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

5750
Ser N4/ 0654
December 13, 2017

CERTIFIED NO: 7015 0640 0002 4677 9626

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

CERTIFIED NO: 7015 0640 0002 4677 9633

Ms. Roxanne Kwan
Hawaii State Department of Health
Environmental Management Division
Solid and Hazardous Waste Branch
2827 Waimano Home Road
Pearl City, HI 96782

Dear Mr. Pallarino and Ms. Kwan:

SUBJECT: ADMINISTRATIVE ORDER ON CONSENT STATEMENT OF WORK SECTION 6 AND SECTION 7 RISK-BASED DECISION CRITERIA AND SENTINEL NETWORK DEVELOPMENT PLANS, RED HILL BULK FUEL STORAGE FACILITY (RED HILL), JOINT BASE PEARL HARBOR-HICKAM, OAHU, HAWAII

The Risk-Based Decision Criteria and Sentinel Well Network Development Plans 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 are enclosed.

The Risk-Based Decision Criteria Development Plan (Enclosure 1) describes the development of risk-based decision criteria and evaluation of current site-specific risk-based levels (SSRBLs) for inclusion in AOC SOW Section 6 and Section 7 deliverables and subsequently, in an update to the Groundwater Protection Plan.

The Sentinel Well Network Development Plan (Enclosure 2) outlines the technical approach for evaluating and establishing a sentinel well network for existing drinking water production locations within the study area in order to provide early warning of potential impacts by chemicals of potential concern to drinking water production locations and monitor groundwater flow to help ensure potential contamination are adequately contained, if needed.

5750
Ser N4/0654
December 13, 2017

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

Enclosures: 1. Risk-Based Decision Criteria Development Plan, Red Hill Bulk Storage Facility, Joint Base Pearl Harbor-Hickam, Oahu, December 11, 2017
2. Sentinel Well Network Development Plan, Red Hill Bulk Storage Facility, Joint Base Pearl Harbor-Hickam, Oahu, December 11, 2017

Red Hill Administrative Order on Consent,
Sentinel Well Network Development Plan 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: 12 DEC 2017

Sentinel Well Network Development Plan, Investigation and Remediation of Releases and Groundwater Protection and Evaluation, Red Hill Bulk Fuel Storage Facility

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

Administrative Order on Consent in the Matter of Red Hill Bulk Fuel Storage Facility, EPA Docket Number RCRA 7003-R9-2015-01 and DOH Docket Number 15-UST-EA-01, Attachment A, Statement of Work Section 6.2, Section 7.1.2, Section 7.2.2, and Section 7.3.2

December 11, 2017
Revision 00

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

This page intentionally left blank

Sentinel Well Network Development Plan, Investigation and Remediation of Releases and Groundwater Protection and Evaluation, Red Hill Bulk Fuel Storage Facility

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

Administrative Order on Consent in the Matter of Red Hill Bulk Fuel Storage Facility, EPA Docket Number RCRA 7003-R9-2015-01 and DOH Docket Number 15-UST-EA-01, Attachment A, Statement of Work Section 6.2, Section 7.1.2, Section 7.2.2, and Section 7.3.2

December 11, 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

This page intentionally left blank

CONTENTS

FIGURES

This page intentionally left blank

ACRONYMS AND ABBREVIATIONS

µg	microgram
AOC	Administrative Order on Consent
BWS	Board of Water Supply, City and County of Honolulu
CF&T	contaminant fate and transport
CLEAN	Comprehensive Long-Term Environmental Action Navy
COPC	chemical of potential concern
CSM	conceptual site model
CTO	contract task order
DLA	Defense Logistics Agency
DOH	Department of Health, State of Hawai‘i
DON	Department of the Navy, United States
EPA	Environmental Protection Agency, United States
ft	foot/feet
g	gram
gal	gallon
GWPP	Groundwater Protection Plan
JBPHH	Joint Base Pearl Harbor-Hickam
JP	Jet Fuel Propellant
L	liter
msl	mean sea level
NAPL	non-aqueous-phase liquid
NATO	North Atlantic Treaty Organization
NAVFAC	Naval Facilities Engineering Command
OSHA	Occupational Safety and Health Administration
RBDC	risk-based decision criteria
RCRA	Resource Conservation and Recovery Act
SOW	scope of work
SSRBL	Site-Specific Risk-Based Level
TPH	total petroleum hydrocarbons
WP	work plan

This page intentionally left blank

1. Introduction

This document presents the plan for evaluating and establishing a sentinel monitoring well network (groundwater monitoring wells and potentially soil vapor wells or vapor monitoring using remote sensing techniques [e.g., thermal imaging, multi-spectral imaging]) for protecting existing water production wells for drinking water ingestion and domestic use, as well as other potential receptors in the study area of the Investigation and Remediation of Releases and Groundwater Protection and Evaluation project at the Red Hill Bulk Fuel Storage Facility ("the Facility") at Joint Base Pearl Harbor-Hickam (JBPHH), Hawai'i. The drinking water production wells in the vicinity of Red Hill include both infiltration galleries (Red Hill Shaft and Hālawa Shaft) and water supply wells (Moanalua Wells). The sentinel monitoring wells will be designed to 1) provide an early warning of potential impacts by chemicals of potential concern (COPCs) to the drinking water production wells, 2) have concentration criteria (updated Site-Specific Risk-Based Levels [SSRBLs]) that will protect drinking/domestic water use, and 3) evaluate groundwater flow gradients to help ensure potential plumes are adequately captured, if needed. The Facility is owned and operated by the United States (U.S.) Navy (DON; Navy) and is funded by Defense Logistics Agency (DLA).

The project *Work Plan / Scope of Work* (WP/SOW) (DON 2017a) presents the process, tasks, and deliverables that address the goals and requirements of Statement of Work Sections 6 and 7 of the *Administrative Order on Consent* (AOC) *In the Matter of Red Hill Bulk Fuel Storage Facility* (EPA Docket No: RCRA 7003-R9-2015-01; DOH Docket No: 15-UST-EA-01). The AOC was issued by the U.S. Environmental Protection Agency (EPA) Region 9 and State of Hawai'i Department of Health (DOH) (EPA Region 9 and DOH 2015) to the Navy/DLA in response to a release of an estimated 27,000 gallons of Jet Fuel Propellant (JP)-8 from one of the Facility's 12.5-million-gallon underground fuel storage tanks (Tank 5) that was confirmed and reported to DOH on January 23, 2014. The bottoms of the Facility's 20 tanks are located approximately 100 feet (ft) above a major groundwater aquifer, which is used to supply both Navy and the City and County of Honolulu drinking water sources.

The planning activities described in the project WP/SOW (DON 2017a) include the preparation of nine documents (including this *Sentinel Well Network Development Plan*), referred to as derivative deliverables, that address specific aspects of the planning process. The flowchart presented on Figure 1 shows the sequencing of the derivative deliverables, and further detail is provided in the WP/SOW. The Facility and vicinity are shown on Figure 2.

This *Sentinel Well Network Development Plan* was prepared for DLA through Naval Facilities Engineering Command (NAVFAC) Hawaii under contract number (no.) N62742-12-D-1829, contract task order (CTO) no. 0053 of the Comprehensive Long-Term Environmental Action Navy (CLEAN) IV program.

1.1 PURPOSE

This plan describes the approach for evaluating and establishing a sentinel monitoring well network for existing drinking water production well locations in the vicinity of the Facility to provide an early warning system of potential impacts from the Facility to protect drinking water receptors. (as stated in the January 4, 2017 WP/SOW; DON 2017a). This plan outlines the process for the identification, evaluation, and selection of wells for the Sentinel Well Network Program, and outlays a general strategy for implementation of the program.

1.2 OBJECTIVE

The overall objective of the Sentinel Well Network Program is to establish a network of monitoring wells that provides an early warning system of potential impacts from the Facility to protect drinking water and other receptors. Specifically, the sentinel monitoring well network will be used to accomplish two primary objectives:

1. Demonstrate that a capture zone is maintained that will contain COPCs, if needed.
2. Evaluate COPC concentrations upgradient from drinking water production wells to determine the need for additional contingency action (e.g., further evaluation, more frequent monitoring, treatment) to protect the water supply, as described in Section 2.7.

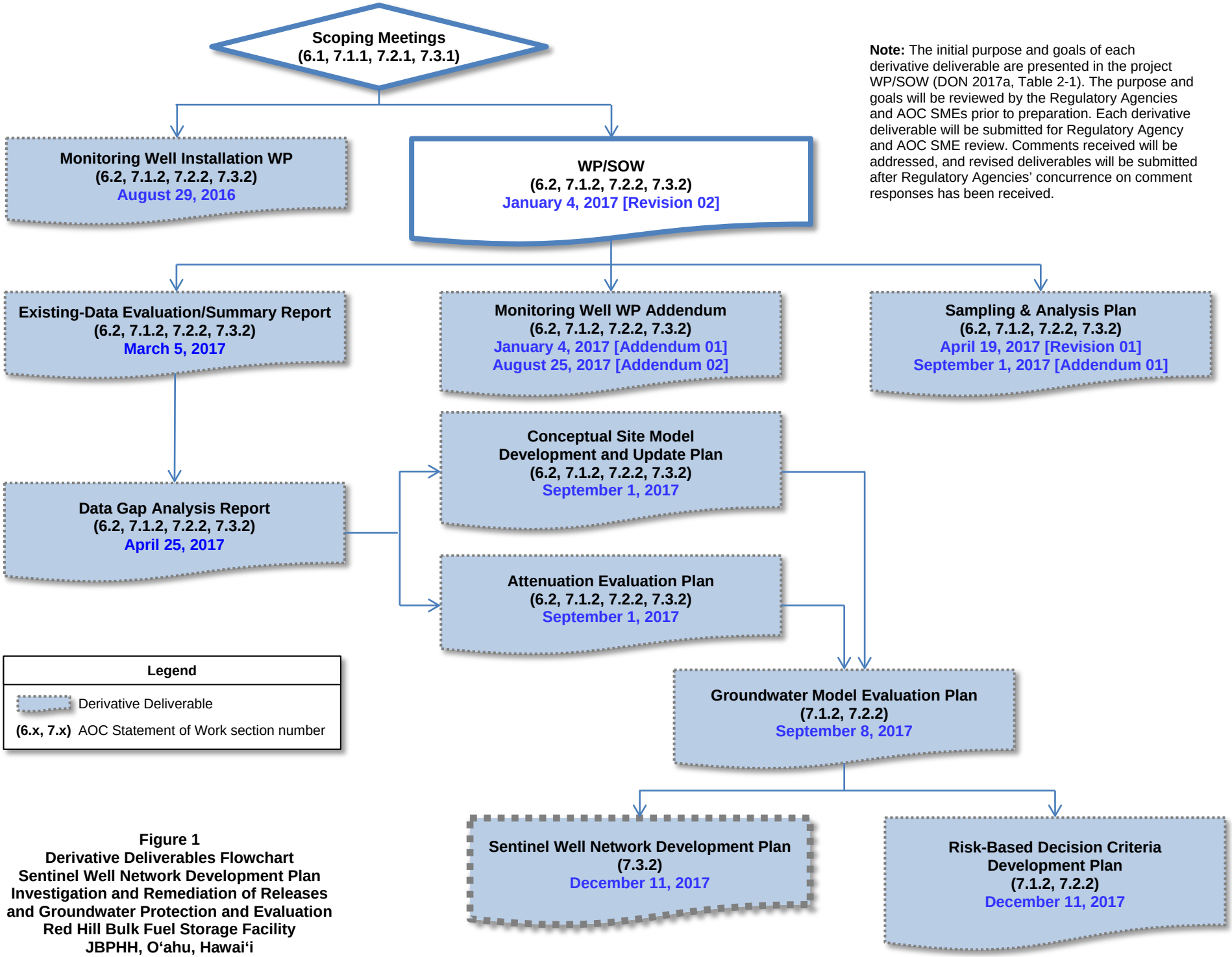
A description of the sentinel monitoring well network will be presented in the forthcoming *Groundwater Monitoring Well Network Report*. Following Regulatory approval of the report and subsequent *Groundwater Monitoring Well Decision Document*, the network will be incorporated in the Red Hill *Groundwater Protection Plan* [GWPP] *Update,* as indicated on the Figure 3 AOC Statement of Work Sections 6 and 7 flowchart.

2. Inputs for Development of Sentinel Monitoring Well Network

Information sources that will have direct or supporting information relevant to the development of the sentinel monitoring well network may include but are not limited to the following:

- Facility information
- Fuel types
- Risk-based decision criteria (RBDC)
- Potential exposure receptors
- Conceptual site model (CSM)
  - Vadose zone
  - Saturated zone
  - Analytical groundwater data
  - Nature and extent of COPCs
  - Attenuation
- Groundwater flow modeling, particle tracking/contaminant capture zone analysis
- Contaminant fate and transport (CF&T) modeling (will be integrated into the final sentinel monitoring well network but will not be used as part of interim decisions)
- Groundwater (and potentially soil vapor) analytical data
- Mass flux analyses

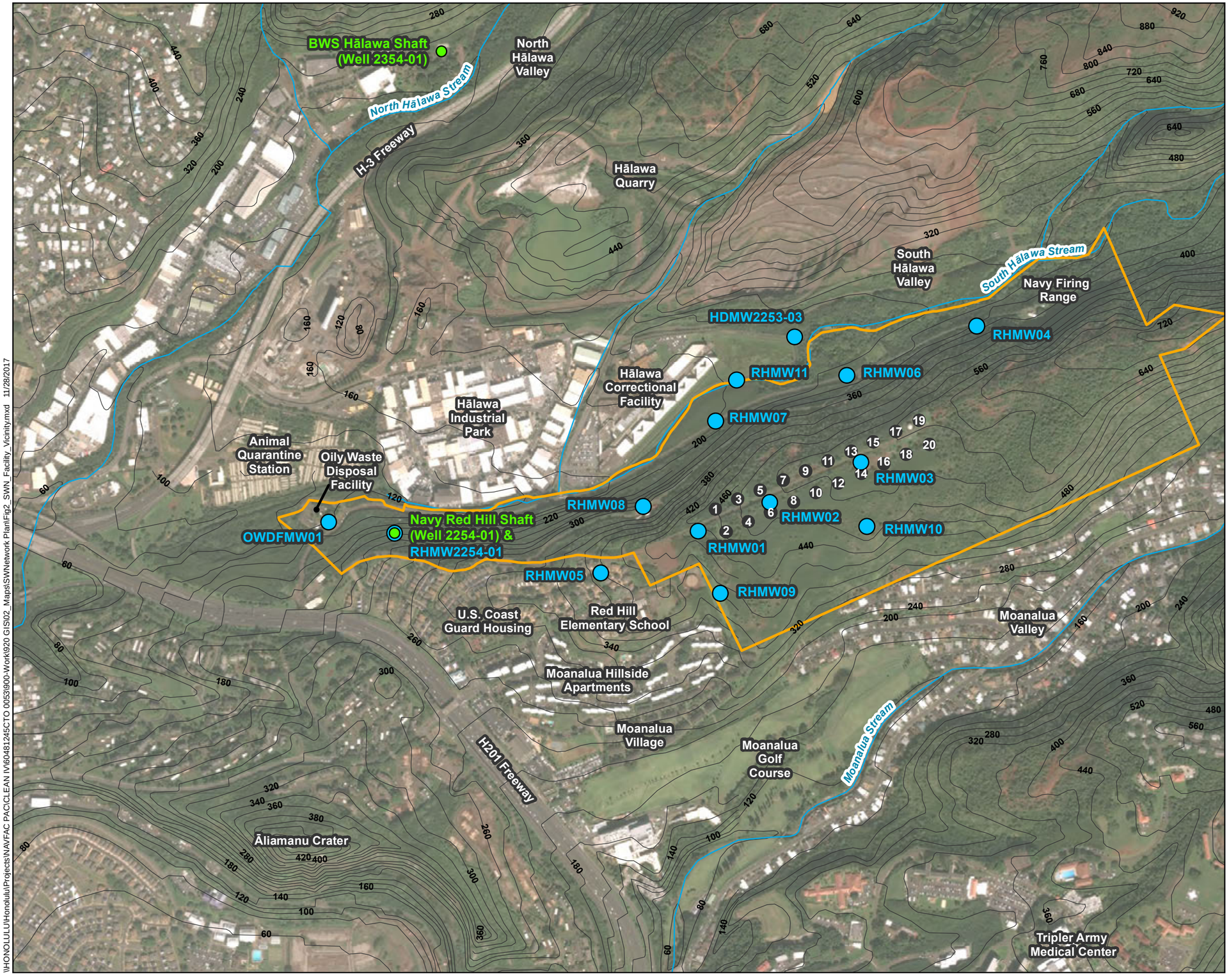
These inputs will be used to support development of the forthcoming *Groundwater Monitoring Well Network Report*. Each of these inputs is further described in the following subsections.



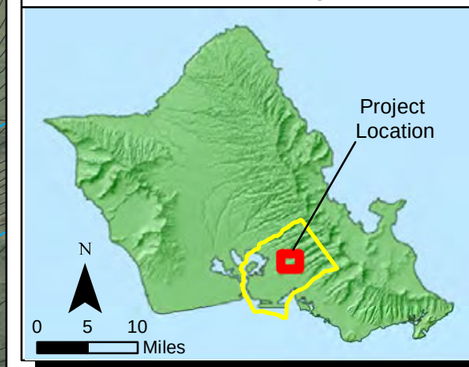
Note: The initial purpose and goals of each derivative deliverable are presented in the project WP/SOW (DON 2017a, Table 2-1). The purpose and goals will be reviewed by the Regulatory Agencies and AOC SMEs prior to preparation. Each derivative deliverable will be submitted for Regulatory Agency and AOC SME review. Comments received will be addressed, and revised deliverables will be submitted after Regulatory Agencies' concurrence on comment responses has been received.

Figure 1
Derivative Deliverables Flowchart
Sentinel Well Network Development Plan
Investigation and Remediation of Releases
and Groundwater Protection and Evaluation
Red Hill Bulk Fuel Storage Facility
JBPHH, O'ahu, Hawai'i

This page intentionally left blank



Location Map



Legend

- Red Hill Installation Boundary
- Existing Monitoring Well Location
- Existing Water Supply Well
- Stream
- 400 — Topographic Contour (feet above mean sea level)
- Red Hill Fuel Storage Tank
- Groundwater Model Area

Notes

1. Map projection: NAD 1983 UTM Zone 4N
2. Base Map: DigitalGlobe, Inc. (DG) and NRCS. Publication_Date: 2015

N

0 1,000 2,000 Feet

Figure 2
Red Hill Bulk Fuel Storage Facility and Vicinity
Sentinel Well Network Development Plan
Investigation and Remediation of Releases and Groundwater Protection and Evaluation
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\SWNetwork Plan\Fig2_SWN_Facility_Vicinity.mxd 11/28/2017

This page intentionally left blank

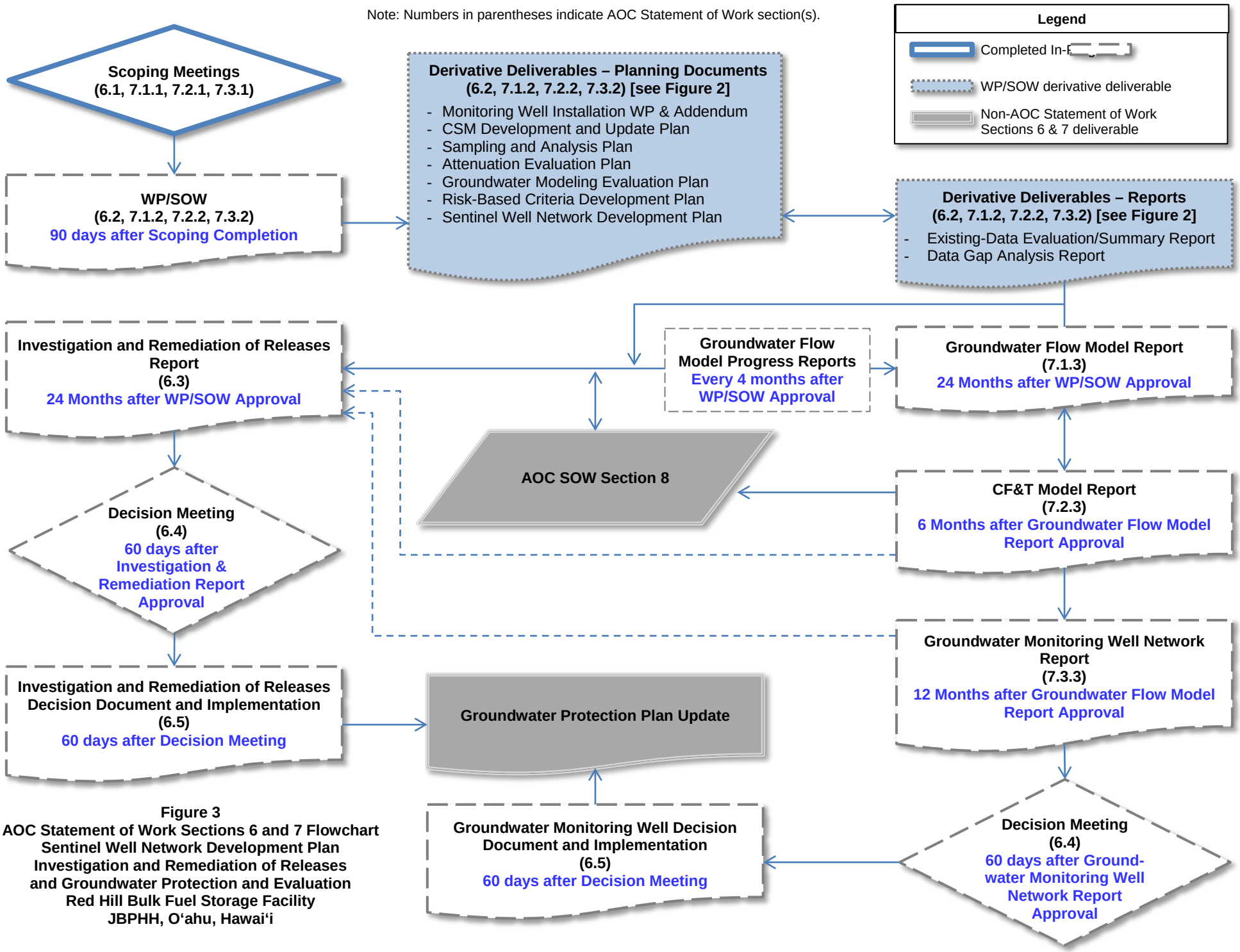


Figure 3
AOC Statement of Work Sections 6 and 7 Flowchart
Sentinel Well Network Development Plan
Investigation and Remediation of Releases and Groundwater Protection and Evaluation
Red Hill Bulk Fuel Storage Facility
JBPHH, O'ahu, Hawai'i

This page intentionally left blank

2.1 FACILITY INFORMATION

The Facility is located on Federal government land (zoned a mix of F-1 Military and Federal and P-1 Restricted Conservation) in south-central O'ahu, approximately 2.5 miles northeast of Pearl Harbor. It is located on a low ridge on the western edge of the Ko'olau Mountain Range that divides Hālawa Valley from Moanalua Valley. The Facility is bordered on the north by Hālawa Correctional Facility and private businesses, on the southwest by the U.S. Coast Guard reservation, on the south by residential neighborhoods, and on the east by Moanalua Valley and conservation land. The Hālawa Quarry is located less than a quarter mile away to the northwest. The Facility occupies 144 acres of land, and the majority of the site surface is at an elevation of approximately 200–500 ft above mean sea level (msl).

The Facility currently contains 18 active and 2 inactive underground fuel storage tanks that are operated by the Navy. Each tank measures approximately 250 ft in height and 100 ft in diameter and has a capacity of approximately 12.5 million gallons. The tanks are constructed of steel-lined concrete and currently contain Jet Fuel Propellant (JP)-5, NATO-grade F-24 jet fuel, and Marine Diesel Fuel (F-76).

The upper domes of the tanks are 100–200 ft below ground surface (bgs), and the lower domes of the tanks are at least 100 ft above the basal aquifer, which is located at approximately 18–20 ft msl. The tanks are connected by upper and lower access tunnels, which contain light rail systems, water and electrical utilities, ventilation systems, and fuel pipelines. In the lower tunnel, each tank is connected by a short access tunnel, which branches off from the main service tunnel and terminates at a "face-wall" under each tank. Ancillary piping extends from each face-wall to connect to the fuel transmission lines, which run approximately 2.5 miles from the Facility to a JBPHH fuel pumping station at Pearl Harbor.

Within the lower tunnel system, NAVFAC Hawaii, Utilities and Energy Division, operates a potable water pumping station at Navy Supply Well 2254-01.

2.2 FUEL TYPES

Kerosene-based jet fuels stored at the facility have included JP-5, JP-8, and F-24. In addition, F-76 is a marine diesel fuel that is also stored at the Facility. In January 2014, the Navy reported that JP-8 fuel was released from Tank 5. Although these jet fuels are all kerosene-based, the fuel's exact composition of aliphatic and aromatic hydrocarbons will vary depending on the crude oil source used to refine the fuels (ATSDR 2017). The *Attenuation Evaluation Plan* (DON 2017b) outlines planned source studies on the fuels involving detailed hydrocarbon analysis and carbon fractionation analysis. The insight into compositional changes in the fuel may inform some elements of the CSM within both the vadose zone and the saturated zone.

2.3 RISK-BASED DECISION CRITERIA DEVELOPMENT PLAN

The process for establishing RBDC for water supply wells and SSRBLs for specific monitoring wells is described in the *RBDC Development Plan* (DON 2017d). The general goals of that plan include the following:

- Evaluate site risk to tap (potable/domestic) water users
- Support Section 6 and Section 7 of the AOC Statement of Work
  - Section 6: Investigation and Remediation of Releases

- Section 7: Groundwater Protection and Evaluation

- Develop site-specific RBDC that will be applied to the drinking water tap
  - Consistent with applicable Regulatory guidance and project-specific agreements
  - COPCs with established Regulatory criteria
  - Modify COPC screening criteria that do not have established Regulatory criteria (e.g., total petroleum hydrocarbons) as appropriate to develop site-specific levels

The RBDC are criteria that are not to be exceeded at the drinking water tap. The RBDC will either consist of currently established Regulatory screening criteria or be developed for COPCs that do not have current established Regulatory screening criteria.

The RBDC will be used along with mass flux of COPCs in groundwater to tap water receptors to establish SSRBLs for sentry wells to ensure that drinking water is protected at the tap. Individual SSRBLs will be established for each sentry well. The SSRBL will account for mass flux and COPC concentration at the well, as described in Section 2.7. The SSRBL will be used as an indicator (early warning system) that additional contingency action (e.g., further evaluation, more frequent monitoring, treatment) is needed to prevent COPC concentrations at the drinking water tap from exceeding the RBDC if the SSRBL is exceeded.

2.4 POTENTIAL EXPOSURE RECEPTORS

Water supply well locations and potential receptors and exposure pathways are discussed below.

2.4.1 Water Supply Well Locations

Water supply wells near the Facility have been identified as transport mechanisms in potentially complete exposure pathways, as reported in the *RBDC Development Plan* (DON 2017d). Currently, it is presumed that the Navy's Red Hill Shaft and the City and County of Honolulu Board of Water Supply (BWS) municipal water supply wells Hālawa Shaft and Moanalua Wells represent the most significant pathways to human receptors due to their known or suspected pumping influence on the aquifer beneath the Facility, the size of their drinking water distribution system(s), and location relative to potential downgradient groundwater flow direction in the vicinity of the Facility. Additional detail is presented in the *Groundwater Model Evaluation Plan* (DON 2017c).

2.4.2 Identified Potential Receptors

Potential exposure to human receptors for ingestion, dermal contact, and inhalation via the groundwater-to-potable water pathway is currently the only potentially complete exposure route for residents (Figure 4). The basis for the development of the Sentinel Well Network Program is primarily oriented around this exposure pathway, i.e., focusing on protection of drinking/domestic water ending at residential taps.

Contributing Source	Transport Mechanism & Exposure Medium	Exposure Route*	Receptors			
			Resident (Adult/Child)	Onsite Occupational Worker	Onsite Construction Worker	Onsite Visitor
Releases from Red Hill Fuel Storage Tanks						
Surface Soil	Direct Contact with Surface Soil	Ingestion:	Incomplete	Incomplete	Incomplete	Incomplete
		Dermal:	Incomplete	Incomplete	Incomplete	Incomplete
Subsurface Soil	Direct Contact with Subsurface Soil	Ingestion:	Incomplete	Incomplete	**Potentially Complete**[1]	Incomplete
		Dermal:	Incomplete	Incomplete	**Potentially Complete**[1]	Incomplete
	Volatilization & Dispersion to Tunnel Air	Inhalation:	Incomplete	**Potentially Complete**[1]	**Potentially Complete**[1]	**Potentially Complete**[1]
	Infiltration to Groundwater	Ingestion:	**Potentially Complete**	**Potentially Complete**[1]	Incomplete	Incomplete
		Dermal:	**Potentially Complete**	**Potentially Complete**[1]	Incomplete	Incomplete
		Inhalation (Bathing/Showering):	**Potentially Complete**	Incomplete	Incomplete	Incomplete
		Inhalation/ Vapor Intrusion:	Insignificant	Insignificant	Insignificant	Insignificant
	Groundwater Discharge to Surface Water	All Pathways:	Incomplete	Incomplete	Incomplete	Incomplete
	Use of Groundwater for Irrigation	All Pathways:	Insignificant	Incomplete	Incomplete	Incomplete

Red outlined cells indicate pathways that are relevant to the Risk-Based Decision Criteria (RBDC) development.

[1] Other Potentially Complete pathways do not warrant RBDC:

- Although unlikely, releases inside the tunnel could affect soil that could be accessed by a construction/utility worker in an excavation/trench.
- Potential exposure to soil gas from fuel system releases assumed to be covered under the Navy's OSHA programs.
- The Fuel Storage Facility uses the public water supply. RBDC for residents would also protect workers.

Figure 4
Human Health Exposure Pathway Evaluation for Groundwater

This page intentionally left blank

The *RBDC Development Plan* outlines the process for evaluating risk and deriving RBDC for the water supply wells (DON 2017d). The *RBDC Development Plan* has detailed the current exposure routes and receptors associated with potentially contaminated groundwater, identified based on various factors:

- Contaminant source (release from Facility fuel storage tanks)
- Contaminated media (groundwater)
- Chemical migration pathways (groundwater flow)
- Exposure pathways (ingestion, dermal contact, inhalation)
- Current and future human receptors (offsite residents)

2.4.3 Pathways Incorporated into RBDC Development Plan

Human exposure to drinking water via groundwater intake to water supply wells and their distribution system is the primary potentially complete exposure pathway. Other pathways recognized in the CSM (direct exposure to soil, inhalation of soil gas, vapor intrusion, exposure via garden irrigation, exposure to golf course irrigation water) were identified as insignificant or incomplete exposure pathways compared to exposure to tap water. The identification as insignificant or incomplete for these other exposure pathways was based on the following:

- Although unlikely, releases inside the tunnel could affect soil that could be accessed by a construction/utility worker in an excavation/trench.
- Potential exposure to soil gas from fuel system releases assumed to be covered under the Navy's Occupational Safety and Health Administration (OSHA) programs.
- The Facility uses the public water supply, and RBDC for residents would also protect workers.
- The nearest golf course with an irrigation well is located approximately 1 mile southwest of the tank farm, and COPC concentrations potentially affecting this well will be detected by the sentry well network.

Water supply wells near the Facility are transport mechanisms in potentially complete groundwater exposure pathways. Water supply wells near the Facility are discussed in Section 2.4.1.

2.5 COMPREHENSIVE CSM

The *CSM Development and Update Plan* (DON 2017d) was prepared to describe the evaluation of contaminant transport pathways and the potential for exposure of human and ecological receptors in support of the current Facility investigation**.** The CSM is currently under development and will be a central tool to provide data and conceptual insights to support the process for the sentinel monitoring well network development. The processes currently under evaluation and analysis include the following:

- Physical geologic and hydrogeologic nature of materials surrounding the Facility tanks and within the model boundaries
- Pathways and barriers to fuel migration
- Fuel and COPC sources in the model domain

- Fuel properties (e.g., effective solubility, Henry's Law constant, vapor pressure, density) and calculated/estimated volatilization and dissolution
- Weathering and biodegradation of both non-aqueous-phase liquid (NAPL) and dissolved-phase COPCs, and differentiating total petroleum hydrocarbons (TPH) using indicator compounds
- Vadose zone moisture content and groundwater recharge
- Groundwater levels, groundwater flow gradients, and flow directions
- Water-transmitting and storage properties of basalt aquifers, variably saturated zones, and aquitards
- Effects of pumping and capture zone analysis
- Spatial and temporal distribution of COPCs in groundwater
- Natural attenuation
- Fate and transport of dissolved COPCs
- Soil vapor data (primary COPCs and biodegradation products carbon dioxide, oxygen, and methane)
- Temperature data in the vadose zone due to NAPL biodegradation
- Potential exposure routes to receptors

2.6 GROUNDWATER MODEL

The groundwater flow and CF&T models and the CSM play a critical role in evaluating proposed sentinel monitoring wells. Of primary importance to the function of sentinel monitoring wells is definition of groundwater flow paths, determination of groundwater flow gradients, and determination of COPC concentrations. Developed and verified models will provide a means to assess transport of potential COPCs and the fate of COPCs in terms of the attenuation processes and mass flux. Details of the modeling are provided in the *Groundwater Model Evaluation Plan* (DON 2017c).

2.7 CAPTURE ZONE ANALYSIS

As noted in Section 1.2, a key of objective of the Sentinel Well Network Program is to monitor the effectiveness of a capture zone that extends outward from the Facility capable of adequately containing potential contamination from inadvertent fuel releases of varying magnitudes and rates. The purpose of establishing the capture zone is to:

- Protect Hālawa Shaft.
- Protect wells in Moanalua Valley.
- Protect the aquifer outside of the capture zone.
- Allow other water supply wells to continue operation.

Optimal pumping rates for maintaining a capture zone can be determined while also allowing for continued operation of Hālawa Shaft and Moanalua Wells. Sentinel groundwater monitoring wells will be used to monitor and evaluate degree of capture (i.e., groundwater flow gradients), and assess if potential contamination from inadvertent fuel releases from the Facility is adequately contained.

Figure 5 presents a hypothetical capture zone based on a network of sentinel monitoring wells and the groundwater flow model. The groundwater flow model including particle tracking model will be used for analysis.

Sentinel monitoring wells will have established SSRBLs based on an integration of the RBDC described in the *RBDC Development Plan* (Section 2.3) combined with a back-calculation of concentrations at the exposure point (tap water) that can be determined based on mass flux and plume concentration, as noted in the following:

$$C_{rhsw} = \frac{\text{Mass Flux / Mass Discharge}}{(M_d/Q_{rhs})Cf}$$

where:

- C_{rhsw} concentration of contaminant "x" in Red Hill Shaft water (parts per billion)
- M_d mass discharge (grams per day)
- Q_{rhs} flow rate of Red Hill Shaft necessary to achieve capture
- CF conversion factor (184 micrograms per gallon per day [µg-gal-day] / grams per liter per day [g-L-day])

An individual SSRBL will be established for each sentry well. The SSRBL will provide an early warning system that, if the SSRBL is exceeded, indicates that additional contingency action (e.g., further evaluation, more frequent monitoring, treatment) is needed to prevent COPC concentrations at the drinking water tap from exceeding the RBDC. Details on additional action to be taken will be provided in a forthcoming Red Hill GWPP Update (DON 2014).

3. Identification, Evaluation, and Selection of Sentinel Monitoring Wells

This section describes the process to identify, evaluate, and select sentinel monitoring wells. Two primary functions of the sentinel monitoring well network are anticipated: 1) hydraulic head/groundwater flow gradients to provide confirmation that the capture zone developed during the capture zone analysis described in Section 2.7 is effective, and 2) effective monitoring of SSRBL concentrations of the selected COPCs. A chart of the overall process is presented on Figure 6.

The proposed process to identify, evaluate, and select sentinel monitoring locations includes:

1. Identify sentinel monitoring wells
2. Screen against identified criteria
3. Qualitatively rank based on criteria
4. Select sentinel monitoring wells

3.1 IDENTIFICATION OF SENTINEL MONITORING WELLS

The initial selection of sentinel monitoring wells will consider a broad spectrum of all potential locations, including:

- All Red Hill groundwater monitoring wells currently in the monitoring well network
- Future wells that are added to the Red Hill monitoring network
- Water supply and observation wells and/or shafts where there is access

- Specific levels or intervals within multi-level wells currently being installed at the site or adjacent to the site

3.2 EVALUATION CRITERIA FOR SENTINEL MONITORING WELLS

The final groundwater flow model and CF&T model along with the comprehensive CSM for the site will provide key tools to evaluate the criteria and will provide documentation of the overall process during the decision phase of the sentinel planning. The interim model and initial Sentinel Well Network Program will not directly consider contaminant attenuation as part of fate and transport, since this will be done at a later time. The criteria for selection of sentinel monitoring wells are divided into primary and secondary criteria. The primary criteria are based on central functions of the sentinel monitoring wells and will be weighted heavier during the evaluation process. Secondary criteria are important factors to be considered during the evaluation. The proposed criteria are presented below:

Primary Criteria

- Horizontal and vertical location of the well and screen interval
- Gradient relationship to source and receptors
- Suitability based on groundwater flow paths and plume capture analysis
- Ability to determine if releases are emanating from different parts of the Facility
- Integration with RBDC

Secondary Criteria

- Well construction
- Historical detection of COPCs
- General water chemistry
- Proximity to groundwater barriers and boundary conditions

Each of the above criteria is detailed below.

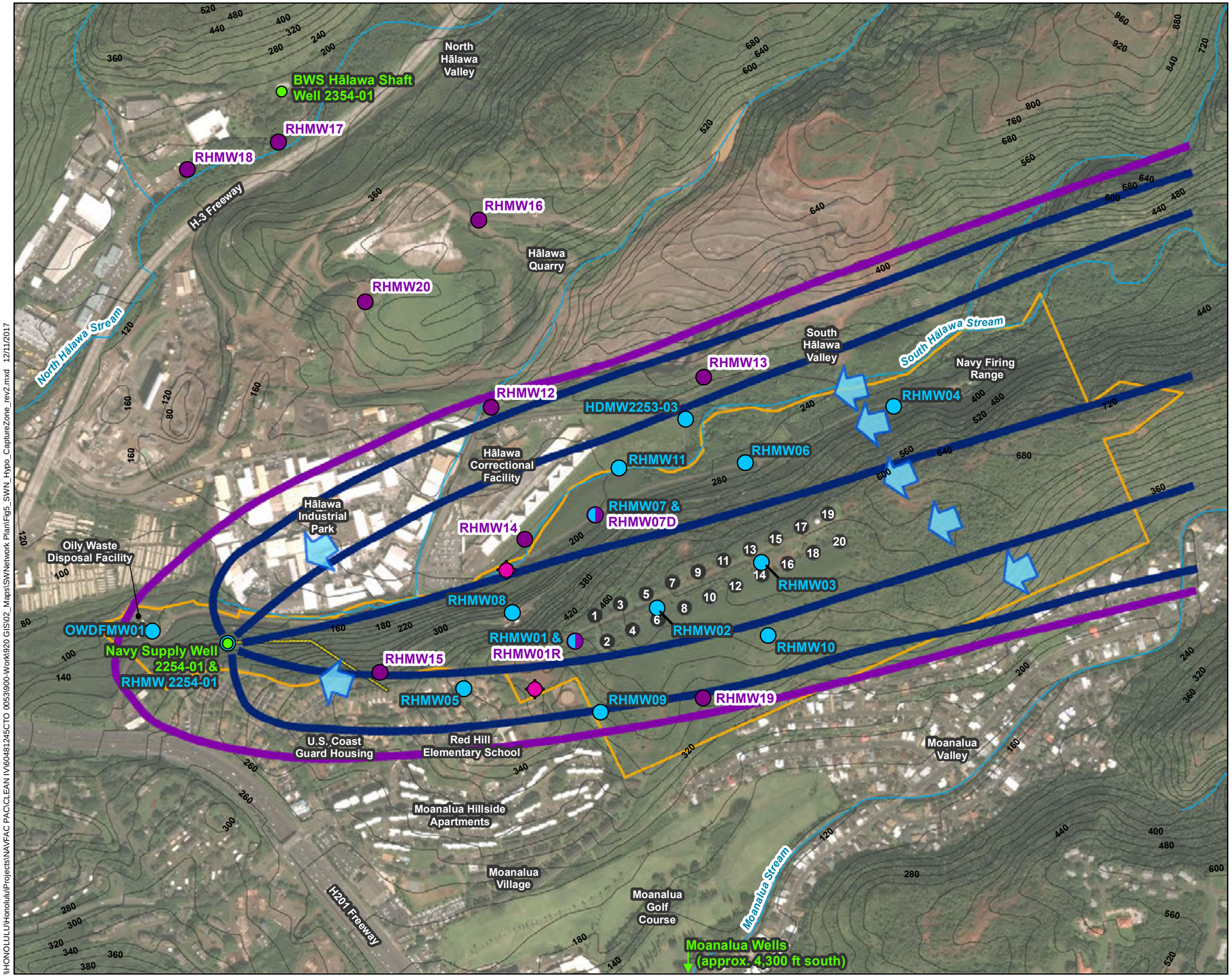
3.2.1 Primary Criteria

As stated above, the primary criteria are based on central functions of the sentinel monitoring wells and will be weighted heavier during the evaluation process. The criteria are based on the spatial and hydraulic relationship to both potential receptors and source areas.

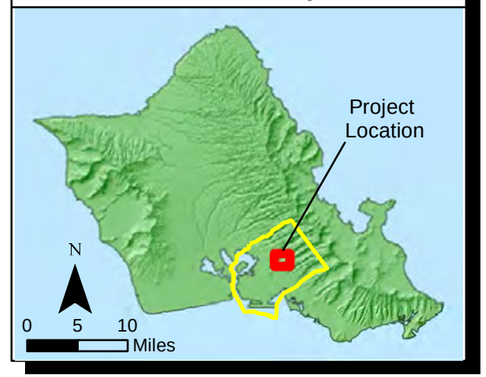
3.2.1.1 HORIZONTAL AND VERTICAL LOCATION OF PROPOSED SENTINEL MONITORING WELLS

The location of the proposed sentinel monitoring wells is of primary importance to the overall evaluation of the monitoring wells. Horizontal locations will be evaluated in terms of proximity to both source and receptors (i.e., potable supply wells), with the objective of positioning sentinel monitoring wells at a variety of distances between potential sources and water supply wells.

Within the existing and proposed future wells, the vertical location of well screen intervals and port sample depths in multi-level wells will be of particular importance, since evaluation of subsurface hydrogeologic units within the CSM may suggest preferable pathways for groundwater flow, such as clinker beds and fracture zones.



Location Map



Legend

- Existing Monitoring Well Location
- Proposed Monitoring Well Location
- Adjacent Existing and Proposed Monitoring Well Locations
- Potential New Sentinel Monitoring Well
- Existing Water Supply Well
- 2254-01 Infiltration Gallery
- Red Hill Fuel Storage Tank
- Flow Direction
- Particle Flow Path in Groundwater (to be estimated during interim modeling)
- Hypothetical Capture Zone (will be determined based on particle flow paths)
- Stream
- Topographic Contour (feet above mean sea level)
- Red Hill Installation Boundary
- Groundwater Model Area

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. A sentinel monitoring well could be identified as an existing well or as a newly proposed monitoring well contingent on results of modeling efforts.

N

0 500 1,000 2,000 Feet

Figure 5
Hypothetical Capture Zone
Near Red Hill Bulk Fuel Storage Facility
Sentinel Well Network Development Plan
Red Hill Bulk Fuel Storage Facility
JBPHH, O'ahu, Hawai'i

\\HONOLULU\Honolulu\Projects\NAVFAC PAC\CLEAN IV\60481245\CTO 0053\900-Work\920 GIS\02_Maps\SWNetwork Plan\Fig5_SWN_Hypo_CaptureZone_rev2.mxd 12/11/2017

This page intentionally left blank

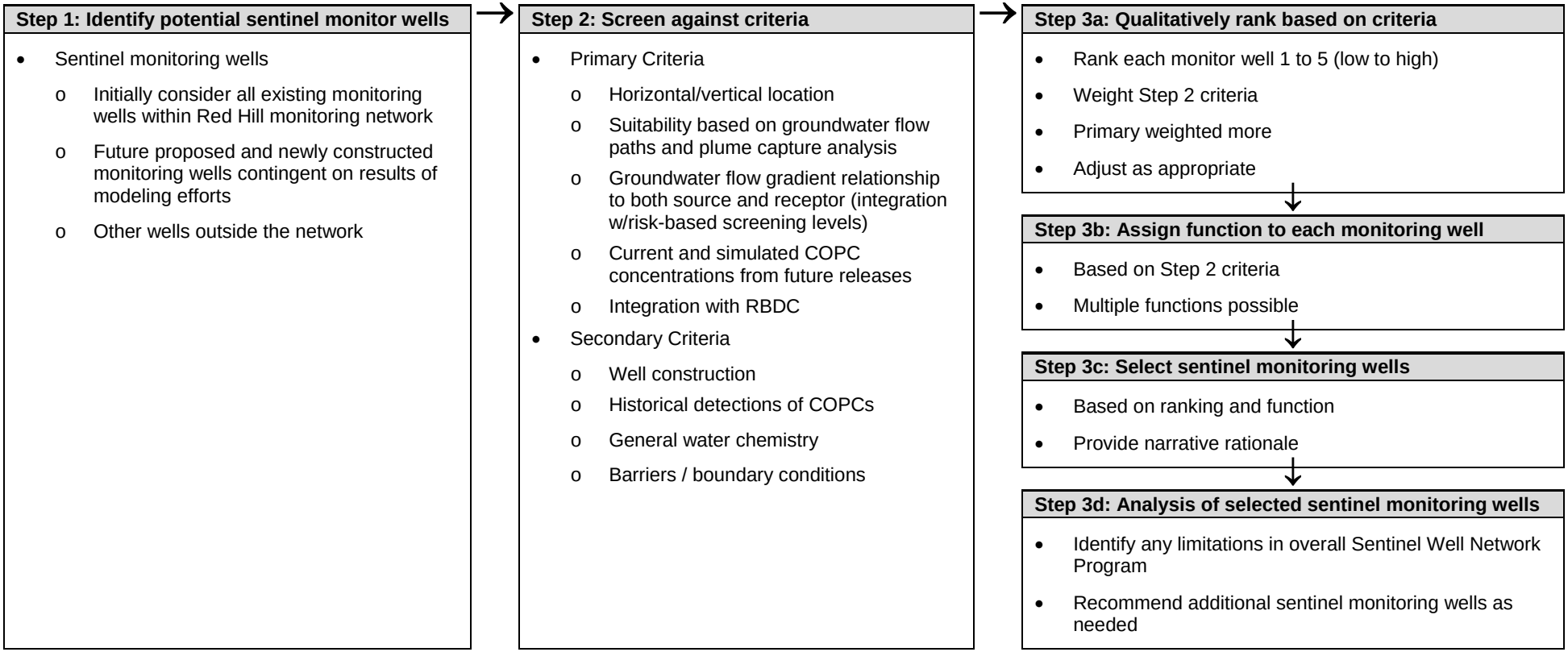


Figure 6
Process for Identifying, Evaluating, and Selecting Sentinel Monitoring Wells

This page intentionally left blank

Since the COPCs at the site are associated with petroleum hydrocarbons, the focus of monitoring will be at and near the water table.

3.2.1.2 Gradient Relationship to Source and Receptors

Closely related to the horizontal and vertical location of the sentinel monitoring well is the groundwater flow gradient relationship to the source and potentially impacted water wells. Both the horizontal and vertical gradients in and around potential sentinel monitoring wells will need to be considered. Strong sentinel monitoring well candidates will have consistent demonstrable relationships between upgradient source areas and downgradient water wells.

3.2.1.3 Suitability Based on Groundwater Flow Paths and Plume Capture Analysis

Based on the capture zone approach described in Section 2.7, sentinel monitoring wells will be selected to monitor and evaluate degree of capture (i.e., groundwater flow gradients), and assess if potential contamination from inadvertent fuel releases from the Facility is adequately contained. This function is more aligned with the hydraulic head/groundwater flow gradients described earlier, and the groundwater flow and CF&T models will be integral to this evaluation.

3.2.1.4 Current and Simulated COPC Concentrations from Potential Future Releases

The record of detections within an existing proposed sentinel monitoring well in the network is a key factor in demonstrating that the well is a currently providing effective monitoring of the tank farm. A sentinel monitoring well candidate with a proven record of effectively monitoring releases from the tank farm area would be a strong indication it will be effective in monitoring future releases for the tank farm area. The record of well impacts from the post-2014 release from Tank 5 is of particular relevance. In addition, sentinel monitoring wells must be located in optimum locations so that COPCs from a release from various parts of the Facility will be detected.

3.2.1.5 Integration with Risk-Based Decision Criteria

Proposed sentinel monitoring wells will be evaluated on how well the SSRBL for each well aligns with the RBDC. The RBDC include criteria that should not be exceeded at the drinking water tap. SSRBLs will be developed based on RBDC developed for water supply wells and integrated into a mass flux evaluation that is protective of water being pumped from water supply wells. The SSRBL will be used to identify COPC concentrations at each sentinel monitoring well that if exceeded provide an indicator that the COPC concentration at the drinking water tap could exceed the RBDC if additional contingency action is not taken. Additional details on the establishment of RBDC and SSRBLs are provided in Sections 2.3 and 2.7.

3.2.2 Secondary Criteria

As stated above, secondary criteria are important factors to be considered during the evaluation. An example is that a proposed sentinel monitoring well might be located near a known groundwater barrier, and that relationship will need to factor in when considering the well for inclusion in the sentinel monitoring well network. Secondary criteria prompt needed evaluation of proposed sentinel monitoring wells that need to be investigated outside the primary criteria.

3.2.2.1 Well Construction

Well construction details will be reviewed and evaluated to verify if the monitoring well will have any limitations. Items such as well materials, submerged screen lengths, casing size, screen size, filter pack, and quality of subsurface logs will be taken into account.

3.2.2.2 HISTORICAL DETECTION OF COPCS (PRE-2014)

If sampled previously, the history of COPC detections in the proposed sentinel monitoring well will be reviewed to evaluate if COPC impacts from tank farm releases have been previously observed. A sentinel candidate with a proven record of effectively monitoring releases from the tank farm area in the past would be a strong indication it will be effective in monitoring future releases for the tank farm area.

3.2.2.3 GENERAL WATER CHEMISTRY

General water chemistry within specific areas of the site may be subject to surface water recharge or other factors that can influence chemistry. A review of general water chemistry will be conducted to reveal possible limitations as a sentinel monitoring well.

3.2.2.4 PROXIMITY TO GROUNDWATER BARRIERS, PREFERENTIAL FLOW PATHS, AND OTHER CONDITIONS

Proximity to groundwater barriers and other subsurface conditions in the saturated zone may affect the function of a proposed sentinel monitoring well. An evaluation will be conducted to reveal possible limitations as a sentinel monitoring well. The local subsurface geology such as barriers and preferential pathways may influence groundwater flow.

3.3 ANALYSIS AND SELECTION OF SENTINEL MONITORING WELLS

Once the group of potential sentinel monitoring wells is compiled, the wells will be qualitatively screened and ranked using the criteria outlined in the previous subsection. This subsection presents the general components of the screening, ranking, and selection of the sentinel monitoring wells. The full completed groundwater flow model and CF&T model (building on the Interim Model and Flow Model) along with the comprehensive CSM for the site will provide key tools to evaluate these criteria.

As stated previously, the sentinel monitoring wells have two primary functions within the Sentinel Well Network Program. These functions include 1) hydraulic head/groundwater flow gradients to provide confirmation of the capture zone developed during the capture zone analysis detailed in Section 2.7, and 2) effective monitoring of SSRBL concentrations of the selected COPCs based on RBDC developed per the *RBDC Development Plan* (DON 2017d). Consequently, prospective monitoring wells can have assigned function for one or both functions. Assignment will be made after the criteria analysis outlined below to ensure that proposed wells are well suited to their intended function.

3.4 RATIONALE FOR SELECTION OF PROPOSED SENTINEL MONITORING WELLS

Once the proposed group of sentinel monitoring wells is established, the wells will be qualitatively ranked on a scale of 1 to 5 (5 being most optimal) for each of the criteria presented in Section 3.2. When possible, these criteria have a description of each level. As an example, for the criterion "Suitability based on groundwater flow paths and plume capture analysis" (Figure 6), the ranking will be determined by a hydrogeologist, engineer, or appropriate professional who will assign a score based on professional judgement and site data and knowledge.

A weighting of criteria will be employed to distinguish between primary and secondary criteria by a factor of 2× multiplier on the primary criteria base score. If additional weighting factor(s) are used, a narrative rationale will be included to provide basis of the weighting.

A comprehensive table will be prepared showing each proposed sentinel monitoring well for both the individual score of each criterion and aggregate score of all the criteria. The table will be used as tool to evaluate and a document the selection for the proposed monitoring wells in the Sentinel Well Network Program. Additionally, a narrative rationale will be prepared for each selected monitoring well.

4. Identification of Additional Sentinel Monitoring Wells

Following identification, evaluation, and selection of the overall proposed sentinel monitoring well network, the network will be reviewed to identify limitations or data gaps to achieve the overall purpose and objectives. This can include additional sentinel monitoring points required for all potentially impacted water supply wells and exposure points outside the Facility boundary and within the groundwater model area, as depicted in the location map on Figure 2. If such limitations are identified, recommendations to address the limitations and data gaps will be prepared and discussed with the Regulatory Agencies. Recommendations may include installation of additional wells or modifications or additions to the existing network.

5. Establishment of Sentinel Well Network Program

The establishment of the Sentinel Well Network Program will follow the decision matrix outlined in the AOC Statement of Work (depicted above on Figure 3), where a *Groundwater Monitoring Well Network Report* will be prepared 12 months after Regulatory approval of the *Groundwater Flow Model Report*. The documents will present the recommendations and conclusions of the sentinel monitoring well evaluation and selection process described above. The report will also present the proposed Sentinel Well Network Program. The program will also include the following elements:

- Regulatory framework under U.S. EPA, Resource Conservation and Recovery Act (RCRA), and DOH programs
- COPCs (developed under the *RBDC Development Plan*)
- Locations and frequency of sampling (based on integration with the leak detection system)
- Integration of SSRBLs based on mass flux and RBDC
- Contingency plans for exceedances and releases
- Optimization and modification of the Sentinel Well Network Program

The *Groundwater Well Network Report* will provide a basis for a Decision Meeting prescribed under the AOC Statement of Work that is to be held 60 days after the *Groundwater Monitoring Well Network Report* is approved. Sixty (60) days following the Decision Meeting, a *Groundwater Monitoring Well Decision Document* will be prepared to provide final documentation of the decision process. Based on the *Groundwater Monitoring Well Decision Document,* the Red Hill GWPP (DON 2014) will be updated.

6. References

Agency for Toxic Substances and Disease Registry (ATSDR). 2017. *Toxicological Profile for JP-5, JP-8, and Jet A Fuels*. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. March.

Department of the Navy (DON). 2014. *Interim Update, Red Hill Bulk Fuel Storage Facility Final Groundwater Protection Plan, Pearl Harbor, Hawaii. (January 2008).* Pearl Harbor, HI: Naval Facilities Engineering Command, Pacific. August.

———. 2017a. *Work Plan / Scope of Work, Investigation and Remediation of Releases and Groundwater Protection and Evaluation, Red Hill Bulk Fuel Storage Facility, Joint Base Pearl Harbor-Hickam, O'ahu, Hawai'i; January 4, 2017, Revision 02*. Prepared by AECOM Technical Services, Inc., Honolulu, HI. Prepared for Defense Logistics Agency Energy, Fort Belvoir, VA, under Naval Facilities Engineering Command, Hawaii, JBPHH HI.

———. 2017b. *Attenuation Evaluation Plan, Investigation and Remediation of Releases and Groundwater Protection and Evaluation, Red Hill Bulk Fuel Storage Facility, Joint Base Pearl Harbor-Hickam, O'ahu, Hawai'i; September 1, 2017, Revision 00*. Prepared by AECOM Technical Services, Inc., Honolulu, HI. Prepared for Defense Logistics Agency Energy, Fort Belvoir, VA, under Naval Facilities Engineering Command, Hawaii, JBPHH HI.

———. 2017c. *Groundwater Model Evaluation Plan, Investigation and Remediation of Releases and Groundwater Protection and Evaluation, Red Hill Bulk Fuel Storage Facility, Joint Base Pearl Harbor-Hickam, O'ahu, Hawai'i; September 8, 2017, Revision 00*. Prepared by AECOM Technical Services, Inc., Honolulu, HI. Prepared for Defense Logistics Agency Energy, Fort Belvoir, VA, under Naval Facilities Engineering Command, Hawaii, JBPHH HI.

———. 2017d. *Risk-Based Decision Criteria Development Plan, Investigation and Remediation of Releases and Groundwater Protection and Evaluation, Red Hill Bulk Fuel Storage Facility, Joint Base Pearl Harbor-Hickam, O'ahu, Hawai'i; December 11, 2017, Revision 00*. Prepared by AECOM Technical Services, Inc., Honolulu, HI. Prepared for Defense Logistics Agency Energy, Fort Belvoir, VA, under Naval Facilities Engineering Command, Hawaii, JBPHH HI.

Environmental Protection Agency, United States, Region 9; and Department of Health, State of Hawaii (EPA Region 9 and DOH). 2015. *Administrative Order on Consent In the Matter of Red Hill Bulk Fuel Storage Facility, EPA Docket No: RCRA 7003-R9-2015-01; DOH Docket No: 15-UST-EA-01*. September.