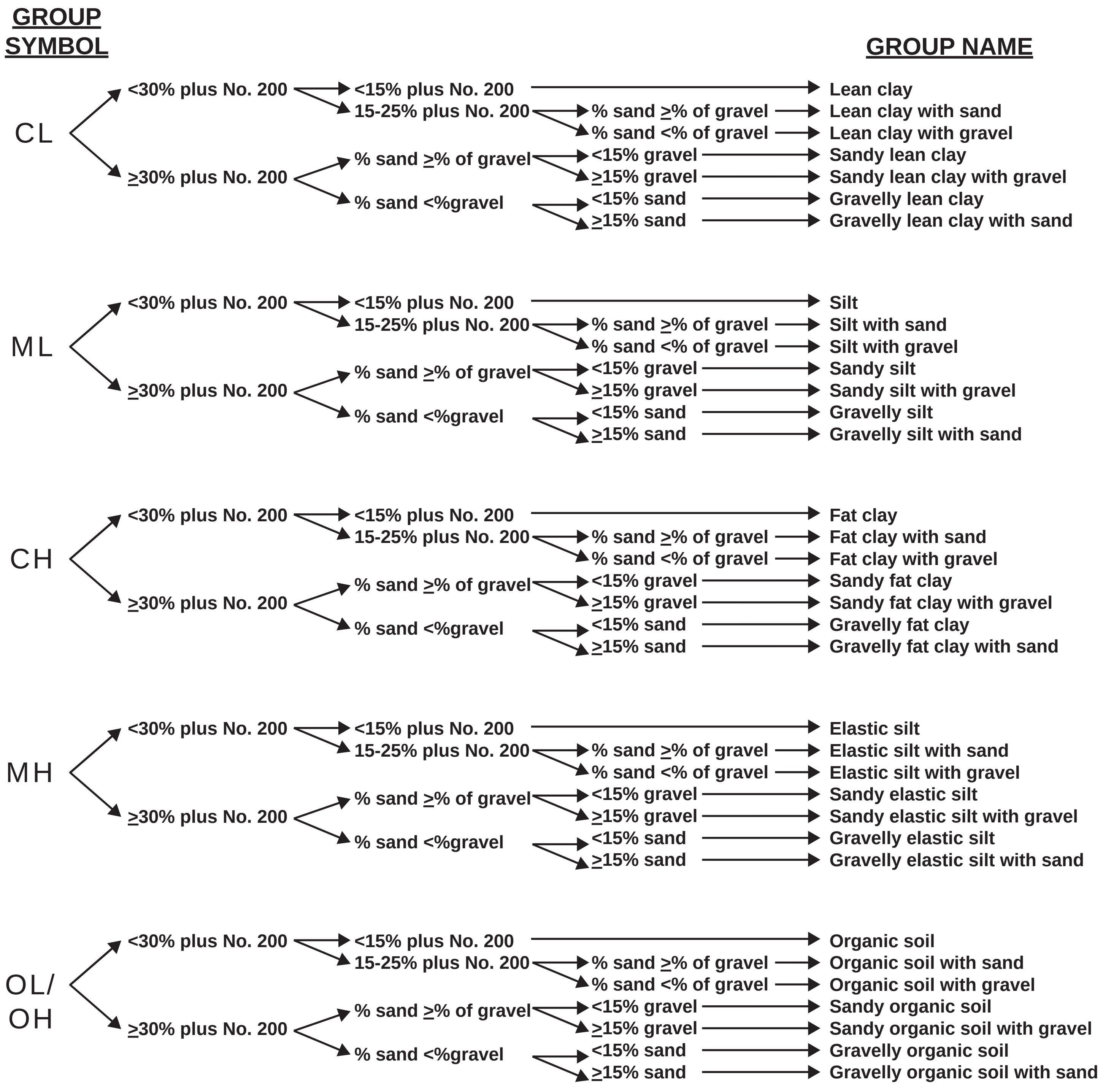
END :

LOGGER :

DEPTH BELOW SURFACE (FT)				STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	USCS	COMMENTS
	INTERVAL (FT)						
		RECOVERY (FT)					
			SAMPLE #/TYPE	6"-6"-6"-6" (N')	SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY, OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY.		DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION. DRILLING ACTIONS/DRILLER COMMENTS PID Readings: Breathing Zone: Above Hole:

ch2m

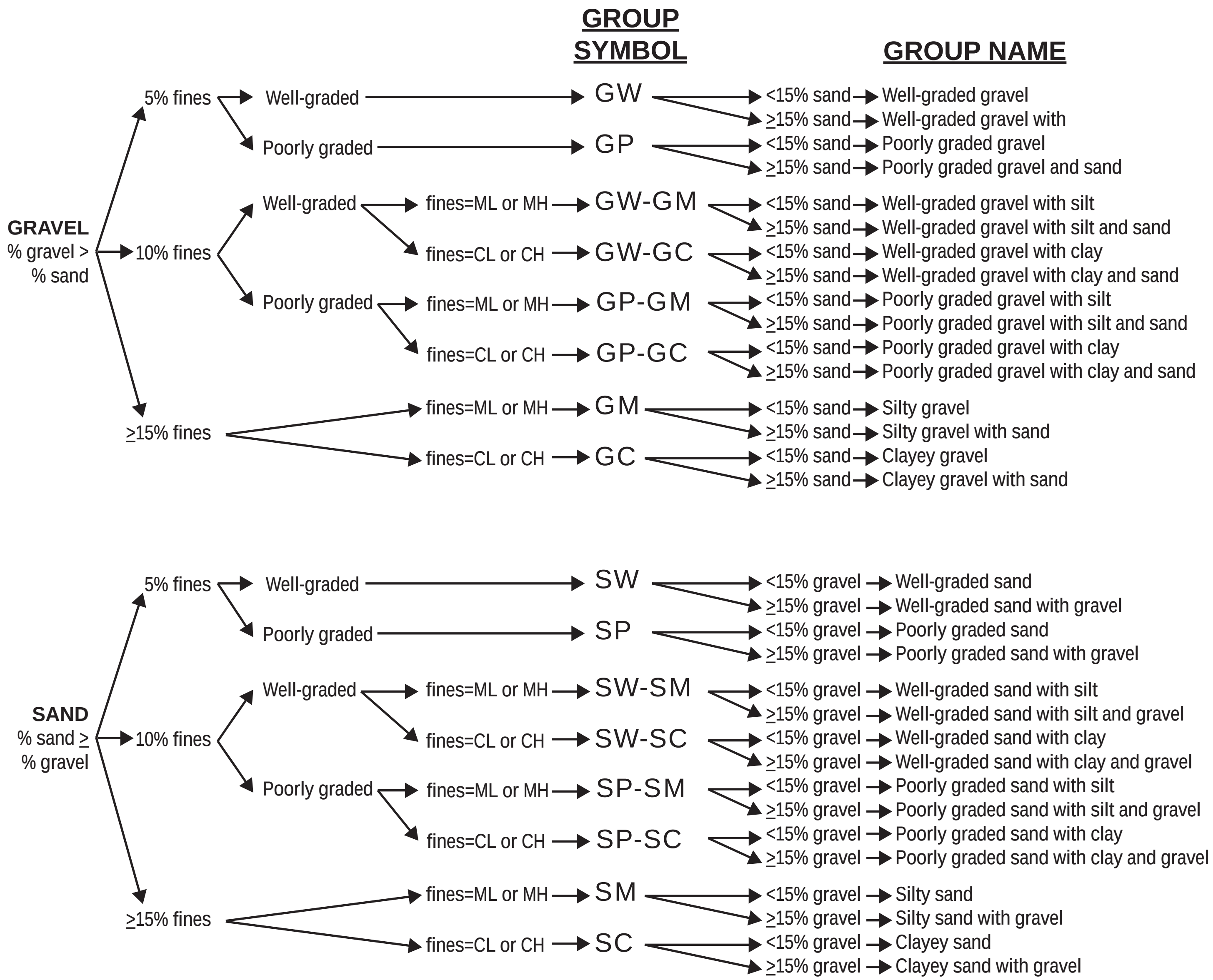
Fine-Grained and Organic Soil Flow Chart



Where cobbles and boulders are present, add to Group Name

Source: ASTM D2488

Coarse-Grained Flow Chart



Where cobbles and boulders are present, add to Group Name

Source: ASTM D2488

FIELD REFERENCE GUIDE

Criteria for Describing Moisture Content

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

Source: ASTM D2488

Relative Density of Coarse-Grained Soil

Blows/Ft	Relative Density
0 - 4	Very loose
5 - 10	Loose
11 - 30	Medium
31 - 50	Dense
50	Very Dense

Source: Sowers, 1979

Consistency of Fine-Grained Soil

Blows/Ft	Consistency	Pocket Penetrometer (TSF)	Torvane (TSF)
<2	Very soft	<0.25	<0.12
2 - 4	Soft	0.25- 0.50	<0.12 - 0.25
5 - 8	Firm	0.50 - 1.0	0.25 - 0.5
9 - 15	Stiff	1.0 - 2.0	0.5 - 1.0
16 - 30	Very stiff	2.0 - 4.0	1.0 - 2.0
30	Hard	>4.0	>2.0

Source: Sowers, 1979

Particle Size Guidance

Description	Sieve Size	Examples
Boulder	Greater than 12 inches	> Basketball
Cobble	3 to 12 inches	Fist to basketball
Coarse Gravel	3/4 to 3 inches	Thumb to fist
Fine Gravel	No. 4 to 3/4 inches (4.75 mm to 3/4 inches)	Pea to thumb
Coarse Sand	No. 10 to No. 4 (2.0 to 4.75 mm)	Rock salt to pea
Medium Sand	No. 40 to No. 10 (0.425 to 2.0 mm)	Sugar to rock salt
Fine Sand	No. 200 to No. 40 (0.075 to 0.425 mm)	Flour to sugar
Silt and Clay	Passing No. 200 (<0.075 mm)	Grains not visible

Source: ASTM D2488

Criteria for Describing Angularity of Coarse-Grained Particles

Description	Criteria
Angular	Particles have sharp edges and relatively plane sides with unpolished surfaces
Subangular	Particles are similar to angular, but have rounded edges
Subrounded	Particles have nearly plane sides, but have well-rounded corners and edges
Rounded	Particles have smoothly curved sides and no edges

Source: ASTM D2488

Criteria for Describing Plasticity

Description	Criteria
Nonplastic	A 1/8-inch (3-mm) thread cannot be rolled at any water content
Low	The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit
Medium	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. The lump crumbles when dried than the plastic limit.
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rerolled several times after reach the plastic limit. The lump can be formed without crumbing when drier than the plastic limit.

Source: ASTM D2488

Criteria for Describing Dilatancy

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

Source: ASTM D2488

Criteria for Describing Reaction with HCl

Description	Criteria
None	No visible reaction
Weak	Some reaction, with bubbles forming slowly
Strong	Violent reaction, with bubbles forming immediately

Source: ASTM D2488

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.

STANDARD OPERATING PROCEDURE – Navy CLEAN PROGRAM

Drinking Water Sampling when Analyzing for Per- and Polyfluoroalklyl Substances (PFASs)

I. Purpose and Scope

This SOP provides guidelines for drinking water sample collection for samples that will be analyzed for Per- and Polyfluoroalklyl Substances (PFASs), aka perfluorinated compounds (PFCs), including perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) via EPA Method 537 (not modified) (USEPA 2009). This SOP was developed in accordance with the *Interim Per- and Polyfluoralkyl Substances (PFAS) Site Guidance for NAVFAC Remedial Project Managers (RPMs)/September 2017 Update* (Navy 2017).

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.

II. Equipment and Materials

Equipment and Materials Required

- Drinking water sample containers (polypropylene bottle with polypropylene screw cap and Trizma preservative)
- Laboratory pre-filled polypropylene bottles containing field reagent blank water and Trizma preservative
- Field Reagent Blank sample containers (polypropylene bottle with polypropylene screw cap and no preservative)
- Shipping supplies (labels, coolers, and ice)
- Loose leaf paper without waterproof coating
- Clip board
- Pen (not Sharpie)
- Nitrile or latex gloves

Equipment and Materials to Avoid During Sampling

Equipment and materials used to collect drinking water samples should not contain any fluorinated compounds, including polytetrafluoroethylene (PTFE), 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.
- New clothing (i.e. clothing requires at least 6 washings since purchase).

- Weather-proof log books with fluorochemical coatings

The sample collection area should be clear of the following items:

- Pre-packaged food wrappers (e.g., fast food sandwich wrappers, candy bars, pizza boxes, etc.)
- Microwave popcorn bags
- Blue ice containers
- Post-it Notes
- Aluminum foil
- Kim-Wipes
- Sunscreen, insect repellant and other personal hygiene products that may contain PFAS

Sample bottles should be polypropylene in accordance with Method 537. PFASs have a tendency to adhere to glass surfaces. Contact the project manager (PM) if the lab sends glass bottles. Sample vials should not have PTFE/Teflon® lined bottles or caps. The laboratory is required to ensure that sample bottles provided to clients have been verified as clean (meeting the acceptance criteria for blanks and analysis) (Navy, 2017).

III. Procedures and Guidelines

A. Setup

1. Obtain well construction information from homeowner, if available, in accordance with homeowner questionnaire developed for your project.

2. Record personnel onsite, address, homeowner name, and designated sample ID in the field logbook. Sample IDs should not contain identifying information about the property location due to potential privacy issues, so be sure both address and designated ID are carefully recorded for tracking. Sample IDs and addresses on the sample bottles and in the sample notebook must be checked by both field team members and the address in the field notebook should be confirmed with the homeowner or resident.

3. As feasible, select a sampling collection point prior to any treatment system installed by the homeowner. For example, if the homeowner has a point of use reverse osmosis or granular activated carbon filter in their kitchen sink, collect at the bathroom sink. If there is a point of entry filtration system, ask if there is a sampling port between the well and the system. If there is no way to bypass the existing treatment system without disconnecting pump components or potentially damaging the system, collect a treated sample and note that the sample was collected post-treatment. Avoid collecting samples through hoses. Instead, disconnect the hose and sample from the spigot if an outside collection station is selected.

3. Wash hands before sampling with dish detergent and don nitrile gloves.

4. Open the tap and allow the system to flush for three to five minutes. Do not open bottles until you are ready to sample.

B. Sample Collection

Once flushing is complete, samples can be collected.

The steps to be followed for sample collection are as follows:

1. Turn the tap off briefly. Remove the cap from the sample bottle. Position the sample bottle under the tap and turn the tap on.
2. Fill the bottle, taking care not to flush out the sample preservative. Samples do not need to be collected headspace free.
3. After collecting the sample, cap the bottle and agitate by hand until the preservative is dissolved.
4. Pack the sample on ice immediately for shipment to the offsite laboratory.

C. Field Reagent Blank Collection

A field reagent blank is required at each drinking water sampling location and is to be collected immediately following collection of the drinking water sample. The steps to complete collection of the field reagent blank are as follows:

1. A preserved field reagent blank for each sample location will be provided by the laboratory along with empty bottles for the field reagent blanks. While still at the drinking water sample collection point, open the preserved field reagent blank water bottle and an empty unpreserved sample bottle.
2. Pour the preserved reagent blank water from the preserved bottle into the unpreserved blank container.
3. Be sure the field reagent blank bottle is labeled and will be labeled and packed in the same cooler as the associated drinking water sampling for shipment to the offsite laboratory.

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

Department of the Navy (Navy), 2017. *Interim Per- and Polyfluoralkyl Substances (PFAS) Site Guidance for NAVFAC Remedial Project Managers (RPMs)/September 2017 Update*. 28 September.

Appendix D

Department of Defense Environmental Laboratory Accreditation Program Accreditation Letters

SCOPE OF ACCREDITATION TO ISO/IEC 17025:2005

VISTA ANALYTICAL LABORATORY
1104 Windfield Way
El Dorado Hills, CA 95762
Martha Maier Phone: 916-673-1520
mmaier@vista-analytical.com

ENVIRONMENTAL

Valid To: September 30, 2019 Certificate Number: 3091.01

In recognition of the successful completion of the A2LA evaluation process, (including an assessment of the laboratory's compliance with ISO IEC 17025:2005, the 2009 TNI Environmental Testing Laboratory Standard, the requirements of the DoD Environmental Laboratory Accreditation Program (DoD ELAP) as detailed in version 5.1 of the DoD Quality Systems Manual for Environmental Laboratories), accreditation is granted to this laboratory to perform recognized EPA methods using the following testing technologies and in the analyte categories identified below:

Testing Technologies

High Resolution Gas Chromatography / Mass Spectrometry
Liquid Chromatography Mass Spectrometry / Mass Spectrometry

Parameter/Analyte	**Potable Water**	**Nonpotable Water**	**Solid Hazardous Waste**	**Tissue**
Dioxins/Furans				
2,3,7,8-Tetrachlorodibenzo-p-dioxin	------------------------	EPA 1613B/8290	EPA 1613B/8290	EPA 1613B/8290
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	------------------------	EPA 1613B/8290	EPA 1613B/8290	EPA 1613B/8290
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	------------------------	EPA 1613B/8290	EPA 1613B/8290	EPA 1613B/8290
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	------------------------	EPA 1613B/8290	EPA 1613B/8290	EPA 1613B/8290
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	------------------------	EPA 1613B/8290	EPA 1613B/8290	EPA 1613B/8290
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	------------------------	EPA 1613B/8290	EPA 1613B/8290	EPA 1613B/8290
1,2,3,4,6,7,8,9-Octachlorodibenzo-p-dioxin	------------------------	EPA 1613B/8290	EPA 1613B/8290	EPA 1613B/8290
2,3,7,8-Tetrachlorodibenzofuran	------------------------	EPA 1613B/8290	EPA 1613B/8290	EPA 1613B/8290
1,2,3,7,8-Pentachlorodibenzofuran	------------------------	EPA 1613B/8290	EPA 1613B/8290	EPA 1613B/8290
2,3,4,7,8-Pentachlorodibenzofuran	------------------------	EPA 1613B/8290	EPA 1613B/8290	EPA 1613B/8290
1,2,3,4,7,8-Hexachlorodibenzofuran	------------------------	EPA 1613B/8290	EPA 1613B/8290	EPA 1613B/8290

Parameter/Analyte	Potable Water	Nonpotable Water	Solid Hazardous Waste	Tissue
1,2,3,6,7,8-Hexachlorodibenzofuran	------------------------	EPA 1613B/8290	EPA 1613B/8290	EPA 1613B/8290
2,3,4,6,7,8-Hexachlorodibenzofuran	------------------------	EPA 1613B/8290	EPA 1613B/8290	EPA 1613B/8290
1,2,3,7,8,9-Hexachlorodibenzofuran	------------------------	EPA 1613B/8290	EPA 1613B/8290	EPA 1613B/8290
1,2,3,4,6,7,8-Heptachlorodibenzofuran	------------------------	EPA 1613B/8290	EPA 1613B/8290	EPA 1613B/8290
1,2,3,4,7,8,9-Heptachlorodibenzofuran	------------------------	EPA 1613B/8290	EPA 1613B/8290	EPA 1613B/8290
1,2,3,4,6,7,8,9-Octachlorodibenzofuran	------------------------	EPA 1613B/8290	EPA 1613B/8290	EPA 1613B/8290
Total Heptachlorodibenzofuran	------------------------	EPA 1613B/8290	EPA 1613B/8290	EPA 1613B/8290
Total Heptachlorodibenzo-p-dioxin	------------------------	EPA 1613B/8290	EPA 1613B/8290	EPA 1613B/8290
Total Hexachlorodibenzofuran	------------------------	EPA 1613B/8290	EPA 1613B/8290	EPA 1613B/8290
Total Hexachlorodibenzo-p-dioxin	------------------------	EPA 1613B/8290	EPA 1613B/8290	EPA 1613B/8290
Total Pentachlorodibenzofuran	------------------------	EPA 1613B/8290	EPA 1613B/8290	EPA 1613B/8290
Total Pentachlorodibenzo-p-dioxin	------------------------	EPA 1613B/8290	EPA 1613B/8290	EPA 1613B/8290
Total Tetrachlorodibenzofuran	------------------------	EPA 1613B/8290	EPA 1613B/8290	EPA 1613B/8290
Total Tetrachlorodibenzo-p-dioxin	------------------------	EPA 1613B/8290	EPA 1613B/8290	EPA 1613B/8290
PCBs				
2-Chlorobiphenyl (1)	------------------------	EPA 168A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
3-Chlorobiphenyl (2)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
4-Chlorobiphenyl (3)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2'-Dichlorobiphenyl (4)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3-Dichlorobiphenyl (5)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3'-Dichlorobiphenyl (6)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,4-Dichlorobiphenyl (7)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,4'-Dichlorobiphenyl (8)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,5-Dichlorobiphenyl (9)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,6-Dichlorobiphenyl (10)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C

Parameter/Analyte	**Potable Water**	**Nonpotable Water**	**Solid Hazardous Waste**	**Tissue**
3,3'-Dichlorobiphenyl (11)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
3,4-Dichlorobiphenyl (12)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
3,4'-Dichlorobiphenyl (13)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
3,5-Dichlorobiphenyl (14)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
4,4'-Dichlorobiphenyl (15)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3-Trichlorobiphenyl (16)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',4-Trichlorobiphenyl (17)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',5-Trichlorobiphenyl (18)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',6-Trichlorobiphenyl (19)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,3'-Trichlorobiphenyl (20)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,4-Trichlorobiphenyl (21)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,4'-Trichlorobiphenyl (22)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,5-Trichlorobiphenyl (23)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,6-Trichlorobiphenyl (24)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3',4-Trichlorobiphenyl (25)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3',5-Trichlorobiphenyl (26)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3',6-Trichlorobiphenyl (27)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,4,4'-Trichlorobiphenyl (28)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,4,5-Trichlorobiphenyl (29)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,4,6-Trichlorobiphenyl (30)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,4',5-Trichlorobiphenyl (31)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,4',6-Trichlorobiphenyl (32)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2',3,4-Trichlorobiphenyl (33)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2',3,5-Trichlorobiphenyl (34)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C

Parameter/Analyte	**Potable Water**	**Nonpotable Water**	**Solid Hazardous Waste**	**Tissue**
3,3',4-Trichlorobiphenyl (35)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
3,3',5-Trichlorobiphenyl (36)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
3,4,4'-Trichlorobiphenyl (37)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
3,4,5-Trichlorobiphenyl (38)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
3,4',5-Trichlorobiphenyl (39)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,3'-Tetrachlorobiphenyl (40)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,4-Tetrachlorobiphenyl (41)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,4'-Tetrachlorobiphenyl (42)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,5-Tetrachlorobiphenyl (43)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,5'-Tetrachlorobiphenyl (44)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,6-Tetrachlorobiphenyl (45)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,6'-Tetrachlorobiphenyl (46)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',4,4'-Tetrachlorobiphenyl (47)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',4,5-Tetrachlorobiphenyl (48)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',4,5'-Tetrachlorobiphenyl (49)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',4,6-Tetrachlorobiphenyl (50)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',4,6'-Tetrachlorobiphenyl (51)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',5,5'-Tetrachlorobiphenyl (52)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',5,6'-Tetrachlorobiphenyl (53)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',6,6'-Tetrachlorobiphenyl (54)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,3',4'-Tetrachlorobiphenyl (55)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,3',4'-Tetrachlorobiphenyl (56)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,3',5-Tetrachlorobiphenyl (57)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,3',5'-Tetrachlorobiphenyl (58)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C

Parameter/Analyte	**Potable Water**	**Nonpotable Water**	**Solid Hazardous Waste**	**Tissue**
2,3,3',6-Tetrachlorobiphenyl (59)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,4,4'-Tetrachlorobiphenyl (60)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,4,5-Tetrachlorobiphenyl (61)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,4,6-Tetrachlorobiphenyl (62)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,4',5-Tetrachlorobiphenyl (63)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,4',6-Tetrachlorobiphenyl (64)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,5,6-Tetrachlorobiphenyl (65)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3',4,4'-Tetrachlorobiphenyl (66)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3',4,5-Tetrachlorobiphenyl (67)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3',4,5'-Tetrachlorobiphenyl (68)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3',4,6-Tetrachlorobiphenyl (69)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3',4',5-Tetrachlorobiphenyl (70)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3',4',6-Tetrachlorobiphenyl (71)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3',5,5'-Tetrachlorobiphenyl (72)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3',5',6-Tetrachlorobiphenyl (73)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,4,4',5-Tetrachlorobiphenyl (74)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,4,4',6-Tetrachlorobiphenyl (75)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2',3,4,5-Tetrachlorobiphenyl (76)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
3,3',4,4'-Tetrachlorobiphenyl (77)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
3,3',4,5-Tetrachlorobiphenyl (78)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
3,3',4,5'-Tetrachlorobiphenyl (79)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
3,3',5,5'-Tetrachlorobiphenyl (80)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
3,4,4',5-Tetrachlorobiphenyl (81)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,3',4-Pentachlorobiphenyl (82)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C

Parameter/Analyte	**Potable Water**	**Nonpotable Water**	**Solid Hazardous Waste**	**Tissue**
2,2',3,3',5-Pentachlorobiphenyl (83)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,3',6-Pentachlorobiphenyl (84)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,4,4'-Pentachlorobiphenyl (85)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,4,5-Pentachlorobiphenyl (86)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,4,5'-Pentachlorobiphenyl (87)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,4,6-Pentachlorobiphenyl (88)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,4,6'-Pentachlorobiphenyl (89)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,4',5-Pentachlorobiphenyl (90)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,4',6-Pentachlorobiphenyl (91)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,5,5'-Pentachlorobiphenyl (92)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,5,6-Pentachlorobiphenyl (93)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,5,6'-Pentachlorobiphenyl (94)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,5',6-Pentachlorobiphenyl (95)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,6,6'-Pentachlorobiphenyl (96)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3',4,5-Pentachlorobiphenyl (97)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3',4,6-Pentachlorobiphenyl (98)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',4,4',5-Pentachlorobiphenyl (99)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',4,4',6-Pentachlorobiphenyl (100)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',4,5,5'-Pentachlorobiphenyl (101)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',4,5,6'-Pentachlorobiphenyl (102)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',4,5,'6-Pentachlorobiphenyl (103)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',4,6,6'-Pentachlorobiphenyl (104)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,3',4,4'-Pentachlorobiphenyl (105)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,3',4,5-Pentachlorobiphenyl (106)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C

Parameter/Analyte	**Potable Water**	**Nonpotable Water**	**Solid Hazardous Waste**	**Tissue**
2,3,3',4',5-Pentachlorobiphenyl (107)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,3',4,5'-Pentachlorobiphenyl (108)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,3',4,6-Pentachlorobiphenyl (109)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,3',4',6-Pentachlorobiphenyl (110)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,3',5,5'-Pentachlorobiphenyl (111)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,3',5,6-Pentachlorobiphenyl (112)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,3',5',6-Pentachlorobiphenyl (113)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,4,4',5-Pentachlorobiphenyl (114)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,4,4',6-Pentachlorobiphenyl (115)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,4,5,6-Pentachlorobiphenyl (116)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,4',5,6-Pentachlorobiphenyl (117)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3',4,4',5-Pentachlorobiphenyl (118)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3',4,4',6-Pentachlorobiphenyl (119)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3',4,5,5'-Pentachlorobiphenyl (120)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3',4,5,'6-Pentachlorobiphenyl (121)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2',3,3',4,5-Pentachlorobiphenyl (122)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2',3,4,4',5-Pentachlorobiphenyl (123)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2',3,4,5,5'-Pentachlorobiphenyl (124)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2',3,4,5,6'-Pentachlorobiphenyl (125)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
3,3',4,4',5-Pentachlorobiphenyl (126)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
3,3',4,5,5'-Pentachlorobiphenyl (127)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,3',4,4'-Hexachlorobiphenyl (128)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,3',4,5-Hexachlorobiphenyl (129)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,3',4,5'-Hexachlorobiphenyl (130)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C

Parameter/Analyte	**Potable Water**	**Nonpotable Water**	**Solid Hazardous Waste**	**Tissue**
2,2',3,3',4,6-Hexachlorobiphenyl (131)	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,3',4,6'-Hexachlorobiphenyl (132)	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,3',5,5'-Hexachlorobiphenyl (133)	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,3',5,6-Hexachlorobiphenyl (134)	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,3',5,6'-Hexachlorobiphenyl (135)	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,3',6,6'-Hexachlorobiphenyl (136)	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,4,4',5-Hexachlorobiphenyl (137)	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,4,4',5'-Hexachlorobiphenyl (138)	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,4,4',6-Hexachlorobiphenyl (139)	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,4,4',6'-Hexachlorobiphenyl (140)	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,4,5,5'-Hexachlorobiphenyl (141)	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,4,5,6-Hexachlorobiphenyl (142)	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,4,5,6'-Hexachlorobiphenyl (143)	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,4,5',6-Hexachlorobiphenyl (144)	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,4,6,6'-Hexachlorobiphenyl (145)	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,4',5,5'-Hexachlorobiphenyl (146)	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,4',5,6-Hexachlorobiphenyl (147)	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,4',5,6'-Hexachlorobiphenyl (148)	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,4',5',6-Hexachlorobiphenyl (149)	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,4',6,6'-Hexachlorobiphenyl (150)	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,5,5',6-Hexachlorobiphenyl (151)	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,5,6,6'-Hexachlorobiphenyl (152)	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',4,4',5,5'-Hexachlorobiphenyl (153)	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',4,4',5',6-Hexachlorobiphenyl (154)	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C

Parameter/Analyte	**Potable Water**	**Nonpotable Water**	**Solid Hazardous Waste**	**Tissue**
2,2',4,4',6,6'-Hexachlorobiphenyl (155)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,3',4,4',5-Hexachlorobiphenyl (156)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,3',4,4',5'-Hexachlorobiphenyl (157)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,3',4,4',6-Hexachlorobiphenyl (158)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,3',4,5,5'-Hexachlorobiphenyl (159)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,3',4,5,6-Hexachlorobiphenyl (160)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,3',4,5',6-Hexachlorobiphenyl (161)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,3',4',5,5'-Hexachlorobiphenyl (162)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,3',4',5,6-Hexachlorobiphenyl (163)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,3',4',5',6-Hexachlorobiphenyl (164)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,3',5,5',6-Hexachlorobiphenyl (165)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,4,4',5,6-Hexachlorobiphenyl (166)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3',4,4',5,5'-Hexachlorobiphenyl (167)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3',4,4',5',6-Hexachlorobiphenyl (168)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
3,3',4,4',5,5'-Hexachlorobiphenyl (169)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,3',4,4',5-Heptachlorobiphenyl (170)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2'3,3',4,4',6-Heptachlorobiphenyl (171)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,3',4,5,5'-Heptachlorobiphenyl (172)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,3',4,5,6-Heptachlorobiphenyl (173)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,3',4,5,6'-Heptachlorobiphenyl (174)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,3',4,5',6-Heptachlorobiphenyl (175)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,3',4,6,6'-Heptachlorobiphenyl (176)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,3',4',5,6-Heptachlorobiphenyl (177)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,3',5,5',6-Heptachlorobiphenyl (178)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C

Parameter/Analyte	**Potable Water**	**Nonpotable Water**	**Solid Hazardous Waste**	**Tissue**
2,2',3,3',5,6,6'-Heptachlorobiphenyl (179)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,4,4',5,5'-Heptachlorobiphenyl (180)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,4,4',5,6-Heptachlorobiphenyl (181)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,4,4',5,6'-Heptachlorobiphenyl (182)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,4,4',5',6-Heptachlorobiphenyl (183)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,4,4',6,6'-Heptachlorobiphenyl (184)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,4,5,5',6-Heptachlorobiphenyl (185)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,4,5,6,6'-Heptachlorobiphenyl (186)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,4',5,5',6-Heptachlorobiphenyl (187)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,4',5,6,6'-Heptachlorobiphenyl (188)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,3',4,4',5,5'-Heptachlorobiphenyl (189)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,3',4,4',5,6-Heptachlorobiphenyl (190)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,3',4,4',5',6-Heptachlorobiphenyl (191)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,3',4,5,5',6-Heptachlorobiphenyl (192)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,3',4',5,5',6-Heptachlorobiphenyl (193)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,3',4,4',5,5'-Octachlorobiphenyl (194)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,3',4,4',5,6-Octachlorobiphenyl (195)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,3',4,4',5,6'-Octachlorobiphenyl (196)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,3',4,4',6,6'-Octachlorobiphenyl (197)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,3',4,5,5',6-Octachlorobiphenyl (198)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,3',4,5,5',6'-Octachlorobiphenyl (199)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,3',4,5,6,6'-Octachlorobiphenyl (200)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,3',4,5',6,6'-Octachlorobiphenyl (201)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,3',5,5',6,6'-Octachlorobiphenyl (202)	------------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C

Parameter/Analyte	Potable Water	Nonpotable Water	Solid Hazardous Waste	Tissue
2,2',3,4,4',5,5',6-Octachlorobiphenyl (203)	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,4,4',5,6,6'-Octachlorobiphenyl (204)	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,3,3',4,4',5,5',6-Octachlorobiphenyl (205)	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl (206)	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,3',4,4',5,6,6'-Nonachlorobiphenyl (207)	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
2,2',3,3',4,5,5',6,6'-Nonachlorobiphenyl (208)	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
Decachlorobiphenyl (209)	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
Decachlorobiphenyl, Total	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
Dichlorobiphenyl, Total	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
Heptachlorobiphenyl, Total	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
Hexachlorobiphenyl, Total	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
Monochlorobiphenyl, Total	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
Nonachlorobiphenyl, Total	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
Octachlorobiphenyl, Total	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
Pentachlorobiphenyl, Total	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
Tetrachlorobiphenyl, Total	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
Trichlorobiphenyl, Total	-----------------------	EPA 1668A/1668C	EPA 1668A/1668C	EPA 1668A/1668C
Per- and Poly-fluorinated compounds				
6:2 Fluorotelomer sulfanate (6:2 FTS)	EPA 537 (Mod.)	EPA 537 (Mod.)	EPA 537 (Mod.) (VAL-PFAS)	EPA 537 (Mod.) (VAL-PFAS)
8:2 Fluorotelomer sulfanate (8:2 FTS)	EPA 537 (Mod.)	EPA 537 (Mod.)	EPA 537 (Mod.) (VAL-PFAS)	EPA 537 (Mod.) (VAL-PFAS)
N-ethyl perfluorooctanesulfonamidoacetic acid (N-EtFOSAA)	EPA 537 EPA 537 (Mod.)	EPA 537 (Mod.)	EPA 537 (Mod.) (VAL-PFAS)	EPA 537 (Mod.) (VAL-PFAS)
N-ethylperfluoro-1-octanesulfonamide (N-EtFOSA)	EPA 537 (Mod.)	EPA 537 (Mod.)	EPA 537 (Mod.) (VAL-PFAS)	EPA 537 (Mod.) (VAL-PFAS)

Parameter/Analyte	**Potable Water**	**Nonpotable Water**	**Solid Hazardous Waste**	**Tissue**
N-ethylperfluoro-1-octanesulfonamido ethanol (N-EtFOSE)	EPA 537 (Mod.)	EPA 537 (Mod.)	EPA 537 (Mod.) (VAL-PFAS)	EPA 537 (Mod.) (VAL-PFAS)
N-methyl perfluorooctanesulfonamidoacetic acid (N-MeFOSAA)	EPA 537 EPA 537 (Mod.)	EPA 537 (Mod.)	EPA 537 (Mod.) (VAL-PFAS)	EPA 537 (Mod.) (VAL-PFAS)
N-methylperfluoro-1-octanesulfonamide (N-MeFOSA)	EPA 537 (Mod.)	EPA 537 (Mod.)	EPA 537 (Mod.) (VAL-PFAS)	EPA 537 (Mod.) (VAL-PFAS)
N-methylperfluoro-1-octanesulfonamido ethanol (N-MeFOSE)	EPA 537 (Mod.)	EPA 537 (Mod.)	EPA 537 (Mod.) (VAL-PFAS)	EPA 537 (Mod.) (VAL-PFAS)
Perfluorobutanesulfonic acid (PFBS)	EPA 537 EPA 537 (Mod.)	EPA 537 (Mod.)	EPA 537 (Mod.) (VAL-PFAS)	EPA 537 (Mod.) (VAL-PFAS)
Perfluorobutanoic acid (PFBA)	EPA 537 (Mod.)	EPA 537 (Mod.)	EPA 537 (Mod.) (VAL-PFAS)	EPA 537 (Mod.) (VAL-PFAS)
Perfluorodecanesulfonate (PFDS)	EPA 537 (Mod.)	EPA 537 (Mod.)	EPA 537 (Mod.) (VAL-PFAS)	EPA 537 (Mod.) (VAL-PFAS)
Perfluorodecanoic acid (PFDA)	EPA 537 EPA 537 (Mod.)	EPA 537 (Mod.)	EPA 537 (Mod.) (VAL-PFAS)	EPA 537 (Mod.) (VAL-PFAS)
Perfluorododecanoic acid (PFDoA)	EPA 537 EPA 537 (Mod.)	EPA 537 (Mod.	EPA 537 (Mod.) (VAL-PFAS)	EPA 537 (Mod.) (VAL-PFAS)
Perfluoroundecanoic acid (PFUnA)	EPA 537	-----------------	------------------	-----------------
Perfluoroheptanesulfonate (PFHpS)	EPA 537 (Mod.)	EPA 537 (Mod.)	EPA 537 (Mod.) (VAL-PFAS)	EPA 537 (Mod.) (VAL-PFAS)
Perfluoroheptanonic acid (PFHpA)	EPA 537 EPA 537 (Mod.)	EPA 537 (Mod.)	EPA 537 (Mod.) (VAL-PFAS)	EPA 537 (Mod.) (VAL-PFAS)
Perfluorohexadecanoic acid (PFHxDA)	EPA 537 (Mod.)	EPA 537 (Mod.)	EPA 537 (Mod.) (VAL-PFAS)	EPA 537 (Mod.) (VAL-PFAS)
Perfluorohexanesulfononic acid (PFHxS)	EPA 537 EPA 537 (Mod.)	EPA 537 (Mod.)	EPA 537 (Mod.) (VAL-PFAS)	EPA 537 (Mod.) (VAL-PFAS)
Perfluorohexanoic acid (PFHxA)	EPA 537 EPA 537 (Mod.)	EPA 537 (Mod.)	EPA 537 (Mod.) (VAL-PFAS)	EPA 537 (Mod.) (VAL-PFAS)
Perfluorononaoic acid (PFNA)	EPA 537 EPA 537 (Mod.)	EPA 537 (Mod.)	EPA 537 (Mod.) (VAL-PFAS)	EPA 537 (Mod.) (VAL-PFAS)
Perfluorooctane sulfonamide (PFOSA)	EPA 537 (Mod.)	EPA 537 (Mod.)	EPA 537 (Mod.) (VAL-PFAS)	EPA 537 (Mod.) (VAL-PFAS)

Parameter/Analyte	**Potable Water**	**Nonpotable Water**	**Solid Hazardous Waste**	**Tissue**
Perfluorooctanesulfonic acid (PFOS)	EPA 537 EPA 537 (Mod.)	EPA 537 (Mod.)	EPA 537 (Mod.) (VAL-PFAS)	EPA 537 (Mod.) (VAL-PFAS)
Perfluorooctanoic acid (PFOA)	EPA 537 EPA 537 (Mod.)	EPA 537 (Mod.)	EPA 537 (Mod.) (VAL-PFAS)	EPA 537 (Mod.) (VAL-PFAS)
Perfluoropentanoic acid (PFPeA)	EPA 537 (Mod.)	EPA 537 (Mod.)	EPA 537 (Mod.) (VAL-PFAS)	EPA 537 (Mod.) (VAL-PFAS)
Perfluorotetradecanoic acid (PFTeDA)	EPA 537 EPA 537 (Mod.)	EPA 537 (Mod.)	EPA 537 (Mod.) (VAL-PFAS)	EPA 537 (Mod.) (VAL-PFAS)
Perfluorotridecanoic acid (PFTrDA)	EPA 537 EPA 537 (Mod.)	EPA 537 (Mod.)	EPA 537 (Mod.) (VAL-PFAS)	EPA 537 (Mod.) (VAL-PFAS)
Perfluoroundecanoic acid (PFUdA)	EPA 537 (Mod.)	EPA 537 (Mod.)	EPA 537 (Mod.) (VAL-PFAS)	EPA 537 (Mod.) (VAL-PFAS)

Accredited Laboratory

A2LA has accredited

VISTA ANALYTICAL LABORATORY

El Dorado Hills, CA

for technical competence in the field of

Environmental Testing

In recognition of the successful completion of the A2LA evaluation process that includes an assessment of the laboratory's compliance with ISO/IEC 17025:2005, the 2009 TNI Environmental Testing Laboratory Standard, and the requirements of the Department of Defense Environmental Laboratory Accreditation Program (DoD ELAP) as detailed in version 5.1 of the DoD Quality System Manual for Environmental Laboratories (QSM), accreditation is granted to this laboratory to perform recognized EPA methods as defined on the associated A2LA Environmental Scope of Accreditation. This accreditation demonstrates technical competence for this defined scope and the operation of a laboratory quality management system (refer to joint ISO-ILAC-IAF Communiqué dated 8 January 2009).

Presented this 5th day of July 2017.

President and CEO
For the Accreditation Council
Certificate Number 3091.01
Valid to September 30, 2019

For the tests to which this accreditation applies, please refer to the laboratory's Environmental Scope of Accreditation.

Appendix E

Laboratory Standard Operating Procedures

NAVFAC
Naval Facilities Engineering Command

Sampling and Analysis Plan
Monitoring Well Installation, Aquifer Testing, Drinking Water Sampling, and Groundwater Sampling
Outlying Landing Field Coupeville

NOTIFICATION: THIS APPENDIX CONTAINS SENSITIVE BUT UNCLASSIFIED INFORMATION WHICH IS PROTECTED BY THE FREEDOM OF INFORMATION ACT

FOIA Exemption 4 (5 USC 552(b)(4))
Protect Trade Secrets and Confidential Business Information

TO REQUEST A COPY OF THE DOCUMENT

PLEASE CONTACT

Department of the Navy
Freedom of Information Act Office

http://www.secnav.navy.mil/foia/Pages/default.aspx

Distribute to U. S. Government Agencies Only