Groundwater Flow Model Progress Report 03, Red Hill Bulk Fuel Storage Facility

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

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

December 3, 2017
Revision 00

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

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ACRONYMS AND ABBREVIATIONS

AOC	Administrative Order on Consent
BWS	Board of Water Supply, City and County of Honolulu
CF&T	contaminant fate and transport
CSM	conceptual site model
CWRM	Commission on Water Resource Management, State of Hawai‘i Department of Land and Natural Resources
DLNR	Department of Land and Natural Resources, State of Hawai‘i
DOH	Department of Health, State of Hawai‘i
EPA	Environmental Protection Agency, United States
ft	foot/feet
GWFMWG	Groundwater Flow Model Working Group
HGU	hydrogeologic unit
SOW	scope of work
SWAP	Source Water Assessment Program
TPH	total petroleum hydrocarbons
TUA	Tank Upgrade Alternatives
USGS	United States Geological Survey
WP	work plan

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1. Introduction

This *Groundwater Flow Model Progress Report 03* is the third in a series of modeling progress reports that describes the technical status of the groundwater flow modeling effort being conducted 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 progress report is a component of the overall project reporting as specified in the project *Work Plan/Scope of Work* (WP/SOW) (DON 2017a). The WP/SOW 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) (EPA Region 9 and DOH 2015). Submittal of groundwater flow model progress reports at a minimum of every 4 months is stipulated in AOC Statement of Work Section 7.1.2.

The objective of the AOC is to take steps to ensure the groundwater resource in the vicinity of the Facility is protected and to ensure that the Facility is operated and maintained in an environmentally protective manner. Work to support Section 6 of the AOC Statement of Work is being conducted in response to the January 2014 release from Tank 5 and to evaluate potential remediation methods for the January 2014 Tank 5 release and any future releases. Work to support Section 7 of the AOC Statement of Work is being conducted to monitor and characterize the flow of groundwater around the Facility and includes groundwater modeling. The collective work conducted under Section 7 will be used to inform changes to the *Groundwater Protection Plan* (DON 2014).

Reporting Period 03 covered in this report represents progress for the third 4-month period (August 5 – December 3, 2017) following conditional approval of the project WP/SOW by the Regulatory Agencies, which was received by the Navy on December 5, 2016 (EPA Region 9 and DOH 2016). *Groundwater Flow Model Progress Report 01* and *Report 02* were submitted on April 5, 2017, and August 4, 2017, respectively.

2. Work Completed This Period

2.1 CURRENT STATUS

The Groundwater Flow Model Working Group (GWFMWG) met three times during this reporting period, on August 17, September 22, and November 17, 2017. The GWFMWG is composed of representatives from the Navy, United States Geological Survey (USGS), United States Environmental Protection Agency (EPA), State of Hawai'i Department of Health (DOH), State of Hawai'i Department of Land and Natural Resources (DLNR) Commission on Water Resource Management (CWRM), City and County of Honolulu Board of Water Supply (BWS), and the University of Hawai'i. The working group was formed to coordinate the development of accurate and reliable groundwater flow and contaminant fate and transport (CF&T) models.

Groundwater flow modeling is being conducted to improve the understanding of the direction and rate of groundwater flow around the Facility. CF&T modeling is being conducted to improve the understanding of the potential fate and transport, degradation, and transformation of contaminants that have been or could be released from the Facility. The groundwater modeling will help ascertain potential risk to water supply wells as a result of a potential range of releases from the Facility under a range of reasonable pumping conditions within the model area. The results of this modeling effort will then be used to:

1. Inform decisions related to the Tank Upgrade Alternatives (TUA), and
2. Inform decisions related to identification and selection of potential remedial alternatives

The focus of the ongoing and upcoming groundwater modeling is to improve understanding of groundwater flow direction and rates in the Facility area to provide a basis for evaluating potential contaminant migration. Groundwater modeling work completed during this reporting period included obtaining and evaluating additional hydrologic and geologic data and developing the conceptual site model (CSM) for groundwater flow and contaminant transport. Boundaries for the model area were discussed and refined based on working group member comments during the August 17, 2017, meeting (see Figure 1).

A *Groundwater Model Evaluation* Plan (DON 2017f) and an Attenuation Evaluation Plan (DON 2017c) were prepared by the Navy and submitted for review by the AOC Parties.

During the September 22 GWFMWG meeting, additional working group member comments on the modeling evaluation plan and attenuation evaluation plan were discussed, which prompted additional review and evaluation by the Navy. During the November 17 meeting, detailed technical responses to all the major comments from BWS were provided by the Navy. Additional draft in-progress work products were presented during the November 17 meeting, including geologic, groundwater flow, and water chemistry information currently being compiled and integrated in the CSM. Newly acquired geologic data showing the estimated depth of saprolite in RHMW11 were provided. New groundwater data and updated hydrogeologic cross sections were also presented by the Navy and discussed during the November meeting.

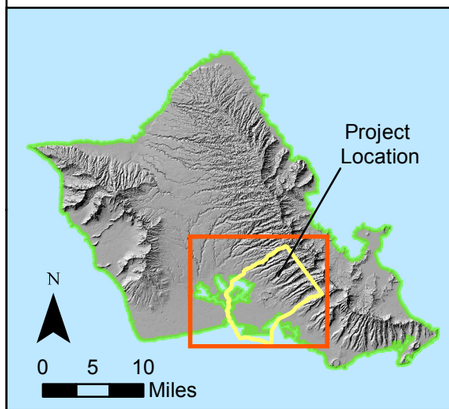
Currently available data within the model area are sufficient to calibrate the numerical groundwater model. Relevant hydrogeologic information and groundwater data include borehole geologic logs, the geologic log of the Red Hill water development tunnel, time-series hydrographs of groundwater levels, barrel logs, borehole geophysical logs, pumping tests, synoptic monitoring data, geologic cross-sections, hydrogeologic unit (HGU) properties, hydraulic gradients, and the hydrologic components of the model area groundwater balance.

Available hydrogeologic data in previous reports and borehole geologic logs from deep wells were evaluated to develop a conceptual understanding of the subsurface geology surrounding Red Hill. Geologic logging of new well RHMW11 indicates that upper basalt layers have been transformed *in situ* by weathering into a low-permeability clayey material (saprolite) beneath valley fill. This saprolite zone at this well location extends to at least 70 feet (ft) below the water table, which is on the north side of South Hālawa Stream. This weathered basalt (saprolite clay) will likely act as a barrier to both groundwater flow and potential contaminant migration from Red Hill to BWS wells located farther to the north.

Additional wells and seismic studies are planned for both North and South Hālawa Valleys to confirm presence and extent of hydraulic barriers. These wells will also provide water level data to further define hydraulic gradients. Completion of the new wells will also allow testing of discrete depth intervals to evaluate hydraulic conductivity utilizing the planned wells' multi-level monitoring system, which will further support the evaluation of barriers.

The 2006 and 2015 synoptic pumping/water level data for Navy Red Hill Shaft and BWS Hālawa Shaft pumping tests by the USGS have been compiled and will be used for model calibration. Soon additional data will also be available from the 2017 synoptic pumping/water level study currently being conducted by the USGS, which will be used to further evaluate hydraulic properties of the aquifer in the study area.

Location Map



Legend

- Current Groundwater Model Area
- 2007 Groundwater Model Area
- 2004 Regional Model Area (see Location Map)
- Red Hill Installation Boundary and Fuel Storage Tanks
- Stream

Notes

1. Map projection: NAD 1983 UTM Zone 4N
2. DigitalGlobe, Inc. (DG) and NRCS. Publication_Date: 2015
3. 2007 Navy Red Hill model: DON (2007) 2004 DOH SWAP model: Whittier et al. (2004)

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Figure 1
Current and Previous Groundwater Model Areas
Groundwater Model Progress Report 03
Red Hill Bulk Fuel Storage Facility
JBPHH, O'ahu, Hawai'i

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Natural attenuation studies currently underway by the Navy are providing additional information on physical, chemical, and microbial processes that cause the weathering and degradation of organic constituents (e.g., fuel) that are released into the environment. Data collected to date indicate that natural attenuation is actively occurring at the site. Site activities conducted in October 2017 included temperature profiling, carbon dioxide measurements in groundwater, soil gas measurements (methane, carbon dioxide, oxygen, compounds associated with total petroleum hydrocarbons [TPH]), and sampling for microbial analyses.

A high-precision topographic survey using Second Order, Class I techniques of the groundwater measuring points for wells in the Red Hill groundwater monitoring network was recently completed. The survey data provide consistent elevations to within 1-millimeter accuracy for evaluating groundwater elevations and flow directions. These new data will accurately establish groundwater elevations for determining hydraulic gradients and groundwater flow directions. The Navy intends to expand the precision topographic survey to include additional wells in the vicinity of Red Hill. A gyroscopic survey of the current monitoring well network was completed in November 2017 to determine if correction factors need to be applied when groundwater elevations are calculated; preliminary results are being evaluated and reviewed by the National Geodetic Survey.

The preliminary results of the high-precision topographic survey indicate no significant differences with previously reported groundwater elevations for key well locations, suggesting that newly calculated hydraulic heads will be similar to those reported by previous studies at the Facility. The new data add confidence that hydraulic gradients and flow directions can be reasonably determined. In addition, data from new wells will provide groundwater elevations and geological information at additional locations and thus will be instrumental in evaluating both horizontal and vertical hydraulic gradients and flow directions surrounding the Facility, particularly between Red Hill and North Hālawa Valley.

During the meetings, the Navy further explained the technical approach for the groundwater modeling, including detailed discussions of the following points:

- Sentry wells, which may include existing or new (future) monitoring well locations, will be used to provide early detection of potential future releases, and facilitate additional measures for containment if needed.
- Extensive regional groundwater level data are available, which can be used to estimate long-term trends in water levels and seasonal fluctuations.
- Calibrating a transient model to long-term available data is not necessary to develop a better model to meet the project objectives. Information has been extracted from available data on model-wide trends and monthly variations.

To evaluate uncertainty, a sensitivity analysis of the model will be performed consistent with ASTM International guidance (ASTM 2002). This analysis will focus on how varying model input parameters within reasonable ranges will affect modeling results. The sensitivity analysis results will be conservatively evaluated with respect to remedial alternatives for protection of potential receptors. A constrained Monte Carlo uncertainty analysis is not planned because it will not add meaningful information relative to key factors (e.g., groundwater flow direction and rate).

2.1.1 Technical Progress

During this period, the Navy made substantial progress in collecting additional hydrogeologic data, drilling and installing monitoring well RHMW11, preparing the updated CSM document, setting up the groundwater model, and planning for a seismic study.

Collecting and evaluating the additional hydrogeologic data are underway to support the groundwater modeling. Immediately prior to the August 17 meeting, the Navy obtained geospatial data sets from the USGS, which were previously developed by the USGS to accompany recent technical reports (Engott et al. 2015; Izuka et al. 2016). The Navy used these USGS data to define the 3D geometry of the Caprock HGU and Basalt HGU throughout the model area. The Navy presented graphics from different perspectives to illustrate the HGU geometry. Updated geospatial data for groundwater recharge rates were also obtained from the USGS and processed by the Navy for input to the groundwater model. Other activities conducted by the Navy during this reporting period include:

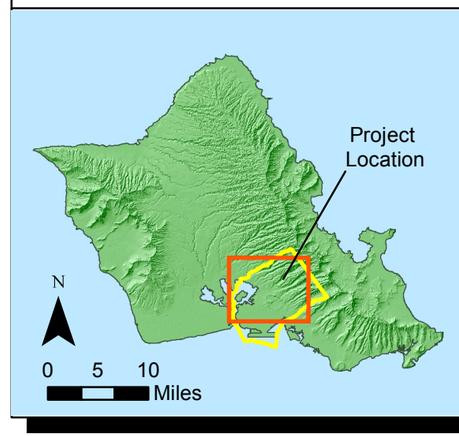
- Compiled and evaluated data from the May 2015 Hālawa Shaft pumping and USGS monitoring study
- Obtained high-precision survey data of wellhead measurement point elevations.
- Re-calculated groundwater elevations from the monitoring wells in the area of interest based on the new survey data.
- Prepared a map of groundwater elevations using the synoptic measurements collected by the Navy and USGS on November 18, 2016.
- Evaluated hydraulic conditions along the updated perimeter boundaries based on available data, as described in the *Groundwater Model Evaluation Plan* (DON 2017f).
- Acquired additional field data to evaluate natural attenuation.
- Completed drilling and coring at RHMW11, establishing depths of valley fill sediments and saprolite underlying South Hālawa Stream.

The USGS began synoptic monitoring of water levels in mid-July 2017 by installing pressure transducers in wells within the area of interest. The monitoring period planned for this study extends through December; however, it may be extended to accommodate periods of controlled pumping in local water supply wells so that the effects of pumping individual wells can be further evaluated.

The BWS provided information for water supply wells within the model area. The Navy prepared maps that show the water supply wells and annual pumping rates of the supply wells located within the model area and outside the boundaries (see Figure 2).

The Navy is planning to conduct a seismic study in December 2017. Two to three transects are planned across each valley. The proposed surveys are intended to increase understanding of geologic structures within the valleys bordering Red Hill. The characterization results will be used to further develop the CSM for the area in support of the project's groundwater flow and CF&T modeling effort.

Location Map



Legend

- Supply Well with Pumping Data
- Supply Well without Pumping Data
- Groundwater Model Area
- Red Hill Installation Boundary and Fuel Storage Tanks
- Stream

Notes

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

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Figure 2
Water Supply Wells within the Model Area
Groudnwater Model Progress Report 03
Red Hill Bulk Fuel Storage Facility
JBPHH, O'ahu, Hawai'i

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August 17 meeting: The Navy presented detailed geologic cross sections showing the basalt layers and other subsurface features at the facility. For the entire model area, the Navy showed the geometry of the HGUs in 3D via interactive computer output from the conceptual model based on the available data. Well locations available for model calibration, including the well intake elevations, were also presented on the 3D visualizations relative to the hydrogeologic units and land surface topography. The plan for establishing the numerical model layers and model bottom were presented and discussed. The Navy presented an overview of the CSM of natural attenuation processes and planned data collection. Scheduled field activities for the additional hydrogeologic data collection were also presented, including precision re-surveying of measurement points, drilling, and monitoring well installation.

Additional monitoring well locations are planned, which will be completed with several different intake intervals isolated by external casing packers and depth-discrete sampling ports (Westbay system). The wells will be completed in this manner to measure hydraulic head with depths and establish vertical hydraulic gradients, to determine hydraulic conductivity of the sample zone, and to obtain water quality data from the sample zones.

September 22 meeting: The Navy presented the planned approach and timeline for interim groundwater modeling. Presentations by the Navy included the following topics:

- Groundwater modeling objectives and purpose of the working group meetings
- Responses to various issues raised by other working group members and action items from previous meetings
- Plans for natural attenuation data collection at Red Hill and current status
- Updated boundaries and layers for the groundwater model
- Technical approach for uncertainty analysis of the groundwater model
- Hydrogeologic unit geometry and hydraulic properties
- USGS synoptic water level study progress
- Land surveying of wellhead measurement point elevations
- Plan for TUA decision support document
- BWS well data requests

At the end of the meeting, the Navy provided the following summary:

- Data from natural attenuation and geologic analyses will be not be incorporated into the interim model but will be used on a general basis and will be incorporated into the fate and transport modeling effort.
- Different model scenarios (e.g., pumping rates) will be solicited by the Navy from members of the GWFMWG prior to running the model.
- Groundwater flow barriers (e.g., valley fill) will not be modeled if there is no evidence that they exist.
- Sensitivity analyses will be conducted to determine the appropriate bounds for key groundwater parameters (e.g., recharge and hydraulic conductivity), and evaluate the model's boundaries.

- Synoptic groundwater elevation data will be used to determine the direction of groundwater flow within the model area, and to evaluate the effect of different pumping scenarios on flow direction.
- Navy, BWS, and EPA will work together in their Data Sharing Group to finalize a data sharing agreement and the details of the Geographic Information System database.
- The CSM will be presented at the next GWMWG meeting.
- The TUA Decision support document and interim model will be submitted electronically in March 2018.

November 17 meeting: In this meeting, the Navy addressed working group member comments from the September 22 meeting, presented the CSM for groundwater flow and described the interim groundwater modeling activities currently underway. Specifically, the presentations by Navy included:

- Responses to the top five issues raised by the working group members to date
- Planned surface geophysical surveys
- Data collection activities currently in progress for evaluating natural attenuation
- Groundwater quality monitoring status and results
- Results to date and plans for high-precision land surveys of additional well heads
- Gyroscopic well survey status
- Forensic chemical analysis of fuels and meaning of total petroleum hydrocarbons reported by labs, including chromatograms from Red Hill groundwater sample analyses
- Lines of evidence that natural attenuation processes are active at Red Hill tank farm area
- Historical photos and geologic logs of Red Hill Water Development Tunnel (the 2254-01 supply well's infiltration gallery)
- Detailed schedule for interim modeling
- Geologic log of core boring RHMW11 showing that saprolite extends to 70 ft below the water table
- Updated north-south hydrogeologic cross-section extending from Hālawa Shaft through Red Hill and southward (including the extent of valley fill/saprolite barriers in both North and South Hālawa Valleys)
- Areas of higher groundwater recharge at Hawaiian Cement's Hālawa Quarry
- Map of borehole locations where perched water has been found above the water table
- Groundwater level hydrographs showing similarity of temporal fluctuations at RHMW07 and other Red Hill monitoring wells
- Groundwater budgets for current model area derived from previous Source Water Assessment Program (SWAP) (Whittier et al. 2004) and USGS models and updated conceptual model of groundwater budget
- Groundwater recharge in model area and uphill of northeast model boundary calculated from most recent USGS recharge rate data

- Supply well pumping and spring discharge rates within model area
- Multiple lines of evidence showing groundwater flow is southwestward from the Red Hill tank farm area
- Graphics showing 50% isochlor interface location, hydraulic conductivity, and water levels for base case conditions simulated by the SUTRA groundwater model (Oki 2005)
- Evaluation of transient groundwater model calibration match to May 2006 pumping test data (DON 2007)
- Conclusions from 2007 Red Hill model in light of new data
- Results of hypothesis testing of deepening the freshwater-saltwater interface depth using 2007 Red Hill model
- Statistical analysis of trends of groundwater level data available for the model area
- Reconfirmation of technical approach for modeling of freshwater-saltwater interface
- Maps and 3D graphics showing updated boundaries and subsurface geometry of hydrogeologic unit layers in interim model
- Calibration targets and weights for updated model
- Website information with downloadable MODFLOW USG transport code
- Summary of planned next steps for the interim modeling

2.1.2 Technical Issues

The work performed so far has revealed several uncertainties and limitations in the available data, including:

- The elevation of the water level measurement point for Hālawa Shaft has not been obtained; this is critical information for evaluating water level data used in the upcoming modeling effort.
- BWS has indicated they have provided all available data requested by the Navy; however, some data such as water level measurements and water quality data for Hālawa Shaft have not been obtained.
- The complete data set will not be available from the USGS synoptic monitoring study within the timeframe required for modeling input to the TUA decision. At this point, it appears that only the initial data set will be available from USGS, which includes data collected in the initial phase of the study through October 2017.
- Sparse data for some hydrologic components create uncertainties in the conceptual groundwater balance for the model area. For instance, submarine groundwater seepage cannot be measured directly.
- If the additional monitoring wells are not installed within the next reporting period, it is anticipated that the data from these wells will not likely be incorporated in the Section 7 *Groundwater Flow Modeling Report* due in December 2018.

2.2 SUBMITTAL OF MODELING DELIVERABLES

Relevant deliverables submitted during this reporting period:

- *Monitoring Well Installation Work Plan Addendum 02,* August 25, 2017 (DON 2017b)
- *Sampling and Analysis Plan Addendum 01,* September 3, 2017 (DON 2017e)
- *Conceptual Site Model Development and Update Plan,* September 3, 2017 (DON 2017d)
- *Attenuation Evaluation Plan,* September 3, 2017 (DON 2017c)
- *Groundwater Model Evaluation Plan,* September 8, 2017 (DON 2017f)
- *Final Third Quarter 2017 - Quarterly Groundwater Monitoring Report,* October 2017 (DON 2017g)

Additional deliverables being prepared at the time of this report's writing include:

- *Digital Leveling Survey Report* presenting results of high-precision survey of Red Hill monitoring well elevations by Second Order, Class I techniques
- *Sampling and Analysis Plan Addendum 02* presenting plan for seismic surveys in Hālawa and Moanalua Valleys)

Additional deliverables due for submittal during the next 4-month reporting period include:

- *Risk-Based Decision Criteria Development Plan* (December 11, 2017)
- *Sentinel Well Network Development Plan* (December 11, 2017)
- *Final Fourth Quarter 2017 - Quarterly Groundwater Monitoring Report* (January 2018)
- *Technical Memorandum, Groundwater Protection and Evaluation Considerations for Tank Upgrade Alternatives Decision* (March 2018)

3. Anticipated Work Next Reporting Period

Anticipated work for Reporting Period 04 (December 4, 2017 – April 2, 2018) includes:

- GWFMWG meetings planned for December 20, 2017 (webinar) and January 11, 2018 (face-to-face)
- Further refining the hydrogeologic unit framework to be used as the interim model layers
- Setting up the interim flow model grid, boundary conditions, initial hydraulic parameter values and calibration targets for 2006, 2015, and 2017 annual average steady-state conditions
- Calibrating the interim steady-state flow model with 2006, 2015, and 2017 annual average water levels and pumping rates
- Setting up and calibrating the transient model for 2006 and 2015 synoptic water level studies
- Performing particle tracking analysis for the capture zones under various pumping scenarios to support the TUA decision process
- Preparing a draft modeling report to summarize the development of the interim model and calibration processes
- Installing pressure transducers in newly installed well RHMW11 in early December 2017 to collect water level data within several discrete zones within the Westbay system. Preliminary results will be discussed.

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