DEPARTMENT OF THE NAVY
COMMANDER
NAVY REGION HAWAII
850 TICONDEROGA ST STE 110
JBPHH, HAWAII 96860-5101

5750
Ser N4/0581
August 25, 2017

CERTIFIED NO: 7016 0910 0001 0899 9808

Mr. Bob Pallarino
U.S. Environmental Protection Agency, Region IX
75 Hawthorne Street
San Francisco, CA 94105

Mr. Steven Y.K. Chang, P.E., Chief
State of Hawaii Department of Health
Solid and Hazardous Waste Branch
919 Ala Moana Boulevard, Room 210
Honolulu, HI 96814

Dear Mr. Pallarino and Mr. Chang:

SUBJECT: ADMINISTRATIVE ORDER ON CONSENT STATEMENT OF WORK SECTION 6 AND SECTION 7 MONITORING WELL INSTALLATION WORK PLAN ADDENDUM 02 REVISION 00, RED HILL BULK FUEL STORAGE FACILITY (RED HILL), JOINT BASE PEARL HARBOR-HICKAM, OAHU, HAWAII

The Monitoring Well Installation (MWI) Work Plan (WP) Addendum No. 2 for Red Hill pursuant to the Administrative Order on Consent (AOC) Statement of Work (SOW) Section 6, Investigation and Remediation of Releases , and Section 7, Groundwater Protection and Evaluation is enclosed.

The MWI WP Addendum 02 details the design of and rationale for the expansion of Red Hill's current groundwater monitoring well network to further the understanding of hydrogeologic conditions, groundwater flow, and potential lateral and vertical migration of chemicals of potential concern at Red Hill and within its surrounding areas pursuant to AOC SOW Section 6, Investigation and Remediation of Releases, and Section 7, Groundwater Protection and Evaluation.

If you have any questions, please contact Aaron Y. Poentis of our Regional Environmental Department at (808) 471-3858 or at aaron.poentis@navy.mil.

Sincerely,

R. D. HAYES, III
Captain, CEC, U.S. Navy
Regional Engineer
By direction of the
Commander

Enclosure: Monitoring Well Installation Work Plan Addendum 02, Red Hill Bulk Storage Facility, Joint Base Pearl Harbor-Hickam, Oahu, August 25, 2017

Red Hill Administrative Order on Consent,
Monitoring Well Installation Work Plan Addendum No. 02 Deliverable

Section 6.2 Investigation and Remediation of Releases Scope of Work
Section 7.1.2 Groundwater Flow Model Report Scope of Work
Section 7.2.2 Contaminant Fate and Transport Model Report Scope of Work
Section 7.3.2 Groundwater Monitoring Well Network Scope of Work

In accordance with the Red Hill Administrative Order on Consent, paragraph 9, DOCUMENT CERTIFICATION

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to be the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information including the possibility of fines and imprisonment for knowing violation.

Signature: ______________________

CAPT Richard Hayes III, CEC, USN
Regional Engineer, Navy Region Hawaii

Date: 8/25/2017

Monitoring Well Installation Work Plan Addendum 02, Red Hill Bulk Fuel Storage Facility

JOINT BASE PEARL HARBOR-HICKAM, O‘AHU, HAWAI‘I

August 25, 2017
Revision 00

NAVFAC
Naval Facilities Engineering Command
NAVFAC HAWAII

Comprehensive Long-Term Environmental Action Navy
Contract Number N62742-12-D-1829, CTO 0053

Monitoring Well Installation Work Plan Addendum 02, Red Hill Bulk Fuel Storage Facility

JOINT BASE PEARL HARBOR-HICKAM, O‘AHU, HAWAI‘I

August 25, 2017
Revision 00

Prepared for:

Defense Logistics Agency Energy
8725 John J Kingman Rd Suite 4950
Fort Belvoir, VA 22060-6222

Prepared by:

AECOM Technical Services, Inc.
1001 Bishop Street, Suite 1600
Honolulu, HI 96813-3698

Prepared under:

Comprehensive Long-Term Environmental Action Navy
Contract Number N62742-12-D-1829, CTO 0053

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APPENDIXES

FIGURES

TABLES

ACRONYMS AND ABBREVIATIONS

%	percent
°C	degree Celsius
AOC	Administrative Order on Consent
API	American Petroleum Institute
ASTM	ASTM International
AVGAS	aviation gasoline
BFB	4-bromofluorobenzene
bgs	below ground surface
btoc	below top of casing
BWS	Board of Water Supply, City and County of Honolulu
CCV	continuing calibration verification
CF&T	contaminant fate and transport
CoC	chain of custody
COLIWASA	composite liquid waste sampler
COPC	chemical of potential concern
COR	Contracting Officer’s Representative
CSM	conceptual site model
CTO	contract task order
DDT	dichlorodiphenyltrichloroethane
DFTPP	decafluorotriphenylphosphine
DLA	Defense Logistics Agency
DO	dissolved oxygen
DoD	Department of Defense, United States
DOH	Department of Health, State of Hawai‘i
DON	Department of the Navy, United States
DQI	data quality indicator
EICP	extracted ion current profile
ELAP	Environmental Laboratory Accreditation Program
EM	electromagnetic
EPA	Environmental Protection Agency, United States
ft	foot/feet
GC	gas chromatography
GPS	Global Positioning System
ICAL	initial calibration
ID	identification
IDW	investigation-derived waste
JBPHH	Joint Base Pearl Harbor-Hickam
JP	Jet Fuel Propellant
LCS	laboratory control sample
LNAPL	light non-aqueous-phase liquid
LOD	limit of detection
LOQ	limit of quantitation
MB	method blank
mL	milliliter

MS	matrix spike
MSD	matrix spike duplicate
msl	mean sea level
MWIWP	Monitoring Well Installation Work Plan
N/A	not applicable
NAD	North American Datum
NAP	natural attenuation parameter
NAPL	non-aqueous-phase liquid
NAVFAC	Naval Facilities Engineering Command
Navy	Department of the Navy, United States
OD	outer diameter
ODEX	overburden drilling with eccentric drilling
ORP	oxidation-reduction potential
PAH	polynuclear aromatic hydrocarbon
PID	photoionization detector
psig	pounds per square inch gauge
PVC	polyvinyl chloride
QA	quality assurance
QC	quality control
QSM	*Quality Systems Manual*
RPD	relative percent difference
RT	retention time
SAP	sampling and analysis plan
SIM	selective ion monitoring
SOP	standard operating procedure
SOW	scope of work
SPR	single-point resistance
TGM	Technical Guidance Manual
TOC	top of casing
TPH	total petroleum hydrocarbons
TPH-d	total petroleum hydrocarbons – diesel range organics
TPH-g	total petroleum hydrocarbons – gasoline range organics
TPH-o	total petroleum hydrocarbons – residual range organics (i.e., TPH-oil)
U.S.	United States
USGS	United States Geological Survey
UV	ultra violet
VOA	volatile organic analyte
VOC	volatile organic compound
WP	work plan

1. Introduction

This *Monitoring Well Installation Work Plan* (MWIWP) *Addendum 02* documents the proposed approach for installing up to 12 new groundwater monitoring wells within the Red Hill Bulk Fuel Storage Facility (the "Facility") and adjacent areas (Figure 1). The effort will expand the current monitoring network and will increase the understanding of groundwater flow gradients (horizontal and vertical), formation hydraulic conductivities, subsurface geology, extent of chemicals of potential concern (COPCs), and potential lateral and vertical migration of COPCs in the project study area. The information will be used to refine the conceptual site model (CSM) and the groundwater flow and contaminant fate and transport (CF&T) models.

This *MWIWP Addendum 02* intends to serve as a streamlined guide, and supplements information presented in the MWIWP dated August 29, 2016 (DON 2016). It supersedes *MWIWP Addendum 01* published on January 4, 2017 (DON 2017a), which addressed proposed installation of two (subsequently reduced to one) new single-level wells and received Conditional Approval by the Regulatory Agencies on February 3, 2017 (Appendix H). An overall revised technical approach has been developed for *MWIWP Addendum 02*, which addresses installation of 12 proposed new multi-level wells.

Detailed site background and project quality objectives are provided in the MWIWP (DON 2016) and are not covered in this *MWIWP Addendum 02*. Additionally, methods and procedures for collecting groundwater samples from the monitoring well, analyzing the groundwater for COPCs, and conducting other investigation activities and analyses are addressed in the project *Work Plan* (WP) */ Scope of Work* (SOW), *Investigation and Remediation of Releases and Groundwater Protection and Evaluation, Red Hill Bulk Fuel Storage Facility* (DON 2017b), the project *Sampling and Analysis Plan* (SAP) (DON 2017d), and any forthcoming SAP addenda.

The activities proposed under this *MWIWP Addendum 02*, the MWIWP (DON 2016), and the project WP/SOW (DON 2017b) are part of an investigation being performed by the United States (U.S.) Department of the Navy (DON; "Navy") and Defense Logistics Agency (DLA) to address the requirements and achieve the objectives of the Administrative Order on Consent (AOC) issued by the U.S. Environmental Protection Agency (EPA) Region 9 and the State of Hawai‘i Department of Health (DOH) (EPA Region 9 and DOH 2015). The investigation specifically addresses the AOC Statement of Work Section 6, Investigation and Remediation of Releases, and Section 7, Groundwater Protection and Evaluation. The monitoring well installation activities proposed under this *MWIWP Addendum 02* will be conducted as part of Task 4 *Expand the Monitoring Well Network* presented in the project WP/SOW (DON 2017b, Section 3.4).

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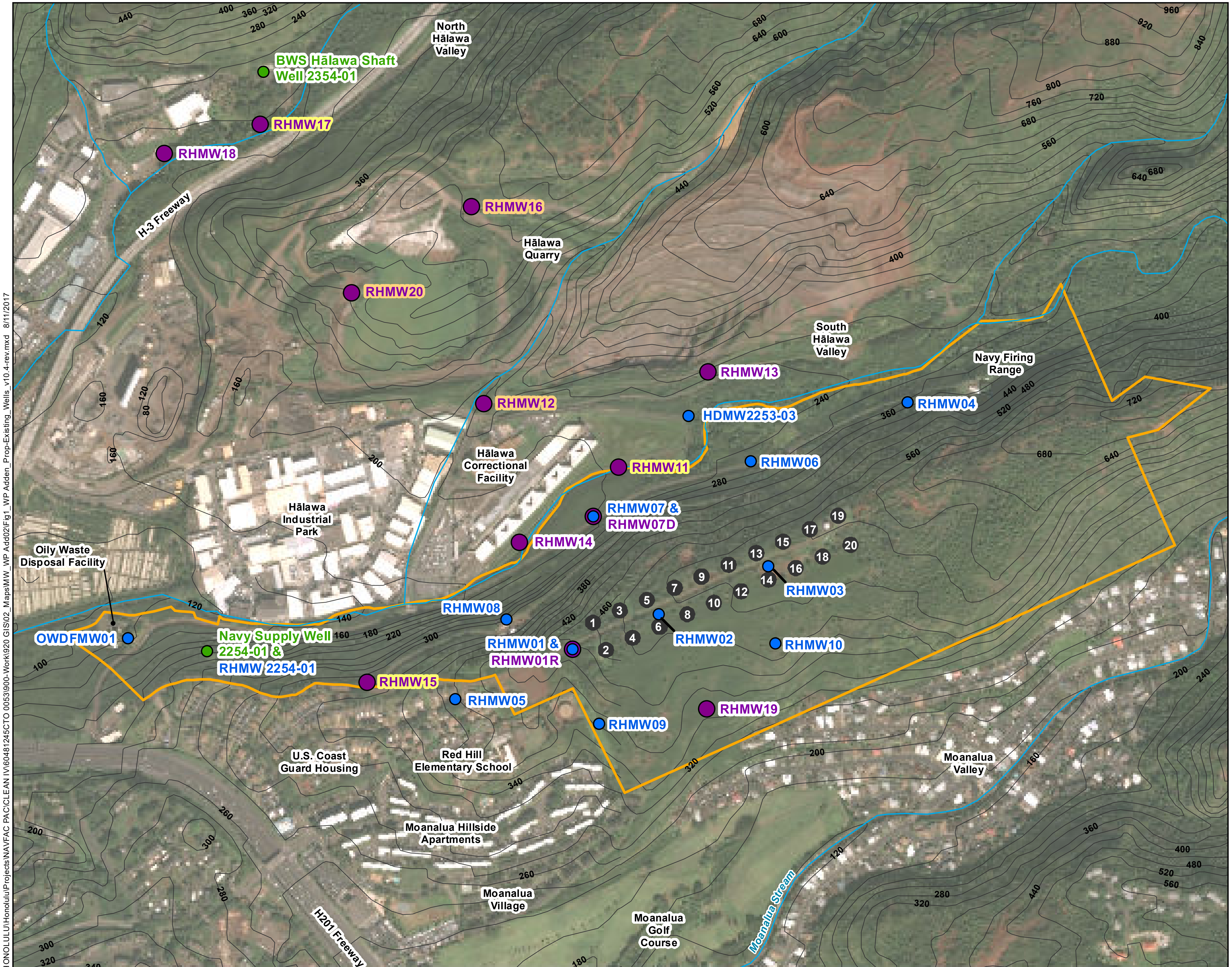
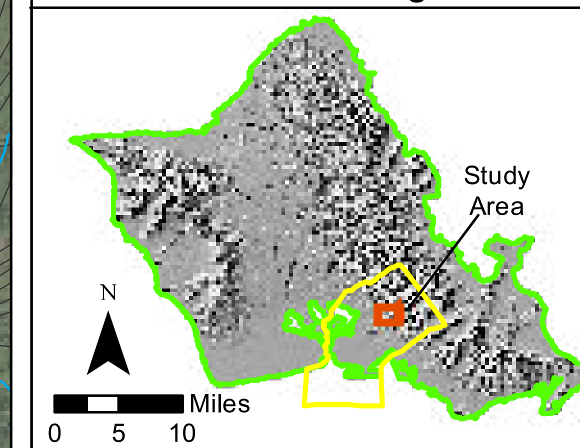


Groundwater Modeling Domain



Legend

- Proposed Monitoring Well Location
- Existing Monitoring Well Location
- Proposed and Existing Monitoring Well Adjacent Locations
- Existing Water Supply Well
- Red Hill Fuel Storage Tank
- Stream
- 400 Topographic Contour (feet above mean sea level)
- Red Hill Installation Boundary
- Regional Model Boundary
- Local Model Boundary

Notes

1. Map projection: NAD 1983 UTM Zone 4N
2. Base Map: DigitalGlobe, Inc. (DG) and NRCS. Publication_Date: 2015
3. Coordinates: NAD 1983 UTM Zone 4N
4. RHMW-- indicates well identified for priority installation.
5. RHMW-- indicates three potential wells, one of which will be identified for priority installation.

N

0 250 500 1,000 Feet

Figure 1
Proposed and Existing Monitoring Well Locations
Monitoring Well Installation Work Plan
Addendum 02
Red Hill Bulk Fuel Storage Facility
JBPHH, O'ahu, Hawai'i

\\HONOLULU\Honolulu\Projects\NAVFAC PAC\CLEAN IV\60481245CTO 0053\900-Work\920 GIS\02_Maps\MW_WP Add02\Fig1_WP Adden_Prop-Existing_Wells_v10.4-rev.mxd 8/11/2017

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2. Monitoring Well Network Expansion Design and Rationale

In accordance with AOC Statement of Work Section 7.3.2 (EPA Region 9 and DOH 2015), this section describes the proposed expansion of the monitoring well network, including the rationale used to select new well locations, and the design and rationale for drilling, unconsolidated material sampling, rock coring, well installation, and development. The design and rationale for subsequent groundwater sampling and analysis is provided in the project WP/SOW (DON 2017b). Twelve monitoring wells are proposed for installation in the project study area, as shown on Figure 1: RHMW01R, RHMW07D, RHMW11, RHMW12, RHMW13, RHMW14, RHMW15, RHMW16, RHMW17, RHMW18, RHMW19, and RHMW20. Four wells have been identified as the highest priority wells: RHMW11, one well located in the vicinity of the Hawaiian Cement Quarry to the northwest of Halawa Correctional Facility (i.e., RHMW12, RHMW16, or RHMW20), RHMW15, and RHMW17.

Three of these wells were previously proposed and conditionally approved for installation as single-level wells screened across the surface of the groundwater table: RHMW01R (proposed in the January 4, 2017, *MWIWP Addendum 01* [DON 2017a]), and RHMW11 and contingent well RHMW12 (proposed in the August 29, 2016, MWIWP [DON 2016]). These three wells are now proposed for installation as multi-level monitoring systems, as described below. The location of RHMW12 has been moved from the original proposed location to the northwest on property used by Hawaiian Cement for quarry operations.

The proposed multi-level well sampling system, Westbay MP38, is a proven technology in establishing multiple discrete sampling zones in deep-bedrock aquifers. Furthermore, the system has a proven record in volcanic basalt aquifers similar to those on Oahu, such as a series of Scientific Investigation Reports by the U.S. Geological Survey (USGS) documenting successful deployment of Westbay system wells in the volcanic-dominated Eastern Snake River Plain aquifer, Idaho National Laboratory, over a period of 6 years (Fisher and Twining 2011; Twining and Fisher 2012, 2015).

All proposed monitoring wells except RHMW01R will be cased to 10 feet (ft) above the water table (which is estimated to occur at 15–20 ft above mean sea level [msl]), and an open borehole will be drilled to approximately 300 ft below the water table. A multi-level well system will be installed within the well casing and open borehole that allows for COPC sampling, water level/groundwater head measurements, and estimates of hydraulic conductivity within discrete zones.

RHMW01R is an in-tunnel well and will be used to augment data from RHMW01 and provide data from soil vapor in the vadose zone, and COPC and geohydrologic data from the water table and deeper portions of the aquifer (up to 300 ft below the water table). Existing well RHMW01 is a 1-inch well with a submerged screen. Provided conditions specified in Section 2.3 are met during drilling, RHMW01R will be designed as a multi-level well similar in design to the above proposed wells, but will include up to three packer-isolated zones in the unsaturated borehole to sample soil vapor within select portions of the vadose zone.

Description, specifications, and installation procedures for the multi-level well construction are presented in Appendix A.

2.1 Monitoring Well Locations

The current Red Hill groundwater monitoring network consists of sampling at 12 locations inside and outside of the Facility boundaries (Figure 1). Further expansion of the groundwater monitoring network at strategic locations is recommended to fill data gaps and address the objectives outlined in Sections 6 and 7 of the AOC Statement of Work (EPA Region 9 and DOH 2015). Determination of the exact well locations will be determined in the field, and based on discussions with respective landowners. The well locations have been selected to provide data that will fill the following primary data gaps:

- Lithological data and groundwater elevation data are needed to evaluate whether or not valley fill sediments and saprolite layers extend below the water table and are of low permeability and thick enough to serve as hydraulic barriers that will restrict groundwater flow between Red Hill and Hālawa Shaft.
- Additional lithological and hydraulic data (i.e., hydraulic conductivity) of the basalt will be used to further characterize the water table aquifer and potential locations of preferential pathways between Red Hill and water supply wells.
- Additional groundwater elevation data are needed between Red Hill and Hālawa Shaft to further evaluate groundwater flow gradients and directions in the shallow and deeper portions of the basal water table aquifer northwest of Red Hill and assess whether groundwater elevations measured in RHMW07 represent anomalies or ambient groundwater flow conditions.
- Additional groundwater quality data are needed from discrete zones in the basal water table aquifer to evaluate the presence or absence of COPCs both vertically and horizontally between Red Hill and nearby water supply wells (i.e., Hālawa Shaft and Moanalua Wells).

Rock cores and subsurface unconsolidated material samples to be collected during monitoring well installation will provide information regarding the physical properties of the subsurface. The locations were also chosen to provide additional sentinel monitoring points between the Red Hill tanks and potential receptors that could be exposed via the drinking water supply system and vapor intrusion pathways. The newly installed monitoring wells will help better characterize groundwater flow patterns, groundwater chemistry, and the geological matrix. They can also be used as potential monitoring and access points for other investigation activities, such as comparison of groundwater to EPA's vapor intrusion screening levels to evaluate vapor intrusion concerns, or to conduct augmentation, if recommended. The number of locations proposed in the vicinity of the Facility tanks was limited due to the need to minimize creation of migration pathways between possible vadose zone contamination and the groundwater aquifer. Potential monitoring well locations in the vicinity of the tanks are also limited by the steep site topography.

The 12 proposed well locations (Figure 1) were chosen based on their potential to provide more information about the site's geology and groundwater, and to achieve the following objectives:

1. *Sentinels:* Provide monitoring points between the Red Hill tanks and receptors potentially exposed via the drinking water supply system, and to guard against the potential for vapor intrusion concerns due to constituents in groundwater. Wells identified as achieving this objective are only considered possible sentinels; the selection and basis of sentinels will be identified in the forthcoming *Sentinel Well Network Development Plan*.
2. *Characterize Flow:* Provide additional groundwater elevation data to evaluate groundwater flow patterns in the vicinity of the Red Hill Facility and refine and calibrate the groundwater flow model. In addition, hydraulic heads will be measured at discrete intervals to depths up to 300 ft below the water table to evaluate horizontal gradients across the shallow and deeper portions of the basal aquifer and vertical gradients between the shallower and deeper portions of the basal aquifer. Hydraulic conductivities will also be measured within the discrete zones and used to estimate potential groundwater velocities.

3. *Characterize Groundwater Chemistry:* Provide water quality data and evaluate COPC concentrations and natural attenuation parameters (NAPs) in both the shallow and deeper portions of the basal aquifer.
4. *Characterize Matrix:* Further characterize the stratigraphy and properties of the valley fill, caprock, and saprolite layers.
5. *Other Uses:* Provide potential monitoring and access points for other activities, such as limited extraction or augmentation, if warranted upon completion of other field activities.

A matrix of the proposed well's objectives fulfilled, rationale for their locations, and how the data can be used to address existing data gaps is presented in Table 2-1.

Table 2-1: Proposed New Monitoring Well Objectives and Location Rationale Matrix

	Meets Objective					
Well	1: Sentinels	2: Characterize Flow	3: Characterize Chemistry	4: Characterize Valley Fill/Caprock/Saprolite	5: Other Uses	Location Rationale
RHMW01R: [a]	✓	✓	✓		✓	RHMW01R is located adjacent to existing well RHMW01. RHMW01R was originally proposed to provide a well at the southwestern end of the tank farm that can be used to detect potential NAPL, which cannot be detected by RHMW01 since the screen interval for RHMW01 is below the water table. With the proposed multi-well design consisting of a sampling port that is located below the water table, the evaluation of the presence or absence of NAPL will be based on field observations (i.e., sheen on purge water) and by comparisons of COPC concentrations to solubility limits for the COPCs. RHMW01R will also be constructed with discrete zones set in the vadose zone that can be used for soil vapor sample collection within the vadose zone near the tank farm. In addition, lithologic data from this location will provide data on the nature of basalt in deeper portions of the basal aquifer in the tank farm area.
RHMW07D	✓	✓	✓		✓	RHMW07D is located adjacent to existing well RHMW07 and will provide data to further evaluate water level elevations observed in shallow well RHMW07, which historically have been measured approximately 4 ft higher than surrounding wells and are considered suspect as to whether or not they represent ambient surrounding groundwater elevations. Additionally, this location will provide groundwater chemistry data to further evaluate the groundwater quality and potential for preferential pathways in both the shallow and deeper portions of the basal aquifer between the Red Hill tank farm and Hālawa Shaft.
RHMW11	✓	✓	✓	✓	✓	RHMW11 is located on the northwest side of South Hālawa Stream to determine if valley fill and saprolite extend below the water table in the area and potentially serve as natural barriers to groundwater flow. This well will also provide a monitoring point north of Red Hill between well RHMW07 and Hālawa Deep Monitor Well 2253-03. Groundwater quality and groundwater elevation data from this location will be used to further evaluate groundwater flow directions in South Hālawa Valley and the groundwater quality between Red Hill and the Hālawa Shaft. The well will also be used to evaluate the potential presence of perched groundwater conditions throughout the entire thickness of the vadose zone in South Hālawa Valley, which can influence recharge and groundwater flow patterns.
RHMW12	✓	✓	✓	✓	✓	RHMW12 will provide groundwater elevation data between Red Hill and the Hālawa Shaft to further evaluate groundwater flow patterns southeast of the quarry pit where surface water may drain and serve as a recharge area that potentially affects groundwater flow. The data from this well will be used to further evaluate groundwater flow patterns in South Halawa Valley. Lithologic data from this location will be used to further define the geometry of the valley fill sediments and saprolite layers in South Hālawa Valley, and groundwater quality data will be used to evaluate the groundwater quality to the northwest.

Well	Meets Objective: 1: Sentinels	2: Characterize Flow	3: Characterize Chemistry	4: Characterize Valley Fill/Caprock/Saprolite	5: Other Uses	Location Rationale
RHMW13	✓	✓	✓	✓	✓	RHMW13 will serve as a monitoring point between Red Hill and the Hālawa Shaft to further evaluate groundwater flow in South Hālawa Valley. This well will provide groundwater elevation data in the upper portion of South Hālawa Valley in addition to data from Hālawa Deep Monitor Well 2253-03, which is completed as a deep open-hole well with water levels that may be affected by vertical flow components. Lithologic data from this location will provide data to further define the geometry of the valley fill sediments and saprolite layers in South Hālawa Valley. Groundwater quality data from this well will be used to evaluate groundwater quality to the northwest.
RHMW14	✓	✓	✓	✓	✓	RHMW14 is located on the northwest side of South Hālawa Stream and will provide a second location in addition to RHMW11 to determine if valley fill and saprolite extend below the water table in the area and potentially serve as natural barriers to groundwater flow. This well will also provide a monitoring point north of Red Hill between well RHMW07 and RHMW08 to evaluate the groundwater quality and groundwater flow directions in South Hālawa Valley. The well will also be used to evaluate the potential presence of perched groundwater conditions throughout the entire thickness of the vadose zone in the area, which can influence recharge and groundwater flow patterns.
RHMW15	✓	✓	✓	✓	✓	RHMW15 will provide a monitoring point located at the upper extent of the Red Hill Shaft infiltration gallery, which is the portion of the infiltration gallery that yields the highest volumes of groundwater supplying Navy Supply Well 2254-01. Groundwater elevation data from this well will improve assessment of the effects of pumping at Navy Supply Well 2254-01. This well will also provide data for additional lithologic characterization near the upper portion of the infiltration gallery, where a significant high-permeability clinker zone may exist within the saturated zone, to further support the CSM. Groundwater quality data from this well will be used to evaluate groundwater quality at the upper reaches of the infiltration gallery.
RHMW16	✓	✓	✓		✓	RHMW16 will provide a monitoring location in the vicinity of the ridge between South Hālawa Valley and North Hālawa Valley. The location is in the vicinity of a quarry pit where surface water may drain and serve as a recharge area that potentially affects groundwater flow. Groundwater elevation data from this location can supplement groundwater elevation data sets for wells in both South Hālawa Valley and North Hālawa Valley to evaluate whether there is a northward regional gradient between Red Hill and Hālawa Shaft or more localized flow patterns in the valleys between Red Hill and Hālawa Shaft. Groundwater quality data will be used to evaluate groundwater quality between Red Hill and Hālawa Shaft in both the shallow and deeper portions of the groundwater aquifer.
RHMW17	✓	✓	✓	✓	✓	RHMW17 is located northwest of North Hālawa Stream and just southeast of Hālawa Shaft to determine if valley fill and saprolite in the area extend below the water table in the area and potentially serve as natural barriers to groundwater flow. This well will also provide a monitoring point to evaluate groundwater quality and can be used along with data collected from RHMW16, RHMW18, and RHMW20 to evaluate groundwater flow directions in North Hālawa Valley. Groundwater elevation data will provide a better assessment of the effects of pumping at Hālawa Shaft on the surrounding water table. The well will also be used to evaluate the potential presence of perched groundwater conditions throughout the entire thickness of the vadose zone in the area, which can influence recharge and groundwater flow patterns.

	Meets Objective					
Well	1: Sentinels	2: Characterize Flow	3: Characterize Chemistry	4: Characterize Valley Fill/Caprock/Saprolite	5: Other Uses	Location Rationale
RHMW18	✓	✓	✓	✓	✓	RHMW18 is located northwest of North Hālawa Stream and will provide a second location along with RHMW17 to determine if valley fill and saprolite extend below the water table in the area and potentially serve as natural barriers to groundwater flow. This well will also provide a monitoring point to evaluate groundwater quality and can be used along with data collected from RHMW16, RHMW17, and RHMW20 to evaluate groundwater flow directions in North Hālawa Valley. Groundwater elevation data will provide a better assessment of the effects of pumping at Hālawa Shaft on the surrounding water table. The well will also be used to evaluate the potential presence of perched groundwater conditions throughout the entire thickness of the vadose zone in the area, which can influence recharge and groundwater flow patterns.
RHMW19	✓	✓	✓		✓	RHMW19 is located between Tank 5 and Moanalua Valley and between RHMW09 and RHMW10 to assess groundwater quality and further evaluate groundwater flow directions in the area. Data from this well will also be used to further evaluate groundwater quality toward Moanalua Valley in both the shallow and deeper groundwater aquifer.
RHMW20	✓	✓	✓		✓	RHMW20 will provide a second monitoring location addition to RHMW16 in the vicinity of the ridge between South Hālawa Valley and North Hālawa Valley. The location is also in the vicinity of a quarry pit where surface water may drain and serve as a recharge area that potentially affects groundwater flow. Groundwater elevation data from this location can supplement groundwater elevation data sets for wells in both South Hālawa Valley and North Hālawa Valley to evaluate whether there is a northward regional gradient between Red Hill and Hālawa Shaft or more localized flow patterns in the valleys between Red Hill and Hālawa Shaft. Groundwater quality data will be used to evaluate groundwater quality between Red Hill and Hālawa Shaft and toward Hālawa Shaft in both the shallow and deeper portions of the groundwater aquifer.

RHMW-- well identified for priority installation

RHMW-- potential priority well; the most expedient of the three Halawa Quarry-area wells (RHMW12, RHMW16, and RHMW20) will be identified for priority installation.

[a] The rationale presented for RHMW01R is for its installation as a multi-level well. If field conditions require installation of RHMW01R as a single-level well (Section 2.3), the rationale is to provide a well screened across the water table surface adjacent to existing well RHMW01, which lacks such a screen.

As shown on Figure 1, two of the proposed wells are located adjacent to existing wells:

- RHMW01R is adjacent to existing single-level well RHMW01. As indicated in its well construction log (reproduced in Appendix B) and recently confirmed by down-hole video logging,[1] the screened interval of RHMW01 does not bracket across the water table surface. Although the multi-level well design also has limitations for non-aqueous-phase liquid (NAPL) detections since the system relies on sampling ports within packer-isolated zones, the sampling port can be positioned to assess NAPL indirectly inferred from dissolved COPCs in proximity to the water table better than the current RHMW01.

[1] The June 8, 2017, video logging measured depth to groundwater at 83.01 ft below top of casing (btoc), and the top of well screen at 90 ft btoc. Groundwater levels have been consistently measured approximately 5–7 ft above the top of screen in well RHMW01. Groundwater levels have been consistently measured approximately 5–7 ft above the top of screen in well RHMW01 (DON 2017e).

- RHMW07D is a deep well adjacent to existing single-level well RHMW07. Historical depth to water levels reported for RHMW07 are considered suspect (i.e., approximately 4 ft higher than other wells in the vicinity) (DON 2017e).

Both of these existing wells will be retained in the monitoring network to enable the evaluation of data paired with the adjacent new wells.

2.2 Installation of Multi-Level Monitoring Wells

Figure 2 displays a preliminary typical well installation diagram for all multi-level wells except RHMW01R; installation of RHMW01R is described in Section 2.3. Anticipated drilling activities include hollow-stem auger drilling through soil overburden, rock coring using wet rotary methods, and downhole hammer with air rotary to ream the boreholes and install casing. Ten-inch diameter conductor casing will be installed as necessary to prevent the downward migration of water from perched water zones, if present, or potential NAPL that could impact the underlying basal aquifer. A 5-inch-diameter Schedule 40 low-carbon steel casing will be installed to 10 ft above the water table (estimated at 15–20 ft msl). An open borehole will be cored to approximately 300 ft below the water table. The multi-level well system will be installed inside the 5-inch casing and open borehole.

Continuous rock cores will be collected as the boreholes are advanced through the basaltic bedrock. Coring of unconsolidated material may also be conducted at depths beyond hollow-stem auger drilling capabilities. A comprehensive borehole geophysical and video logging program will be conducted within each borehole following boring in each upper and lower section. The data will be used to set the multi-level sampling intervals and to support refinement of the CSM and the groundwater flow and CF&T models.

After rock coring is complete, each borehole will be reamed to total depth with a conventional, open-hole or overburden drilling with eccentric drilling (ODEX) air rotary drilling rig to increase the borehole diameter for installation of 5-inch Schedule 40 low-carbon steel casing to 10 ft above the water table. The boring will be further advanced to a depth of 300 ft below the water table, the open borehole will then be developed, and the multi-level Westbay MP38 sampling system will be installed within the well casing and borehole.

The Westbay MP38 System allows groundwater sampling, water level/groundwater head measurements, and estimates of hydraulic conductivity within discrete zones. An estimated three to ten zones will be established within each well, with each zone isolated by a permanent packer system. The zones will be identified by Navy team geologists and hydrogeologists based on boring logs and hydrogeologic properties of rock formations within each borehole. Packers will be installed in rock units deemed to be of lower permeability. The packers will isolate rock units characterized by higher permeability based on the evaluation.

The wells will be constructed within the boreholes in general compliance with the DOH *Technical Guidance Manual for the Implementation of the Hawai‘i State Contingency Plan* (TGM) (DOH 2016) as applicable. The wells will be completed as aboveground, bollard-protected, and steel-locking enclosures with concrete footings and pads or inside flush-mount manholes or subsurface as necessary to accommodate surrounding site conditions and use.

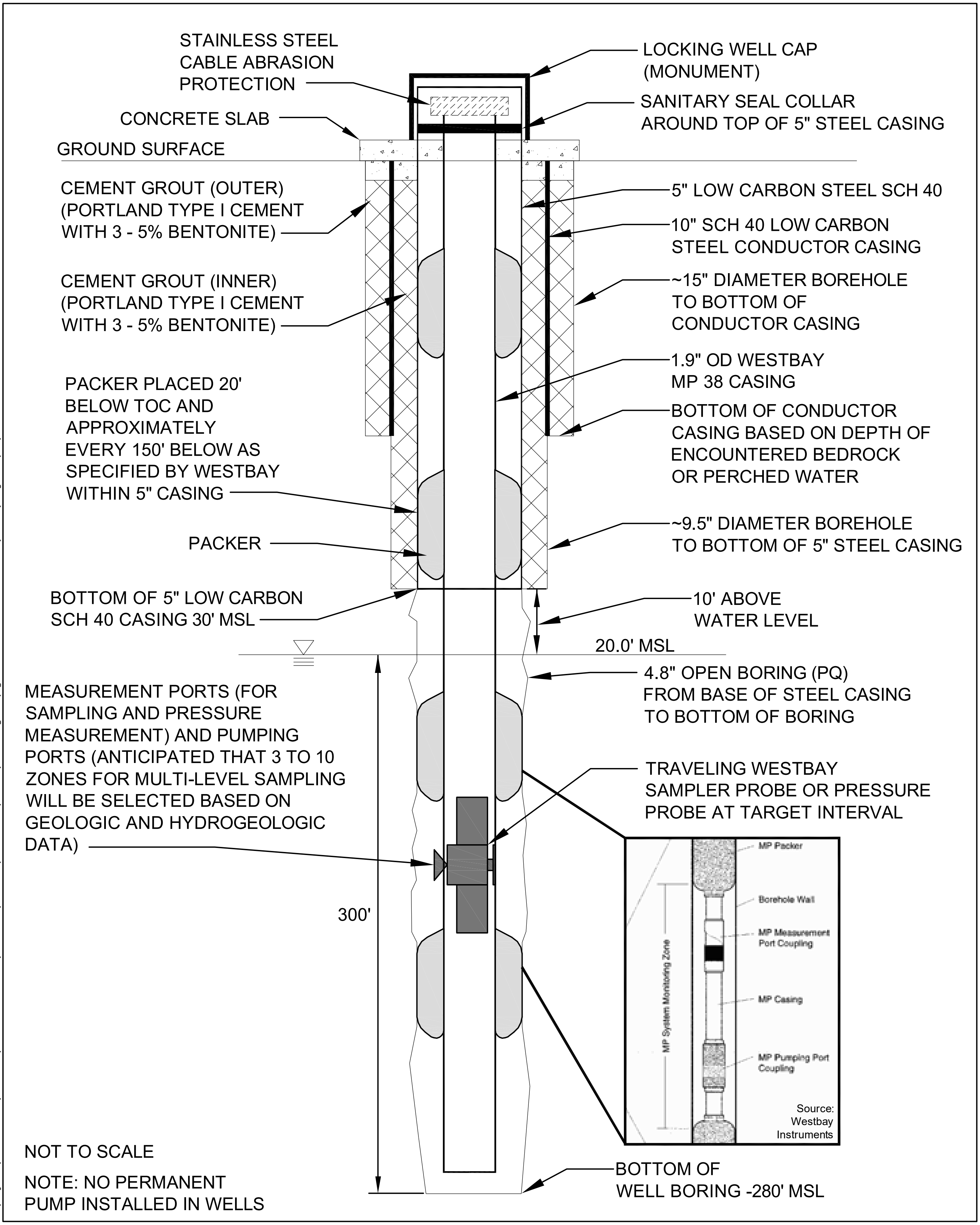

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Figure 2
General Cross Section of Borehole and
Multi-Level Westbay System Well
Monitoring Well Installation Work Plan Addendum 02
Red Hill Bulk Fuel Storage Facility
JBPHH, O‘ahu, Hawai‘i

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Potable water to be used for drilling and well installation activities will be sampled for laboratory analysis of COPCs. Subsurface geotechnical samples of unconsolidated material will be collected if unsaturated zones of unconsolidated material or significant layers of clay or low-permeability zones are encountered during rock coring within the Red Hill Facility site boundaries and at the Hālawa Correctional Facility. If unconsolidated material is present at depths below 100 ft below ground surface (bgs) or if contamination in the vadose zone is observed, samples of subsurface unconsolidated material will be collected for laboratory analysis of COPCs to provide additional data on the level of contamination present in the area. Geotechnical samples will also be collected for evaluation of potential low-permeability unconsolidated valley fill or saprolitic material encountered below the water table that may serve as a hydraulic barrier to groundwater flow.

All wells (including RHMW01R regardless of its installation type; see Section 2.3) will be accurately surveyed using Second Order, Class I survey methods for northing and easting coordinates and top-of-casing (TOC) elevation, which will be tied into the same North American Datum (NAD) 83 datum as surrounding previously surveyed wells to establish accurate groundwater elevations and estimate groundwater flow directions at the proposed new multi-level wells. All existing wells in the Red Hill groundwater monitoring network have recently been surveyed following these same techniques (DON 2017c). Table 2-2 summarizes the estimated proposed borehole and well dimensions for multi-level wells.

Table 2-2: Anticipated Borehole and Well Dimensions for Multi-Level Wells

Proposed Multi-Level Well (Westbay MP38)	Surface Elevation (ft msl)	Estimated Depth to Bedrock (ft bgs	Estimated Depth to Groundwater (ft bgs)	Open Borehole Interval (ft bgs) [a]	Estimated Total Depth (ft bgs)
RHMW01R [b]	103 [c]	N/A	84 [d]	~30–384 [e]	384
RHMW07D	200	25–60	180	175–480	480
RHMW11	230	180–210 [f]	210	205–510	510
RHMW12	243	25–60	223	218–523	523
RHMW13	260	25–60	240	235–540	540
RHMW14	190	140–160 [f]	170	165–470	470
RHMW15	320	25–60	300	295–600	600
RHMW16	260	25–60	240	235–560	540
RHMW17	160	100–180 [f]	140	135–440	440
RHMW18	145	85–165 [f]	125	120–425	425
RHMW19	420	25–60	400	395–700	700
RHMW20	400	25–60	380	375–680	680

N/A not applicable
[a] Based on open borehole 5 ft above water table.
[b] RHMW01R will be installed as a multi-level well only if conditions specified in Section 2.3 are met.
[c] RHMW01R surface elevation is based on the Facility lower tunnel floor, which is located in bedrock at approximately 312 ft bgs.
[d] Estimated based on groundwater levels in RHMW01.
[e] Casing will end higher in RHMW01R to accommodate soil vapor sampling ports with the Westbay system.
[f] Estimated depth to bedrock is based on Figure 25 in (Wentworth 1942).

2.3 INSTALLATION OF RHMW01R

Installation of RHMW01R as a multi-level well is contingent on meeting two conditions:

- No perched water or evidence of contamination (i.e., visual, olfactory, or elevated photoionization detector [PID] readings) is encountered in the vadose zone during drilling.

- No significant (defined as 0.25 inch) thickness of light non-aqueous-phase liquid (LNAPL) is measured on the water table surface during drilling. During installation, drilling will be temporarily halted at 5 ft below the water table, and following a stabilization period of 24 hours, an interface probe will be used to measure the thickness of any LNAPL that may be present on the water surface. Measurements will be recorded in the field logbook.

If both of the above conditions are met (i.e., no perched water or evidence of contamination in the vadose zone, and no significant LNAPL on the water table surface, is encountered), then RHMW01R will be installed as a multi-level well, as summarized in Section 2.2 and detailed in Section 3. Figure 3 displays a preliminary well installation diagram for RHMW01R as a multi-level well. As indicated on Figure 3, additional packer zones for RHMW01R (as a multi-level well) will be installed above the water table to accommodate soil vapor sampling ports. The number of packer zones in the vadose zone will be determined based on results of field observations and geophysical borehole logging.

If perched water or evidence of contamination is encountered in the vadose zone, or if significant LNAPL is measured, then RHMW01R will be installed as a single-level well screened across the water table surface. Installation procedures are presented in Appendix C. These procedures have been modified from those previously presented in *MWIWP Addendum 01* (DON 2017a) to reflect responses to the comments provided with the Regulatory Agencies’ February 3, 2017, Conditional Approval letter for *MWIWP Addendum 01* (comments and responses are presented in Appendix H). Variances from the *MWIWP Addendum 01* procedures are summarized as follows:

- Conductor casing will be low-carbon steel.
- Centralizer intervals will be 20 ft for both conductor casing and well casing.
- A Schedule 80 polyvinyl chloride (PVC) well will be installed with a screen interval of 29.5–9.5 ft msl. The screen interval will be 10 ft above the water table to 10 ft below the water table to assess localized vertical COPC attenuation when sampling is paired with existing well RHMW01.

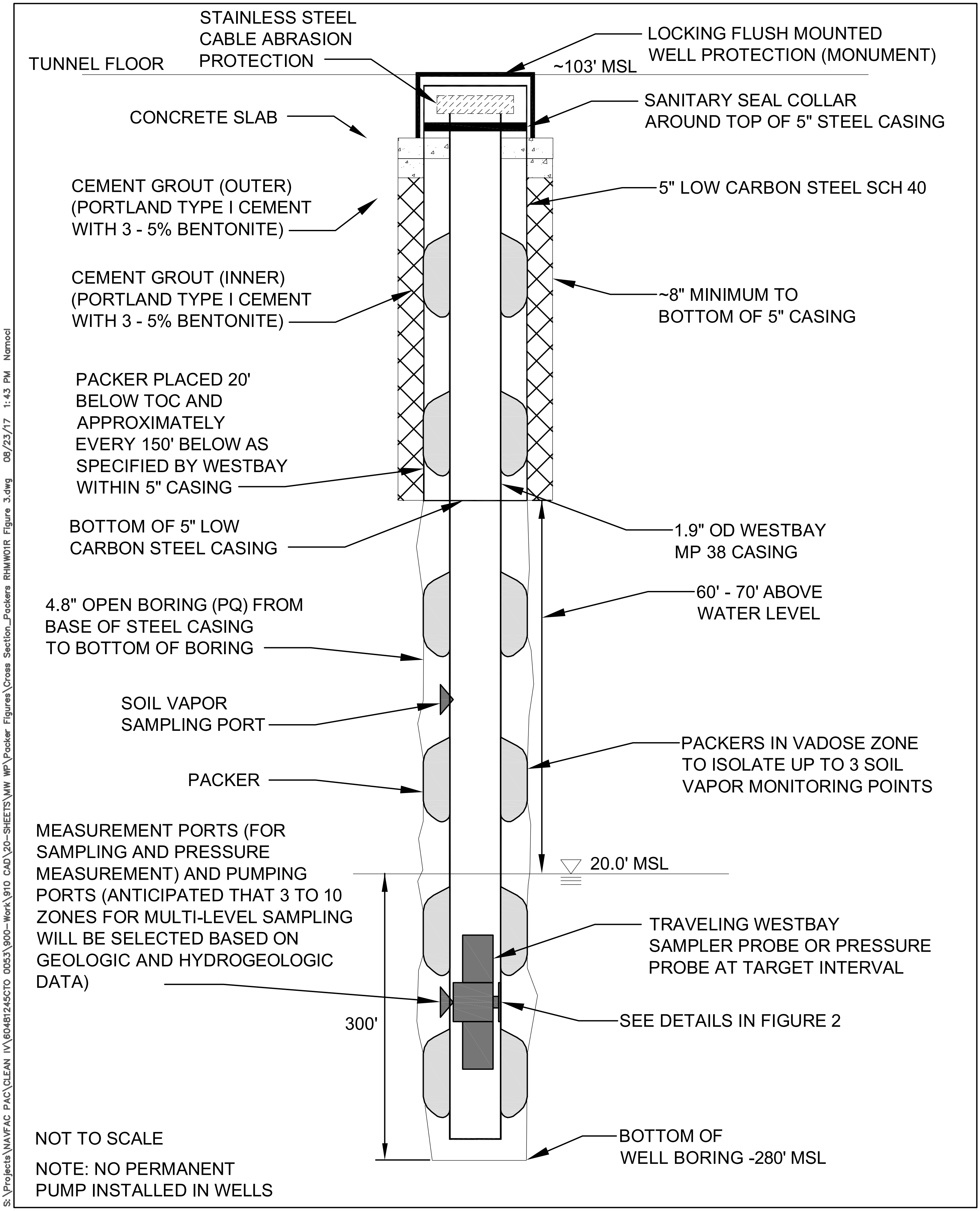

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Figure 3
General Cross Section of Borehole for RHMW01R
Multi-Level Westbay System Well
Monitoring Well Installation Work Plan Addendum 02
Red Hill Bulk Fuel Storage Facility
JBPHH, Oʻahu, Hawaiʻi

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2.4 PETROGRAPHIC ANALYSIS OF CORE SAMPLES

The core to be collected in RHMW01R and select testing of sections of previous Red Hill core borings presently in storage are proposed for petrographic analysis. This analysis will enable evaluation of 1) general occurrence of hydrocarbons using white light and UV light for hydrocarbon fluorescence throughout the entire core; 2) analysis of trapped hydrocarbons, if identified in the core; and 3) estimation of residual fuel, mobility of the fuel, and effective porosity within various rock types within the core. Analysis will include testing mobility of fuel in the core both found in situ and from fuel introduced to core samples at the laboratory based on the location and depth of residual NAPL identified in the core during the UV hydrocarbon fluorescence imaging. Additionally, sections of core within the Red Hill core inventory will be selected for the “introduced” fuel mobility testing, based on results from the RHMW01R core UV hydrocarbon fluorescence imaging and/or the necessity of the characterizing other rock types. These tests have a direct application to providing refinement to the CSM and CF&T models. Specifically, these tests will support an assessment of the capacity of NAPL to be immobilized by capillary forces (often referred to as residual saturation or residual NAPL). The approach includes the following laboratory analysis:

- Collection, shipment, and transport of the entire RHMW01R rock core to the petrophysical laboratory:
  - Laboratory core processing (entire 100-ft core) by cutting core in half lengthwise. (core must be frozen following recovery at the drill site)
  - Digital fluorescence imaging under white light and UV light for hydrocarbon fluorescence
- Petrographic analysis of select areas within the core:
  - Testing rock types for pore fluid saturations (NAPL and water)
  - Testing rock types for effective porosity
  - Testing rock types for NAPL mobility
  - Includes initial saturations, residual saturations, total porosity, grain, and dry bulk density
  - Testing on core subsections exhibiting evidence of residual NAPL based on digital fluorescence imaging
  - Testing rock types for residual NAPL saturation by water/NAPL displacement
  - Includes introduced Jet Fuel Propellant (JP)-8 or similar kerosene-based jet fuel laboratory initial saturations
  - To be conducted on select rock types within the core as determined by results of digital fluorescence imaging
- Petrographic analysis of select core samples from other Red Hill Facility borings:
  - Testing rock types for residual NAPL saturation by water/NAPL displacement
  - Includes introduced JP-8 or similar kerosene-based jet fuel laboratory initial saturations
  - Conducted on samples in the project borings in the core repository
- Testing JP-8 or similar kerosene-based jet fuel for viscosity (dynamic) and density, interfacial tension (a fuel sample will be identified and sent to laboratory)

The number and location of specific petrographic tests conducted within the RHMW01R core will be determined based on the results of the digital fluorescence imaging, rock type, and depth.

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3. Field Project Implementation

Procedures described in this section apply to the installation of the proposed multi-levels wells. The procedures specific to drilling and well installation presented below apply to RHMW01R only if it is installed as a multi-level well, the conditions for which are presented in Section 2.3. If RHMW01R is installed as a single-level well (Section 2.3), its drilling and installation procedures are described in Appendix C.

3.1 Project Procedures

All drilling, monitoring well installation, and other field activities will be conducted as applicable in accordance with the DOH TGM (DOH 2016) and the standard operating procedures (SOPs) summarized in Table 3-1 and included in the MWIWP (DON 2016), which are from the *Project Procedures Manual, U.S. Navy Environmental Restoration Program, NAVFAC Pacific* (DON 2015). A Health and Safety Plan has been prepared under separate cover to address potential health and safety concerns that may arise during field work (DON 2017f).

Table 3-1: Field SOPs Reference Table

Reference Number	Title, Revision Date and/or Number [a]	Originating Organization of Sampling SOP	Equipment Type
I-A-5	*Utility Clearance*	NAVFAC Pacific	Geophysical equipment (electromagnetic, magnetic, and ground-penetrating radar)
I-A-6	*Investigation Derived Waste Management*	NAVFAC Pacific	N/A
I-A-8	*Sample Naming*	NAVFAC Pacific	N/A
I-B-1	*Soil Sampling*	NAVFAC Pacific	Split-spoon sampler and liners with hollow-stem or solid-stem auger
I-B-2	*Geophysical Testing*	NAVFAC Pacific	Low frequency electromagnetic induction, magnetometers, and ground-penetrating radar
I-B-5	*Surface Water Sampling*	NAVFAC Pacific	N/A
I-C-1	*Monitoring Well Installation and Abandonment*	NAVFAC Pacific	Continuous coring drill rig
I-C-2	*Monitoring Well Development*	NAVFAC Pacific	Surge block or submersible pump
I-D-1	*Drum Sampling*	NAVFAC Pacific	COLIWASA or glass thieving tubes
I-E	*Soil and Rock Classification*	NAVFAC Pacific	N/A
I-F	*Equipment Decontamination*	NAVFAC Pacific	N/A
I-I	*Land Surveying*	NAVFAC Pacific	Theodolite - horizontal and vertical control; GPS
III-A	*Laboratory QC Samples (Water, Soil)*	NAVFAC Pacific	N/A
III-B	*Field QC Samples (Water, Soil)*	NAVFAC Pacific	N/A
III-D	*Logbooks*	NAVFAC Pacific	N/A
III-E	*Record Keeping, Sample Labeling, and Chain of Custody*	NAVFAC Pacific	N/A
III-F	*Sample Handling, Storage and Shipping*	NAVFAC Pacific	N/A

COLIWASA composite liquid waste sampler
GPS Global Positioning System
N/A not applicable
QC quality control
[a] Applicable procedures from the *Project Procedures Manual* (DON 2015).

3.2 SITE SURVEYS AND PREPARATION

3.2.1 Site Surveys

A licensed surveyor will establish the horizontal and vertical coordinates of each borehole and well location and other key site features. The survey will be conducted using Second Order, Class I procedures consistent with the procedures described in the *Technical Memorandum, Topographic Survey* (DON 2017c). Land survey activities will be conducted as applicable in accordance with Procedure I-I, *Land Surveying* (DON 2015).

3.2.2 Site Preparation

Site preparation will include vegetation clearance, access pathway and drill site grading, and cutting or coring of asphalt and asphaltic concrete, as required to facilitate drilling and well completion. Each borehole location will be marked once the area is cleared and the staging area is established.

Vegetation clearance will be performed to provide access for a drill rig, support truck, or excavator to all drilling sites as needed. It is anticipated that an approximately 750-ft-long × 15- to 20-ft-wide pathway will be required to access the location to RHMW19, and an approximately 60-ft × 80-ft minimal area will be required at each drilling location. Minor vegetation clearance may also be required at drilling locations. Vegetation clearance, preparation, shipment, and disposal will be conducted in accordance with Navy and landowner requirements for proper disposal of green waste to prevent the spread of the coconut rhinoceros beetle, as described in Section 3.9. The contractor will coordinate with the Navy Contract Task Order (CTO) Contracting Officer's Representative (COR) to ensure that the most current guidance is obtained and followed. Stockpiling green waste for more than 24 hours is not permitted.

Grading will be performed as necessary to advance the pathway to RHMW19 and create a level drill pad in the cleared drilling location. The ground surface will be stabilized for the movement of heavy equipment, and the pathway will be finished with an 8-inch-thick layer of coarse gravel no larger than 6 inches in any dimension. An approximately 60-ft × 80-ft minimal drilling pad will be established at the drilling location, by grading and filling to level the area, as much as practicable, to provide an even working surface or drill pad for the drill rig. The drill pad will be finished with an 8-inch-thick layer of coarse gravel no larger than 6 inches in any dimension. In order to redirect drilling noise away from nearby receptors, an earthen or gravel berm will be constructed on the perimeter of the drill pad between the drilling location and the receptors. The berm will be approximately 3 ft high, constructed asymmetrically with the shallower slope facing inward to the drill rig to deflect noise upward.

Noise control measures as required by noise permits will be implemented at all proposed well installation locations and will be maintained throughout air rotary drilling activities.

Replacement well RHMW01R will be placed approximately 10–20 ft away from existing well RHMW01 to avoid interferences during installation. Site preparation at this location will include cutting or coring of the concrete tunnel floor, as required to facilitate drilling and well completion.

3.2.3 Utility Clearance

Geophysical surveys will also be performed by a qualified subcontractor to locate and provide delineation of subsurface utilities in the vicinity of the soil boring/monitoring well locations using geophysical techniques through the use of magnetic, electromagnetic (RD4000 or equivalent), and ground-penetrating radar. If subsurface utilities or other features are detected during the geophysical survey at any location, all utility clearance activities will be conducted in accordance with

Procedure I-A-5, *Utility Clearance* (DON 2015). Prior to drilling, each borehole will be manually advanced to 5 ft bgs to ensure that the location is cleared of utilities. If necessary, the proposed well locations may be adjusted accordingly.

3.2.4 Air Knifing at Proposed RHMW11

Retaining wall tie-backs and footings along South Hālawa Stream at the location of proposed monitoring well RHMW11 cannot be definitively located from historical documents, plans, and as-built drawings, and may pose a subsurface hazard to activities and the site. Air knife technology using compressed air will be used to break soil structure and allow for removal of the soil while reducing the potential for direct contact between buried utilities and the air knife operator. The compressed air will insulate the operator from directly contacting the buried utility or structure. Compressed air, typically 90–100 pounds per square inch gauge (psig), is converted to a supersonic jet while flowing through a specially designed nozzle. Air knife will be used at the site to up to 22 ft bgs or deeper if feasible.

3.3 DRILLING AND WELL INSTALLATION

Solid basalt bedrock is anticipated to be contacted at shallow depths (i.e., between 25 and 60 ft bgs) at all proposed well locations except at in-tunnel well RHMW01R, which begins at bedrock, and at RHMW11, RHMW14, RHMW17, and RHMW18, where bedrock may be much deeper. Anticipated drilling activities include:

- Hollow-stem auger drilling through soil overburden
- Rock coring using wet rotary methods
- Air rotary drilling (ODEX)
- Air rotary and downhole hammer drilling for reaming boreholes and installing casing

Prior to drilling, all onsite activities must be coordinated with the Navy CTO COR to ensure that all requirements such as obtaining site access, working hours, use/accessing potable water supply sources, or other requirements are understood and followed. The drill rig will be leveled at least twice a day to prevent potential borehole deviation. In addition, the well borings will initially be cored, which will help ensure that the initial borings are straight. After coring, the borehole will be reamed to a larger diameter, during which a pilot bit will be used below the primary bit to ensure that the boring follows and is centered over the corehole. After the well 5-inch casing is completed, a quantitative true vertical depth analysis using a gyroscopic alignment instrument will be performed so appropriate corrections can be made to wireline-measured depth to water.

3.3.1 Drilling

Each borehole will be drilled using a drilling rig equipped with hollow-stem augering, rock coring, and air rotary capabilities in accordance with Procedure I-C-1, *Monitoring Well Installation and Abandonment* (DON 2015) as applicable. All boreholes except RHMW01R (which begins in bedrock) will initially be advanced to refusal using a minimum 4¼-inch-inner-diameter hollow-stem auger and/or ODEX system that can be used as a temporary surface casing during rock coring activities to stabilize boreholes during drilling and reaming in unconsolidated materials. Characterization samples of unconsolidated material will be collected at 5-ft intervals beginning at 10 ft bgs with 1.5-ft-long, 2-inch-diameter split spoons. Split-spoon unconsolidated material samples will be collected after retracting the hammer and running the sampler in the open hole. It is possible that basalt cobbles and boulders will be encountered, making augering difficult for characterization sampling of unconsolidated material (i.e., poor recovery) or resulting in refusal, in which case an air hammer or rotary coring may be used.

Perched water or contamination could be encountered in the vadose zone. To minimize the potential for perched water or contamination to migrate downward and impact the basal aquifer, which is a drinking water source, conductor casing will be installed if perched water or contaminated unconsolidated material is encountered. Temporary conductor casing (i.e., not grouted in place) will be used if perched water is encountered and there is no evidence of contamination (i.e., visual, olfactory, or elevated PID readings) observed in the field. If evidence of contamination is observed in the field, the conductor casing will be grouted in place. Temporary surface or conductor casing, composed of 10-inch-diameter Schedule 80 polyvinyl chloride (PVC) casing, will be installed in each borehole. For borings that require installation of permanent conductor casing, Schedule 40 low-carbon steel casing will be required.

Unless evidence of contamination is observed in the field, the conductor casing will initially be installed temporarily. Permanent casing will be required if perched groundwater or contaminated unconsolidated material is encountered. The purpose of the conductor casing is to isolate freshwater zones so that they are not contaminated and to prevent cross contamination between the perched groundwater/contaminated unconsolidated material and the basal aquifer and to maintain hole stability during drilling. To facilitate identification of perched groundwater or contaminated unconsolidated material, water levels, if present in the borehole, will be measured at the beginning and end of each day, before drilling has started and after drilling has been completed for the day. Additionally, the presence of contamination may be indicated by staining on drill cuttings and recovered rock cores and by elevated PID readings. This information will be recorded in the field logbook.

The diameter of the borehole will be at least 4 inches greater than the outer diameter (OD) of the conductor casing (Figure 2). Permanent conductor casing will be centered within the borehole using welded steel centralizers spaced at approximately 40-ft intervals. The centralizers will be aligned so that they do not interfere with the insertion and removal of the tremie pipe, if necessary. The annular space to be grouted will be a minimum of 2 inches beyond the casing. The conductor casing will be pressure-grouted in place as soon as possible after installation using a packer assembly and tremie pipe installed inside of the conductor casing that will allow the grout to be pumped through the packer assembly until it rises to the ground surface around the casing, or with tremie placed in the annular space around the casing. The annulus will be sounded to check for settling of the grout within 24 hours of placement. Placing the grout in the annular space will be done in stages with time allowed for the grout to set between stages in order to prevent distortion or collapse of the casing by heat or pressure. Following the pressure grouting procedure, the grout will be left undisturbed for a minimum of 24 hours for curing.

If permanent casing is installed and a deeper horizon with evidence of contamination (i.e., visual, olfactory, elevated PID readings, or staining on drill cuttings and recovered rock cores) is encountered, the boring will be abandoned by grouting as described in Section 3.3.2. A new boring will then be advanced so that multiple contaminated zones can be cased off, or a larger-diameter boring will be advanced that can accommodate the installation of multiple casings with a minimum 2-inch annular space.

In bedrock, subsurface material will be continuously sampled using rotary wireline coring to record the lithologic characteristics and sample description of the subsurface material during the drilling of the wells in accordance with Procedure I-B-1, *Soil Sampling* (DON 2015). Continuous rock cores will be collected as the monitoring well boreholes are advanced through the basaltic bedrock. Rock coring will commence when the borings reach competent bedrock. All drilling in rock will be accomplished by diamond core drilling methods in general accordance with ASTM D2113 (ASTM 2014).

The drill rig will be equipped with 4.83-inch OD core barrel (yielding a 3.35-inch-diameter rock [PQ]) Borings may intersect fault zones where poor rock or difficult drilling conditions may be encountered. All reasonable measures to maximize core recovery will be taken, including timely replacement of worn equipment such as drill bits or core sleeves before wear-induced loss of recovery occurs, and changes in type of drill bit, rate of feed, down-pressure on the drill bit, volume of cooling water, length of coring interval, or type of coring equipment. Grinding of the core after a core barrel has become blocked will not be permitted. A blocked core barrel will be pulled regardless of the interval drilled. Clean water will be brought in from an offsite potable water source for use as circulation fluid during rock coring and drilling.

The cores will be inspected and logged to characterize the lithology and evaluate potential pathways for migration of NAPL and associated constituents. A summary rock core chart will be used in the field to log the information. In general, each log will note rock-quality designation; rock color; texture; strength; degree and angle of fracturing; shape, size and volume of voids; weathering; and secondary staining or mineralization. Additionally, details of basalt flow and intraflow structures (e.g., a‘ā clinker flow-top breccias [clinker sub-types], accretionary lava clasts, simple vesicular flow tops, vesicular flow lobes, inflated pāhoehoe lobes, spatter deposits, lava tubes, a‘ā columnar dense core interiors, a‘ā clinker flow-bottom breccias, normal flow bottoms, and flow levees) will be included in logging of the core. Fracture types (i.e., the difference between tectonic fractures, primary cooling joints, and drilling-induced fractures) will also be noted as well as mineralization within the fractures. High-resolution photographs will be taken to photodocument the cores, and detailed photo logs will be prepared. The Geological Society of America rock color chart with Munsell color chips will be used for color characterization (Munsell 2009). Lithologic descriptions, photoionization detector screening results, and other observations will be recorded on the geologic logs in conformance with Procedure I-E, *Soil and Rock Classification* (DON 2015). Discrete subsurface unconsolidated material sampling is described in Section 3.5.

After rock coring is complete to 10 ft above the water table, each borehole will be reamed to total depth with a conventional, open-hole air rotary drilling rig to increase the borehole diameter to a minimum of 9.5 inches, as required for monitoring well installation (Figure 2). The lower portion of the boring from 10 ft above the water table to 300 ft below the water table will be drilled with 4.83-inch OD core barrel (yielding a 3.35-inch-diameter rock [PQ]) borehole to the bottom of the well. This lower boring will be left as uncased open rock formation in preparation for the installation of the multi-level sampling system described later. Limited amounts of clean, potable water (and environmentally safe drilling foam, only if pre-approved by the Navy) will be injected during drilling to mitigate dust and remove cuttings from the boreholes. Prior to use, potable water for drilling will be sampled and analyzed for COPCs as described in Section 3.4. Cuttings removed from the boreholes will be collected in 55-gallon drums equipped with air stacks to reduce dust.

3.3.2 Borehole Abandonment

Boreholes may be abandoned if drilling refusal occurs prior to reaching the target depth for well construction. Abandonment will be performed in accordance with Procedure I-C-1, *Monitoring Well Installation and Abandonment* (DON 2015), which involves sealing the borehole with bentonite-cement grout. The grout will be placed with a tremie pipe in one operation from the bottom of the boring to within a minimum of 2 ft of the ground surface. Additional grout may need to be placed if settlement occurs.

3.3.3 Monitoring Well Development

Monitoring well development will be performed in accordance with Procedure I-C-2, *Monitoring Well Development* (DON 2015). In accordance with Procedure I-C-2, well development will be conducted in the open borehole after drilling of the lower 4.83-inch borehole and before installation of the multi-level Westbay monitoring system. Well development in open boreholes that will be installed with Westbay systems requires ensuring that drilling fluids and fines are removed to the extent practicable. Well development will consist of pumping groundwater with a submersible pump and bailing until fine sediment particles have been removed and the water clarifies along 30-ft zones throughout the 300-ft saturated lower open borehole. Temporary packers may be employed to isolate zones. The parameters of dissolved oxygen (DO), oxidation-reduction potential (ORP), pH, temperature, specific conductance, and turbidity will be monitored during the development cycle. Because DO and ORP are affected by the agitation of surging and pumping, the values obtained for these parameters during development may vary, and are not representative of the aquifer water. Generally, if the development water is not relatively clear and sediment free after 10 well volumes, it will be assumed that further development will not be beneficial, and development will be considered complete. However, additional water exceeding 10 well volumes will be extracted in clinker zones and other highly permeable zones if needed. The well development activities will be documented in the field book and on computer-generated well development forms.

3.3.4 Geophysical and Video Logging

A comprehensive borehole geophysical logging program will be conducted within the open cored boreholes following PQ rock boring in the both the lower and upper sections of well. The survey will include as applicable three-arm caliper, Natural gamma, resistivity (8-, 16-, 32-, and 64-inch normal) single-point resistance (SPR), electromagnetic (EM) induction, fluid temperature and conductivity, optical and acoustic televiewer, borehole camera, and suspension logging. A full list of proposed geophysical methods and probes is presented in Appendix D. The presence of steel casing, boreholes without fluid, or unstable boreholes may inhibit the use of some geophysical methods. The survey may be deployed in two stages: the first following the completion of the upper unsaturated zone prior to installation of casing materials, and the second stage in the lower open borehole saturated zone prior to installation of the multi-level groundwater monitoring system. If instability of the upper zone is noted, Navy team geologists may case the upper zone, and geophysical surveying would only be conducted in the lower open borehole. The geophysical logging will enable assessment of salinity in the open borehole in the saturated zone via fluid conductivity measurements.

3.3.5 Dedicated Westbay MP38Sampling System Installation

After the boreholes have been reamed with the air rotary drilling equipment, casings will be installed in general accordance with Procedures I-C-1, *Monitoring Well Installation and Abandonment* and I-C-2, *Monitoring Well Development* (DON 2015) as applicable. Additionally, system-specific installation procedures for the Westbay MP38 multi-level monitoring system are presented in Appendix A. Groundwater in the basal aquifer is expected to be encountered at approximately 15-20 ft msl. Five-inch-diameter, Schedule 40 low-carbon steel-cased monitoring wells will be constructed within the boreholes to 10 ft above the surface of the water table (Figure 2). Once the upper 5-inch casing has been emplaced, open borehole will be drilled to approximately 300 ft below the water table. The Westbay MP38 System will be installed within the well casing and open borehole that allows COPC sampling, water level/groundwater head measurements, and estimates of hydraulic conductivity within discrete zones. Borehole geology will be evaluated to help ensure that packers are place in non-fractured, competent rock intervals to help ensure good seals. Criteria for selection of discrete packered zones will include but are not limited to the following:

- Rock integrity (e.g., stability, lack of fractures), from assessment of boring logs
- Potential presence of clay layers, from assessment of geophysical logs
- Potential to acquire data in pre-identified numerical groundwater model layers, targeting data vital to building the numerical groundwater model
- Hydrogeologic properties of rock formations: assessment of permeability within the borehole to target zones with higher potential for preferred groundwater flow within each borehole

Estimated total depths range from 385 to 700 ft bgs.

As described in Section 3.3.1, 10-inch-diameter, Schedule 40 low-carbon steel surface or conductor casing will be installed to the depth of bedrock except at in-tunnel well RHMW01R (which begins within bedrock). If perched groundwater or contaminated unconsolidated material is encountered, the conductor casing will be installed deeper to prevent contamination from perched groundwater or other potential contaminant sources that could cross-contaminate and impact groundwater quality.

The conductor casing will then be grouted in-place prior to installation of the 5-inch-diameter monitoring well. The annular space to be grouted will extend a minimum of 2 inches around the outside of the conductor casing, and will be grouted as soon as possible after installation of the casing. Grout (Portland cement Type I or II and a minimum of 3–5 percent bentonite) will be placed by pumping (i.e., pressure grouting method or using a tremie pipe in the annular space around the casing). The driller will sound annulus to check for settling of the grout within 24 hours of placement. Placing the grout in the annular space may be done in stages with time allowed for the grout to set between stages in order to prevent distortion or collapse of the casing by heat or pressure.

To ensure the 5-inch-diameter casing is centered in the 9.5-inch-diameter borehole, centralizers will be installed at the top and bottom of screened sections and also placed at 40-ft intervals on blank well casing. The centralizers will be aligned from top to bottom of the casing so that they do not interfere with the insertion and removal of the tremie pipe. All devices used to affix centralizers to the casing will not puncture the casing or contaminate the groundwater with which they come in contact. Centralizers will be low-carbon steel centralizers welded to casing. Once the upper 5-inch casing has been emplaced, the PQ-sized open borehole drilled to approximately 300 ft below the water table, and the open borehole developed. A Westbay MP38 System will be installed within the well casing and open borehole. An estimated three to ten zones will be established within the open borehole in each well; the zones will be isolated by a permanent packer system as identified by Navy team geologists and hydrogeologists based on the boring logs, borehole geophysical survey, and hydrogeologic properties of rock formations within each borehole. A description of the MP38 System, its specifications, and installation procedures are presented in Appendix A.

Because the rock formation is not pressured, blowouts are not anticipated to occur. However, as described above, voids are anticipated to be encountered and need to be taken into consideration during well installation. In the event that voids or blowouts are encountered, bentonite chips will be emplaced down hole to close out or plug the void.

3.3.6 Monitoring Well Surface Completion

The monitoring wells will be completed in accordance with Procedures I-C-1, *Monitoring Well Installation and Abandonment* and I-C-2, *Monitoring Well Development* (DON 2015). Generally, proposed monitoring wells except RHMW01R will be completed above ground with a

12-inch-diameter steel protective casing fitted with a locking, tamper-proof lid that covers the protective casing and well head. The lock will be recessed and covered for added protection, and permanent labels will be applied both inside and outside of the casing via painting, marking, or engraving on the protective casing or surface completion. The steel casings will be set in concrete at the well head for strength, security, and to provide a surface seal. A 3.5-ft by 3.5-ft square concrete pad, 2 ft thick, will be installed around each protective steel casing. The minimum stickup height of the steel casing will be 3 ft. Approximately 1 ft of the concrete pad will extend above the ground surface. The protective steel casings will extend above the well casings so that there is approximately 6 inches of clearance between the well head and locking lid. Coarse sand will be poured into the space between the well and protective casing to a level of approximately 6 inches below the well head. Four steel bollards will be placed slightly beyond each corner of the concrete pads. The bollards will extend approximately 2 ft bgs and approximately 3 ft above ground surface, and each will be individually set in concrete. The bollards and protective steel casing will be painted bright yellow for high visibility.

Depending on the specific conditions surrounding a well, some wells may require a flush-mount traffic rated steel cover. Flush-mounted covers are anticipated to be either a 12-inch flush mount or a stainless-steel vault with dimensions of 18 inches × 18 inches in area and 12 inches in height (or depth if completed as a vault). The covers will be corrosion resistant, leak resistant, and lockable. The concrete pad surrounding traffic-rated covers will extend at least 1 ft beyond the edge of the cover and will be at least 1 ft thick.

Monitoring well RHMW01R will be completed flush-mount to avoid obstructing any portion of the lower access tunnel. The flush-mount surface completion will consist of a 12-inch-diameter, circular steel skirt or rectangular utility-type box with a gasket to prevent leaks and traffic-rated locking lid over the recessed well. The circular skirt or box will be set in concrete flush with the grade surface of the tunnel to provide strength and a watertight surface seal.

The size and dimension of the covers must be will be reviewed by the Navy team to ensure they can withstand the site-specific demands of traffic or other potential damaging conditions and have sufficient room to contain all equipment, hoses, and tubing associated with the well.

3.4 POTABLE WATER SAMPLING

Prior to using potable water during drilling and well installation activities, at least one potable water sample per drilling location will be collected for laboratory analysis of COPCs to characterize the potable water. The potable water analytical results will be evaluated to determine if the potable water is a possible source of contamination to the drinking water aquifer during drilling activities. Collection of the potable water sample will be conducted in accordance with Procedure I-B-5, *Surface Water Sampling* and samples will be handled in accordance with Procedure III-F, *Sample Handling, Storage, and Shipping* (DON 2015). Potable water will be collected from the water source or from drilling water pump outflows directly into lab-provided sample containers as specified in Section 4. Vials for volatile organic compound (VOC) samples will be filled completely, with no headspace. Samples will be labeled with the sampling location, date and time of collection, and unique sample identifier as discussed in Section 4.1, and recorded in the field logbook. Sample containers will be placed in re-sealable plastic zip bags, kept in coolers containing wet ice, and preserved in accordance with analytical method requirements and as specified in Section 4. Samples will be shipped to the laboratory via overnight airfreight.

3.5 SUBSURFACE UNCONSOLIDATED MATERIAL SAMPLING

Subsurface geotechnical samples of unconsolidated material (i.e., soil or any material of small grain size, including coarse-grained sand or smaller grain size, such as clay, sands, and clinker zone sand) will be collected if unsaturated zones of unconsolidated material or significant layers of clay or low-permeability zones are encountered during rock coring.

Collection of subsurface material for laboratory analysis will be conducted in accordance with Procedure I-B-1, *Soil Sampling,* and samples will be handled in accordance with Procedure III-F, *Sample Handling, Storage, and Shipping* (DON 2015). Unconsolidated material will be collected from split-spoon samplers from surface to within an estimated range of 25–210 ft bgs (i.e., prior to encountering solid basalt), and from core barrels thereafter. Additionally, if unconsolidated material is present at depths below 100 ft bgs or if contamination in the vadose zone is observed, samples of subsurface unconsolidated material will be collected for laboratory analysis of COPCs to provide additional data on the level of contamination present in the area. Like the rock cores, the subsurface unconsolidated material samples will be inspected for evidence of contamination (visual, olfactory, or elevated PID readings) in order to characterize the lithology and evaluate the potential migration of NAPL and associated constituents. Using the discrete sampling approach, approximately 100 grams of unconsolidated material for non-VOC analyses will be collected using disposable scoops or spoons and placed in appropriate containers for each subsurface unconsolidated material sample as specified in Section 4. Material collected for VOC analysis will be collected using 5-gram plugs using EnCore, Terra Core, or equivalent samplers. To minimize VOC loss during the sampling effort, the VOC sample plugs will be collected as quickly as possible and placed in laboratory-supplied water- and methanol-preserved containers. All sample containers will be labeled with the sampling location, date and time of collection, and unique sample identifier as discussed in Section 4.1, and recorded in the field logbook. Sample containers will be placed in re-sealable plastic zip bags, kept in coolers containing wet ice, and preserved in accordance with analytical method requirements and as specified in Section 4. Samples will be shipped to the analytical laboratory via overnight airfreight.

Field quality control (QC) samples of unconsolidated material will be collected in accordance with the specifications presented in Table 3-2.

Table 3-2: Field Quality Control Samples for Unconsolidated Material

QC Sample	Analytical Group [a]	Frequency [b]	DQI	Measurement Performance Criteria
Field duplicate	All	10% of primary samples collected per matrix per analytical method	Precision	RPD ≤100% unconsolidated material (judgmental) [c]
Ambient blank	All	Once per potable water sampling event	Contamination during sample collection	<1/2 of LOQ
Trip blank	VOCs, TPH-g (soil/unconsolidated material)	One per cooler	Contamination during sample transport	≤2 of LOQ

% percent
DQI data quality indicator
LOQ limit of quantitation
RPD relative percent difference
TPH-g total petroleum hydrocarbons – gasoline range organics
[a] Refer to Section 4.2 for a list of all analytical groups.
[b] Per *Project Procedures Manual,* Procedure III-B, *Field QC Samples* (DON 2015).
[c] Per *Project Procedures Manual,* Procedure II-A, *Data Validation* (DON 2015).

3.6 CORE SAMPLING FOR PETROGRAPHIC ANALYSIS

Core samples from RHMW01R will be collected within an acetate sleeve, immediately sectioned into lengths that can fit to a large cooler, and capped on each sleeve end to create a tight seal. Each capped core section will be marked with top and bottom depths to the nearest 0.01 ft. Facing the core, left will be "top" and right will be "bottom" the end caps will be labeled top and bottom. Multiple cores will be labeled sequentially using A, B, C…. etc., starting with A on the top (shallowest sleeve). The core sleeves will be wrapped with bubble wrap to prevent direct contact with dry ice (direct contact can cause fracturing of the sleeve), and placed in a cooler containing enough dry ice to maintain a frozen state during shipping. Excess space within the cooler will be filled with extra bubble wrap or foam packing to immobilize the cores and prevent breakage of the acetate sleeves during shipment. A properly completed chain-of-custody (CoC) within a zip lock plastic bag will be placed within the cooler. The cooler will then be secured, labeled with the proper declarations for dry ice, and shipped to the analytical laboratory via overnight airfreight. Additional instructions for core handling and field preservation are presented in Appendix E.

JP-8, F-24 jet fuel, or similar kerosene-based fuel will be sent to the analytical laboratory in advance to setup preparations to perform the testing for residual saturation. Quantities of fuel required will be based on the number of samples specified, and that number will be based on the digital core imaging and lithology. A set of four 40-milliliter (ml) vials are required for a one-time analysis of the "introduced" residual fuel properties (i.e., viscosity, density, and interfacial tension). Additionally, 0.5 liter of fuel will be required per each residual saturation test with introduced fuel. Small volumes of fuel will be sent to the laboratory within appropriately labeled and U.S. Department of Transportation-approved corrugated containers. No preservation is required.

Core samples will be selected from other Red Hill Facility borings and sent to the laboratory for introduced fuel mobility analyses. The selections for introduced residual fuel mobility analysis will be based on rock type, location, and depth.

Laboratory analytical procedures for petrographic analysis of Red Hill cores are presented in Appendix G.

3.7 HYDRAULIC TESTING OF MULTI-LEVEL WELLS

Each new multi-level well will undergo hydraulic testing in its respective discrete pack-isolated intervals to determine hydraulic properties specific to each well. The multi-level wells can be used as a single-point device for performance of hydraulic tests, or as a multiple-point device to observe effects of hydraulic disturbance applied separately. The optimal approach will be determined at the time of testing. A description of hydraulic testing within the multi-level Westbay well is presented in Appendix A.4 (page 17). Variable head tests can be conducted simply and efficiently using the following:

- Determine the stable formation fluid level.
- Create a pre-determined head difference in the fluid inside the Westbay tubing.
- Deploy the Pumping Port tool and pressure transducer.
- Open the pumping port to initiate the test.
- Datalog the recovery of fluid level until it is stable.

3.7.1 Post-Installation Hydraulic Testing of Discrete Zones

Constant-rate or constant head injection tests can be conducted at the discretion of the project's principal hydrogeologist by means of the pumping ports. In environments with high hydraulic conductivity (e.g., clinker zones), the slim geometry of the Westbay System can make it unsuitable for single-point variable-head tests, where the formation response is more rapid than the capability of the testing device.

3.7.2 Monitoring During Pumping Water Supply Well Events

Where a multi-level completion is used as a multi-point observation well, during planned pumping in regional water supply wells, a dedicated pressure transducer can be installed in each Westbay zone and connected to a datalogger at the surface for real time multilevel measurement of hydraulic disturbances. This approach is applicable in high-transmissivity environments and can provide valuable information on the vertical connectivity between observation zones; it will be employed during scheduled pumping events.

3.7.3 Optional Hydraulic Assessments

Other means to assess formation hydraulic parameters are uniquely available with the Westbay System, such as monitoring and analyzing the hydraulic effects of natural barometric fluctuations or of earth tides. The Westbay System (unlike conventional open-screened wells) provides shut-in measurements of formation pressure. The measurements from the Westbay System are highly sensitive to small changes of formation pressure, and are not affected by monitoring well time lag effects.

3.8 Equipment Decontamination

Equipment will be decontaminated in accordance with Procedure I-F, *Equipment Decontamination* (DON 2015).

3.9 Investigation-Derived Waste Management and Disposal

Green waste generated during vegetation clearance will be processed in accordance with the most recent Navy direction on green waste disposal to prevent the spread of the coconut rhinoceros beetle. The contractor will need to coordinate with the Navy CTO COR to ensure that the most current guidance is obtained and followed. The most recent direction at the time of this MWIWP Addendum's publication (*JBPHH Green Waste Disposal Direction,* August 18, 2016) is reproduced in Appendix F. Processed green waste will be collected each day and will be transported to and disposed of at the designated disposal facility no more than 24 hours from time of generation.

Unconsolidated material and liquid investigation-derived waste (IDW) generated during monitoring well installation and development activities will be collected at the end of each day. The IDW will be evaluated based on the corresponding unconsolidated material and groundwater sampling data and IDW samples (including liquid wastes generated during drilling operations, well development water, and decontamination liquids) to select appropriate disposal methods. Well development water will be in large quantities (3,000–6,000 gallons) due to the 300-ft open borehole where the multi-level sampling system will be installed. Consequently, well development water will be stored in larger portable tanks capable of containing up to 6,000 gallons of liquids if feasible. With the exception of well development water in large portable tanks, IDW will be stored in U.S. Department of Transportation-approved 55-gallon steel drums, placed on pallets, covered with tarps, and temporarily stored at a secure, Navy-designated staging area. As an alternative and to facilitate drilling activities, drill cuttings may be placed in roll-off containers. Roll-off containers will be covered with a tarp to prevent them from filling up with precipitation.

The IDW will be handled, stored, and labeled in accordance with Procedure I-A-6, *Investigation-Derived Waste Management* (DON 2015). The drums will be segregated according to source and matrix, and at least one representative composite IDW samples will be collected from each grouping for waste characterization in accordance with Procedure I-D-1, *Drum Sampling* (DON 2015). IDW characterization samples will be submitted to a Department of Defense (DoD) Environmental Laboratory Accreditation Program (ELAP)-certified laboratory for analysis. Waste profile forms will be prepared and submitted to potential disposal facilities for approval. The IDW will be kept at the staging area until the IDW analytical data are received and associated waste profile forms are approved by the disposal facilities. The IDW will then be removed from the staging area, transported, and disposed of at the approved disposal facilities. IDW will be disposed of within 90 calendar days of the generation date. Disposable personal protective equipment and disposable sampling equipment will be collected in plastic trash bags and disposed of as municipal solid waste.

4. Sample Details

Details of subsurface unconsolidated material, geotechnical, potable water, and petrographic/fuel samples are presented in Table 4-1, Table 4-2, Table 4-3, and Table 4-4, respectively. Additional analytical details are presented in Appendix G.

Table 4-1: Subsurface Unconsolidated Material Sample Details

				Analysis Group:	TPH-d/TPH-o	TPH-g	VOCs	PAHs
				Analytical Method:	SW-846 8015	SW-846 8015	SW-846 8260	SW-846 8270
				Container Type:	8-oz clear or amber borosilicate wide-mouth jar, with Teflon-lined lid	Pre-weighed 40-mL clear or amber borosilicate VOA vial, with Teflon septum-lined cap	Pre-weighed 40-mL clear or amber borosilicate VOA vial, with Teflon septum-lined cap	8-oz clear or amber borosilicate wide-mouth jar, with Teflon-lined lid
				Preservative:	≤6 °C	1 × 5mL methanol-preserved; ≤6 °C	2 × 10mL water-preserved; 1 × 5mL methanol-preserved; ≤6 °C	≤6 °C
Analytical laboratory: APPL, Inc.				Holding Time (Preparation/Analysis):	14 days	14 days	7 days (water); 14 days (methanol)	14 days
Site	Matrix	Sampling Point	Sample ID	Depth/Sampling Interval				
Red Hill	Unconsolidated Material [a,b]	RHMW01R	RHMW01R-BS01-S01-Dff.f	TBD	✓	✓	✓	✓
Red Hill	Unconsolidated Material [a,b]	RHMW07D	RHMW07D-BS01-S01-Dff.f	TBD	✓	✓	✓	✓
Red Hill	Unconsolidated Material [a,b]	RHMW11	RHMW11-BS01-S01-Dff.f	TBD	✓	✓	✓	✓
Red Hill	Unconsolidated Material [a,b]	RHMW12	RHMW12-BS01-S01-Dff.f	TBD	✓	✓	✓	✓
Red Hill	Unconsolidated Material [a,b]	RHMW13	RHMW13-BS01-S01-Dff.f	TBD	✓	✓	✓	✓
Red Hill	Unconsolidated Material [a,b]	RHMW14	RHMW14-BS01-S01-Dff.f	TBD	✓	✓	✓	✓
Red Hill	Unconsolidated Material [a,b]	RHMW15	RHMW15-BS01-S01-Dff.f	TBD	✓	✓	✓	✓
Red Hill	Unconsolidated Material [a,b]	RHMW16	RHMW16-BS01-S01-Dff.f	TBD	✓	✓	✓	✓
Red Hill	Unconsolidated Material [a,b]	RHMW17	RHMW17-BS01-S01-Dff.f	TBD	✓	✓	✓	✓
Red Hill	Unconsolidated Material [a,b]	RHMW18	RHMW18-BS01-S01-Dff.f	TBD	✓	✓	✓	✓

				Analysis Group:	TPH-d/TPH-o	TPH-g	VOCs	PAHs
				Analytical Method:	SW-846 8015	SW-846 8015	SW-846 8260	SW-846 8270
				Container Type:	8-oz clear or amber borosilicate wide-mouth jar, with Teflon-lined lid	Pre-weighed 40-mL clear or amber borosilicate VOA vial, with Teflon septum-lined cap	Pre-weighed 40-mL clear or amber borosilicate VOA vial, with Teflon septum-lined cap	8-oz clear or amber borosilicate wide-mouth jar, with Teflon-lined lid
				Preservative:	≤6 °C	1 × 5mL methanol-preserved; ≤6 °C	2 × 10mL water-preserved; 1 × 5mL methanol-preserved; ≤6 °C	≤6 °C
Analytical laboratory: APPL, Inc.				Holding Time (Preparation/Analysis):	14 days	14 days	7 days (water); 14 days (methanol)	14 days
Site	Matrix	Sampling Point	Sample ID	Depth/Sampling Interval				
Red Hill	Unconsolidated Material [a,b]	RHMW19	RHMW19-BS01-S01-Dff.f	TBD	✓	✓	✓	✓
Red Hill	Unconsolidated Material [a,b]	RHMW20	RHMW20-BS01-S01-Dff.f	TBD	✓	✓	✓	✓
Field QC Samples								
Red Hill	Field Duplicate	TBD	Aaaaaa-BScc-Dee-Dff.f	TBD	✓	✓	✓	✓
Red Hill	Matrix Spike/Matrix Spike Duplicate	TBD	Aaaaaa-BScc-See-Dff.f	TBD	✓	✓	✓	✓
Red Hill	Ambient Blank	TBD	Aaaaaa-WQ-Aee-ffffff	—	✓	✓	✓	✓
Red Hill	Trip Blank	TBD	Aaaaaa-WQ-Tee-ffffff	—	—	✓	✓	—
Miscellaneous Samples								
Red Hill	IDW	RHMW01R	RHMW01R-IDW-01-ffffff	—	✓	✓	✓	✓
Red Hill	IDW	RHMW07D	RHMW07D-IDW-01-ffffff	—	✓	✓	✓	✓
Red Hill	IDW	RHMW11	RHMW11-IDW-01-ffffff	—	✓	✓	✓	✓
Red Hill	IDW	RHMW12	RHMW12-IDW-01-ffffff	—	✓	✓	✓	✓
Red Hill	IDW	RHMW13	RHMW13-IDW-01-ffffff	—	✓	✓	✓	✓
Red Hill	IDW	RHMW14	RHMW14-IDW-01-ffffff	—	✓	✓	✓	✓
Red Hill	IDW	RHMW15	RHMW15-IDW-01-ffffff	—	✓	✓	✓	✓
Red Hill	IDW	RHMW16	RHMW16-IDW-01-ffffff	—	✓	✓	✓	✓
Red Hill	IDW	RHMW17	RHMW17-IDW-01-ffffff	—	✓	✓	✓	✓
Red Hill	IDW	RHMW18	RHMW18-IDW-01-ffffff	—	✓	✓	✓	✓
Red Hill	IDW	RHMW19	RHMW19-IDW-01-ffffff	—	✓	✓	✓	✓
Red Hill	IDW	RHMW20	RHMW20-IDW-01-ffffff	—	✓	✓	✓	✓
Total Number of Samples to the Laboratory					13 (minimum)			

✓	analysis is applicable to sample
—	analysis is not applicable to sample
°C	degree Celsius
Aaaaaa	sampling point
APPL	Agriculture & Priority Pollutants Laboratories, Inc. 908 N Temperance Ave., Clovis, CA 93611
cc	consecutive sampling location number
ee	chronological sample number from a particular sampling location
ff.f	depth of sample in ft bgs (measured to the tenth of a foot)
ffffff	sample collection date (e.g., "021518" for February 15, 2018)
oz	ounce
PAH	polynuclear aromatic hydrocarbon
TBD	to be determined
TPH-d	total petroleum hydrocarbons – diesel range organics
TPH-g	total petroleum hydrocarbons – gasoline range organics
TPH-o	total petroleum hydrocarbons – residual range organics (i.e., TPH-oil)
VOA	volatile organic analyte

[a] Unconsolidated material includes soil, coarse-grained sand, and smaller grain size material, such as clay, sands, and clinker zone sand.
[b] Unconsolidated material will be sampled as described in Section 3.5.

1 **Table 4-2: Geotechnical Sample Details**

				Analysis Group:	Atterberg Limits	Effective Porosity	Permeability	Moisture Content and Density
				Analytical Method: [a]	ASTM D4318	API RP40	ASTM D5084	ASTM D2937
				Container Type:	Core	Core	Core	Core
				Preservative:	≤6 °C	≤6 °C	≤6 °C	≤6 °C
Analytical laboratory: APPL, Inc.				Holding Time (Preparation/Analysis):	N/A	N/A	N/A	N/A
Site	Matrix	Sampling Point	Sample ID	Depth/Sampling Interval				
Red Hill	Unconsolidated material [b,c]	RHMW07D	RHMW07D-BS01-S01-Dff.f	TBD	✓	✓	✓	✓
Red Hill	Unconsolidated material [b,c]	RHMW11	RHMW11-BS01-S01-Dff.f	TBD	✓	✓	✓	✓
Red Hill	Unconsolidated material [b,c]	RHMW12	RHMW12-BS01-S01-Dff.f	TBD	✓	✓	✓	✓
Red Hill	Unconsolidated material [b,c]	RHMW13	RHMW13-BS01-S01-Dff.f	TBD	✓	✓	✓	✓
Red Hill	Unconsolidated material [b,c]	RHMW14	RHMW14-BS01-S01-Dff.f	TBD	✓	✓	✓	✓
Red Hill	Unconsolidated material [b,c]	RHMW15	RHMW15-BS01-S01-Dff.f	TBD	✓	✓	✓	✓
Red Hill	Unconsolidated material [b,c]	RHMW16	RHMW16-BS01-S01-Dff.f	TBD	✓	✓	✓	✓
Red Hill	Unconsolidated material [b,c]	RHMW17	RHMW17-BS01-S01-Dff.f	TBD	✓	✓	✓	✓
Red Hill	Unconsolidated material [b,c]	RHMW18	RHMW18-BS01-S01-Dff.f	TBD	✓	✓	✓	✓
Red Hill	Unconsolidated material [b,c]	RHMW19	RHMW19-BS01-S01-Dff.f	TBD	✓	✓	✓	✓
Red Hill	Unconsolidated material [b,c]	RHMW20	RHMW20-BS01-S01-Dff.f	TBD	✓	✓	✓	✓

(cont.)

				Analysis Group:	Grain Size Distribution	Cation Exchange Capacity	pH	Total Organic Carbon
				Analytical Method: [a]	ASTM D422	EPA 9081	EPA 9045D	Walkley Black
				Container Type:	Core	Core	Core	Core
				Preservative:	≤6 °C	≤6 °C	≤6 °C	≤6 °C
Analytical laboratory: APPL, Inc. (cont.)				Holding Time (Preparation/Analysis):	N/A	N/A	as soon as possible	N/A
Site	Matrix	Sampling Point	Sample ID	Depth/Sampling Interval				
Red Hill	Unconsolidated material [a,b]	RHMW07D	RHMW07D-BS01-S01-Dff.f	TBD	✓	✓	✓	✓
Red Hill	Unconsolidated material [a,b]	RHMW11	RHMW11-BS01-S01-Dff.f	TBD	✓	✓	✓	✓
Red Hill	Unconsolidated material [a,b]	RHMW12	RHMW12-BS01-S01-Dff.f	TBD	✓	✓	✓	✓
Red Hill	Unconsolidated material [a,b]	RHMW13	RHMW13-BS01-S01-Dff.f	TBD	✓	✓	✓	✓
Red Hill	Unconsolidated material [a,b]	RHMW14	RHMW14-BS01-S01-Dff.f	TBD	✓	✓	✓	✓
Red Hill	Unconsolidated material [a,b]	RHMW15	RHMW15-BS01-S01-Dff.f	TBD	✓	✓	✓	✓
Red Hill	Unconsolidated material [a,b]	RHMW16	RHMW16-BS01-S01-Dff.f	TBD	✓	✓	✓	✓
Red Hill	Unconsolidated material [a,b]	RHMW17	RHMW17-BS01-S01-Dff.f	TBD	✓	✓	✓	✓
Red Hill	Unconsolidated material [a,b]	RHMW18	RHMW18-BS01-S01-Dff.f	TBD	✓	✓	✓	✓
Red Hill	Unconsolidated material [a,b]	RHMW19	RHMW19-BS01-S01-Dff.f	TBD	✓	✓	✓	✓
Red Hill	Unconsolidated material [a,b]	RHMW20	RHMW20-BS01-S01-Dff.f	TBD	✓	✓	✓	✓

Note: Geotechnical analytical services will be subcontracted by APPL to: Hushmand Associates, Inc., 250 Goddard, Irvine, CA 92618.

✓ analysis is applicable to sample
ff.f depth of sample in ft bgs (measured to the tenth of a foot)
API American Petroleum Institute
ASTM ASTM International
N/A not applicable
TBD to be determined

[a] Unconsolidated material includes soil, coarse-grained sand, and smaller grain size material, such as clay, sands, and clinker zone sand.
[b] Unconsolidated material will be sampled as described in Section 3.5.

Table 4-3: Potable Water Sample Details

				Analysis Group:	TPH-d/TPH-o	TPH-g	VOCs	PAHs
				Analytical Method:	SW-846 8015	SW-846 8015	SW-846 8260	SW-846 8270
				Container Type:	2-L amber borosilicate wide- or narrow-mouth bottle, with Teflon-lined lid	2 × 40-mL clear or amber borosilicate VOA vial, with Teflon septum-lined cap	2 × 40-mL clear or amber borosilicate VOA vial, with Teflon septum-lined cap	2-L amber borosilicate wide- or narrow-mouth bottle, with Teflon-lined lid
				Preservative:	≤6 °C	HCl-preserved; ≤6 °C	HCl-preserved; ≤6 °C	≤6 °C
Analytical laboratory: APPL, Inc.				Holding Time (Preparation/Analysis):	7 days	14 days	14 days	7 days
Site	Matrix	Sampling Point	Sample ID	Depth/Sampling Interval				
Red Hill	Water	Potable Water [a]	Aaaaaa-PW01-S01-ffffff	TBD	✓	✓	✓	✓
Total Number of Samples to the Laboratory					1			

✓ analysis is applicable to sample
Aaaaaa sampling point
ffffff sample collection date (e.g., “021518” for February 15, 2018)
TBD to be determined
[a] Potable water will be sampled prior to potable water use during drilling activities as described in Section 3.4.

Table 4-4: Petrographic and NAPL/Fuel Sample Details

				Analysis Group:	Core Slabbing/ Digital Core Imaging	Effective Porosity [a]	Pore Fluid Saturation Group	Mobility Group Centrifuge
				Analytical Method: [b]	API RP40 ASTM D5079	ASTM D425M	API RP40	ASTM D425M
				Container Type:	Acetate Core Sleeve	Acetate Core Sleeve	Acetate Core Sleeve	Acetate Core Sleeve
				Preservative:	Freeze at <4 °C	Freeze at <4 °C	Freeze at <4 °C	Freeze at <4 °C
Analytical laboratory: Core Laboratories				Holding Time (Preparation/Analysis):	N/A	N/A	N/A	N/A
Site	Matrix	Sampling Point	Sample ID	Depth/Sampling Interval				
Red Hill	Core	RHMW01R	RHMW01R-BS01-P01-Dff.f	TBD	✓	✓	✓	✓

				Analysis Group:	Mobility Group Water Drive	Fluid Properties Group [c]
				Analytical Method: [b]	ASTM D425M8	ASTM D445 ASTM D971 ASTM D1481
				Container Type:	Acetate Core Sleeve	Four (4) 40-ml vials
				Preservative:	Freeze at <4 °C	N/A
Analytical laboratory: Core Laboratories (cont.)				Holding Time (Preparation/Analysis):	N/A	N/A
Site	Matrix	Sampling Point	Sample ID	Depth/Sampling Interval		
Red Hill	Core	RHMW01R	RHMW01R-BS01-P01-Dff.f	TBD	✓	
Red Hill	Product	TBD	RHSF-JP8-P01-ffffff	N/A		✓

✓ analysis is applicable to sample
ff.f depth of sample in feet (ft) bgs (measured to the tenth of a foot)
ffffff sample collection date (e.g., “021518” for February 15, 2018)
ml milliliter
N/A not applicable
TBD to be determined
Core Laboratories – Petroleum Services Division: 3437 Landco Drive, Bakersfield, CA 93308
[a] Effective porosity includes total porosity.
[b] Includes viscosity (dynamic) and density at three temperatures, interfacial tension for each fluid pair (air/water, NAPL/water, air/NAPL) at ambient temperature.

4.1 SAMPLE CUSTODY REQUIREMENTS

Each sample will be assigned a chain of custody (CoC) sample identification (ID) number and a descriptive ID number in accordance with NAVFAC Pacific Environmental Restoration Program Procedure I-A-8, *Sample Naming* (DON 2015). All sample ID numbers will be recorded in the field logbook in accordance with Procedure III-D, *Logbooks* (DON 2015). The CoC sample ID number (the only ID number submitted to the analytical laboratory) is used to facilitate data tracking and storage. The CoC sample ID number allows all samples to be submitted to the laboratory without providing information on the sample type or source. The descriptive ID number is linked to the CoC sample ID number, which provides information regarding sample type, origin, and source.

4.1.1 CoC Sample Identification Number

A CoC sample ID number will be assigned to each sample as follows, to facilitate data tracking and storage:

ERHxxx

Where:

ERH	=	Designates the samples for the Red Hill Bulk Fuel Storage Facility Groundwater Long-Term Monitoring program
xxx	=	Chronological number, starting with next consecutive number (will be determined prior to field work and is dependent on the last number used in the most recent sampling event)

QC samples will be included in the chronological sequence.

4.1.2 Descriptive Identification Number

A descriptive ID number (for internal use only) will identify the sampling location, type, sequence, matrix, and depth. The descriptive ID number is used to provide sample-specific information (e.g., location, sequence, and matrix). The descriptive identifier is not revealed to the analytical laboratory. The descriptive ID number for all samples is assigned as follows:

Aaaaaa-bbcc-dee-Dff.f

Where:

Aaaaaa	=	Site area (Table 4-5)
bb	=	Sample type and matrix (Table 4-6)
cc	=	Location number (e.g., borehole 01, 02, 03)
d	=	Field QC sample type (Table 4-7)
ee	=	Chronological sample number from a particular sampling location (e.g., 01, 02)
D	=	The letter “D” denoting depth
ff.f	=	Depth of sample in ft bgs (measured to the tenth of a foot). For water matrix samples, the depth field will contain the month, day, and year of collection (e.g., 021518 for February 15, 2018).

For example, the sample number RHMW11-BS01-S01-D20.0 would indicate that the sample is the first sample collected from the first subsurface unconsolidated material location, encountered at 20 ft bgs, from the borehole advanced for monitoring well RHMW11. The duplicate sample would be designated as RHMW11-BS01-D01-D20.0. These characters will establish a unique descriptive identifier that will be used during data evaluation.

Table 4-5: Area Identifiers

Identifier	Site Area
RHMW01R	Monitoring Well RHMW01R
RHMW07D	Monitoring Well RHMW07D
RHMW11	Monitoring Well RHMW11
RHMW12	Monitoring Well RHMW12
RHMW13	Monitoring Well RHMW13
RHMW14	Monitoring Well RHMW14
RHMW15	Monitoring Well RHMW15
RHMW16	Monitoring Well RHMW16
RHMW17	Monitoring Well RHMW17
RHMW18	Monitoring Well RHMW18
RHMW19	Monitoring Well RHMW19
RHMW20	Monitoring Well RHMW\20

Table 4-6: Sample Type and Matrix Identifiers

Identifier	Sample Type	Matrix
BS	Subsurface Unconsolidated Material	Unconsolidated Material
WQ	Water Blanks	Water
PW	Potable Water	Water
CO	Rock Core	Core
PR	Jet Fuel	Product

Table 4-7: Field QC Sample Type Identifiers

Identifier	Field or QC Sample Type	Description
S	Primary Sample	All field samples, except QC samples
D	Duplicate	Co-located for unconsolidated material
E	Equipment Blank	Water
B	Field Blank	Water
T	Trip Blank	Water
A	Ambient Blank	Water

4.1.3 Handling, Shipping, and Custody

All samples collected for analysis will be recorded in the field logbook in accordance with Procedure III-D, *Logbooks* (DON 2015). All samples will be labeled and recorded on CoC forms in accordance with Procedure III-E, *Record Keeping, Sample Labeling, and Chain-of-Custody* (DON 2015). Samples will be handled, stored, and shipped in accordance with Procedure III-F, *Sample Handling, Storage, and Shipping* (DON 2015). All samples collected on this project will be shipped to the analytical laboratory via overnight airfreight.

All samples received at the analytical laboratory will be managed in accordance with laboratory SOPs for receiving samples, archiving data, and sample disposal and waste collection, as well as, storage and disposal per Section 5.8, "Handling of Samples" of the DoD *Quality Systems Manual (QSM)* v. 5.1 (DoD 2017).

4.2 LABORATORY QC SAMPLES

Laboratory QC samples will be prepared and analyzed in accordance with the methods and procedures listed Table G-5 in Appendix G.2.

5. Data Verification and Validation

Table 5-1 displays the Steps I and IIa/IIb data verification and validation process.

Table 5-1: Data Verification and Validation (Steps I and IIa/IIb) Process Table

Data Review Input	Description	Responsible for Verification (title)	Step I/IIa/IIb [a]	Internal/External
Field procedures	Determine whether field procedures are performed in accordance with this MWIWP Addendum 02 and prescribed procedures.	QA Program Manager	Step I	Internal
Field logbook and notes	Review the field logbook and any field notes on a weekly basis and place them in the project file. Copies of the field logbook and field notes will be provided to the CTO manager and included in the Field Audit Report.	Field Manager	Step I	Internal
CoC and field QC logbook	Examine data traceability from sample collection to project data generation.	Project Chemist	Step IIa	Internal
Sampling plan	Determine whether the number and type of unconsolidated material and potable water samples specified in Table 4-1, Table 4-2, Table 4-3, and Table 4-4 were collected.	Project Chemist and Field Manager	Step IIb	Internal
Field QC samples	Establish that the number of QC samples specified in Table 4-1, Table 4-2, Table 4-3, and Table 4-4 were collected.	Project Chemist	Step IIb	Internal

[a] IIa Compliance with methods, procedures, and contracts. See Table 10, page 117, UFP-QAPP Manual, V.1 (DoD 2005).
IIb Comparison with measurement performance criteria in the project SAP (DON 2017d). See Table 11, page 118, UFP-QAPP Manual, V.1 (DoD 2005).

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Appendix A:
Westbay MP38 System Documentation

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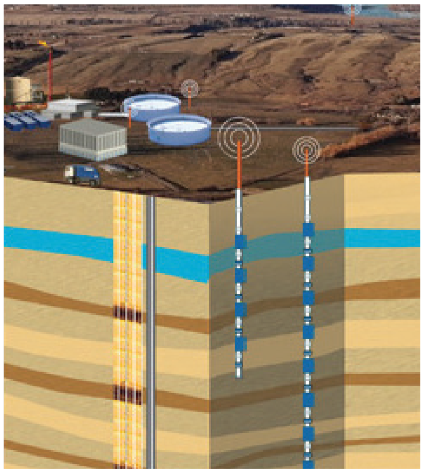
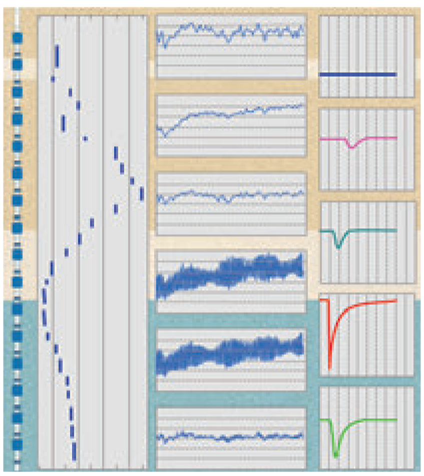
Westbay System

Multilevel Technology for Subsurface Characterization and Monitoring

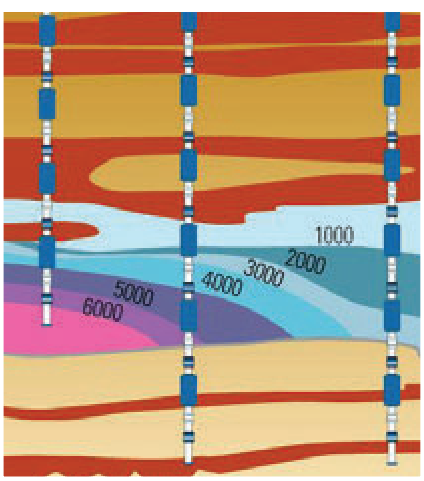
Is Groundwater Monitoring Important?



Environmental monitoring for unconventional oil and gas



4D subsurface characterization using Westbay technology



Characterization of contamination plume using Westbay System

WHY GROUNDWATER MONITORING?

Groundwater is an essential resource of great social, environmental and economic importance. With continuous population growth and industrial expansion impacting the state of groundwater around the world, implementing comprehensive groundwater management strategies is critical.

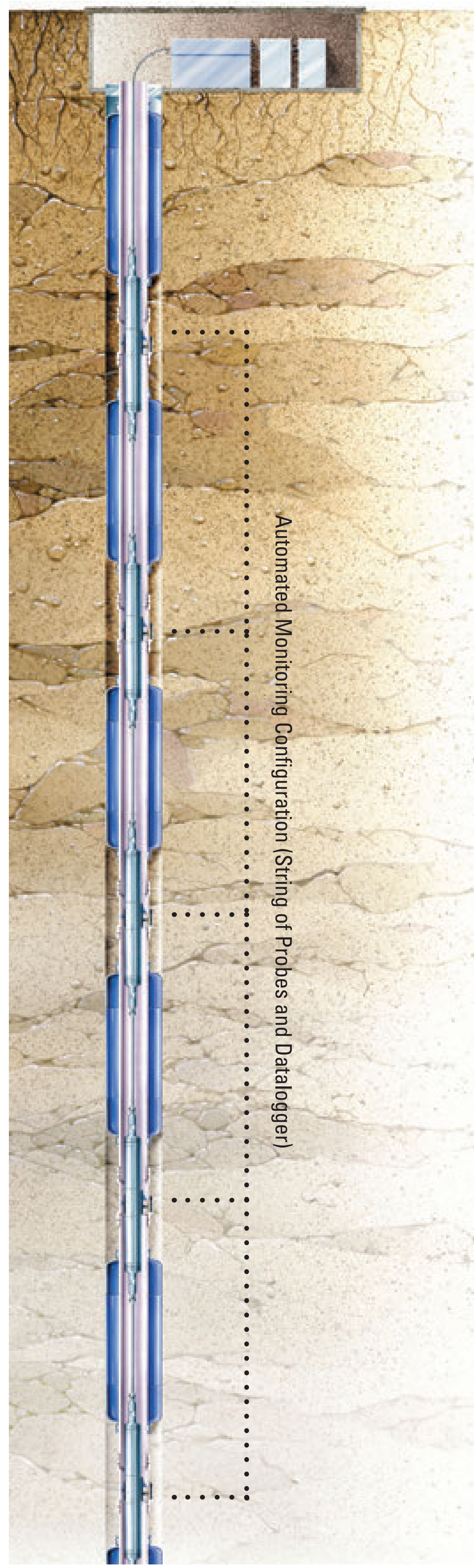
As an essential component of water management, groundwater monitoring networks are designed to optimize the collection of vast amounts of field data during the life of a project. Collection, analysis, and management of water levels and water quality parameters provide fundamental baseline information necessary for identifying potential risks and managing groundwater as a sustainable resource.

Groundwater monitoring networks:

- provide baseline data to map the spatial and temporal distribution of water quality
- identify short-term changes to groundwater flow from pumping, natural recharge and discharge, agricultural and industry use
- isolate impacts to groundwater from contaminant spills and releases
- present early warning of potential risks and the need for mitigation measures
- offer real-time accounting of water use and compliance with regulatory guidelines

OUR SOLUTION

Since 1978, the Westbay* System has provided its clients with a cost-effective, multilevel monitoring technology designed for long-term groundwater monitoring and data acquisition. The Westbay System is designed for collecting subsurface data at any number of discrete positions within a single well. Under even the most complex hydrogeologic conditions, this completely customizable system is a cost-effective, reliable solution that surpasses traditional monitoring methods.



Westbay System

Flexible, industry-tested design offers *Superior Performance*

OVERVIEW

The Westbay System is a completely versatile, multilevel monitoring technology that allows testing of hydraulic conductivity, monitoring of fluid pressure and collection of fluid samples from multiple zones within a single borehole. Designed for reliability and defensibility, the Westbay System can accommodate a wide variety of borehole conditions including diameter, depth, temperature and chemistry considerations.

Westbay System advantages:

- obtain measurements and samples at any number of discrete locations along a single borehole
- collect samples without purging
- designed for long-term monitoring
- engineered to operate at great depths
- reduced drilling and installation costs, with minimal site disturbance
- removable probes allow for convenient calibration and servicing
- built-in defensible QA/QC procedures

WELL COMPLETIONS

Westbay Systems are engineered with a unique, customizable casing system. The casing system is available in two sizes (MP38 and MP55) and manufactured from plastic or stainless steel to fit various borehole dimensions and operational requirements. Hydraulically-inflated packers and/or backfill provide engineered seals between monitoring zones, preventing unnatural flow and cross-contamination. Valved ports in the zones provide access for monitoring, sampling and hydraulic testing.

Westbay Systems can be installed in a number of different ways to suit geologic conditions, drilling methods, and project objectives.

Completion methods include:

- packers in open borehole
- packers through temporary casing
- packers in a cased well
- packers in cemented and perforated well
- direct backfill

WESTBAY SYSTEM PROBES

A variety of probes are available for use with the Westbay System. Reliable, accurate, and portable wireline-operated probes can be lowered into the casing system and used to:

- measure groundwater pressure
- test hydraulic parameters
- collect samples in-situ
- perform system specific tests

COLLECTING GROUNDWATER SAMPLES

Westbay Systems offer the unique ability to collect discrete fluid samples at formation pressure. For sample collection the probe and sample container are lowered to the desired depth, where the sample is collected into the container. The probe and container are then retrieved to the surface for further analysis.

Westbay System sampling allows you to:

- collect samples with minimal disturbance and without repeated purging
- maintain samples at formation pressure
- monitor pressure during sampling
- document quality assurance

1 PACKERS

- Engineered seal in a range of borehole sizes
- No dedicated inflation lines
- Controlled hydraulic inflation with record of pressure and volume
- Quality control tests to confirm performance at any time after installation

2 MEASUREMENT PORT

- For fluid pressure measurements, fluid sampling and low-k testing

3 PUMPING PORT

- For purging, hydraulic conductivity testing, and quality control testing.

Accurate, reliable long-term monitoring delivers *Definitive Results*

MEASURING GROUNDWATER PRESSURE

Westbay pressure probes can be used to take periodic, manual measurements of in-situ fluid pressures or to automatically monitor pressures using telemetry.

With a single probe, pressures are measured one port at a time. The output from the probes is digitized and transmitted through a rugged but lightweight wireline to a control unit at the surface. By attaching a standard laptop to the interface, data can easily be downloaded and stored for interpretation and analysis.

For automated multilevel measurements of fluid pressures, a string of pressure probes can be distributed down the well with each probe located at a selected measurement port. Each probe has a unique identity, allowing them to be polled individually or simultaneously by the datalogger.

Westbay Systems allow you to:

- measure pressure at multiple locations in a single well
- measure manually or automatically
- redeploy probes in alternate locations
- select from a variety of logging modes
- perform in-situ calibration checks
- document quality assurance

TESTING HYDRAULIC PARAMETERS

Westbay technology provides many effective methods for evaluating and testing the hydraulic characteristics of a site.

Discrete monitoring ports offer the unique ability to observe and record details within a single well.

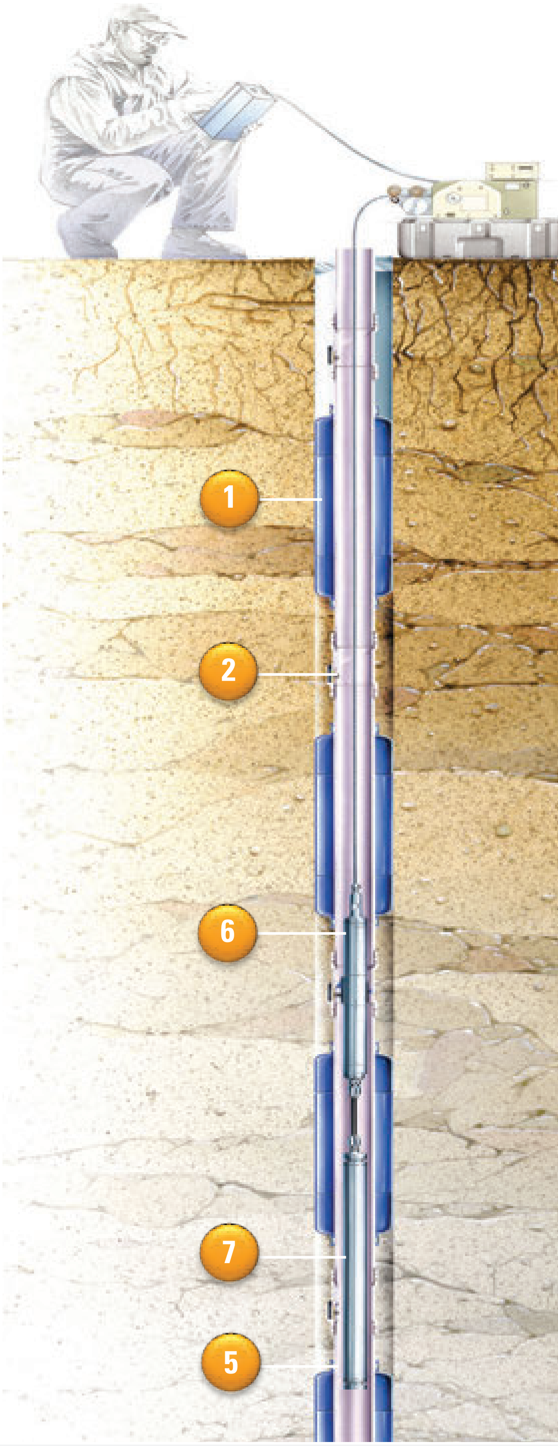
Westbay Systems allow you to:

- observe detailed distributions of groundwater pressures
- observe the effects of pumping tests or changes in barometric pressures
- gain insight into permability variations
- generate a stress in a monitoring zone and observe responses of neighbouring zones and wells

A number of qualitative and quantitative tests can be performed to determine the hydraulic parameters of formation materials or to verify the operation of the system.

- single-zone tests
- slug tests
- pulse-interference tests
- constant-head tests
- vertical interference tests
- cross hole tests
- tracer tests

As part of a complete environmental monitoring project, Westbay Systems are engineered to meet the rigorous demands of a wide range of operations. Westbay Systems provide the highest level data quality necessary to support critical decisions.



4 CENTRAL ACCESS CASING

- Made of plastic (PVC) or stainless steel
- Two sizes: 38 mm [1.5 in], 55 mm [2.2 in]
- Operational capability to depths of 1,200m [4,000 ft]

5 SEALED CONNECTIONS

- All casing connections sealed by o-rings

6 SAMPLER PROBE

- Independently controlled sampling valve
- Silicon strain-guage pressure transducer
- Location/activation mechanism compatible with Westbay System

7 SAMPLE CONTAINER

- Maintains sample pressure during recovery
- Easy to clean

Applications

Groundwater Resource Management	■ Groundwater basin management ■ Manage aquifer recharge operations ■ Seawater intrusion ■ Detailed long-term monitoring
Contaminant Site Investigations	■ Site characterization ■ Plume delineation ■ Remediation design and performance monitoring
Geologic Repositories	■ Site characterization ■ Determine feasibility of underground disposal site
Geotechnical Projects	■ Monitoring of pore pressure, slope stability for tunnels, subsidence and drainage ■ Groundwater pressure monitoring at large dams
Mining	■ Pre-feasibility planning and support ■ Subsurface characterization and monitoring ■ Acid rock drainage assessment and control ■ Monitoring of leach operations ■ Environmental impact assessment and site closure ■ Sub-permafrost groundwater monitoring
Unconventional Oil and Gas	■ Site characterization to reduce risk and minimize regulatory pushback ■ Evaluation of water management alternatives ■ Optimum placement, design and construction of injection wells ■ Compliance monitoring and minimization of cross-contamination ■ Closure design and performance monitoring

Features and Benefits

Features	■ Unlimited number of monitoring zones in a single well ■ Additional data at small incremental cost ■ Sealed monitoring zones ■ Collect water samples without repeated purging ■ Automated pressure monitoring at multiple depths	■ Wide suite of hydraulic test methods ■ Removable and upgradeable probes ■ Improved security ■ Excellent field quality control procedures ■ Custom components available to meet operational requirements
Benefits	■ Improve understanding of hydrogeological conditions and contaminant transport ■ Minimize drilling cost and time ■ Reduce site disturbances	■ Minimize wellbore storage effects ■ Minimize cross-contamination ■ Increase confidence in data ■ Reduce health, safety and environmental risks

Westbay Instruments

Operating worldwide since 1978

Over 2000 wells installed

www.westbay.com

WB-15-09-25 Printed in Canada.

NOVA METRIX

Westbay MP38 System

General Description

The plastic MP38 System is part of the Westbay* System, a multilevel groundwater monitoring system which is manufactured in two sizes (38 mm and 55 mm ID) to meet a variety of geologic, hydrogeologic and drilling conditions. The Westbay System provides a means of re-establishing and maintaining the natural distribution of fluids (their hydraulic heads and chemistry) in a borehole. The casing provides central access tube that allows for the passage of tools and probes to the valved couplings for sampling, testing, pressure measurement, and packer inflation. The specifications[1] below are for the plastic MP38 System.

Materials

PVC, ABS, Polyurethane, 201 SS, 316L SS, Inconel, Teflon, Delrin, Viton, Buna N, Kevlar, Ceramic Magnets, Nylon

General System Specifications (@ 20° C)

ΔP_{MAX} (internal > external)	100	psi	7	bar	
ΔP_{MAX} (external > internal) during operation	200	psi	14	Bar	
ΔP_{MAX} across a single packer					At diameter
For 74 mm packer (Part No. 0238)	75	psi	5	bar	4 in [100 mm]
For 82 mm packer (Part No. 0239)	150	psi	10	bar	4 in [100 mm]
For 100 mm packer (Part No. 0235)	75	psi	5	bar	4.5 in [115 mm]
For 110 mm packer (Part No. 0232)	150	psi	10	bar	5 in [127 mm]
Maximum depth[2]	4,000	ft	1200	m	

Dimensions

Maximum outside diameters (at run in)				
For 74 mm packer (Part No. 0238)	2.9	in	74	mm
For 82 mm packer (Part No. 0239)	3.2	in	82	mm
For 100 mm packer (Part No. 0235)	3.9	in	100	mm
For 110 mm packer (Part No. 0232)	4.3	in	110	mm
Nominal inside diameter	1.4	in	36	mm
Maximum inside diameter	1.5	in	38	mm
Nominal drift for tools to run inside	1.2	in	30	mm

Maximum Tensile Loads (@ 20° C)

	With 0224 Pumping Port				With 0206 Pumping Port			
Ultimate (failure at 2 to 5 minutes)	800	lb	360	kg	1,400	lb	640	kg
Short term (1 to 2 weeks)	400	lb	180	kg	700	lb	320	kg
Long term (>2 weeks)	200	lb	90	kg	350	lb	160	kg

Maximum Compressive Loads (@ 20° C)

Ultimate (failure at 2 to 5 minutes)	2300	lb	1050	kg
Short term (1 to 2 weeks)	800	lb	360	kg
Long term (>2 weeks)	400	lb	180	kg

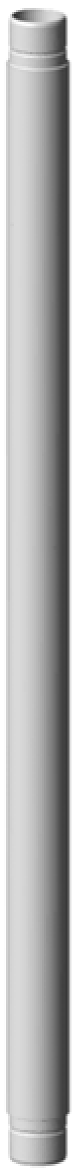
Maximum Temperatures

PVC	104	° F	40	° C
Urethane Packers: >30 year anticipated lifetime (in clean, fresh water)	104	° F	40	° C

Notes: 1. Specifications subject to change without notice.
2. Maximum depth can vary based on site-specific conditions and components used. (stated value assumes use of hydraulic pumping ports and open hole depth to water <330 ft [100 m] bgs).

* Mark of Nova Metrix Ground Monitoring (Canada) Ltd.

Westbay MP38 System
MP38 Casing
Part No. 0201xx



General Description

This casing provides an access tube for the passage of tools and probes to the valved couplings and packers in a plastic MP38 System installation. External ends interlock with the internal ends of Plastic MP38 couplings.

Materials

PVC

Dimensions & Weight

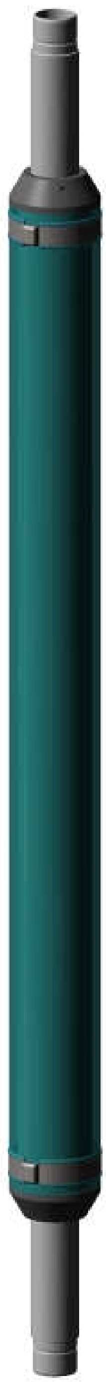
Outside Diameter	1.9 in	48 mm -
Inside Diameter[2]	1.5 in	38 mm -

MP38 System Casing Weights and Standard Lengths				
Part No.	Nominal Length[3]	Actual Length[4]	Dry Weight	Submerged Weight
020110	10 ft [3.05 m]	115.9 in [294 cm]	6.17 lb [2.8 kg]	1.70 lb [0.77 kg]
020105	5 ft [1.52 m]	55.9 in [142 cm]	2.98 lb [1.35 kg]	0.82 lb [0.37 kg]
020102	2 ft [0.61 m]	19.9 in [50.5 cm]	1.06 lb [0.48 kg]	0.29 lb [0.13 kg]
020101	1 ft [0.30 m]	7.9 in [20 cm]	0.42 lb [0.2 kg]	0.11 lb [0.05 kg]

Notes:
1. Specifications subject to change without notice.
2. Drift diameter is typically 1.2 in [30 mm] but may be less and varies with length of tool.
3. See MP38 System Length Definition.
4. Lengths can vary by ± 2mm.

Product Specification

Westbay MP38 System
MP38 Packer – 100 mm (5F/1.5M)
Part No. 0235



General Description

This packer is designed for use in borehole diameters ranging from 4.3 in to 6.3 in [115 mm to 160 mm]. It incorporates a polyurethane elastic gland and an inflation valve mounted on a plastic mandrel. The gland is inflated using an MP38 System Inflation Tool. No permanent inflation line is required. External ends seal and interlock with the internal ends of Plastic MP38 couplings.

Materials

PVC, Polyurethane, Viton, Kevlar, 201 SS, 316L SS

Dimensions & Weight

Nominal Length[2]	5	ft	1.52	m
Actual Length[2]	55.9	in	1.42	m
Gland Sealing Length	~3	ft	~0.9	m
Outside Diameter	3.9	in	100	mm
Inside Diameter[3]	1.5	in	38	mm
Dry Weight	16	lb	7.3	kg
Submerged Weight	3.1	lb	1.4	kg

Performance

Minimum Borehole Diameter[4]	4.5	in	115	mm -
Maximum Recommended Diameter	6.3	in	160	mm -
Maximum Differential Pressure[5]	75	psi	5	bar -

Notes:
1. Specifications subject to change without notice.
2. Lengths can vary by ± 2mm.
3. Drift diameter is typically 1.2 in [30 mm] but may be less and varies with length of tool.
4. Minimum borehole diameter assumes good quality bedrock.
5. Differential pressure rating is for sealing in boreholes with diameter of 4.5 in [115 mm]. The pressure rating would be lower in larger boreholes.

Westbay Instruments

Product Specification

Westbay MP38 System
MP38 Measurement Port
Part No. 0205

General Description

This coupling provides access for probes and tools to measure fluid pressure, obtain discrete samples, and carry out hydraulic tests. Internal ends seal and interlock with the external ends of plastic MP38 casing and packers.

Materials

PVC, Nylon, Viton, Inconel, 316L SS

Dimensions & Weight

Length[2]	7.0	in	178	mm -
Outside Diameter	2.3	in	60	mm -
Inside Diameter[3]	1.5	in	38	mm -
Dry Weight	0.53	lb	240	g -
Submerged Weight	0.14	lb	65	g -

Notes:
1. Specifications subject to change without notice.
2. Lengths can vary by ± 2mm.
3. Drift diameter is typically 1.2 in [30 mm] but may be less and varies with length of tool.

Westbay MP38 System
MP38 Pumping Port
Part No. 0224

General Description

This coupling provides access for injecting and withdrawing fluid for purposes such as hydraulic conductivity testing, purging, sampling, and injecting tracers. It has an external screen, and an internal sliding valve, which is operated by an MP38 Open/Close Tool (Model No. 6012). Internal ends seal and interlock with the external ends of plastic MP38 casing and packers.

Materials

PVC, Nylon, Viton, 316 SS

Dimensions & Weight

Length[2]	7.0	in	178	mm
Outside Diameter	2.4	in	61	mm
Inside Diameter[3]	1.5	in	38	mm
Dry Weight	0.56	lb	255	g
Submerged Weight	0.12	lb	55	g

Maximum Tensile Loads

Ultimate (2 to 5 minutes)	800	lb	360	kg
Short Term (1 to 2 weeks)	400	lb	180	kg
Long Term (>2 weeks)	200	lb	90	kg

Notes:
1. Specifications subject to change without notice.
2. Lengths can vary by ± 2mm.
3. Drift diameter is typically 1.2 in [30 mm] but may be less and varies with length of tool.

Westbay MP38 System
MP38 Hydraulic Pumping Port
Part No. 0206

General Description

This coupling provides access for injecting and withdrawing fluid for purposes such as hydraulic conductivity testing, purging, sampling, and injecting tracers. It has an external sliding valve, which is operated by a MOSDAX* Sampler Probe (Model No. 2532). Internal ends seal and interlock with the external ends of plastic MP38 casing and packers.

Materials

316L SS, Nylon, Viton, Buna N

Dimensions & Weight

Length[2]	10.0	in	254	mm -
Outside Diameter	2.7	in	68	mm -
Inside Diameter[3]	1.5	in	38	mm -
Dry Weight	7.2	lb	3.3	kg -
Submerged Weight	6.2	lb	2.8	kg -

Notes:
1. Specifications subject to change without notice.
2. Lengths can vary by ± 2mm.
3. Drift diameter is typically 1.2 in [30 mm] but may be less and varies with length of tool.

Westbay MP38 System
MP38 Regular Coupling
Part No. 0202

General Description

This coupling provides a modular connection between sections of plastic MP38 System casing and/or packers. Internal ends seal and interlock with the external ends of plastic MP38 casing and packers.

Materials

PVC, Nylon, Viton

Dimensions & Weight

Length[2]	7.0	in	178	mm
Outside Diameter	2.3	in	60	mm
Inside Diameter[3]	1.5	in	38	mm
Dry Weight	0.52	lb	235	g
Submerged Weight	0.14	lb	62	g

Notes:
1. Specifications subject to change without notice.
2. Lengths can vary by ± 2mm.
3. Drift diameter is typically 1.2 in [30 mm] but may be less and varies with length of tool.

Westbay MP38 System
MP38 End Cap
Part No. 0203

General Description

This end cap provides a sealed closure to the bottom of a plastic MP38 System installation. It is also used to protect the top of an installation between operations. The internal end will seal and interlock with the external end of a plastic MP38 casing or packer.

Materials

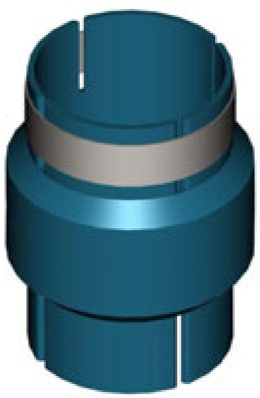
PVC, Nylon, Viton

Dimensions & Weight

Length[2]	1.9	in	48	mm
Outside Diameter	2.2	in	56	mm
Dry Weight	0.1	lb	45	g
Submerged Weight	0.01	lb	5	g

Notes: 1. Specifications subject to change without notice.
2. Lengths can vary by ± 2mm.

Westbay MP38 System Magnetic Location Collar Part No. 0216



General Description

This collar is used to confirm the location of MOSDAX* probes in a Westbay* System well. It is attached to the outside of the casing with one or two stainless steel clamps. When a probe or tool equipped to detect the presence of a location collar passes by, the probe transmits a signal to the MAGI unit at the surface and an audible tone is emitted. The tone alerts the operator that the tool has passed a location collar.

Materials

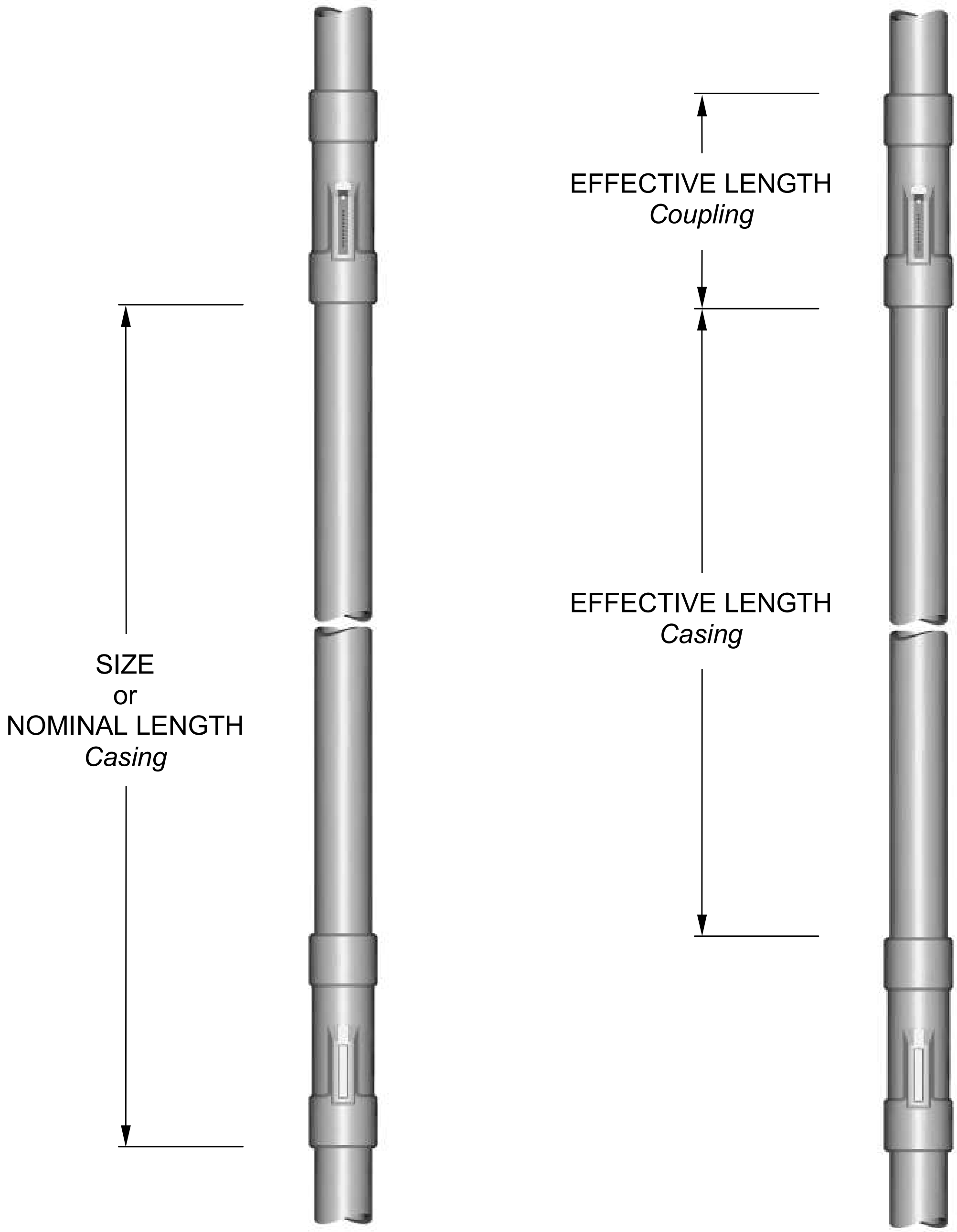
ABS, Ceramic Magnets, 301 SS

Dimensions & Weight

Length	3.3	in	84	mm
Outside Diameter	2.5	in	64	mm
Inside Diameter[3]	1.9	in	38	mm
Dry Weight	0.13	lb	60	g
Submerged Weight	Nil			

Notes: 1. Specifications subject to change without notice.

Westbay MP38 System
Length Definition



Multi-Level Groundwater Monitoring with the MP System'

Abstract

Defining the extent of a groundwater contaminant plume in geologic materials requires a three-dimensional array of sampling points. Such an array is commonly installed by placing a single access tube and inlet screen in each of a series of boreholes. With this method, the number of sampling points at a given site is generally limited by the high cost of drilling. An alternative is to install monitoring points at many levels in each borehole. Multi-level monitoring can provide increased data density and therefore an improved understanding of site conditions. This paper describes how the MP System', one type of multi-level monitoring well, is installed and operated. Field quality control procedures, 1) to verify the integrity of the access tube, inlet valves, and borehole seals, and 2) to confirm the operation of measuring and sampling equipment, are also discussed.

Introduction

When groundwater contaminant plumes are suspected of having significant depth as well as lateral distribution, a three-dimensional array of monitoring points is needed to identify and characterize such plumes. Thus, groundwater data must be obtained from a number of different locations and from a number of different depths at each location. As a result, either a large number of boreholes are required, each with a separate instrument installed, or instruments must be combined and installed at multiple levels in each of a smaller number of boreholes.

Multi-level groundwater monitoring devices have been described by many writers, some discussing the technical benefits and others the advantages to schedules and costs which can result when multi-level monitoring devices are used to reduce the number of boreholes required. Most important, however, are the advantages that accrue from the increased data density and from the field verification procedures that are available. The very fact that one is capable of accessing several different discrete zones in one monitoring well provides a testing and verification capability that is simply not possible in a single-level device such as a standpipe monitor well.

The basic requirements of any groundwater monitoring system are that it provide the user with the ability to measure fluid pressure, purge the monitoring zone, collect fluid samples, and undertake standard hydrogeologic tests, such as permeability tests and tracer tests. In addition, quality assurance plans for groundwater monitoring programs have led to a requirement for periodic testing and calibration of all aspects of groundwater monitoring devices.

Quality assurance plans normally require field verification tests immediately following installation and again at periodic intervals during the operating lifetime of the installation. In fact, few groundwater monitoring devices are designed to allow extensive field verification tests to be carried out. However, some types of multi-level monitoring instruments, such as the MP System' developed by Westbay Instruments Inc., were designed with field verification tests in mind (Patton and Smith, 1986). With such systems, questions of data quality can be readily addressed.

General Description of the MP System

The MP System is a modular multi-level groundwater monitoring device employing a single, closed access tube with valved ports. The valved ports are used to provide access to several different levels of a borehole through a single well casing. The modular design permits as many monitoring zones as desired to be established in a borehole. Furthermore, at the time of installation, zones may be added or modified without affecting other zones or significantly complicating the installation. As a result, the number and location of monitoring zones can be decided based on the information obtained during drilling. Only a broad scope of requirements need be defined in advance of drilling.

The MP System consists of casing components, which are permanently installed in the borehole, portable pressure measurement and sampling probes, and specialized tools. The casing components include casing sections of various lengths, regular couplings, two types of valved port couplings with different capabilities, and packers, which seal the annulus between the monitoring zones. The MP System has been used in many different geologic and climatic environments in boreholes ranging from a few feet to over 4,000 ft (1,200 m) in length. The 1.5-inch (38 mm) I.D. MP38 System has been used in the field since 1978, while the 2.25-inch (55 mm) I.D. MP55 System was developed in 1990-91.

Casing Components

The casing components of the MP System are made in either plastic or stainless steel. While the illustrations are of plastic components, the descriptions of operating principles that follow apply to both types of materials. Most of the components referred to are shown in Figures 1 and 2.

Casing

MP casing is supplied in a number of different lengths to provide flexibility in establishing the position of monitoring zones and associated seals in the borehole. Common nominal casing lengths are 2 ft (0.5 m), 5 ft (1.5 m) and 10 ft (3.0 m). Actual casing lengths are less than the nominal lengths to account for the lengths of the couplings. The casing ends are machined to mate with MP System couplings.

Telescoping casing sections are used to protect the casing string from damage when ground movements are anticipated or where measurements of vertical displacements are desired.

Regular Couplings and End Caps

MP regular couplings are used to connect casing lengths where valved couplings are not required. The couplings incorporate O-rings for a positive hydraulic seal. A flexible shear rod provides a tensile connection. No adhesives are used when joining casings and couplings. MP38 regular couplings incorporate an internal, helical shoulder for the accurate location of probes and tools in the well. MP55 regular couplings do not incorporate a helical shoulder.

End caps are placed on the bottom of a casing string. They also incorporate an O-ring seal so that the entire casing string is hydraulically sealed during installation. End caps are frequently used to seal the top of the casing between monitoring periods.

Valved Couplings

There are two types of valved couplings, measurement port couplings and pumping port couplings. Measurement port couplings (or measurement ports) are used where pressure measurements and fluid samples are required. In addition to the features of a regular coupling (including the helical shoulder in the case of MP55), measurement ports incorporate a valve in the wall of the coupling, a leaf spring which normally holds the valve closed, and a cover plate or screen which holds the spring in place. When the valve is opened, an access port is provided for the groundwater to enter the coupling.

Pumping port couplings (or pumping ports) are used where the injection or withdrawal of larger volumes of fluid is desired than would be reasonable through the relatively small measurement port valve (such as for purging or hydraulic conductivity testing). Pumping ports incorporate a sleeve valve, sealed by O-rings, which can be moved to expose or cover slots that allow groundwater to pass through the wall of the coupling. A screen is normally fastened around the coupling outside the slots.

Annulus Seals

When there are many monitoring zones in a single borehole, multiple seals are required to prevent fluid migration from one zone to another along the annular opening between the borehole wall and the casing. Placement of these seals can be difficult with any groundwater monitoring device. However, considerable success has been achieved with three types of well completion used with the MP System, provided each is combined with appropriate drilling and placement methods.

With the MP System, seals can be obtained by:
a) backfilling with alternating layers of sand and bentonite or grout, b) using hydraulic (water) inflated packers or
c) using packers inside a cased well with multiple screens. Figure 1 illustrates a borehole containing the MP System with packers. Figure 2 illustrates a single measurement zone where the MP System is completed by each of the three common methods. Each sealing method is possible in most environments, but in many situations one method will stand out as the most advantageous.

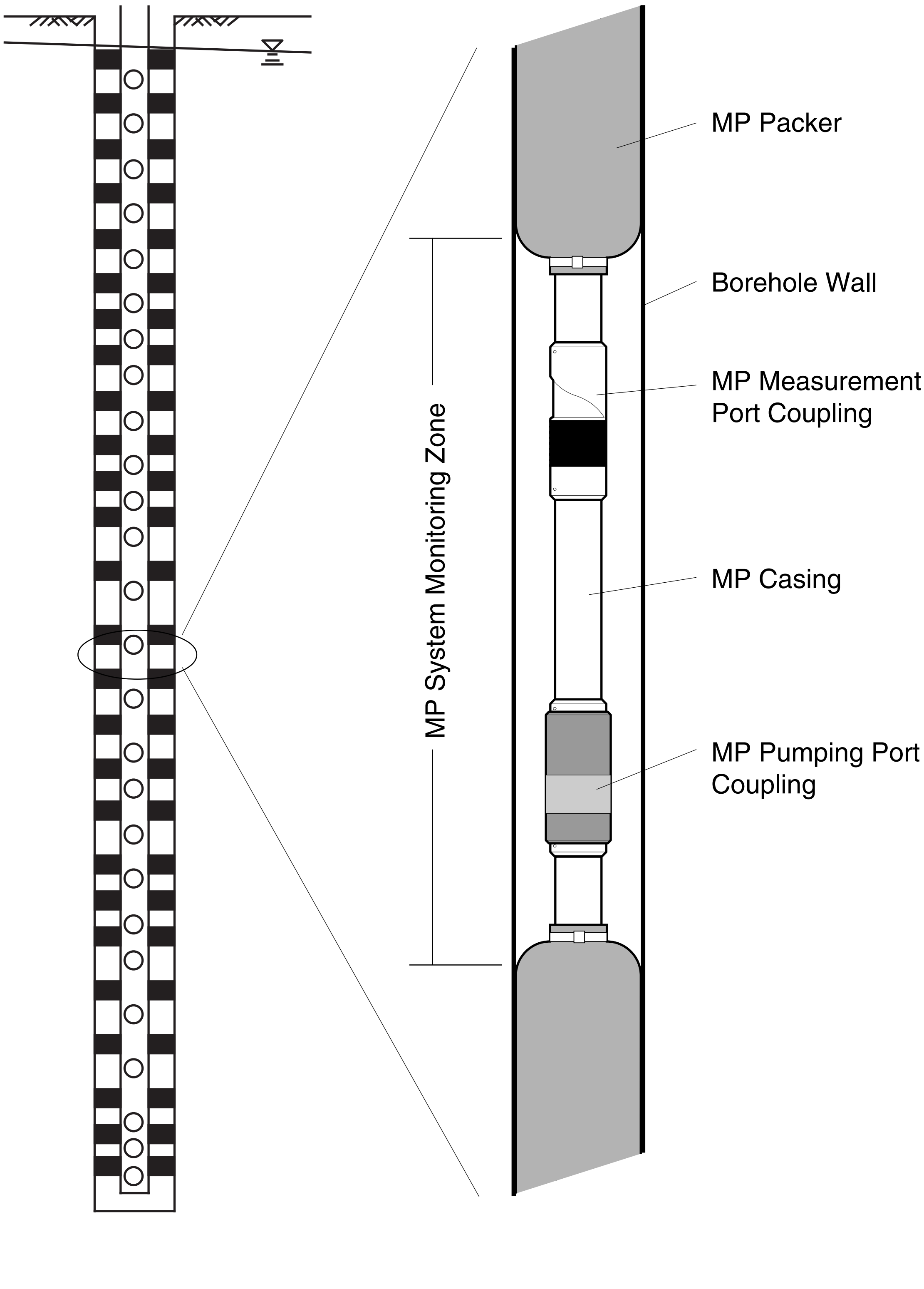


Figure 1. MP System installation with monitoring zones isolated by packers.

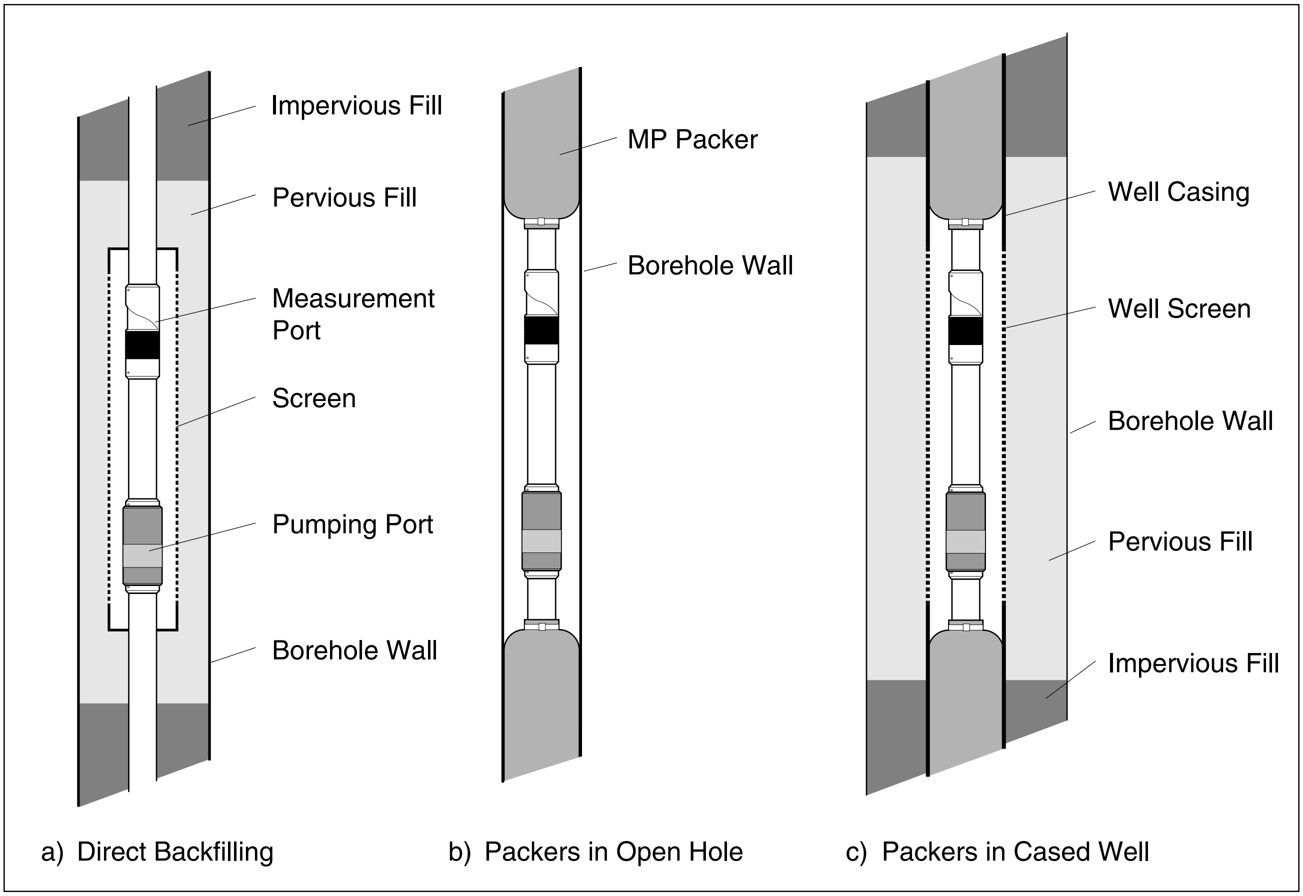


Figure 2. Common completion methods for the MP System.

Direct backfilling (Figure 2a) is recommended for: 1) large diameter boreholes, 2) shallow boreholes, 3) boreholes where little or no fluid circulation is anticipated in the hole during installation (i.e., when near-hydrostatic fluid pressures or low hydraulic conductivity is present over the length of the borehole), and d) where packer gland materials are incompatible with the chemistry of the fluids present.

When direct backfilling is considered and fluid sampling is required, a very clean drilling method must be employed. While the MP System does permit purging of monitoring zones, the small size of the casing (particularly MP38) prevents sufficient energy being generated to develop the monitoring zone.

Backfill seals may include bentonite and/or grout slurries, bentonite chips or pellets or other materials with a relatively low hydraulic conductivity in comparison to that of the natural formations present.

MP casing packers incorporate an expandable gland mounted over a standard length of MP casing. The casing incorporates a one-way valve that allows fluid to travel through the wall of the casing into the packer and prevents this fluid from flowing back out of the packer. Gland lengths are typically 3 ft (~1 m).

Packers in an open borehole (Figure 2b) are typically recommended for: 1) small diameter boreholes (those too small for good quality backfilling to be achieved), 2) deep boreholes, and 3) sealing against significant flows (e.g., flowing artesian conditions) in the borehole. When packers are used, field labour is reduced since packer inflation is generally much faster than backfilling. When using packers, additional measurement ports are installed between monitoring zones. Such additional ports provide additional fluid pressure data for quality assurance (QA) purposes.

Packers in a cased well (Figure 2c) is a completion method that has proven very successful, particularly for environments where available hole sizes are too large for packers and/or where drilling additives, such as mud, must be used. This completion method involves drilling a large diameter hole, typically 12-inch (300 mm) and installing a 4-inch (100 mm) (for MP38) nominal diameter well casing with multiple screens. The well screens are located at all of the desired monitoring levels, based on information gathered during and following drilling. Layers of backfill are placed to provide filters around the well screens and annular seals between. Each monitoring zone is then developed through the well casing. Following development, MP casing, ports and packers are installed inside the well casing. The MP packers are inflated against the inside of the well casing, providing interior annular seals between the monitoring zones. This completion method provides the ability to properly develop mud from deep mud-rotary boreholes, as well as to service the MP System during the operating life of the monitoring well.

Whenever casing packers are used, whether in open boreholes or cased wells, additional measurement ports are installed between monitoring zones for QA purposes. Measurements and tests carried out through these additional "QA ports" enable an evaluation of the effectiveness of each annulus seal. In open hole installations, such additional ports also provide added information on piezometric pressures in the portions of the borehole between primary monitoring zones.

Screens and Filters

Where both pumping ports and measurement ports are being used and the ports are likely to be surrounded by sand fill or collapsed geologic material, a single well screen is generally placed over both the measurement port coupling and pumping port coupling in each monitoring zone as shown in Figure 2a. The screen helps ensure that the zone influenced by pumping through a pumping port coupling will extend to and include the region surrounding the adjacent measurement port coupling. Screen slot size and length should be chosen with a knowledge of local site conditions. If only fluid pressure measurements are required, a simpler fabric filter tube can be placed over the measurement port coupling and clamped at either end. This filter will help maintain the length of the monitoring zone and protect the measurement port valve from fine particles. The filter material should be compatible with the chemistry of fluids present.

Installation Procedures

Selection of Casing Components

The valved couplings (measurement port couplings and pumping port couplings) allow many monitoring zones to be established in a single borehole. Horizons of hydrogeological interest are targeted on the basis of the best borehole geologic and geophysical logs available. An installation log is prepared showing the locations of the casing components. If only fluid pressures are needed, only a measurement port coupling is required in each monitoring zone. If sampling, fluid withdrawal or fluid injection is anticipated, both a pumping port coupling and a measurement port coupling are recommended in each monitoring zone. This is the case illustrated in Figures 1 and 2.

The casing lengths are chosen based on the desired locations of the monitoring zones and sealing elements. This requires an interpretation of the hydrogeologic conditions anticipated in each borehole. Caliper logs and borehole video can be useful in selecting packer locations.

If consolidation or heave is expected along the borehole axis, telescoping casing sections may be used to minimize the opportunity for compressional or tensile forces to damage the casing.

MP Casing Installation

The downhole MP System components - casing, couplings and packers - are laid out at the site of the proposed monitoring well in accordance with the casing installation log. At that time, any last minute adjustments required to make the positions of the monitoring zones and seals match hydrogeologic details of the borehole are completed and the appropriate revisions made to the installation log.

Next, the required coupling is attached to the top of each length of casing. The casing layout is checked again for compliance with the installation log. Serial numbers of measurement ports, pumping ports and packers are recorded, indicating their position on the installation log. The length of all casing sections is measured and recorded on the log.

The casing string is then assembled by lowering the casing segments into the borehole and attaching each successive segment to the adjacent coupling one at a time. As each successive MP casing section is attached to the string in the well, the section number is checked and recorded on the installation log. The coupling joint is then subjected to an internal hydraulic pressure to verify its hydraulic integrity and the test result is recorded on the log. At intervals during placement of the MP System casing clean water is added to the inside of the MP casing to reduce its buoyancy.

In collapsing soil and poor quality rock, MP casing with packers and screens may be installed through flush-jointed guide tube such as drill rods or casing. Table 1 provides ranges of borehole, casing and guide tube sizes for the MP38 and MP55 Systems. Figure 3 illustrates the major stages of installing through a guide tube:
A) Following completion of drilling, the guide tube is positioned in the hole. All parts of the guide tube, including any shoe attached to the bottom, must be flush on the interior and of sufficient inside diameter to permit the MP components to pass through; B) The MP components are assembled and lowered into the guide

System	I.D.		Max. Depth		Borehole/Casing Size		Min. Guide Tube Size	
	in.	mm	ft	m	in.	mm	in.	mm
Plastic MP38	1.5	38	1,500	450	3-4 1/2	75-115	3	75
Steel MP38	1.5	38	5,000	1,500	4-4 1/2	100-115	4	100
Plastic MP55	2.25	55	4,000	1,200	4 3/4-6 1/4	121-159	4 3/4	121
Steel MP55	2.25	55	6,600	2,000	4 3/4-6 1/4	121-159	4 3/4	121

Table 1. Important dimensions for the MP System.

tube in such a fashion that the packers and ports will be correctly positioned in the hole when the bottom of the MP is resting on the bottom of the borehole; C) The guide tube is pulled back to expose a packer and that packer is inflated. The pulling/inflating sequence is repeated until all of the packers have been inflated. More than one packer may be exposed during each pull of the guide tube, depending upon the stability of the borehole walls.

Casing without packers can be placed in various sizes of boreholes, with or without protective casing, as long as the borehole diameter (and casing) is compatible with the backfilling method. Good backfilling techniques involve the use of one or more tremie pipes.

Once the MP casing has been placed in the borehole, the packers are inflated (see Figure 3) or backfill is placed. If the MP casing was lowered inside a guide tube, the guide tube may be withdrawn all at once or in steps as the packer inflation or backfilling operation proceeds. An incremental casing withdrawal can reduce the opportunity for the borehole wall to loosen and cave prior to the placement of seals.

Packer Inflation

Figure 4a shows the appearance of a casing packer when it has been placed in a borehole before inflation. Figure 4b shows how the MP System casing packers are individually inflated using a packer inflation tool. This tool is lowered down the inside of the MP casing and is located in the correct position by the location arm seating in a coupling adjacent to the packer.

Two small packers (tool packers) are inflated, isolating the short segment of the casing containing the valve for the casing packer. At a pre-set pressure, the tool injection valve opens and water is injected into the casing packer. During inflation the vent-head mechanism on the tool holds open the measurement port beneath the packer. This vents the pressure in the zone below the packer, allowing the packer to square-off without generating unnatural squeeze pressures. Figure 4c shows the inflated MP packer after the inflation tool has been removed. At increments of volume during the inflation process, pumping is stopped and the fluid pressure of the inflation system is measured and recorded. The pressure/volume data is plotted and kept for quality assurance purposes.

Packer inflation proceeds from the bottom of the hole to the top. There are no permanent inflation lines leading to each packer. As a result, there is no limit to the number of packers that can be placed in a borehole apart from the finite limitations of packer length and borehole length.

Purging Monitoring Zones

The strategy for purging the monitoring zones may vary depending on site conditions. Figure 5 shows a typical sequence of events in drilling and completing a monitoring well. Figure 5a shows a typical borehole environment where the invasion of drilling fluids and/or the unnatural circulation of formation fluids has caused groundwater adjacent to the borehole to be nonrepresentative of the formation fluid. Once the casing and annular seals (packer seals are shown in Figure 5b) have been installed, it is usually desirable to remove the nonrepresentative fluid. This removal, or purging, can be done in one of two basic ways: 1) Purging by natural groundwater flow, or 2) Pumping to purge monitoring zones.

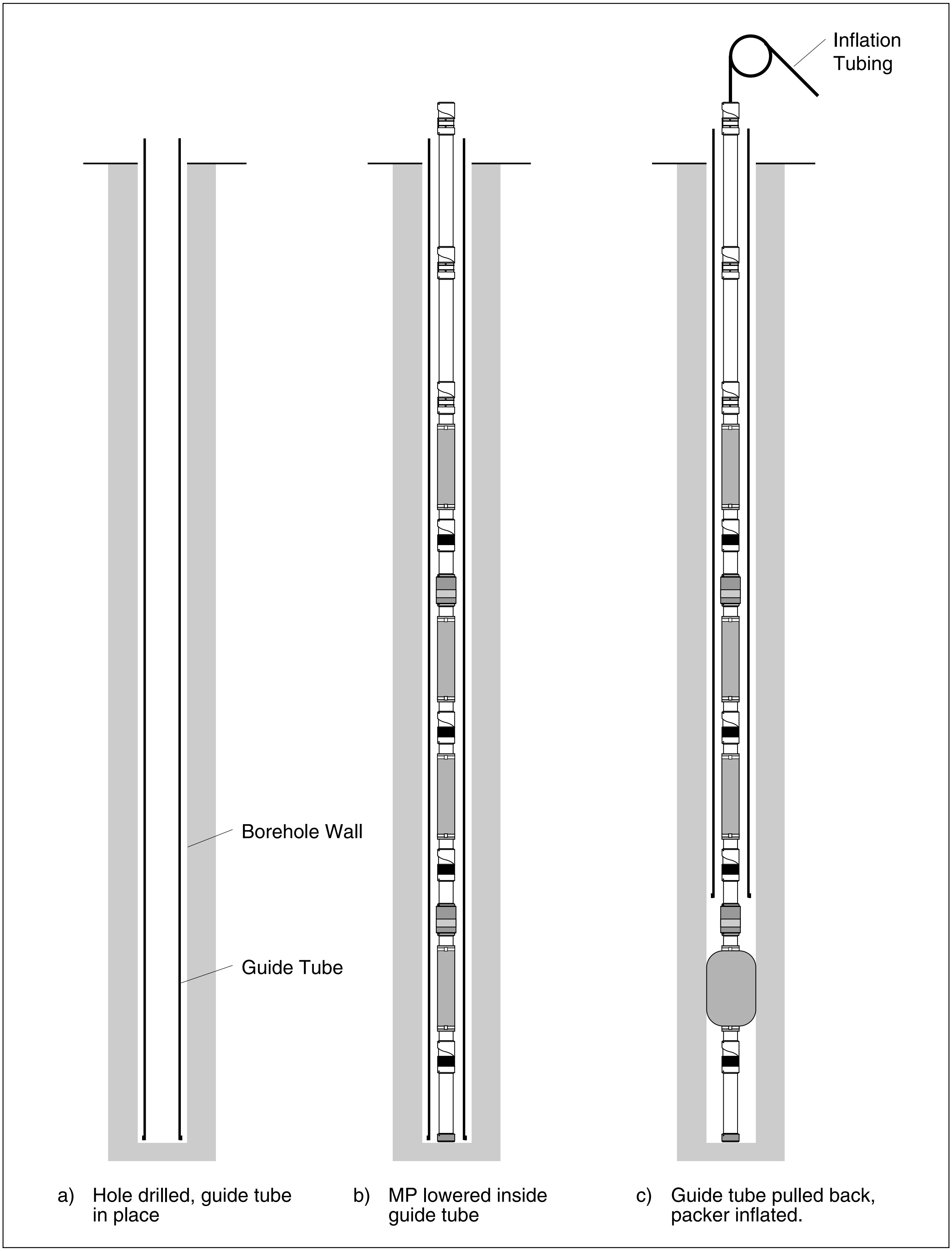


Figure 3. Installation of MP casing through a guide tube.

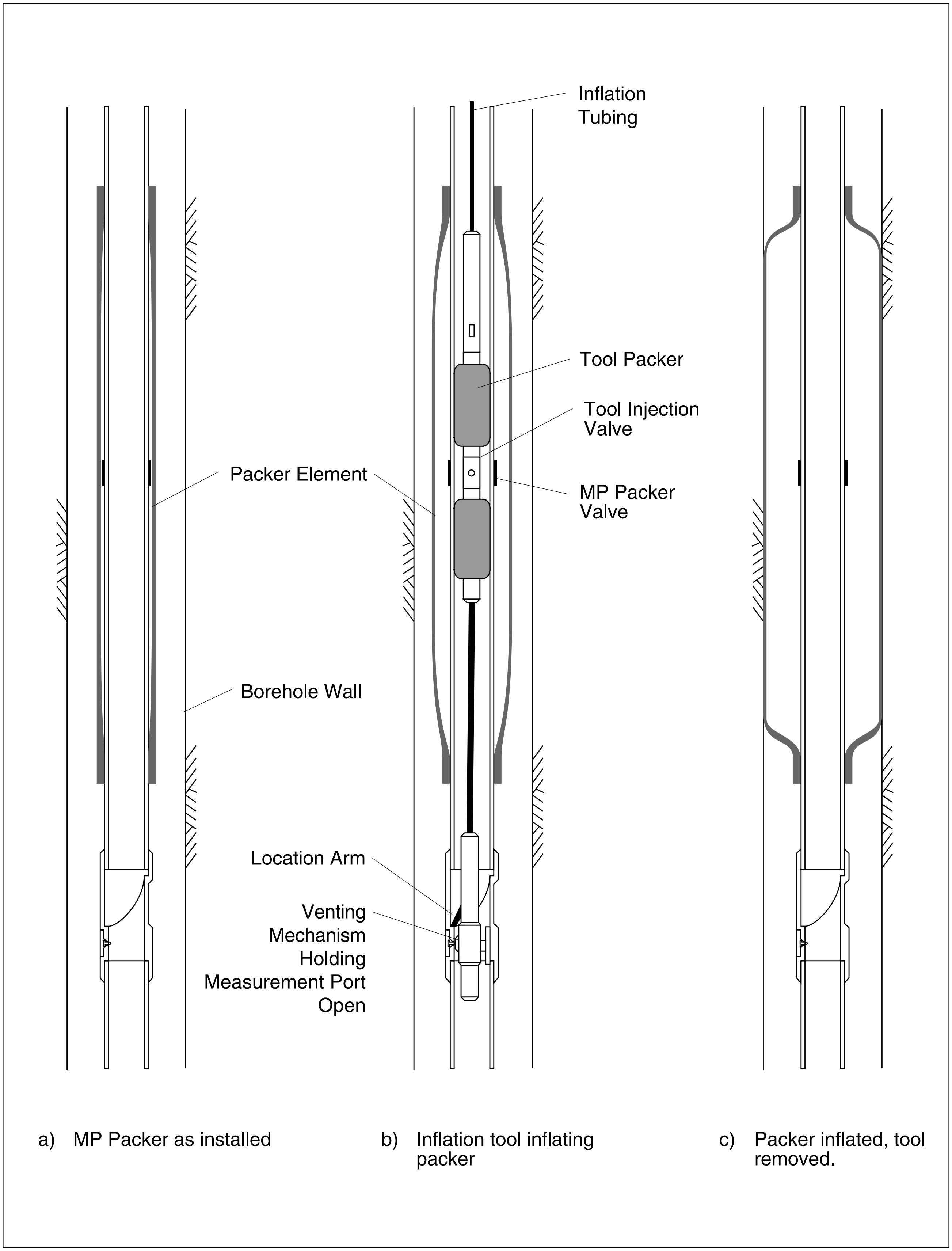


Figure 4. Steps in the inflation of an MP System packer.

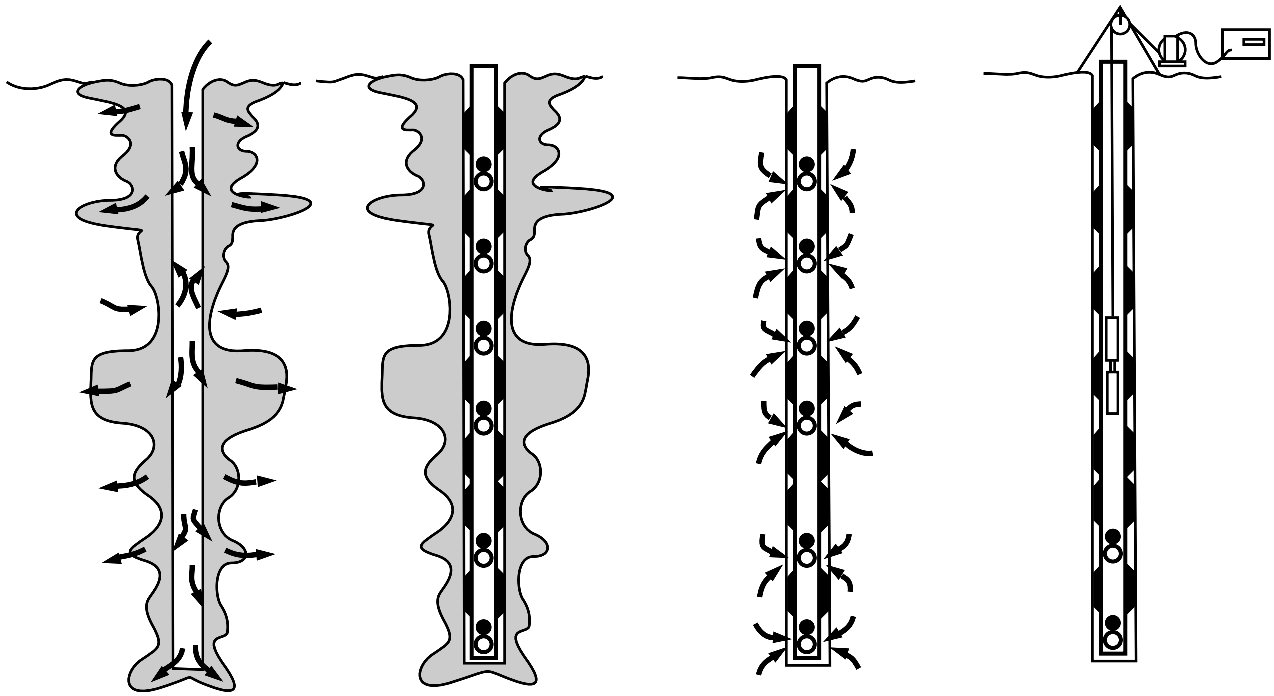


Figure 5. Typical sequence of events in purging monitoring zones.

Purging by natural groundwater flow is attractive, particularly in environments where groundwater flow is understood to be relatively rapid. In such an environment, unnatural fluids introduced during drilling may no longer be adjacent to the borehole by the time the monitoring system has been installed. In such a case, there may be little to be gained from the investment of time and resources to pumping an arbitrary volume of water from each monitoring zone. Rather, fluid samples might be collected over a period of time and analytical results compared in order to evaluate the stabilization of conditions in the monitoring zone.

When purging by natural flow is not acceptable, monitoring zones can be purged by pumping. Zones may be pumped individually or several at a time (as shown in Figure 5c). Individual hydrogeologists and hydrochemists may prefer different purging techniques depending upon local conditions. However, the purging procedures are essentially the same as would be used for a single standpipe piezometer. One procedure which has been successfully used is described below.

1) An acceptable and convenient tracer is added to the drill fluid during drilling.

2) After the casing has been installed and the packers have been inflated, the pumping ports in all or a portion of the monitoring zones are opened with the use of an open/close tool.

3) Fluid from the inside of the MP casing is pumped out of the well. The volume of fluid removed and the pumping time will depend on many factors including: the drilling method, the length of time the hole was left open prior to completion, the hydrogeological conditions in the borehole, and the accuracy required. The use of a tracer can be helpful in determining when the pumping is completed.

4) Once pumping has been completed, all the pumping ports except one are closed with the use of the open/close tool. With one pumping port open, the MP casing is hydraulically identical to a standpipe piezometer. A quantity of fluid may be pumped from inside the MP casing to complete the development of this monitoring zone. Hydrogeologic testing of this zone and its adjacent casing seals can be done at this time. For example, slug tests can be undertaken to obtain transmissivity and storativity values. This

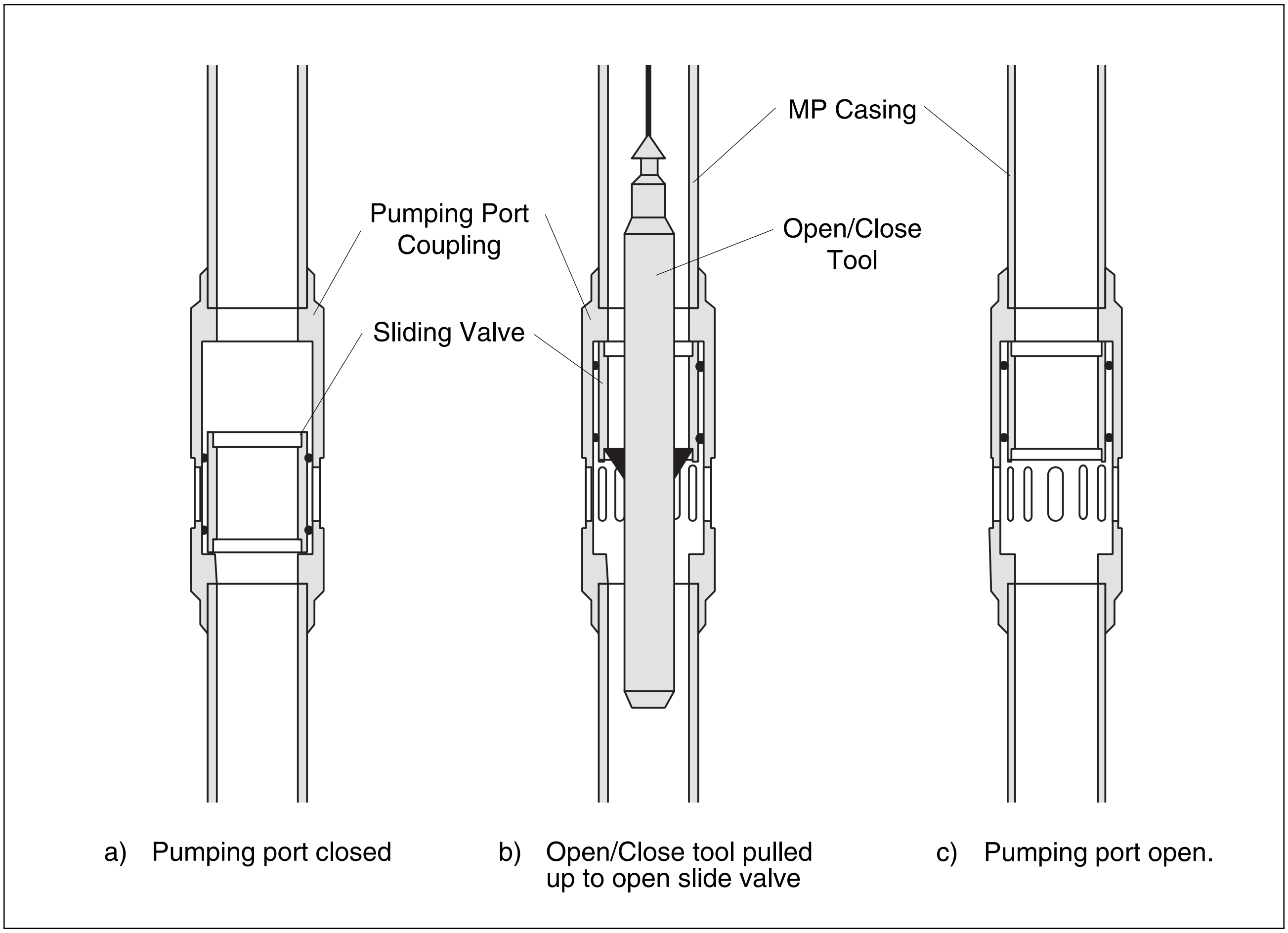


Figure 6. Operation of an MP pumping port.

pumping port can then be closed, the next one opened and the process repeated.

Following purging, the MP System is ready for sampling and for pressure measurements as indicated in Figure 5d.

Operation of the Pumping Ports

To operate the pumping port valve, an open/close tool is used as illustrated in Figure 6. This tool has spring-loaded "jaws" which can be mechanically activated from the surface. The pumping port is shown closed in Figure 6a. To open the valve, the tool is lowered on a wireline with the jaws extended and pointing upward (i.e., so that they will catch on shoulders when the tool is raised). In this condition, the jaws will spring through the couplings as the tool is lowered to just below the desired pumping port coupling. The tool is then pulled up so that the jaws engage the bottom shoulder of the sliding valve. By continuing to pull up on the wireline, the valve can be opened, as in Figure 6b. Once the valve is opened, the jaws can be collapsed into the housing and the tool recovered. With this one valve opened, fluids can be added to or removed from the monitoring interval by injecting or pumping from the MP casing. Other zones may still be monitored in the normal manner using a pressure probe or sampling probe as they will not be hydraulically connected to the interior of the casing.

To close the pumping port coupling, the open/close tool is brought to the surface and the housing is reversed so that the jaws point downward (i.e., the tool will stop on exposed shoulders when the tool is lowered). The tool is lowered to the open pumping port with the jaws collapsed into the housing. Once the tool is located near the pumping port, the jaws are released and the valve is closed by tapping on the top shoulder of the sliding valve with the tool.

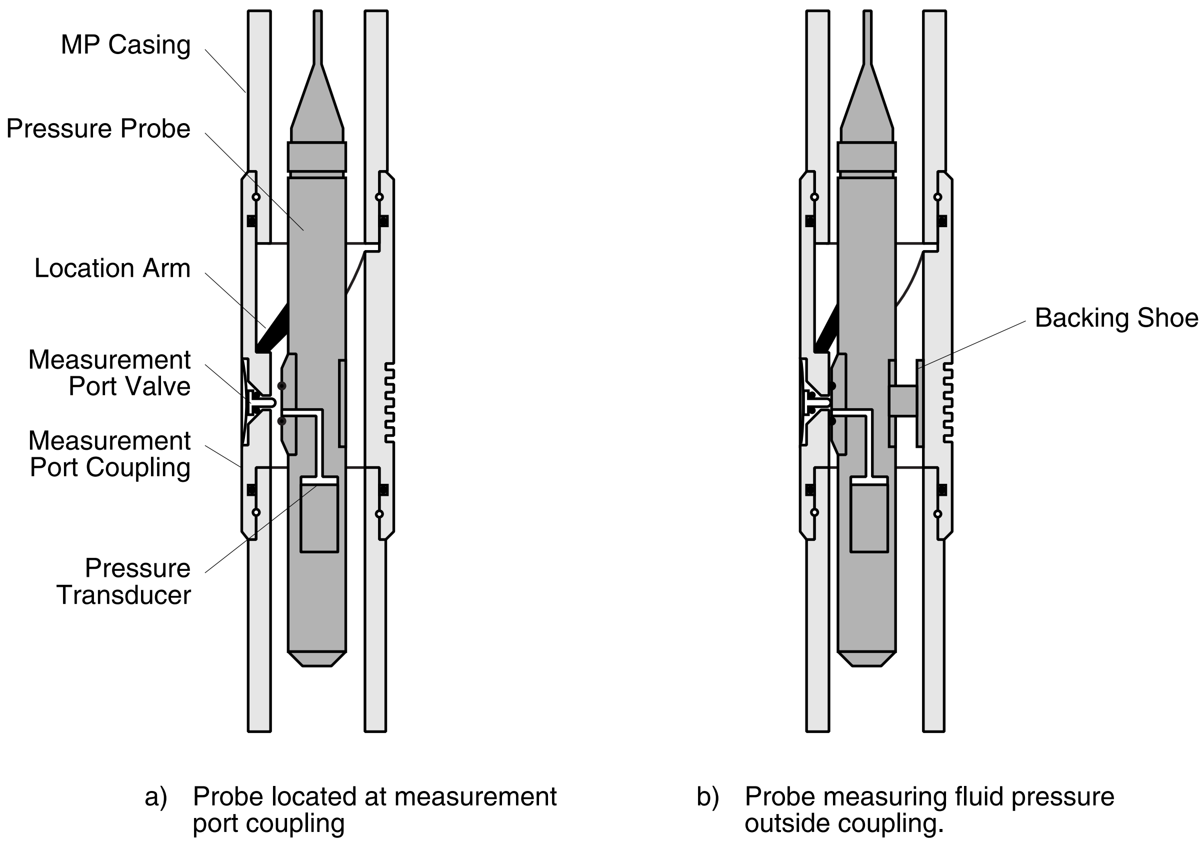


Figure 7. Operation of a pressure probe.

Testing and Monitoring

Fluid Pressure Measurements

Fluid pressure measurements can be made at each location in a borehole where an MP measurement port coupling has been installed. The measurement coupling includes a helical landing ring and a leaf spring valve which is normally closed. The fluid pressure is measured using a MOSDAX® pressure probe which incorporates a location arm, a backing shoe, a face seal, and a fluid pressure transducer. These features are shown on Figure 7. The probe is operated on a cable connected to an interface and portable computer at the top of the monitoring well. Using MProfile™ software, the computer displays the pressure both graphically and digitally, along with transducer temperature, well information and probe status (see Figure 8).

The following procedure is used to make fluid pressure measurements. The probe is lowered to a point below the first measurement port to be accessed (usually the deepest). The location arm is released from within the probe body. The probe is raised to just above the measurement port coupling and then lowered until the location arm rests on the helical landing ring in the coupling. The weight of the probe causes it to rotate into position at the correct depth and orientation to operate the valve (Fig. 7a). At this point the pressure transducer is measuring the fluid pressure inside the MP casing at that depth. This reading will be displayed on the surface computer and is recorded. If convenient, the depth to water inside the MP casing is also measured and recorded at this time as a check on the pressure transducer.

The backing shoe is then activated. It pushes the probe to the wall of the coupling so that the face seal on the probe seals around the measurement port valve at the same time as the face of the probe pushes the valve open. The transducer is now hydraulically connected to the fluid outside the coupling and isolated from the fluid inside the casing (Fig. 7b). The reading displayed on the surface computer will be the fluid pressure in the formation outside the measurement port. The pressure outside the port can be observed as long as desired and recorded as often as desired. After the reading has been recorded, the probe backing shoe is deactivated (retracted) and the valve in the coupling reseals. The probe will again be

Figure 8. Data display on surface computer when using MProfile software to operate a MOSDAX pressure probe.

measuring the fluid pressure inside the MP casing (Fig. 7a). The pressure in the casing is again recorded, for quality assurance purposes.

Measuring Pressure in Low Permeability Environments

Very low permeability environments present a special challenge for measuring fluid pressures. When the routine profiling procedures described above are followed, a stable pressure may be observed through the measurement port. However, the act of opening the port may have been sufficient to change the pressure in the monitoring zone, and if the zone is very tight, that pressure change may not dissipate quickly enough to be observed. In such an environment it is always difficult to determine the validity of a static measurement unless some form of dynamic test is carried out as well. In the case of the MP System, this is done throught the use of a MOSDAX sampler probe. As illustrated in Figure 9a), the MOSDAX sampler incorporates all of the features of a pressure probe, plus a valved passage which is controlled via the surface computer. With the sampling valve closed the probe acts identically to a pressure probe and thus may be used for single-probe profiling. The difference is that once the probe is located and activated (Fig. 9b), the fluid level inside the MP casing may be adjusted to a level slightly higher or lower than the piezometric level in the monitoring zone. The sampling valve is then opened (Fig. 9c), exposing the monitoring zone to the fluid pressure in the MP casing. In very low permeability environments, no water will flow during this time. The sampling valve may be kept open for a specified period of time (such as one minute). The sampling valve is then closed (Fig. 9d) and the pressure recovery in the monitoring zone is recorded vs. time (Fig. 10). Standard analytical methods can be applied to the pressure recovery data in order to determine the apparent pressure in the monitoring zone. The same procedure can be used for testing hydraulic conductivity in low-k zones.

Pressure Monitoring Methods

The two principle methods of monitoring fluid pressure with the MP System are illustrated in Figure 11. Single probe profiling (Fig. 11a) involves an operator

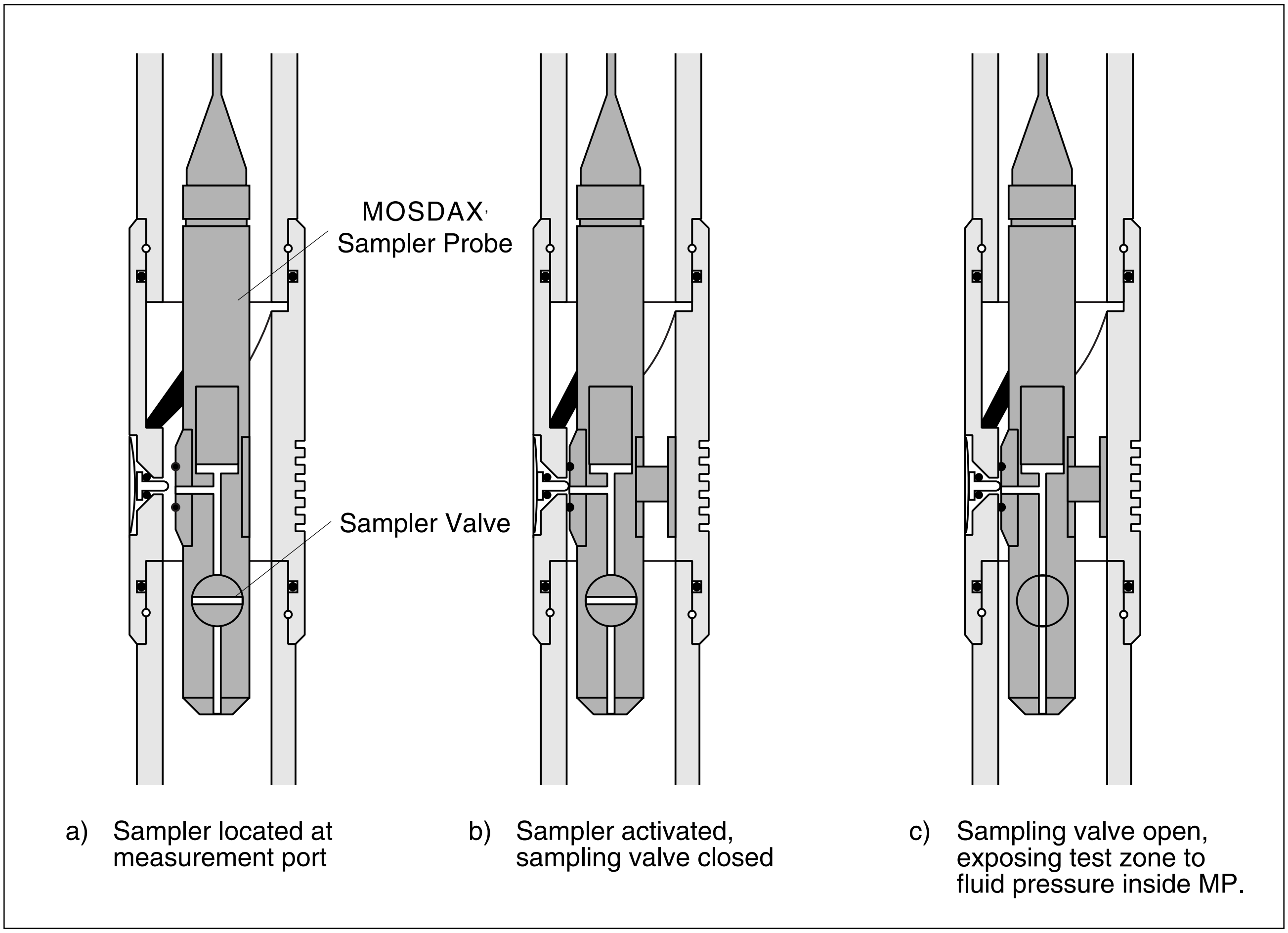


Figure 9. Using a sampler probe for testing hydraulic conductivity and verifying fluid pressure measurements in low permeability environments.

travelling to each well with a set of portable equipment including a pressure probe, cable and reel, interface and computer. The operator manually locates the probe at each measurement port and carries out fluid pressure measurements one at a time. MProfile stores the data on disk with each record tagged as to the location of the probe in the well, date, time, and probe status. Single probe profiling is generally adequate for monitoring fluid pressure up to a frequency of once per month.

When pressure measurements are desired more frequently than is reasonable for single-probe profiling, or when continual observation and recording of unanticipated events is required, the monitoring well can be configured for automated datalogging (Fig. 11b). Any or all of the measurement ports in a well may be selected for automated monitoring. Lengths of cable are made up to span the distance between each probe and the next. The string of probes and cable is assembled and lowered into the well. The datalogger and a computer are attached at the surface and the lowermost probe is located and activated in the appropriate measurement port. The

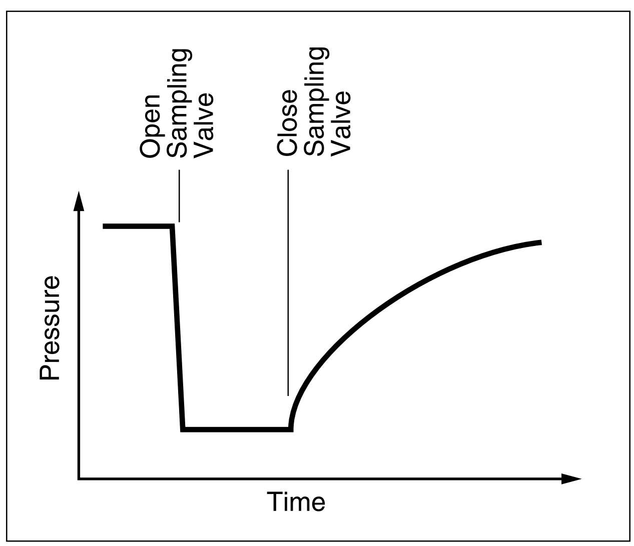


Figure 10. Typical data record from a test in a low permeability zone using sampler.

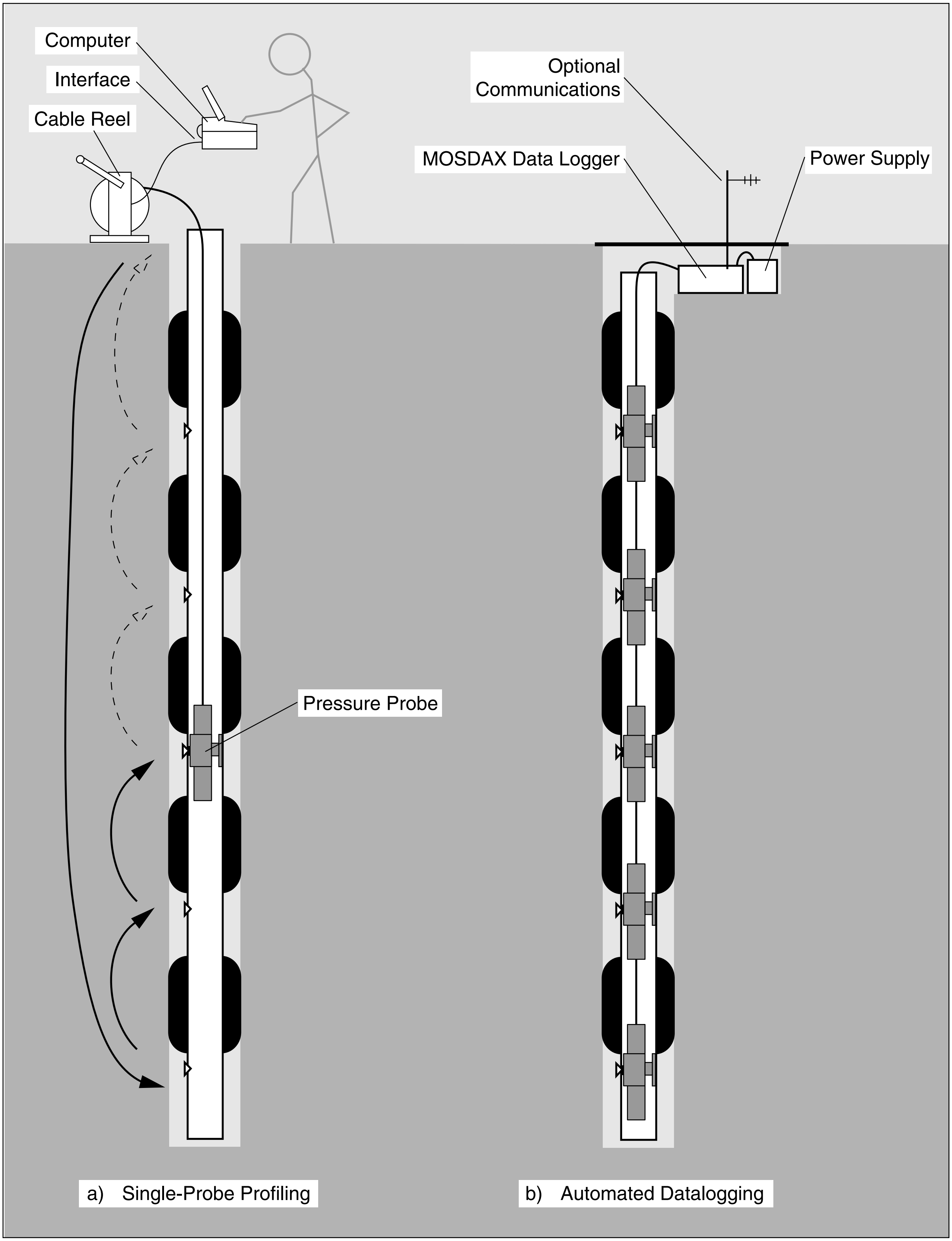


Figure 11. Methods of monitoring fluid pressure with the MP System.

remaining probes are located and activated sequentially from the bottom of the well to the top. Once all of the probes are activated, the computer is used to program the datalogger.

Recording of pressure measurements may be carried out on a simple time basis (e.g., one reading per hour or one per day), or the logger may be programmed to continually scan each probe and record pressures if a specific threshold value is exceeded. Each probe may be assigned an independent threshold (i.e., record data if probe 1's reading changes by 1 ft of water, probe 2 by 3 ft, etc.).

The datalogger may stand unattended, in which case an operator would periodically visit the site to download the stored data, or the datalogger may be connected to a telemetry system such as an RF modem, cell phone system, or landline. When connected to a communication device, a second threshold can be designated for each probe which will cause the logger to transmit an alarm signal to the host computer.

A unique aspect of monitoring in the MP System is that unusual pressure readings can often be verified by means of an in-situ calibration check. When an alarm condition is received, a natural first reaction is to question the validity of the measurement ("is it real, or is it the instrument?"). When datalogging with the MP System, if an alarm were received, the operator can log onto the well via remote communications, deactivate two or more probes including the one causing the alarm and compare their measurements of the fluid pressure within the MP casing. The column of fluid inside the MP casing is independent of all of the monitoring zones and thus serves as a reference pressure source. If the deactivated probes agree on the internal pressure, the alarm condition can be taken to be valid and the probes can be reactivated to resume monitoring. If the probe cauaing the alarm did not agree with the others, instrument error might be suspected. In such a case, an operator could visit the well, remove the string of probes, replace the offending probe and reinstall the string to resume monitoring. The offending probe could then be calibrated and serviced in a laboratory.

Fluid Sampling

Fluid samples are obtained by lowering a sampling probe and sample container to the desired measurement port coupling. As shown on Figure 12, the sampling probe operates in similar fashion to the pressure probe except that a groundwater sample is drawn through the measurement port coupling. Whenever the sampling probe is operated with the sampling valve closed, it is identical to a pressure probe, supplying the same data.

The procedure for taking a groundwater sample is as follows. A clean, empty sample container is attached to the sampling probe. The probe and container are prepared (e.g., evacuated) in a manner suited to the specific project and the sampling valve is closed to prevent the fluid inside the MP casing from entering the sample container. The probe and container are lowered to below the selected measurement port coupling. The location arm is released and the probe is positioned in the measurement port coupling (Fig. 12a). The fluid pressure inside the MP casing is recorded.

The backing shoe is activated and pushes the probe to the wall of the coupling so that the face seal on the probe seals around the measurement port valve at the same time as the face of the probe pushes the valve open. The interior passage of the probe is now hydraulically connected to water outside the coupling (Fig. 12b), but no fluid movement takes place. During this operation the change in fluid pressure is observed at the surface and may be recorded.

The sampling valve in the probe is opened, allowing fluid from outside the measurement port to flow through the probe and enter the sample container (Fig. 12c). The fluid displayed at ground surface drops and then recovers as the fluid in the container builds to formation pressure. Once the container is full, the sampling valve is closed (Fig. 12b), the backing shoe is deactivated (retracted) (Fig. 12a) and the fluid pressure inside the MP casing is once again recorded. The sampling probe and sample container are then pulled to the surface. The sampling probe can then be cleaned, a clean container attached and the procedure repeated.

When using a non-vented sample container, the fluid sample is maintained at formation pressure while the probe and container are returned to the top of the well. Once recovered, there are a variety of methods of handling the sample:

- the sample may be depressurized and decanted into alternate containers for storage and transport,
- the sample container may be sealed and transported to a laboratory with the fluid maintained at formation pressure,
- the sample may be transferred under pressure into alternate pressure containers for storage and transport.

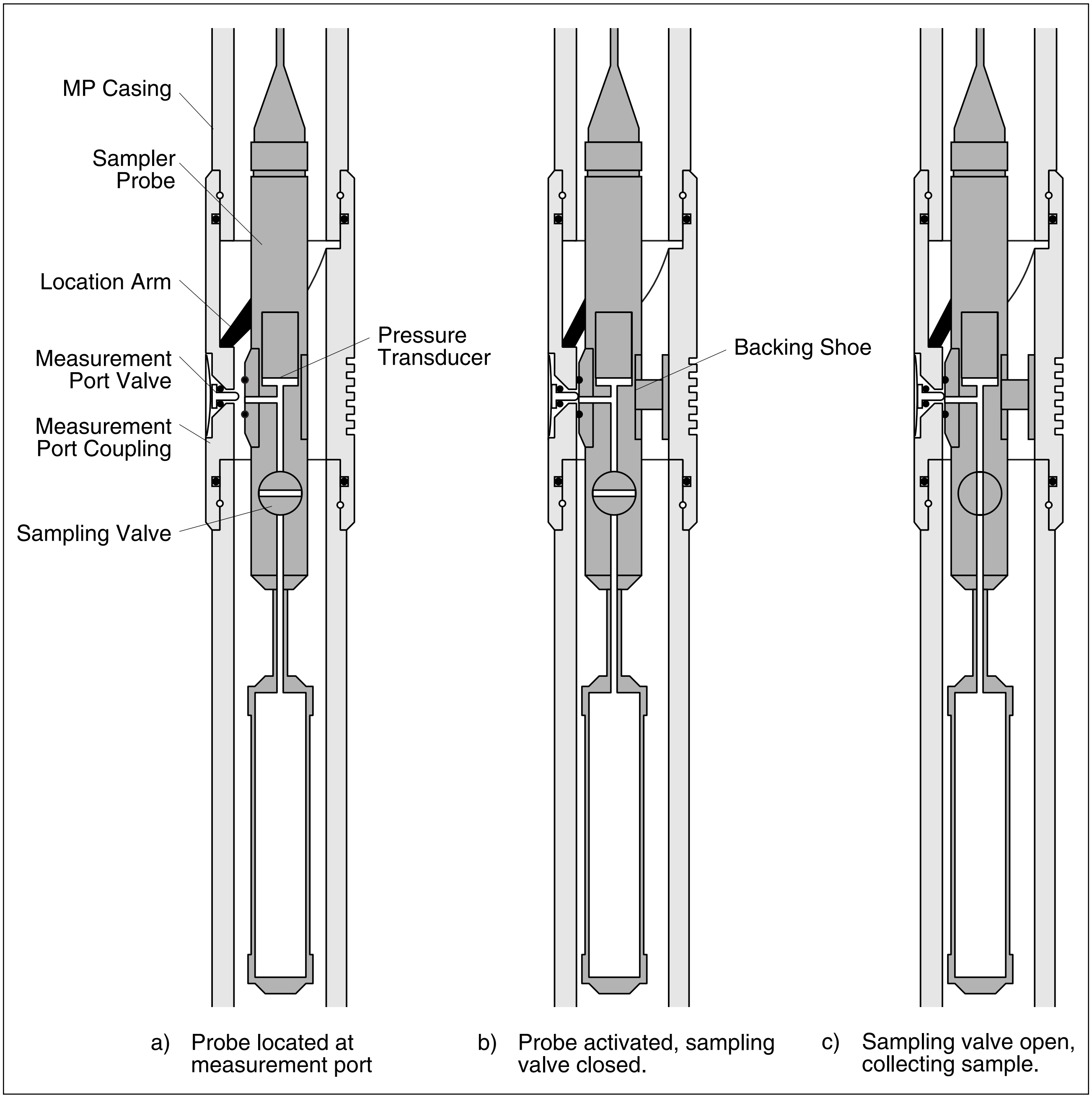


Figure 12. Operation of a sampler probe.

The advantages of this discrete sampling method can be summarized as follows:

1) The sample is drawn directly from formation fluids outside the measurement port. Therefore, there is no need for pumping a number of well volumes prior to each sampling event. Because there is no pumping prior to sampling, the sample is obtained with minimal distortion of the natural groundwater flow regime, the storage and disposal of large volumes of hazardous purge fluids is eliminated, and operator exposure to hazardous fluids is reduced.
2) The lack of pumping means samples can be obtained quickly, even in relatively low permeability environments.
3) The sample travels a short distance into the sample container, typically from 1 to 2 ft (0.3 to 0.6 m), regardless of depth.
4) The risk and cost of storing and disposing of hazardous purge fluids is virtually eliminated.

Hydraulic Conductivity Testing

A variety of different test methods can be employed to measure the hydraulic conductivity of formation materials with the MP System. These include variable head, constant head and pressure-pulse tests.

Variable head tests are the single well test method most commonly used with the MP System. Using these types of tests in the MP System, hydraulic conductivities between 10^{-2} and 10^{-8} cm/sec can be measured.

For variable head tests the valved pumping port couplings are used to provide the hydraulic connection between the interior of the MP riser tube and the test zone. In cases where monitoring zones are to be purged, it is convenient to carry out hydraulic conductivity testing just prior to or following purging. The head (fluid level) inside the MP casing can be adjusted while all port valves are closed, then the selected pumping port can be opened in a controlled manner (pumping port operation is described in the discussion of purging). This allows accurate measurement of both the initial head change and the time at which the head change is applied (t_0). The pumping port valve is opened rapidly (in less than one second), which satisfies the theoretical requirement that an instantaneous head change be applied to the tested zone.

For rising head tests the water level inside the MP casing is bailed or pumped down to a pre-determined level below the static water level in the test zone. For falling head tests the water level is raised to a level above the static water level in the zone to be tested. Measurement equipment is set in place and the pumping port valve is opened. Recovery of the water level in the MP casing is measured and recorded vs. time. A water level tape or pressure transducer is commonly used to record the water level changes. Figure 13 shows a typical record of water levels during a rising head hydraulic conductivity test.

Slug tests are carried out by opening the pumping port coupling at the zone to be tested and allowing the water level in the MP casing to equilibrate to the static water level for that zone with measurement equipment in place. The initial head change is then applied by rapidly lowering a displacement slug (a length of solid rod or sealed pipe) into the water. The recovery of the water level is measured and recorded vs. time. The slug test can be repeated and recorded again when the slug is removed from the water. Figure 14 shows a typical record of water levels during a slug test of hydraulic conductivity.

Data from variable head hydraulic conductivity tests may be analysed using any preferred calculation method. The most commonly used methods are those of Hvorslev (1951), Cooper et al. (1967) and Bouwer and Rice (1976). Selection of these or any other analytical method should be based upon an assessment of how well the test conditions comply with the simplifying assumptions inherent in the analytical method.

In very low permeability environments (hydraulic conductivity less than 10^{-7} or 10^{-8} cm/sec) the formation fluid pressure can be changed with very little fluid movement. As a result, tests can be carried out through the measurement port valve rather than the pumping port valve. Using a sampler probe with a transducer the zone to be tested may be exposed to the fluid pressure inside the MP casing for a period of time (see Fig. 9 and discussion of measuring fluid pressure in low-k environments). The zone may then be shut-in and the recovery of fluid pressure over time measured and recorded. Figure 10 shows a data record from such a test.

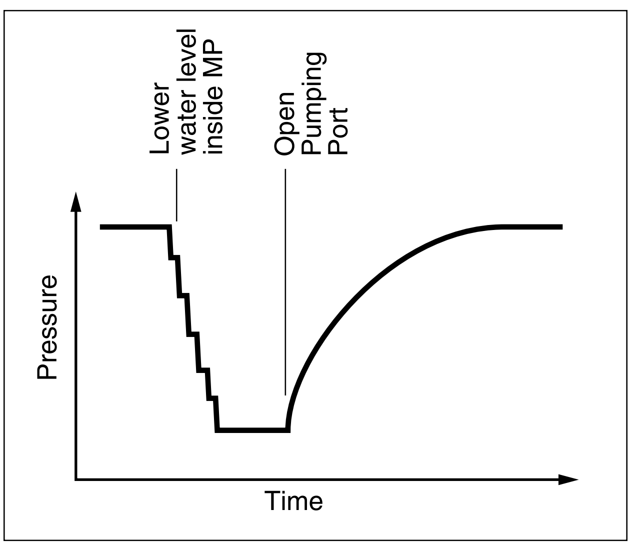


Figure 13. Typical data record from a rising head test.

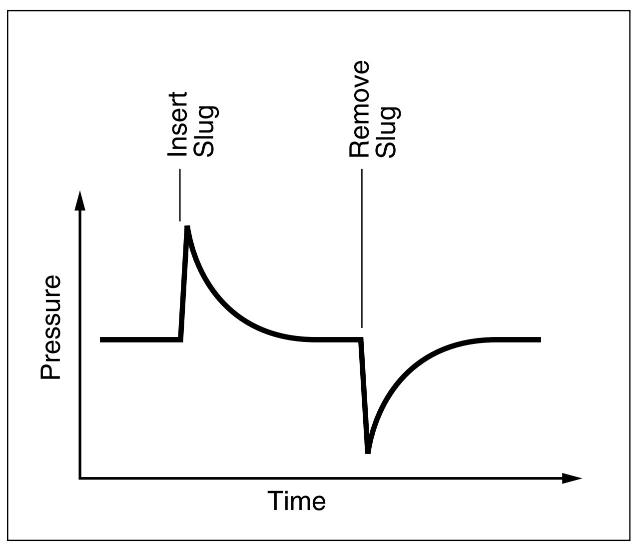


Figure 14. Typical data record from a slug test.

Field Quality Control

There are two distinctive parts to any quality assurance program. The first involves manufacturing and testing procedures which avoid the production or installation of equipment that may result in the collection of erroneous data. The second involves field operational procedures which will ensure that erroneous data are not generated as a result of the failure of any component to function as intended. Although the first part is necessary to allow the installation of useful monitoring wells, the second must also be rigorously applied to identify sources of erroneous and misleading results.

The MP System has many unique features for field quality control which clearly separate it from other types of groundwater monitoring instrumentation. These features are the result of designing components in response to the stringent requirements of users in the fields of nuclear and hazardous waste management.

Quality control tests are carried out at various points during the field use of the MP System and tend to be grouped into three periods: during installation, following installation, and during routine monitoring.

During Installation

During installation of the MP System the following operations form part of the quality control procedures:

Drill core or cuttings and geophysical logs are carefully checked to see that monitoring zones and annular seals are placed at the optimum positions. In cased wells, the well casing is inspected to verify that the interior surfaces are suitable for establishing good quality packer seals and backfill is placed under carefully controlled conditions with frequent measurements of material depths.

Westbay casing components are carefully inspected to see that critical surfaces are undamaged, sealing O-rings are clean and in place, and components are correctly oriented. Serial numbers are recorded along with component position in the installation. These operations link the field quality control to production test results.

As each section of MP casing is attached, the connection is pressurized with water and observed for any signs of leakage. Test results are recorded on the installation log.

During inflation of each MP packer, incremental volumes and pressures are recorded and plotted. These data allow an evaluation of borehole conditions and provide the first indication of the quality of the annular seal obtained.

Following Installation

Immediately following installation further checks are carried out to verify the operation of the system. These include the initial pressure profile which serves to confirm the operation of the inlet valves of the measurement port couplings. Observed head differences across exterior casing seals directly indicate the seal effectiveness. Where such head differences are not observed, the annular seals can be artificially stressed by opening a pumping port in one monitoring zone and withdrawing or adding a slug of water from inside the casing while using the pressure probe to observe the pressure response in the monitoring zone on the other side of the seal. In cased wells and wells in low permeability environments, stresses can be applied through measurement ports in order to evaluate seal integrity.

Additional measurement ports are routinely installed between monitoring zones, further enhancing the ability to carry out thorough quality control tests.

Fluid can be added to packers at any time following installation and the pressure at which further fluid injection occurs can be compared with the injection pressures recorded during the initial inflation.

During Routine Monitoring

A number of quality control checks are built into the routine monitoring procedures.

When measuring fluid pressures, the pressures measured inside the MP casing at each measurement port are recorded immediately before and after the measurement made through the port. These inside casing values serve a number of purposes: 1) comparison of the two values confirms that the transducer was operating the same way after the reading as before, 2) comparison of the inside values from one set of measurements to the next confirms transducer stability over the intervening time period (assuming the water level inside the casing is the same), and 3) if the head of fluid inside the MP casing is known, an in-situ calibration check of head of water versus transducer output is obtained. Any unacceptable changes which show up during monitoring can be checked and corrected through laboratory calibration of the instrument.

Water sampling procedures with the MP System improve quality control because: 1) the short flow path between the formation and the container greatly reduces the surface area contacted by the sample, 2) the contacts between the water sample and the atmosphere are eliminated, 3) observing and recording the water level inside the MP casing during sampling confirms that the sample obtained is from outside the casing, and 4) sampling without purging reduces the disturbance of the natural system, minimizing unnatural changes in chemistry. Sampling methods can be varied to compare the effects of atmospheric contact versus no atmospheric contact and maintaining the sample under pressure versus allowing depressurization of the sample.

During water sampling, sample blanks and spikes may be collected using identical procedures for sampling, preservation, handling and shipping. Travel blanks and spikes may also be collected using identical procedures for handling, preservation and shipping. The chemical analyses of samples obtained using the MP System may be compared with those of samples collected from the same zone by alternate means.

Finally, the pumping port may be reopened should further purging appear to be desirable.

For both fluid pressure and water quality data, the MP System can provide corroborative data. That is, a high density of data can be obtained in a single installation so that significant changes in piezometric pressure and / or water quality can appear as transitions along a depth profile. Thus, neighboring values will corroborate one another rather than indicating abrupt changes which would cause one to question anomalous values.

Serviceability

In the event that quality control testing should reveal a component which is not operating properly, various steps can be taken to remedy the problem including, if certain cases, removing the MP casing string, replacing faulty components and reinstalling the string.

Table 2. Summary of major quality control aspects of the MP System.

Provides the Ability to Verify	
Well Integrity	✓
Individual Seals	✓
Sample Origin	✓
Fluid Pressures	✓
Well is Serviceable	✓

Summary

The modular nature of the MP System permits a large number of monitoring zones to be accessed through valves placed inside a single closed tube or casing installed in a single borehole. Such a monitoring system can provide a detailed view of the variation of piezometric pressure and water quality with depth. The valved couplings permit purging of the well following installation and allow all standard hydrogeologic tests to be carried out in each zone. Routine sampling is carried out without repeated purging, eliminating the need to store and dispose of large volumes of purge fluid and reducing operator exposure to hazardous fluids. The valves also permit an evaluation of the condition of exterior casing seals at any time after installation. Casing packers allow multiple seals to be established easily and quickly, providing the required hydraulic isolation of each monitoring zone. The modular design of the downhole components means the number and location of monitoring zones and seals can be modified on the basis of the best information available in the field at the time of installation. The exact depth of monitoring zones need not be known when equipment is purchased.

Field quality control procedures have been established which permit the quality of a well installation and the proper operation of testing and sampling procedures and equipment to be routinely verified. Thus, groundwater data and the additional data required to define the quality of the field data can be routinely collected. Furthermore, when a high density of groundwater monitoring zones are installed by using multi-level monitoring wells, the redundant monitoring points can provide important corroborative field data to an extent which is not available with single level monitoring wells. The result is a monitoring system which provides data with a degree of defensibility unattainable with any other monitoring method, single or multi-level.

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MP38 System – Summary of Guide Tube Installation Procedure - PQ Borehole

The basic procedure used for installation of the MP38 System in bedrock or unconsolidated soil environments where borehole collapse or caving is of concern involves the following major steps:

1. The borehole is completed to the desired depth. If wireline drilling is used, then the typical borehole is PQ-size (4.8-inch or 122mm diameter). Monitoring zones and seating areas for the MP System packers are chosen based on geologic and geophysical information obtained during and following drilling.

2. If required, the drilling contractor carries out primary purging and development of individual borehole sections in the open hole.

3. To protect the borehole from caving as the Westbay components are lowered into place, a temporary casing or guide tube is placed in the borehole first. The guide tube is generally steel pipe, such as wireline drill rods or casing. Any such guide tube must be smooth on the interior (including connections) and of a suitable inside diameter to accommodate the MP casing and packers.

   Model 0235 MP38 packers without stiffeners are compatible with boreholes from 4 to 6.3 inches (102 to 160 mm) diameter and can also be used where installation is through a guide tube such as PQ drill rod (4.07-inch or 103.4-mm ID). These packers have a nominal un-inflated outside diameter (O.D.) of 3.9-inches (99-mm) and are rated for a differential pressure equivalent to a fresh water head of approximately 150ft (i.e., 75 psi) in a 4-inch (101 mm) borehole.

4. A reaming shoe or other such thin-kerf bit is typically placed on the bottom of the guide tube. The bottom of the guide tube is typically placed near (but not on) the bottom of the borehole, and clamped at the wellhead. The inside of the guide tube is sounded to confirm that it is clear.

   - ***Guide Tube Positioning Cautions***

     Accurate Information concerning the length of guide tube is vital; not knowing where the bottom of the guide tube is relative to the position of the packer being inflated could cause serious problems to the installation with possible devastating results. The drill contractor must maintain careful measurements and counting of the guide tube being installed or removed.

5. The MP38 System components are arranged in sequence on layout racks, checked against a well design log and assembled at the wellhead. Each connection is hydraulically tested, as it is made-up at the wellhead.

6. The assembled MP38 System components are lowered into the guide tube. The MP38 System well design is configured such that inflatable packers are positioned in the borehole above and below each monitoring interval. When the distance between monitoring zones is long, additional packers may be required for a “load sharing” purpose to distribute the weight of the MP38 casing as well as to prevent unnatural vertical flow along the annulus.

7. After the MP System components are lowered in the guide tube and rested on the bottom of the borehole, an MP38 cap is placed on top to protect the interior of the MP casing. The guide tube is carefully raised to expose one or more of the MP38 packers.

8. **Guide Tube Handling Cautions:**

   During the guide tube raising it is important for the operator to proceed slowly, and to take care that the guide tube does not hang up on the MP casing components inside. It is also important to note while handling the guide tube during retrieval that it can only be lifted upward, and when disconnecting the joints at the wellhead only the top section of guide tube can be rotated.

- ***Lowering the guide tube may cause damage to the MP casing components inside. Therefore, lowering of the guide tube, even by a small distance, is not permitted.***

- ***Turning the guide tube may cause damage to the MP casing components inside. Therefore, turning of the downhole part of the guide tube during disassembly and retrieval is not permitted.***

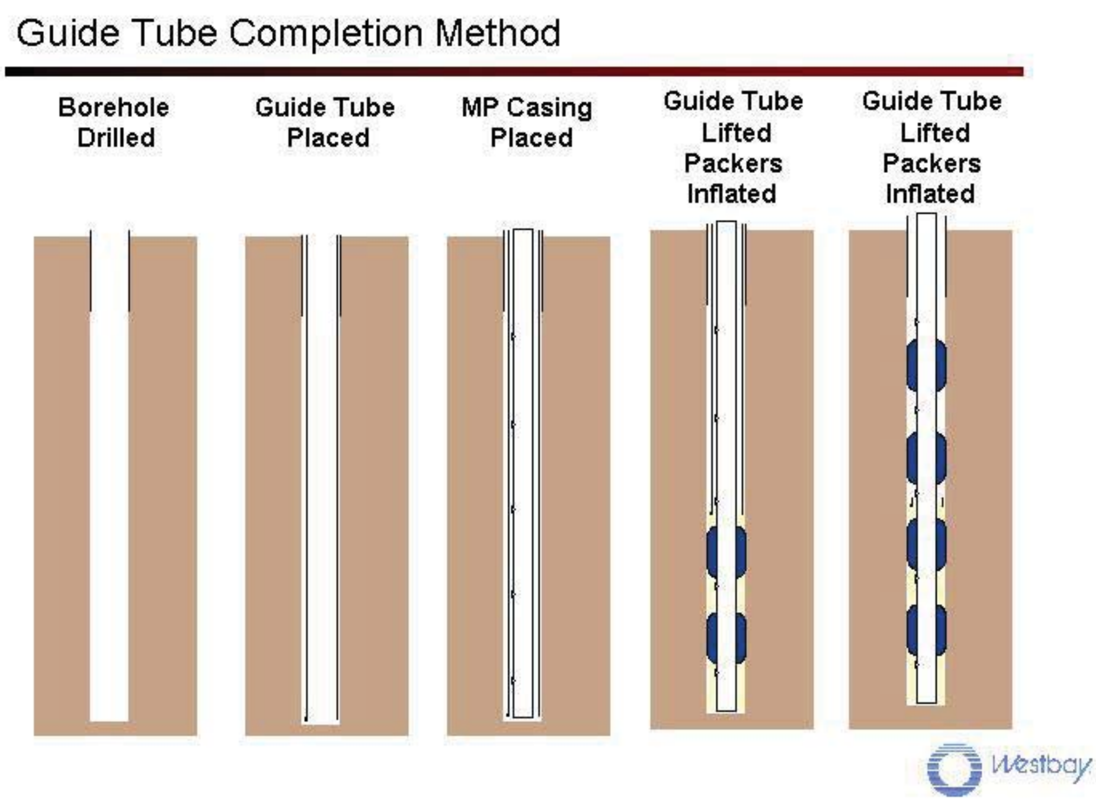
- ***If the drill operator experiences difficulty in retrieving the guide tube, care must be taken in applying conventional retrieval aids, such as pumping fluid down inside the guide tube or use of jar hammers, as these could cause damage to the MP casing components inside. Please consult with the Westbay representative before proceeding.***

9. The MP casing is lifted to position the packers at the design location. The exposed packers are inflated individually with water, thus sealing against the borehole wall.

10. After the exposed packers have been inflated, and before the guide tube is raised the inflation tool and hose must be removed from the MP casing. After the inflation tool has been vented mark the position by wrapping tape around the inflation hose. This will allow you to return to the same location after the guide tube has been raised and count up to the next exposed packer.

11. The cycle of packer inflation and guide tube rising is repeated until the guide tube is removed from the borehole and all of the packers have been inflated.

12. Remember that when inflating packers in this type of installation that the volume of water taken by each packer will differ depending on the diameter of the surrounding borehole (sometimes not known).



Summary of Westbay MP38 System Installation Procedure

Following is a summary of the installation procedure for the plastic MP38 system. In this outline emphasis has been placed on Q/A checks and documents generated. All Westbay equipment will be operated as set out in the appropriate operators' manuals. All documents are noted in **bold text**. It has been assumed that the installation work is carried out by customer personnel with on-site assistance from a Westbay field representative.

A. Pre-Installation Activities

Based on the available monitoring well information on depths of well screens, blank pipes, backfill interfaces and expected head distributions, borehole water levels and fluid temperatures a proposed **Westbay Installation Log** from Westbay's Well Designer Software is produced, detailing the position of each component to be installed. For clarity the following discussions will only refer to the **Westbay Installation Log**.

The proposed Westbay well completion design typically includes packers positioned above and below each monitoring zone. A measurement port and pumping port are included in each monitoring zone. Measurement ports are also placed below each packer for squeeze relief venting during later inflation of the packers. The signature of the client's responsible representative is required on the proposed **Westbay Installation Log** to confirm acceptance of the proposed well design, the suitability of the Westbay tubing components for the installation, and the suitability of the well for installation to proceed. The signed copy of the **Westbay Installation Log** serves as the field installation guide for the well.

The stable open-hole water level will be measured and recorded by the client.

Cased-Hole Installation

In this case a nominal 4-inch ID multi-screen well casing will have been placed and backfilled as described in documentation provided by the client.

B. Layout and Lowering of the Westbay Tubing Components

The required MP casing components (tubing, couplings, magnetic location collars, etc.) will be laid out on pie racks or equivalent and numbered in sequence according to the order indicated on the **Westbay Installation Log**. Magnetic Location Collars are typically placed 2.5 ft (0.75 meters) below the top of the respective assembled MP casing sections.

The length of each section of Westbay tubing will be measured and recorded on the **Westbay Installation Log**. Measurements will be made to the nearest millimeter and the temperature of the Westbay tubing items at the time of measurement will be recorded. The Westbay packers should be protected from direct sunlight when laid out.

The Westbay Joint test Tool equipment will be set up and tested, and the test results recorded on the **Westbay Installation Log**. Only clean water supplied by the client will be used. Each connection in the Westbay casing will be pressure tested prior to lowering and the results noted on the **Westbay Installation Log.** In general a minimum test pressure of 100 psi and a minimum test duration of 1 minute should be used for all couplings and ports. The test pass criteria of no observable water leakage must be met by all couplings before lowering. Any couplings not passing the test must be dis-connected, refurbished or replaced as necessary, and successfully re-tested and passed.

Each section of Westbay tubing will be visually inspected to confirm that the inside is clear. Before attachment of a section of Westbay tubing to the downhole casing string, the Joint Test Tool will be passed through to confirm that the inside of the Westbay casing is clear.

in deeper wells a hoist and dynamometer are required for lowering the Westbay tubing. The Westbay tubing weight, differential pressure (both inside to outside, and outside to inside) and the buoyancy force on the casing bottom will be kept within operating limits. When necessary, the tensile load of the MP casing will be measured at the wellhead and noted on the **Westbay Installation Log**.

A test will be carried out to confirm the hydraulic integrity of the Westbay tubing by measuring the inside water level over a period of time and the results will be noted on the **Westbay Installation Log**. A differential head for this test would typically be at least 30 ft (10m) of water outside over inside, though other differential pressures may be deemed suitable by the Westbay field representative. The test result is accepted (passed) if the water level inside the MP casing is stable for at least 30 minutes.

A pre-inflation pressure profile will be carried out. The data will be recorded on a **Piezometric Pressures/Levels Field Data and Calculation Sheet** (manually recorded data) or recorded to disk and reported in a **MOSDAX Data Report.**

C. Packer Inflation

The water level inside the Westbay tubing will be adjusted (if necessary) prior to inflation of the packers.

The inflation tool equipment will be set up and tested, and lowered into the well. The packers will be inflated, beginning with the lowermost packer in the well. Injection pressure (packer element pressure) and pumped volume will be recorded at intervals as determined by the Westbay operator (typically one reading for each 0.5 liters pumped). The data for all inflations will be recorded by computer. Selected data points will be recorded manually on a separate **Packer Inflation Field Record** for each packer. Packer inflation will be terminated as determined by the operator based on pressure and/or volume according to the type of packer being inflated and the expected well diameter.

On completion of inflation pumping the packer valve will be closed. A QA check will be carried out to confirm that the valve has been successfully closed. The final injected volume and pressure will be calculated for each packer.

A **Summary Log** will be prepared to show the final “as-built” configuration of the well, and will include a sketch of the position and dimensions of significant items at the top of the well, such as the final top of the Westbay tubing, steel borehole casings, BOP and tubing hanger, and ground level/concrete pad, etc.

As soon as possible after packer inflation, a post-inflation profile will be carried out to document the function of each measurement port and to record the initial measurements of in-situ fluid pressure. The data will be recorder on a **Piezometric Pressures/Levels Field Data and Calculation Sheet** (manually recorded data) or recorded to disk and reported in a **MOSDAX**

Data Report. A graphical presentation of the results of the pressure profiles will be plotted on a **Piezometric Profile** sheet.

The Westbay field crew will later prepare a **Completion Report** which will summarize all installation activities while on site and will present all documentation, measurements and test results obtained.

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Appendix B:
RHMW01 Boring and Monitoring Well Construction Log
(DON 2002)

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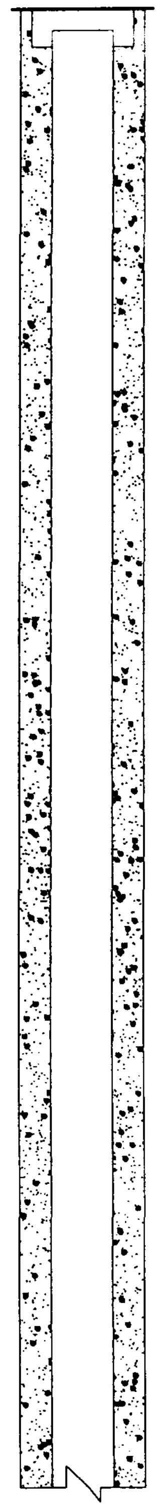
PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

Boring/Monitoring Well No. B-V1D
Project No. CTO 0229

LOCATION: V1D - Basal Aquifer	ELEVATION: 102.56		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 2/13/01	LOGGED BY: Lance Williams	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: 86.0	COMPL.: 86.1
BORING ANGLE: 90	WELL DIAMETER (inch): 1"		

Corrected Elevation/ Boring Length (ft)	Depth	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	Graphic Log	SOIL DESCRIPTION
102.56	0	1	NM		100		Concrete 0-2' over fine to coarse sand with fine gravel and silt 2-2.5; basalt 2.5'; no odor
102.06		2	172		83		
98.56			NM				Small to large vesicles; no odor; 10YR 3/1
		3	NM 99.2		71		Small to medium vesicles; no odor; 10YR 3/1 to 2/1
95.36							
94.16		4	NM		0		Small vesicles; no odor; 5YR 3/2 to 10YR 2/2
93.66		5	NM		33		Small to medium vesicles; no odor; 5YR 3/2 to 10YR 2/2
91.76	10	6			100		
		7	124		105		Small to large vesicles; no odor; 10YR 2/2
		8			93		Small to large vesicles; no odor; 10YR 2/2 to 3/2
86.06		9	NM		96		Primarily small to medium vesicles; no odor; 10YR 2/2
81.66	20	10	NM		100		Small to primarily large vesicles; no odor; 10YR 2/2 to 5YR 3/2 to 10YR 3/1
76.26		11	3.2		100		Small to large vesicles; no odor; 10YR 3/1 to 5YR 3/2
71.26	30	12	10.8		100		Small to medium vesicles; no odor; 5YR 3/2 to 10YR 3/1
66.16		13	NM		102		Small to large vesicles; no odor; 5YR 3/2 to 10YR 3/1
60.96	40	14	NM		100		Small to large vesicles; no odor; 10YR 2/2 to 5YR 3/2
57.26							
56.91		15	NM		98		Small to medium vesicles; no odor; 10YR 2/2 to 5YR 3/2
53.06							Void
	50	16	NM		98		Small to medium vesicles; no odor; 10YR 2/2 to 5YR 3/2
48.06		17	1.0		89		Small to medium vesicles; no odor; 10YR 2/2 to 5YR 3/2
43.36	60	18	6.9		100		Small to large vesicles; no odor; 10YR 3/1 to 2/2 to 5YR 3/2
38.36		19	1.8		83		Small to large vesicles; no odor; 10YR 2/5 to 5YR 3/2
34.26	70	20	0.0		92		Small to medium vesicles; no odor; 10YR 2/1 to 2/2 tp 5YR 3/2
29.16		21	0.0	RH-BR-V1D-S01	102		Small vesicles; no odor; 10YR 2/1

WELL CONSTRUCTION



This information pertains only to this boring and sh... not be interpreted as being indicitive of the site.

Corrected elevations are provided for angle borings.

PROJECT: Red Hill Bulk Storage Facility
CLIENT: PACNAVFACENGCOM

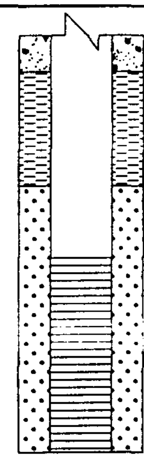
Boring/Monitoring Well No. B-V1D
Project No. CTO 0229

LOCATION: V1D - Basal Aquifer	ELEVATION: 102.56		
DRILLER: Salisbury & Associates, Inc.	DATE DRILLED: 2/13/01	LOGGED BY: Lance Williams	
DRILL RIG: SAITECH EH5, Portable Core Drill	DEPTH TO WATER>	FIRST: 86.0	COMPL.: 86.1
BORING ANGLE: 90	WELL DIAMETER (inch): 1"		

Corrected Elevation/ Boring Length (ft)	Core Run Number	PID Reading (ppm)	Sample Number	Core Recovery %	SOIL DESCRIPTION
24.06	22	0		100	Medium vesicles; no odor; 10YR 2/2
18.86	23	0.0	RH-BR-V1D-S02	106	Medium vesicles; no odor; 10YR 2/2
15.66	24	0.0		96	Large vesicles; no odor; 10YR 2/1
10.16					
9.56	25	0.0		86	Small vesicles; no odor; 10YR 2/2
					Clinker zone 93-100'
6.56					
4.96	26	0.0		56	Medium vesicles; clinker zone; no odor; 10YR 2/1
4.96	27	0.0	RH-BR-V1D-S03	50	Medium vesicles; clinker zone; no odor; 10YR 2/2
2.56					Clinker zone
					B-V1D terminated at 100.0'

Boring length scale (ft): 80, 90, 100, 110, 120, 130, 140, 150

WELL CONSTRUCTION



This information pertains only to this boring and sh… not be interpreted as being indicative of the site.

Corrected elevations are provided for angle borings.

Appendix C:
Installation Procedures for RHMW01R as a Single-Level Screened Well

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1. Introduction

This appendix presents drilling and well installation procedures for installing RHMW01R as a single-level, screened monitoring well. Conditions that determine whether RHMW01 is installed as a single-level well are presented in Section 2.3 of the *Monitoring Well Installation Work Plan* (MWIWP) *Addendum 02*.

The field procedures presented below are specific to those required for drilling and installation of RHMW01R as a single-level well. All other field procedures will follow those presented in Section 3 of *Addendum 02* and/or the August 29, 2016 MWIWP (DON 2016). These include site preparation; utility clearance; drill rig access; borehole abandonment; monitoring well development; dedicated groundwater pump system installation; potable water, subsurface unconsolidated material, and geotechnical sampling; petrographic analysis and sampling of RHMW01R core; surveying; and investigation-derived waste management.

Except where noted, the drilling and well installation procedures presented below supersede those presented in *MWIWP Addendum 01* (DON 2017a).

2. Replacement Well Design and Installation

Table C-1 summarizes well construction details for RHMW01R if it is constructed as a single-level well screened across the water table surface.

Table C-1: Well Construction Details for RHMW01R as a Single-Level Screened Well

Well ID	Ground Surface (ft msl) [a]	Top of Casing (ft msl)	Casing Diameter and Type	Estimated Depth to Bedrock (ft)	Groundwater Surface (ft msl) [b]	Well Screen Interval (ft msl)	Top of Filter Pack (ft msl)	Borehole Bottom Depth (ft bgs)	Borehole Bottom Elevation (ft msl)
RHMW01R	103	TBD	4" SCH 80 [c]	N/A	19.72–20.13	29.5–9.5	31.5	95	9.5

N/A not applicable
SCH Schedule
TBD to be determined
[a] Surface elevation is based on the Facility lower tunnel floor, which is located in bedrock at approximately 312 ft bgs.
[b] Source: *Final Second Quarter 2017 - Quarterly Groundwater Monitoring Report* (DON 2017c).
[c] 2-inch Schedule 80 polyvinyl chloride (PVC) will be installed in a 6-inch low-carbon steel conductor casing if perched water or evidence of contamination is encountered above the water table. If drilling and well installation difficulties are encountered and a 2-inch-diameter well cannot be installed, then the Navy will consult with the Regulatory Agencies prior to making any final decisions on how to proceed.

The well will be constructed with a screened interval fully spanning the anticipated seasonal range of groundwater surface elevation. As noted in Section 2.3 of *Addendum 02*, a 4-inch Schedule 80 PVC well will be installed at the site if the presence of light non-aqueous-phase liquid (LNAPL) of a thickness of greater than 0.25 inch is measured using an interface probe and there is no other evidence of contamination or perched water in the unsaturated zone above the water table. If perched water or evidence of contamination is observed during drilling, then coring will be discontinued and conductor casing will be installed to seal off the zone of perched water or contamination. The borehole will be grouted closed, as an approximately 2-week period will be needed to re-tool the drilling rig for a larger borehole. After the drilling of a larger 10-inch diameter borehole at the same location, a 6-inch low-carbon steel conductor casing will then be permanently grouted in place. Following installation of the conductor casing, continuous coring creating an approximately 5.5-inch borehole below the conductor casing will resume through the open conductor casing to approximately 95 ft beneath the tunnel floor.

After rock coring is complete, the borehole will be reamed to a larger diameter for well installation using rotary drilling techniques. Well installation will include either a 4-inch-diameter SCH 80 polyvinyl chloride (PVC) well if no conductor casing is installed, or a 2-inch-diameter SCH 80 PVC well if it is installed through 6-inch-diameter, SCH 40 low-carbon steel conductor casing. The well will be completed with slotted PVC screen. Coarse silica sand filter pack will be placed around the screen interval, and the well will be sealed with a bentonite pellet seal followed by bentonite slurry and cement-bentonite grout. The well will be completed as flush mount due to the limited access area within the tunnel and to avoid potential interference with Facility operations. Figure C-1 shows the general proposed well construction details for RHMW01R without conductor casing. Figure C-2 shows the general proposed well construction details if a conductor casing is required (see Section 3.2 below).

3. Field Project Implementation

3.1 PROJECT PROCEDURES

All drilling, monitoring well installation, and other field activities will be conducted in accordance with the DOH TGM (DOH 2016) and the standard operating procedures (SOPs) from the *Project Procedures Manual, U.S. Navy Environmental Restoration Program, Naval Facilities Engineering Command* [NAVFAC]*, Pacific* (DON 2015) that are presented in Appendix A of the MWIWP (DON 2016).

3.2 DRILLING AND WELL INSTALLATION

Solid basalt bedrock is anticipated to be encountered at shallow depths at the proposed well location for RHMW01R (i.e., directly below surface). Anticipated drilling activities include:

- Rock coring using wet rotary wireline methods
- Wet rotary drilling to increase borehole diameter for well installation

All onsite activities must be coordinated with the Navy contract task order (CTO) contracting officer’s representative (COR) to ensure that all requirements such as obtaining site access, working hours, using/accessing potable water supply sources, and other requirements are understood and followed. Prior to any drilling, a hand auger or other hand tool will be used if there is overburden present at the drilling location to manually hand auger/dig to refusal and evidence of bedrock to ensure the location is cleared of utilities.

The drill rig will be leveled at least twice a day to prevent potential borehole deviation. In addition, the well borings will initially be cored, which will help ensure that the initial borings are straight. After coring, the borehole will be reamed to a larger diameter, during which a pilot bit will be used below the primary bit to ensure that the boring follows and is centered over the core hole. After the well construction is completed, a quantitative true vertical depth analysis using a gyroscopic alignment instrument will be performed so appropriate corrections can be made to wireline-measured depth to water. The gyroscopic alignment will be conducted on all wells within the Red Hill groundwater monitoring program; details regarding the procedures to be followed are presented in the project *Sampling and Analysis Plan* (SAP) (DON 2017b).

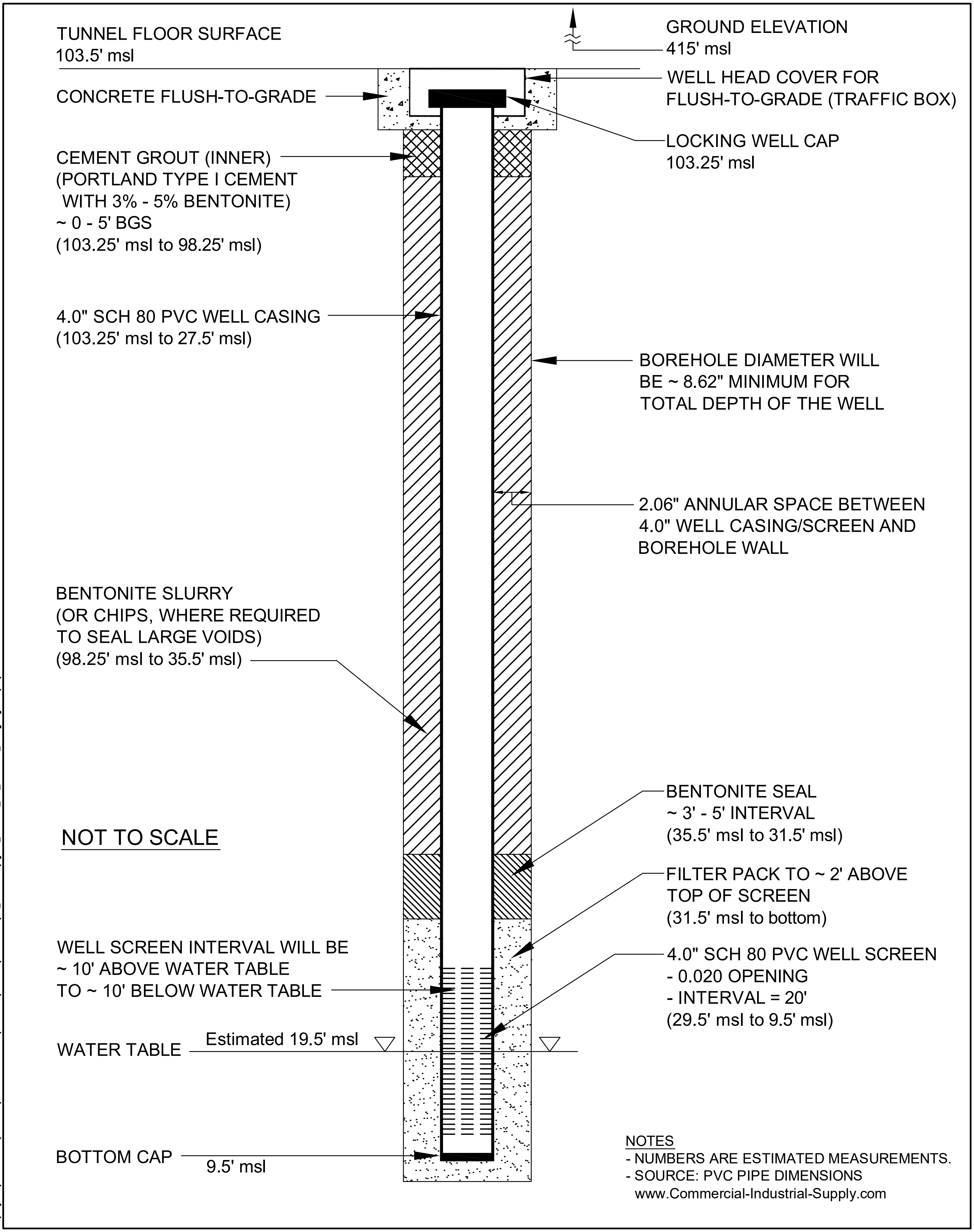

Figure C-1

Cross Section of RHMW01R Single-Level Monitoring Well without Conductor Casing

Monitoring Well Installation Work Plan Addendum 02

Red Hill Bulk Fuel Storage Facility

JBPHH, O'ahu, Hawai'i

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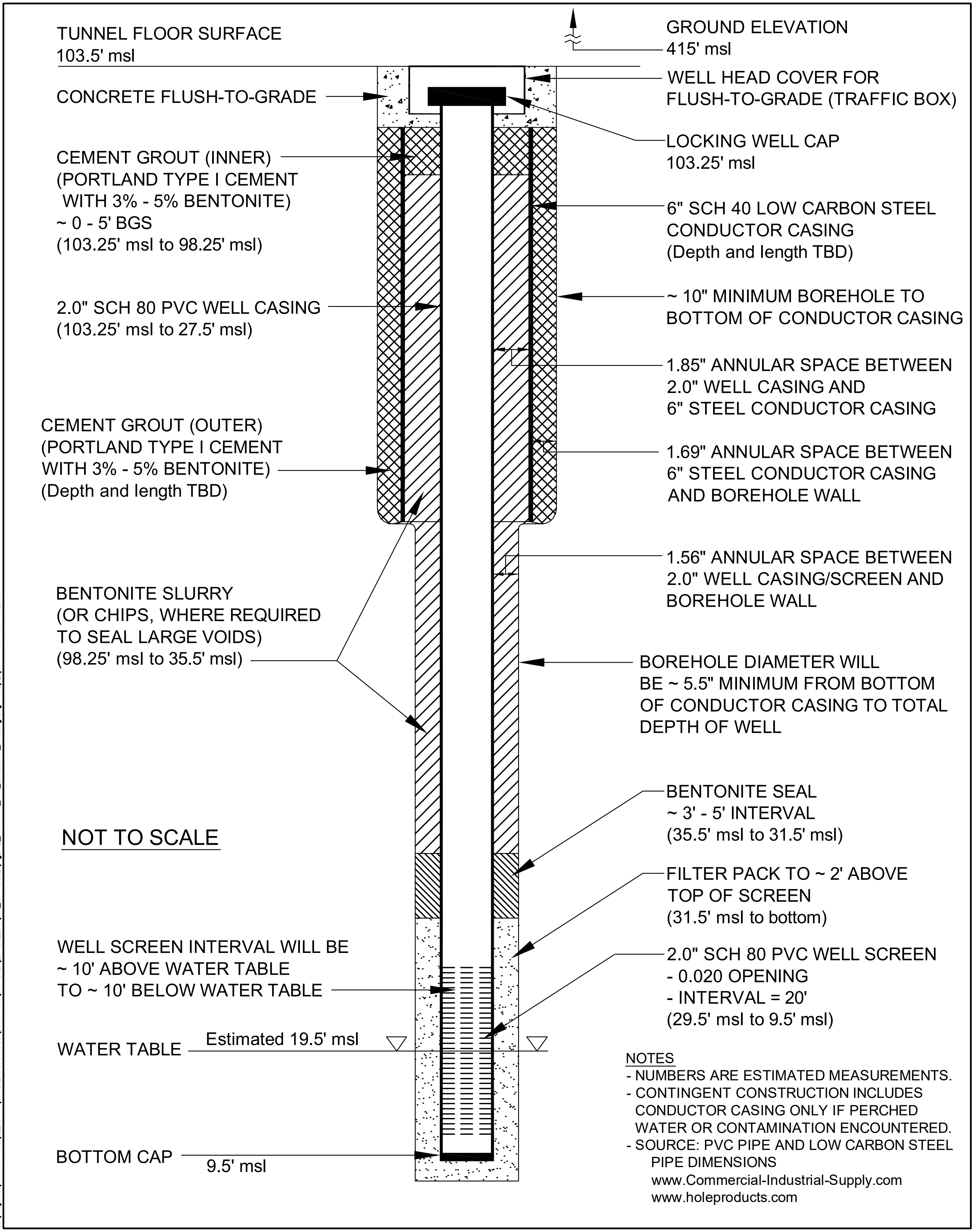

Figure C-2
Cross Section of RHMW01R Single-Level Monitoring Well with Conductor Casing
Monitoring Well Installation Work Plan Addendum 02
Red Hill Bulk Fuel Storage Facility
JBPHH, O'ahu, Hawai'i

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Perched water or evidence of contamination (i.e., visual, olfactory, or elevated photoionization detector [PID] readings) may be encountered in the vadose zone. To facilitate identification of perched groundwater or subsurface contamination, the borehole will be checked for standing water using an interface probe at least four times a day during drilling. Measurements will be made at least at the beginning and end of each shift (i.e., twice before and twice after lunch), but also more frequently based on the presence of features that may suggest perched water (e.g., porous zones [saturated soil cuttings, sand, gravel, or clinker zones] overlying lower-permeability zones [silt, clay, or low-porosity basalt layer]) based on visual observation. A bailer and an oil/water interface probe will also be used to check for the presence of a sheen or NAPL at the same frequency as water level measurements are made. Additionally, the presence of contamination may be indicated by staining on drill cuttings and recovered rock cores and by sustained PID readings above ambient background conditions. This information will be recorded in the project field book.

A sounding tube is not proposed for installation at the replacement well location. The well diameter selected will allow the installation of equipment for well gauging and sampling. However, if conductor casing is required for RHMW01R, then a smaller-diameter well will be installed that may require dedicated sampling equipment be removed to allow for well gauging or other activities. Details regarding the installation of replacement well RHMW01R are presented below in Section 3.2.1.

3.2.1 Drilling and Well Installation Procedures

3.2.1.1 Drilling

Drilling at RHMW01R will be conducted in accordance with Procedure I-C-1, *Monitoring Well Installation and Abandonment* (DON 2015). Drilling will be conducted using an electrically operated drill rig equipped with rock coring and wet rotary drilling capabilities. Solid basalt bedrock is anticipated to be encountered directly below the lower access tunnel floor. Coring will be conducted once competent bedrock is encountered as described above in Section 3.2.2.

Checks for perched water or evidence of contamination will be made as described in the introductory portion of Section 3.2. If perched water or evidence of contamination is observed, then 6-inch-diameter Schedule 40 PVC conductor casing will be installed as described below in Section 3.2.3. If perched water or evidence of contamination is not observed, coring will be conducted until the target depth (approximately 95 ft bgs) is reached. After rock coring is complete, the borehole will be reamed to total depth with a conventional rotary drilling rig to increase the borehole diameter to a minimum of 8 inches (Figure C-1). If a conductor casing is required, it will require a 10-inch-diameter borehole for the length of the conductor (length to be determined), and a 5.5-inch-diameter borehole below the conductor casing (Figure C-2). Clean potable water (and environmentally safe drilling foam, only if pre-approved by the Navy) and bentonite drilling mud will be injected as needed during drilling to mitigate dust, lubricate downhole tools, stabilize the borehole, and remove cuttings from the borehole. Attempts will be made to limit fluids injected during drilling, but the amount of fluid used will be dependent on the porosity of the formation being drilled. Prior to use, potable water for drilling will be sampled and analyzed for COPCs as described in *Addendum 02* Section 3.4. Cuttings removed from the borehole will be collected in 55-gallon drums. Use of wet rotary drilling methods and injection of water during drilling will significantly reduce the generation of dust during drilling.

3.2.1.2 Monitoring Well Installation

After the borehole has been reamed with the wet rotary drilling equipment, the monitoring well will be installed in accordance with Procedures I-C-1, *Monitoring Well Installation and Abandonment* and I-C-2 *Monitoring Well Development* (DON 2015). Groundwater in the basal aquifer is expected to be encountered at approximately 15–20 ft mean sea level (msl). Within the borehole, 4-inch-diameter, Schedule 80 PVC-casing with 30 ft of 0.02-inch slotted screen will be constructed (Figure C-1). However, if a 6-inch-diameter Schedule 40 low-carbon steel conductor casing is required, then a 2-inch-diameter Schedule 80 PVC monitoring well will be installed inside the conductor casing. The well will be screened within the basal aquifer approximately 10 ft above and 10 ft below the groundwater surface. The estimated total depth for RHMW01R is approximately 95 ft below the tunnel floor.

To ensure that the well casing is centered in the borehole, centralizers will be installed at the top and bottom of screened sections and also placed at 20-ft intervals on any PVC well casing. Welded low-carbon steel centralizers at 40-ft intervals will be used on 6-inch-diameter Schedule 40 low-carbon steel conductor casing for the conductor casing if casing is required. The centralizers will be aligned from top to bottom of the casing so that they do not interfere with the insertion and removal of the tremie pipe. All devices and/or welds used to affix centralizers to the casing will not puncture the casing or contaminate the groundwater with which they come in contact. To ensure even distribution of filter pack, bentonite seal, and grout materials around the well within the borehole, the well casing and screen will be suspended with a threaded hoisting plug and not allowed to rest on the bottom of the borehole. If installation of a conductor casing is required, the well will be installed through the length of the conductor casing and within the open borehole below the bottom of the conductor casing (Figure C-2).

Coarse #3 Monterey silica sand will be emplaced via tremie pipe into the borehole annulus to approximately 2 ft above the slotted well screen, followed by a 3- to 5-ft thick bentonite pellet seal, then wet bentonite grout slurry (e.g., Wyo-Ben Enviroplug Grout) to within 5 ft of the tunnel floor. If large voids are encountered, then bentonite chips may be required to seal the voids. The proposed well construction details for RHMW01R are shown on Figure C-1 for the standard 4-inch-diameter well, and on Figure C-2 in the event a conductor casing is required. The bentonite slurry (or chips, where required) will be slowly emplaced via tremie pipe to ensure proper filling of the annulus and to avoid bridging. The slurry will be placed to within approximately 7 ft of the tunnel floor. Dry bentonite chips, where used, will be tremied and hydrated with clean potable water using at least 5 gallons of water per 50-pound bag of chips. The remaining annular space from approximately 7 to 2 ft bgs will be finished by grouting with cement bentonite grout. Well construction diagrams will be provided on the geologic logs.

Because the rock formation is not pressured, blowouts are not anticipated to occur. However, as described above, voids are anticipated to be encountered and need to be taken into consideration during well installation. In the event that voids or blowouts are encountered, bentonite chips will be emplaced down hole to close out or plug the void.

3.2.1.3 MONITORING WELL SURFACE COMPLETION

The monitoring well will be completed in accordance with Procedure I-C-1, *Monitoring Well Installation and Abandonment*. Monitoring well RHMW01R will be completed flush-mount to avoid obstructing any portion of the lower access tunnel. The flush-mount surface completion will consist of a 12-inch-diameter, circular steel skirt or rectangular utility-type box with a gasket to prevent leaks and traffic-rated locking lid over the recessed well. The circular skirt or box would be set in concrete flush with the grade surface of the tunnel to provide strength and a watertight surface seal.

3.2.2 Rock Coring

In bedrock, subsurface material will be continuously sampled using wet rotary wireline coring to record the lithologic characteristics and sample description of the subsurface material during the drilling of the well in accordance with Procedure I-B-1, *Soil Sampling* (DON 2015). Continuous rock cores will be collected as the monitoring well borehole is advanced through the basaltic bedrock. Rock coring will commence when the boring reaches competent bedrock, which is anticipated to occur just beneath the lower-tunnel access concrete floor. All drilling in rock will be accomplished by diamond core drilling methods in general accordance with ASTM D2113 (ASTM 2014).

The drill rig will be equipped with 5-ft-long, 3.78-inch outer diameter (OD) core barrels (yielding a 2.5-inch-diameter rock core [HQ bit size]), and the cores will be recovered with a wireline and quad-latch retrieval system. A 4.83-inch-OD core barrel (yielding a 3.35-inch-diameter rock core [PQ bit size]) may also be used, depending on site conditions. The boring may intersect fault zones where poor rock or difficult drilling conditions may be encountered. All reasonable measures to maximize core recovery will be taken, including timely replacement of worn equipment such as drill bits or core sleeves before wear-induced loss of recovery occurs, and changes in type of drill bit, rate of feed, down-pressure on the drill bit, volume of cooling water, length of coring interval, or type of coring equipment. Grinding of the core after a core barrel has become blocked will not be permitted. A blocked core barrel will be pulled regardless of the interval drilled. Clean water will be brought in from an offsite potable water source for use as circulation fluid during rock coring and drilling. Cores will be collected within an acetate sleeve to facilitate packing and shipping to a laboratory for petrographic analysis. Petrographic analysis is described in *Addendum 02* Section 3.6.

Checks will be made to identify the presence of perched groundwater or contaminated unconsolidated material while drilling as described above in the introductory portion of Section 3.2. If perched groundwater conditions or zones of contamination are identified, then permanent conductor casing will be installed as described below in Section 3.2.3. If additional intervals of unconsolidated material or groundwater contamination are observed after permanent conductor casing has been installed, then the borehole will be abandoned as described in the MWIWP (DON 2016), and a new boring will be advanced with permanent conductor casing set below the depth of the deepest contamination encountered and in a low-permeability zone (e.g., clay, silt, or low-porosity basalt layer) based on visual observation of unconsolidated material samples or rock core.

The cores will be inspected and logged to characterize the lithology and evaluate potential pathways for migration of NAPL and associated constituents. A summary rock core chart will be used in the field to log the information. In general, each log will note rock-quality designation; rock color; texture; strength; degree and orientation of fracturing; shape, size and volume of voids; weathering; and secondary staining or mineralization. Additionally, details of basalt flow and intraflow structures (e.g., a‘ā clinker flow-top breccias [clinker sub-types], accretionary lava clasts, simple vesicular flow tops, vesicular flow lobes, inflated pāhoehoe lobes, spatter deposits, lava tubes, a‘ā columnar dense core interiors, a‘ā clinker flow-bottom breccias, normal flow bottoms, and flow levees) will be included in logging of the core. Fracture types (i.e., the difference between tectonic fractures, primary cooling joints, and drilling-induced fractures) will also be noted. High-resolution photographs will be taken to photodocument the cores, and detailed photo logs will be prepared. The Geological Society of America rock color chart with Munsell color chips will be used for color characterization (Munsell 2009). Lithologic descriptions, photoionization detector screening results, and other observations will be recorded on the geologic logs in conformance with Procedure I-E, *Soil and Rock Classification* (DON 2015). Discrete subsurface unconsolidated material sampling is described in *Addendum 02* Section 3.5. Logging will not be conducted immediately following coring since cores will be collected in acetate sleeves and shipped to a laboratory for petrographic analysis as detailed in *Addendum 02* Section 3.6. Following laboratory petrographic analysis, the core (now cut in half parallel to the long axis of the core) will be returned for field logging.

Cores will be stored in a secure on-island location so that they are available for inspection until the work conducted under AOC Sections 6 and 7 is complete. Storage required beyond the completion of AOC Sections 6 and 7 will be evaluated by the Navy.

3.2.3 Conductor Casing

To minimize the potential for perched water or contaminated media to migrate downward and impact the basal aquifer, which is a drinking water source, 6-inch Schedule 40 low carbon steel conductor casing will be installed if zones of perched water or contamination are identified. The purpose of the conductor casing is to isolate zones of perched water or contaminated media to prevent cross contamination between the perched groundwater/contaminated media and the basal aquifer. The conductor casing will be centered within the borehole using welded low-carbon steel centralizers spaced at approximately 40-ft intervals. The centralizers will be aligned so that they do not interfere with the insertion and removal of the tremie pipe, if necessary. The annular space to be grouted will be a minimum of 1.5 inches beyond the casing. The conductor casing will be pressure-grouted in place as soon as possible after installation using a packer assembly and tremie pipe installed inside of the conductor casing that will allow the grout to be pumped through the packer assembly until it rises to the ground surface around the casing, or with tremie placed in the annular space around the casing. The annulus will be sounded to check for settling of the grout within 24 hours of placement. Following the grouting procedure, the grout will be left undisturbed for a minimum of 24 hours for curing. Drilling activities will then be resumed until the target depth is reached.

If permanent casing is installed and a second layer with evidence of contamination (i.e., visual, olfactory, sustained PID readings above ambient background conditions, or staining on drill cuttings and recovered rock cores) is encountered, the boring will be abandoned by grouting as described in the MWIWP (DON 2016). A new boring will then be advanced so that multiple contaminated zones can be cased off.

4. References

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Appendix D:
Geophysical Survey Tools

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The following geophysical tools will be used in the downhole investigation:

- Three-arm caliper
- Natural gamma
- Resistivity (8-, 16-, 32-, and 64-inch normal) single-point resistance (SPR)
- Electromagnetic (EM) induction
- Optical televiewer
- Acoustic televiewer
- Borehole camera
- Suspension logging

Descriptions of the logging methods are presented below.

Three-Arm Caliper

Within the cased portion of the borehole, this log identifies potential casing wall or casing joint defects. In the open-hole section of the borehole, this log can be used to aid in identifying irregularities in borehole diameter that may be associated with collapsed portions of the borehole, washout zones, fractures, or fracture zones.

The caliper log is run in the upward direction starting at the bottom of the borehole. It can be run in dry, fluid-filled, cased or uncased boreholes. The log can also provide information about the length and diameter of the well casing. The borehole diameter data provides important correlative information for analysis of the other logs.

Natural Gamma

The natural gamma tool provides data about the amount of gamma radiation naturally existing in the formations intersected by a borehole. This type of geophysical logging is extensively used to identify lithologic variations in the subsurface geological units. It is also used to provide information valuable in performing clay content analysis. In addition, the gamma tool can be used when evaluating information about facies changes, geological boundaries analysis, and change in the particle size of the formations crossed. The log may also provide information about the porosity of the formation and potential fractures. Relatively high gamma emissions are usually associated with clay- and shale-bearing rocks.

Normal Resistivity

Normal resistivity logs use two (or more) electrodes lowered into the borehole and measurements are often recorded at various fixed-electrode separations. The most common separations are 8, 16, 32, and 64 inches. These dimensions are roughly equivalent to the zone of investigation into the borehole, thus a greater electrode separation results in a greater zone of investigation into the formation from the borehole.

The normal resistivity log is useful for locating water-bearing zones because porous media with a higher pore water content typically exhibit lower resistivity than less porous, or impermeable, geologic media. Use of this log assumes that there would be discernable contrast between the resistivity of the groundwater contained in fractures compared to the geologic formation. Normal resistivity logs can also be used to identifying potential lithologic interfaces (e.g., formation changes). Normal resistivity logs require a fluid-filled borehole and do not provide reliable information within metal or PVC casing. For this investigation, 8-, 16-, 32-, and 64-inch normal resistivity data will be recorded simultaneously with spontaneous potential (SP), SPR, and gamma data and will be acquired in the down direction.

Single-Point Resistance

The SPR log can differentiate different rock formations due to the wide variety in their electrical properties. The SPR tool measures the resistance between a single downhole electrode and a surface electrode that has been grounded. A constant current is passed between the two electrodes, and the voltage variations are recorded by the tool as it is moved either upward or downward in the borehole. The SPR logs usually respond well to fractures and indicate variations in resistivity of the formations.

Spontaneous Potential

Spontaneous potentials are naturally occurring electrical potentials (voltages) that result from chemical and physical changes at the contacts between different types of subsurface geologic materials. In a borehole, potentials also occur between the drilling fluid and the formation and between the drilling fluid and the filter cake. The potential is measured in millivolts and results from an electro-chemical potential from a contrast between the resistivities of the borehole fluid and the formation pore fluid and an electro-mechanical potential, or streaming potential, from fluid flow directly into or out of the formation. This streaming potential becomes more pronounced when pressures in the borehole greatly exceed pressure in the formation. In boreholes drilled with fresh water mud and formations containing fresh water, permeable water-bearing sand formations will cause a negative deflection of the SP curve. In the typical arrangement, this deflection will be to the left. The SP log is used for geologic correlation and to estimate bed thickness and identify porous and non-porous units.

EM Induction

The EM induction log provides measurement of formation conductivity, which is inversely proportional to resistivity. The induction log provides comparable information to the normal resistivity log but has the advantage of being effective in logging both in dry and fluid-filled sections of the boring and therefore provides applicable information on the stratigraphic conditions with the unsaturated portions of the valley fill strata.

Fluid Temperature and Conductivity

The fluid temperature and fluid conductivity measurements are used to determine anomalies caused by events such as groundwater flow or changes in lithology with different thermal properties. The tool also provides salinity calculations, identification of zones of different water quality, and data for well monitoring and saltwater intrusion studies. The borehole fluid conductivity depends on the mineral content dissolved. In addition, changes in temperature can provide information about the location of fractures or shear zones, if hydrological gradients exist within the rock mass.

Acoustic Televiewer

The acoustic televiewer provides high-resolution acoustic amplitude and travel time data, which can aid in characterizing features, including fractures and solution enlarged joints. In general, open fractures produce lower amplitude responses due to relatively weak reflected signal, whereas more competent rock produces higher amplitude responses due to a relatively stronger reflected signal.

The acoustic televiewer probe consists of a high-frequency piezoelectric ceramic crystal and a rotating mirror. Through specifically designed synchronization, the crystal serves as both transducer and receiver of the acoustic signal. The acoustic signal travels from probe, through the borehole fluid, and to the borehole wall, where some energy is transmitted into the formation, while some is reflected back to the crystal, providing a high-resolution image of the borehole wall. The acoustic elements and impedance are matched to the borehole fluid in order to provide optimum reflected amplitude and high-resolution images. In addition, data are corrected to magnetic north by a series of magnetometers and accelerometers. The tool also simultaneously records azimuth, pitch, and roll data. These measurements provide corrections that aid in the determination of fracture orientation. The acoustic televiewer will be oriented with compass and depth.

The acoustic televiewer log requires a fluid-filled borehole because the fluid transmits the acoustic signal. The log can be run in cased and uncased portions of a borehole. However, data cannot be acquired within metal cased sections of the borehole.

Optical Televiewer

The optical televiewer provides a high-resolution image of the borehole using a digital color camera and light source. Data are oriented to magnetic north by use of an internal magnetometer. Oriented images of the length of the borehole can be presented as an unwrapped core as if viewing the borehole outward from the center. Analysis can be used to determine fracture, joint, and void orientation including depth, dip direction, and angle. Data can be collected in cased and uncased as well as fluid filled or non-fluid filled portions of the borehole. The optical televiewer will be oriented with compass and depth.

Borehole Camera

The borehole camera provides a high-resolution video images of the borehole using a digital color camera and light source. Analysis can be used to complement the televiewer logs regarding the character of fractures, joints, and voids. The video can be collected in cased and uncased as well as in fluid-filled or non-fluid-filled portions of the borehole.

Suspension P-S Velocity Logging

The suspension P-S log provides an effective means of measuring the compressional (P-wave) and shear wave (S-wave) velocity of the strata. The P-S suspension probe contains a powerful hammer source and two receivers, separated by acoustic damping tubes. To acquire data, the probe is lowered to the selected depth and the source is fired at the command of the operator. The firing command initiates a solenoid-operated shuttle aligned across the borehole axis to strike plates on opposite sides of the probe, in turn setting up a pressure doublet in the surrounding fluid. The resultant fluid motion produces a tube wave at the borehole wall with velocity close to the shear velocity of the formation together with a compressional wave. As the waves propagate parallel to the borehole axis, they set up corresponding fluid movements that are detected by two 3D hydrophone receivers. The data are subsequently analyzed to provide the P-wave and S-wave velocities of the subsurface strata. The suspension log can be run in water- or mud-filled sections of the boring. It is effective in open (uncased) or PVC-cased borings. It is generally not effective in steel-cased borings.

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Appendix E:
Petrographic Field SOPs

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Petroleum Services Division
3437 Landco Dr.
Bakersfield, California 93308
Tel: 661-325-5657
Fax: 661-325-5808
www.corelab.com

Recommended Core Handling and Field Preservation Methods for Contaminated Shallow Subsurface Investigations

Introduction

Core size, recovery and preservation are all critical for any successful laboratory analyses of shallow, unconsolidated subsurface core. Actual coring methods are beyond the scope of these recommendations and will be best addressed by the consultant, site conditions and coring company.

It is imperative that the field team understand that the goal of the coring program is to obtain representative, undisturbed cores that will be preserved and sent to the laboratory for analyses. Whenever possible the largest practical diameter core will yield the most representative results. For laboratory programs involving core imaging and advanced analyses a 3" diameter (Shelby tube) core is recommended. Contact your local Core Laboratories Project Manager for core size recommendations. Total core length is driven by the interval of investigation. Individual core length is determined by the sampling equipment, shipping containers and lab capabilities. For practical purposes 2½ - 3' sections will fit in large marine (160qt) coolers that can be shipped by FedEx and handled in the lab.

Basic Procedure

1. Rapidly bring core to the surface, immediately place horizontal and remove from the drill string.
2. Remove core from the sampler.
   a. If the core is in sleeves, cut off any void space or fill tightly with Saran wrap to help minimize core movement during transport. Tape plastic end caps on each end.
   b. If core is not in sleeves, slide core from sampler on to split PVC supports (contact Core Laboratories for details) and wrap with Saran wrap and seal using clear box tape.
3. Label each core section with top and bottom depths to the nearest 0.01ft.
   a. When facing the core, left will be "Top" and right "Bottom". Be consistent for the project.
   b. Label the end caps with "Top" and "Bottom".
   c. If there are multiple sleeves label sequentially using A, B, C … etc starting with A on the top (shallowest) sleeve.
4. Immediately place cores in a cooler containing dry ice and freeze to minimize core pore fluid migration and/or volatization.
   a. Do not place acetate sleeves in direct contact with dry ice. They will fracture over time. Use "bubble wrap", foam packing, newspaper etc for insulation.
5. Fill out COC completely and place in Ziploc bag taped to the inside of the cooler lid.
6. Ship cores at the end of the day by FedEx for next day delivery to Core Laboratories.
   a. For Saturday delivery ship priority overnight and contact Core Laboratories so personnel will be available for receipt. Overtime charges may apply.
   b. If cores are held over the weekend make sure sufficient dry ice is placed in each cooler.
   c. For previously frozen core approximately 20 pounds of dry will be required per day per cooler.

Contact your Core Laboratories Representative with any questions.

Shipper's Declaration not Required.

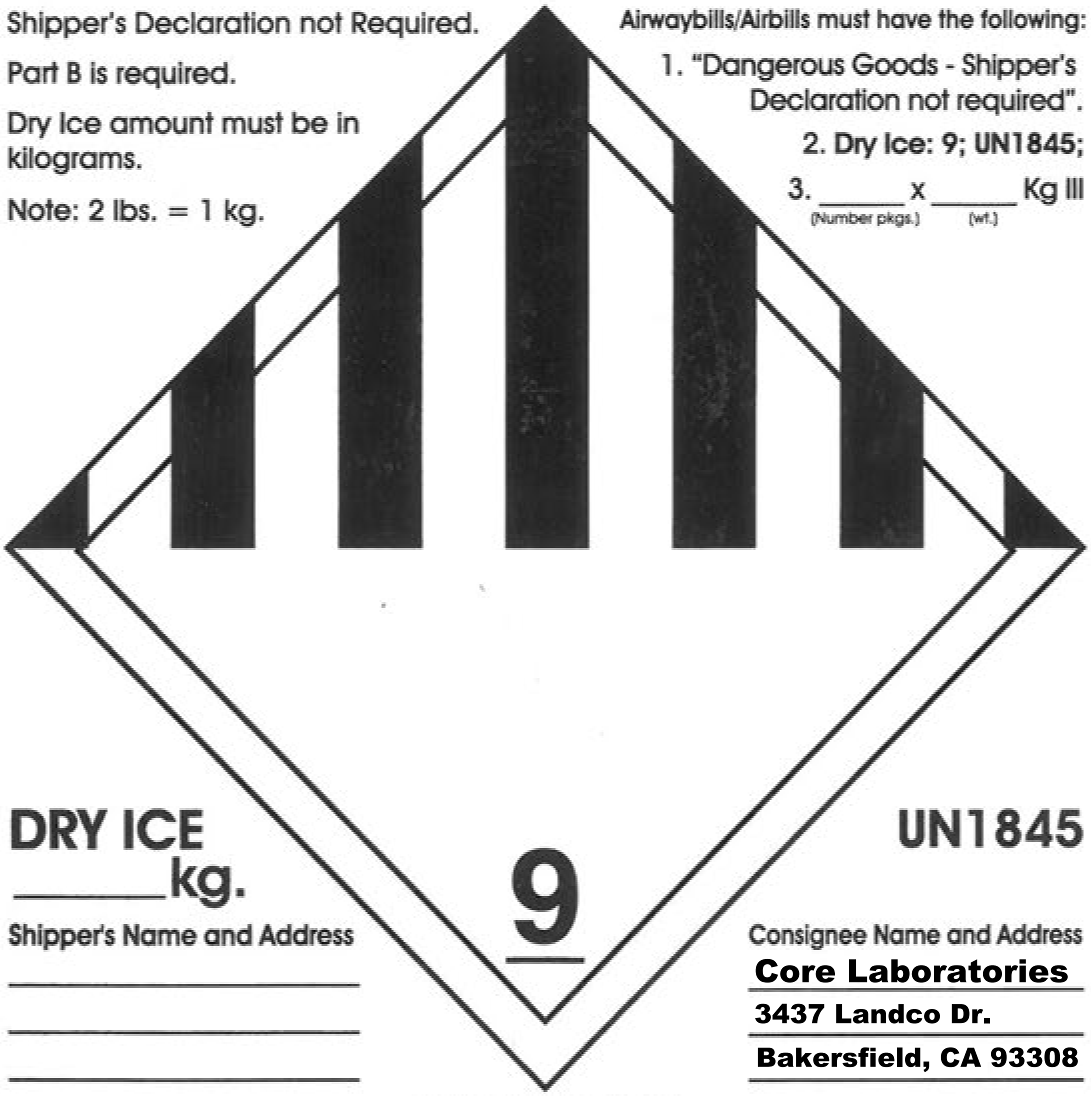
Part B is required.

Dry Ice amount must be in kilograms.

Note: 2 lbs. = 1 kg.

Airwaybills/Airbills must have the following:

1. "Dangerous Goods - Shipper's Declaration not required".
2. Dry Ice: 9; UN1845;
3. ______ x ______ Kg III
   (Number pkgs.) (wt.)



DRY ICE

______ kg.

Shipper's Name and Address

____

____

____

UN1845

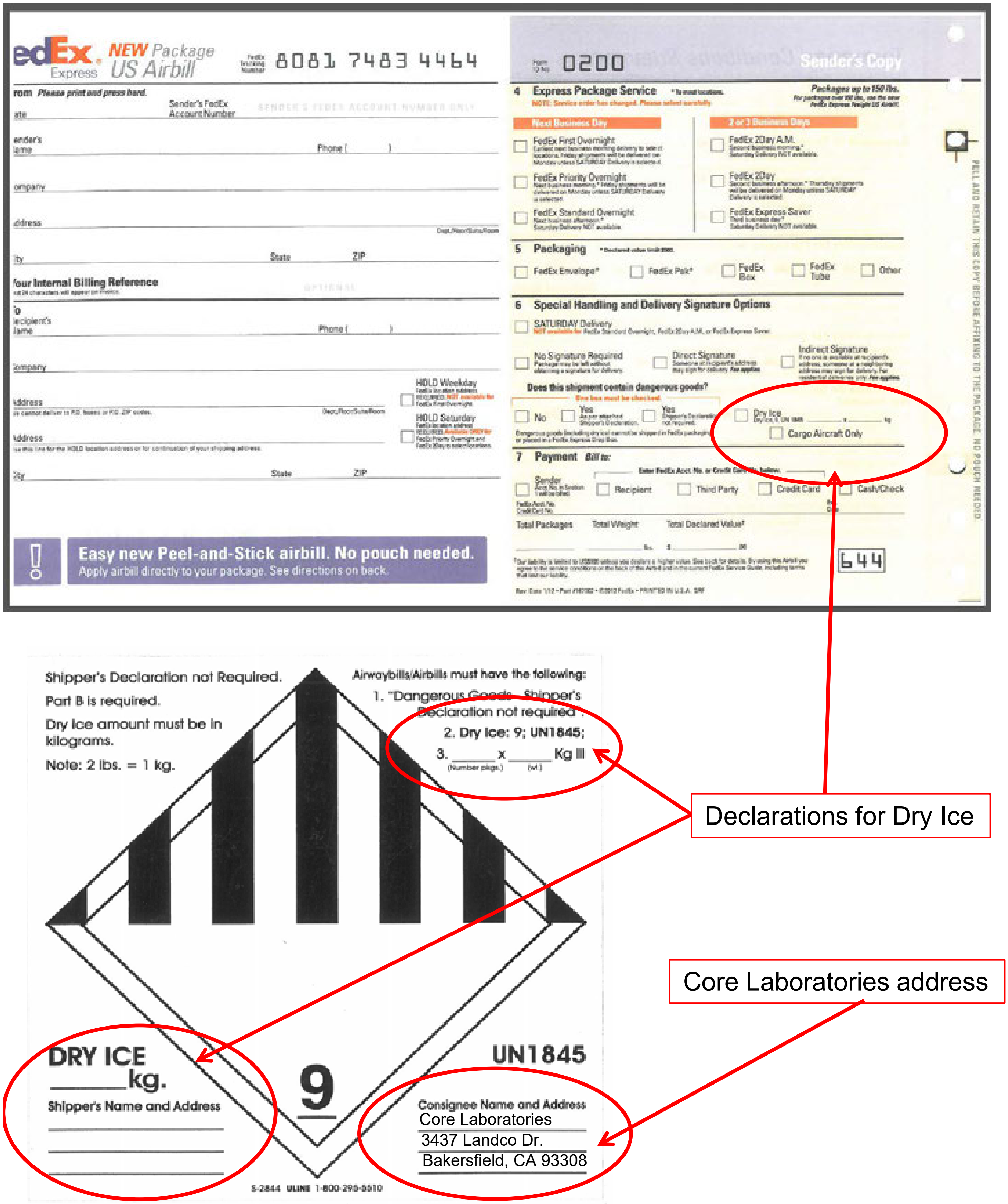
Consignee Name and Address

Core Laboratories

3437 Landco Dr.

Bakersfield, CA 93308

S-2844 ULINE 1-800-295-5510



FedEx Express
NEW Package US Airbill
8081 7483 4464
0200
Sender's Copy
4 Express Package Service
5 Packaging
6 Special Handling and Delivery Signature Options
Does this shipment contain dangerous goods?
Dry Ice
Cargo Aircraft Only
7 Payment Bill to:
Easy new Peel-and-Stick airbill. No pouch needed.
Apply airbill directly to your package. See directions on back.
Shipper's Declaration not Required.
Part B is required.
Dry Ice amount must be in kilograms.
Note: 2 lbs. = 1 kg.
Airwaybills/Airbills must have the following:
1. "Dangerous Goods - Shipper's Declaration not required".
2. Dry Ice: 9; UN1845;
3. ____ x ____ Kg III
(Number pkgs.) (wt.)
DRY ICE
____ kg.
Shipper's Name and Address
9
UN1845
Consignee Name and Address
Core Laboratories
3437 Landco Dr.
Bakersfield, CA 93308
S-2844 ULINE 1-800-295-5510
Declarations for Dry Ice
Core Laboratories address

SOIL IMPORT PROCEDURES

Soil samples that are to be analyzed for basic or advanced physical properties should not be treated by heat. Soil may be authorized for movement, without treatment, to a facility approved in advance and permitted by the Plant Protection and Quarantine (PPQ) Division of the US Department of Agriculture (USDA). Core Laboratories in Bakersfield, California is a permitted facility authorized to directly receive untreated soil.

- Soil shipments may be imported to the US by freight, mail, or hand carried as personal baggage.
- All freight and mail shipments with "Soil Samples Restricted Entry" PPQ Form 550 labels identify the shipment as regulated material moving under permit to a permitted facility.
- It is important that complete information identifying the approved facility is attached to the shipping package. Approved Core Laboratories facility information:

  Permit Number: P330-16-00187
  Core Laboratories
  3437 Landco Drive
  Bakersfield, CA 93308
  Phone +1 661 325 5657
  Attn: Chris LaLonde (christopher.lalonde@corelab.com) or Larry Kunkel (larry.kunkel@corelab.com)

- Each shipment is inspected to verify that the packaging is leak proof, secure, and adequately labeled.
- PPQ officials will also check the destination against the current list of approved facilities. Shipments that are adequately packaged and consigned to approved facilities will be released by PPQ to move to the destination.
- Soil shipments are only authorized to move from port of entry to the destination in the care of a bonded carrier or by mail.

Copies of Core Laboratories Soil Permit P330-16-00187 that authorizes shipments from all foreign sources and PPQ Form 550 "Soil Samples Restricted Entry" labels are enclosed for attachment with your soil or core shipment.

SHIPPING PROCEDURE

1. Prepare core or soil samples for shipping (refer to Core Laboratories *Recommended Core Handling and Preservation Field Methods for Contaminated Shallow Subsurface Investigations*)**.** Seal core tubes with Teflon™ film or suitable material, attach plastic end caps and seal with tape.
2. Attach PPQ Form 550 label to every core sample or bag.
3. Place the cores or soil samples in a sturdy, leak proof container for shipping. Containers most suitable for shipping soil samples are insulated plastic ice chests with attached lids.
4. Include a copy of Core Laboratories Soil Permit P330-16-00187 inside with soil samples.
5. Attach PPQ Form 550 label and Core Laboratories Soil Permit to the outside of the shipping container.
6. Ship by overnight courier such as DHL or FedEx, international freight company or mail.
7. Notify Core Laboratories Representative by email with tracking number of shipment.

Animal and Plant Health Inspection Service

Plant Protection & Quarantine

United States Department of Agriculture
Animal and Plant Health Inspection Service
4700 River Road
Riverdale, MD 20737

Permit to Receive Soil

Regulated by 7 CFR 330

This permit was generated electronically via the ePermits system.

PERMITTEE NAME:	Mr. Christopher Lalonde	**PERMIT NUMBER:**	P330-16-00187
COMPANY:	Core Laboratories	**APPLICATION NUMBER:**	P525-160401-001
RECEIVING ADDRESS:	3437 Landco Drive Bakersfield, CA 93308	**DATE ISSUED:**	06/02/2016
MAILING ADDRESS:	3437 Landco Drive Bakersfield, CA 93308		
PHONE:	(661) 325-5657		
FAX:	(661) 325-5808	**EXPIRES:**	**06/02/2019**

PORTS OF ARRIVAL/PLANT INSPECTION STATIONS: AK, Anchorage; AL, Huntsville; AL, Mobile; AZ, Douglas; AZ, Lukeville; AZ, Naco; AZ, Nogales; AZ, Phoenix; AZ, San Luis; AZ, Tucson; CA, Calexico; CA, El Segundo; CA, Fresno; CA, Long Beach; CA, Oakland; CA, Ontario; CA, Otay Mesa; CA, Port Hueneme; CA, Sacramento; CA, San Diego; CA, San Francisco; CA, San Jose; CA, San Ysidro; CA, Tecate; CO, Denver; CT, Hartford; CT, New Haven; DE, Dover; DE, Wilmington; FL, Ft. Lauderdale; FL, Ft. Myers; FL, Ft. Pierce; FL, Jacksonville; FL, Key West; FL, Miami; FL, Miami (For Cargo and Courier Packages Only); FL, Orlando; FL, Pensacola; FL, Port Canaveral; FL, Port Everglades; FL, Sanford; FL, Tampa; FL, West Palm Beach; GA, Atlanta; GA, Savannah; GU, Agana; HI, Hilo; HI, Honolulu; HI, Kahului; HI, Kailua-Kona; HI, Lihue; ID, Eastport; IL, Chicago; IN, Indianapolis; KY, Louisville; MA, South Boston; MD, Baltimore; MD, Beltsville; ME, Bangor; ME, Calais; ME, Houlton; ME, Portland; MI, Detroit; MI, Port Huron; MI, Romulus; MI, Sault Saint Marie; MN, Duluth; MN, Grand Portage; MN, International Falls; MN, Minneapolis; MO, Kansas City; MO, St. Louis; MP, Commonwealth of the Northern Mariana Islands; MS, Gulfport; MS, Port Bienville; MT, Raymond; MT, Roosville; MT, Sweetgrass; NC, Raleigh; NC, Wilmington; ND, Dunseith; ND, Pembina; ND, Portal; NJ, Linden; NJ, Newark; NM, Albuquerque; NM, Columbus; NM, SantaTeresa; NV, Las Vegas; NY, Albany; NY, Alexandria Bay; NY, Brooklyn; NY, Buffalo; NY, Champlain, Rouses Point; NY, Jamaica; NY, Jamaica; NY, Newburgh; OH, Ashtabula; OH, Cincinnati; OH, Cleveland; OH, Columbus; OH, Toledo; OH, Wilmington; OK, Oklahoma City; OR, Portland; PA, Allentown; PA, Harrisburg; PA, Philadelphia; PA, Pittsburgh; PA, Scranton; PR, Aguadilla; PR, Carolina; PR, Fajardo; PR, Mayaguez; PR, Ponce; RI, Warwick/Providence; SC, Charleston; TN, Memphis; TN, Nashville; TX, Austin; TX, Brownsville; TX, Corpus Christi; TX, Dallas; TX, Del Rio; TX, Eagle Pass; TX, El Paso; TX, Fabens; TX, Falcon; TX, Fort Hancock; TX, Galveston; TX, Hidalgo; TX, Humble; TX, Laredo; TX, Los Indios; TX, Pharr; TX, Port Arthur; TX, Presidio; TX, Progresso; TX, Rio Grande City; TX, Roma; TX, San Antonio; TX, Victoria; UT, Salt Lake City; VA, Dulles; VA, Norfolk; VI, St. Croix; VI, St. Thomas; VT, Berlin; WA, Blaine; WA, Oroville; WA, Port Angeles; WA, SeaTac; WA, Sumas; WI, Green Bay; WI, Milwaukee

HAND CARRY: No

Under the conditions specified, this permit authorizes the following:

Quantity of Soil per Shipment and Treatment

Over 3 lbs - Your facility MUST be inspected and approved to receive this soil

SPECIAL INSTRUCTIONS TO INSPECTORS

See permit conditions below

Permit Number P330-16-00187

THIS PERMIT HAS BEEN APPROVED ELECTRONICALLY BY THE FOLLOWING PPQ HEADQUARTER OFFICIAL VIA EPERMITS.	DATE
Mark A. Stull	06/02/2016

WARNING Any alteration, forgery or unauthorized use of this Federal Form is subject to civil penalties of up to $250,000 (7 U.S.C s 7734(b)) or punishable by a fine of not more than $10,000, or imprisonment of not more than 5 years, or both (18 U.S.C s 1001)

U.S. DEPARTMENT OF AGRICULTURE
ANIMAL AND PLANT HEALTH INSPECTION SERVICE
PLANT PROTECTION AND QUARANTINE
4700 RIVER RD., UNIT 136
RIVERDALE, MD 20737-1236

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
(MAR 95)

☆U.S.GPO: 1995–621-030

U.S. DEPARTMENT OF AGRICULTURE
ANIMAL AND PLANT HEALTH INSPECTION SERVICE
PLANT PROTECTION AND QUARANTINE
4700 RIVER RD., UNIT 136
RIVERDALE, MD 20737-1236

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For release without treatment if addressee is currently listed as approved by Plant Protection and Quarantine.

PPQ FORM 550
(MAR 95)

☆U.S.GPO: 1995–621-030

Appendix F:
JBPHH Green Waste Disposal Direction
(August 18, 2016)

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JBPHH Green Waste Disposal Direction

Intent: The intent of this document is to provide direction to all tenants, contractors and all others working on JBPHH for the proper disposal of green waste to prevent the spread of the Coconut Rhinoceros Beetle (CRB).

Scope: All green waste generated on JBPHH or Navy owned property on Oahu.

Definitions:

- Green waste as used in this document
  - Includes: all tree, bush, hedge, flower trimmings in part or whole, grass, mulch, compost heaps, fruit and vegetable scraps, decaying stumps and other plant matter.
  - Excludes: fresh grass clippings removed from JBPHH within 12 hrs, soil

Direction: All green waste will be brought to a designated green waste collection point throughout JBPHH (see below) between the hours of 0700-1800 on M-F except federal holidays. At least 1 hour advanced notification to the NAVFAC Green Waste Disposal Coordinator is required for all disposals (contact info below). If any stage of CRB is suspected in your green waste, do not disturb or transfer material and call the Pest Hotline immediately at 679-5244. All material disposed of must be free of garbage or any other non-green waste.

Leave whole vs. chipping:

- Deciduous and evergreen material- If 2” (inch) diameter or greater, cut in 5 to 6 foot lengths. If less than 2” diameter, chip.

- Palmaceous material - If 2” (inch) diameter or greater, cut in 3 foot lengths. If less than 2” diameter, leave whole. Do not chip any palm material. Palm fronds should be delivered whole. Palms must be inspected by HDOA prior to removal. Call PestHotline to coordinate at 679-5244.

How to transport green waste: All green waste will be completely enclosed or covered with tarp to prevent spread of CRB during transport.


Stock piling: Stockpiling green waste for more than 24 hrs is not permitted on JBPHH.

Green waste collection points:

- Main base
    - Fire Training Area (FTA) - see map below.
      Alternate location: Barber's Point at Biosolid Treatment Facility

Points of Contacts:

- NAVFAC Green Waste Disposal Coordinator – Lonnie Felise , 347-2645
- Pest Hotline/HDOA – 679-5244

Appendix G:
Analytical Documentation

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Appendix G.1:
Analytical Data Package Requirements for Chemical Analyses

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GC-FID Stage 4 Deliverables

Item No.	Deliverable
1	Chain of Custody
2	Sample results with analysis and extraction/preparation dates
3	Summary of MS/MSD/Duplicate recoveries and control limits (listing or link with associated samples)
4	Summary of LCS/LCSD recoveries and control limits (listing or link with associated samples)
5	Method blanks (listing or link with associated samples)
6	Summary of surrogate recoveries
7	Summary of initial calibration data (RF and %RSD, or r if applicable)
8	Summary of continuing calibration (%D)
9	Injection logs
10	Extraction/preparation logs
11	Case narrative to discuss anomalies
12	Raw data associated with the summary forms listed above
13	Raw data for item #2 which includes chromatograms, log books, quantitation reports, and spectra

Note: The data deliverable package must have a table of contents and be paginated.
%D percent difference
%RSD percent relative standard deviation
GC-FID gas chromatography-flame ionization detector
MS matrix spike
MSD matrix spike duplicate
LCS laboratory control sample
LCSD laboratory control sample duplicate
RF response factor

GC-MS Stage 4 Deliverables

Item No.	Deliverable
1	Chain of Custody
2	Sample results with analysis and extraction/preparation dates
3	Summary of MS/MSD/Duplicate recoveries and control limits (listing or link with associated samples)
4	Summary of LCS/LCSD recoveries and control limits (listing or link with associated samples)
5	Method blanks (listing or link with associated samples)
6	Summary of instrument blanks - metals only (listing or link with associated samples)
7	Summary of surrogate recoveries
8	Summary of initial calibration data (RRF and %RSD, or r if applicable)
9	Summary of continuing calibration (%D and RRF)
10	Summary of internal standards (area response and retention time)
11	Summary of instrument tuning (listing or link with associated samples, must show 12-hour clock)
12	Injection logs
13	Extraction/preparation logs
14	Case narrative to discuss anomalies
15	Raw data associated with the summary forms listed above
16	Raw data for item #2 which includes chromatograms, log books, quantitation reports, and spectra

Note: The data deliverable package must have a table of contents and be paginated.
GC-MS gas chromatography-mass spectrometry
RRF relative response factor

General Chemistry Stage 4 Deliverables

Item No.	Deliverable
1	Chain of custody
2	Sample results with analysis and extraction/preparation dates
3	Summary of MS/MSD/Duplicate recoveries and control limits (listing or link with associated samples)
4	Summary of LCS/LCSD recoveries and control limits (listing or link with associated samples)
5	Method blanks (listing or link with associated samples)
6	Summary of initial calibration data (correlation coefficient, r)
7	Summary of continuing calibration (%D or % recovery), if applicable
8	Injection logs
9	Extraction/preparation logs, if applicable
10	Case narrative to discuss anomalies
11	Raw data associated with the summary forms listed above
12	Raw data for item #2, which includes log books, quantitation reports, and spectra

Note: The data deliverable package must contain a table of contents and be paginated.

HARD COPY DATA DELIVERABLES COMPACT DISK REQUIREMENTS

The compact disk (CD) shall contain exactly the same information as the hard copy data deliverables (HDD) including amended and additional pages requested during data review and validation. Upon completion of data review and validation by AECOM Technical Services, Inc. or third-party, the laboratory shall be required to provide the CD with the following:

- The images shall be clear and legible.
- The images shall be right side up.
- The images shall be straight.
- The images shall be in the same order as the HDD.
- Images may be submitted in PDF, TIFF, or other equivalent imaging format. Files shall be burned for each page and each CD shall be indexed. The laboratory shall log in samples based on project number, project name and sample delivery group (also known as batch or work order).
- If the images are not clear, legible, right side up, straight or in order, then the laboratory shall resubmit the CD.
- The CD label shall contain the following information:
  - Navy contract number
  - Contract task order name and number
  - Sample delivery group number
  - Matrices and methods
  - Date of submittal

Appendix G.2:
Field Sampling, Analytical, and Quality Management Reference Tables

- Table G-1: Location-Specific Sampling Methods/SOP Requirements
- Table G-2: Analyte List and Reference Limits
- Table G-3: Preparation and Analytical Requirements for Field and QC Samples
- Table G-4: Analytical Services
- Table G-5: Analytical SOP References
- Table G-6: Laboratory QC Samples
- Table G-7: Analytical Instrument and Equipment Maintenance, Testing, and Inspection
- Table G-8: Analytical Instrument Calibration
- Table G-9: Data Verification and Validation (Steps I and IIa/IIb) Process

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APPENDIX G.2 – ACRONYMS AND ABBREVIATIONS

%D	percent difference
APPL	Agriculture & Priority Pollutants Laboratories, Inc.
BFB	4-bromofluorobenzene
CA	corrective action
CAS	Chemical Abstracts Service
CCB	continuing calibration blank
CCV	continued calibration verification
D	difference
DFTPP	decafluorotriphenylphosphine
DoD	Department of Defense
DQI	data quality indicator
DQO	data quality objective
EICP	extracted ion current profile
EPA	Environmental Protection Agency, United States
g	gram
GC	gas chromatography
GC-FID	gas chromatography-flame ionization detector
GC-MS	gas chromatography-mass spectrometry
H_2SO_4	sulfuric acid
HCl	hydrogen chloride
HNO_3	nitric acid
ICAL	initial calibration
ICP-AES	inductively coupled plasma-atomic emission spectroscopy
ICV	initial calibration verification
IS	internal standard
L	liter
LCS	laboratory control sample
LDC	Laboratory Data Consultants
LOD	limit of detection
LOQ	limit of quantitation
MB	method blank
mg/kg	milligram per kilogram
mL	milliliter
MPC	measurement performance criteria
MS	matrix spike
MSD	matrix spike duplicate
N/A	not applicable
$NaHSO_4$	sodium bisulfate
NIST	National Institute of Standards and Technology
oz	ounce
PFTBA	perfluorotributylamine
QA	quality assurance
QC	quality control
QSM	Quality Systems Manual
RPD	relative percent difference
RRT	relative retention time
RSD	relative standard deviation

RT	retention time
SOP	standard operating procedure
TBD	to be determined

Table G-1: Location-Specific Sampling Methods/SOP Requirements

Sampling Location/ID Number	Matrix	Depth (ft bgs)	Analytical Group	Number of Samples	Sampling SOP Reference
RHMW01R, RHMW07D, RHMW11, RHMW12, RHMW13, RHMW14, RHMW15, RHMW16, RHMW17, RHMW18, RHMW19, RHMW20	Unconsolidated Material	approx. 100–900	Chemical Analyses: VOCs, PAHs, TPH	1 primary per location [a, b] 1 duplicate per location [b] 1 MS/MSD pair per event [b] 1 trip blank per event [c]	Procedure I-B-1 *Soil Sampling*
RHMW01R, RHMW07D, RHMW11, RHMW12, RHMW13, RHMW14, RHMW15, RHMW16, RHMW17, RHMW18, RHMW19, RHMW20	Unconsolidated Material, Potable Water	approx. 100–900	Chemical Analyses: TPH with Silica Gel Cleanup	Contingent on non-Silica Gel Cleaned TPH-d and TPH-o detections [d]	Procedure I-B-1 *Soil Sampling* Procedure I-B-5 *Surface Water Sampling*
RHMW07D, RHMW11, RHMW12, RHMW13, RHMW14, RHMW15, RHMW16, RHMW17, RHMW18, RHMW19, RHMW20	Unconsolidated Material	approx. 100–900	Geotechnical Analyses: Atterberg Limits, Effective Porosity, Permeability, Moisture Content and Density, Grain Size Distribution, Cation Exchange Capacity, pH, Total Organic Carbon	1 primary per location [a, b]	Procedure I-B-1 *Soil Sampling*
RHMW01R, RHMW07D, RHMW11, RHMW12, RHMW13, RHMW14, RHMW15, RHMW16, RHMW17, RHMW18, RHMW19, RHMW20	Potable Water	not applicable	Chemical Analyses: VOCs, PAHs, TPH	1 primary per event [e] 1 ambient blank per event [f]	Procedure I-B-5 *Surface Water Sampling*
RHMW01R	Core	approx.100	Petrographic Analysis: Digital Fluorescence Imaging	1 primary [g]	Procedure I-B-1 *Soil Sampling*
RHMW01R	Core	approx.100	Petrographic Analyses: Pore Fluid Saturations, Effective Porosity, Initial Saturation, Residual Saturation, Total Porosity, Grain Density, Dry Bulk Density	1 primary [g, h]	Procedure I-B-1 *Soil Sampling*
JP-8 or similar kerosene-based jet fuel	Product	not applicable	Dynamic viscosity, density, interfacial tension	1 primary [i]	Procedure I-B-1 *Soil Sampling*

Notes: Procedures are from the *Project Procedures Manual* (DON 2015).

[a] Actual number of unconsolidated material samples will be dependent on field observations during coring. Unconsolidated material samples will only be collected if present at depths below 100 ft below ground surface or if contamination in the vadose zone is observed.

[b] Volumes for geotechnical, field duplicate, and MS/MSD samples will only be collected if sufficient unconsolidated material is present at each sampling interval. If limited volume is present, collecting volume for VOCs, PAHs, and TPH will take priority.

[c] One trip blank will be collected during each unconsolidated material sampling event.

[d] TPH with silica gel cleanup will only be analyzed for sample with detections of TPH-d and TPH-o from the non-silica gel cleaned extract.

[e] At minimum one primary potable water sample will be collected from each water pump outflow during drilling activities at each monitoring well location.

[f] At minimum one ambient blank will collected during each potable water sampling event to demonstrate field conditions.

[g] The entire length of core from RHMW01R will be submitted to the petrographic laboratory for analysis.

[h] At least one section of the core will be used for the analyses based on lab observations of the unconsolidated and consolidated intervals along the core length.

[i] JP-8 or similar fuel will be submitted to the laboratory either from volume collected from NAVSUP FLC supplies or a third-party vendor and shipped directly to the petrographic laboratory.

Table G-2: Analyte List and Reference Limits

Matrix **Potable Water**

Analyte	CAS Number	Screening Criterion [a] (µg/L)	Project LOQ Goal (µg/L)	Project LOD Goal (µg/L)	Laboratory-Specific Limits (µg/L)		
					LOQ	LOD	DL
TPH							
TPH-g (C5–C11)	-3547	100	33	10	20	18	8.6
TPH-d (C10–C24)	-3527	100	33	10	40	25	13.07
TPH-o (C24–C40)	-35	100	33	10	40	40	5.54
VOCs							
Benzene	71-43-2	5	1.3	0.5	1.0	0.30	0.16
Ethylbenzene	100-41-4	30	10	3.0	1.0	0.50	0.23
Toluene	108-88-3	40	13	4.0	1.0	0.30	0.17
Total Xylenes	1330-20-7	20	6.7	2.0	2.0	0.30	0.19
PAHs							
1-Methylnaphthalene	90-12-0	6	3	0.6	0.20	0.10	0.060
2-Methylnaphthalene	91-57-6	10	3.3	1.0	0.20	0.10	0.060
Naphthalene	91-20-3	17	5.7	1.7	0.20	0.10	0.050

CAS Chemical Abstracts Service
[a] DOH Tier 1 EALs (Summer 2016, updated January 2017), Table D1-b Groundwater Action Levels, for groundwater is a current or potential drinking water resource and surface water body is not located within 150 meters of release site.

Matrix **Unconsolidated Material**

Analyte	CAS Number	Screening Criterion [a] (mg/kg)	Project LOQ Goal (mg/kg)	Project LOD Goal (mg/kg)	Laboratory-Specific Limits (mg/kg)		
					LOQ	LOD	DL
TPH							
TPH-g (C5–C11)	-3547	100	33	10	1	0.75	0.305
TPH-d (C10–C24)	-3527	100	33	10	5	1	0.65
TPH-o (C24–C40)	-35	500	167	50	50	10	3.5
VOCs							
Benzene	71-43-2	0.3	0.1	0.03	0.005	0.002	0.0006
Ethylbenzene	100-41-4	3.7	1.2	0.37	0.005	0.002	0.001
Toluene	108-88-3	3.2	1.1	0.32	0.005	0.002	0.0013
Total Xylenes	1330-20-7	2.1	0.7	0.21	0.01	0.005	0.003
PAHs							
1-Methylnaphthalene	90-12-0	2.5	0.83	0.25	0.005	0.0017	0.001
2-Methylnaphthalene	91-57-6	4.1	1.4	0.41	0.005	0.0017	0.0009
Naphthalene	91-20-3	4.4	1.5	0.44	0.005	0.0017	0.0009

mg/kg milligrams per kilogram
[a] DOH Tier 1 EALs (Summer 2016, updated January 2017), Table A-1 Groundwater Action Levels, for groundwater is a current or potential drinking water resource and surface water body is not located within 150 meters of release site.

Table G-3: Preparation and Analytical Requirements for Field and QC Samples

Matrix	Analytical Group	Preparation Reference/Method SOP Analytical Reference/Method SOP	Containers	Sample Volume	Preservation Requirement	Maximum Holding Time (preparation/analysis)
Unconsolidated Material	TPH-g, VOCs	Preparation Method: EPA 5035C Preparation SOP: ANA8260 Analysis Method: EPA 8260C Analysis SOP: ANA8260	2 × 10mL water-preserved; 1 × 5mL methanol-preserved; Teflon-lined septum caps	40 mL	Cool to ≤6°C	7 days (water-preserved); 14 days (methanol-preserved)
	TPH-d, TPH-o	Preparation Method: EPA 3550C Preparation SOP: SON004 Analysis Method: EPA 8015C Analysis SOP: ANA8015	1 × 8 oz glass jar, Teflon-lined lid	30 g	Cool to ≤6°C	Samples extracted within 14 days and analyzed within 40 days following extraction.
	TPH-d, TPH-o with Silica Gel Cleanup	Preparation Method: EPA 3550C/EPA 3630 Preparation SOP: SON004/CLN004 Analysis Method: EPA 8015C Analysis SOP: ANA8015		30 g	Cool to ≤6°C	Samples extracted within 14 days and analyzed within 40 days following extraction.
	PAHs	Preparation Method: EPA 3550C Preparation SOP: SON009 Analysis Method: EPA 8270D SIM Analysis SOP: ANA8270SIM		30 g	Cool to ≤6°C	Samples extracted within 14 days and analyzed within 40 days following extraction.
	Atterberg Limits	Preparation/Analysis Method: ASTM D4318 Preparation/Analysis SOP: ASTM D4318	1 × core section, or 4 × 8 oz glass jar, Teflon-lined lid	core	None	None
	Effective Porosity	Preparation/Analysis Method: ASTM D6836M Preparation/Analysis SOP: ASTM D6836M				
	Permeability	Preparation/Analysis Method: ASTM D5084 Preparation/Analysis SOP: ASTM D5084				
	Moisture Content and Density	Preparation/Analysis Method: ASTM D2937 Preparation/Analysis SOP: ASTM D2937				
	Grain Size Distribution	Preparation/Analysis Method: ASTM D422 Preparation/Analysis SOP: ASTM D422				
	Cation Exchange Capacity	Preparation/Analysis Method: EPA 9081 Preparation/Analysis SOP: ANA9081				
	pH	Preparation/Analysis Method: EPA 9045 Preparation/Analysis SOP: ANA9045				
	Total Organic Carbon	Preparation/Analysis Method: Walkley Black Preparation/Analysis SOP: ANAWALKLEY				

Matrix	Analytical Group	Preparation Reference/Method SOP Analytical Reference/Method SOP	Containers	Sample Volume	Preservation Requirement	Maximum Holding Time (preparation/analysis)
Potable Water	TPH-g, VOCs	Preparation Method: EPA 5030B Preparation SOP: ANA8260 Analysis Method: EPA 8260C Analysis SOP: ANA8260	5 × 40-mL vials, Teflon-lined septum caps	40 mL	No headspace, cool to ≤6°C and adjust to pH <2 with H_2SO_4, HCl, or solid $NaHSO_4$	Maximum holding time is 7 days if pH >2 or 14 days if pH <2.
	TPH-d, TPH-o	Preparation Method: EPA 3510C Preparation SOP: SEP11 Analysis Method: EPA 8015C Analysis SOP: ANA8015	2 × 1-L amber glass, Teflon-lined lid	1 L	Cool to ≤6°C	Samples extracted within 7 days and analyzed within 40 days following extraction.
	TPH-d, TPH-o with Silica Gel Cleanup	Preparation Method: EPA 3510C/EPA 3630 Preparation SOP: SEP11/CLN004 Analysis Method: EPA 8015C Analysis SOP: ANA8015				
	PAHs	Preparation Method: EPA 3510C Preparation SOP: SEP004 Analysis Method: EPA 8270D SIM Analysis SOP: ANA8270SIM	2 × 1-L amber glass, Teflon-lined lid	1 L	Cool to ≤6°C	Samples extracted within 7 days and analyzed within 40 days following extraction.
Core	Digital Fluorescence Imaging	Preparation/Analysis Method: ASTM D5079 Preparation/Analysis SOP: Core Photography	acetate core sleeves	entire core length	Freeze to <4°C	None
	Pore Fluid Saturation	Preparation/Analysis Method: Dean Stark, API RP40 Preparation/Analysis SOP: Pore Fluid Saturations – Distillation Extraction Method	1 × acetate core sleeve	core section	Freeze to <4°C	None
	Effective Porosity, Total Porosity, Grain Density, Dry Bulk Density	Preparation/Analysis Method: ASTM D425M-88 Preparation/Analysis SOP: Effective Porosity – Centrifugal Drainage Method				
	Total Porosity, Bulk Density, Grain Density	Preparation/Analysis Method: ASTM D425M-88 Preparation/Analysis SOP: Free Product (NAPL) Mobility – Centrifugal Method				
	Initial Saturation, Residual Saturation	Preparation/Analysis Method: ASTM D425 Mod. Preparation/Analysis SOP: Residual Saturation by Water Drive				
Product	Dynamic Viscosity	Preparation/Analysis Method: ASTM D445 Preparation/Analysis SOP: Kinematic Viscosity	4 × 40-mL vial, Teflon-lined lid	40 mL	None	None
	Density	Preparation/Analysis Method: ASTM D971 Preparation/Analysis SOP: Density of Viscous Materials				
	Interfacial Tension	Preparation/Analysis Method: ASTM D1481 Preparation/Analysis SOP: Interfacial Tension				

g gram
H_2SO_4 sulfuric acid
HCl hydrogen chloride
L liter
mL milliliter
$NaHSO_4$ sodium bisulfate
oz ounce

Table G-4: Analytical Services

Matrix	Analytical Group	Sampling Locations/ ID Numbers	Analytical SOP	Data Package Turnaround Time	Laboratory/Organization (name and address)
Unconsolidated Material	VOCs (BTEX) TPH-g, TPH-d, TPH-o PAHs (1-methylnaphthalene, 2-methylnaphthalene, naphthalene)	RHMW01R, RHMW07D, RHMW11, RHMW12, RHMW13, RHMW14, RHMW15, RHMW16, RHMW17, RHMW18, RHMW19, RHMW20	ANA8260, ANA8015, ANA8270SIM	14 days after samples are received at laboratory	APPL [a] 908 North Temperance Avenue Clovis, CA 96311
Unconsolidated Material	Atterberg Limits, Effective Porosity, Permeability, Moisture Content and Density, Grain Size Distribution, Cation Exchange Capacity, pH, Total Organic Carbon	RHMW07D, RHMW11, RHMW12, RHMW13, RHMW14, RHMW15, RHMW16, RHMW17, RHMW18, RHMW19, RHMW20	ASTM D4318, ASTM D6836M, ASTM D5084, ASTM D2937, ASTM D422, TBD	30 days after samples are received at laboratory	APPL [a] 908 North Temperance Avenue Clovis, CA 96311 (subcontracted to Hushmand Associates, Inc.)
Potable Water	VOCs (BTEX) TPH-g, TPH-d, TPH-o PAHs (1-methylnaphthalene, 2-methylnaphthalene, naphthalene)	RHMW01R, RHMW07D, RHMW11, RHMW12, RHMW13, RHMW14, RHMW15, RHMW16, RHMW17, RHMW18, RHMW19, RHMW20	ANA8260, ANA8015, ANA8270SIM	14 days after samples are received at laboratory	APPL [a] 908 North Temperance Avenue Clovis, CA 96311
Core	Digital Fluorescence Imaging, Pore Fluid Saturations, Effective Porosity, Initial Saturation, Residual Saturation, Total Porosity, Grain Density, Dry Bulk Density	RHMW01R	ASTM D5079, API RP40, ASTM D425M	30 days after samples are received at laboratory	Core Lab – Petroleum Services Division 3437 Landco Drive Bakersfield, CA 93308
Product	Dynamic viscosity, density, interfacial tension	JP-8 or similar kerosene-based jet fuel	ASTM D445, ASTM D971, ASTM D1481	30 days after samples are received at laboratory	Core Lab – Petroleum Services Division 3437 Landco Drive Bakersfield, CA 93308

[a] Laboratory meets DOD ELAP or AASHTO accreditation requirements, as applicable, to support project needs.

Table G-5: Analytical SOP References

Laboratory: APPL
Point of Contact: Libby Cheeseborough
Point of Contact Phone Number: 559-275-2175

Lab SOP Number	Title, Revision Date, and/or Number	Definitive or Screening Data	Matrix and Analytical Group	Instrument	Variance to QSM (Yes/No)	Modified for Project Work? (Yes/No)
Preparatory Methods						
ANA8260	Analysis Of Water/Soil/Sludge By EPA Method 8260, Rev 18, 12/22/16	Definitive	VOCs, TPH-g (Unconsolidated Material, Water)	Preparation	No	No
SON001	Sonication Extraction of Soil, Sludge, and Solid (EPA Method 3550C), Rev 3, 06/23/17	Definitive	TPH-d, TPH-o, PAHs (Unconsolidated Material)	Preparation	No	No
SEP11	Total Hydrocarbon (THC) Separatory Funnel Extraction of Water, Rev 5, 01/24/17	Definitive	TPH-d, TPH-o (Water)	Preparation	No	No
CLN004	3630C Silica Gel Cleanup, Rev 2, 12/22/16	Definitive	TPH-d, TPH-o Silica Gel Cleanup (Water)	Preparation	No	No
SEP004	625/8270 Separatory Funnel Extraction of Water (EPA Method 3510C), Rev 3, 01/24/17	Definitive	PAHs (Water)	Preparation	No	No
Analytical Methods						
ANA8260	Analysis Of Water/Soil/Sludge By EPA Method 8260, Rev 18, 12/22/16	Definitive	VOCs, TPH-g (Unconsolidated Material, Water)	GC-MS	No	No
ANA8015	Determination Of Total Extractable Petroleum Hydrocarbons (TPH) In Water, Sludges And Soils By GC-FID, Rev 9, 5/15/17	Definitive	TPH-d, TPH-o (Unconsolidated Material, Water)	GC-FID	No	No
ANA8270SIM	PAH By SIM By EPA Method 8270, Rev 7, 4/27/17	Definitive	PAHs (Unconsolidated Material, Water)	GC-MS	No	No
ANA9081	Cation-Exchange Capacity of Soils (Sodium Acetate), Rev 1, 01/25/17	Definitive	Cation Exchange Capacity (Unconsolidated Material)	ICP-AES	No	No
ANA9045	pH in Soil and Waste (EPA SW846 Method 9045D), Rev 4, 02/03/17	Definitive	pH (Unconsolidated Material)	pH Probe	No	No
ANAWALKLEY	Total Organic Carbon in Soil (Walkley-Black, modified), Rev 2, 01/25/17	Definitive	Total Organic Carbon (Unconsolidated Material)	Titration	No	No

Note: The laboratory SOPs listed in the table are the most current revisions at the time of publication of this *MWIWP Addendum 02*. The Navy consultant will review the laboratory SOPs immediately prior to sample submittal to ensure that the laboratory uses SOPs that are in compliance with the DoD QSM annual review requirement.
GC-FID gas chromatography-flame ionization detector
GC-MS gas chromatography-mass spectrometry
ICP-AES inductively coupled plasma-atomic emission spectroscopy

Laboratory: APPL (subcontracted to Hushmand Associates, Inc.)
Point of Contact: Libby Cheeseborough
Point of Contact Phone Number: 559-275-2175

Lab SOP Number	Title	Definitive or Screening Data	Matrix and Analytical Group	Instrument	Modified for Project Work? (Yes/No)
Preparatory/Analytical Methods					
ASTM D4318	Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils, ASTM D4318	Definitive	Atterberg Limits (Unconsolidated Material)	Liquid limit device	No
ASTM D5084	Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter, ASTM D5084	Definitive	Permeability (Unconsolidated Material)	Hydraulic system	No
API RP40	Recommended Practices for Core Analysis, Recommended Practice 40, API RP40	Definitive	Total Porosity (Unconsolidated Material)	Porosimeter	No
ASTM D2937	Standard Test Method for Density of Soil in Place by the Drive-Cylinder Method, ASTM D2937	Definitive	Moisture Content and Density (Unconsolidated Material)	Drive cylinder	No
ASTM D422	Standard Test Method for Particle-Size Analysis of Soils, ASTM D422	Definitive	Particle Size Distribution (Unconsolidated Material)	Hydrometer and sieve	No

Note: The laboratory SOPs listed in the table are the most current revisions at the time of publication of this *MWIWP Addendum 02*. The Navy consultant will review the laboratory SOPs immediately prior to sample submittal to ensure that the laboratory uses SOPs that are in compliance with the AASHTO review requirement.

Laboratory: Core Lab – Petroleum Services Division
Point of Contact: Larry Kunkel
Point of Contact Phone Number: 661-325-5657

Lab SOP Number	Title	Definitive or Screening Data	Matrix and Analytical Group	Instrument	Modified for Project Work? (Yes/No)
Preparatory Methods					
Core Slabbing	Core Slabbing	Definitive	Digital Fluorescence Imaging (Core)	Preparation	No
Analytical Methods					
Core Photography	Core Photography	Definitive	Digital Fluorescence Imaging (Core)	White and UV light camera	
Effective Porosity	Effective Porosity – Centrifugal Drainage Method (Method: ASTM D425M-88)	Definitive	Effective Porosity, Total Porosity, Grain Density, Dry Bulk Density (Core)	Centrifuge	No
Free Product (NAPL) Mobility	Free Product (NAPL) Mobility – Centrifugal Method (Method: ASTM D425M-88)	Definitive	Total Porosity, Bulk Density, Grain Density (Core)	Centrifuge	No
Pore Fluid Saturations	Pore Fluid Saturations – Distillation Extraction Method (Method: Dean Stark, API RP 40)	Definitive	Pore Fluid Saturation (Core)	Distillation assembly	No
Residual Saturation	Residual Saturation by Water Drive	Definitive	Initial Saturation, Residual Saturation (Core)	Hassler-Type triaxial flow cell	No
Kinematic Viscosity	Kinematic Viscosity	Definitive	(Core)	Viscometer	No
Interfacial Tension	Interfacial Tension	Definitive	(Core)	Tensiometer	No
Density of Viscous Materials	Density of Viscous Materials	Definitive	(Core)	Pycnometer	No

Note: The laboratory SOPs listed in the table are the most current revisions at the time of publication of this *MWIWP Addendum 02*. The Navy consultant will review the laboratory SOPs immediately prior to sample submittal to ensure that the laboratory uses SOPs that are in compliance with the AASHTO review requirement.

Table G-6: Laboratory QC Samples for Chemistry Analyses

Matrix	**Unconsolidated Material, Potable Water**
Analytical Group	**VOCs, TPH-g**
Analytical Method/SOP Reference	Analytical Method: SW-846 8260C Preparation Method: EPA 5035A, EPA 5030B Laboratory SOPs: ANA8260
Analytical Organization	APPL

QC Sample	Frequency & Number	Method/SOP QC Acceptance Limits	Corrective Action	Personnel Responsible for Corrective Action	DQI	Measurement Performance Criteria
LOD determination and verification	At initial set-up and verified quarterly. If a laboratory uses multiple instruments for a given method, the LOD must be verified on each.	The apparent signal to noise ratio must be at least 3 and the results must meet all method requirements for analyte identification.	If the LOD verification fails, the laboratory must: 1) Repeat the detection limit determination and LOD verification at a higher concentration; or 2) Perform and pass two consecutive LOD verifications at a higher concentration. The LOD is set at the higher concentration.	Analyst Lab QA Officer Project Chemist	Bias/ Representativeness	QC acceptance criteria as specified by Lab SOP ANA8260.
LOQ establishment and verification	At initial setup: 1) Verify LOQ; and 2) Determine precision and bias at the LOQ. Subsequently, verify LOQ quarterly. If a laboratory uses multiple instruments for a given method, the LOQ must be verified on each.	1) The LOQ and associated precision and bias must meet client requirements and must be reported; or 2) In the absence of client requirements, must meet control limits of the LCS. 3) If the method is modified, precision and bias at the new LOQ must be demonstrated and reported. See Volume 1, Module 4, Section 1.5.2 of the DoD QSM 5.0 (DoD 2013).	If the LOQ verification fails, the laboratory must either establish a higher LOQ or modify method to meet the client-required precision and bias.	Analyst Lab QA Officer Project Chemist	Sensitivity/Bias	QC acceptance criteria as specified by Lab SOP ANA8260 and at least as stringent as specified by DoD QSM 5.0 (DoD 2013).
Tune check	Prior to the ICAL and prior to each 12-hour period of sample analysis.	Specific ion abundance criteria of BFB or DFTPP from method.	Retune instrument and verify.	Analyst Lab QA Officer Project Chemist	Sensitivity/Bias	No samples may be analyzed without a passing tune.
CCV	Before sample analysis, after every 10 field samples, after every 12 hours of analysis time, and at the end of the analysis sequence.	All reported analytes and surrogates within established RT windows. All reported analytes and surrogates within ±20% of true value. All reported analytes and surrogates within ±50% for the end of the analytical batch CCV.	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.	Analyst Lab QA Officer Project Chemist	Accuracy/Precision	Results may not be reported without a valid CCV. If reanalysis cannot be performed, data must be qualified and explained in the case narrative. If the specific version of a method requires additional evaluation (e.g., average response factors) these additional requirements must also be met.

QC Sample	Frequency & Number	Method/SOP QC Acceptance Limits	Corrective Action	Personnel Responsible for Corrective Action	DQI	Measurement Performance Criteria
MB	Each time analytical batch.	No analytes detected >1/2 LOQ or >1/10 the amount measured in any sample or 1/10 the regulatory limit, whichever is higher. For common lab contaminants, no analytes detected >LOQ.	Correct problem. If required, re-prep and reanalyze MB and all samples processed with the contaminated blank.	Analyst Lab QA Officer Project Chemist	Bias	No analytes detected >1/2 LOQ or >1/10 the amount measured in any sample or 1/10 the regulatory limit, whichever is higher. For common laboratory contaminants, no analytes detected >LOQ.
LCS	One per batch of at most 20 samples analyzed of similar matrix per analytical method.	Per DoD QSM Appendix C Limits, Method SW-846 8260C and Lab SOP ANA8260.	Correct problem. If required, re-prep and reanalyze the LCS and all samples processed in the associated preparatory batch for the failed analytes. Results may not be reported without a valid LCS.	Analyst Lab QA Officer Project Chemist	Accuracy	QC acceptance criteria at least as stringent as specified by DoD QSM 5.0 (DoD 2013).
MS/MSD pair	One per analytical method for each batch of at most 20 samples.	Per DoD QSM Appendix C Limits, Method SW-846 8260C and Lab SOP ANA8260. MSD or Matrix Duplicate: RPD of all analytes ≤20%.	Examine the PQOs. Notify Lab QA officer and project chemist about additional measures to be taken.	Analyst Lab QA Officer Project Chemist	Accuracy/Precision	For matrix evaluation, use QC acceptance criteria at least as stringent as specified by DoD QSM 5.0 (DoD 2013).
Internal standards verification	Every field sample, standard, and QC sample.	Retention time ±10 seconds from retention time of the midpoint standard in the ICAL; EICP area within -50% to +100% of ICAL midpoint standard.	Inspect mass spectrometer and GC for malfunctions. Reanalysis of samples analyzed while system was malfunctioning is mandatory.	Analyst Lab QA Officer Project Chemist	Accuracy/Precision/ Representativeness	Laboratory in-house method manual to be followed for acceptance criteria.
Surrogate spike	All field and QC samples.	Per DoD QSM Appendix C Limits, Method SW-846 8260C and Lab SOP ANA8260.	For QC and field samples, correct problem then re-prep and reanalyze all failed samples for failed surrogates in the associated preparatory batch, if sufficient sample material is available. If obvious chromatographic interference with surrogate is present, reanalysis may not be necessary.	Analyst Lab QA Officer Project Chemist	Accuracy/Precision/ Representativeness	QC acceptance criteria at least as stringent as specified by DoD QSM 5.0 (DoD 2013).
Trip blank	1 per cooler.	Target analytes ≤1/2 LOQ.	Reanalyze for confirmation through a second analysis of the trip blank. Examine the PQOs.	Analyst Lab QA Officer Project Chemist	Accuracy/Bias, Representativeness/ Contamination	Target analytes ≤1/2 LOQ.

Matrix	**Unconsolidated Material, Potable Water**
Analytical Group	**TPH-d, TPH-o with and without Silica Gel Cleanup**
Analytical Method/SOP Reference	Analytical Method: EPA Method 8015C Preparation Method: EPA 3550C/3630C, EPA 3510C/3630C Laboratory SOPs: SON001, CLN004, SEP11, ANA8015
Analytical Organization	APPL

QC Sample	Frequency & Number	Method/SOP QC Acceptance Limits	Corrective Action	Personnel Responsible for Corrective Action	DQI	Measurement Performance Criteria
LOD determination and verification	At initial set-up and verified quarterly. If a laboratory uses multiple instruments for a given method, the LOD must be verified on each.	The apparent signal to noise ratio must be at least 3 and the results must meet all method requirements for analyte identification.	If the LOD verification fails, the laboratory must: 1) Repeat the detection limit determination and LOD verification at a higher concentration; or 2) Perform and pass two consecutive LOD verifications at a higher concentration. The LOD is set at the higher concentration.	Analyst Lab QA Officer Project Chemist	Bias/ Representativeness	QC acceptance criteria as specified by Lab SOP ANA8015.
LOQ establishment and verification	At initial setup: 1) Verify LOQ; and 2) Determine precision and bias at the LOQ. Subsequently, verify LOQ quarterly. If a laboratory uses multiple instruments for a given method, the LOQ must be verified on each.	1) The LOQ and associated precision and bias must meet client requirements and must be reported; or 2) In the absence of client requirements, must meet control limits of the LCS. 3) If the method is modified, precision and bias at the new LOQ must be demonstrated and reported. See Volume 1, Module 4, Section 1.5.2 of the DoD QSM 5.0 (DoD 2013).	If the LOQ verification fails, the laboratory must either establish a higher LOQ or modify method to meet the client-required precision and bias.	Analyst Lab QA Officer Project Chemist	Sensitivity/Bias	QC acceptance criteria as specified by Lab SOP ANA8015, and at least as stringent as specified by DoD QSM 5.0 (DoD 2013).
CCV	Before sample analysis, after every 10 field samples, and at the end of the analysis sequence.	All reported analytes and surrogates within established RT windows. All reported analytes and surrogates within ±20% of true value.	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.	Analyst Lab QA Officer Project Chemist	Accuracy/Precision	Results may not be reported without a valid CCV. If reanalysis cannot be performed, data must be qualified and explained in the case narrative.
MB	Each time samples are extracted and one per matrix per analytical method for each batch of at most 20 samples.	No analytes detected >1/2 LOQ or >1/10 the amount measured in any sample or 1/10 the regulatory limit, whichever is higher. For common lab contaminants, no analytes detected >LOQ.	Correct problem. If required, re-prep and reanalyze MB and all samples processed with the contaminated blank.	Analyst Lab QA Officer Project Chemist	Sensitivity/Bias	No analytes detected >1/2 LOQ or >1/10 the amount measured in any sample or 1/10 the regulatory limit, whichever is higher. For common laboratory contaminants, no analytes detected >LOQ.

QC Sample	Frequency & Number	Method/SOP QC Acceptance Limits	Corrective Action	Personnel Responsible for Corrective Action	DQI	Measurement Performance Criteria
LCS	One per batch of at most 20 samples analyzed of similar matrix per analytical method.	Per DoD QSM Appendix C Limits, Method 8015C and Lab SOP ANA8015.	Correct problem. If required, re-prep and reanalyze the LCS and all samples processed in the associated preparatory batch for the failed analytes.	Analyst Lab QA Officer Project Chemist	Accuracy	QC acceptance criteria at least as stringent as specified by DoD QSM 5.0 (DoD 2013).
Internal standards verification	Every field sample, standard, and QC sample.	Retention time ±30 seconds from retention time of the midpoint standard in the ICAL; EICP area within -50% to +100% of ICAL midpoint standard.	Inspect mass spectrometer and GC for malfunctions. Reanalysis of samples analyzed while system was malfunctioning is mandatory.	Analyst Lab QA Officer Project Chemist	Accuracy/Precision/ Representativeness	Laboratory in-house method manual to be followed for acceptance criteria.
Surrogate spike	All field and QC samples.	Per DoD QSM Appendix C Limits, Method 8015C and Lab SOP ANA8015.	For QC and field samples, correct problem then re-prep and reanalyze all failed samples for failed surrogates in the associated preparatory batch, if sufficient sample material is available. If obvious chromatographic interference with surrogate is present, reanalysis may not be necessary.	Analyst Lab QA Officer Project Chemist	Accuracy/Precision/ Representativeness	QC acceptance criteria at least as stringent as specified by DoD QSM 5.0 (DoD 2013).
Surrogate spike for silica gel cleanup procedure	All field and QC samples.	Acceptable recovery range of 0 to 1% of spiked amount of polar hydrocarbon surrogate.	For QC and field samples, if sufficient sample extract is available, re-run extracts through silica gel cleanup procedure and reanalyze all failed samples for failed surrogates in the associated preparatory batch. Otherwise, re-extract samples and re-run silica gel cleanup on re-extract prior to re-analysis, if sufficient sample material is available.	Analyst Lab QA Officer Project Chemist	Accuracy/Precision/ Representativeness	Polar hydrocarbon surrogate recovered at ≤1% of spiked amount.
MS/MSD pair	One per analytical method for each batch of at most 20 samples.	Per DoD QSM Appendix C Limits, Method 8015C and Lab SOP ANA8015. MSD or Matrix Duplicate: RPD of all analytes ≤30%.	Examine the PQOs. Notify Lab QA officer and project chemist about additional measures to be taken.	Analyst Lab QA Officer Project Chemist	Accuracy/Precision	For matrix evaluation, use QC acceptance criteria at least as stringent as specified by DoD QSM 5.0 (DoD 2013).

Matrix	**Unconsolidated Material, Potable Water**
Analytical Group	**PAHs**
Analytical Method/SOP Reference	Analytical Method: EPA Method 8270D SIM Preparation Method: EPA 3550C, EPA 3510C Laboratory SOPs: SON001, SEP004, ANA8270SIM
Analytical Organization	APPL

QC Sample	Frequency & Number	Method/SOP QC Acceptance Limits	Corrective Action	Personnel Responsible for Corrective Action	DQI	Measurement Performance Criteria
LOD determination and verification	At initial set-up and verified quarterly. If a laboratory uses multiple instruments for a given method, the LOD must be verified on each.	The apparent signal to noise ratio must be at least 3 and the results must meet all method requirements for analyte identification.	If the LOD verification fails, the laboratory must: 1) Repeat the detection limit determination and LOD verification at a higher concentration; or 2) Perform and pass two consecutive LOD verifications at a higher concentration. The LOD is set at the higher concentration.	Analyst Lab QA Officer Project Chemist	Bias/ Representativeness	QC acceptance criteria as specified by Lab SOP ANA8270SIM.
LOQ establishment and verification	At initial setup: 1) Verify LOQ; and 2) Determine precision and bias at the LOQ. Subsequently, verify LOQ quarterly. If a laboratory uses multiple instruments for a given method, the LOQ must be verified on each.	1) The LOQ and associated precision and bias must meet client requirements and must be reported; or 2) In the absence of client requirements, must meet control limits of the LCS. 3) If the method is modified, precision and bias at the new LOQ must be demonstrated and reported. See Volume 1, Module 4, Section 1.5.2 of the DoD QSM 5.0 (DoD 2013).	If the LOQ verification fails, the laboratory must either establish a higher LOQ or modify method to meet the client-required precision and bias.	Analyst Lab QA Officer Project Chemist	Sensitivity/Bias	QC acceptance criteria as specified by Lab SOP ANA8270SIM, and at least as stringent as specified by DoD QSM 5.0 (DoD 2013).
Performance check	Before ICAL and sample analysis, and at the beginning of each 12-hour shift.	Degradation of DDT must be ≤20%. Benzidine and pentachlorophenol will be present at their normal responses, and will not exceed a tailing factor of 2.	Correct problem, then repeat performance checks.	Analyst Lab QA Officer Project Chemist	Sensitivity/Bias	Degradation of DDT must be ≤20%; and benzidine and pentachlorophenol must be present at normal responses and tailing factor is ≤2. No samples must be analyzed until performance check is within criteria.
Tune Check	Prior to the ICAL and prior to each 12-hour period of sample analysis.	Specific ion abundance criteria of BFB or DFTPP from method.	Retune instrument and verify	Analyst Lab QA Officer Project Chemist	Sensitivity/Bias	No samples may be analyzed without a passing tune.

QC Sample	Frequency & Number	Method/SOP QC Acceptance Limits	Corrective Action	Personnel Responsible for Corrective Action	DQI	Measurement Performance Criteria
CCV	Before sample analysis, after every 10 field samples, after every 12 hours of analysis time, and at the end of the analysis sequence.	All reported analytes and surrogates within established RT windows. All reported analytes and surrogates within ±20% of true value.	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.	Analyst Lab QA Officer Project Chemist	Accuracy/Precision	Results may not be reported without a valid CCV. If reanalysis cannot be performed, data must be qualified and explained in the case narrative.
MB	Each time samples are extracted and one per matrix per analytical method for each batch of at most 20 samples.	No analytes detected >1/2 LOQ or >1/10 the amount measured in any sample or 1/10 the regulatory limit, whichever is higher. For common lab contaminants, no analytes detected >LOQ.	Correct problem. If required, re-prep and reanalyze MB and all samples processed with the contaminated blank.	Analyst Lab QA Officer Project Chemist	Sensitivity/Bias	No analytes detected >1/2 LOQ or >1/10 the amount measured in any sample or 1/10 the regulatory limit, whichever is higher. For common laboratory contaminants, no analytes detected >LOQ.
LCS	One per batch of at most 20 samples analyzed of similar matrix per analytical method.	Per DoD QSM Appendix C Limits, Method 8270D SIM and Lab SOP ANA8270SIM.	Correct problem. If required, re-prep and reanalyze the LCS and all samples processed in the associated preparatory batch for the failed analytes.	Analyst Lab QA Officer Project Chemist	Accuracy	QC acceptance criteria at least as stringent as specified by DoD QSM 5.0 (DoD 2013).
Internal standards verification	Every field sample, standard, and QC sample.	Retention time ±10 seconds from retention time of the midpoint standard in the ICAL; EICP area within -50% to +100% of ICAL midpoint standard.	Inspect mass spectrometer and GC for malfunctions. Reanalysis of samples analyzed while system was malfunctioning is mandatory.	Analyst Lab QA Officer Project Chemist	Accuracy/Precision/ Representativeness	Laboratory in-house method manual to be followed for acceptance criteria.
Surrogate spike	All field and QC samples.	Per DoD QSM Appendix C Limits, Method 8270D SIM and Lab SOP ANA8270SIM.	For QC and field samples, correct problem then re-prep and reanalyze all failed samples for failed surrogates in the associated preparatory batch, if sufficient sample material is available. If obvious chromatographic interference with surrogate is present, reanalysis may not be necessary.	Analyst Lab QA Officer Project Chemist	Accuracy/Precision/ Representativeness	QC acceptance criteria at least as stringent as specified by DoD QSM 5.0 (DoD 2013).
MS/MSD pair	One per analytical method for each batch of at most 20 samples.	Per DoD QSM Appendix C Limits, Method 8270D SIM and Lab SOP ANA8270SIM. MSD or Matrix Duplicate: RPD of all analytes ≤20%.	Examine the PQOs. Notify Lab QA Officer and project chemist about additional measures to be taken.	Analyst Lab QA Officer Project Chemist	Accuracy/Precision	For matrix evaluation, use QC acceptance criteria at least as stringent as specified by DoD QSM 5.0 (DoD 2013).

Matrix	**Unconsolidated Material, Potable Water**
Analytical Group	**pH, TOC, CEC**
Analytical Method/SOP Reference	Analytical Method: EPA 9045, Walkley Black, EPA 9081 Preparation Method: EPA 9045, Walkley Black, EPA 9081 Laboratory SOPs: TBD
Analytical Organization	APPL

QC Sample	Frequency & Number	Method/SOP QC Acceptance Limits	Corrective Action	Personnel Responsible for Corrective Action	DQI	Measurement Performance Criteria
LOD determination and verification	At initial set-up and verified quarterly. If a laboratory uses multiple instruments for a given method, the LOD must be verified on each.	The apparent signal to noise ratio must be at least 3 and the results must meet all method requirements for analyte identification.	If the LOD verification fails, the laboratory must: 1) Repeat the detection limit determination and LOD verification at a higher concentration; or 2) Perform and pass two consecutive LOD verifications at a higher concentration. The LOD is set at the higher concentration.	Analyst Lab QA Officer Project Chemist	Bias/ Representativeness	QC acceptance criteria as specified by Lab SOP TBD.
LOQ establishment and verification	At initial setup: 1) Verify LOQ; and 2) Determine precision and bias at the LOQ. Subsequently, verify LOQ quarterly. If a laboratory uses multiple instruments for a given method, the LOQ must be verified on each.	1) The LOQ and associated precision and bias must meet client requirements and must be reported; or 2) In the absence of client requirements, must meet control limits of the LCS. 3) If the method is modified, precision and bias at the new LOQ must be demonstrated and reported. See Volume 1, Module 4, Section 1.5.2 of the DoD QSM 5.0 (DoD 2013).	If the LOQ verification fails, the laboratory must either establish a higher LOQ or modify method to meet the client-required precision and bias.	Analyst Lab QA Officer Project Chemist	Sensitivity/Bias	QC acceptance criteria as specified by Lab SOP TBD, and at least as stringent as specified by DoD QSM 5.0 (DoD 2013).
MB	Each time samples are extracted and one per matrix per analytical method for each batch of at most 20 samples.	No analytes detected >1/2 LOQ or >1/10 the amount measured in any sample or 1/10 the regulatory limit, whichever is higher. For common lab contaminants, no analytes detected >LOQ.	Correct problem. If required, re-prep and reanalyze MB and all samples processed with the contaminated blank.	Analyst Lab QA Officer Project Chemist	Sensitivity/Bias	No analytes detected >1/2 LOQ or >1/10 the amount measured in any sample or 1/10 the regulatory limit, whichever is higher. For common laboratory contaminants, no analytes detected >LOQ.
LCS	One per batch of at most 20 samples analyzed of similar matrix per analytical method.	Per DoD QSM Appendix C Limits, Method TBD and Lab SOP TBD.	Correct problem. If required, re-prep and reanalyze the LCS and all samples processed in the associated preparatory batch for the failed analytes.	Analyst Lab QA Officer Project Chemist	Accuracy	QC acceptance criteria at least as stringent as specified by DoD QSM 5.0 (DoD 2013).

Note: No laboratory QC samples are generated for geotechnical and petrographic analyses.

Table G-7: Analytical Instrument and Equipment Maintenance, Testing, and Inspection

Instrument/ Equipment	Maintenance Activity	Testing Activity	Inspection Activity	Frequency	Acceptance Criteria	Corrective Action	Responsible Person	SOP Reference [a]
GC-FID and GC-MS	Change gas purifier.	N/A.	Visually inspect if traps are changing color.	Every 6–12 months	No moisture	Replace indicating traps.	Analyst or certified instrument technician	ANA8015, ANA8270SIM, ANA8270
	Change syringes/syringe needles.	N/A.	Visually inspect for wear or damage.	Every 3 months	N/A	Replace syringe if dirt is noticeable in the syringe.	Analyst or certified instrument technician	
	Change inlet liner, liner O-rings, and inlet septum.	N/A.	Visually inspect for dirt or deterioration.	Weekly for liner Monthly for O-rings Daily for septum	N/A	Replace and check often.	Analyst or certified instrument technician	
	Change front-end column.	N/A.	Check peak tailing, decreased sensitivity, retention time changes, etc.	Weekly, monthly, or when needed	N/A	Remove 1/2 to 1 meter from the front of the column when experiencing problems.	Analyst or certified instrument technician	
	Clean injector ports.	N/A.	N/A.	As needed	N/A	N/A.	Analyst	
	Replace trap on purge-and-trap systems.	N/A.	N/A.	Bi-monthly or as needed	N/A	N/A.	Analyst	
	Replace columns.	N/A.	N/A.	If chromatograms indicate possible contamination	N/A	N/A.	Analyst	
GC-FID	Replace detector jets.	N/A.	N/A.	As needed	N/A	N/A.	Analyst	ANA8015
	Replace hydrocarbon traps and oxygen traps on helium and hydrogen gas lines.	N/A.	N/A.	Every 4–6 months	N/A	N/A.	Analyst	
	Replace chemical trap.	N/A.	N/A.	Yearly or as needed	N/A	N/A.	Analyst	
	Replace converter tube in gas purifier system.	N/A.	N/A.	Yearly or as needed	N/A	N/A.	Analyst	

Instrument/ Equipment	Maintenance Activity	Testing Activity	Inspection Activity	Frequency	Acceptance Criteria	Corrective Action	Responsible Person	SOP Reference [a]
GC-MS	Change tune MSD, check the calibration vial, and replace the foreline pump oil.	N/A.	Visually inspect and monitor the fluid becoming discolored.	As needed or every 6 months	In accordance with manufacturer's recommendation or lab SOP	Keep plenty of PFTBA; refill the vial and check the fluid; change when the fluid becomes discolored.	Analyst or certified instrument technician	ANA8270SIM, ANA8270
	Run tuning program to determine if source is functioning properly.	N/A.	N/A.	Daily	N/A	Cool system, vent, disassemble, and clean.	Analyst	ANA8270SIM, ANA8270
	N/A	Tune instrument.	N/A.	Daily or every 12 hours	Per method	Liner and septa are replaced; tune file used is manually adjusted.	Analyst	
	Vacuum rough pump oil level is checked.	N/A.	N/A.	Every 4-6 weeks	N/A	Add oil if needed.	Analyst	
	Replace/refill carrier gas line oxygen and moisture traps.	N/A.	N/A.	Yearly or as needed	N/A	N/A.	Analyst	
Water Bath (Precision Microprocessor controlled)	Check instrument connections, water level, and thermometer.	Measure water temperature against a calibrated thermometer.	Visually inspect for wear or damage and indicator from computer controls.	Daily and annual maintenance from manufacturer	Refer to manufacturer's recommendation	Return to manufacturer for recalibration or call for maintenance service.	Analyst or certified instrument technician	INS001
Drying Oven	Thermometer indicator.	Measure oven temperature against a calibrated thermometer.	Visually inspect for wear or damage and indicator from computer controls.	Daily and annual maintenance from manufacturer	Refer to manufacturer's recommendation	Return to manufacturer for recalibration or call for maintenance service.	Analyst or certified instrument technician	INO003
Analytical Balance	Check digital LCD display and ensure a flat base for the Instrument.	Calibrate against verified (NIST) mass.	Visually inspect for wear or damage and indicator from computer controls.	Daily and annual maintenance from manufacturer	Refer to manufacturer's recommendation	Return to manufacturer for recalibration or call for maintenance service.	Analyst or certified instrument technician	INO011
pH Meter	Check LCD display and pH probe.	3 point calibration using known standards.	Visually inspect for wear or damage and indicator from computer controls.	Daily and annual maintenance from manufacturer	±0.05 units	Return to manufacturer for recalibration or call for maintenance service.	Analyst or certified manufacture instrument technician	INO038

Note: No instrument and equipment maintenance, testing, and inspection criteria for geotechnical and petrographic analyses.
N/A not applicable
PFTBA perfluorotributylamine
[a] See Analytical SOP References table (Table G-5).

Table G-8: Analytical Instrument Calibration

Instrument	Calibration Procedure	Frequency of Calibration	Acceptance Criteria	Corrective Action	Person Responsible for Corrective Action	SOP Reference [a]
GC-MS EPA Methods 8260C, 8720D SIM	Tuning	Prior to ICAL and at the beginning of each 12-hour period	Refer to method for specific ion criteria.	Retune instrument and verify. Rerun affected samples.	Lab Manager/Analyst or certified instrument technician	ANA8270SIM, ANA8270
	Breakdown check (DDT-Method 8270 only)	At the beginning of each 12-hour period, prior to analysis of samples	Degradation ≤20% for DDT. Benzidine and pentachlorophenol should be present at their normal responses, and should not exceed a tailing factor of 2.	Correct problem, then repeat breakdown checks.	Lab Manager/Analyst or certified instrument technician	
	Minimum 5-point ICAL for linear calibration Minimum 6-point ICAL for quadratic calibration	Prior to sample analysis	RSD for each analyte ≤15% or least square regression ≥0.995. Non-linear least squares regression (quadratic) for each analyte ≤0.995.	Correct problem then repeat ICAL.	Lab Manager/Analyst or certified instrument technician	
	Second source calibration verification	After ICAL	All analytes within ±20% of expected value.	Correct problem and verify second source standard; rerun second source verification. If fails, correct problem and repeat ICAL.	Lab Manager/Analyst or certified instrument technician	
	RT window position for each analyte and surrogate	Once per ICAL	Position will be set using the midpoint standard for the ICAL.	N/A.	Lab Manager/Analyst or certified instrument technician	
	RRT	With each sample	RRT of each target analyte in each calibration standard within ±0.06 RRT units of ICAL.	Correct problem, then reanalyze all samples analyzed since the last RT check. If fails, then rerun ICAL and samples.	Lab Manager/Analyst or certified instrument technician	
	CCV	Daily, before sample analysis, unless ICAL performed same day and after every 10 samples and at the end of the analysis sequence	All analytes within ±20% of expected value (%D). All reported analytes and surrogates within ±50% for end of analytical batch CCV.	Immediately analyze two additional consecutive CCVs. If both pass, samples may be reported without reanalysis. If either fails, take corrective action(s) and re-calibrate; then reanalyze all affected samples since the last acceptable CCV.	Lab Manager/Analyst or certified instrument technician	
	IS	Each CCV and sample	RT ±10 seconds from RT of the ICAL mid-point standard. EICP area within -50% to +100% of area from IS in ICAL mid-point standard.	Inspect mass spectrometer and GC for malfunctions. Reanalysis of samples analyzed during failure is mandatory.	Lab Manager/Analyst or certified instrument technician	

Instrument	Calibration Procedure	Frequency of Calibration	Acceptance Criteria	Corrective Action	Person Responsible for Corrective Action	SOP Reference [a]
GC-FID EPA Method 8015C	Minimum 5-point ICAL for linear calibration Minimum 6-point ICAL for quadratic calibration	Prior to sample analysis	RSD for each analyte ≤20% or least square regression ≥0.995. Non-linear least squares regression (quadratic) for each analyte ≤0.995.	Correct problem then repeat ICAL.	Lab Manager/Analyst or certified instrument technician	ANA8015
	Second source calibration verification	Once after each ICAL	Analytes within ±20% of expected value (initial source), and within established RT windows.	Correct problem and verify second source standard. Rerun second source verification. If fails, correct problem and repeat ICAL.	Lab Manager/Analyst or certified instrument technician	
	RT window width	At method set-up and after major maintenance	RT width is ±3 times standard deviation for each analyte RT from 72-hour study. For TPH-d: calculate RT based on C12 and C25 alkanes.	N/A.	Lab Manager/Analyst or certified instrument technician	
	Establishment and verification of the RT window for each analyte and surrogate	Once per ICAL and at the beginning of the analytical shift for establishment of RT; and with each CCV for verification of RT	Using the midpoint standard or the CCV at the beginning of the analytical shift for RT establishment; and analyte must fall within established window during RT verification.	N/A.	Lab Manager/Analyst or certified instrument technician	
	Run second source calibration verification (ICV)	ICV: Daily, before sample analysis, unless ICAL performed same day	All analytes within ±20% of expected value (%D).	Correct problem and rerun ICV. If fails, repeat ICAL.	Lab Manager/Analyst or certified instrument technician	
	CCV	Daily, before sample analysis, unless ICAL performed same day and after every 10 samples and at the end of the analysis sequence	All analytes within ±20% of expected value (%D).	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.	Lab Manager/Analyst or certified instrument technician	
Water Bath	Measure water temperature against a calibrated thermometer	Annually	In accordance with unit model and manufacturer's recommendation or laboratory SOP.	Terminate analysis, recalibrate, and verify before sample analysis.	Lab Manager/Analyst or certified instrument technician	INS001
Drying Oven	Measure oven temperature against a calibrated thermometer	Annually	In accordance with unit model and manufacturer's recommendation or laboratory SOP.	Terminate analysis, recalibrate, and verify before sample analysis.	Lab Manager/Analyst or certified instrument technician	INO003

Instrument	Calibration Procedure	Frequency of Calibration	Acceptance Criteria	Corrective Action	Person Responsible for Corrective Action	SOP Reference [a]
Analytical Balance	Calibrate against verified (NIST) mass	Daily or prior to analyzing samples	In accordance with unit model and manufacturer’s recommendation or laboratory SOP.	Terminate analysis, recalibrate, and verify before sample analysis.	Lab Manager/Analyst or certified instrument technician	INO011
pH Meter	Run a minimum 3-point calibration; run CCV	Daily or prior to analyzing samples; one CCV for every 10 samples	±0.05 unit.	Terminate analysis, recalibrate, and verify before sample analysis.	Lab Manager/Analyst or certified instrument technician	INO038

Note: No instrument calibration procedures for geotechnical and petrographic analyses.
%D percent difference
CA corrective action
CCV continued calibration verification
D difference
DDT dichlorodiphenyltrichloroethane
ICAL initial calibration
ICV initial calibration verification
IS internal standard
NIST National Institute of Standards and Technology
RRT relative retention time
RSD relative standard deviation
RT retention time
[a] See Analytical SOP References table (Table G-5).

Table G-9: Data Verification and Validation (Steps I and IIa/IIb) Process

Data Review Input	Description	Responsible for Verification (name, organization)	Step I/IIa/IIb [a]	Internal/External
Laboratory system audits	Determine whether the laboratory holds a current DoD ELAP certification for all analyses to be performed for the project.	Project Chemist (Navy consultant)	Step I	Internal
Field procedures	Determine whether field procedures are performed in accordance with this SAP and prescribed procedures.	QA Program Manager (Navy consultant)	Step I	Internal
Field logbook and notes	Review the field logbook and any field notes on a weekly basis and place them in the project file. Copies of the field logbook and field notes will be provided to the Navy consultant CTO manager and included in the Field Audit Report.	Field Manager (Navy consultant)	Step I	Internal
Instrument calibration sheets	Determine whether instruments are calibrated and used in accordance with manufacturer's' requirements.	Project Chemist (Navy consultant) & Data Validator (LDC)	Step I	Internal & External
CoC forms	Review CoC completed forms and verify them against the corresponding packed sample coolers. A copy of each CoC will be placed in the project file. The original CoC will be taped inside the cooler for shipment to the analytical laboratory.	Project Chemist (Navy consultant)	Step I	Internal
Sampling analytical data package	Verify all analytical data packages for completeness prior to submittal of the data to the data validator.	Laboratory Project Manager (APPL)	Step I	External
Analytes	Determine whether all analytes specified in Table G-2 were analyzed and reported on by the laboratory.	Project Chemist (Navy consultant)	Step IIa	Internal
CoC and field QC logbook	Examine data traceability from sample collection to project data generation.	Project Chemist (Navy consultant)	Step IIa	Internal
Laboratory data and SAP requirements	Assess and document the performance of the analytical process. A summary of all QC samples and results will be verified for measurement performance criteria and completeness. Full Validation will be performed on 10% of the data and Standard Validation will be performed on 90% of the data. A report will be prepared within 21 days of receipt.	Data Validator (LDC) & Project Chemist (Navy consultant)	Steps IIa & IIb	Internal & External
VOCs	Complete Procedure II-B, *Level C and Level D Data Validation Procedure for GC/MS Volatile Organics by SW-846 8260B* (DON 2015).	Data Validator (LDC)	Step IIa	External
PAHs and SVOCs	Complete Procedure II-C, *Level C and Level D data Validation Procedure for GC/MS Semivolatile Organics by SW-846 8270C* (Full Scan and SIM) (DON 2015).	Data Validator (LDC)	Step IIa	External

Data Review Input	Description	Responsible for Verification (name, organization)	Step I/IIa/IIb [a]	Internal/External
TPH	Complete Procedure II-H, *Level C and Level D Data Validation Procedure for Extractable Total Petroleum Hydrocarbons by SW-846 8015B* (DON 2015).	Data Validator (LDC)	Step IIa	External
Sampling plan	Determine whether the number and type of samples specified in Table G-1 were collected and analyzed.	Project Chemist (Navy consultant) & Field Manager (Navy consultant)	Step IIb	Internal
Field QC samples	Establish that the number of QC samples specified in Table G-1 were collected and analyzed.	Project Chemist (Navy consultant)	Step IIb	Internal
Project quantitation limits and data qualifiers	Establish that sample results met the project quantitation limits and qualify the data in accordance with Procedure II-A, *Data Validation Procedure* (DON 2015).	Data Validator (LDC) & Project Chemist (Navy consultant)	Step IIb	Internal & External
Validation report	Summarize outcome of data comparison to MPC in the SAP. Include qualified data and an explanation of all data qualifiers.	Data Validator (LDC)	Step IIa	External

MPC measurement performance criteria
[a] IIa Compliance with methods, procedures, and contracts. See Table 10, page 117, UFP-QAPP manual, V.1 (DoD 2005).
IIb Comparison with measurement performance criteria in the SAP. See Table 11, page 118, UFP-QAPP manual, V.1 (DoD 2005).

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Appendix H:
Regulatory Agency Conditional Approval Letter and Responses to Regulatory Agency Comments

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UNITED STATES ENVIRONMENTAL
PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105

STATE OF HAWAII
DEPARTMENT OF HEALTH
P. O. BOX 3378
HONOLULU, HI 96801-3378

FEB 03 2017

Captain Richard D. Hayes
Regional Engineer
Navy Region Hawaii
850 Ticonderoga Street, Suite 110
Pearl Harbor, Hawaii 96860-5101

Re: Conditional Approval of Red Hill AOC SOW Derivative Deliverable under Sections 6 & 7 – Monitoring Well Installation Work Plan Addendum 01, Red Hill Bulk Fuel Storage Facility, January 4, 2017

Dear Captain Hayes:

The U.S. Environmental Protection Agency ("EPA") and Hawaii Department of Health ("DOH"), collectively the "Regulatory Agencies", have reviewed the derivative deliverable *Monitoring Well Installation Work Plan Addendum 01, Red Hill Bulk Fuel Storage Facility* ("MWIWP Addendum") submitted by the U.S. Navy ("Navy") and Defense Logistics Agency ("DLA") on January 4, 2017. The Regulatory Agencies are conditionally approving the MWIWP Addendum, pursuant to AOC Sections 7(b)(b).

The purpose of this work plan is to propose the replacement of two existing groundwater monitoring wells, designated as OWDFMW01 and RHMW01 (the replacement wells are designated as OWDFMW01R and RHMW01R). The primary reason for replacement is because the top of the well screens in the current wells do not extend across the potentiometric water surface level. Because of this, analytical data from these wells may not identify the presence of non-aqueous phase liquids (NAPL) or be representative of concentrations at the potentiometric surface level. The Regulatory Agencies appreciate the Navy's efforts to address the perceived deficiencies in the existing wells.

However, as detailed in our attached comments, the Regulatory Agencies believe that replacing monitoring well OWDFMW01, while allowing for the relocation of the screen interval, may not yield data that materially changes the Conceptual Site Model and the Regulatory Agencies do not recommend that the Navy proceed with a replacement well for OWDFMW01. The Regulatory Agencies recognize the substantial expense associated with well installation and believe these monies could be more effectively used to address larger gaps in the Conceptual Site Model, such as the nature and extent of soils within the North and South Halawa Valley.

The Regulatory Agencies do support the replacement of RHMW01. However, while we acknowledge the challenges present in installing a monitoring well in the lower tunnel of the Facility, we strongly encourage the Navy to make every effort to install a well casing in RHMW01R that is 2 inches or greater in diameter. If conditions are such during drilling that the Navy believes that installation of a conductor casing will be necessary, we recommend that installation of the well be halted and that the Navy consult with the Regulatory Agencies before proceeding with the installation of a well less than 2 inches in diameter. We want to ensure that all possible solutions are considered before having to use a 1-inch well casing, which is the same size well casing that is currently installed in the existing RHMW01.

In addition to recommending that the Navy pursue a minimum 2-inch diameter well when constructing RHMW01R, the Regulatory Agencies recommend that the screen interval of the replacement well extend from +27 to +12 feet above mean sea level (ft. msl). Screening the replacement well at this shallower depth will allow RHMW01R and existing well RHMW01 to act as a well pair, monitoring the shallow and deeper zone in this area. This information may ultimately be used to evaluate the attenuation of dissolved contaminant concentrations with respect to depth. For this reason, we believe that the Navy should not abandon RHWM01 at this time.

A summary of the Regulatory Agencies' comments and recommendations is presented as an attachment, below.

The Regulatory Agencies have discussed these comments with the Navy on a conference call held on January 23, 2017 and we believe we are all in agreement on how to proceed. If the Navy has further questions or would like to discuss this conditional approval in more detail, please contact us. Bob Pallarino can be reached at (415) 947-4128 or at pallarino.bob@epa.gov and Steven Chang can be reached at (808) 586-4226 or at steven.chang@doh.hawaii.gov.

Sincerely,

Bob Pallarino
EPA Red Hill Project Coordinator

Steven Chang, P.E.
DOH Red Hill Project Coordinator

Enclosure

cc: Mr. Mark Manfredi, U.S. Navy
Mr. John Montgomery, U.S. Navy
Mr. Aaron Poentis, NAVFAC

Comments on the Red Hill Monitoring Well Installation Work Plan Addendum-01, Red Hill Bulk Fuel Storage Facility, January 4, 2017

Replacement Well OWDFMW01R

The Regulatory Agencies believe it is questionable whether the gains of a replacement well for the existing OWDFMW01 will justify the cost. The *Remedial Investigation Phase II – Red Hill Oily Waste Disposal Facility – Halawa, Oahu, Hawaii – Volume 1 Technical Report (EarthTech, 2000)* details the drilling and installation of the basal monitoring wells in the Oily Waste Disposal Basin (OWDB). Pages 2-9 and 2-12 of that report provide a description of the five basal aquifer borings in the OWDB and Appendix C contains the geologic boring logs. For each well, groundwater was not encountered until significantly below the expected depth. Once groundwater was encountered it rose up in the borehole indicating confined conditions for all wells drilled in this area. The elevation where groundwater was first encountered varied from -20 to -1 ft. mean sea level (msl), well below the static water level of about +20 ft. msl. The top of screen elevation for OWDFMW01 is about +4 ft. msl, below the water table but above the confining layer. The solid rock of the confining layer is essentially a solid casing that extends below the water table preventing sampling formation water at an elevation equivalent to that of the potentiometric surface. The Regulatory Agencies believe that little will be gained in installing a new well to replace the existing OWDFMW01 until the extent of the confining layer is better defined. Ensuring that proper procedures are used when sampling from this well is likely a more suitable approach to collecting a sample that is representative of dissolved phase contamination in the groundwater in the vicinity of this former Superfund site.

Replacement Well RHMW01R

1. As stated in our letter, the Regulatory Agencies strongly recommend the Navy uses at least a 2-inch well casing for the new monitoring well RHMW01R. While installing a 1-inch casing will still allow the Navy to adjust the screened interval of the well, there are many disadvantages to a 1-inch well casing.
    a. As is the case with existing well RHMW01, a 1-inch well is much slower to sample and more susceptible to blockage.
    b. It will be very difficult to get a true vertical depth to water since the well bore will be too narrow to accommodate the gyroscopic instrument that is necessary to measure deviations from vertical.
    c. A 1-inch well will continue the requirement to remove the downhole sampling pump for the monthly oil/water interface measurements.

    If the Navy finds that it is unable to install a well less than 2" in diameter, we request that the Regulatory Agencies are consulted prior to making any final decisions on how to proceed.

2. The Regulatory Agencies understand that existing well RHMW01 is screened from +12.61 to +2.61 ft. msl, and that the typical groundwater elevation is +19.54 ft. msl.

Because the screen is submerged, we agree that samples collected from this well may not accurately represent the maximum concentrations typically found at the top of the groundwater table. Nevertheless, the Regulatory Agencies have no reason to believe that samples collected from RHMW01 are not adequately representative of groundwater from +12.61 to +2.61 ft. msl, and believe that these data may be useful in evaluating contaminant concentration with respect to depth. Because of this, the Regulatory Agencies recommend that RHMW01R be constructed with a screen interval extending from +27 to +12 ft. msl. This construction will allow RHMW01R and RHMW01 to act as a monitoring well pair, which would improve our understanding of contaminant attenuation with respect to depth. We believe this information may be useful when developing the Conceptual Site Model.

3. In Section 2.2.1, the Navy indicates their intent to use a PVC conductor casing if perched water or evidence of contamination is observed during borehole advancement. PVC does not appear to be the appropriate material for a standard conductor casing, and the Regulatory Agencies recommend using a steel conductor casing. If PVC is to be used, please explain how the conductor casing will be protected from damage during drilling operations.

4. Section 3.3.1.1 describes the procedures for installation of RHMW01R. Note that the procedure described from line 27 to 37 only addresses the installation of the well if conductor casing is not used (i.e. *"...the borehole will be reamed to total depth with a conventional, rotary drilling rig to increase the borehole diameter to a minimum of 8 inches..."*). This section does not describe the installation procedure if conductor casing is used. Please modify this section to describe the procedures to be used if conductor casing is deemed necessary.

5. Throughout the document, the Navy proposes the use of centralizers at 40-ft intervals for both the conductor casing and well casing. This seems to be a fairly large separation. The Regulatory Agencies recommend that the Navy consider reducing the separation to 20-ft intervals.

6. Section 3.4 appears to indicate that after well installation, *"[a]ll wells in the groundwater monitoring network will be resurveyed and their vertical alignment will be checked to see if corrections need to be made to account for any significant deviation."* Is this statement correct, or is the Navy's intent only to survey the newly installed well(s)?

Project Title: Monitoring Well Work Plan Addendum 01, Red Hill Bulk Fuel Storage Facility
Joint Base Pearl Harbor-Hickam, O‘ahu, HI
January 4, 2017; Revision 00
Reviewers: Bob Pallarino, U.S. Environmental Protection Agency, Red Hill Coordinator
Steven Chang, State of Hawai‘i Department of Health, Red Hill Coordinator
Date: February 3, 2017

Comment No.	Comment
Replacement Well OWDFMW01R	
—	The Regulatory Agencies believe it is questionable whether the gains of a replacement well for the existing OWDFMW01 will justify the cost. The Remedial Investigation Phase II-Red Hill Oily Waste Disposal Facility-Halawa, Oahu, Hawaii- Volume 1 Technical Report (EarthTech, 2000) details the drilling and installation of the basal monitoring wells in the Oily Waste Disposal Basin (OWDB). Pages 2-9 and 2-12 of that report provide a description of the five basal aquifer borings in the OWDB and Appendix C contains the geologic-bo1ing logs. For each well, groundwater was not encountered until significantly below the expected depth. Once groundwater was encountered it rose up in the borehole indicating confined conditions for all wells drilled in this area. The elevation where groundwater was first encountered varied from -20 to -1 ft. mean sea level (msl), well below the static water level of about +20 ft. msl. The top of screen elevation for OWDFMW01 is about +4 ft. msl, below the water table but above the confining layer. The solid rock of the confining layer is essentially a solid casing that extends below the water table preventing sampling formation water at an elevation equivalent to that of the potentiometric surface. The Regulatory Agencies believe that little will be gained in installing a new well to replace the existing OWDFMW01 until the extent of the confining layer is better defined. Ensuring that proper procedures are used when sampling from this well is likely a more suitable approach to collecting a sample that is representative of dissolved phase contamination in the groundwater in the vicinity of this former Superfund site.
Response: The Navy concurs with this assessment and has agreed in conjunction with the Regulatory Agencies that OWDFMW01 will not be replaced. Plans for its installation have been excluded from *Monitoring Well Installation Work Plan (MWIWP) Addendum 02*.	
Replacement Well RHMW01R	
1	As stated in our letter, the Regulatory Agencies strongly recommend the Navy uses at least a 2-inch well casing for the new monitoring well RHMW01R. While installing a 1-inch casing will still allow the Navy to adjust the screened interval of the well, there are many disadvantages to a 1-inch well casing. a. As is the case with existing well RHMW01, a 1-inch well is much slower to sample and more susceptible to blockage. b. It will be very difficult to get a true vertical depth to water since the well bore will be too narrow to accommodate the gyroscopic instrument that is necessary to measure deviations from vertical. c. A 1-inch well will continue the requirement to remove the downhole sampling pump for the monthly oil/water interface measurements. If the Navy finds that it is unable to install a well less than 2" in diameter, we request that the Regulatory Agencies are consulted prior to making any final decisions on how to proceed.

Comment No.	Comment

Response: The Navy recognizes the value of having a well with a diameter 2 inches or more. Provided field conditions described in *MWIWP Addendum 02* Section 2.3 are met, RHMW01R is proposed for installation as a 1.9-inch outer diameter multi-level well installed in an open-borehole with a diameter of 4.83 inches, from 10 ft above the water table to 300 ft below the water table.

If the prescribed field conditions are not met and RHMW01R requires installation as a screened water table well, then the current plans are to install a 4-inch-diameter well. However, if perched water or contamination is encountered during drilling, then conductor casing will be required to seal off those areas. The current drilling constraints (e.g., height and dimensions of the tunnel, ventilation, power source) limit the type of drilling rig that can be used. Consequently, the drilling options to create the required borehole diameter and depth in the subsurface rock units underlying the drill site are limited. If conductor casing is required, the Navy has explored different options and will plan to install a 2-inch-diameter well inside a 6-inch conductor casing. If drilling and well installation difficulties are encountered and a 2-inch-diameter well cannot be installed, the Navy will consult with the Regulatory Agencies prior to making any final decisions on how to proceed.

2	The Regulatory Agencies understand that existing well RHMW01 is screened from +12.61 to +2.61 ft. msl, and that the typical groundwater elevation is +19.54 ft. msl. Because the screen is submerged, we agree that samples collected from this well may not accurately represent the maximum concentrations typically found at the top of the groundwater table. Nevertheless, the Regulatory Agencies have no reason to believe that samples collected from RHMW01 are not adequately representative of groundwater from +12.61 to +2.61 ft. msl, and believe that these data may be useful in evaluating contaminant concentration with respect to depth. Because of this, the Regulatory Agencies recommend that RHMW01R be constructed with a screen interval extending from +27 to +12 ft. msl. This construction will allow RHMW01R and RHMW01 to act as a monitoring well pair, which would improve our understanding of contaminant attenuation with respect to depth. We believe this information may be useful when developing the Conceptual Site Model.

Response: Water level data from RHMW01 has ranged from 17.93 ft msl to 20.97 ft msl over an approximately 12-year period. Provided the field conditions described in *MWIWP Addendum 02* Section 2.3 are met, RHMW01R is proposed for installation as a multi-level well with up to seven zones isolated by a permanent packer system. Samples collected from the discrete zones will provide data that can be used to evaluate chemical concentrations at depth.

If the prescribed field conditions are not met and RHMW01R requires construction as a screened water table well, then the proposed well screen interval is 29.5–9.5 ft msl, as indicated in *MWIWP Addendum 02* Appendix C, Table C-1.

3	In Section 2.2.1, the Navy indicates their intent to use a PVC conductor casing if perched water or evidence of contamination is observed during borehole advancement. PVC does not appear to be the appropriate material for a standard conductor casing, and the Regulatory Agencies recommend using a steel conductor casing. If PVC is to be used, please explain how the conductor casing will be protected from damage during drilling operations.

Response: Provided the field conditions described in *MWIWP Addendum 02* Section 2.3 are met, the Navy proposes to install a 5-inch-diameter Schedule 40 low-carbon steel conductor casing to 10 ft above the water table, through which a multi-level well will be installed.

If the prescribed field conditions are not met and RHMW01R requires installation as a screened water table well, then 6-inch low carbon steel will be used as the conductor casing, as recommended in the comment.

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Steven Chang, State of Hawaiʻi Department of Health, Red Hill Coordinator
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Comment No.	Comment
4	Section 3.3.1.1 describes the procedures for installation of RHMW01R. Note that the procedure described from line 27 to 37 only addresses the installation of the well if conductor casing is not used (i.e. *"...the borehole will be reamed to total depth with a conventional, rotary drilling rig to increase the borehole diameter to a minimum of 8 inches..."*). This section does not describe the installation procedure if conductor casing is used. Please modify this section to describe the procedures to be used if conductor casing is deemed necessary.

Response: The text in *MWIWP Addendum 02* describes installation of a 5-inch-diameter Schedule 40 low-carbon steel conductor casing to 10 ft above the water table if no perched water or evidence of contamination and no significant (defined as 0.25-inch) thickness of LNAPL are encountered. If these conditions are not met, the well will be installed as a water table well.

The details regarding the installation of RHMW01R as a water table well are now described in Appendix C of the *MWIWP Addendum 02*, which includes details regarding conductor casing if needed. If no evidence of perched water or contamination is observed in the vadose zone but significant LNAPL thickness is encountered, the well will be installed without conductor casing as a 4-inch well with screen that brackets the water table. If perched water or evidence of contamination is encountered in the vadose zone, then 6-inch low carbon steel conductor casing will be required and a 2-inch well with screen that brackets the water table will be installed inside the conductor casing. Details regarding the installation of conductor casing are included in *MWIWP Addendum 02* Appendix C, Section 2.

Comment No.	Comment
5	Throughout the document, the Navy proposes the use of centralizers at 40-ft intervals for both the conductor casing and well casing. This seems to be a fairly large separation. The Regulatory Agencies recommend that the Navy consider reducing the separation to 20-ft intervals.

Response: The Navy concurs with the use of centralizers every 20 ft for the installation of small-diameter PVC pipe (2 inches or less), which is more flexible than larger-diameter pipe. However, if RHMW01R is installed as a multi-level well, low-carbon steel conductor casing will be installed to 10 ft above the water table, as described in Response to Comment No. 4. The proposed installation includes steel centralizers welded to the casing, and the Navy believes that spacing centralizers every 40 ft will be adequate for this installation.

If RHMW01R requires installation as a 2-inch diameter PVC screened well inside steel conductor casing, then the centralizer intervals will be 20 ft for the PVC well casing, as recommended in the comment. The outer steel conductor casing, however, will have welded low-carbon steel centralizers at 40-ft intervals.

Comment No.	Comment
6	Section 3.4 appears to indicate that after well installation, *"[a]ll wells in the groundwater monitoring network will be resurveyed and their vertical alignment will be checked to see if corrections need to be made to account for any significant deviation."* Is this statement correct, or is the Navy's intent only to survey the newly installed well(s)?

Response: The statement is correct. All existing wells in the Red Hill groundwater monitoring network have recently been resurveyed to address potential inconsistencies from previous surveys regarding the top of casing (TOC) datum, as indicated in Section 2.2 of *MWIWP Addendum 02*. All newly installed wells will be surveyed following the same procedures and datum reference benchmarks.

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