JOSH GREEN, M.D.
GOVERNOR OF HAWAI'I
KE KIA'ĀINA O KA MOKU'ĀINA 'O HAWAI'I

KENNETH S. FINK, MD, MGA, MPH
DIRECTOR OF HEALTH
KA LUNA HO'OKELE

STATE OF HAWAI'I
DEPARTMENT OF HEALTH
KA 'OIHANA OLAKINO
P. O. BOX 3378
HONOLULU, HI 96801-3378

In reply, please refer to:
File:

November 15, 2023

Rear Admiral Stephen Barnett
Commander, Navy Region Hawai'i
850 Ticonderoga Street, Suite 110
Joint Base Pear Harbor Hickam, Hawai'i 96860
[via email only: stephen.d.barnett.mil@us.navy.mil]

Dear Rear Admiral Barnett,

Subject: Red Hill Shaft Flow Optimization Study
Red Hill Bulk Fuel Storage Facility

The Hawai'i Department of Health (DOH) is in receipt of the U.S. Department of the Navy's (Navy's) September 19, 2023 *Final Report of Findings, Red Hill Shaft Flow Optimization Study,* hereinafter referred to as the "Final Report." Following our review of the Final Report, the DOH believes it does not provide sufficient evidence to support the assertion that a reduction in the average pumping rate of the Red Hill Shaft (RHS) granulated activated carbon (GAC) system will not result in harm to human health and/or the environment. Consequently, the DOH is disapproving the Final Report justifying the Navy's August 1, 2023 request to reduce operation of the RHS GAC system. However, the DOH recognizes the importance of conserving our natural resources and outlines a path forward to reduced pumping with increased monitoring and evaluation that may be implemented upon the DOH's approval, once defueling activities have been completed and the risk of catastrophic release from the facility is no longer present.

Review of the Flow Optimization Study

Following a precursory review of the draft August 17, 2023 *Report of Findings, RHS Flow Optimization Study*, the DOH had initially believed that the average pumping rate of the RHS GAC system could likely be reduced; however, after receiving the groundwater sampling data collected during the flow optimization study and conducting a thorough review of the Final Report, the DOH noted multiple areas of concern associated with the lines of evidence presented to support the Navy's request.

These concerns are briefly touched on below, with a more detailed review presented in the enclosed November 1, 2023 technical memo.

- As previously noted in the DOH's August 30, 2023 comments on the draft report, the DOH does not rely on modeling results that are inconsistent with actual site data and basic hydrogeologic principles for decision making. The flow optimization study conclusions are still primarily based on models, one of which the DOH has previously disapproved.
- The Final Report provides no analysis of the relationship between groundwater contaminant concentrations and the change in the average pumping rate of the RHS GAC system. Of particular concern are the significantly elevated total petroleum hydrocarbons as diesel fuel and total petroleum hydrocarbons as oil concentrations that occurred at RHMW04 and RHMW19 during the Flow Optimization Study test periods. In addition, the Navy changed the sample collection frequency in the middle of the study from weekly to monthly, which adds to the difficulty in determining whether the elevated concentrations may have been due to the natural fluctuation of contaminant concentrations at the site or are a result of the reduced average pumping rates.
- Vertical gradient data is included in the Final Report, but no evaluation was done as to how this data relates to the capture zone for the RHS. Consequently, it fails to inform as to whether there are any potential consequences associated reducing the average pumping rate of the RHS GAC system.
- Multiple water quality parameters were continuously measured; however, in many cases the loggers were temporarily removed and not returned to the previously installed depth. Consequently, these shifts in monitoring depths lead to uncertainty as to the source of observed changes in the water quality parameters.

As the DOH is unable to rely on the "direct" lines of evidence (i.e., the modeling), and the "indirect" lines of evidence as presented in the Final Report are ambiguous and do not provide sufficient information as to whether a reduction in the average pumping rate of the RHS GAC system will have an impact on contaminant migration, additional data collection and evaluation is necessary to identify any potential impacts a reduction in the average pumping rate may have. Therefore, a strict reduction of pumping is not approved at this time.

Path to Reduced Pumping
Once defueling activities have been completed and the risk of catastrophic release from the facility is no longer present, a reduction in the average pumping rate of the RHS GAC system accompanied with increased monitoring and evaluation is appropriate.

Because insufficient analysis was provided in the Final Report to show that no adverse impacts would result from reducing the pumping rate of the RHS GAC system, the DOH requires that any reduction in the pumping rate be accompanied by increased monitoring and evaluation. Prior to reducing the average pumping rate of the RHS GAC system to the requested 1.7 million gallons per day (mgd), a plan outlining the increased monitoring and evaluation shall be submitted to the DOH for review and approval. The plan shall include measures to ensure that potential migration of contaminants under the reduced average pumping rate is identified in a timely manner, how the data will be evaluated, and what actions will be taken if potential migration of contaminants is identified. This can potentially be accomplished through increased groundwater monitoring frequency; expedited turn-around-time for analytical results and data validation; collecting field volatile organic compound measurements from within the wells just above the water table; regular monitoring of water quality parameters and water levels; a timely evaluation and reporting of this data and evaluation; and immediately increase pumping as needed based on evaluated data. Submit a plan for this increased monitoring and evaluation for the DOH's review as soon as possible so that this plan may potentially be implemented soon after defueling is complete. Allow time for our regulatory review of the submission.

Should you have any questions regarding this letter, please contact Ms. Kelly Ann Lee, Red Hill Project Coordinator, at (808) 586-4226 or at kellyann.lee@doh.hawaii.gov.

Sincerely,

Kathleen Ho

KATHLEEN S. HO
Deputy Director for Environmental Health

Enclosure: "Review of the Department of the Navy's (Navy's) Proposal to reduce Red Hill Shaft (RHS) Pumping Rate," dated November 1, 2023

c: Ms. Claire Trombadore, U.S. Environmental Protection Agency [via email only]
Mr. Matthew Cohen, U.S. Environmental Protection Agency [via email only]
Mr. Joshua Stout, Navy Region Hawai'i [via email only]

JOSH GREEN, M.D.
GOVERNOR OF HAWAI'I
KE KIA'ĀINA O KA MOKU'ĀINA 'O HAWAI'I

KENNETH S. FINK, MD, MGA, MPH
DIRECTOR OF HEALTH
KA LUNA HO'OKELE

STATE OF HAWAII
DEPARTMENT OF HEALTH
KA 'OIHANA OLAKINO
P.O. BOX 3378
HONLULU, HAWAII 96801-3378

In reply, please refer to:
File: SDWB
FILE NAME.docx

November 1, 2023

TO: Lene Ichinotsubo, P.E. Acting Branch Chief
Solid and Hazardous Waste Branch

THROUGH: Gaudencio C. Lopez, P.E. Branch Chief *Gaudencio C. Lopez*
Drinking Water Branch

FROM: Robert Whittier, Geologist
Safe Drinking Water Branch

SUBJECT: Review of the Department of the Navy's (Navy's) Proposal to Reduce Red Hill Shaft (RHS) Pumping Rate

Introduction: These are my comments and recommendations after a review of *Final Report of Findings, Red Hill Shaft Flow Optimization Study, September 19, 2023* (Final Report). The Navy has requested permission from the Regulatory Agencies (RAs, i.e., U.S. Environmental Protection Agency, Hawaii Department of Health, and the Hawaii Commission on Water Resources Management) to reduce the RHS pumping rate currently set at 4.3 million gallons per day (mgd). This pumping rate was established in 2022 as part of the *Red Hill Shaft Recovery and Monitoring Plan*. The purpose was to remove contamination and create a contaminant capture zone in the vicinity of the RHS. The water currently being captured by the RHS is passed through large Granular Activated Carbon (GAC) vessels then discharged to South Halawa Stream. Under this arrangement the discharged water serves no beneficial use. The logic for continuing to pump the RHS would be if doing so will prevent future migration of contamination off-site. The potential for off-site contaminant migration is dependent on the mass and mobility of the remaining contamination, and the effectiveness that controls, such as pumping the RHS, have on contaminant containment.

To assess the utility of RHS pumping to immobilize or remove contamination, the Navy pursued multiple Lines of Evidence (LOE). The Navy conducted a series of tests, observing the effect that stepped pumping reductions had on multiple aquifer parameters. These LOEs include:

- Computer modeling including an analytical element model, forward particle tracking models based on water levels, and the best available groundwater flow model.
- Indirect LOEs:
    - Three-point groundwater gradient calculations,

- Vertical gradients in those wells with multi-level instrument ports and wells with multi-level screens,
- Continuous water level and water quality measurements collected using multi-parameter data loggers,
- Isotopes of water, and
- Organic contamination data.

Below is my assessment of how well the LOEs presented by the Navy to support the conclusion that reducing the RHS pumping rate will have no adverse impacts. Since the modeling is so critical to the Navy's conclusions, I will discuss it first.

Computer Modeling: The Final Report states the primary LOE indicating groundwater capture is forward particle tracking using a water level surface based on measured groundwater elevations, an Analytical Element Model, and the "Best Available" groundwater flow model. The Navy uses modeled particle track trajectories to support the conclusion that under most conditions the RHS will capture any contamination released from the underground storage tanks or the associated piping within the Red Hill Facility. Critical to modeling of the particle track trajectories is the estimated horizontal anisotropy in controlling the particle trajectory. The strength of the Navy's conclusions depends on how accurately the models replicate that actual flow conditions within the model domains. Much of modeling was done using the Navy's Best Available Groundwater Flow Model (BAGWFM) documented in a report to the RAs in May 2023 (NAVFAC, 2023). In the BAGWFM Report, the Navy uses chloride data in an attempt to validate the flow across the model boundaries. I will comment on both modeling issues.

Aquifer Anisotropy: The particle tracking and modeling conclusions depend heavily on a high longitudinal to transverse anisotropy. The estimated anisotropy values are significantly greater than those used by other models. For example, Oki (2005) used a horizontal anisotropy of 3:1 for his regional model of the Pearl Harbor area. A deviation from the established anisotropy needs to be sufficiently supported to be acceptable. Critical to this support is adhering to hydrologic assumptions or presenting why violating those assumptions doesn't significantly alter the resulting conclusions. The Navy does recognize that the methods used to estimate anisotropy assume a point pumping source and a homogeneous and spatially expansive aquifer; however, these conditions are not met at Red Hill. What was not provided was to what degree the violation of assumptions affects the computed anisotropy. From a qualitive perspective the impact of the assumption violations would be significant. The Red Hill Shaft Infiltration Gallery (RHS IG) is basically a 1,200-foot short circuit roughly down the axis of the Red Hill Ridge, providing a direct connection between multiple flow channels. It is not reasonable to expect the drawdowns induced by this long linear short circuit to be consistent with those formed by a point source. The impact of the large anisotropy on the particle track trajectories is evident in Final Report Figures 4-11a through 4-11c, and Figure 4-20b. Figures 4-11a through 4-11c test how anisotropies of 5.3, 10.4, and 15 respectively affect particle track trajectory. The differences in particle track trajectories show how sensitive the Groundwater Desktop Model is to anisotropy. Figure 4-20b compares the particle tracks simulated with Analytical Element Model and the BAGWFM with those generated by the Groundwater Desktop Model utility. Both the Analytical Element Model and the BAGWFM depend on a strong anisotropy. The measured groundwater gradient exerts a greater influence on Groundwater Desktop Model particle track trajectories. The approaches produce very different particle track trajectories. Anisotropy is a very important parameter and much more effort needs to be devoted to choosing the most representative value.

Red Hill Chlorides: In Section 4.4.6 of the BAGWFM Technical Memorandum (NAVFAC, 2023), the Navy attempts to address longstanding concerns expressed by DOH SMEs (e.g., Beckett et al., 2018; DOH, 2022) that the general chemistry of the groundwater beneath the Red Hill Facility is not consistent with the simulated down ridge groundwater flow trajectory. The observed general groundwater chemistry can be better explained using a conceptual model proposed by Mink (1980) where groundwater in the Honolulu Aquifer is deflected toward the Pearl Harbor Aquifer by the poorly permeable caprock. The Navy did a simplified chloride simulation using the BAGWFM (NAVFAC, 2023) by sequentially assigning a unit concentration of a generic solute at the Recharge, Dike Region, GHB Southeast, and bottom (midpoint of the freshwater/saltwater transition zone) boundaries. They then observed the contribution from each boundary to the Red Hill and Halawa Shafts. Once the relative contribution to the shafts from these boundaries was simulated, the resulting chloride concentration at the RHS was calculated using representative boundary chloride concentrations and the fraction of flow simulated from each boundary. The modeled chloride concentration for the RHS was compared to that measured in Table 4-8 of the BAGWFM report (NAVFAC, 2023). The modeled results appear to compare favorably with the average chloride concentrations leading the Navy to conclude there is no conflict between the observed groundwater chemistry and the modeled groundwater flow trajectories. The results in Table 4-8 are only valid if representative chloride concentrations were used at the model boundaries and that other factors not simulated don't significantly affect the computed chloride concentration at the RHS.

I reviewed the chloride chemistry at the BAGWFM boundaries and the methodology that the Navy used. Recharge and Dike Region Chloride uses the Chloride Mass Balance (CMB) approach which assumes the chloride is conservative; meaning chloride is not lost or altered during infiltration making the chloride concentration proportional to the ratio of rainfall minus runoff to recharge. The Navy selected an estimated average rainfall chloride concentration of 11 mg/L. This seems to be a reasonable value based on literature and recent studies (Brennis et al., 2023). The CMB method used to estimate the chloride concentration in the recharge is also reasonable and consistent with what I had proposed in a presentation during the Water

Resources Research Center Spring Seminar Series (Whittier and Thomas, 2022).

To perform a general assessment how appropriate the Navy's selected chloride concentrations are, I performed some independent analysis. Using the USGS published recharge coverage for Oahu (Engott, 2017) and the Navy's CMB equation used in Section 4.4.6 of the BAGWFM Report (shown below), I mapped the recharge chloride concentration for the Moanalua/Red Hill/Halawa area.

$$Chloride_{Recharge}\left[\frac{mg}{l}\right] = 11\left[\frac{mg}{l}\right] * \frac{\left(rainfall\left[\frac{in}{yr}\right] - runoff\left[\frac{in}{yr}\right]\right)}{recharge\left[\frac{in}{yr}\right]}$$

The result is shown graphically in Figure 1 and the discussion below evaluates the chloride concentrations that Navy computed (Table 4-8 of the BAGWFM Report). For the Rainfall Recharge boundary, the Navy only considered recharge within the Red Hill Facility. This is incorrect because recharge upslope from the Red Hill Facility, but within the model domain boundary, should also be considered. The chloride concentration in most of the upslope recharge is too low to support the Navy computed Rainfall Recharge chloride concentration of 45 mg/L. Considering the Dike Region boundary, the contributing area is between the northeast model boundary and inland boundary of the Honolulu and Pearl Harbor aquifers. This area is enclosed with the blue bordered polygon in Figure 1. Nearly all the chloride in this area has a concentration less than 20 mg/L, which is significantly less than 30 mg/L used by the Navy for this boundary condition. No rationale is given in the BAGWFM Report as to why a chloride concentration of 40 mg/L was chosen for the GHB Southeast Boundary. The chloride concentration for this boundary can be estimated using available groundwater data. Figure 1 shows that the USGS NAWQA Study (Hunt, 2004) sampled two wells near the GHB Southeast Boundary, the Kamehameha School B Well with a chloride concentration of 41.1 mg/L and the Kalihi Pump Station with a chloride concentration of 80.9 mg/L. Using the available data, the most appropriate chloride concentration for the GHB Southeast Boundary would be 60 mg/L, an average of the two wells' chloride concentrations.

The fourth boundary was the bottom boundary where the chloride concentration at the mid-point of the Freshwater/saltwater transition zone was assumed. The Navy places a significant importance to this boundary stating that "The simulation demonstrates that chloride concentrations in either shaft can be dominated by a relatively small proportion (0.6 to 1.2%) of source water attributed to upconing from the freshwater/salter interface… ." Using the chloride concentrations and the flow weighting given in the BAGWFM Table 4-8, 75 percent of the chloride mass for the Navy's analysis comes from the freshwater/saltwater interface boundary. This is highly problematic because as the chloride concentration increases the density of the groundwater also increases. Without this chloride concentration to density relationship Hawaii's freshwater lenses would not exist. A density dependent model such as SEAWAT or SUTRA is required to do this assessment. Using MODFLOW and a specified chloride concentration of 9,500 mg/L (one-half of the seawater chloride concentration) at the bottom boundary will greatly over-estimate the chloride contribution to the RHS. Basically, the Navy's conclusion that chloride analysis "adds confidence to the model calibration" is incorrect because the only way to get the modeled chloride concentration to agree with the measured chloride concentration at the RHS is to ignore the fundamental fluid dynamics of density dependent flow. If an appropriate chloride concentration was used there would be a significant chloride deficit that would have to be made up at one of the other boundaries. The chloride concentrations at the Recharge and Dike Region boundaries can be estimated with reasonable confidence using chloride mass balance and are likely less than what the Navy stated. Therefore, the required chloride mass must be coming from the GHB Southeast Boundary, consistent with the hypothesis of Mink (1980) and at odds with the groundwater flow trajectories simulated by the BAGWFM. This analysis shows that the flow trajectories produced by the BAGWFM fall well short of accounting for the measured chloride concentrations at the RHS. The ultimate purpose of the numerical modeling is to inform as to the migration trajectory of dissolved contamination. The current BAGWFM fails to adequately simulate chloride contribution to the RHS and in its current form is not a reliable basis for making RHS Flow Optimization decisions.

The numerical modeling fails to provide sufficient evidence that reducing the RHS pumping rate will not result in harm. No analysis was provided into how violating the assumptions critical to the anisotropy analysis will affect the resulting calculations. The Navy's attempt to address the long-standing RA concerns that the simulated flow trajectories are inconsistent with the observed groundwater chemistry fail to address those concerns. Rather, when basic hydrologic principles are applied there is a significant chloride deficit that must be compensated for at one of the model boundaries. Regardless of which boundary the increased flow occurs at, the currently modeled groundwater flow trajectories are in error making it necessary to evaluate the indirect LOEs to determine if the Navy has properly supported their contention that a reduction in the RHS pumping rate will not result in adverse consequences.

Three-Point Gradient Calculations: The Final Report was dismissive of this LOE, stating that groundwater elevation uncertainties and the very low gradient made three-point gradient vector calculations challenging. No evidence is provided to show that the relative groundwater elevations measured have errors of a magnitude to make this LOE unusable. A review of Figure 4-10 (graphic showing the results of the three-point gradient calculations) fails to show any coherent regional flow trajectory. In many cases the computed flow vector points away from the RHS IG. The reason could be measurement errors or that there is no coherent regional flow trajectory in the shallow groundwater beneath the Red Hill Facility. For the purposes of this study the three-point gradient calculations fail to support a RHS capture zone nor does this LOE show any coherent flow trajectory response to pumping rate steps. My assessment is the three-point gradient analysis does not inform as to the consequences of reducing RHS pumping.

Vertical Gradients: While vertical gradient data were presented, no evaluation was done as to how this data helps to define a capture zone for the RHS. Most of the vertical gradients were downward, with little change in response to changes in pumping rates. The prevalence of downward gradients would tend to indicate lack of capture since the RHS IG is a water table feature and either no or upward vertical gradients would be expected. The measurement of vertical gradients fails to inform as to the consequences of reducing RHS pumping.

Continuous Water Quality Measurements: The Final Report states that multiple water quality parameters were continuously measured. Time series graphs were provided as well as maps showing where the greatest changes were over the sampling period. The Final Report further states that the wells showing the greatest change in water quality parameter values were wells near the RHS and in the vicinity of the Red Hill Ridge. There is no discussion as to how these data might be used to delineate a RHS capture zone or show that there will be no adverse consequences if the RHS pumping rate is reduced. Further complicating any interpretation of the water quality parameter data is that in many cases when the loggers were temporarily removed, they were not returned to the previously installed depth. The pre- and post-installation depths varied by several feet in multiple wells (e.g., RHMW05, RHMW06, RHP03, and RHP04C). Shifts in monitoring depths results in uncertainty as to whether the RHS pumping, or the depth change caused the observed changes in the water quality parameters. As with the previous LOEs the water quality parameter monitoring fails to demonstrate that no harm can come from a reduction in RHS pumping.

Isotopic Composition of Water: In Item 8 of the Response to Comments – DOH section of the Final Report, the Navy addressed concerns about the insufficient analysis of the isotope data by stating "...the samples were collected as requested by DOH." This response does not sufficiently address our concerns. The Final Report states that there was no observed correlation between isotopic composition and sample elevation as had been observed on Maui and Hawaii Island. What the Navy misses was that the correlation found on Maui and Hawaii Island by Scholl et al. (1995, and 2002) and Fackrell et al. (2020) was a correlation between isotopic composition and rainfall, not groundwater. The isotopic composition of groundwater would be an integration of recharge along the flow path (see Fackrell et al., 2020). If the flow trajectories indicated by the particle tracking are valid, the isotopic composition of the Red Hill Monitoring Network groundwater should be closely constrained due to integration of the isotopic chemistry along the mountain to coastal flow trajectory. However, there is a wide variation in isotopic values nearly as great as for the entire southern-leeward slope of the Koolau Mountain and reported by the USGS (Hunt, 2004). So rather than having poor diagnostic value as the Navy assumes, the isotope data collected by this study fail to support the groundwater flow trajectories presented by the Navy. What the isotope data show in Final Report Figure 4-17 is an isotopically heterogeneous aquifer beneath the Red Hill Facility indicating groundwater that was recharged under very different conditions. If groundwater followed the flow trajectories postulated by the Navy, the isotopic composition should be much more uniform due to mixing along the mountain-to-coastal flow path.

Organic Contamination Data:

TPH-o from the May 2021 Release: In Section 4.5.5 the Navy states that "TPH-o analytical data collected after the May 2021 release are considered. These data provide a line of evidence that anisotropy of the aquifer if high enough to create flow conditions generally along dip rather than in the direction of the hydraulic gradients." The Navy proposes that the TPH-o results shows a plume migrating from the spill site near Tanks 18 through 20 down the axis of the Red Hill Ridge then being captured by the Red Hill Shaft Pumps. Table 4-10 in the Final Report lists wells considered, date of first detection, and computed average groundwater velocity. Charts 4-2 through 4-7 show the TPH-o traces for RHMW03, RHMW02, RHMW01R, RHMW05, RHMW2254-01, and the RHS pre-chlorination spigot. There are some serious problems with this analysis. First, the spill occurred over 100 ft above the water table so unsaturated zone transport needs to be considered when estimating groundwater flow velocities. Some of the wells used for this analysis should be removed due to insufficient data. RHMW01R has no indication of TPH-o that exceeds background except for an isolated result in November, well after the stated first detection at the RHS pre-chlorination spigot. The first May 2021 post-release sample collected at RHMW05 was on September 29, 2021, again well after the plume had become evident at the RHS pre-chlorination spigot. Since no sample was taken earlier, it is inappropriate to compute a groundwater velocity using RHMW05 data. RHMW2254-01 has no detections above background. This leaves us with RHMW03, RHMW02, and the RHS pre-chlorination spigot to evaluate the plume migration characteristics. In Figure 2a and b, I plotted the TPH-o data versus time. Figure 2a plots the TPH-o data for RHMW03 and RHMW02. Figure 2b plots the TPH-o data for RHMW03 and the RHS pre-chlorination spigot. For both graphs an empirical best fit line was generated. This simple exercise shows there is no temporal offset in the plumes at these wells with the plume traces peaking at approximately the same time at all three locations. Contrary to the Navy's conclusions, the TPH-o data following the May 2021 release do not support a saturated zone plume migration down the axis of the Red Hill Ridge and don't provide physical evidence supporting the very high horizontal anisotropy that is needed for the particle track analysis to indicate capture.

TPH-d prior and during the Flow Optimization Testing: While organic contamination data were collected during the Flow Optimization Study there is very little discussion or evaluation of the results. The Final Report instead compares the analytical results to the DOH Environmental Action Levels and does not evaluate potential trends or increased concentrations. DOH downloaded the data from the Environmental Data Management System (EDMS) and plotted the TPH-d results for a period from May 2022 through early August 2023. We observed that several wells showed elevated TPH-d detections during the Flow Optimization Test period. Figures 3a through 3c graph the TPH-d data for the wells that showed elevated concentrations. The wells are segregated into three groups, wells in the Red Hill Ridge line (3a), southeast region of the Red Hill Facility (3b), and the northwest regions of the Red Hill Facility (3c). Elevated TPH-d concentrations were most prevalent in the northwest region wells. Prior to any change in RHS pumping rates, the potential relationship between groundwater contaminants and the various pumping rates needs to be further evaluated, or else additional monitoring will be needed to identify potential contaminant migration during a reduction in the average pumping rate.

Conclusions: The previously discussed indirect LOEs have failed to inform as to whether continued pumping of the Red Hill Shaft is necessary to prevent spread of current or future contamination. The remaining LOEs are dependent on the numerical modeling. As DOH's August 30, 2023 (DOH, 2023) letter states we will not accept the results of a model that has not been appropriately validated. What remains is no actionable analysis upon which DOH can base a decision on.

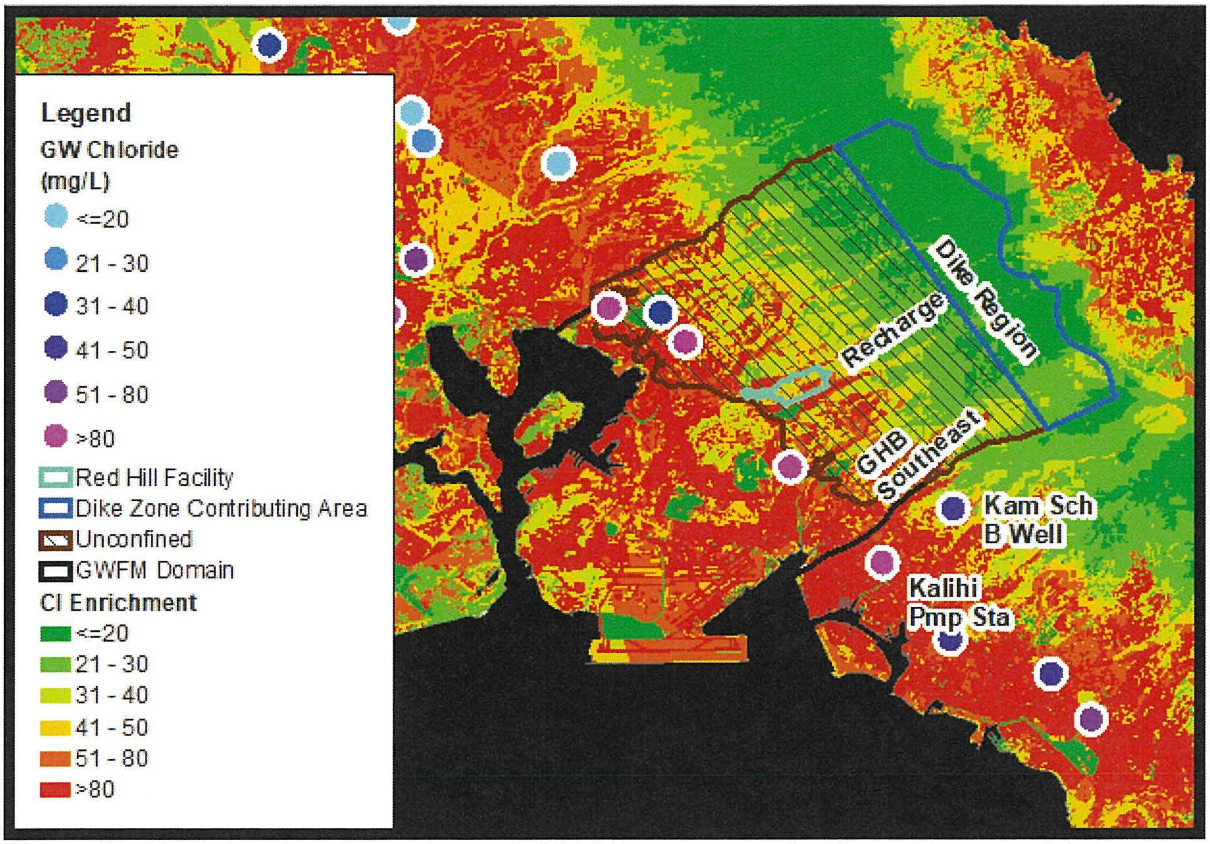

Figure 1. Map showing the estimated chloride concentration in recharge and the measured groundwater chloride concentrations.

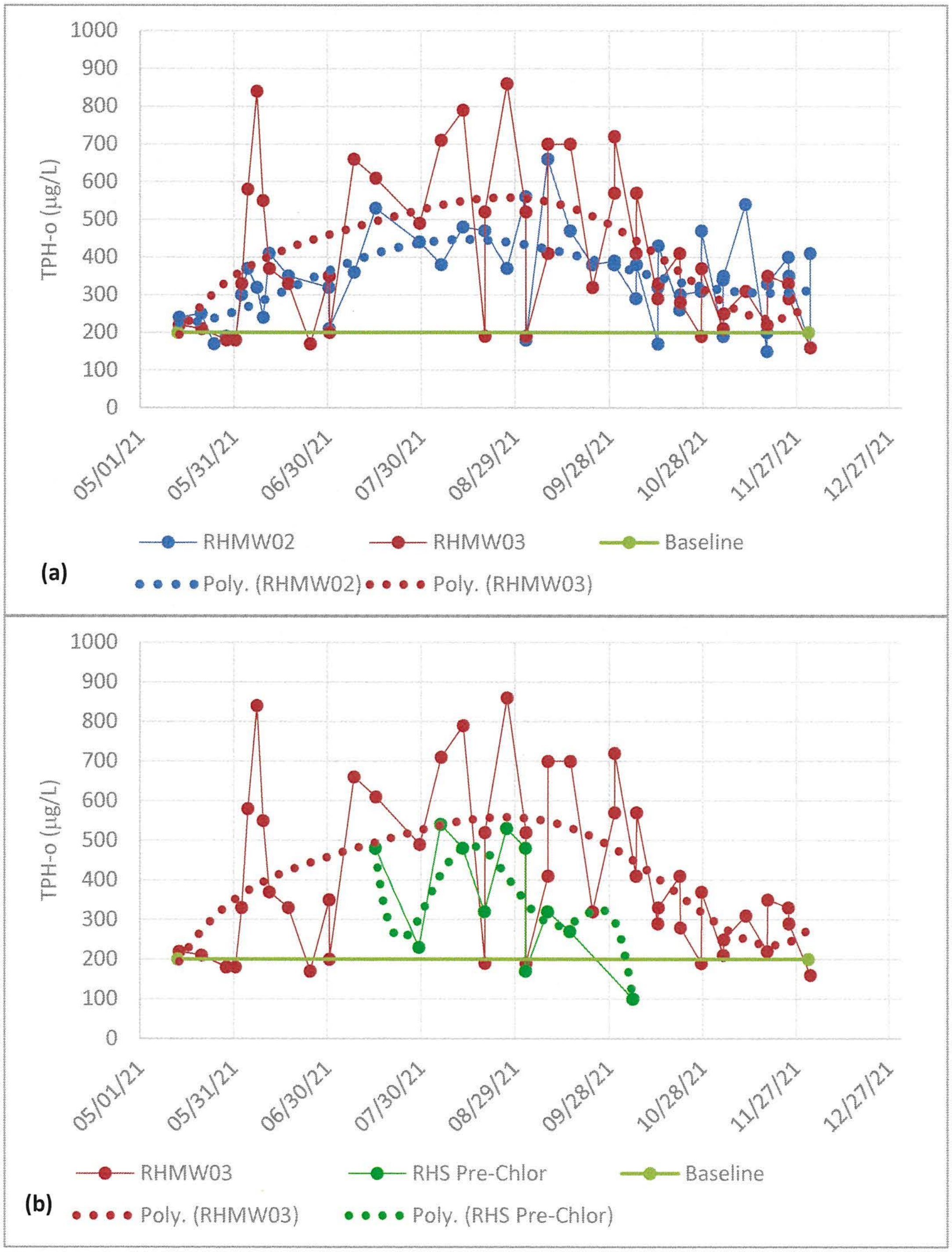

Figure 2. Graphs of the TPH-o concentrations in RHMW03 versus RHMW02 (a) and RHMW03 and RHS Pro-Chlorination Spigot show that at all three locations the plume is temporally synchronized. The empirical best fit lines shows that the plumes at all three wells peak at nearly the same time indicating that some process other than saturated zone transport down the axis of the Red Hill Ridge.

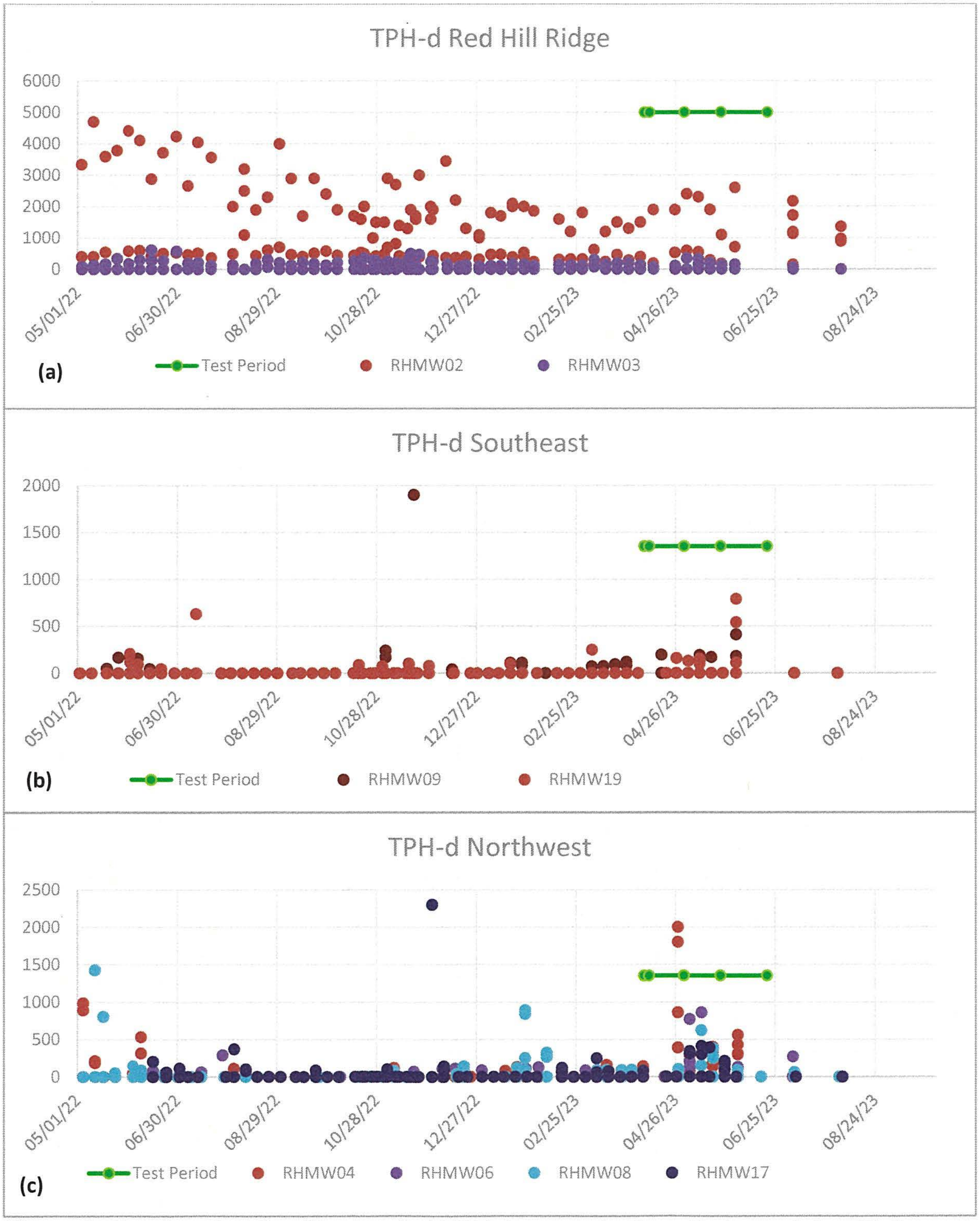

Figure 3. Graphs of wells with elevated TPH-d concentrations that correlate with the flow optimization study test periods.

REFERENCES

Beckett, G., Thomas, D., Tonkin, M., and Whittier, R. 2018. Comments on TUA Deliverables Red Hill Bulk Fuel Storage Area – Oahu, Hawaii. Presented at the Red Hill Groundwater Modeling Working Group Meeting, August 14, 2018

Brennis, T., Lautze, L, Whittier, W., Torri, G., and Thomas, D. 2023. Understanding the origins of and influences on precipitation major ion chemistry on the Island of O'ahu, Hawai'i. Environmental Monitoring and Assessment. 195. Pages not yet assigned

DOH. 2022. Attachment B – HDOH SME Deficiencies Identified, Red Hill Groundwater Modeling Report dated March 25, 2020. Attachment to EPA and DOH Letter to CAPT Gordie Meyer, CEC, USN, Subject: Disapproval of the Groundwater Flow Model Report. Dated – March 17, 2022

DOH. 2023. Letter to Rear Admiral Stephen Barnett, Commander, Navy Region Hawai'i, Subject: Initial Comments on Draft Report of Findings, Red Hill Shaft Flow Optimization Study. Dated August 30, 2023

Engott, J.A., Johnson, A.G., Bassiouni, Maoya, Izuka, S.K., and Rotzoll, Kolja, 2017, Spatially distributed groundwater recharge for 2010 land cover estimated using a water-budget model for the Island of O'ahu, Hawai'i (ver. 2.0, December 2017): U.S. Geological Survey Scientific Investigations Report 2015–5010, 49 p., https://doi.org/10.3133/ sir20155010.

EPA and DOH. Letter to Rear Admiral Stephen Barnett, Commander, Navy Region Hawai'i, Subject: Limited Utility of the 2023 Best Available (Groundwater Flow) Model. Dated September 29, 2023

Hunt, C.D. 2004. Ground-Water Quality and its Relation to Land Use on Oahu, Hawaii, 2000-01 – U.S. Geological Survey Water-Resources Investigations Report 03-4305.

Fackrell, J.K., Glenn, C.R., Thomas, D., Whittier, R., and Popp, B.N. 2020. Stable isotopes of precipitation and groundwater provide new insight into groundwater recharge and flow in a structurally complex hydrogeologic system: West Hawai'i, USA. Hydrogeology Journal. 28. 1191-1208

Mink, J.F. 1980. State of the Groundwater Resources of Southern Oahu. Board of Water Supply City and County of Honolulu

Mink, J.F. and Lau, S.L. 1990. Aquifer identification and classification for Oahu: Groundwater protection strategy for Hawaii – WRRC Technical Report No. 179. Water Resources Research Center, University of Hawaii at Manoa.

NAVFAC. 2022. Red Hill Shaft Flow Optimization Work Plan Red Hill Blk Fuel Storage Facility – JBPHH, O'ahu, Hawai'i. September 2022 – Flow optimization Work Plan

NAVFAC. 2023. Groundwater Flow Model Technical Memorandum – Red Hill Bulk Fuel Storage Facility JBPHH, O'ahu, Hawai'i. May 17, 2023

Scholl, M.A., Ingebritsen, S.E., Janik, C.J., and Kauahikaua, J.P. 1995. An Isotope Hydrology Study of the Kilauea Volcano Area, Hawaii, U.S. Geological Survey Water-Resources Investigations Report 95-4213

Scholl, M.A., Gingerich, S.B., and Tribble, G.W. 2002. The influence of microclimates and fog on stable isotope signatures used in interpretation of regional hydrology: East Maui, Hawaii. Journal of Hydrology. 264. 170-184

Whittier, R. and Thomas, D. 2022. Groundwater Flow in the Moanalua/Red Hill/Halawa Region: Evaluating Rates, Directions and Contamination Risks – Presentation at the Water Resources Research Center, Spring Seminar Series 2022. March 18, 2022