Data Gap Analysis Report, 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

April 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

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April 25, 2017
Revision 00

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Contract Number N62742-12-D-1829, CTO 0053

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TABLES

ACRONYMS AND ABBREVIATIONS

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
CWRM	Commission on Water Resource Management
DLA	Defense Logistics Agency
DLNR	Department of Land and Natural Resources, State of Hawai‘i
DO	dissolved oxygen
DOH	Department of Health, State of Hawai‘i
EC	equivalent carbon
EDR	Existing Data Summary and Evaluation Report
EHE	Environmental Hazard Evaluation
EPA	Environmental Protection Agency, United States
ft	foot/feet
GIS	geographic information system
GWPP	Groundwater Protection Plan
HDOT	State of Hawai‘i Department of Transportation
HGU	hydrogeologic unit
JP	Jet Fuel Propellant
LTM	long-term monitoring
MAE	mean absolute error
ME	mean error
msl	mean sea level
NAP	natural attenuation parameter
NAPL	non-aqueous-phase liquid
NAVFAC	Naval Facilities Engineering Command
NGS	National Geodetic Survey
PAL	project action level
QA/QC	quality assurance / quality control
RAGS	Risk Assessment Guidance for Superfund
RMSE	root mean squared error
SAP	sampling and analysis plan
SME	subject matter expert
SOW	scope of work
SSRBL	site-specific risk-based level
SVM	soil vapor monitoring
TAMC	Tripler Army Medical Center
TDS	total dissolved solids
TGM	Technical Guidance Manual
TPH-d	total petroleum hydrocarbons – diesel range organics
USGS	United States Geological Survey
WP	work plan

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1. Introduction

This *Data Gap Analysis* [DGA] *Report* presents the rationale for data requirements, evaluates the suitability of existing data, and identifies data gaps in order to develop Red Hill's conceptual site model (CSM), groundwater flow model, and contaminant fate and transport (CF&T) model in accordance with the January 4, 2017 AOC Statement of Work Section 6 and Section 7 Work Plan/Scope of Work (WP/SOW) (DON 2017a). This report has been prepared for the Investigation and Remediation of Petroleum Product Releases and Groundwater Protection and Evaluation project at the Red Hill Bulk Fuel Storage Facility ("Facility"), Joint Base Pearl Harbor-Hickam, O‘ahu, Hawai‘i.

The project 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/Defense Logistics Agency (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 feed 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 ten documents (including this DGA Report), referred to as derivative deliverables, that will address specific aspects of the planning process. The flowchart presented on Figure 1 shows the sequencing of the derivative deliverables. Additional information on each of the other derivative deliverables is provided in the WP/SOW.

Two of the tasks identified in the project WP/SOW to support AOC Statement of Work Section 6 (Investigation and Remediation of Releases) and Section 7 (Groundwater Protection and Evaluation) are (a) *Update the Existing Groundwater Flow Model* and (b) *Update the Contaminant Fate and Transport Model and Evaluate Whether to Perform a Tracer Study*. The existing groundwater flow and CF&T models for the Facility were originally developed during 2005–2007 by the University of Hawai‘i (DON 2007), and are being updated for this project using data generated since that time. Where assumptions were previously made in the 2007 modeling effort that cannot be verified with actual data, then a conservative assumption will be made in the revised model. Objectives of the current modeling effort are to better understand the short- and long-term flow conditions and to evaluate potential measures to remediate and contain any potential contaminant plume associated with fuel releases from the Facility.

Two of the WP/SOW derivative deliverables that support the groundwater flow and CF&T modeling tasks are the previously published *Existing Data Summary and Evaluation Report* (EDR) (DON 2017c) and this follow-on *Data Gap Analysis Report*. The EDR presented data to be used to update the groundwater flow and CF&T models that have been compiled to date; evaluated those data for their usability and limitations in supporting the update of the groundwater flow and CF&T models; and preliminarily identified additional data needed to support the modeling effort that have not yet been obtained. This DGA Report expands on the usability assessment started in the EDR by providing screening against established criteria (i.e., source/quality, age/shelf life, and completeness) for data sets in the EDR. This DGA Report also identifies the data gap needs to support the modeling efforts into categories of primary and secondary data gaps according to impact to the models' development, and develops an acquisition plan that identifies sources and timeline to address the identified data gaps.

Four additional forthcoming derivative deliverables (Figure 1) will also support the modeling tasks:

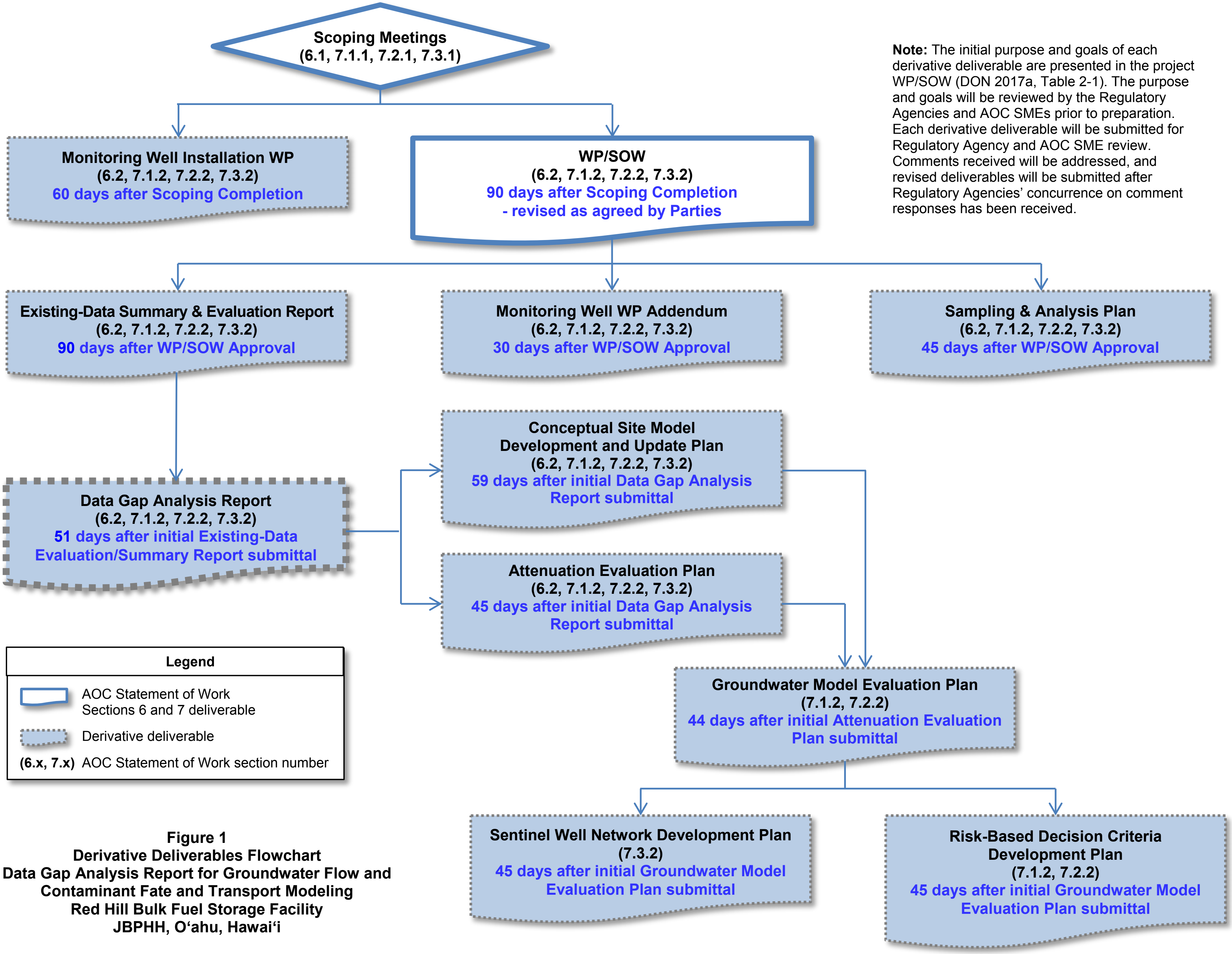
- The *Conceptual Site Model Development and Update Plan* will present a plan for developing the preliminary CSM and periodically updating it, including an approach for evaluating potential migration rates and directions for non-aqueous-phase liquid (NAPL) movement in the vadose to estimate areas on the water table that may directly be impacted by NAPL on the water table surface and for dissolved-phase chemicals of potential concern (COPCs) in groundwater from all areas of the Facility.
- The *Attenuation Evaluation Plan* will present a plan for collecting and analyzing data to evaluate and bound the likely rate of fuel attenuation in the subsurface groundwater from the range of releases that could occur at the Facility.
- The *Groundwater Model Evaluation Plan* will describe the process for reviewing the existing model in a manner that identifies uncertainties and describes options for reducing uncertainty, and will present exact values and parameters for use in the model.
- The *Sentinel Well Network Development Plan* will present a plan for evaluating and establishing a sentinel network for the existing groundwater water supply production points in the study area.

This report was prepared for DLA under Naval Facilities Engineering Command (NAVFAC) Hawaii, 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 Physical Boundaries of the Study

This project involves three principal types of physical boundaries:

- *Facility boundary:* As shown on Figure 2, the Facility is located on federal government land (zoned F1-Military and Federal) in Hālawa Heights, approximately 2.5 miles northeast of Pearl Harbor. It is situated on a low ridge on the western edge of the Koʻolau 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. The private Hālawa Quarry is located less than one-quarter mile away to the northwest. The Facility occupies 144 acres of land, and the majority of the site's surface is at an elevation ranging from approximately 200 to 500 ft above mean sea level (msl).
- *Study area boundary:* The current project study area extends beyond the Facility boundaries to include the entire area depicted on the main panel of Figure 2. This area is bounded on the northeast by the upper slopes of Red Hill, on the southeast by Moanalua Valley, on the southwest by residential housing, and on the northwest by Hālawa Valley. The collection of physical (e.g., geologic data, water level data) and chemical data will be focused on the study area. Data acquired during the investigation will be reviewed in coordination with the Regulatory Agencies to determine whether the study area boundaries should be expanded and/or modified (e.g., additional monitoring wells may be installed at locations outside the current study area, if necessary, to fill data gaps and ensure that the Red Hill monitoring well network is adequate to achieve the project objectives).



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
Data Gap Analysis Report for Groundwater Flow and Contaminant Fate and Transport Modeling
Red Hill Bulk Fuel Storage Facility
JBPHH, O‘ahu, Hawai‘i

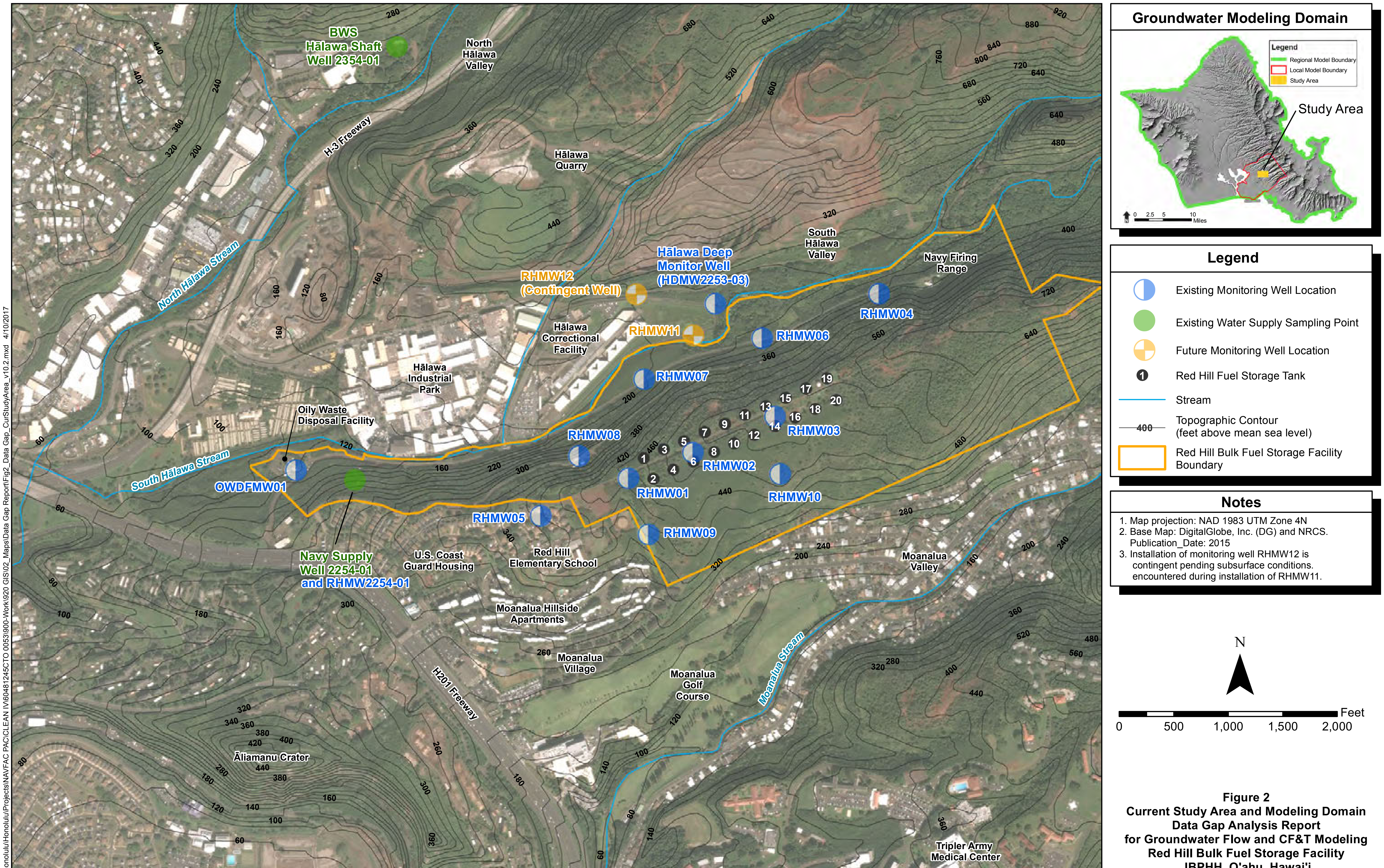


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Figure 2
Current Study Area and Modeling Domain
Data Gap Analysis Report
for Groundwater Flow and CF&T Modeling
Red Hill Bulk Fuel Storage Facility
JBPHH, O'ahu, Hawai'i

- *Modeling domain boundary:* As depicted on the inset map of Figure 2, the current extent of the local modeling domain (based on the original DON 2007 model) is bounded to the northwest by the center of Waimalu Valley, to the southeast by the middle of Kalihi Valley, and to the west by the caprock aquifer and Pearl Harbor shore. The appropriateness of these boundaries will be evaluated collaboratively with the Regulatory Agencies and AOC Subject Matter Experts (SMEs) based on all available data. Input parameters and assumptions will be reviewed to verify appropriateness due to the additional data that have been collected since 2007. The overall approach for the groundwater modeling task is presented in Section 3.4 of the project WP/SOW (DON 2017a), and will be further discussed in the forthcoming *Groundwater Model Evaluation Plan*.

1.2 Project Quality Objectives

Table 1-1 places this DGA Report in the context of the overall project scoping understandings, procedures, performance, and design goals established in the Sections 6 and 7 scoping meetings. The table provides a general summary of each of the study goals with breakdown of core elements (e.g., study questions, procedural approach, develop/optimize design) that range from the initial scoping activities to design efforts and that are identified in the project WP/SOW (DON 2017a). Specific WP/SOW sections are referenced in the header of each table column. Additionally, the table provides a tie-in of the core elements to this DGA Report and other derivative deliverables where appropriate.

1.3 Existing Data Usability Evaluation Criteria and Screening

The data presented in the EDR (DON 2017c) were further evaluated for their suitability in supporting CSM development and groundwater flow/CF&T modeling.to satisfy the objectives of the AOC. The following criteria were used to evaluate the data sets:

- *Data Source Quality:* Source of the data is from an accepted established agency, firm, reference, or study/investigation pertinent to the project groundwater flow and CF&T modeling effort (e.g., Regulatory Agencies and SMEs, professionally reviewed studies, peer-reviewed journals, and government and municipal public databases).
- *Currency/Shelf Life:* Data do not have any limitations based on age (e.g., old non-digital survey accuracy, outdated analytical data methods and detection limits, or changed environment).
- *Completeness:* Existing data available to the project team are fully usable, and no additional data are needed to complete the data set.

Data that do not meet the Data Source Quality and Currency/Shelf Life criteria are not used for the modeling effort. Data that do not meet the Completeness criterion can be used for the modeling effort, but may need to be augmented as identified in Sections 3 and 4.

The existing data sets are evaluated for their usability in the modeling effort according to the above criteria in Appendix A. For subjective criteria such as Data Source Quality, the evaluation typically employed best professional judgment by experienced hydrogeologists, geologists, chemists, and modelers. As shown in Table A-1, several data sets were found to be partially incomplete, but the existing data in those data sets met the Data Source Quality and Currency/Shelf Life criteria and are thus retained for use in the groundwater modeling effort. One data set, Groundwater Monitoring Wells in the Red Hill Area (EDR Appendix A Table WELL-1; DON 2017c), did not meet the Data Source Quality criterion (due to variable well elevations reported by multiple surveys) and is thus excluded from use in the groundwater monitoring effort. The upcoming water level elevation survey (DON 2017d) will provide usable well elevation data.

Table 1-1: Summary of AOC Statement of Work Sections 6 and 7 Quality Objectives

Problem Definition (WP/SOW Sec. 2.1)	**Principal Study Questions (WP/SOW Sec. 2.2)**	**Study Boundaries (WP/SOW Sec. 2.3)**	**Information Input (WP/SOW Sec. 2.5)**	**Performance & Acceptance Criteria (WP/SOW Sec. 2.6) (see also Section 1.3)**	**Procedural Approach (WP/SOW Sec. 2.4)**	**Develop & Optimize the Design for Obtaining Data (WP/SOW Sec. 2.7)**
Study Goal: COPCs in Groundwater (Scoping & WP/SOW Tasks 1, 2, 3, 4)						
• A release of an estimated 27,000 gallons of petroleum-related products from the Facility's Tank 5 to the subsurface occurred in January 2014. Dissolved-phase petroleum-related COPCs have been detected in the groundwater aquifers in the study area. • Previous investigation results indicate that human exposure to COPCs in drinking water from the supply wells is a potentially complete exposure pathway.	• What is the general nature of the Red Hill vadose zone, and how do the characteristics of the vadose zone, including perched groundwater conditions, affect the movement of petroleum from the original source area? – What do surface outcrops and subsurface data reveal about the location and orientation of high- and low-permeability lithologic units and potential preferential pathways in the vadose zone? – Where have perched water and low-permeability zones been identified during drilling of historical and new borings and monitoring wells? • What are the COPCs that should be investigated? – What do historical records reveal about the potential COPCs that may impact groundwater? – What are target COPCs based on DOH TGM guidance?	• **Study area:** Bounded by upper slopes of Red Hill to the northeast, Moanalua Valley to the southeast, residential housing to the southwest, and Hālawa Valley on the northwest. • **Modeling domain:** Bounded by center of Waimalu Valley to the northwest, center of Kalihi Valley to the southeast, and the caprock aquifer and Pearl Harbor shore to the west. • **Temporal boundaries:** Remedial investigation and groundwater flow modeling to occur over the 24 months following Regulatory Agencies' approval of the WP/SOW. CF&T modeling and groundwater monitoring well network evaluation will occur over the 180 days and 12 months, respectfully, following Regulatory Agencies' approval of the *Groundwater Flow Modeling Report*.	• Review of previous investigations and records • DOH EHE and TGM guidance (DOH 2016a, 2016b) • Review of historical releases from neighboring properties • Analytical results of groundwater samples	• Selection of new well locations based on review of previous investigations and records, location of human health receptors relative to the Facility, and expected vadose zone and groundwater flow directions as agreed during the initial project scoping meetings with AOC Parties. • Appropriate QA/QC procedures implemented to ensure that data collected (e.g., analytical data) are accurate and sufficient to meet the requirements of the investigation. • Groundwater samples collected in accordance with procedures outlined in the Red Hill groundwater LTM program and the approved project SAP (DON 2017b), to which the AOC Parties have agreed. • Analysis uses current PALs. • Third-party validation of all collected analytical samples.	• Install four water table monitoring wells RHMW08 through RHMW11 with potential to do another contingent well (RHMW12). • Conduct sampling rounds periodically (at a minimum, quarterly) at all available locations in the Red Hill groundwater monitoring network. • Include, at a minimum, one wet-season and one dry-season groundwater sampling event to establish baseline water levels and COPC concentrations, and to evaluate seasonal variations in groundwater conditions.	• Conduct acquisition and planning of all work in accordance with the WP/SOW (DON 2017a), which presents the process, tasks, and deliverables that address the goals and requirements. • Review study area and modeling domain boundaries in coordination with Regulatory Agencies and SMEs to determine whether either should be modified based on available data. • Compile existing historic data in *Existing Data Summary and Evaluation Report* (DON 2017c). • Identify additional data needs/gaps to support groundwater flow and CF&T modeling not currently available to the project team, and provide a plan for acquisition of the data as detailed in forthcoming *Data Gap Analysis Report*. • Evaluate need for a subsurface geophysical survey.

Problem Definition (WP/SOW Sec. 2.1)	**Principal Study Questions (WP/SOW Sec. 2.2)**	**Study Boundaries (WP/SOW Sec. 2.3)**	**Information Input (WP/SOW Sec. 2.5)**	**Performance & Acceptance Criteria (WP/SOW Sec. 2.6) (see also Section 1.3)**	**Procedural Approach (WP/SOW Sec. 2.4)**	**Develop & Optimize the Design for Obtaining Data (WP/SOW Sec. 2.7)**
Study Goal: Groundwater Flow (Scoping & WP/SOW Task 1, 4, 5)						
• The direction, rate, and behavior of groundwater flow within aquifers at and close to the Facility need to be adequately defined to evaluate potential threats to receptors and establish a sentinel monitoring network.	• What are the appropriate hydrologic boundaries to be used for the groundwater flow model? – What are the appropriate layers to use in the model based on review of historic and newly collected lithologic data? • What are the groundwater flow patterns in the study area and within the modeling domain? – What are the hydraulic gradients based on historical and current water level data? – What are the effects of recharge on hydraulic gradients at the site? – What are the hydraulic gradients and resultant groundwater flow directions under normal transient pumping conditions? – What are the effects of pumping water supply wells on hydraulic gradients and flow directions under various pumping scenarios at the site?	(see above)	• Review of previous investigations and professional publications • Results of water level monitoring and transducer studies that include a range of pumping rates at water supply wells • A developed and updated CSM • Geologic, hydrogeologic, and COPC isoconcentration mapping of the study area • Analytical and geotechnical results of subsurface unconsolidated material and rock core samples from representative lithologies	• Appropriate QA/QC procedures implemented to ensure that collected data (e.g., groundwater elevation and lithologic data) are accurate and sufficient to meet the requirements of the investigation. • Calibration performed using a systematic, objective, iterative process such that flow model parameters are consistent with site data for groundwater levels and conceptual hydrogeologic model. • Calibration goals for flow model include minimizing the mean error (ME), mean absolute error (MAE), and root mean squared error (RMSE) water level range less than 15%. • Survey data collected in accordance with *FGCS Specifications and Procedures to Incorporate Electronic Digital/Bar-Code Leveling Systems; FGCSVERT* (FGCS 2004). • NGS and USGS review of survey reports.	• Perform surface geologic mapping. • Develop CSM of hydrogeology and groundwater flow in modeling domain. • Obtain Regulatory input on CF&T model setup and parameter values via periodic *Groundwater Modeling Progress Reports*. • Calibrate groundwater flow model. • Conduct a 4-month water level monitoring study; calibration procedures for equipment to be used are included in the project SAP (DON 2017b). • Conduct a Second Order, Class I survey to address TOC elevation datum issues. • Prepare *Groundwater Model Evaluation Plan* to facilitate regulatory review	• Identify additional data needs/gaps to support groundwater flow and CF&T modeling not currently available to the project team and provide a plan for acquisition of the data as detailed in forthcoming *Data Gap Analysis Report*. • Prepare iterative CSM updates in accordance with forthcoming *CSM Development and Update Plan*. • Evaluate results of synoptic water level study from Nov. 2016. • Evaluate results of 4-month water level monitoring study in forthcoming *Groundwater Model Evaluation Plan*. • Evaluate effects of area water supply well pumping, barometric pressure, precipitation, and surface water recharge on collected water level data in forthcoming *Groundwater Model Evaluation Plan*. • Evaluate results of Second Order, Class I survey; adjust water elevations for existing data accordingly.

Problem Definition (WP/SOW Sec. 2.1)	Principal Study Questions (WP/SOW Sec. 2.2)	Study Boundaries (WP/SOW Sec. 2.3)	Information Input (WP/SOW Sec. 2.5)	Performance & Acceptance Criteria (WP/SOW Sec. 2.6) (see also Section 1.3)	Procedural Approach (WP/SOW Sec. 2.4)	Develop & Optimize the Design for Obtaining Data (WP/SOW Sec. 2.7)
Study Goal: Fate and Transport (Scoping & WP/SOW Tasks 1, 2, 3, 4, 5, 6)						
• A better understanding of the subsurface is necessary to reduce uncertainty related to the nature and extent of contamination at Red Hill as well as the fate, transport, and transformation of fuel released at the Facility and its potential to threaten drinking water quality. • A better understanding of the site-specific fate and transport (e.g., movement and degradation) of petroleum constituents related to the release is needed to identify and evaluate potential impacts to the groundwater resource that are related to the Facility.	• What fate and transport processes affect the petroleum constituents released from the facility to groundwater? – What is the nature of the subsurface geology and how does it affect the fate and transport of fuel releases at the Facility? – What are the temporal and spatial trends of NAPs and COPCs in groundwater? – What natural attenuation processes are occurring and what are estimated rates of natural attenuation? – What COPCs should be evaluated in the CF&T model based on mobility, toxicity, and detected concentrations? – How does pumping water supply wells (existing and potential new wells) affect the migration of COPCs (e.g., TPH-d, naphthalene) in groundwater? – How does implementation of potential remedial alternatives affect the migration and concentrations of COPCs (e.g., TPH-d, naphthalene) in groundwater?	(see above)	• Groundwater flow modeling results • Relevant COPC data collected since 2007 • DOH EHE and TGM guidance (DOH 2016a, 2016b) • Surface geologic mapping. • A developed and updated CSM • Temporal and spatial COPC isoconcentration trends/mapping of the study area • JP-8 fuel hydrocarbon fractionation (fingerprinting) and Stable Isotope Probing investigation results • Results of NAP analyses	• Appropriate QA/QC procedures implemented to ensure that collected data (e.g., groundwater elevation and lithologic data) are accurate and sufficient to meet the requirements of the investigation. • Available site data used to develop conceptual model of attenuation processes, and make conservative assumptions to estimate solute transport parameter values. • Calibration performed using a systematic, objective, iterative process to adjust parameter values to be consistent with site water chemistry data. • Appropriate QA/QC procedures implemented to ensure that data collected (e.g., analytical data) are accurate and sufficient to meet the requirements of the investigation.	• Perform surface geologic mapping. • Develop detailed CSM, including description of geologic layers in source area and surrounding area vadose zone based on boring and lithological data from existing reports and data obtained from the new wells (RHMW08 through RHMW11 and RHMW01R). • Update 2007 model with newly collected data (e.g., water quality data). • Obtain Regulatory input on CF&T model setup and parameter values via periodic *Groundwater Modeling Progress Reports*. • Calibrate model. • Conduct JP-8 fuel hydrocarbon fractionation (fingerprinting) and Stable Isotope Probing investigations	• Identify additional data needs/gaps to support groundwater flow and CF&T modeling not currently available to the project team and provide a plan for acquisition of the data as detailed in forthcoming *Data Gap Analysis Report*. • Prepare iterative CSM updates in accordance with forthcoming *CSM Development and Update Plan.* • Evaluate and bound the likely rate of fuel attenuation in the subsurface from a range of potential releases in accordance with forthcoming *Attenuation Evaluation Plan*. • Further evaluate results of file review, site reconnaissance, and subsurface geology to minimize the probability of missing a preferential flow path that may indicate that NAPL and dissolved-phase constituents are migrating toward Navy Supply Well 2254-01, the Hālawa Shaft, or other potential offsite receptors.

Problem Definition (WP/SOW Sec. 2.1)	Principal Study Questions (WP/SOW Sec. 2.2)	Study Boundaries (WP/SOW Sec. 2.3)	Information Input (WP/SOW Sec. 2.5)	Performance & Acceptance Criteria (WP/SOW Sec. 2.6) (see also Section 1.3)	Procedural Approach (WP/SOW Sec. 2.4)	Develop & Optimize the Design for Obtaining Data (WP/SOW Sec. 2.7)
Study Goal: Remediation (Scoping & WP/SOW Tasks 1, 2, 3, 4, 5, 6, 7)						
• Alternatives for investigating and mitigating the Tank 5 release and any potential releases from the Facility need to be evaluated.	• What are the alternatives for further investigating and remediating any petroleum products that are both present in groundwater and may pose unacceptable risk to receptors? – What are the impacted media that require remediation? – What is the feasibility of potential technologies for remediating NAPL in the subsurface and dissolved COPCs in groundwater? • How do the characteristics of the vadose zone impact the alternatives for investigating and remediating NAPL? – How do the characteristics of the subsurface geology (e.g., heterogeneous nature, presence of high and low permeability layers, dikes, voids and lava tubes) impact alternatives for remediating and investigating NAPL? • What is the potential for recovering NAPL released to the environment? – Is NAPL identified at the site? – What is the anticipated effectiveness of NAPL remediation if identified?	(see above)	• Results of site investigations and Risk/Vulnerability Assessment (AOC Statement of Work Section 8) • Temporal and spatial COPC isoconcentration trends/mapping of the study area • Results of groundwater flow and CF&T modeling • Results of NAP analyses • Microbial investigation	• Procedures conducted in accordance with regulatory (DOH, EPA) guidance.	• Identify remedial action objectives. • Identify technologies for remediating subsurface NAPL and COPCs in groundwater. • Identify technologies appropriate and available to investigate the geology of the study area. • Conduct individual and comparative analysis of remedial alternatives.	• Evaluate need to conduct non-intrusive (surface) technologies to further characterize geology and presence of NAPL. • Evaluate potentially feasible in-situ and/or ex-situ technologies to achieve more effective and efficient results.

Problem Definition (WP/SOW Sec. 2.1)	**Principal Study Questions (WP/SOW Sec. 2.2)**	**Study Boundaries (WP/SOW Sec. 2.3)**	**Information Input (WP/SOW Sec. 2.5)**	**Performance & Acceptance Criteria (WP/SOW Sec. 2.6) (see also Section 1.3)**	**Procedural Approach (WP/SOW Sec. 2.4)**	**Develop & Optimize the Design for Obtaining Data (WP/SOW Sec. 2.7)**
Study Goal: Future Groundwater Protection (Scoping & WP/SOW Tasks 1, 2, 3, 4, 5, 6, 7)						
• The monitoring well network needs to be evaluated and, where necessary, improved to ensure that sufficient data are collected to support the groundwater flow and CF&T models. • The GWPP (DON 2014) needs to be updated to ensure protection of drinking water supply wells.	• How much further evaluation of the nature and extent of groundwater contamination is necessary? – Is further evaluation of groundwater flow direction needed? – Is the groundwater flow and CF&T model adequate to assess COPC risk at exposure end points? – Do predictions of COPC transport in groundwater indicate that COPCs are migrating to areas where no wells are located? – Are additional monitoring wells needed to further characterize the extent of COPCs in groundwater? • What are the potential impacts from future releases on the groundwater resource? – Do the risk-based criteria need to be refined?	(see above)	• Sampling of groundwater monitoring network and COPC data • Temporal and spatial COPC isoconcentration trends/mapping of the study area • Results of groundwater flow and CF&T modeling • Results of human health risk and exposure assessment to potential receptors	• Sentinel monitoring well network established in accordance with DOH EHE and TGM guidance (DOH 2016a, 2016b), and to which AOC Parties have agreed. • Human health risk and exposure assessment to potential receptors conducted in accordance with current EPA RAGS (1989, et al.) and DOH (2016b) TGM guidance.	• Iteratively evaluate groundwater monitoring network and COPC data. • Establish an effective sentinel monitoring well network. • Develop release scenarios based on developed, calibrated, and validated groundwater flow and CF&T models. • Detail the procedures for updating, recalibrating, sensitivity assessment, and future use of the groundwater flow and CF&T model developed for the site. • Refine existing risk-based criteria (SSRBLs) for the GWPP and contingency plans.	• Evaluate and establish a sentinel network for existing water production points in accordance with forthcoming *Sentinel Well Network Development Plan*. • Refine SSRBLs in accordance with forthcoming *Risk-Based Decision Criteria Development Plan*. • Evaluate future use of the groundwater flow and CF&T model for groundwater protection. • Select locations within study area where data gaps are identified to install groundwater monitoring wells to further monitor COPCs in groundwater.

EHE	Environmental Hazard Evaluation	QA/QC	quality assurance / quality control
GWPP	Groundwater Protection Plan	RAGS	Risk Assessment Guidance for Superfund
LTM	long-term monitoring	RMSE	root mean squared error
MAE	mean absolute error	SAP	sampling and analysis plan
ME	mean error	SSRBL	site-specific risk-based level
NAP	natural attenuation parameter	TGM	Technical Guidance Manual
NGS	National Geodetic Survey	TPH-d	total petroleum hydrocarbons – diesel-range organics
PAL	project action level	USGS	United States Geological Survey

1.4 REPORT ORGANIZATION

Section 1.4 presents background on data needs for the CSM and the numerical flow model. Section 3 identifies key uncertainties and data needed to resolve the uncertainties, cross-references to relevant existing data from the EDR, and the resulting data gaps along with sources where those data can be obtained. Section 4 presents a plan for acquiring the needed data. Section 5 summarizes the results of the data gap analysis and evaluates the impact of not acquiring needed additional data. Section 6 lists references for literature cited in the document.

2. Background

A CSM was previously developed based on a large amount of site-specific information (DON 2007). Since 2007, additional information for fuel releases, contamination and hydrogeology has become available, which prompted concerns about potential risks to potential receptors. This DGA Report evaluates whether information is currently incomplete or unavailable and necessary for developing the CSM and the numerical groundwater modeling now planned for this project. Where more data are needed for a component of the model, these are identified as data gaps. Data needs associated with development of the CSM and numerical groundwater flow and CF&T model are described below.

2.1 DATA NEEDS FOR THE CONCEPTUAL SITE MODEL

The CSM will be developed prior to numerical modeling and will be used as the basis for developing the numerical model. The refined CSM needs to identify characteristics of the study area that affect groundwater flow, the distribution of COPCs in groundwater, and the fate and transport of the released fuel in the environment. The CSM will also need to identify exposure routes and receptors, and assess whether each route is potentially complete, potentially complete but insignificant, or incomplete. The CSM will also need to support modeling and engineering analyses to evaluate remediation alternatives to address the fuel release. The CSM will be prepared in general accordance with current guidance including but not limited to the following:

- *Standard Guide for Development of Conceptual Site Models and Remediation Strategies for Light Nonaqueous-Phase Liquids Released to the Subsurface*, ASTM E2531-06(2014) (ASTM 2014b)
- *Standard Guide for Developing Conceptual Site Models for Contaminated Sites*, ASTM E1689-95 (reapproved 2014) (ASTM 2014a)
- *Environmental Cleanup Best Management Practices: Effective Use of the Project Life Cycle Conceptual Site Model* (EPA 2011)
- *Evaluating Natural Source Zone Depletion at Sites with LNAPL* (ITRC 2009)
- LNAPL Conceptual Site Model module in: *LNAPL Training Part 2: LNAPL Characterization and Recoverability – Improved Analysis* (ITRC 2008)
- Section 3.3 Conceptual Site Models in: *Technical Guidance Manual for the Implementation of the Hawaii State Contingency Plan* (TGM) (DOH 2016b)
- *Conceptual Site Model Tool,* NAVFAC Technology Transfer, Environmental Restoration website (URL: http://t2.serdp-estcp.org/t2template.html#tool=CSM&page=S1)

The CSM will describe potential impacts to receptors from NAPL and related COPCs associated with the release. The vadose zone is heterogeneous and composed of a series of complex alternating layers of basalt flows that vary from high to low permeability and influence migration pathways. Data provided in existing reports and obtained during the installation of new wells (RHMW08 through RHMW11 and RHMW01R) and geologic mapping will be used to make a qualitative assessment of the vadose zone and estimate how NAPL could migrate from a release source and impact the underlying groundwater, which will provide a foundation for setting up CF&T modeling assumptions.

The same heterogeneous basalt flows noted above in the vadose likely extend throughout the saturated zone. Information contained in geologic logs will be used to assess the presence of clinker zones that may create preferred flow pathways for groundwater and NAPL movement in the Facility source area. Understanding how these structural features influence the groundwater (the principal transport mechanism for the dissolved COPCs in groundwater) will provide a foundation for setting up the numerical groundwater flow and CF&T modeling assumptions.

For the Red Hill Facility area, the key components of the CSM include but are not limited to the following:

- Contaminant source areas
- Identification of potential receptors
- Subsurface geology
  - Strike and dip of basalt and clinker beds
  - Fracture zones (related to cooling of flows, or other process)
  - Spatial distribution of effective porosity in basalt flows and clinker zones
- Pathways and barriers for NAPL migration
- NAPL and COPC weathering and attenuation processes
- Potential groundwater pathways for NAPL and dissolved-phase COPCs to migrate to receptors (water supply wells)

The details of the plan to develop the CSM will be included in the forthcoming derivative deliverable *Conceptual Site Model Development and Update Plan,* as noted on Figure 1.

2.2 DATA NEEDS FOR THE NUMERICAL GROUNDWATER MODEL

Although some elements of the numerical model (e.g., boundary conditions) will be evaluated prior to development of the CSM, the numerical model will be based on the CSM and developed after the CSM is developed. The numerical groundwater model will need to be refined to quantitatively evaluate the groundwater flow and COPC migration. This model will be set up based on the hydrogeologic components of the CSM and calibrated to reflect the site groundwater data. For the numerical model, a much larger area needs to be included to allow the model to reflect regional pumping, groundwater recharge and discharge. The perimeter boundaries of the numerical model are planned to coincide with natural hydrogeologic boundaries at least 2 miles from the Facility. Thus the CSM needs to incorporate hydrogeologic information extending throughout the numerical modeling domain, including:

- Hydrogeologic features along perimeter boundaries
- Valley fill depth, lithology and water-transmitting properties

- Basalt depth, lithology, and water-transmitting properties
- Saprolite depth, lithology, and water-transmitting properties
- Caprock depth, lithology, and water-transmitting properties
- Geologic structures in modeling domain that may affect groundwater flow
- Water balance for groundwater flow system
- Groundwater flow rates (mass flux rates) along each side of numerical model area
- Groundwater recharge and discharge rates and areas within modeling domain
- Pumping well locations, withdrawal rates and seasonal changes

Additional groundwater data will be needed to calibrate the updated numerical groundwater flow model, including:

- Groundwater level elevations, hydraulic heads and gradients at wells throughout the modeling area during non-pumping and expected future pumping conditions
- Elevation of regional aquifer base (base of brackish water)

To refine the CF&T model, the following information is needed:

- Water chemistry data to better define the COPC extent, estimate source concentrations and biodegradation processes
- Evaluate geologic information at the Facility to estimate physical properties, NAPL migration direction and extent

Results of the planned groundwater flow modeling will be used to improve understanding of flow in the vicinity of the Facility, and evaluate migration of COPCs and assess potential risk to receptors. Further details of the groundwater flow modeling plans will be included in the forthcoming derivative deliverable *Groundwater Model Evaluation Plan,* as noted on Figure 1.

3. Data Gap Analysis

The following subsections present key uncertainties currently associated with the CSM development and groundwater flow and CF&T modeling effort. For the numerical modeling effort, data are needed to:

- Develop the CSM using data and information on contaminant sources, potential impacted media, site geologic and hydrogeologic information, contaminant pathways, and potential receptors as described in Section 2.1.
- Determine appropriate modeling domain boundaries (e.g., natural features such as low permeability formations, groundwater divides, and surface water bodies).
- Define hydrogeologic units (HGUs) of similar lithology and hydraulic parameters that can be represented as model layers.
- Establish appropriate grid spacing by identifying areas of interest and spatial distribution of data.

- Define hydrogeologic parameters for each model layer (e.g., input values for groundwater elevations, hydraulic properties [e.g., hydraulic conductivity, effective porosity, and specific yield]).
- Specify hydraulic properties and flow rates for model boundaries, including groundwater recharge and discharge rates.
- Evaluate groundwater heads and flow patterns during non-pumping periods (static conditions) and effects of pumping wells using groundwater elevation data measured within the modeling area.
- Calibrate model by adjusting hydraulic parameter values to enable the model to simulate well data for static and pumping conditions (e.g., calibrated model will match historical data for water levels and well discharges).
- Develop pumping scenarios to be simulated by model.
- Identify contaminant source areas and input data on COPC concentrations and water chemistry measured in site monitoring wells.
- Select values for dispersivity, decay constants, and adsorption parameters.

The EDR (DON 2017c) compiled existing data collected at the site and within the modeling area. These data, including geologic and hydrogeologic data, were evaluated with respect to Data Source Quality, Currency/Shelf Life, and Completeness and details regarding the types of data collected. The results of this evaluation are presented in Appendix A (Table A-1). The majority of data collected were determined to be of good quality and usable for meeting the AOC objectives; however, the primary data needs identified include obtaining accurate and consistent measuring point survey information for wells for the determination of accurate groundwater elevations, well pumping data, and lithologic data supporting the presence or absence of a hydraulic barrier between Red Hill and Hālawa Shaft.

The groundwater flow and CF&T model is intended to provide a tool for evaluating potential COPC migration in groundwater and remedial alternatives for the site. Key uncertainties and the data needed to address each uncertainty were identified for various aspects of the modeling effort, including:

- Groundwater flow directions, rates, and migration
- Effects of supply well pumping
- Freshwater–saltwater interface
- Geologic features that affect groundwater flow
- Hydraulic head and flux conditions
- Basal aquifer hydraulic and physical properties
- Groundwater recharge and discharge rates
- Distribution of COPCs in groundwater
- Water quality impacts to groundwater resources
- Other physical properties of basalt affecting CF&T
- Source area extent, mass loading, and natural attenuation rates

In each subsection, a table identifies the uncertainty (or data needs for the models), the task or information need arising out of that uncertainty, cross-references to relevant existing data that are compiled in the EDR (DON 2017c), and the remaining data needs identified to complete that task or fill that information need, along with the source where those data can be obtained.

The data gaps identified in this section are categorized as Primary or Secondary data need and are defined as follows:

- **Primary Data Need [P]:** A primary data need is defined as crucial data element that the project does not currently have that has a direct relationship to evaluating risk to a receptor. These data are critical elements required for completing a thorough investigation and numerical modeling. Without filling primary data needs, conservative assumptions will be required. An example is COPC concentrations in the groundwater that are migrating toward a known water supply well and the determination of the flow direction and fate and transport of those COPCs.
- **Secondary Data Need [S]:** A secondary data need is defined as supporting data that the project does not currently have that does not have a direct relationship to evaluating risk to a receptor. Secondary data needs provide additional data for completing the investigation and further refinement of the numerical model, but are not considered critical elements that must be obtained for completing the investigation and numerical modeling. An example is natural attenuation parameters (NAPs), or transport pathways from the release source to the groundwater plume.

Both primary and secondary data needs are identified in the tables below, and are summarized in Section 5.

3.1 GROUNDWATER FLOW DATA GAPS

3.1.1 Groundwater Flow Directions and Rates, and Migration of COPC-Impacted Groundwater from the Facility

The depths of older alluvial sediment fill and saprolite are uncertain beneath North and South Hālawa valleys. Detailed borehole geologic logs at selected locations near the Facility would reduce this uncertainty, however resolving the hydraulic gradients and groundwater flow directions is of primary importance and may reduce or obviate the need to collect additional geologic data to define the low permeability materials in these valleys. The groundwater level data that would provide a basis for defining groundwater flow directions and hydraulic gradients are currently limited by 1) sparse synoptic water level data, 2) lack of water level data acquired under presumed pumping rates at water supply wells, and 3) uncertainty in the measurement point elevations at some or all of the wellheads. These limitations are described in more detail below.

Synoptic groundwater level data are sparse, and there is substantial uncertainty in the spatial distribution of groundwater level elevations, hydraulic heads, and gradients. Water level measurements are available for different times during unknown pumping conditions, but currently only one set of synoptic groundwater level measurements is available from the Facility’s monitoring wells, those collected on November 18, 2016. Red Hill Shaft was not pumping for an extended period prior to that date, and thus these data will be useful for preparing a potentiometric map and developing the CSM under non-pumping conditions at Red Hill Shaft. However, the synoptic water level data are of limited use for calibrating the numerical flow model unless pumping rates in other nearby wells, including Hālawa Shaft, are obtained for that period. The Navy will be conducting a

Second-Order, Class I survey of the measuring points of all wells in the Red Hill Groundwater Monitoring Network in 2017, which will provide more accurate survey data allowing for more accurate determinations of hydraulic heads and gradients.

A significant limitation of the available groundwater level data is the uncertainty in the measurement point elevations at some or all of the wellheads. Different benchmarks and datum elevations may cause inaccuracy in calculating the groundwater level elevations. Even though previous efforts to resurvey the wellhead elevations were conducted after 2007 (DON 2010), questions remain about apparent inaccuracies of the survey data. The planned resurvey of the wellhead elevations will fill this data gap and allow better definition of hydraulic gradients to estimate groundwater flow directions.

Table 3-1: Data Gaps for Modeling Groundwater Flow Directions, Rates, and Migration

Key Uncertainty	Task or Information Need	Existing Data [a]	Data Gaps and Sources [b]
Groundwater flow directions, rates and migration of groundwater impacted by COPCs from the Facility	Define depths of older alluvial sediment fill and saprolite beneath North and South Hālawa valleys, using geologic logs and well construction details for wells in the numerical groundwater modeling area.	• Boring logs from Red Hill, North Hālawa Valley, and Pearl Harbor area (Tables GEO-1 to GEO-4; Appendix D) • Sedimentary deposit information (Table HYDRO-1) • Well construction details from existing and newly installed wells within the modeling domain (Tables WELL-1 to WELL-4)	• **S:** Boring logs from South Hālawa Valley and other non-Facility wells (e.g., well borings at Tripler Army Medical Center) if available *Source:* Army, BWS, CWRM, DLNR • **S:** Well construction details from existing and newly installed wells within the modeling domain not identified in (DON 2017c) *Source:* Army, BWS, DLNR, Army • **S:** Data from existing studies by the USGS (Engott et al. 2015, 2015; Izuka et al. 2016) *Source:* USGS • **S:** Estimates of stream seepage along the valleys *Source:* USGS

Key Uncertainty	Task or Information Need	Existing Data [a]	Data Gaps and Sources [b]
Groundwater flow directions, rates and migration of groundwater impacted by COPCs from the Facility (cont.)	Estimate groundwater flow directions.	• Water levels during 2015 USGS aquifer test for Hālawa, Hālawa T-45, Red Hill, Waiawa, and Manaiki wells (Tables GW-1 and GW-4 to GW-6) • Pumping rates during 2015 USGS aquifer test for Hālawa Shaft, Hālawa, and Moanalua pumping stations (Tables GW-2, GW-7, and GW-8) • Groundwater levels for Red Hill monitoring network wells, Fort Shafter well, ‘Aiea Navy well, TAMC-2 well, and Hālawa Shaft (November 2006 to October 2016) (Tables GW-9 to GW-24) • O‘ahu aquifer characteristics, included aquifer type and use (Table GW-60) • Manual water level measurements collected on November 18, 2016 by Navy (Table GW-61) • Normal pumping rates for water supply wells (Table WELL-4) • Red Hill Storage Facility pumping information, including maximum pumping rates (Table WELL-5) • Pumping rates for wells within the groundwater modeling domain (Table WELL-6) • Summary of Joint Base Pearl Harbor-Hickam water supply system (Table FAC-5) • Depth to groundwater time-series for monitoring wells within the Red Hill monitoring network (Appendix B)	• **S:** Water levels measured for all wells monitored during the 2015 USGS aquifer the test *Source*: USGS • **P:** Accurate water level measurements and elevations (i.e., resurveying, gyroscopic survey) *Source:* Navy • **P:** Water supply well pumping rates for Red Hill Shaft, Hālawa Shaft, and Moanalua-area wells *Source:* BWS • **P:** Groundwater level data (November 2016 onward) *Source:* Navy, USGS, BWS, DLNR, other parties as applicable

Key Uncertainty	Task or Information Need	Existing Data [a]	Data Gaps and Sources [b]
Groundwater flow directions, rates and migration of groundwater impacted by COPCs from the Facility (cont.)	Better define the spatial distribution of hydraulic heads (groundwater levels) in the Facility area, including Hālawa Shaft, Red Hill Shaft, and the Moanalua and TAMC Wells, during non-pumping and pumping conditions.	• Water levels during 2015 USGS aquifer test for Hālawa, Hālawa T-45, Red Hill, Waiawa, and Manaiki wells (Tables GW-1 and GW-4 to GW-6) • Pumping rates during 2015 USGS aquifer test for Hālawa Shaft, Hālawa, and Moanalua pumping stations (Tables GW-2, GW-7, and GW-8) • Groundwater levels for Red Hill monitoring network wells, Fort Shafter well, ‘Aiea Navy well, TAMC-2 well, and Hālawa Shaft (November 2006 to October 2016) (Tables GW-9 to GW-24) • Manual water level measurements collected on November 18, 2016 by Navy (Table GW-61) • Normal pumping rates for water supply wells (Table WELL-4) • Red Hill Storage Facility pumping information, including maximum pumping rates (Table WELL-5) • Pumping rates for wells within the groundwater modeling domain (Table WELL-6) • Depth to groundwater time-series for monitoring wells within the Red Hill monitoring network (Appendix B)	• **P:** Using collected synoptic data, as further discussed in Sections 3.1.2, 3.2.2, and 3.1.6 below, prepare potentiometric maps representative of groundwater levels when all of the supply wells are not pumping, and similar maps during other periods when each of the wells is pumping at a relatively steady rate. *Source:* Navy • **S:** Using information from the current USGS groundwater model, evaluate vertical gradients for initial steady-state conditions. *Source*: USGS

[a] References in parentheses refer to the *Existing Data Summary and Evaluation Report for Groundwater Flow and Contaminant Fate and Transport Modeling* (DON 2017c) (table numbers are from Appendix A of the report).
[b] **P:** Primary data need
S: Secondary data need

3.1.2 Effects of Pumping Hālawa Shaft, Red Hill Shaft, and Moanalua-Area Wells on Migration of Affected Groundwater

In addition to the groundwater level uncertainties described in the previous section, the available data for groundwater pumping rates in water supply wells are limited. A major uncertainty is how groundwater levels change in response to pumping of Hālawa Shaft, Red Hill Shaft, and the Moanalua-area wells. The Commission on Water Resource Management (CWRM) database contains pumping information that is likely applicable and useful for refining the model (Izuka et al. 2016). Historical pumping rates for individual wells should be available by request from the United States Geological Survey (USGS) and/or the CWRM, which should be useful for developing the detailed CSM and establishing pumping rates for wells in the modeling domain.

Table 3-2: Data Gaps for Modeling Effects of Supply Well Pumping

Key Uncertainty	Task or Information Need	Existing Data [a]	Data Gaps and Sources [b]
Effects of pumping Hālawa Shaft, Red Hill Shaft, and Moanalua-area wells on migration of the affected groundwater	Obtain information from water level monitoring studies and aquifer testing.	• Water levels during 2015 USGS aquifer test for Hālawa, Hālawa T-45, Red Hill, Waiawa, and Manaiki wells (Tables GW-1 and GW-4 to GW-6) • Pumping rates during 2015 USGS aquifer test for Hālawa Shaft, Hālawa, and Moanalua pumping stations (Tables GW-2, GW-7, and GW-8) • Groundwater levels for Red Hill monitoring network wells, Fort Shafter well, ʻAiea Navy well, TAMC-2 well, and Hālawa Shaft (November 2006 to October 2016) (Tables GW-9 to GW-24) • Normal pumping rates for water supply wells (Table WELL-4) • Red Hill Storage Facility pumping information, including maximum pumping rates (Table WELL-5) • Pumping rates for wells within the groundwater modeling domain (Table WELL-6) • Depth to groundwater time-series for monitoring wells within the Red Hill monitoring network (Appendix B)	• **S:** Evaluation of the USGS pumping test data (May 2015) and other aquifer test and water level data *Source:* BWS, Navy, USGS • **S:** Water levels during 2015 USGS aquifer tests for all other wells involved in or impacted by the test *Source*: BWS, CWRM, DLNR, USGS • **S:** Information for Hālawa Quarry and Hawaiian Cement Plant Operations: – Water supply sources – Groundwater volumes pumped and used – Discharge points and flow rates – Water quality permit limits and violations *Source:* DLNR, DOH, Hawaiian Cement

[a] References in parentheses refer to the *Existing Data Summary and Evaluation Report for Groundwater Flow and Contaminant Fate and Transport Modeling* (DON 2017c) (table numbers are from Appendix A of the report).
[b] **P:** Primary data need
S: Secondary data need

3.1.3 Depth of Freshwater–Saltwater Interface throughout the Modeling Area

At present, the bottom elevation of the groundwater model is set at the estimated base of the fresh water in the basal aquifer (DON 2007). However, the base of fresh water may vary due to pumping and the current elevation of it is uncertain. After the 2007 groundwater modeling, a USGS study (Rotzoll 2010) evaluated the depth of the freshwater lens and may provide useful information for evaluating and possibly refining the base elevation of the 2007 groundwater flow model. That study showed that eight deep monitoring wells are located in the modeling domain (Rotzoll 2010). Information in that report also suggests that more recent salinity profiles may be available for checking and if needed, updating the bottom elevation of the 2007 groundwater model.

Table 3-3: Data Gaps for Modeling Freshwater–Saltwater Interface

Key Uncertainty	Task or Information Need	Existing Data [a]	Data Gaps and Sources [b]
Depth of the freshwater–saltwater interface throughout groundwater modeling area	Define the current elevation of the base of freshwater aquifer throughout the groundwater modeling area.	• Groundwater levels for Red Hill monitoring network wells, Fort Shafter well, ʻAiea Navy well, TAMC-2 well, and Hālawa Shaft (November 2006 to October 2016) (Tables GW-9 to GW-24) • Oʻahu aquifer characteristics, included aquifer type and use (Table GW-60) • Summary of Joint Base Pearl Harbor-Hickam water supply system (Table FAC-5) • Depth to groundwater time-series for monitoring wells within the Red Hill monitoring network (Appendix B)	• **S:** Compile available salinity profiles from all deep monitoring wells in modeling area and/or obtain map of freshwater–saltwater elevation contours. *Source:* BWS, CWRM, USGS • **P:** Set bottom elevation of groundwater model to include the full thickness of the freshwater aquifer. *Source:* BWS, CWRM, USGS

[a] References in parentheses refer to the *Existing Data Summary and Evaluation Report for Groundwater Flow and Contaminant Fate and Transport Modeling* (DON 2017c) (table numbers are from Appendix A of the report).
[b] **P:** Primary data need
S: Secondary data need

3.1.4 Geologic Features that Provide Preferred Groundwater Flow Pathways or Barriers in the Facility Vicinity

Geologic information from the Facility area indicates that massive lava flows generally act as low-permeability barriers to vertical migration and that interbedded clinker deposits provide high-permeability pathways in the basalt flows underlying the Facility. These types of features in the Basalt HGU likely affect groundwater flow in the Facility area. Information contained in geologic logs and from geologic mapping will be used to evaluate potential NAPL movement mechanisms in the Facility source area and preferred dissolved contaminant flow pathways. A qualitative evaluation will be conducted to provide estimates of various release scenarios and potential NAPL impact on groundwater.

Table 3-4: Data Gaps for Modeling Geologic Features that Affect Groundwater Flow

Key Uncertainty	Task or Information Need	Existing Data [a]	Data Gaps and Sources [b]
Geologic features that provide preferred groundwater flow pathways or barriers in the Facility vicinity	Better define spatial distribution of clinker zones, paleo-channels, faults, dense low-permeability lava flows and dikes in the primary area of interest for groundwater modeling.	• Boring logs from Red Hill, North Hālawa Valley, and Pearl Harbor area (Tables GEO-1 to GEO-4; Appendix D) • Sedimentary deposit information (Table HYDRO-1) • Hydrogeologic properties of HGUs within the modeling domain (Table HYDRO-2) • Well construction details from existing and newly installed wells within the modeling domain (Tables WELL-1 to WELL-4)	• **P:** Compile and evaluate all existing geologic maps and logs of borings (e.g., Tripler Army Medical Center wells), tunnels and excavations not identified in (DON 2017c) that are located within the primary area of interest to develop detailed CSM including geologic features that affect NAPL migration in the vadose zone and groundwater flow and COPC migration. *Source:* Army, BWS, City and County of Honolulu, CWRM, DLNR, HDOT, USGS • **S:** Identification of surface geophysical methods that would likely be effective in better defining such geologic features. *Source:* Navy • **S:** Potential field-scale pilot study to demonstrate the effectiveness of method(s) for delineating subsurface extent of such features above and below water table. *Source:* Navy • **P:** Refine groundwater model layers to be consistent with detailed CSM. *Source:* Navy

[a] References in parentheses refer to the *Existing Data Summary and Evaluation Report for Groundwater Flow and Contaminant Fate and Transport Modeling* (DON 2017c) (table numbers are from Appendix A of the report).
[b] **P:** Primary data need
S: Secondary data need

3.1.5 Hydraulic Head and Flux Conditions along Modeling Area Perimeter Boundaries

The northeastern boundary of the 2007 model (DON 2007), located approximately 2 miles to the northeast of the Facility, and the model domain extends within the area of dike-free basalt. Hydrogeologic data are sparse to non-existent in the area lying along the northeastern boundary, but more data appear to be available along the other boundaries. To update the 2007 model, it will be useful to incorporate more information on hydraulic heads or groundwater fluxes along these boundaries, which appears to be available from USGS and CWRM.

Table 3-5: Data Gaps for Modeling Hydraulic Head and Flux Conditions

Key Uncertainty	Task or Information Need	Existing Data [a]	Data Gaps and Sources [b]
Hydraulic head and flux conditions along modeling area perimeter boundaries	Better define the hydraulic heads and flux rates along each of the model boundaries. Adjust valley fill depth if needed along northwest and southeast boundaries based on available geologic data. Refine 2007 model to be consistent with the boundaries of the USGS model currently being developed.	• Boring logs from Red Hill, North Hālawa Valley, and Pearl Harbor area (Tables GEO-1 to GEO-4; Appendix D) • Sedimentary deposit information (Table HYDRO-1) • Hydrogeologic properties of HGUs within the modeling domain (Table HYDRO-2) • Daily precipitation totals for Moanalua and North Hālawa Valley precipitation gauges (January 2007 to December 2016) (Tables GW-26 to GW-47) • Ratios of runoff to rainfall used in Izuka et al. 2016 for O‘ahu (Table GW-57) • Discharge rates for O‘ahu springs (Tables GW-58 and GW-59) • Well construction details from existing and newly installed wells within the modeling domain (Tables WELL-1 to WELL-4)	• **S:** Compile and evaluate hydrogeologic data available along 2007 model boundaries. *Source:* USGS • **S:** Obtain and evaluate information from the USGS regional model currently being developed, including electronic files of hydraulic heads, conductance and fluxes along boundaries, and model layer elevations. *Source:* USGS • **S:** Obtain and evaluate other available information from the USGS and/or CWRM regarding springs, and subsurface groundwater outflow along shoreline. *Source:* CWRM, USGS

[a] References in parentheses refer to the *Existing Data Summary and Evaluation Report for Groundwater Flow and Contaminant Fate and Transport Modeling* (DON 2017c) (table numbers are from Appendix A of the report).
[b] **P:** Primary data need
S: Secondary data need

3.1.6 Hydraulic and Physical Properties of Basal Aquifer that Affect Groundwater Flow in the Facility Vicinity

The recent USGS report (Izuka et al. 2016) provides an updated and detailed summary of the available hydrogeology information in the vicinity of the Facility. However, there does not appear to be any additional data for hydraulic or physical property data other than those available for the 2007 local groundwater flow model (DON 2007). The only information for hydraulic properties in the modeling domain collected since 2007 are the USGS pumping test data collected in May 2015 from the BWS Hālawa Shaft. These may be potentially useful for refining aquifer hydraulic properties in the model, which include:

- Transmissivity
- Hydraulic conductivity
- Heterogeneity and anisotropy
- Storativity
- Specific yield

The May 2015 pumping test data set now available to the Navy appears to be incomplete, and the variable pumping rates create uncertainties in evaluating the data. For example, flow rate data for Red Hill Shaft do not include the entire pumping test period. Prior to May 22, 2015, the pumping rates for Red Hill Shaft do not appear to be available. To address this uncertainty and provide better hydraulic property data for the model, it is important to perform the currently planned regional-scale aquifer test, which entails synoptic monitoring of groundwater levels in all the Red Hill monitoring wells while measuring pumping rates of supply wells located near the Facility. To provide the data needed for calibrating the model parameters, this regional-scale aquifer test will involve turning off the pumps at the Hālawa Shaft, Red Hill Shaft, and Moanalua Wells for about one week. After a week of no pumping of any well in the Facility area, each well will resume pumping in sequence each week. In week 1, Hālawa Shaft would pump constantly at its normal rate. In week 2, both Hālawa Shaft and Red Hill Shaft would pump constantly at its normal rate. In week 3, all three of these wells would pump constantly at their normal rates. At the end of week 3, pumping of all three wells would cease for a period of 1 week.

Table 3-6: Data Gaps for Modeling Basal Aquifer Hydraulic and Physical Properties

Key Uncertainty	Task or Information Need	Existing Data [a]	Data Gaps and Sources [b]
Hydraulic and physical properties of basalt aquifer that affect groundwater flow in the Facility vicinity	Better define the spatial distribution of groundwater model parameter values in primary area of interest.	• Hydrogeologic properties of HGUs within the modeling domain (Table HYDRO-2) • Water levels during 2015 USGS aquifer test for Hālawa, Hālawa T-45, Red Hill, Waiawa, and Manaiki wells (Tables GW-1 and GW-4 to GW-6) • Pumping rates during 2015 USGS aquifer test for Hālawa Shaft, Hālawa, and Moanalua pumping stations (Tables GW-2, GW-7, and GW-8) • Groundwater levels for Red Hill monitoring network wells, Fort Shafter well, ‘Aiea Navy well, TAMC-2 well, and Hālawa Shaft (November 2006 to October 2016) (Tables GW-9 to GW-24) • Normal pumping rates for water supply wells (Table WELL-4) • Red Hill Storage Facility pumping information, including maximum pumping rates (Table WELL-5) • Pumping rates for wells within the groundwater modeling domain (Table WELL-6) • Depth to groundwater time-series for monitoring wells within the Red Hill monitoring network (Appendix B)	• **P:** Perform regional-scale pumping tests of Red Hill Shaft, Hālawa Shaft, and Moanalua Wells (individually and consecutively) with continuous monitoring of pumping rates and water levels at all wells to provide data for further calibration of model parameters including: transmissivity, hydraulic conductivity, heterogeneity, anisotropy, storativity, and specific yield. *Source:* Navy • **P:** Through the process of iterative calibration, adjust groundwater model parameters to reasonably match available data from primary area of interest, including regional pumping test drawdown data, hydraulic gradients, and groundwater level contour maps for non-pumping and pumping conditions. *Source:* Navy

[a] References in parentheses refer to the *Existing Data Summary and Evaluation Report for Groundwater Flow and Contaminant Fate and Transport Modeling* (DON 2017c) (table numbers are from Appendix A of the report).
[b] **P:** Primary data need
S: Secondary data need

3.1.7 Groundwater Recharge Rates

For the groundwater flow model, in addition to recharge from precipitation it is also important to account for interactions between groundwater and surface water. The principal surface water features in the primary area of interest include North Hālawa Stream, South Hālawa Stream, and Moanalua Stream. Where the water table lies below the streams, as is the case in the Facility area, the streams do not receive groundwater discharge. Rather, streambed seepage causes groundwater recharge. To update the 2007 model (DON 2007), it will be important to incorporate better estimates of groundwater recharge, especially in the Facility area.

It appears that the detailed maps of groundwater recharge rates from recent USGS studies (Engott et al. 2015; Izuka et al. 2016) can be used as direct input to the updated groundwater flow model for most, if not all, of the modeling areas. However, in the area north of the Facility, the Hālawa Quarry and Hawaiian Cement plant operations have modified the natural watershed topography and likely changed groundwater recharge rates. Recharge rates in those areas need to be further evaluated, and likely modified to account for such anthropogenic effects. Currently however, the available data are limited to visual observations of air photographs. More data need to be collected to evaluate the surface water use and discharges at these operations to develop the CSM and estimate reasonable groundwater recharge rates in that area.

Natural groundwater discharge also occurs along the coast and thus the model update needs to specify the rate of this flux. However, groundwater discharge rates are not estimated in the recent USGS reports (Engott et al. 2015; Izuka et al. 2016), but estimates may be available from the USGS modeling studies currently underway.

Table 3-7: Data Gaps for Modeling Groundwater Recharge Rates

Key Uncertainty	Task or Information Need	Existing Data [a]	Data Gaps and Sources [b]
Groundwater recharge rates	Better define the spatial distribution of groundwater recharge rates in the 2007 model.	• Sedimentary deposit information (Table HYDRO-1) • Hydrogeologic properties of HGUs within the modeling domain (Table HYDRO-2) • Daily streamflow values for Kalihi and North Hālawa Streams (January 2007 to December 2016) (Tables HYDRO-5 to HYDRO-37) • Daily precipitation totals for Moanalua and North Hālawa Valley precipitation gauges (January 2007 to December 2016) (Tables GW-26 to GW-47) • Water-budget estimates for O‘ahu under regular and drought, as well as pre- and recent development conditions (Tables GW-48 to GW-54) • Freshwater use estimates for O‘ahu (Table GW-55) • Ratios of fog interception to rainfall used in Izuka et al. 2016 for O‘ahu (Table GW-56) • Ratios of runoff to rainfall used in Izuka et al. 2016 for O‘ahu (Table GW-57) • Discharge rates for O‘ahu springs (Tables GW-58 and GW-59) • O‘ahu aquifer characteristics, included aquifer type and use (Table GW-60)	• **S:** Obtain recent USGS recharge study results as GIS shapefiles and import directly into groundwater model. *Source:* USGS recharge study • **S:** Obtain information on surface water discharges and extent of impermeable surfaces at the Hālawa Correctional Facility. Adjust recharge rates as needed in primary area of interest *Source:* Navy • **S:** Groundwater discharge rate estimates *Source:* USGS modeling studies in progress

GIS geographic information system

[a] References in parentheses refer to the *Existing Data Summary and Evaluation Report for Groundwater Flow and Contaminant Fate and Transport Modeling* (DON 2017c) (table numbers are from Appendix A of the report).
[b] **P:** Primary data need
S: Secondary data need

3.2 CONTAMINANT FATE AND TRANSPORT DATA GAPS

3.2.1 Distribution of COPCs in Groundwater in the Red Hill Area

Groundwater quality data are being collected from monitoring wells at locations potentially downgradient from the Facility, which should provide information about the distribution of COPCs in groundwater. Data collected so far show elevated levels of some COPCs at a well near the Tank 5 source (RHMW02) including total petroleum hydrocarbons – diesel range organics (TPH-d) and naphthalene. However, the currently available data show very low concentrations at only one well (RHMW01) and non-detect concentrations of the COPCs at select other monitoring wells. Overall, the currently available water quality data do not provide a basis for delineating the extent of contamination. Additional data collection from the planned monitoring wells used to further monitor COPCs in groundwater should address this uncertainty.

Table 3-8: Data Gaps for Modeling COPCs in Groundwater

Key Uncertainty	Task or Information Need	Existing Data [a]	Data Gaps and Sources [b]
Distribution of the COPCs in groundwater in the Red Hill area, including potential NAPL on the water table and dissolved-phase constituents within the water table aquifer	Estimate distribution of COPCs in groundwater including potential NAPL on the water table surface and dissolved-phase contamination within the water table aquifer.	• Major ion and cation groundwater concentrations (Table GW-25) • Groundwater monitoring sampling results (February 2005 to October 2016) (Tables CHEM-1 to CHEM-34) • COPC concentration trends over time (February 2005 to October 2016) (Appendix C)	• **P:** Groundwater monitoring sampling results (November 2016 onward) *Source:* Navy • **P:** COPC concentration trends (November 2016 onward) *Source:* Navy • **S:** Field observations, including evidence of contamination *Source:* Navy • **P:** Available data from non-Navy petroleum contamination sources *Source:* DOH
	Estimate potential NAPL movement from the Facility fuel tanks. A detailed geologic model of Red Hill is needed to characterize the basalt flow layers and interbedded clinker beds.	• Boring logs from Red Hill, North Hālawa Valley, and Pearl Harbor area (Tables GEO-1 to GEO-4; Appendix D) • Sedimentary deposit information (Table HYDRO-1) • Hydrogeologic properties of HGUs within the modeling domain (Table HYDRO-2) • Chemical and physical characteristics of COPCs (Tables CHEM-35 to CHEM-37) • SVM results (Navy SVM reports, 2008 to December 2016)	• **P:** Basalt flow layer and clinker zone thickness, dip, estimates of effective porosity and moisture content *Source:* BWS, CWRM, DLNR, Navy, USGS • **S:** Depth and extent of perched aquifers *Source:* BWS, CWRM, DLNR, Navy, USGS

Key Uncertainty	Task or Information Need	Existing Data [a]	Data Gaps and Sources [b]
Distribution of the COPCs in groundwater in the Red Hill area, including potential NAPL on the water table and dissolved-phase constituents within the water table aquifer (cont.)	Obtain site-associated COPC data for the CF&T modeling.	• Red Hill fuel storage tank dimensions, historic contents, and current contents (Table FAC-1) • Hālawa Correctional Facility storage tank dimensions, and historic contents and releases (Tables FAC-2 and FAC-3) • Hawaiian Cement releases (Table FAC-4) • Groundwater monitoring sampling results (February 2005 to October 2016) (Tables CHEM-1 to CHEM-34) • COPC concentration trends over time (February 2005 to October 2016) (Appendix C)	• **S:** Chemical composition of JP-8 fuel stored at the Facility *Source:* Navy • **S:** Primary petroleum compounds in TPH-d detected in RHMW02 *Source:* Navy • **S:** Solubility limits of the principal compounds in TPH-d, naphthalene, and the other COPCs at the site groundwater temperature *Source:* Navy • **S:** Site-specific groundwater chemistry for NAPs *Source:* Navy

BWS Board of Water Supply, City and County of Honolulu
CWRM Commission on Water Resource Management
DLNR Department of Land and Natural Resources, State of Hawaiʻi
SVM soil vapor monitoring
[a] References in parentheses refer to the *Existing Data Summary and Evaluation Report for Groundwater Flow and Contaminant Fate and Transport Modeling* (DON 2017c) (table numbers are from Appendix A of the report).
[b] **P:** Primary data need
S: Secondary data need

3.2.2 Potential Water Quality Impacts to Groundwater Resources

As described in the previous section, the CWRM database will provide some useful historical information for supply well pumping rates, including wells that may supply water to Hālawa Quarry and Hawaiian Cement Plant operations. However, the CWRM database will not likely provide contemporaneous measurements of groundwater levels and pumping rates in the Facility area. Thus conducting synoptic monitoring of groundwater levels in all the Red Hill monitoring wells while also measuring pumping rates of supply wells located near the Facility, as currently planned for this project, is essential to fill this important data gap for refining the model.

Table 3-9: Data Gaps for Modeling Water Quality Impacts to Groundwater Resources

Key Uncertainty	Task or Information Need	Existing Data [a]	Data Gaps and Sources [b]
Potential water quality impacts to the groundwater resources	Identify current and projected water supply needs.	• Water-budget estimates for O‘ahu under regular and drought, as well as pre- and recent development conditions (Tables GW-48 to GW-54) • Freshwater use estimates for O‘ahu (Table GW-55) • Discharge rates for O‘ahu springs (Tables GW-58 and GW-59) • O‘ahu aquifer characteristics, included aquifer type and use (Table GW-60) • Well construction details from existing and newly installed wells within the modeling domain (Tables WELL-1 to WELL-4) • Normal pumping rates for water supply wells (Table WELL-4) • Red Hill Shaft pumping information, including maximum pumping rates (Table WELL-5) – Pumping rates for wells within the groundwater modeling domain (Table WELL-6) • Summary of Joint Base Pearl Harbor-Hickam water supply system (Table FAC-5) • Land cover parameters used in Izuka et al. 2016 water-budget calculations (Table FAC-6) • Land cover types as fraction of aquifer-system area (Table FAC-7)	• **P:** Information on water resource development – Current groundwater withdrawals and usage – Anticipated future water resource needs *Source:* BWS, CWRM, DLNR, Navy, USGS • **P:** Planned future water supply wells *Source:* BWS, DLNR, Navy

[a] References in parentheses refer to the *Existing Data Summary and Evaluation Report for Groundwater Flow and Contaminant Fate and Transport Modeling* (DON 2017c) (table numbers are from Appendix A of the report).
[b] **P:** Primary data need
S: Secondary data need

3.2.3 Other Physical Properties of Basalt that Affect Groundwater Contaminant Fate and Transport

Site-specific values for effective porosity and dispersivity of the aquifer are uncertain. For the 2007 model (DON 2007), regional studies provided the basis for estimating values for these parameters.

Table 3-10: Data Gaps for Modeling Other Physical Properties of Basalt Affecting CF&T

Key Uncertainty	Task or Information Need	Existing Data [a]	Data Gaps and Sources [b]
Other physical properties of basalt that affect groundwater contaminant fate and transport	Obtain site-specific values for effective porosity and dispersivity for the contaminant fate and transport (CF&T) modeling.	• Boring logs from Red Hill, North Hālawa Valley, and Pearl Harbor area (Tables GEO-1 to GEO-4; Appendix D) • Sedimentary deposit information (Table HYDRO-1) • Hydrogeologic properties of HGUs within the modeling domain (Table HYDRO-2) • Well construction details from existing and newly installed wells within the modeling domain (Tables WELL-1 to WELL-4)	• **S:** Developing the detailed CSM will allow additional estimates of effective porosity for clinker and interbedded dense lava flows beneath the Facility. *Source:* Navy, USGS • **S:** Currently available regional parameter values (e.g., for effective porosity and dispersivity) may suffice for the CF&T modeling with conservative assumptions. However, an evaluation will be made on whether to conduct a tracer study after calibrating the groundwater flow model. *Source:* Navy, USGS

[a] References in parentheses refer to the *Existing Data Summary and Evaluation Report for Groundwater Flow and Contaminant Fate and Transport Modeling* (DON 2017c) (table numbers are from Appendix A of the report).
[b] **P:** Primary data need
S: Secondary data need

3.2.4 Source Area Extent, Mass Loading, and Natural Attenuation Rates

Extent of the source area, COPC mass loading rates and site-specific values for natural attenuation rates of the COPCs are uncertain. Site-specific values for COPC sorption and degradation rates were not available. For the 2007 model (DON 2007), regional studies provided the basis for estimating values for all these parameters.

It is planned to evaluate natural attenuation rates using existing data augmented by new data and a series of new, limited focused studies, including:

- Spatial and temporal trends of COPC data in the known groundwater plume
  - Time series plots and maps (from existing data and augmented analysis)
  - Solute transport modeling (new study)
- Source studies
  - Fuel composition
- Natural attenuation of petroleum fuels and dissolved compounds
  - Groundwater chemical analyses of NAPs
  - Microbial analyses

Details of the plans to evaluate natural attenuation will be included in the forthcoming derivative deliverable *Attenuation Evaluation Plan,* as noted on Figure 1.

Table 3-11: Data Gaps for Modeling Source Area Extent, Mass Loading, and Natural Attenuation Rates

Key Uncertainty	Task or Information Need	Existing Data [a]	Data Gaps and Sources [b]
Source area extent, COPC mass loading, and natural attenuation rates	Estimated volumes and type of fuel released with respect to time series plots of the concentrations of COPCs and NAPs in the Red Hill monitoring wells to estimate mass loading in source area through time and model natural attenuation processes.	• Major ion and cation groundwater concentrations (Table GW-25) • O‘ahu aquifer characteristics, included aquifer type and use (Table GW-60) • Red Hill fuel storage tank dimensions, historic contents, and current contents (Table FAC-1) • Hālawa Correctional Facility storage tank dimensions, and historic contents and releases (Table FAC-2 and FAC-3) • Hawaiian Cement releases (Table FAC-4) • Groundwater monitoring sampling results (February 2005 to October 2016) (Tables CHEM-1 to CHEM-25) • Groundwater NAP concentrations (Tables CHEM-26 to CHEM-34) • Chemical and physical characteristics of COPCs, NAPs, gasoline, JP-5, and JP-8 (Tables CHEM-35 to CHEM-37) • COPC concentration trends over time (February 2005 to October 2016) (Appendix C)	• **S:** To better understand the fuel degradation processes and develop the CSM for the vadose zone migration, it would be useful to better define the composition of leaked fuel, including the aliphatic and aromatic fractions subdivided by equivalent carbon (EC) numbers. The available analytical data do not define the aliphatic and aromatic fractions of the TPH in groundwater using equivalent carbon (EC) numbers. *Source:* Navy • **S:** For the CF&T modeling of TPH-d, it would be useful to have TPH-d values with the components subdivided by EC number to estimate physical and chemical properties of the contaminants that affect fate and transport (e.g., solubility, vapor pressure, and partition coefficients). Analyses that define the components of TPH-d by EC number would also be useful, especially for the source area, for evaluating sorption and degradation. *Source:* Navy • **S:** Comparing the EC fractions in the fuel to groundwater COPC time series data may also help characterize the natural attenuation processes in the vadose zone. The time series data for COPCs dissolved in groundwater may also be useful in estimating decay rates in groundwater if these COPCs are detected in a well directly downgradient of the source area. *Source:* Navy

[a] References in parentheses refer to the *Existing Data Summary and Evaluation Report for Groundwater Flow and Contaminant Fate and Transport Modeling* (DON 2017c) (table numbers are from Appendix A of the report).
[b] **P:** Primary data need
S: Secondary data need

4. Data Acquisition Plan

Table 4-1 lists the data gaps and corresponding data sources identified in Table 3-1 through Table 3-11, and presents the method planned to acquire the data and the timeframe those data are needed according to the indicated modeling tasks. Data from Navy sources will be generated by investigation activities or procured from relevant Navy departments. Data from agency (e.g., BWS, USGS, CWRM) sources will be requested through appropriate channels. Data from published literature sources will be acquired directly from the published documents. The data acquired will be used to update the CSM and conduct groundwater flow and CF&T modeling.

Table 4-1: Summary of Data Gaps and Data Acquisition Plan

Data Gap	Source for Data	Method to Acquire the Data	Timeline Needed	Related CSM/Modeling Task(s)
GROUNDWATER FLOW				
[Table 3-1:] Groundwater Flow Directions, Rates, and Migration				
Depths of older alluvial sediment fill and saprolite beneath North and South Hālawa valleys				
• Boring logs from South Hālawa Valley and other non-Facility wells (e.g., Tripler Army Medical center wells) if available	Army, BWS, CWRM, DLNR	Collect and review available borehole geologic logs	Before start of flow modeling, to develop CSM	Estimate valley fill thickness for detailed CSM.
• Well construction details from existing and newly installed wells within the modeling domain not identified in (DON 2017c)	BWS, DLNR	Collect and review available well logs	Before start of flow modeling, to develop CSM	Develop CSM and assign well screen intervals to model layers at start of flow modeling.
• Data from existing studies by the USGS (Engott et al. 2015, 2015; Izuka et al. 2016)	USGS	Collect and review data and GIS files from USGS studies	Before start of flow modeling, to develop CSM	Use to define spatial distribution of groundwater recharge for detailed CSM.
• Estimates of stream seepage along the valleys	USGS	Collect and review data and GIS files from USGS studies	Before start of flow modeling, to develop CSM	Use to refine spatial distribution of groundwater recharge for detailed CSM.
Groundwater flow directions				
• Water levels during 2015 USGS aquifer tests for all other wells involved in the test	USGS	Collect and review data from USGS and BWS	Before start of flow modeling, to evaluate data and develop CSM	Use to evaluate effects of Hālawa Shaft pumping on Red Hill monitoring wells, if possible, and develop CSM before start of flow modeling; if possible, also use pumping data to calibrate flow model.
• Accurate water level measurements and elevations (i.e., resurveying, gyroscopic survey)	Navy	Second-Order, Class I survey of Navy-owned wells, with benchmarks for surveys of non-Navy wells to use as tie-in points	Before start of flow modeling, to evaluate data and develop CSM	Use data to calculate accurate groundwater level elevations, prepare potentiometric maps for pumping and non-pumping periods, and develop CSM; also use data to calibrate flow model.
• Water supply well pumping rates for Red Hill Shaft, Hālawa Shaft, and Moanalua-area wells	BWS	Collect and review data from USGS, CWRM and BWS	Before start of flow modeling, to evaluate data and develop CSM	Use data to develop CSM and calibrate flow model.

Data Gap	Source for Data	Method to Acquire the Data	Timeline Needed	Related CSM/Modeling Task(s)
• Groundwater level data (November 2016 onward)	Navy	Evaluate new data being collected	Before start of flow modeling, to evaluate data and develop CSM	Use data to develop CSM and calibrate flow model.
Better definition of spatial distribution of hydraulic heads in the Facility area during non-pumping and pumping conditions				
• Potentiometric maps representative of groundwater levels when all of the supply wells are not pumping, and similar maps during other periods when each of the wells is pumping at a relatively steady rate	Navy	Use groundwater level measurements and new survey data to calculate accurate groundwater level elevations and prepare potentiometric maps for pumping and non-pumping periods, and develop CSM; also use data to calibrate flow model	Before start of flow modeling, to evaluate data, prepare maps, and develop CSM	Use to develop CSM and calibrate flow model.
• Evaluation of vertical gradients for initial steady-state conditions	USGS	Obtain data from the current USGS groundwater model	Before start of flow modeling, to develop CSM	Use to develop CSM and calibrate flow model.
[Table 3-2:] Effects of Supply Well Pumping				
• Evaluation of the USGS pumping test data (May 2015) and other aquifer test and water level data	BWS, Navy, USGS	Collect data from USGS and BWS databases	Before start of flow modeling, to evaluate data	Use to develop CSM and calibrate flow model.
• Water levels during 2015 USGS aquifer tests for all other wells involved in or impacted by the test	BWS, CWRM, DLNR, USGS	Collect data from USGS and BWS databases	Before start of flow modeling, to evaluate data	Use to develop CSM and calibrate flow model.
• Information for Hālawa Quarry and Hawaiian Cement Plant Operations: – Water supply sources – Groundwater volumes pumped and used – Discharge points and flow rates – Water quality permit limits and violations	DLNR, DOH, Hawaiian Cement	Collect data from agency databases and existing reports	Before start of flow modeling, to evaluate data, prepare maps, and develop CSM	Need to develop CSM and for input to flow model.
[Table 3-3:] Freshwater–Saltwater Interface				
• Compiled available salinity profiles from all deep monitoring wells in modeling area and/or obtain map of freshwater–saltwater elevation contours	BWS, CWRM, USGS	Send letter request to each agency	Before start of flow modeling, to evaluate data, prepare maps, and develop CSM	Develop CSM and provide input to flow model.

Data Gap	Source for Data	Method to Acquire the Data	Timeline Needed	Related CSM/Modeling Task(s)
• Define model layers to include thickness of the freshwater aquifer	BWS, CWRM, USGS	Use info described above to define aquifer thickness	Before start of flow modeling, to evaluate data, prepare maps, and setup flow model	Develop CSM and provide input to flow model.
[Table 3-4:] Geologic Features that Affect Groundwater Flow				
• Compile and evaluate all existing geologic maps and logs of borings (e.g., Tripler Army Medical center wells), tunnels and excavations not identified in (DON 2017c) that are located within the primary area of interest to develop detailed CSM including geologic features that affect groundwater flow and NAPL migration	Army, BWS, City and County of Honolulu, CWRM, DLNR, HDOT, USGS	Collect data from agency databases and existing reports	At beginning of CSM development	Develop detailed geologic CSM of vadose zone in UST source area prior to CF&T modeling.
• Identification of surface geophysical methods that would likely be effective in better defining such geologic features	Navy	Review existing case studies	At beginning of CSM development	Develop detailed geologic CSM prior to flow modeling.
• Potential field-scale pilot study to demonstrate the effectiveness of method(s) for delineating subsurface extent of such features above and below water table	Navy	Develop and plan field pilot test in coordination with USGS	Before completing CSM	Develop detailed geologic CSM prior to flow modeling.
• Refine groundwater model layer thickness and extent, as needed to be consistent with updated detailed CSM	Navy	Integrate available geologic data to define HGU thickness and flow model layers	Before finishing flow model calibration	Develop detailed geologic CSM prior to flow modeling.
[Table 3-5:] Hydraulic Head and Flux Conditions				
• Hydrogeologic data available along 2007 model boundaries	USGS	Collect and integrate existing hydrogeologic and geologic data to define boundary conditions for flow model	Before flow model setup	Develop detailed geologic CSM prior to flow modeling.

Data Gap	Source for Data	Method to Acquire the Data	Timeline Needed	Related CSM/Modeling Task(s)
• Information from the USGS regional model currently being developed, including electronic files of hydraulic heads, conductance and fluxes along boundaries, and model layer elevations	USGS	Meet with USGS to obtain flow model files from USGS modeling work in progress	Before flow model setup	Develop detailed groundwater flow CSM prior to flow modeling.
• Other available information from the USGS and/or CWRM regarding springs, and subsurface groundwater outflow along shoreline	CWRM, USGS	Meet with USGS to obtain existing data from CWRM, and flow model files from USGS modeling work in progress	During CSM development, prior to flow modeling	Develop detailed groundwater flow CSM prior to flow modeling.
[Table 3-6:] Basal Aquifer Hydraulic and Physical Properties				
• Regional-scale pumping tests of Red Hill Shaft, Hālawa Shaft, and Moanalua Wells (individually and consecutively) with continuous monitoring of pumping rates and water levels at all wells	Navy	Currently planned field data collection, synoptic monitoring	During CSM development, prior to flow modeling	To develop detailed groundwater flow CSM and calibrating flow model, prior to simulating future pumping scenarios.
• Through iterative calibration, adjust groundwater model parameters to allow model to reasonably simulate available site data, especially pumping test data and groundwater level contour maps, for non-pumping and pumping conditions.	Navy	Use data from item above	At beginning of flow model calibration	Develop detailed groundwater flow CSM and calibrating flow model, prior to simulating future pumping scenarios.
[Table 3-7:] Groundwater Recharge Rates				
• Recent USGS recharge study results as GIS shapefiles	USGS recharge study	Collect data from USGS databases and existing report	During CSM development, prior to flow modeling	Develop detailed groundwater flow CSM.

Data Gap	Source for Data	Method to Acquire the Data	Timeline Needed	Related CSM/Modeling Task(s)
• Obtain information on surface water discharges and extent of impermeable surfaces at the Hālawa Correctional Facility, and adjust recharge rates in model as needed.	Navy, DLNR, DOH, Hawaiian Cement	Collect data from agency databases and existing reports	Before start of flow modeling, to evaluate data, prepare maps, and develop CSM	Prepare CSM and provide input for groundwater flow model.
• Groundwater discharge rate estimates	USGS modeling studies in progress	Meet with USGS to obtain flow model files from USGS modeling work in progress	Before start of flow modeling, to evaluate data, prepare maps, and develop CSM	Prepare CSM and provide input for groundwater flow model.
CONTAMINANT FATE AND TRANSPORT				
[Table 3-8:] Distribution of COPCs in Groundwater				
Potential NAPL on the water table surface and dissolved-phase contamination within the water table aquifer				
• Groundwater monitoring sampling results (November 2016 onward)	Navy	Review Red Hill Quarterly Groundwater Monitoring Reports	Before start of CF&T modeling, to develop CSM	Evaluate the distribution of COPCs in groundwater and develop CSM.
• COPC concentration trends (November 2016 onward)	Navy	Evaluate Red Hill Quarterly Groundwater Monitoring Reports	Before start of CF&T modeling, to develop CSM	Evaluate the distribution of COPCs in groundwater and develop CSM.
• Field observations, including for evidence of contamination	Navy	Field logs for new monitoring well installation and Red Hill groundwater monitoring events	Before start of CF&T modeling, to develop CSM	Evaluate the presence of COPCs in groundwater and develop CSM. Evaluate the distribution of COPCs in groundwater and develop CSM.
• Available data from non-Navy petroleum contamination sources	DOH	Collect information from agency databases and reports	Before start of CF&T modeling, to develop CSM	Evaluate the distribution of COPCs in groundwater and develop CSM.
Estimation of NAPL movement from the Facility fuel tanks				
• Basalt flow layer and clinker zone thickness, dip, estimates of effective porosity and moisture content	BWS, CWRM, DLNR, Navy, USGS	Review boring logs; estimate porosity based on geologic logs and core photos	Before start of flow modeling	Develop detailed geologic CSM of vadose zone in fuel tank source area.
• Depth and extent of perched aquifers	BWS, CWRM, DLNR, Navy, USGS	Review existing reports and borehole logs	Before start of flow modeling	Develop detailed CSM of groundwater recharge and flow.

Data Gap	Source for Data	Method to Acquire the Data	Timeline Needed	Related CSM/Modeling Task(s)
Site-associated COPC data for the CF&T modeling				
• Chemical composition of JP-8 fuel stored at the Facility	Navy	If possible to collect representative JP-8 fuel sample, perform lab analysis to define composition of JP-8 fuel, including individual compound concentrations	Before start of CF&T modeling	Characterize fresh and weathered JP-8 (if sampling possible) to elucidate biodegradation effect on NAPL, and develop detailed CSM of fuel attenuation processes in vadose zone.
• Primary petroleum compounds in TPH-d detected in RHMW02	Navy	Perform lab analysis to define composition of TPH-d in groundwater beneath source area, including individual compound concentrations	Before start of CF&T modeling	Identify individual compounds that make up TPH-d and develop detailed CSM of COPC attenuation and migration. Use as input for source term in CF&T model.
• Solubility limits of the principal compounds in TPH-d, naphthalene, and the other COPCs at the site groundwater temperature	Navy	To be based on lab analysis cited above	Before start of CF&T modeling	Use as input for source term in CF&T model.
• Site-specific groundwater chemistry for NAPs	Navy	Lab analysis of groundwater samples from Red Hill monitoring wells	Before start of CF&T modeling	Use to develop detailed CSM of COPC attenuation and migration.
[Table 3-9:] Water Quality Impacts				
• Information on water resource development – Current groundwater withdrawals and usage – Anticipated future water resource needs	BWS, CWRM, DLNR, Navy, USGS	Collect data from agency databases and existing reports	Before start of flow modeling, to evaluate data, prepare maps, and develop CSM	Need as model input to simulate normal and future pumping scenarios.
• Planned future water supply wells	BWS, DLNR, Navy	Send letter request to each agency	After flow model calibration but before simulating future pumping scenarios	Need as model input to simulate future pumping scenarios.
[Table 3-10:] Other Physical Properties of Basalt				
• Additional estimates of effective porosity for clinker and interbedded dense lava flows beneath the Facility	USGS	Review boring logs; estimate porosity based on geologic logs and core photos	Before start of CF&T modeling	Provide input for CF&T model.
• Values for effective porosity and dispersivity at the site	Navy, USGS	Evaluate the need for a tracer study	Before start of CF&T modeling	Provide input for CF&T model.

Data Gap	Source for Data	Method to Acquire the Data	Timeline Needed	Related CSM/Modeling Task(s)
[Table 3-11:] Data Gaps for Modeling Source Area Extent, Mass Loading, and Natural Attenuation Rates				
• Better definition of composition of leaked fuel, including the aliphatic and aromatic fractions subdivided by equivalent carbon (EC) numbers	Navy	If possible to collect representative JP-8 fuel sample, perform lab analysis to define composition of JP-8 fuel, including individual compound concentrations	Before start of CF&T modeling	Develop detailed CSM of vadose zone natural attenuation and provide input to CF&T model.
• Analytical results of components of TPH-d subdivided by EC number	Navy	Perform lab analysis to define composition of TPH-d in groundwater beneath source area, including individual compound concentrations	Before start of CF&T modeling	Input to CF&T model.
• EC fractions compared to groundwater COPC time series data	Navy	Perform lab analysis to define composition of TPH-d in groundwater beneath source area, including individual compound concentrations	Before start of CF&T modeling	Input to CF&T model.

Shaded row indicates Primary data need

5. Summary of Data Gap Analysis

Table 5-1 presents a summary of key uncertainties, task or information needs, acquired and additional data needed, and the impact of not acquiring the needed additional data. The primary objective of the analysis is to facilitate resolution of the key uncertainties identified in the table.

The analysis found that the three biggest overall data gaps essential to updating the CSM and conducting modeling are:

- Establishing accurate elevations tied to a common datum for measuring points from which groundwater levels are measured to reduce uncertainties in groundwater elevations used for evaluation of hydraulic heads and groundwater flow gradients.
- Obtaining comprehensive pumping data (discharge rates and durations) for water supply wells located within the modeling domain for evaluating impacts on hydraulic heads, groundwater flow gradients, and contaminant movement and to establish a basis for future transient pumping scenarios.
- Obtaining data that can be used to confirm whether a hydraulic barrier is present between Red Hill and Hālawa Shaft.

Table 5-1: Summary of Analysis and Results

Key Uncertainty (see Table 3-1 through Table 3-11)	Task or Information Need (see Table 3-1 through Table 3-11)	Data Already Acquired (summarized from Table 3-1 through Table 3-11)	Data Gaps (summarized from Table 4-1)	Impact of Not Acquiring Needed Additional Data
Conceptual Site Model and Groundwater Flow Model				
Data Gaps for Modeling Groundwater Flow Directions, Rates, and Migration				
Determine groundwater flow directions, rates and migration of groundwater impacted by COPCs from the Facility	• Define depths of older alluvial sediment fill and saprolite beneath North and South Hālawa valleys, using geologic logs and well construction details for wells in the numerical groundwater modeling area. • Estimate groundwater flow directions. • Better define the spatial distribution of hydraulic heads (groundwater levels) in the Facility area, including Hālawa Shaft, Red Hill Shaft, and the Moanalua and TAMC Wells, during non-pumping and pumping conditions.	• Lithologic data have been obtained from Red Hill, North Hālawa Valley, and the Pearl Harbor area. Much of the lithologic data are from borings that are too shallow to determine the vertical and horizontal extent of valley fill and saprolite, which could serve as hydraulic barriers if they extend below the water table. • During investigation activities conducted in 2016 and 2017, the Navy has installed, logged, measured and analyzed water from three new monitoring wells screened across the basal aquifer water table. Twelve wells screened within the basal aquifer and the sampling point adjacent to the water supply well at Red Hill Shaft (RHMW2254-01) are included in the current Red Hill Monitoring Well network. Twelve of these are located in the immediate vicinity of Red Hill, and one well is located in South Hālawa Valley. No other monitoring wells exist between Red Hill and Hālawa Shaft. • Synoptic water level studies have been performed in May 2015 and November 2016. These studies and data collection efforts were performed or coordinated by the USGS and provide the best, most comprehensive data sets to date. • Pumping rates for some water supply wells in the vicinity of Red Hill have been obtained; however, the data sets are not comprehensive data sets for all water supply wells for the period 2007 through 2017.	• The Navy currently has plans to install up to two additional basal aquifer monitoring wells (RHMW11 and RHMW12 [contingent]). The need for additional monitoring wells is being evaluated and will continue as new data are obtained. • All measuring point elevations for wells within the Red Hill Monitoring Well Network need to be resurveyed. In addition, a gyroscopic survey of the monitoring well network is needed to determine if corrections need to be made to water level measurements for vertical alignment of monitoring wells. • Data from existing studies on groundwater recharge, including seepage from streams, and spring discharge rates need to be obtained, preferably in GIS files if available. • Water level data and records of supply well discharge rates are needed. • Pumping rates for water supply wells in the vicinity of Red Hill, Hālawa Valley, and Moanalua Valley will need to be obtained for the periods during which the water level studies were conducted. Additionally, pumping rates for the last 10 years will be needed to develop historical pumping trends for use in transient model calibration.	• It is important to collect additional data on the depth of valley fill, which may impede groundwater from flowing toward Hālawa Shaft. If additional data do not confirm the thickness of valley fill extends below the water table to create a barrier, the groundwater flow model cannot be setup to include such a hydraulic barrier. • If all the well measuring points are not resurveyed to obtain accurate groundwater level elevations, the model results will not be acceptable. • Data on groundwater recharge and seepage rates have a direct impact on flow into and out of the model domain. If such data are not obtained, the model results would be questionable. • It is essential to obtain additional water level data in 2017, both for pumping and for non-pumping periods, for the groundwater modeling. These data are needed from Hālawa Shaft, Red Hill Shaft, and the Tripler- Moanalua wells. The water level data are needed to develop potentiometric maps and timed-series graphs for evaluating groundwater flow directions. These data are also needed to evaluate ambient groundwater flow conditions and the effects of pumping water supply wells on hydraulic gradients and groundwater flow directions. • Obtaining the historical records of water supply well discharge rates is also important. These data are needed to evaluate ambient groundwater flow conditions and the effects of pumping water supply wells on hydraulic gradients and groundwater flow directions.
Data Gaps for Modeling Effects of Supply Well Pumping				
Effects of pumping Hālawa Shaft, Red Hill Shaft, and Moanalua-area wells on migration of the affected groundwater	• Obtain information from water level monitoring studies and aquifer testing.	• Synoptic water level studies have been performed in May 2015 and November 2016. These studies and data collection efforts were performed or coordinated by the USGS and provide the best, most comprehensive data sets to date. • Pumping rates for some water supply wells in the vicinity of Red Hill have been obtained; however, the data sets are not comprehensive data sets for all water supply wells for the period 2007 through 2017.	• Water level data and records of supply well discharge rates are needed. • Pumping rates for water supply wells in the vicinity of Red Hill, Hālawa Valley, and Moanalua Valley will need to be obtained for the periods during which the water level studies were conducted. Additionally, pumping rates for the last 10 years will be needed to develop historical pumping trends for use in transient model calibration. • Data on vertical hydraulic gradient will be useful in calibrating initial steady-state conditions.	• Obtaining additional water level data is essential. These data are needed to develop potentiometric maps and timed-series graphs for evaluating groundwater flow directions. These data are also needed to evaluate ambient groundwater flow conditions and the effects of pumping water supply wells on hydraulic gradients and groundwater flow directions. • Obtaining records of water supply well discharge rates is essential. These data are needed to evaluate ambient groundwater flow conditions and the effects of pumping water supply wells on hydraulic gradients and groundwater flow directions. • The groundwater flow model can be calibrated without data on vertical hydraulic gradients; however, these data will provide for better model calibration of steady-state conditions.
Data Gaps for Modeling Freshwater Saltwater Interface				
Depth of the freshwater–saltwater interface throughout groundwater modeling area	• Define the current elevation of the base of freshwater aquifer throughout the groundwater modeling area.	• Water level data from monitoring activities have been obtained and are of good quality for evaluating the changes in the water table surface over time. • Salinity profiles for Hālawa Deep Monitor Well 2253-03 have been acquired; however, additional data from other wells will provide a more comprehensive evaluation of the depth of the freshwater/saltwater interface, which will be established as the base of the numerical model.	• Salinity profiles should be obtained for all deep wells in the modelling domain. If available, showing the base of the freshwater/saltwater transition zone will be most useful in establishing the thickness of the freshwater aquifer.	• Establishing the thickness of the freshwater aquifer as accurately as possible is essential. The model can be calibrated with data obtained to date; however, lack of additional data will result in uncertainty in elevation of the base of the numerical model.
Data Gaps for Modeling Geologic Features that Affect Groundwater Flow				
Geologic features that provide preferred groundwater flow pathways or barriers in the Facility vicinity	• Better define spatial distribution of clinker zones, paleo-channels, faults, dense low-permeability lava flows and dikes in the primary area of interest for groundwater modeling.	• Lithologic data (i.e., boring logs and barrel logs in the vicinity of Red Hill including Red Hill Shaft, information on sedimentary deposits), hydrogeologic properties within the modeling domain, and well construction details have been obtained and provide useful information on the location and depths of lava flows of varying permeability. However, most of the data obtained are limited to the immediate vicinity of Red Hill.	• Additional geologic information from existing borings (e.g., South Hālawa Valley) that have not been compiled in the EDR (DON 2017c) and from new well installations, as well as geologic mapping focused in the vicinity of Red Hill is planned. • Surface geophysical methods could potentially provide useful information in better defining geologic features that could affect groundwater flow.	• The model can be developed using currently available information; however, additional information will also help to reduce uncertainty in the model. Obtaining additional information on subsurface geology is essential in building a robust CSM. This information will also help to better define the model layer thickness and extent, which will help build a more defensible model. • The CSM can be developed using currently available information; however, data from surface geophysical methods could potentially help to better define subsurface geology and potential pathways where NAPL could flow. However, it is not known how successful these methods will be at Red Hill considering that the vadose zone is a thick unit up to several hundred feet thick at higher elevations on Red Hill and the complicated nature of the physical properties of basalt layers, clinker zones and fractures within the vadose zone.

Key Uncertainty (see Table 3-1 through Table 3-11)	Task or Information Need (see Table 3-1 through Table 3-11)	Data Already Acquired (summarized from Table 3-1 through Table 3-11)	Data Gaps (summarized from Table 4-1)	Impact of Not Acquiring Needed Additional Data
Data Gaps for Modeling Hydraulic Head and Flux Conditions				
Hydraulic head and flux conditions along modeling area perimeter boundaries	• Better define the hydraulic heads and flux rates along each of the model boundaries. Adjust valley fill depth if needed along northwest and southeast boundaries based on available geologic data. Refine 2007 model to be consistent with the boundaries of the USGS model currently being developed.	• Lithologic data (e.g., boring logs, information on sedimentary deposits), hydrogeologic properties within HGUs within the modeling domain, precipitation records, discharge rates for springs, and well construction details have been obtained. The data obtained are of good quality and useful in better defining hydraulic heads and flux rates; however, flux rates are not available for the same locations as the current perimeter of the Red Hill groundwater model.	• Additional hydrogeologic data available along 2007 model boundaries and information from the USGS regional model currently being developed, including electronic files of hydraulic heads, conductance and fluxes along boundaries, and model layer elevations should be obtained. • Other available information from the USGS and/or CWRM regarding springs and subsurface groundwater outflow along the shoreline will supplement and help to better define the model boundary conditions.	• The model can be developed using current existing information; however, better definition of the model boundary conditions and fluxes along the boundaries will improve model calibration and reduce uncertainty.
Data Gaps for Modeling Basal Aquifer Hydraulic and Physical Properties				
Hydraulic and physical properties of basalt aquifer that affect groundwater flow in the Facility vicinity	• Better define the spatial distribution of groundwater model parameter values in primary area of interest.	• Published USGS hydrogeology and groundwater modeling reports have been obtained and evaluated, Data from USGS reports are considered good quality and will be considered in the modeling effort. • Synoptic water level studies have been performed in May 2015 and November 2016. These studies and data collection efforts were performed or coordinated by the USGS and provide the best, most comprehensive data sets to date. • Pumping rates for some water supply wells in the vicinity of Red Hill have been obtained; however, the data sets are not comprehensive for all water supply wells for the period 2007 through 2017.	• Results of regional-scale pumping tests of Red Hill Shaft, Hālawa Shaft, and Moanalua Wells (individually and consecutively) with continuous monitoring of pumping rates and water levels at all wells are needed for model calibration.	• Obtaining regional pumping test data in addition to data already described above will provide for better model calibration and reduce uncertainty associated with the model. The planned 4-month synoptic water level study will include data from more wells than previously monitored and with coordinated pumping schedules at area supply wells, which will provide a much more comprehensive data set for model calibration.
Data Gaps for Modeling Recharge Rates				
Groundwater recharge rates	• Better define the spatial distribution of groundwater recharge rates in the 2007 model.	• Published USGS reports and other data have been obtained and evaluated. • Data obtained includes lithologic data, data on hydrogeologic properties within the modeling domain, streamflow rates, precipitation records, spring discharge rates, water budget estimates, and information on aquifer characteristics. The data obtained are from reliable sources and are considered useful for the modeling effort.	• GIS maps of groundwater recharge rates from USGS will expedite and facilitate accurate entry of recharge data into the numerical model. • Information on discharge rates into surface water and from springs will help refine boundary conditions.	• The model can be developed using existing recharge data and surface water and spring discharge data. However, obtaining GIS files will be more efficient and will allow more refined entry of USGS data into the model.
Conceptual Site Model and Contaminant Fate and Transport Model				
Data Gaps for Modeling COPCs in Groundwater				
Distribution of COPCs in groundwater in the Red Hill area, including potential NAPL on the water table and dissolved-phase constituents within the water table aquifer	• Estimate COPC contamination including potential NAPL on the water table surface and dissolved-phase contamination within the water table aquifer.	• COPC concentration trends, major ion and cations, and NAP concentrations in groundwater over time (February 2005 to October 2016). Overall, the data obtained are of good quality. However, consistent data qualifiers have not been used over time, and the qualifiers need to be evaluated closely to ensure any data constraints or limitations are identified.	• Groundwater sampling data from recent monitoring events and future events conducted prior to CF&T model calibration need to be obtained. Changes in analyte concentrations and data trends will need to be evaluated to and used for model calibration. • Field observations from newly installed wells to assess the potential for the presence of NAPL. • Any data on non-Navy petroleum contamination sources not currently identified will need to be obtained and considered in the modeling effort.	• Incorporation of new data and evaluation of data trends is essential in model calibration. The model can be developed using existing data; however, use of new data will help refine the model, improve calibration, and reduce uncertainty. • Any evidence of the presence of NAPL will help identify potential areas where NAPL is most likely to impact groundwater. • Incorporation of any new data from non-Navy sources is critical in assessing impacted areas and differentiating between impacts from Red Hill and impacts from other potential sources.
	• Estimate potential NAPL movement from the Facility fuel tanks. A detailed geologic model of Red Hill is needed to characterize the basalt flow layers and interbedded clinker beds.	• Boring logs from Red Hill, North Hālawa Valley, and the Pearl Harbor area have been obtained. In addition, information on sedimentary deposits within the model are has been obtained. The data are generally of good quality and can be used in developing of the CSM and the CF&T model. However, additional information will help to further define preferential pathways along which NAPL could travel from a release location to the groundwater. • Hydrogeologic properties of HGUs within the modeling domain have been obtained and provide useful information in establishing ranges of parameters for the modeling effort.	• Characteristics of the basalt flows (presence of clinker zones, high- and low-permeability zones, effective porosity and moisture content) and the location of perched aquifers, to help identify potential preferential pathways where NAPL could travel from a release and impact the basal aquifer	• The model can be developed using existing data; however, additional information on preferential pathways will help to refine the model and provide better estimates of where NAPL could directly impact the basal aquifer, which helps to reduce modeling uncertainty.

Key Uncertainty (see Table 3-1 through Table 3-11)	Task or Information Need (see Table 3-1 through Table 3-11)	Data Already Acquired (summarized from Table 3-1 through Table 3-11)	Data Gaps (summarized from Table 4-1)	Impact of Not Acquiring Needed Additional Data
	• Obtain site-associated COPC data for the CF&T modeling.	The data identified below are considered of good quality and will be used in the modeling effort: • Chemical and physical characteristics of COPCs. • SVM results (Navy SVM reports, 2008 to December 2016). • Red Hill and non-Navy fuel storage tank dimensions, historic contents, and current contents have been obtained from previous reports. The information obtained is of good quality and will be useful in determining potential release sources and the nature of any petroleum contamination that may move through the vadose zone.	• Chemical composition of JP-8 fuel stored at the facility • Primary petroleum compounds in TPH-d detected in RHMW02 • Solubility limits of principal compounds in the COPCs at the site groundwater temperature	• Modeling can be conducted using existing data; however, the composition of JP-8 varies depending on the petroleum source. Additional information on the composition of JP-8 used at the facility, data identifying the primary compounds detected in RHMW02, and data on solubility limits of the primary compounds will provide more site specific and relevant information and reduce uncertainty of the model. Assumptions based on general knowledge or use of default parameters will likely result in a more conservative model.
Data Gaps for Modeling Water Quality Impacts				
Potential water quality impacts to the groundwater resources	• Identify current and projected water supply needs.	The data described below are considered to be of good quality and will be used in the development of the model: • Published USGS reports with water-budget estimates for O'ahu under regular and drought conditions, as well as pre- and recent development conditions, Land cover parameters, water-budget calculations, and land cover types as a fraction of the aquifer system. • Data regarding freshwater use estimates for O'ahu, discharge rates for O'ahu springs, and O'ahu aquifer characteristics have been obtained and are considered to be of good quality. • Normal and maximum pumping rates for water supply at Red Hill Shaft and pumping rates for some other wells within the groundwater modeling domain have been obtained from BWS and the Navy and are considered of good quality. • Summary of Joint Base Pearl Harbor-Hickam water supply system. • Well construction details from existing and newly installed wells within the modeling domain.	• Information on water resource development • Current groundwater withdrawals and usage • Anticipated future water resource needs • Planned future water supply wells	• Numerical model calibration and predictions will be uncertain if updated information and future plans for pumping wells is not obtained and incorporated into model.
Data Gaps for Modeling other Physical Properties of Basalt				
Other physical properties of basalt that affect groundwater contaminant fate and transport	• Obtain site-specific values for effective porosity and dispersivity for the CF&T modeling.	• Boring logs from Red Hill, North Hālawa Valley, and Pearl Harbor area and sedimentary deposit information has been obtained and is considered to be of good quality for the purposes of modeling. Hydrogeologic properties of HGUs within the modeling domain and well construction details from existing and newly installed wells within the modeling domain have been obtained and is considered to be of good quality for the purposes of modeling.	• Additional estimates of effective porosity for clinker and interbedded dense lava flows beneath the Facility. • Evaluate the need for more definitive values for effective porosity and dispersivity at the site. Will evaluate whether a tracer study is necessary after calibration of the groundwater flow model is completed.	• Modeling can be conducted without obtaining this additional data; however, incorporation of the data would be used to refine the model and provide, improve calibration, and reduce uncertainty.
Data Gaps for Modeling Source Area Extent, Mass Loading, and Natural Attenuation Rates				
Source area extent, COPC mass loading, and natural attenuation rates	• Estimated volumes and type of fuel released with respect to time series plots of the concentrations of COPCs and NAPs in the Red Hill monitoring wells to estimate mass loading in source area through time and model natural attenuation processes.	The data described below is of good quality and will be useful in determining potential release sources and the nature of any petroleum contamination that may move through the vadose zone. • COPC concentration trends, major ion and cations, and NAP concentrations in groundwater over time (February 2005 to October 2016). Overall, the data obtained are of good quality. However, consistent data qualifiers have not been used over time and the qualifiers need to be evaluated closely to ensure that any data constraints or limitations are identified. • O'ahu aquifer characteristics, including aquifer type and use. • Red Hill fuel storage tank dimensions, historic contents, and current contents. • Red Hill and non-Navy fuel storage tank dimensions, historic contents, current contents, and release history have been obtained from previous reports. • Chemical and physical characteristics of COPCs, NAPs, gasoline, JP-5, and JP-8.	• Better definition of the composition of the leaked fuel • Analytical results of the specific components of TPH detected in groundwater at the site	• The data will help to refine the model calibration and provide more refined and technically supportable site-related predictions of the location and expected migration of COPCs in groundwater.

To date, the Navy has installed five new monitoring wells (RHMW06 through RHMW10) since the January 2014 Tank 5 release, and more locations for monitoring wells are being identified in coordination with the Regulatory Agencies and AOC SMEs, which will further help to evaluate hydraulic heads and flow gradients, evaluate the effects of pumping water supply wells on hydraulic heads and groundwater flow gradients, and determine whether or not a hydraulic barrier is present between Red Hill and Hālawa Shaft.

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Appendix A:
Detailed Evaluation of Existing Data Sets

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Table A-1: Detailed Evaluation of Existing Data Sets

Data Table from EDR Appendix A (DON 2017c)		Criteria: Data Source Quality	Criteria: Currency/ Shelf Life	Criteria: Completeness	Comments
Geologic Data Tables ("GEO")					
GEO-1	Red Hill Storage Facility Borings with Geologic Information Drilled Near the Underground Fuel Tanks	✓	✓	✓	—
GEO-2	Red Hill Storage Facility Borings with Geologic Information Drilled from the Ground Surface	✓	✓	✓	
GEO-3	Red Hill Storage Facility Borings with Geologic Information Drilled Inside Facility Tunnels	✓	✓	✓	No values for borehole diameter or estimated permeability were located.
GEO-4	Groundwater Model Area Soil Borings	✓	✓	✓	Only driller's logs were located for some borings (e.g., Hālawa Deep Monitor Well), but these still provide useful data.
Hydrogeologic Data Tables ("HYDRO")					
HYDRO-1	Information on Sedimentary Deposits in the Red Hill Area	✓	✓	✓	—
HYDRO-2	Hydrogeologic Properties of Hydrogeologic Units	✓	✓	⊘	Few to no values for horizontal and longitudinal hydraulic conductivity and transverse and longitudinal dispersivity were located for the HGUs.
HYDRO-3	Active Stream Gauges Within the Red Hill Groundwater Model Area	✓	✓	✓	—
HYDRO-4	Inactive Stream Gauges Within the Red Hill Groundwater Model Area	✓	✓	✓	—
HYDRO-5	Kalihi Stream Flow (ft^3/sec)- 2007	✓	✓	✓	Table values are daily averages.
HYDRO-6	Kalihi Stream Flow (ft^3/sec)- 2008	✓	✓		
HYDRO-7	Kalihi Stream Flow (ft^3/sec)- 2009	✓	✓	✓	
HYDRO-8	Kalihi Stream Flow (ft^3/sec)- 2010	✓	✓	✓	
HYDRO-9	Kalihi Stream Flow (ft^3/sec)- 2011	✓	✓	✓	
HYDRO-10	Kalihi Stream Flow (ft^3/sec)- 2012	✓	✓	✓	
HYDRO-11	Kalihi Stream Flow (ft^3/sec)- 2013	✓	✓	✓	
HYDRO-12	Kalihi Stream Flow (ft^3/sec)- 2014	✓	✓	✓	
HYDRO-13	Kalihi Stream Flow (ft^3/sec)- 2015	✓	✓	✓	
HYDRO-14	Kalihi Stream Flow (ft^3/sec)- 2016	✓	✓	✓	
HYDRO-15	10 Year Average Streamflow (ft^3/sec) for Kalihi Stream	✓	✓	✓	—

Data Table from EDR Appendix A (DON 2017c)		Criteria			Comments
		Data Source Quality	Currency/ Shelf Life	Completeness	
HYDRO-16	North Halawa Stream Flow (ft^3/sec) Near Quarantine Station-2007	✓	✓	✓	Table values are daily averages.
HYDRO-17	North Halawa Stream Flow (ft^3/sec) Near Quarantine Station-2008	✓	✓	✓	
HYDRO-18	North Halawa Stream Flow (ft^3/sec) Near Quarantine Station-2009	✓	✓	✓	
HYDRO-19	North Halawa Stream Flow (ft^3/sec) Near Quarantine Station-2010	✓	✓	✓	
HYDRO-20	North Halawa Stream Flow (ft^3/sec) Near Quarantine Station-2011	✓	✓	✓	
HYDRO-21	North Halawa Stream Flow (ft^3/sec) Near Quarantine Station-2012	✓	✓	✓	
HYDRO-22	North Halawa Stream Flow (ft^3/sec) Near Quarantine Station-2013	✓	✓	✓	
HYDRO-23	North Halawa Stream Flow (ft^3/sec) Near Quarantine Station-2014	✓	✓	✓	
HYDRO-24	North Halawa Stream Flow (ft^3/sec) Near Quarantine Station-2015	✓	✓	✓	
HYDRO-25	North Halawa Stream Flow (ft^3/sec) Near Quarantine Station-2016	✓	✓	✓	
HYDRO-26	10 Year Average Streamflow (ft^3/sec) for North Halawa Stream Near Quarantine Station	✓	✓	✓	—
HYDRO-27	North Halawa Stream Flow (ft^3/sec) Near Honolulu- 2007	✓	✓	✓	Table values are daily averages.
HYDRO-28	North Halawa Stream Flow (ft^3/sec) Near Honolulu- 2008	✓	✓	✓	
HYDRO-29	North Halawa Stream Flow (ft^3/sec) Near Honolulu- 2009	✓	✓	✓	
HYDRO-30	North Halawa Stream Flow (ft^3/sec) Near Honolulu- 2010	✓	✓	✓	
HYDRO-31	North Halawa Stream Flow (ft^3/sec) Near Honolulu- 2011	✓	✓	✓	
HYDRO-32	North Halawa Stream Flow (ft^3/sec) Near Honolulu- 2012	✓	✓	✓	
HYDRO-33	North Halawa Stream Flow (ft^3/sec) Near Honolulu- 2013	✓	✓	✓	
HYDRO-34	North Halawa Stream Flow (ft^3/sec) Near Honolulu- 2014	✓	✓	✓	
HYDRO-35	North Halawa Stream Flow (ft^3/sec) Near Honolulu- 2015	✓	✓	✓	
HYDRO-36	North Halawa Stream Flow (ft^3/sec) Near Honolulu- 2016	✓	✓	✓	
HYDRO-37	10 Year Average Streamflow (ft^3/sec) for North Halawa Stream Near Honolulu	✓	✓	✓	—
Groundwater Data Tables ("GW")					
GW-1	Halawa 2015 Aquifer Test Results	✓	✓	⊘	No flow rate data were located for Hālawa Shaft.
GW-2	Estimated Halawa Pump Station Runtime and Pumpage Rates (2015)	✓	✓	✓	—
GW-3	Halawa T-45 2015 Aquifer Test Results	✓	✓	⊘	No flow rate data were located for Hālawa T-45 well.
GW-4	Red Hill 2015 Aquifer Test Results	✓	✓	⊘	No water level data were located for Red Hill Shaft.
GW-5	Waiawa 2015 Aquifer Test Results	✓	✓	✓	—
GW-6	Manaiki 2015 Aquifer Test Results	✓	✓	⊘	No flow rate data were located for Manaiki well.

Data Table from EDR Appendix A (DON 2017c)		Criteria: Data Source Quality	Criteria: Currency/ Shelf Life	Criteria: Completeness	Comments
GW-7	Moanalua Pumping Rates (2015)	✓	✓	⊘	No water level data were located for Moanalua wells.
GW-8	Halawa Shaft Pumping Rates (2015)	✓	✓	⊘	No water level data were located for Hālawa Shaft.
GW-9	OWDFMW01 Groundwater Levels, and Physical and Chemical Properties	✓	✓	⊘	The following data were not located for the indicated periods: - TDS (prior to Jan. 2016) - Turbidity (Nov. 2012 to July 2015) - Salinity (July 2013 to Oct. 2015)
GW-10	RHMW01 Groundwater Levels, and Physical and Chemical Properties	✓	✓	⊘	The following data were not located for the indicated periods: - TDS (prior to Jan. 2016) - Turbidity (Oct. 2012 to July 2015) - Salinity (July 2013 to Oct. 2015)
GW-11	Fort Shafter Well Groundwater Levels, and Physical and Chemical Properties	✓	✓	✓	—
GW-12	Aiea Navy Well Groundwater Levels, and Physical and Chemical Properties	✓	✓	✓	—
GW-13	TAMC-2 Well Groundwater Levels, and Physical and Chemical Properties	✓	✓	⊘	No data were located for water temperature, chloride concentration, specific conductance, or instantaneous flow rate.
GW-14	RHMW2254-01 Groundwater Levels, and Physical and Chemical Properties	✓	✓	⊘	The following data were not located for the indicated periods: - Depth to water (prior to Oct. 2012) TDS (prior to Jan. 2016) - Turbidity (Oct. 2012 to July 2015) -Salinity (July 2013 to Oct. 2015)
GW-15	HDMW2253-03 Groundwater Levels, and Physical and Chemical Properties	✓	✓	⊘	The following data were not located for the indicated periods: - TDS (prior to Jan. 2016) - Turbidity (Nov. 2012 to July 2015) - Salinity (July 2013 to Oct. 2015)
GW-16	Halawa Shaft (Well # 212305157542601) Groundwater Levels, and Physical and Chemical Properties	✓	✓	⊘	No records were located for TDS, turbidity, pH, DO, water temperature, specific conductance, or salinity levels.

Data Table from EDR Appendix A (DON 2017c)		Criteria: Data Source Quality	Criteria: Currency/ Shelf Life	Criteria: Completeness	Comments
GW-17	RHMW02 Groundwater Levels, and Physical and Chemical Properties	✓	✓	⃠	The following data were not located for the indicated periods: - TDS (prior to Jan. 2016) - Turbidity (Oct. 2012 to July 2015) - Salinity (July 2013 to Oct. 2015)
GW-18	RHMW03 Groundwater Levels, and Physical and Chemical Properties	✓	✓	⃠	The following data were not located for the indicated periods: - TDS (prior to Jan. 2016) - Turbidity (Oct. 2012 to July 2015) - Salinity (July 2013 to Oct. 2015)
GW-19	RHMW04 Groundwater Levels, and Physical and Chemical Properties	✓	✓	⃠	The following data were not located for the indicated periods: - TDS (prior to Jan. 2016) - Turbidity (prior to Oct. 2015) - Salinity (prior to Jan. 2016)
GW-20	RHMW05 Groundwater Levels, and Physical and Chemical Properties	✓	✓	⃠	The following data were not located for the indicated periods: - TDS (prior to Jan. 2016) - Turbidity (July 2012 to July 2015) Salinity (July 2013 to Oct. 2015)
GW-21	RHMW06 Groundwater Levels, and Physical and Chemical Properties	✓	✓	⃠	The following data were not located for the indicated periods: - TDS (prior to Jan. 2016) - Turbidity (prior to Oct. 2015)
GW-22	RHMW07 Groundwater Levels, and Physical and Chemical Properties	✓	✓	⃠	The following data were not located for the indicated periods: - TDS (prior to Jan. 2016) - Turbidity (prior to Oct. 2015)
GW-23	RHMW08 Groundwater Levels, and Physical and Chemical Properties	✓	✓	✓	—
GW-24	RHMW09 Groundwater Levels, and Physical and Chemical Properties	✓	✓	✓	—

Data Table from EDR Appendix A (DON 2017c)		Criteria			Comments
		Data Source Quality	Currency/ Shelf Life	Completeness	
GW-25	Major Ion and Cation Concentrations	✓	✓	⊘	Phosphate, ferrous iron, strontium, methane, TOC, TDS, specific conductance, water temperature, and dissolved oxygen, and ORP were not located for some wells.
GW-26	Moanalua Precipitation (Total Inches)- 2007	✓	✓	✓	Table values are daily averages.
GW-27	Moanalua Precipitation (Total Inches)- 2008	✓	✓	✓	
GW-28	Moanalua Precipitation (Total Inches)- 2009	✓	✓	✓	
GW-29	Moanalua Precipitation (Total Inches)- 2010	✓	✓	✓	
GW-30	Moanalua Precipitation (Total Inches)- 2011	✓	✓	✓	
GW-31	Moanalua Precipitation (Total Inches)- 2012	✓	✓	✓	
GW-32	Moanalua Precipitation (Total Inches)- 2013	✓	✓	✓	
GW-33	Moanalua Precipitation (Total Inches)- 2014	✓	✓	✓	
GW-34	Moanalua Precipitation (Total Inches)- 2015	✓	✓	✓	
GW-35	Moanalua Precipitation (Total Inches)- 2016	✓	✓	✓	
GW-36	10 Year Average Daily Precipitation (Total Inches) at the Moanalua Precipitation Gauge	✓	✓	✓	—
GW-37	North Halawa Valley Precipitation (Total Inches)- 2007	✓	✓	✓	Table values are daily averages.
GW-38	North Halawa Valley Precipitation (Total Inches)- 2008	✓	✓	✓	
GW-39	North Halawa Valley Precipitation (Total Inches)- 2009	✓	✓	✓	
GW-40	North Halawa Valley Precipitation (Total Inches)- 2010	✓	✓	✓	
GW-41	North Halawa Valley Precipitation (Total Inches)- 2011	✓	✓	✓	
GW-42	North Halawa Valley Precipitation (Total Inches)- 2012	✓	✓	✓	
GW-43	North Halawa Valley Precipitation (Total Inches)- 2013	✓	✓	✓	
GW-44	North Halawa Valley Precipitation (Total Inches)- 2014	✓	✓	✓	
GW-45	North Halawa Valley Precipitation (Total Inches)- 2015	✓	✓	✓	
GW-46	North Halawa Valley Precipitation (Total Inches)- 2016	✓	✓	✓	
GW-47	10 Year Average Daily Precipitation (Total Inches) at the Moanalua Precipitation Gauge	✓	✓	✓	—
GW-48	Water-Budget Estimate for O'ahu, 2001-2010 (by Volume)	✓	✓	✓	—
GW-49	Water-Budget Estimate for O'ahu, Pre- and Recent Development (by Volume)	✓	✓	✓	—
GW-50	Water-Budget Estimate for O'ahu, 2001-2010 (by Depth)	✓	✓	✓	—
GW-51	Water-Budget Estimate for O'ahu, Pre- and Recent Development (by Depth)	✓	✓	✓	—
GW-52	Water-Budget Estimate for O'ahu for Average and Drought Conditions	✓	✓	✓	—
GW-53	Water-Budget Estimate for the Honolulu Aquifer Sector for Average and Drought Conditions	✓	✓	✓	—
GW-54	Water-Budget Estimate for the Pearl Harbor Aquifer Sector for Average and Drought Conditions	✓	✓	✓	—
GW-55	Freshwater-Use Estimates for O'ahu	✓	✓	✓	—
GW-56	Ratios of Fog Interception to Rainfall for O'ahu	✓	✓	✓	—

Data Table from EDR Appendix A (DON 2017c)		Criteria: Data Source Quality	Criteria: Currency/ Shelf Life	Criteria: Completeness	Comments
GW-57	Ratios of Runoff to Rainfall for O'ahu	✓	✓	✓	—
GW-58	Spring Discharge Rates (MGD)	✓	✓	✓	—
GW-59	Pearl Harbor Spring Discharge (2005)	✓	✓	✓	—
GW-60	Aquifer Characteristics	✓	✓	✓	—
GW-61	Manual Water Level Measurements Collected on November 18, 2016	✓	✓	✓	—
Well Data Tables ("WELL")					
WELL-1	Groundwater Monitoring Wells in the Red Hill Area	⊘	✓	✓	Red Hill monitoring well elevations from multiple surveys do not match, and vary by as much as 0.5 ft for a given well.
WELL-2	Proposed Red Hill Groundwater Monitoring Wells	✓	✓	✓	—
WELL-3	Wells in the Entire Groundwater Model Area	✓	✓	⊘	Well use, top of casing elevation, depth to bedrock and groundwater, and borehole diameter data were not located for some wells within the groundwater modeling area.
WELL-4	Water Supply Wells Within the Groundwater Model Area	✓	✓	⊘	Few values were located for average and/or permitted flow rates for water supply wells within the groundwater modeling area.
WELL-5	Red Hill Storage Facility Pump Information	✓	✓	⊘	Few values were located for average and/or permitted flow rates for water pumps at the Facility.
WELL-6	Water Pumps Within the Groundwater Model Area	✓	✓	⊘	Few values were located for average and/or permitted flow rates for water pumps within the groundwater modeling area.
Facility Data Tables ("FAC")					
FAC-1	Red Hill Storage Facility Tank Information	✓	✓	✓	—
FAC-2	Halawa Correctional Facility Tank Information	✓	✓	⊘	Coordinates and reference datums were not located for the tanks.
FAC-3	Historic Halawa Correctional Facility UST Fuel Releases and Leaks	✓	✓	⊘	Data for releases from non-Navy sources are presumed incomplete.
FAC-4	Historic Hawaiian Cement/Halawa Quarry Fuel Releases and Leaks	✓	✓	⊘	Data for releases from non-Navy sources are presumed incomplete.
FAC-5	Joint Base Pearl Harbor-Hickam Water System Summary	✓	✓	✓	—
FAC-6	Land Cover Parameters Used in Izuka 2016 Water-Budget Calculations	✓	✓	✓	—

Data Table from EDR Appendix A (DON 2017c)		Criteria: Data Source Quality	Criteria: Currency/ Shelf Life	Criteria: Completeness	Comments
FAC-7	General Land Cover Types, as Fraction of Aquifer-System Area, O'ahu	✓	✓	✓	—
Chemistry Data Tables (“CHEM”) [a]					
CHEM-1	Groundwater Concentrations for RHMW2254-01 (Detects)	✓	✓	✓	—
CHEM-2	Groundwater Concentrations for RHMW2254-01 (Non-Detects)	✓	✓	✓	—
CHEM-3	Groundwater Concentrations for HDMW2253-03 (Detects)	✓	✓	✓	—
CHEM-4	Groundwater Concentrations for HDMW2253-03 (Non-Detects)	✓	✓	✓	—
CHEM-5	Groundwater Concentrations for OWDFMW01 (Detects)	✓	✓	✓	—
CHEM-6	Groundwater Concentrations for OWDFMW01 (Non-Detects)	✓	✓	✓	—
CHEM-7	Groundwater Concentrations for RHMW01 (Detects)	✓	✓	✓	—
CHEM-8	Groundwater Concentrations for RHMW01 (Non-Detects)	✓	✓	✓	—
CHEM-9	Groundwater Concentrations for RHMW02 (Detects)	✓	✓	✓	—
CHEM-10	Groundwater Concentrations for RHMW02 (Non-Detects)	✓	✓	✓	—
CHEM-11	Groundwater Concentrations for RHMW03 (Detects)	✓	✓	✓	—
CHEM-12	Groundwater Concentrations for RHMW03 (Non-Detects)	✓	✓	✓	—
CHEM-13	Groundwater Concentrations for RHMW04 (Detects)	✓	✓	✓	—
CHEM-14	Groundwater Concentrations for RHMW04 (Non-Detects)	✓	✓	✓	—
CHEM-15	Groundwater Concentrations for RHMW05 (Detects)	✓	✓	✓	—
CHEM-16	Groundwater Concentrations for RHMW05 (Non-Detects)	✓	✓	✓	—
CHEM-17	Groundwater Concentrations for RHMW06 (Detects)	✓	✓	✓	—
CHEM-18	Groundwater Concentrations for RHMW06 (Non-Detects)	✓	✓	✓	—
CHEM-19	Groundwater Concentrations for RHMW07 (Detects)	✓	✓	✓	—
CHEM-20	Groundwater Concentrations for RHMW07 (Non-Detects)	✓	✓	✓	—
CHEM-21	Groundwater Concentrations for RHMW08 (Detects and Non-Detects)	✓	✓	✓	—
CHEM-22	Groundwater Concentrations for RHMW09 (Detects and Non-Detects)	✓	✓	✓	—
CHEM-23	Groundwater NAP Concentrations for RHMW2254-01	✓	✓	✓	—
CHEM-24	Groundwater NAP Concentrations for HDMW2253-03	✓	✓	✓	—
CHEM-25	Groundwater NAP Concentrations for OWDFMW01	✓	✓	⃠	No degradation rates were located for hydrocarbon chains (e.g., C5–C7 aromatics).
CHEM-26	Groundwater NAP Concentrations for RHMW01	✓	✓	✓	—
CHEM-27	Groundwater NAP Concentrations for RHMW02	✓	✓	✓	—
CHEM-28	Groundwater NAP Concentrations for RHMW03	✓	✓	✓	—
CHEM-29	Groundwater NAP Concentrations for RHMW04	✓	✓	✓	—
CHEM-30	Groundwater NAP Concentrations for RHMW05	✓	✓	✓	—
CHEM-31	Groundwater NAP Concentrations for RHMW06	✓	✓	✓	—
CHEM-32	Groundwater NAP Concentrations for RHMW07	✓	✓	✓	—
CHEM-33	Groundwater NAP Concentrations for RHMW08	✓	✓	✓	—
CHEM-34	Groundwater NAP Concentrations for RHMW09	✓	✓	✓	—

Data Table from EDR Appendix A (DON 2017c)		Criteria: Data Source Quality	Criteria: Currency/ Shelf Life	Criteria: Completeness	Comments
CHEM-35	Chemicals of Potential Concern Chemical and Physical Characteristics	✓	✓	✓	—
CHEM-36	NAP Chemical and Physical Characteristics	✓	✓	⊘	No solubility values were located for calcium, copper, magnesium, nitrate, potassium, sodium, strontium, and sulfate.
CHEM-37	Fuel Chemical and Physical Characteristics	✓	✓	⊘	Few values for solubility limit, partition coefficient, vapor pressure, and Henry's constant were located for fuel constituents.

Note: The EDR presented a comprehensive compilation of known existing available data and other relevant information pertaining to the modeling effort. Not all data compiled in the EDR are deemed necessary for the modeling effort; hence, not all the data sets flagged as incomplete in this table are identified as data gaps in Section 3 of this report.

✓ Data meet all criteria.

⊘ Current data are incomplete, but existing data in the data set are usable.

⊘ Current data do not meet Data Source Quality and/or Currency/Shelf Life criteria and are not usable for the modeling effort.

DO dissolved oxygen

EDR *Existing Data Summary and Evaluation Report* (DON 2017c)

TDS total dissolved solids

[a] Various issues associated with chemistry data for the Red Hill monitoring wells (e.g., analytical methods, varying data qualifiers, level of data validation undertaken) are discussed in detail in the EDR, Section 3.2 (Applicability and Limitations of Compiled Existing Data, Chemistry Data). The discussion concluded that the chemistry data are usable and applicable for their intended purpose, but noted that if total petroleum hydrocarbon (TPH)-related anomalies are identified during the modeling effort, then TPH data should undergo further review.