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December 20, 2017

Mark Manfredi
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Joint Base Pearl Harbor- Hickam, Hawai'i 96860

Dear Mr. Manfredi:

Subject: Regulatory Agency Comments on Recently Submitted Derivative Deliverables under Administrative Order on Consent Sections 6 and 7

The U.S. Environmental Protection Agency and Hawaii Department of Health, collectively the "Regulatory Agencies", have reviewed the following four derivative deliverables:

1. "Conceptual Site Model Development and Update Plan, Investigation and Remediation of Releases and Groundwater Protection and Evaluation" Submitted September 1, 2017
2. "Sampling and Analysis Plan Addendum No. 1" Submitted September 1, 2017
3. "Attenuation Evaluation Plan, Investigation and Remediation of Releases and Groundwater Protection and Evaluation" Submitted September 1, 2017
4. "Monitoring Well Installation Work Plan Addendum 02" Submitted August 25th, 2017

These products are not considered deliverables pursuant to Administrative Order on Consent, and do not require formal "approval". The comments of the Regulatory Agencies are attached and reflect a collection of professional opinions. Overall, we believe that the accelerated effort to obtain data and install new monitoring wells is positive, and we are encouraged to see an accelerated pace on the environmental investigation and assessment efforts.

The Navy and Defense Logistics Agency have devoted a significant amount of resources to develop and execute these plans. The Regulatory Agencies believe this additional work is necessary in order to improve the reliability of the conceptual site and groundwater flow models, though it will be a challenge to collect all necessary data given the relatively short timeframe remaining for completing the groundwater flow model report. In addition to the new information that will be obtained from implementing these plans, the Regulatory Agencies believe that existing data will add value as it is analyzed and incorporated into the model, as it will demonstrate that the model can reliably account for historic data.

Also attached are comments the Regulatory Agencies received on these documents from the Honolulu Board of Water Supply. The Navy should also consider these comments as they move forward on collecting data to support the modeling efforts.

Sincerely,

Robert Pallarino

Bob Pallarino,
U.S. EPA Region IX

Roxanne Kwan,
Hawaii Department of Health

Enclosures

cc: Cory Waki, US Navy

Regulatory Agencies comments on Navy Derivative Deliverables.

General Comments

There is much emphasis on small-scale tests when the focus should be on macro-scale tests (such as a tracer test). The planned small scale tests include:

1. Petrographic analysis of the rock cores to evaluate NAPL retention and mobility;
2. A very limited number of hydraulic infiltration tests (double ring infiltrometer tests) to assess infiltration of precipitation;
3. The equivalent of slug tests in the multi-level monitoring wells to assess hydraulic conductivity; and
4. CO_2 flux monitoring on top of the Red Hill Ridge.

Test No. 1 - concentrates on evaluating the amount of fuel that can held within the rock matrix (micro-scale). It is likely that more of the residual fuel in the vadose zone resides in dead end pore space and as a film on the rock (macro-scale). An approach needs to be articulated that can provide defensible numbers for fuel retention both at the micro- and macro-scales. Also, these numbers could change dramatically depending on whether a leak occurs during the dry season (more residual fuel) or wet season (less residual fuel due to water being the wetting fluid and also filling the available dead-end pore space).

Test No. 2 - The upscaling issue is also an issue for the double ring infiltrometer measurements. It will take quite a bit of work to do the double ring infiltrometer tests that will only evaluate less the 1.5 ft^2 of the ridge top. It will be challenging to upscale the very small tested area to evaluate how much rainwater infiltrates through the saprolite cap, through present or future contaminated zones, then down to the water table. The proposed tests can certainly produce numbers confirming that saprolite has low permeability, but since the low permeability of saprolite is already well known how will the results further inform the Red Hill investigation process?

Test No. 3 - The procedure and analytical methods for testing hydraulic conductivity as laid out in Appendix 2 page 17 are essentially slug tests. Slug tests are small scale tests for porous media. Small scale hydraulic conductivity of layered basalts will span several orders of magnitude. It will be challenging to convert the results of these test to a scale that is meaningful for assessing contamination migration. This comment is made with the understanding that hydraulic conductivity will be one of the parameters evaluated when modeling the aquifer responses to pumping stresses at the Red Hill and Halawa Shafts. However, there are other tests that fall between small scale slug tests and aquifer scale tests that should be considered. First would be an analysis of existing pump test data. Rotzoll et al., (2008) detailed methods for estimating hydraulic conductivity from well capacity tests. The well specific capacity is an attribute in the DLNR well data table making the required data easily available. Also, if the BWS is willing to collaborate, pumping tests could be done using production wells that are within the model domain. This type of test would be particularly valuable if water level observation points could be found near the pumping wells. There is such an arrangement at the Moanalua Well field.

Test No. 4 - We recognize that CO_2 is a product of natural attenuation. However, the prospects for a successful CO_2 flux test are very minimal. The ground surface is separated from the zone of contamination and the water table by hundreds of feet of permeable basalt. Air moves freely through the basalts as observed by Stearns when watching the blasting to excavate a water development tunnel (Steans, 1985) or the observations of the USGS at the fractured rock at Yucca Mountain, Nevada (Thortenson et al., 1989). This air exchange will likely dilute and CO_2 signal below any useful concentration for flux analysis. Also, the tunnels in Red Hill have positive ventilation pressures making and CO_2 flux measurements inside of the tunnels meaningless.

The Red Hill hydrologic conceptual model seems to rely heavily on two things being true. There are frequent mentions of focused recharge in the Halawa Quarry and inferences of little to no recharge through the saprolite cap above the USTs. It appears a significant amount of resources are directed toward demonstrating that a groundwater high exists between the Red Hill Facility and the Halawa Shaft thus preventing contamination migration to the Halawa Shaft. This logic can certainly be pursued, but for it to be accepted it must be shown by a preponderance of the evidence that such a groundwater ridge exists. Before expending too many resources on this effort some good desk top analysis could be informative as to whether or not this logic is valid.

It is not that the above tests have no value, but rather, is the value of data acquired justified by the cost required to do the test? How does the Navy plan to upscale tests that very localized test to assess what is happening on an aquifer wide scale? Perhaps a more beneficial expenditure of resources would be a comprehensive analysis of the existing data. The design of the remainder of the Red Hill investigation could benefit immensely from a comprehensive and objective analysis of existing data.

Conceptual Site Model (CSM) Development Plan

The CSM Development Plan does not discuss uncertainty. In previous discussions with the Navy, the Regulatory Agencies had stressed the importance of developing a hypothesis, providing backup data to support the hypothesis, and discussing uncertainty with respect to the Navy's future conclusion.

For example, preferential pathways such as lava tubes or fractured bedrock are an important uncertainty to acknowledge as unmapped fractures, lava tubes, and clinker zones could cause contamination and light non-aqueous phase liquid (LNAPL) to migrate in unexpected ways. The Regulatory Agencies understand that it is difficult to accurately map these preferential pathways, therefore the uncertainty they add to the modeling process can be significant.

Monitoring Well Installation Workplan (MWIWP) Addendum 2

Page 2-1; Lines 31-37 and Page 2-3; Table 2-1

The one-inch casing used in the existing RHMW01 results in very slow sample pump flow rates that require an extended period of time to collect adequate sample volume. Also, the solid casing in this well extends beneath the water table preventing the detection of LNAPL should it be present on the water table at the location of RHMW01. The Navy currently collects monthly oil/water interface measurements from the existing RHMW01 to check for the presence of LNAPL, though the depth of the casing makes this measurement of questionable value. The new monitoring well, RHMW01R will resolve the sample collection time issue. The proposal to install the Westbay system in order to collect groundwater samples at various depths will provide useful information however it will prevent the Navy from using the oil/water interface probe it has historically used to check for the presence of LNAPL. The Navy has stated that the presence of LNAPL on the water table can be inferred by whether there is a sheen on water purged from the well and the concentrations of chemicals of potential concern. However, neither the MWIWP nor the Sampling and Analysis Plans and Addendums indicate the frequency of checking for the presence of LNAPL in the new RHMW01R and whether the Navy intends to continue collecting monthly data on the presence of LNAPL at this location.

Page2-3; Table 2-1, RHMW07D

The Regulatory Agencies believe that the purpose and rationale of the new RHMW07D requires additional explanation as to the possible causes of the water table elevation anomaly and where the replacement well will be located to ensure that the groundwater encountered in the new well does not suffer from the same problems as the existing well. A suggestion is to delay installation of RHMW07D and revisit its location installation after testing of RHMW11. Information from this well could help fine tune the location of RHMW07D.

Page 2-9; Table 2-2

Some of the estimated surface elevations seem to be in error. For example, the ground elevation at RHMW16 appears to more than 500 ft. rather than 260 ft. as stated in table 2-2.

Page 2-10; Section 2.3 Installation of RHMW01R

The Navy should consider evaluating the vadose zone for past occurrences of perched water (i.e. zones of weathered rock or rock with mineral deposits on the surface). Isolating such a zone with packers and installation of a sampling port may prove useful in evaluating movement of water and contamination in the vadose zone during periods of heavy rain or during a fuel release. Past cores from the tunnel wells have shown evidence consistent with transitory perched water as have some of the soil vapor monitoring probes.

Page 3-4; Lines 3-12

As stated in previous reviews of the MWIWP, perched water will almost certainly be encountered in some of the boreholes. This includes RHMW11, RHMW07D, RHMW12, RHMW13 due to their proximity to the stream or areas where perched water has been found previously. Thus, it is critical that the tests for perched water be frequent since perched water zones could be drilled through quickly. See other comments below on this subject. A more comprehensive check for perched water is stated in Appendix C, Page C-7, Lines 2-8 and should also be included in this section or appropriately referenced.

References

Rotzoll, K., and A.I. El-Kadi. 2008. Estimated hydraulic conductivity from specific capacity for Hawaii Aquifers, USA. Hydrogeology Journal. 16(5). 696-979

Thorstenson, D.C., E.P. Weeks, H. Haas, J.C. Woodward. 1989. Physical and Chemical Characteristics of Topographically Affected Airflow in an Open Borehole at Yucca Mountain, Nevada. http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/21/076/21076588.pdf

Stearns, H.T. 1985. Geology of the State of Hawaii, 2nd Edition. Pacific Books Publishers, Palto Alto, Ca. Page 297

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November 13, 2017

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and

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Dear Messrs. Pallarino and Chang:

Subject: Conceptual Site Model Development and Update Plan, Investigation and Remediation of Releases and Groundwater Protection and Evaluation, Red Hill Bulk Fuel Storage Facility, Dated September 1, 2017

The Honolulu Board of Water Supply (BWS) has reviewed the subject document (DON, 2017a) and offers the comments below. In summary, the Conceptual Site Model Development Plan (CSM Plan) as written does not address directives from the Regulatory Agencies and lacks sufficient explanation to develop a defensible conceptual site model (CSM) of the Red Hill Bulk Fuel Storage Facility (RHBFSF) and its vicinity.

General Comments

The United States Environmental Protection Agency (EPA) and Hawaii Department of Health (DOH) directed the Navy (EPA and DOH, 2016) to ensure that the CSM Plan will "*...create a defensible initial conceptual site model, and subsequent updates to the conceptual site model, that acknowledges uncertainty and is based on all data available for the site.*" Our review shows that the CSM Plan provides almost no discussion of uncertainty in the conceptual features and processes driving the migration of Red Hill contamination through the vadose zone and our aquifer. Like the Groundwater Model Evaluation Plan (DON, 2017b), the CSM Plan is not based on "all data available" because it ignores data and modeling that provide valuable insights into how Red Hill contaminants may migrate. One example is the apparent dismissal of the May 2015 pumping test data. The CSM Plan incorrectly states that the data are "incomplete" and does not even mention how those data show that the groundwater level at Halawa Shaft is about 4 feet lower than the groundwater level at Red Hill. Another example is that the CSM Plan ignores the data collected during the November 2016 synoptic water level survey. BWS asks that the CSM Plan be revised so that it definitively addresses the Regulatory Agencies' directive from September 15, 2016.

EPA and DOH (2016) also stated that "*The conceptual site model needs to evaluate NAPL [non-aqueous phase liquid] movement in the saturated and unsaturated zones for the purposes of risk characterization. The plan for the conceptual site model needs to describe an approach for evaluating the potential migration rates and directions for NAPL movement from all areas of the Facility.*" Based on our review, the CSM Plan does not comply with the directive from the Regulatory Agencies and should be revised. For example, the CSM Plan has no description of how the Navy will estimate the NAPL travel distance and rate for different sizes of fuel releases and instead focuses on estimating the volume of NAPL that will be retained in the vadose zone. Such an approach will most likely greatly underestimate the risk to the water supply from Red Hill contamination because it does not address rapid, long-distance travel in the vadose zone that will occur during large fuel releases. EPA and DOH (2016) state that this information is needed to understand the "consequences of potential future releases", but the CSM Plan does not discuss ranges of volumes and migration rates that are possible for future releases.

We find that the CSM Plan inadequately addresses our important concerns about how uncertainty should be addressed in the CSM. We wrote in Lau (2016), "*We agree that uncertainties must be addressed in the groundwater flow and transport models. However, these uncertainties must be first addressed in the CSM, before the numerical models are constructed, so that construction of the numerical models will capture these important uncertainties.*" Our concerns are even more pertinent today because the Navy has yet to explain how the present-day uncertainties about groundwater flow rates and directions, hydrogeologic properties and geometries, and recharge are to be handled in the interim flow and transport models and in the version of the CSM that will underpin those models. We hold the same concerns about how the next version of the CSM and final models will treat uncertainty about the most important inputs. The Regulatory Agencies should ensure that the CSM Plan is revised to provide quantitative evaluation of all uncertainties that are important to estimating the risks to our drinking water supply from Red Hill fuel releases.

Our review found that the CSM Plan lacks sufficient information about schedule and the interdependencies between the CSM development, field activities, and modeling. Field activities and modeling are underway, yet the CSM Plan states that the CSM will incorporate new field data which together will be used in developing the flow and transport models. The CSM Plan should explain how the CSM and numerical models will be developed in the absence of the field data, especially for the interim groundwater flow and transport modeling, and provide timelines for getting and incorporating new data into the CSM and then into the models.

Specific Comments

Section 2, page 7 of 26, lines 11-12. This sentence states: "*The initial CSM will be developed prior to numerical groundwater modeling and will then be used as the basis for developing the numerical model.*" How will the CSM influence the interim flow and transport model given that the CSM is not even in draft form and the interim models are scheduled to be completed by January 2018? How will the CSM be updated as information from the new monitoring wells becomes available and how will that influence the final flow and transport model? Where is the schedule that explains how field data, CSM, and numerical models will be produced and updated?

Section 2, page 7 of 26, lines12-14. This sentence states: "*An iterative and collaborative process will be followed during development of the CSM to obtain input from Regulatory Agencies and AOC subject matter experts (SMEs).*" The BWS reminds the Navy and the Regulatory Agencies that the SMEs offer technical recommendations to work product content for consideration by the Navy and the Regulatory Agencies. The use of such comments is at the sole discretion and decision of the Navy.

Section 2.1.1, page 8, lines 16-19. This section states: "*Surficial soils are not expected to be a significant component of the CSM since releases are expected to occur at depth within the vadose zone. Valley fill sediments and saprolitic clay-rich soils have been identified at depth that are low in permeability and have the potential to restrict contaminant migration depending on the vertical and horizontal extent to which they occur.*" The BWS understanding is that valley fill sediments have been identified to be potentially present but not confirmed. The permeability and any "potential to restrict contaminant migration depending on the vertical and horizontal extent to which they occur" of these valley fill sediments is simply unknown in Halawa and Moanalua Valleys. The sentence gives the impression that valley fill sediments are present in these valleys without any direct evidence, so it should be revised or deleted.

Section 2.1.3, page 9, lines 15-18. This section states: "*...the groundwater CSM will evaluate the groundwater level data from site area wells to define hydraulic gradients* *during pumping and non-pumping conditions to improve the understanding of the direction and rate of groundwater flow within the aquifers around the Facility.*" The BWS understands that this information will also be summarized in the groundwater model report and perhaps this should be made clear in this section. Also, the aquifers the Navy is referring to (names/locations) should be defined.

Section 2.2, page 9, line 22. The contaminant of potential concern (COPC) plume is identified as a potentially complete exposure pathway. It should be noted in this section that a light non-aqueous phase liquid (LNAPL) plume is potentially present as an exposure pathway and could impact water supplies, including Red Hill Shaft at a minimum, as well as South Halawa stream.

Section 3.1, page 10, lines 24 to 26. This sentence says "*In reviewing that data gap analysis, the Regulatory Agencies requested that the Navy should identify only the data gaps that would remain following evaluation of data needs in consideration of existing data.*" We cannot understand this sentence and ask that it be clarified.

BWS believes the CSM Plan must address all important data gaps and also explain how the CSM and numerical models will use conservative assumptions if the data gaps and uncertainties are not resolved at the time of writing. The CSM Plan should explicitly state that only conservative interpretations or conceptualizations will be selected if uncertainty in the available data or data gaps lead to multiple interpretations. A single non-conservative conceptualization should not be permissible for conceptual or numerical modeling.

Section 3.1.5, page 14, lines 20 and 21. This sentence states, "*However, a clay-rich saprolitic soil of substantial thickness is present at the Red Hill ground surface and extends throughout the Facility vicinity*" and that the presence of this clay unit "probably" reduces the recharge rates in the Red Hill vicinity. Based on the presence of significant moisture and free water in the Red Hill facility tunnels, the BWS feels this is an incorrect assumption (see our comment on Section 3.5, page 18, line 35 below). Potentially clay-rich soils present on the surface apparently do little to prevent significant moisture and free water in the vadose zone and certainly do not prevent subsurface leaks from the buried fuel tanks.

Section 3.1.5, page 14, line 37. The Navy indicates that they will be dependent on United States Geological Survey (USGS) recharge and discharge rates and if these are not available the data gaps will be further evaluated. How will recharge/discharge rates be evaluated in the model if nothing is available from USGS?

Section 3.4, page 17, lines 31 to 40. This paragraph states that the CSM will describe how the light non-aqueous phase liquid (LNAPL) will likely move from the tanks through the vadose zone. However, it lacks any explanation of how travel distances and migration rates will be estimated and it lacks any description of the data that will be needed to make these estimates. This paragraph gives the impression that simply looking at the "smaller pore spaces" is primarily what is needed. In actual fact, LNAPL migration for larger releases will more likely be controlled by the large pore spaces such as lava tubes and extensive clinker zones. This section should be expanded to describe these features and processes that will primarily control migration rates and extents, not just retention, in the vadose zone.

Section 3.5, page 18, line 35. The CSM Plan does not discuss that recharge/infiltration rates can be directly measured in the upper and lower access tunnels. It suggests infiltrometer measurements but ignores soil mapping data that are readily available. Red Hill soils are described as "well-drained" Manana Series or thinly covered or exposed bedrock in the on-line Hawaii soils atlas produced by the University of Hawaii (http://gis.ctahr.hawaii.edu/SoilAtlas#map). Copious volumes of water seeping into the Red Hill tunnels are collected and treated by the oil-water collection system. An example of the flow rates is the image of a worker standing knee deep in water while excavating a Red Hill tunnel in the Navy's recent historical video (see minute 1:40 in https://www.youtube.com/watch?v=0Bx81rD206A&feature=youtu.be). Seepage into the tunnels is readily apparent to those who have toured the Red Hill facility.

Recharge through the fuel-contaminated Red Hill vadose zone is a significant contamination source for our drinking water. The BWS believes that the Regulatory Agencies should direct the Navy to adopt conservative approaches for representing key hydrologic processes in their conceptual and numerical models.

Section 3.5, page 18, lines 40-41 and page 19, line 1. The CSM Plan states that perched water "...is an indication of local groundwater recharge". How is this relevant to the basalt aquifer affected by Red Hill contamination? Given that perched zones are by definition saturated intervals located on low permeability lenses or units above the regional aquifer, what is the basis that these zones are providing significant local recharge to the regional aquifer? This statement should be deleted from the CSM Plan in the absence of justification.

Section 3.6, page 19, line 26 and lines 37 – 38. This section about hydrogeological inputs discusses valley fill geometry and valley fill depths as hydrogeologic unit characteristics and geologic structures that may affect groundwater flow respectively. This section appears to indicate that the Navy currently has this data. This section lacks any discussion of how these units will be treated both conceptually and numerically if there are no or very limited data. This section should be expanded to explain how the Navy will develop versions of the CSM in the absence of confirmatory data.

Section 3.6, page 20, lines 6 – 9. This section mentions the water balance as a hydrogeological input. BWS believes that calculating an independent water balance is a critical CSM component and that such a water balance will be a useful check on numerical model results. The Navy's contractors agreed to carry out such a water balance during the fourth meeting of the groundwater modeling work group in September 2017; the CSM Plan should be revised to explain the data and the calculations to be used.

Section 3.10, page 21, line 23. This section should include a discussion of a "complete" pathway such as the COPC concentrations detected in water samples collected from Red Hill Shaft on multiple occasions in the past.

Section 5, page 23, lines 2 – 5. This section should specify a schedule for updating the CSM and sharing new findings and understanding with stakeholders, SMEs, and the public.

Thank you for the opportunity to comment. If you have any questions, please feel free to call Erwin Kawata at 808-748-5080.

Very truly yours,

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References

Department of the Navy (DON). 2017a. Conceptual Site Model Development and Update Plan, Investigation and Remediation of Releases and Groundwater Protection and Evaluation, Red Hill Bulk Fuel Storage Facility, JOINT BASE PEARL HARBOR-HICKAM, O'AHU, HAWAI'I, Administrative Order on Consent in the Matter of Red Hill Bulk Fuel Storage Facility, EPA Docket Number RCRA 7003-R9-2015-01 and DOH Docket Number 15-UST-EA-01, Attachment A, Statement of Work Section 6.2, Section 7.1.2, Section 7.2.2, and Section 7.3.2. Revision 00. September 1.

Department of the Navy (DON). 2017b. Groundwater Model Evaluation Plan, Investigation and Remediation of Releases and Groundwater Protection and Evaluation, Red Hill Bulk Fuel Storage Facility JOINT BASE PEARL HARBOR-HICKAM, O'AHU, HAWAI'I 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. September 8.

Environmental Protection Agency (EPA) and Hawaii Department of Health (DOH). 2016. Letter to Mr. James Miyamoto, Naval Facilities Engineering Command, Hawaii: Disapproval of Red Hill Administrative Order on Consent ("AOC")- Attachment A Statement of Work ("SOW") Deliverable for Sections 6 and 7 – Work Plan/ Scope of Work, Investigation and Remediation of Releases and Groundwater Protection and Evaluation, Red Hill Bulk Fuel Storage Facility ("Facility"), May 4, 2016. Letter dated September 15, 2016.

Lau, E. (2016). Letter to Mr. Bob Pallarino, EPA, and Mr. Steven Chang, Hawaii Department of Health: Board of Water Supply (BWS) Comments to the United States Environmental Protection Agency and Hawaii Department of Health letter disapproving the United States Navy's Statement of Work ("SOW") Deliverable for Sections 6 and 7 – Work Plan/ Scope of Work, Investigation and Remediation of Releases and Groundwater Protection and Evaluation, Red Hill Bulk Fuel Storage Facility ("Facility"), dated May 4, 2016. Letter dated October 4, 2016.

BOARD OF WATER SUPPLY

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October 26, 2017

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Dear Messrs. Pallarino and Chang:

Subject: Review Comments – *Monitoring Well Installation Work Plan Addendum 02, Red Hill Bulk Fuel Storage Facility*, Dated August 25, 2017

The Honolulu Board of Water Supply (BWS) offers the following comments to the Navy's Monitoring Well Installation Work Plan Addendum 02, Red Hill Bulk Fuel Storage Facility submitted to the United States Environmental Protection Agency (EPA) and Department of Health (DOH) on August 25, 2017 (Navy, 2017).

General Comment

Section 2, page 2-1, lines 20-25. The subject Addendum 02 is making an overall assumption that Oahu basalt are similar to Snake River Plain basalts. This is inappropriate. The Snake River Plain basalt flows are largely pahoehoe-type lava flows, that significantly differ from Hawaiian pahoehoe flows in that many of the basalt flows are vastly larger in both size (areal extent – cover 50 to >100 square miles) and thickness (often 80 to >150 ft-thick). The Snake River Plain basalt flows are considered to have more in common with the Columbia River flood-basalt flows than Hawaiian basalt flows. A review of United States Geological Survey (USGS) publications that describes the use of the Westbay system to measure/sample head differences encountered within the Snake River Plain aquifer (Fisher and Twining 2011; Twining and Fisher 2012, 2015) indicate that the differences in the head profiles are attributed to the great lateral extent of the basalt flows and their dense flow interiors that form a thick confining layer. The Ko'olau basalt flows do not possess thick, aerially extensive dense flow interiors. The absence of aerially extensive, thick dense flow interiors is due to the fact that individual Ko'olau basalt flows were low-volume compound, shoestring lava flows and flow fields which have relatively thin dense flow interiors without significant lateral extents. The Snake River Plain basalts also contain a significant number of sedimentary interbeds that, combined with the basalt flow dense interiors, formed confining layers. The Ko'olau Basalt is not noted for containing sedimentary interbeds. It appears very likely that the Navy will have particular difficulty finding enough dense flow interior locations within the Ko'olau Basalt for packer set points, and, if found, these dense flow interiors will likely be open to the same interconnected interval.

Specific Comments

Section 2.2, page 2-6, lines 31-34 (setting packers in the Ko'olau Basalt). BWS is seriously concerned that below the surface of the basal aquifer, the Navy will encounter mostly pahoehoe flows that are devoid of "dense interiors" and likely what will be encountered are a series of thin vesicular flow lobes (e.g., Stearns, 1940; Macdonald, 1941; Wentworth, 1942; TEC (Appendix A), 2007; Battelle and Parsons, 2015). This will limit the areas for packer set points and therefore potentially make the use of Westbay wells limited at best.

Section 2.4, page 2-13, lines 22-24 "Testing rock types". The Work Plan does not specifically mention attempting to test primary cooling joints (fractures) as a "rock type". The BWS believes that overlooking cooling joint features would be a serious mistake and the presence of such should be studied, evaluated, measured, and documented.

Section 3.3.1, Page 3-5 line 1. The BWS believes this statement should read "coring will commence when auger boring reaches point of refusal". The term "competent bedrock" isn't specific enough in this context.

Appendix D, Page D-3, lines 7-8. The Work Plan states that the Navy will use magnetometers on the geophysical tools (within the borehole) to correct the data to magnetic north. Since all basalts are highly magnetic due to their mineralogy, this will not work.

Appendix D, Page D-3, line 16. The Work Plan states that the Navy will use the compass in the televiewer tool (in the borehole) to determine magnetic north. The Navy should use a gyroscopic tool in the borehole to determine magnetic north.

Thank you for the opportunity to comment. If you have any questions, please feel free to call Erwin Kawata, Program Administrator of our Water Quality Division at 808-748-5080.

Very truly yours,

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References Cited

Navy. 2017. Monitoring Well Installation Work Plan Addendum 02, JOINT BASE PEARL HARBOR-HICKAM, O'AHU, HAWAI'I. August 25.

Fisher, J. C., and B. V. Twining. 2011. Multilevel Groundwater Monitoring of Hydraulic Head and Temperature in the Eastern Snake River Plain Aquifer, Idaho National Laboratory, Idaho, 2007–08. Scientific Investigations Report 2010–5253. Prepared in Cooperation with the U.S. Department of Energy, DOE/ID-22213. U.S. Geological Survey.

Twining, B. V., and J. C. Fisher. 2012. Multilevel Groundwater Monitoring of Hydraulic Head and Temperature in the Eastern Snake River Plain Aquifer, Idaho National Laboratory, Idaho, 2009–10. Scientific Investigations Report 2012–5259. Prepared in Cooperation with the U.S. Department of Energy, DOE/ID-22221. U.S. Geological Survey.

———. 2015. Multilevel Groundwater Monitoring of Hydraulic Head and Temperature in the Eastern Snake River Plain Aquifer, Idaho National Laboratory, Idaho, 2011–13. Scientific 5042. Prepared in Cooperation with the U.S. Department of Energy, 235. U.S. Geological Survey.

Stearns, H.T., 1940. Supplement to the geology and ground-water resources of the Island of Oahu, Hawaii: U.S. Geological Survey Bulletin 5, 164 p.

Macdonald, G.A., 1941. Geology of the Red Hill and Waimalu areas, Oahu, in relation to the underground fuel storage project of the U.S. Navy: U.S. Geological Survey letter report to the U.S. Navy Public Works Office, Pearl Harbor, 76 p.

Wentworth, C.K., 1942. Geology and ground-water resources of the Moanalua-Halawa District: Report prepared for the Board of Water Supply, Honolulu, Hawaii, 156 p.

TEC, 2007. Red Hill Bulk Fuel Storage Facility final technical report: prepared for the Department of the Navy, NAVFAC, Pearl Harbor, Hawaii, by TEC, Inc., 174 p.

Battelle and Parsons, 2015. Monitoring well installation report (Draft) Red Hill Bulk Fuel Storage Facility, Joint Base Pearl Harbor-Hickam, Hawaii: prepared for the Department of the Navy, NAVFAC, Pearl Harbor, Hawaii, by Battelle, Columbus, Ohio, and Parsons, South Jordan, Utah, 1874 p.

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October 24, 2017

Mr. Bob Pallarino
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and

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Department of Health
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Dear Messrs. Pallarino and Chang:

Subject: Review Comments – *Attenuation Evaluation Plan, Investigation and Remediation of Releases and Groundwater Protection and Evaluation, Red Hill Bulk Fuel Storage Facility*, dated September 1, 2017

The Honolulu Board of Water Supply (BWS) offers the following comments to the Navy's *Attenuation Evaluation Plan, Investigation and Remediation of Releases and Groundwater Protection and Evaluation, Red Hill Bulk Fuel Storage Facility* submitted to the United States Environmental Protection Agency (EPA) and Department of Health (DOH) on September 1, 2017 (Navy, 2017).

General Comments

1. The Attenuation Evaluation Plan (AEP) does not acknowledge or incorporate the impacts of the many documented releases of different petroleum fuels from the Red Hill Bulk Fuel Storage Facility since its construction; and instead limits its scope to "potential current and future risk to human health and the environment from the release of jet fuel (JP-8) from Tank 5 in January 2014 and any potential future releases from the Facility" (Navy, 2017 – Section 2, Page 1). Failure to recognize other types of fuel that were stored and released could have direct

impacts on the assessment of non-aqueous-phase liquid (NAPL) chemical concentrations, identified as a primary line of evidence (LOE) in the document.

2. The AEP does not provide any analysis or discussion regarding the adequacy of the existing site characterization infrastructure (groundwater monitoring wells, vapor monitoring points, etc.) to provide a representative analysis of the NAPL source zone and the attenuation of petroleum hydrocarbons. The location of the existing monitoring wells installed by the Navy have, to this point in time, been intended to define the magnitude and extent of the petroleum hydrocarbon plume. The AEP should provide a more detailed discussion regarding whether the existing data points are adequate to support the objectives of this plan. There seems to be a lack of appreciation for the magnitude and size of this facility and the distances between wells. Given the age of the facility, records of multiple releases from numerous tanks, and the inability to reliably detect "small" releases from the tanks, the area of historic NAPL flux to groundwater should incorporate, at a minimum, the area beneath the entire tank farm. This results in a potential source zone that is approximately one third of a mile long by several hundred feet wide. For most petroleum contaminated sites, analyses and decisions regarding source zone depletion and natural attenuation are made with data points spaced within tens of feet of a discrete source. At Red Hill, monitoring locations are typically over 500 feet apart, and the point of discharge of NAPL to groundwater is poorly understood. The AEP should include a defensible analysis of the adequacy of all the identified data points to provide meaningful inputs to models and for decision making purposes. This analysis should also include a discussion regarding the adequacy of the number of samples (e.g. three infiltrometer test locations **[Section 4.2.1]**) and frequency of sampling events (e.g. one event for natural attenuation parameters **[Section 4.2.3]**), for each location and for all data types.

<u>Specific Comments</u>

Section 2, Page 1, Lines 30-32; and Section 4.2.2.2, Page 30, Lines 35-37. It is stated that the objective of this project includes an evaluation of future risk to human health and the environment from future releases from the Facility. The BWS acknowledges that the Administrative Order of Consent (AOC) includes an analysis of the risk of future releases from the facility; however, the BWS strongly opposes any suggestion that the results of the AEP be used to identify a threshold volume of a release that would not impact current drinking water withdraw points. The basal aquifer beneath Red Hill has been designated a Sole-Source Aquifer by the EPA, and any potential further contamination of the aquifer from a future release should not be tolerated by either EPA or DOH, regardless of the attenuation capacity identified through the execution of the AEP.

Section 2, Page 7, Lines 7-10. The AEP should discuss how the Site-Specific Risk-Based Levels (SSRBLs) being developed now will be different from the SSRBLs described in the current Groundwater Protection Plan (GWPP) that has been approved by the DOH.

Figures 3 and 4. These figures are very difficult to read from the electronic form due to overlying duplication of text and graphics.

Section 3.1, Page 8; Section 3.2, Page 14; Table 2, Page 16; Table 3, Page 21; and Section 4.2.3, Page 32. The AEP should include a discussion as to why natural attenuation parameters manganese and hydrogen sulfide have been omitted from consideration.

Section 4.1.1, Page 19. Analyses of spatial and temporal trends should incorporate all available data related to pumping events and flow rates at drinking water sources (e.g. Red Hill Shaft and Halawa Shaft). Any interpretation of contaminant trends at monitoring points should include a thorough understanding of the impacts of pumping on groundwater flow patterns and the ability to decipher attenuation versus mobilization away from monitoring wells as a result of changes in pumping intervals and rates (e.g. prolonged shut down of Red Hill Shaft for maintenance in 2016).

Section 4.1.2, Page 19. Given the history of releases from the tanks, the Source Studies should include all fuel types that have been documented to have spilled, or more conservatively, have been stored in the tanks since put into service. The AEP needs clarification as to what fuels will be evaluated.

Section 4.1.2.1, Page 20, Lines 4-8. The AEP is unclear with regards to the purpose of collecting samples of the tank bottom water and from which tanks these samples will be collected. Since F-24 is now used in the tanks, how will samples from these tanks be compared to the products that have been released? Or are these samples for related to analyses associated with future releases?

Section 4.1.2.3, Page 25, Lines 9-11. This section specifies that only data from existing cores will be used in the evaluation of physical characteristics of basalt layers. The AEP needs a discussion on how it incorporates blast-induced fracturing immediately adjacent to the underground storage tanks and the lower access tunnel in the evaluation of effective porosity and connection of clinker zones.

Section 4.2.1, Page 30. How will the existing recharge rates published by the United States Geologic Survey (USGS) be used to validate or calculate local recharge rates?

Section 4.1.2.3, Page 31, Lines 24 through 28. The AEP indicates that the Navy will use EPA's Hydrocarbon Spill Screening Model (HSSM) (a screening-level analytical program that can simulate movement of NAPL and dissolution of soluble components of the NAPL in *one* dimension) to estimate the movement of NAPL at the tank source release site by applying HSSM within the updated geologic framework. This approach is too restrictive because it ignores that NAPL released from the tanks will migrate through three-dimensional preferential flow paths present throughout the vadose zone. These pathways include clinker zones, lava tubes, and fracture networks. The proposed use of the one-dimensional HSSM to describe the extent and rate of NAPL migration is inappropriate because it will underestimate the migration distances by fuel releases. This underestimate of NAPL migration along sub-horizontal pathways away from the Red Hill tanks will also underestimate the risk to our water supplies from Red Hill fuel releases. The Regulatory Agencies should direct the Navy to use a more appropriate, realistic, and conservative three-dimensional model to estimate the distances traveled by NAPL through the three-dimensional pathways observed in the Ko'olau basalt.

Section 4.2.2.5, Page 31, Lines 31 & 32. Are recoverable "sediments" from monitoring wells RHMW01 and RHMW02 representative of saprolite or alluvial material that occurs across the screen interval of these wells? If the basalt intervals through which these wells are screened are competent, would any occurring sediment production be expected that was not resultant from slough or milling of the basalt from an unknown depth in the borehole?

Section 4.2.3, Page 31, Lines 43 & 44. The AEP states "The project Work Plan/Scope of Work (WP/SOW) includes collecting and evaluating additional natural attenuation parameter data from Red Hill monitoring wells to show biodegradation processes are active in reducing the mass of contaminates of potential concern (COPC)." This statement assumes that Red Hill monitoring wells lie along flow paths from NAPL sources at the water table through the dissolved phase plume. It may be likely that biodegradation is occurring in the Red Hill subsurface in ways similar to other sites, but the presence of natural attenuation parameters does not equate to reductions of COPC masses that are significant. The AEP appears to have reached a pre-determined conclusion because its proposed analysis appears to assume that just because there is evidence of biodegradation occurring somewhere in the subsurface, it must be occurring throughout the aquifer at rates that are large enough to reduce significant amounts of COPCs despite high advection rates and associated short residence times. In brief, the Navy has not yet determined where the sources are at the water table, which direction(s) is(are) downgradient, the rates of groundwater flow and residence times along those flow paths, and whether the biodegradation rates are significant relative to the residence times in those areas that support biodegradation.

Thank you for the opportunity to comment. If you have any questions, please feel free to call Erwin Kawata, Program Administrator of our Water Quality Division at 808-748-5080.

Very truly yours,

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References Cited

Navy. 2017. *Attenuation Evaluation Plan, Investigation and Remediation of Releases and Groundwater Protection and Evaluation, Red Hill Bulk Fuel Storage Facility*, JOINT BASE PEARL HARBOR-HICKAM, O'AHU, HAWAI'I, 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. September 1.

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November 13, 2017

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Dear Messrs. Pallarino and Chang:

Subject: Groundwater Model Evaluation Plan (GMEP), Investigation and Remediation of Releases and Groundwater Protection and Evaluation, Red Hill Bulk Fuel Storage Facility Administrative Order on Consent (AOC) 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 (SOW) Section 6.2, Section 7.1.2, Section 7.2.2, and Section 7.3.2 Dated September 8, 2017

The Honolulu Board of Water Supply (BWS) has reviewed the subject document (DON, 2017) and offers the following comments. In summary, the Groundwater Model Evaluation Plan (GMEP) as written is not a suitable basis for developing defensible groundwater flow and transport models for the Red Hill Bulk Fuel Storage Facility (RHBFSF) and its vicinity.

General Comments

The GMEP appears to describe the methods that the Navy and its modeling team will use for the final groundwater flow and transport models due in late 2018. It lacks a description of the methods to be used in the interim flow and transport models due in early 2018 and how those methods differ (or not) from those for the final models. The Navy should explain how all the modeling will be completed in a timely manner to allow stakeholders and regulators to review and comment.

The GMEP does not provide an approach that will estimate the risk to Halawa Shaft, other water supplies, and our drinking water aquifer from migration of Red Hill contaminants released in the past or in the future that will be suitable for use in Sections 3, 6, 7, and 8 of the AOC SOW. The GMEP lacks a description of how the modeling process will generate a set of possible outcomes for transport from the RHBFSF to Halawa Shaft based on the current understanding of the conceptual site model (CSM), available data, and known data gaps.

Given that little is known about site-specific hydrogeology and the focus on risk from contaminant migration, the GMEP lacks adequate evaluation of uncertainty in the stresses that drive groundwater flow and contaminant transport, groundwater levels, flow direction and rates, and hydraulic properties. The Regulatory Agencies should ensure that the GMEP is revised to provide quantitative evaluation of all uncertainties that are important to estimating the risks to our drinking water supply from RHBFSF fuel releases.

The BWS is very concerned that implementing the GMEP will affect the quality and defensibility of the interim and final groundwater models. Our review found that the GMEP contains misstatements and mischaracterizations of Oahu hydrogeology. Also, the GMEP appears to focus primarily on the DON (2007) model report yet ignores and often contradicts studies published by workers at the United States Geological Survey (USGS) and others about valley fill, groundwater levels and flow directions, recharge, etc. Exclusion of readily available, relevant data from the GMEP is a grave concern because the omitted data provide valuable insights into groundwater flow direction from Red Hill across Halawa Valley to Halawa Shaft.

The GMEP states that the modeling process will follow American Society for Testing and Materials (ASTM) guidelines for modeling and calibration. However, the GMEP does not comply with the appropriate ASTM guidelines in several important areas such as boundary conditions and calibration. The BWS requests that the Regulatory Agencies require that the Navy either revise the GMEP to comply with ASTM guidelines or to specifically state which parts of the ASTM guidelines they are following and which parts they are not following.

Section 1 Comments

Lines 36 and 37 in the GMEP Section 1 state that "Where assumptions were previously made in the 2007 modeling effort that cannot be verified with actual data or technically defensible hydrogeologic interpretation, a conservative assumption will be made in the revised model." The BWS welcomes this statement, but there is no explanation about what is meant. The GMEP should list the well-known data gaps, e.g., valley fill geometry and properties, regional groundwater flow, recharge rates, etc., and explain the conservative assumptions that are expected to be made for the interim model and the SOW Sections 6 and 7 models.

GMEP Section 1.1 states "The model boundary locations were discussed, evaluated and adjusted collaboratively with the Regulatory Agencies and AOC Regulatory Agencies' Subject Matter Experts (SMEs)." This greatly overstates the agreements reached during the groundwater modeling work group meetings. The BWS and the USGS SMEs shared their opinions about the Navy's choices of boundaries, but the GMEP boundaries do not reflect the choices or recommendations of the SMEs, including the BWS.

Section 2 Comments

The second paragraph in GMEP Section 2 states "The overall objective of the planned groundwater modeling is to incorporate more recent and definitive hydrogeologic and attenuation data into a refined model to further evaluate groundwater flow and contaminant movement from the Facility to potential receptors." The BWS is very concerned about this objective. First, it specifies to "further evaluate groundwater flow and contaminant movement" without explaining further from what. Further than the Oki (2005) groundwater flow and transport model? Further than the DON (2007) model? As the BWS has explained in meetings and in writing, the DON (2007) model contains numerous inaccuracies and serious flaws that should preclude it from being used to understand and predict groundwater flow in Moanalua and Halawa Valleys. Second, this objective appears to ignore important uncertainties that have been identified previously and focuses on only getting model predictions. The BWS recommends that the objective should focus on getting model predictions that reflect the important uncertainties in the subsurface. Thus, the Navy models should be used to evaluate the likelihood that contamination from the RHBFSF could migrate to water supplies and to other environmental receptors given the uncertainty in the hydraulic properties and the groundwater flow field.

The third paragraph in GMEP Section 3 states the modeling will investigate capture zones for key water supply wells. The GMEP should list the key water supply wells.

Given that pumping rates at the water supply wells will change if more RHBFSF fuel contaminates the groundwater, we recommend the capture zone analysis include a variety of pumping scenarios in order to better estimate the risk to water supplies.

The third paragraph in GMEP Section 2 states the modeling will investigate movement of light non-aqueous phase liquid (LNAPL) along the surface of the groundwater. This approach is too restrictive because it ignores the lateral migration of LNAPL in the vadose zone before it reaches the water table. There are preferential flow paths throughout the vadose zone, so the LNAPL could migrate farther and faster than it would along the groundwater surface where it must navigate around water-filled voids. Therefore, the GMEP modeling should address the potential of LNAPL migration in both the unsaturated and saturated zones. Furthermore, the proposed use of one-dimensional analytical models to describe the extent of LNAPL migration is overly simplistic and will likely underestimate the lateral migration distances by fuel releases because the preferential pathways are actually three-dimensional features.

The Navy interim model described in GMEP Section 2 paragraph 3 is intended to support the evaluation of the tank upgrade alternatives (TUA). If this is the case, then the model must examine the potential for migration outcomes given the uncertainty in the sparse set of Site-specific data. In the absence of supporting Site-specific data, the Navy interim model should adopt conservative assumptions for the well-established data gaps. All or most of the new information about groundwater levels, geology, and groundwater chemistry from the proposed new monitoring wells will likely not be available for use in the Navy interim model because it has an early 2018 deadline.

The third paragraph in GMEP Section 2 states that the Navy will use the "model to determine conditions that would not result in an exceedance of the Maximum Contaminant Levels (MCLs) or State of Hawaii Tier 1 Environmental Action Levels (EALs) at receptors..." The focus should be on determining the risk from the RHBFSF to receptors. The modeling focus should be revised to define the conditions that do cause significant contamination to reach receptors, instead of focusing on defining those conditions that do not cause significant contamination. That is, our water supply's safety depends on knowing what conditions increase the risk, not just the set of conditions that pose no risk.

There is no discussion of the data for attenuation at the RHBFSF in this section or elsewhere in the GMEP. Nor is there any text that defines the range of potential releases that are to be simulated in the flow and transport models.

This section makes no mention of how the modeling will incorporate uncertainty to estimate the risks to groundwater from Red Hill fuel releases. The GMEP should be revised to include a constrained uncertainty analysis as recommended by Dr. Sorab Panday, with agreement from the BWS, during the 3rd groundwater modeling work group (GWMWG) meeting on August 17, 2017.

Section 3 Comments

Line 7 in GMEP Section 3 states "Hydrologic features in the groundwater flow modeling area" are pertinent for the groundwater modeling work but there is no explanation of what is meant by these features and how they differ from the groundwater sources and sinks (line 11). There is no further mention of hydrologic features in the remainder of the GMEP. Please clarify or remove.

Line 9 in GMEP Section 3 cites temporal changes on groundwater levels and flow directions caused by pumping. This is an incomplete list of the important temporal changes in groundwater. The GMEP should be revised to include temporal changes caused by recharge, spring discharge, movement of the freshwater-seawater interface, surface water flow, and other relevant processes. If the Navy does not believe that temporal variations from causes other than pumping are not important, then they should provide the data and the analysis to support their claim.

Section 3.1 of the GMEP introduces the CSM for the Red Hill vicinity and simply states that the CSM will be used to "develop and refine" the numerical groundwater flow model. This section (and the entire GMEP) lacks a schedule for CSM deliverables and when the numerical models will be updated using the so-called "living document". As of this writing, there has been no CSM deliverable other than the CSM draft development plan (cited as DON 2017i), shared with the Regulatory Agencies and SMEs. The BWS has two serious concerns about the lack of clarity in the development of the CSM and the interim and final models:

1) How will the CSM influence the interim flow and transport models given that the CSM is not even in draft form and the interim models are scheduled to be completed by January 2018?
2) How will the CSM be updated as information from the new monitoring wells becomes available and how will the updated CSM influence the final flow and transport model?

The first sentence of the third paragraph in GMEP Section 3.1 is supposition with no factual basis provided. It should be removed or else revised. Weathered intervals could also create "local confined conditions" and are likely to be of greater lateral extent than individual a'a flows.

The last sentence of the third paragraph in GMEP Section 3.1 states "Previous modeling efforts in the area have successfully used an equivalent porous medium approach to simulate groundwater flow under these conditions". Please clarify what is meant by "successfully"? Were there comparisons of the equivalent porous media (EPM) model results with results from a fractured media model? If there is no demonstration of the differences between EPM and fractured media models, then "successfully" should be deleted. This section should also address whether there is any evidence that EPM models of contaminant transport have been calibrated against observed contaminant concentrations for the Ko'olau basalt. Are EPM models appropriate for plume-scale models or for LNAPL migration models? This section should be revised to answer these questions.

The GMEP does not provide an adequate discussion of the important information found in the extensive scientific literature for Oahu hydrogeology. This further adds to the BWS's concerns about the quality and defensibility of the modeling work to be produced using the GMEP. The GMEP states that valley fill sediments are generally fine grained in paragraph 4 of GMEP Section 3.1. This statement contradicts Hunt (1996) and Oki (2005), who instead state that the valley fill sediments include materials from boulder to sand size (page B26 of Hunt, 1996) and "fine-grain particles to boulders" (page 15 of Oki, 2005). This paragraph fails to explain that there are large differences in weathering and hydraulic properties between younger and older valley fill alluvium and that measurements of valley-fill hydraulic conductivity range from 50 feet/day (ft/d) to less than 1 ft/d (Table 1 of Hunt, 1996).

In the same vein, the discussion of saprolite in paragraph 4 of Section 3.1 makes no mention that weathering beneath streams and other locations is highly variable and leads to wide ranges in hydraulic properties. Hunt (1996) and Oki (2005) describe the wide range of saprolite thickness and Oki (2005) cites a study that shows saprolite hydraulic conductivity values range from 283 ft/d to less than 1 ft/d.

Paragraph 9 in Section 3.1 presents such a limited discussion of changes in groundwater levels and flow direction due to pumping that it should be either expanded or deleted. There are more data sets for changes in groundwater levels and possible flow direction than the May 2006 observations. Important examples are the May 2015 and November 2016 USGS data sets, both of which show different flow directions than the 2006 data set. BWS requests that the GMEP describe in detail all available data about groundwater levels and flow directions, not solely an apparently arbitrarily chosen subset of the available data.

Paragraph 10 in Section 3.1 introduces the question of uncertainty in understanding groundwater flow directions because of surveying errors and the relatively small magnitude hydraulic gradients. It does not mention other sources of uncertainty, such as measurement frequency and times, pumping rates and times, and the effects of existing and planned monitoring well locations on discerning groundwater flow directions. This paragraph should be expanded to explain how each of these types of uncertainty will be assessed and how the proposed new monitoring wells will affect these uncertainties.

The discussion of groundwater levels in Section 3.2 of the GMEP is inappropriately limited because it does not discuss observations from all readily available synoptic water level surveys made in the area. This section primarily describes a very limited set of groundwater levels both temporarily and spatially, at Red Hill monitoring wells from the 2006 pumping test and provides no information to support its statements about observed groundwater gradients. This section lacks any discussion of the groundwater gradients observed during the USGS May 2015 water level study. For example, the USGS May 2015 water level study revealed that groundwater levels at Halawa Shaft were about 4 feet lower than the levels at the Red Hill monitoring wells during the period of steady pumping, were still lower than Red Hill monitoring well levels when Halawa Shaft ceased pumping, and became much larger when Halawa Shaft's pumping rate was increased nearly twofold. Furthermore, there is no discussion of water levels and gradients from the USGS November 2016 synoptic water level study. The study was in part conducted by some of the Navy's modeling team and so they should have ready access to this data.

Exclusion of readily available, relevant data from the GMEP is a grave concern because the omitted data provide valuable insights into the groundwater flow direction from Red Hill across Halawa Valley to Halawa Shaft. The BWS recommends that the GMEP discuss all the groundwater level information so that: 1) the Navy's modeling team use all available data appropriately to develop their CSM and numerical models; and, 2) to prevent an appearance of cherry-picking of the available data.

The second and third paragraphs of GMEP Section 3.2 discuss the apparent effects of pumping at Red Hill Shaft on groundwater levels and flow direction during the May 2006 study. However, there is no discussion about whether the observed changes in groundwater levels were appropriate (or not) based on the distance from the Red Hill Shaft. The word "conversely" in the third paragraph is unsupported interpretation and should be deleted because there is no explanation of the competing mechanisms. For example, is the water level change (drawdown) at the Halawa Deep Monitoring Well explained simply by its much greater distance from Red Hill Shaft than the Red Hill monitoring wells? BWS is concerned that the GMEP's discussion minimizes the importance of the distance-drawdown relationship and so presents a premature conclusion that could have deleterious influences on the CSM and the groundwater models. Another example that raises concern is the lack of discussion whether barometric influences had been recorded and removed from the 2006 data set. The BWS recommends that the Regulatory Agencies direct the Navy to provide an appropriate analysis and discussion of the data from the 2006 test in this section. We also note that:

1) The 2006 pump test results indicate any reduction to pumping in Red Hill Shaft due to future contamination would also change groundwater flow directions and rates in Halawa and Moanalua Valleys; and,
2) It is highly likely that the groundwater levels observed at the Halawa Deep Monitoring Well during the 2006 test are not indicative of changes in levels near Halawa Shaft given the differences in their locations relative to Red Hill and along the valley axis.

The last paragraph of GMEP Section 3.2 gives an inadequate description of the groundwater levels and changes observed during the May 2015 pumping study by the USGS. Groundwater levels from that study revealed that the level at Halawa Shaft is consistently several feet lower than the groundwater levels at Red Hill. The text in this paragraph ignores the observed differences in groundwater levels and instead mentions only that Halawa Shaft pumping rate changes "may" have caused changes in levels at Red Hill monitoring wells. The BWS wishes to know why the Navy team has not yet analyzed these important data to better understand groundwater levels across Halawa Valley, especially if they indicate a hydraulic connection between North Halawa Valley and South Halawa Valley. The BWS recommends that the Regulatory Agencies direct the Navy to analyze the USGS data for use in developing the CSM and groundwater models.

Like Section 3.1, Section 3.2 lacks sufficient discussion of the uncertainties in hydrogeologic data for the GMEP study area. This section should be expanded to describe the magnitude and importance of uncertainties caused by errors in groundwater level measurements from surveying and pumping influences, lack of sufficient measurement locations in Halawa and Moanalua Valleys, errors in hydraulic gradients estimated using the current Red Hill monitoring well network, and the very small magnitudes in hydraulic gradients. This section should be revised to discuss the importance of the new monitoring wells to be installed in both North and South Halawa Valleys and any expected reduction in some of these uncertainties.

The BWS observed that Section 3.3 of the GMEP is not only inadequate in its presentation of hydraulic properties, but also misleading and factually incorrect. Lines 32 through 34 in GMEP Section 3.3.1 state that "**In the Facility vicinity**, the arithmetic mean, geometric mean, and median values of hydraulic conductivity for dike-free volcanic rocks were respectively 1700, 900, and 1200 feet/day (DON 2007)" (emphasis added). This is a factually incorrect statement because these hydraulic conductivity values are from a hydrogeologic study of central Maui (see DON, 2007 and Rotzoll and El Kadi, 2007), not of the Red Hill vicinity. Factual errors like these add to our concerns about the defensibility of the models that will be based on the GMEP as written. The GMEP should be revised to provide descriptions of the hydrogeology of Moanalua and Halawa Valleys using all relevant information from the Navy's own studies and the scientific literature.

Lines 31 and 32 of Section 3.3.1 state that horizontal hydraulic conductivity is "orders of magnitude" larger than vertical hydraulic conductivity. This statement may be true, but is potentially misleading speculation because it doesn't explain what is known and what is estimated. Available estimates of horizontal to vertical anisotropy are inherently difficult to determine, and, in this case, are solely based on flow models. According to Hunt (1996), "Anisotropy has not been measured directly in Hawaiian lavas." Hunt (1996) listed anisotropy rates of 5:1 to 200:1 for models of regional flow on Maui and Oahu. This sentence should be revised to explain that horizontal-vertical anisotropy has not been measured and estimates are highly uncertain because they are based on models only. This suggests that anisotropy may be scale-dependent, and so for contaminant transport, it may depend on plume length. The Navy should state what they believe is a reasonable range of anisotropy ratios for hydraulic conductivity in the site area based on the Site-specific literature.

We note that the longitudinal to transverse horizontal anisotropy used by Oki (2005) is a calibration parameter for a regional scale model of groundwater flow. Since there are no measurements available, horizontal anisotropy in hydraulic conductivity should be examined in the CSM and numerical models as a highly uncertain and scale-dependent parameter.

Section 3.3 in the GMEP is titled "Hydraulic Properties", yet it makes no mention of storage properties or porosity for the different hydrogeologic units. Porosity and storage properties are hydraulic properties and should be discussed in this section. This section should also describe the ranges of values and uncertainties in hydraulic properties if the GMEP is following ASTM guidelines as stated in Section 1. The following Section 3.4 shows estimated storage property and porosity values from the 2007 groundwater model calibration (Rotzoll and El Kadi, 2007) but there is no discussion of storage properties and porosity from other studies, even though this information is readily available in Hunt (1996) and others. It is important to understand that the storage values yielded by the flow calibration in Rotzoll and El Kadi (2007) required imposing different arbitrary offsets of over a foot to the simulated water levels; consequently, the storage properties from this model calibration can only be very rough estimates that should be recalculated using new survey elevations for tops of well casings. Given the importance of groundwater dynamics and the focus on fate and transport modeling and potential future remedial actions, the GMEP should be revised to carry out transient calibrations so that estimates of storage properties can be improved.

Section 3.3 should be expanded to describe collection and analysis of field data from the proposed Westbay monitoring wells to generate point estimates of hydraulic properties. The text should also describe the challenges in upscaling the point estimates and the approach that the Navy will use to do the upscaling.

The discussion of valley fill sediments and their three-dimensional geometry in GMEP Section 3.3.3 is vague and confusing. Some of the statements can be applied to other valleys on Oahu, but not to Halawa or Moanalua Valleys. The text refers only to the Navy's 2007 model (DON, 20070; Rotzoll and El Kadi, 2007), and there is no mention of the information specific to Halawa and Moanalua Valleys provided in Wentworth (1942), Izuka (1992), and Hunt (1996). The BWS is concerned that the GMEP is overly focused on the Navy's 2007 model and should be revised to cite the important findings from other studies. The text in this section describes one of the scenario's modeled in Oki (2005) but does not: 1) discuss other scenarios such as the no valley fill scenario; and 2) does not mention that the calibration to observed water levels in the Halawa and Moanalua Valleys showed no significant difference if valley fill was present in North Halawa Valley or not.

BWS is very concerned about the choice of modeling scenarios given the lack of evidence for valley fill sediments below the water table in Halawa and Moanalua Valleys. The second sentence of the last paragraph in GMEP Section 3.3.3 mentions the "somewhat uncertain" control of these sediments on groundwater flow. At present there is no evidence that: 1) valley fill sediments are even present below the water table between Red Hill and our water supplies; and, 2) the sediment properties are sufficiently uniform in value to impede groundwater contaminants from migrating through them. Is the Navy backing away from their commitment (as stated in previous GWMWG meetings) to make conservative assumptions in the absence of compelling evidence? Until such evidence is available, BWS asks the Regulatory Agencies to direct the Navy to use a "no valley fill" scenario as the primary scenario for assessing the risk to Halawa Shaft during the interim and final modeling instead of simulating a "range of scenarios" that are based only on speculation. The Regulatory Agencies should apply the precautionary principal and require risk estimates based on the available evidence and conservative assumptions.

Another important concern for BWS is that the GMEP Section 3.4 titled "Previous Groundwater Flow Modeling" describes only the DON (2007) model. Why didn't the

GMEP include a review of Oki (1998), Oki (2005), and other models of the Pearl Harbor area? A detailed review of Oki (2005), which was calibrated to groundwater levels, spring discharge, and salinity values, would provide the best available understanding of groundwater flow rates and directions through the end of the year 2000. The BWS would like the Regulatory Agencies to require the GMEP to describe other models, especially if those models, like some of the Oki (2005) results, do not support the Navy's 2007 model results.

The last two paragraphs of GMEP Section 3.4 describe some of the findings from the DON (2007) transport modeling. As this section is about groundwater flow models, these paragraphs should be moved to Section 3.6 or Section 5. The second paragraph should clarify what is meant by "sufficient quantities" of LNAPL. There should be a discussion of the accuracy and validity of the DON (2007) transport model given that petroleum hydrocarbons have been consistently detected at Red Hill Shaft.

GMEP Section 3.5 "Evaluation of Fuel Sources" is vague and does not present or analyze site-specific data. Examples include the following:

- The GMEP introduces the important concept of effective solubility but provides no Site-specific data for locations and times when concentrations of fuel constituents (e.g., total petroleum hydrocarbons for diesel range organics and naphthalenes) were near to or exceeded their effective solubilities at Red Hill monitoring wells.
- The GMEP states "BTEX [benzene, toluene, ethylbenzene, xylenes] in JP-5 and JP-8 is rapidly degraded by natural attenuation mechanisms, such as by the metabolism of microbes naturally present in the groundwater under both aerobic and anaerobic conditions". While this may be true at many fuel contamination sites, where is the evidence from the Red Hill site?
- The statement "Methane is an indicator compound for active anaerobic biodegradation of petroleum" is potentially misleading because anaerobes can produce methane by degrading materials other than petroleum fuels.
- The GMEP states "A depletion of dissolved oxygen (DO) near these wells along with relatively high DO levels in groundwater outside the source area further indicates that active biodegradation is occurring in the area." This statement may be true for other fuel contamination sites, but is it relevant to the Red Hill site? There are no Site-specific data presented to support or contradict this statement.
- The BWS questions the omission of relevant, Site-specific, observed data. The BWS requests that the Regulatory Agencies require the Navy to update the GMEP to include a discussion of the observed detections of petroleum hydrocarbons at the Red Hill Shaft.

- The GMEP mentions that more groundwater chemistry data have been collected since the 2007 model report, but there is no explanation of how those data will be used to build, calibrate, and apply the flow and transport models, either interim or final. This explanation should be added so that the Regulatory Agencies and stakeholders can review and comment.

Section 3.6 in the GMEP discusses the reactive transport simulations from DON (2007). A key assumption is that "Natural attenuation rates were computed from degradation stoichiometry and rates calibrated for another NAPL degradation study at Hill Air Force Base, Utah (Guoping et al. 1999)." The 2007 model did not examine the sensitivity of its predictions to those degradation rates, which were estimated for a porous medium that has longer residence times than those expected for the Ko'olau basalt. Why should the degradation rates for a sedimentary aquifer be appropriate for a high-permeability basalt aquifer? Also, this section does not explain how the observed detections of petroleum hydrocarbons at Red Hill Shaft compare with the DON (2007) modeling results.

Section 4 Comments

Section 4 begins with the sentence "Substantial effort has already been expended to develop and apply the 2007 groundwater models, which are based on time-tested models and accurately reflected the observed data" (DON 2007). This statement should be either justified or deleted because it contains unjustified interpretation. How is it possible that the model's predictions of groundwater flow, which had to be adjusted using different but arbitrary values, "accurately reflected the observed data"? Please clarify what is meant by "time-tested models"? Is the GMEP referring to models of groundwater flow that include the Red Hill area? Is the GMEP referring to modeling codes? If the latter, then why does the GMEP propose to use a solute transport code that has very few users and a very short track record?

While the MODFLOW-USG flow code is USGS approved and has been tested by a wide user base, the MODFLOW-USG (beta) transport code proposed in GMEP Section 4.1 is neither documented nor tested by the larger groundwater modeling community. As far as we are aware, the transport code has a very small user base, primarily Dr. Sorab Panday. The BWS has grave concerns about using an unverified and untested transport code on the high-risk Red Hill site. Accordingly, we request that the Navy provide stakeholders with the following:

- the source code for the transport code,
- a hard copy of the code documentation,

- communication from the authors of GMS to confirm whether or not the transport code is fully functional in GMS,
- communication from the USGS regarding their involvement with the development or verification of the transport code,
- communication from the USGS regarding their plans for developing a transport code for MODFLOW-USG,
- electronic copies of reports that have used Dr. Panday's transport code, and,
- a list of references that provide third-party verification of the accuracy of the MODFLOW-USG transport code.

According to Dr. Panday, the MODFLOW-USG transport code has been applied to only two projects, for which there are no final reports available for review, and the source code and documentation were to be made available in September 2017. As of this writing, neither the Navy nor Dr. Panday have made the source code and documentation available. BWS is not comfortable with the Navy's planned use of Dr. Panday's MODFLOW-USG transport code.

The MODFLOW-USG flow code is a part of the USGS MODFLOW 6 modeling codes. It is our understanding that MODFLOW 6 will have a USGS-developed solute transport code that will be compatible with MODFLOW-USG but that will be separate from the transport code that Dr. Panday is proposing to use for Red Hill modeling. The BWS recommends that the Regulatory Agencies direct the Navy to adopt flow and transport modeling codes that have been well tested and well documented.

In Section 4.2, the GMEP states that "The GWMWG also requested use of the MODFLOW Seawater Intrusion 2 (SWI2) Package (Bakker et al. 2013) to simulate a sharp interface at the bottom of the freshwater model domain". This is not correct. USGS and BWS SMEs recommended that the full freshwater-seawater dynamics be included and suggested SWI2 as a compromise.

We have previously agreed with Dr. Delwyn Oki that the Navy' s modeling team should use variable density flow and transport to give the most defensible estimate of the seawater-freshwater interface. Of the two methods to represent the seawater-freshwater interface proposed in GMEP Section 4.2, BWS believes setting a no-flow boundary along the inferred interface location will likely cause fewer problems than setting equivalent freshwater heads to simulate the interface. However, the location of the seawater-freshwater interface is not well defined and has changed significantly since the early 1900s. The locations of the no-flow boundary condition cells will likely be very different in a flow simulation for the 1950s compared to a flow simulation for the 1990s or for the present-day. How will the Navy estimate the location of the present-day interface? Will this interface be appropriate for simulations of future scenarios?

BWS requests that the Navy modeling team demonstrate that their use of no-flow boundary cells to represent the seawater-freshwater interface gives acceptable results by comparing their results against those from companion models that either directly simulate variable density flow (e.g., using the USGS SEAWAT code) or approximate the governing physics (e.g., using the SWI2 package).

Section 4.2.1 text states that general head boundary condition cells (GHBs) will be used to define the northwest lateral boundary along Waimalu Valley and no-flow boundary condition cells will be used to define the southeast lateral boundary along Kalihi Valley. Figure 6 shows that GHBs are to be used for the southeast lateral boundary. Please clarify what boundary condition(s) will be used for the southeast lateral boundary.

Please clarify how will the boundary head and conductance values (i.e., GHB parameter values) will be determined for all GHB cells. During the fourth meeting of the GWMWG, USGS and BWS SMEs explained that the boundary heads will vary with location, depth, applied pumping and recharge stresses, and time. Dr. Panday stated that they would use the calibration and sensitivity analyses to estimate the GHB parameter values; however, the USGS and BWS SMEs pointed out that there are likely many hundreds to thousands of such GHB cells. Please clarify how the Navy plans to calculate defensible estimates of the values for hydraulic head and conductance needed for so many GHB cells.

The Section 4.2.1 text states that specified-flux boundary condition cells will be placed along the northeast boundary. How will the total flux rate from those cells compare in quantity to the flux from areal recharge?

Section 4.2.2 explains: "Based on technical discussions and feedback from prior GWMWG meetings, the Navy has decided that the refined model will have five layers, unless the updated CSM and additional information indicate a different approach is needed for the layers." The choice of layering is the Navy's decision, but feedback from BWS SMEs was limited to questions that have yet to be answered. Beginning in the June 2017 GWMWG meeting, BWS SMEs asked to review the locations of calibration targets, pumping intervals, and contaminant sources and then decide on layering so that the layering accurately reflects the screen intervals of monitoring wells or pumping intervals and sources. The BWS would like the GMEP to explain how the choice of layering is defensible for target well screens, pumping intervals, and solute sources.

The proposed model layering seems inadequate for simulating transport or even particle tracks. Layer 2 is proposed to be 30 feet thick whereas LNAPL penetration and subsequent solute transport may be shallower in vertical extent than 30 feet. We note that the Navy has yet to install monitoring well screens that intercept groundwater deeper than 10 or 15 feet below the water table (barring monitoring wells OWDFMW01 and RHMW01), so there are no data for groundwater concentrations at those depths. The choice of a 30-foot layer could serve to dilute simulated contaminant concentrations in the numerical transport model and thereby underestimate impacts at receptor wells.

Section 4.2.2 describes the assignment of valley fill to the model grid in this way: "However, where valley fill sediment is distinguishable as a distinct geologic unit underlying stream valleys above the coastal plain, the hydraulic properties of Layer 1 will be assigned parameter values consistent with valley fill sediment reported by investigations prior to Izuka (2016) [sic]." The lack of clarity and the apparent intent of this text to include valley fill sediments in the saturated zone regardless of the lack of direct evidence further heightens our often-stated concerns. Valley fill sediments have been mapped at ground surface in Halawa and Moanalua Valleys, as shown by Izuka et al. (2016), Sherrod et al. (2007), and Stearns (1939). There are no data that demonstrate valley fill sediments are present at and far below the water table in Halawa and Moanalua Valleys. DON (2007) simply assumed the valley fill sediments were present in the saturated zone and they did not test how their assumption affected their model results. The BWS would like the Regulatory Agencies to instruct the Navy to revise the GMEP to simulate no valley fill sediments in the saturated zone as the most likely scenario unless and until there are compelling data for including scenarios with valley fill.

In Section 4.2.3, the GMEP proposes minimum model cell dimensions of 10 meters by 10 meters within the "area of interest". Please clarify what is the extent of the "area of interest" and the water supplies that are encompassed within it. Please also clarify whether the Navy modeling team has estimated the Courant number for the different cell sizes and determined whether it will (will not) force very small time steps for the transport modeling.

Section 4.3 is titled "Water Balance" but it lacks any discussion of the conceptual inflows, outflows, and changes in storage for the model domain. The first paragraph discusses instead the water balance error for the DON (2007) flow model, which is not the only water balance of concern. This section should be expanded to describe and provide estimates of all the conceptual inflows, outflows, and changes in storage for the modeled area. This simple calculation should be included in the CSM report and used as a check on the simulated water balances in the groundwater model reports for the interim and final flow models. Given the importance of changes over time, water balances should be calculated for different time periods and then used as comparators to evaluate whether simulated inflows, outflows, and storage changes from "averaged" stress models fall within the range of conceptual water balances.

Section 4.3.1 presents an incomplete summary of available recharge estimates. This section makes no mention of the recharge rates estimated for the Pearl Harbor area, including the Navy's past and proposed model domains, from 1900 to the end of 2000 by Oki (2005). Calculated using the Shade and Nichols (1996) approach, the Oki (2005) recharge rates provide useful insight into how rates vary across the domain over time. This section should be expanded to discuss these recharge rates, those in Engott et al. (2015), and contrast and compare them.

Section 4.3.1 lacks any explanation of how recharge will be estimated for the interim and final models. Since recharge and hydraulic conductivity are correlated, it is recommended practice to determine fluxes, such as recharge rates, and then proceed to flow calibration, because calibrating both recharge and hydraulic conductivity leads to an infinite number of non-unique solutions (see ASTM, 1996). The GMEP should clearly state how recharge is to be estimated for the time periods to be modeled.

Section 4.3.1 discusses how the Navy modeling team may revise recharge estimates made by Engott et al. (2015), a USGS publication. Given the lack of discussion about important studies of Oahu hydrogeology and modeling found in the GMEP (see above), the BWS is concerned that the revisions to recharge will not be defensible. For example, the GMEP states that the "low permeability of the thick saprolitic soil overlying the Red Hill ridge was not accounted for by the USGS study". BWS finds such a statement to contradict readily available information about the soils on Red Hill, which are described as "well-drained" Manana Series or thinly covered or exposed bedrock in the on-line Hawaii soils atlas produced by the University of Hawaii (http://gis.ctahr.hawaii.edu/SoilAtlas#map). This statement also belies the copious volumes of water seeping into the Red Hill tunnels that are collected and treated by the oil-water collection system as well as the image of a worker standing knee deep in water while excavating a Red Hill tunnel in the Navy's recent historical video (see minute 1:40 in https://www.youtube.com/watch?v=0Bx81rD206A&feature=youtu.be). Seepage into the tunnels is readily apparent to those who have toured the RHBFSF. Even so, Navy consultants repeatedly mentioned a "RCRA [Resource Conservation and Recovery Act] cap" over Red Hill ridge and needing to make infiltrometer measurements at the surface during the past GWMWG meetings. Why would the GMEP propose to measure infiltration at the surface (at two locations) when there is ample water flowing into deep vadose zone tunnels that could readily provide measurements of recharge instead?

Recharge through the fuel-contaminated Red Hill vadose zone is a significant contamination source for our drinking water. The BWS recommends that the Regulatory Agencies direct the Navy to adopt conservative approaches for representing key hydrologic processes in their conceptual and numerical models.

Section 4.4 "Model Parameters" consists of a single paragraph and gives no details regarding how the model will be parameterized. This is not acceptable for a groundwater modeling work plan. This section should be expanded to discuss how it follows the ASTM guidelines that the GMEP states it follows. For example, it should discuss the ranges in values for the hydraulic properties that will tested during the calibration process, per ASTM (1996):

> *"For each calibration parameter, identify the range of possible realistic values that parameter may have in the physical hydrogeologic system. Establish these ranges before beginning any simulations."*

This section should also describe the errors associated with each of the parameters. Per ASTM (1996), "*For each such datum, include the error bars associated with the measurement or estimate*," where datum refers to the calibration targets.

GMEP Section 4.5 "Calibration" lacks critical components and contradicts the calibration approach described by the Navy contractor at the fourth GWMWG meeting in September 2017. This section should be rewritten to clearly explain:

1. How the interim model will be calibrated,
2. How the final model will be calibrated, and
3. Describe all the calibration targets and their associated error bars (as per ASTM, 1996).

The BWS has identified the following non-exhaustive list of problems with the proposed calibration approach:

- No discussion of how hydraulic parameters will be represented or be quantitatively constrained during calibration.
- There is no explanation about how hydraulic properties will be varied spatially nor how this will be constrained to the conceptual model or available data.
- There is mention of calibrating recharge along with hydraulic properties. As noted above, this is well known to be a poor modeling practice given the non-uniqueness stemming from the correlation between recharge and hydraulic properties (see ASTM, 1996 and our comments above).
- The section lacks any discussion about criteria for field data that will be used for adjusting recharge.
- Will the simulated root mean square error (RMSE) be scaled to the range in observed heads and compared to the industry-standard normalized error of 10% or less?

- There is no discussion of how the major data gaps will be addressed during calibration.
- There is no discussion of how the calibration will be tested or verified using the various synoptic water level data sets and the 2016 pump test data. It is particularly important that the Navy modeling team conduct transient calibration simulations so that the models can evaluate the estimates of storage properties and the boundary condition choices and parameterization (see our comments above). As we stated in our recent letter to you about the proposed steady-state calibration approach presented in the GWMWG meeting of September 2017 (Lau, 2017), "*Moreover, the task of developing calibration targets for a single steady-state calibration will introduce even more uncertainty into the model results than using transient calibration data. For instance, error bars for monitoring well water level and springs flow calibration targets for a steady-state model will be much larger than the error bars associated with the point measurements for the same monitoring well water levels and spring flows for a transient model.*"
- This section mentions that pump test results will be incorporated into the calibrated model yet there is no discussion of which pump test results, their limitations and error bars, and how the results will be used in the calibration process.
- The section states that groundwater levels, spring discharges, and the magnitudes and directions of observed hydraulic gradients will be calibration targets. However, it does not provide any descriptions or the calibration data and their associated error bars, which is not acceptable modeling practice. According to ASTM (1996), this should be done before the calibration begins.

The BWS requests that the Regulatory Agencies direct the Navy to provide a complete description of the calibration process such that it addresses our concerns noted above and follows ASTM guidelines and that the GWMWG review and provide comments on this approach before the calibration begins. We are very concerned that the interim model results will be severely compromised because they will be based on an incomplete and poorly documented calibration that does not follow industry guidelines.

Section 4.6 of the GMEP is inconsistent with itself and statements made by the Navy contractor during the fourth GWMWG meeting. On page 4-10, the GMEP states that the Navy modeling team will do both sensitivity and uncertainty analyses, but on page 4-11 it states they will do sensitivity analysis and that they will consider doing an uncertainty analysis. During the fourth GWMWG meeting, Dr. Panday stated that they will consider doing an uncertainty analysis for the final model but not the interim model. BWS's primary concern is the range of outcomes (e.g., particle tracks) from Red Hill contamination at potential receptors given the uncertainty in important properties and processes caused by lack of data and incorrect characterization.

During the 3rd GWMWG meeting, BWS asked if the Navy modeling team will conduct an uncertainty analysis to quantify risk given the lack of data to characterize the site hydrogeology, the very flat hydraulic gradients, and the potentially important transience of the system. BWS was pleased to hear that Dr. Sorab Panday state that such an analysis would be valuable and would be conducted. Dr. Panday and the BWS discussed that the null-space Monte Carlo method is a proven approach for quantifying uncertainty, is documented in several USGS reports, and is often implemented using the PEST software (Watermark Numerical Computing, 2016).

BWS is concerned that the sensitivity analysis briefly discussed by the Navy's modeling team will not provide an estimate of risk to groundwater that is as defensible as the risk estimate from an uncertainty analysis. During the September 22nd meeting, BWS stated that the uncertainty analysis that includes the null-space Monte Carlo method is one of the most defensible ways to quantify the range of possible groundwater flow paths from Red Hill tanks to potential receptors given the uncertainty and data gaps in important hydrogeologic variables and processes. Such an uncertainty analysis would describe the range of possible flow paths using "spaghetti" plots of particle tracks from Red Hill generated from the various calibrated flow models. These plots could then be used to estimate the risk to Oahu drinking water. The Navy's modeling team did not explain how their sensitivity analyses would be done, but the BWS believes that sensitivity analyses will describe variations in a single "spaghetti strand" and, unlike the uncertainty analysis, will not estimate the risk by evaluating all the strands.

The RHBFSF stores an enormous amount of fuel above Oahu's sole-source aquifer and near to one of the BWS's most important drinking water supply points. As such, the continuing deterioration of the steel and concrete in the Red Hill tanks poses a risk to the drinking water supply for much of Oahu. Understanding this risk should be a necessary first step before the AOC Parties choose a TUA. Therefore, the interim model should estimate the risk by capturing likely outcomes of contaminant migration from Red Hill given the data gaps and uncertainties. The same is true of the final model.

Section 4.6 should be expanded to discuss how the Navy modeling team will investigate the effects of uncertainty in parameters that don't affect flow predictions but do affect solute transport predictions. For example, there is no mention of how they will evaluate the uncertainty in porosity and layer thickness that can affect predictive transport results but to which flow model predictions will be relatively insensitive.

Section 5 Comments

Section 5 is limited to describing the solute transport modeling for the final model. It provides no information about the transport modeling for the interim model. This is one of many flaws that concern the BWS. Others include:

- Section text states "The previous CF&T [contaminant fate and transport] modeling study showed that both aerobic and anaerobic degradation are strong components of the geochemical groundwater system in the basal aquifer beneath the Facility (DON 2007)." Given that there are no site-specific data to show aerobic and anaerobic degradation, this statement is unsupported interpretation and should be deleted. DON (2007) study simply assumed rates from another site, a site that has a very different hydrogeologic environment and residence time.
- Dr. Panday's comments during the September 2017 GWMWG meeting indicated that he had not fully reviewed the GMEP. The BWS is concerned this entire GMEP section does not reflect the actual approach that will be used for the final model and we are concerned that there is no description of the approach for the interim model.
- It is not stated whether transport modeling will include Halawa Shaft and Moanalua Wells as potential receptors. These should be explicitly included as potential receptors.
- The proposed modeling lacks a defensible conceptual understanding of source behavior. For example, Section 5.4.5 states "Available data also show decreasing concentrations both over time and with distance from the tanks, which is likely attributable to ongoing natural attenuation. For example, concentrations of these constituents in monitoring wells RHMW01 and RHMW02 decreased steadily from 2005 to 2013." These observed changes in concentration may be almost entirely caused by changes in vadose zone loading (mass flux) to the aquifer and advection with little or no contribution from degradation. These statements are unjustified interpretation and should be removed.
- Section 5 lacks any discussion of the locations for LNAPL at the water table and the extents of these source areas. It lacks any discussion of what the expected residence times are for solutes within the source areas that have the right conditions to support degradation. Nor is there any discussion of the competing relationship between advection rates and degradation rates and how this will change with the amount of LNAPL released.
- No discussion is provided of the LNAPL volumes or masses to be simulated to estimate the risk to our drinking water supply. Given the large volume contained in each tank, the Regulatory Agencies should direct the Navy to evaluate a range

of release volumes that are larger than the roughly 30,000 gallons released in January 2014.

- The single paragraph about calibration of the transport model in Section 5.5 is too short to provide sufficient explanation about what will be done. This should be expanded to discuss the approach, the targets, their error bounds, and to explain how the calibration will or will not succeed given that the existing well network does not intercept actual flow paths with groundwater levels expected for upgradient and downgradient areas.

Overall, the BWS requests that the Regulatory Agencies direct the Navy to provide a clear description of how transport modeling will be conducted for both the interim and final models. The text in Section 5 is too incomplete to evaluate, raising yet another serious concern. The BWS is willing to provide more detailed technical evaluation of the actual transport modeling approaches to be used for both interim and final models when they are made available.

Thank you for the opportunity to comment. If you have any questions, please feel free to call Erwin Kawata at 808-748-5080.

Very truly yours,

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References

ASTM. 1996. ASTM Standard Guide D5981-96. Standard Guide for Calibrating a Ground-Water Flow Model Application.

Department of the Navy (DON). 2007. Red Hill Bulk Fuel Storage Facility Final Technical Report, Pearl Harbor, Hawaii. Prepared by TEC Inc., Honolulu, HI. Pearl Harbor, HI: Naval Facilities Engineering Command, Pacific. August.

Department of the Navy (DON). 2017. Groundwater Model Evaluation Plan, Investigation and Remediation of Releases and Groundwater Protection and Evaluation, Red Hill Bulk Fuel Storage Facility JOINT BASE PEARL HARBOR-HICKAM, O'AHU, HAWAI'I 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. September 8.

Engott, J. A., A. G. Johnson, M. Bassiouni, and S. K. Izuka. 2015. Spatially Distributed Groundwater Recharge for 2010 Land Cover Estimated Using a Water-Budget Model for the Island of O'ahu, Hawai'i. Scientific Investigations Report 2015–5010. Prepared in cooperation with the State of Hawai'i Commission on Water Resource Management and the City and County of Honolulu Board of Water Supply. U.S. Geological Survey.

Hunt Jr., C. D. 1996. Geohydrology of the Island of Oahu, Hawaii. Professional Paper 1412B. U.S. Geological Survey.

Izuka, S. K. 1992. Geology and Stream Infiltration of North Halawa Valley, Oahu, Hawaii. Water- Resources Investigations Report 91-4197. Prepared in cooperation with the State of Hawaii Department of Transportation. Honolulu: U.S. Geological Survey.

Izuka, S.K., Engott, J.A., Bassiouni, M., Johnson, A.G., Miller, L.D., Rotzoll, K., and Mair, A., 2016. Volcanic aquifers of Hawai'i—hydrogeology, water budgets, and conceptual models: U.S. Geological Survey Scientific Investigations Report 2015-5164, 158 p.

Oki, D. S. 1998. Geohydrology of the Central Oahu, Hawaii, Ground-Water Flow System and Numerical Simulation of the Effects of Additional Pumping. Water-Resources Investigations Report 97–4276. U.S. Geological Survey.

Oki, D. 2005. Numerical Simulation of the Effects of Low-Permeability Valley-Fill Barriers and the Redistribution of Ground-Water Withdrawals in the Pearl Harbor Area, Oahu, Hawaii. Scientific Investigations Report 2005-5253. U.S. Geological Survey.

Rotzoll, K., and A. I. El-Kadi. 2007. Numerical Ground-Water Flow Simulation for Red Hill Fuel Storage Facilities, NAVFAC Pacific, Oahu, Hawaii. [Appendix L in: Department of the Navy (2007), Red Hill Bulk Fuel Storage Facility Final Technical Report, Pearl Harbor, Hawaii; Prepared by TEC Inc. for Naval Facilities Engineering Command, Pacific]. Prepared for The Environmental Company (TEC). Honolulu, HI: University of Hawaii, Water Resources Research Center. August.

Shade, P. J., and W. D. Nichols. 1996. Water Budget and the Effects of Land-Use Changes on Ground-Water Recharge, Oahu, Hawaii. Professional Paper 1412C. U.S. Geological Survey.

Sherrod, D. R., J. M. Sinton, S. E. Watkins, and K. M. Brunt. 2007. Geologic Map of the State of Hawai'i. Open-File Report 2007-1089. U.S. Geological Survey.

Stearns, H. T. 1939. Geologic Map and Guide of the Island of Oahu, Hawaii. Bulletin 2. Prepared in cooperation with the Geological Survey. Honolulu: Hawaii (Terr.) Department of Public Lands, Division of Hydrography.

Wentworth, C.K. 1942. Geology and ground-water resources of the Moanalua-Halawa District, Hawai'i: Honolulu Board of Water Supply, Honolulu, Hawai'i, 156 p.