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APR 22 2019

Captain Marc Delao
Regional Engineer
Navy Region Hawaii
850 Ticonderoga St. STE 110
Joint Base Pearl Harbor Hickam, Hawaii 96860

Re: Comments on Environmental Work and Development of the Contaminant Fate and Transport Model for the Red Hill Administrative Order on Consent (“AOC”) Statement of Work (“SOW”)

Dear Captain Delao:

The U.S. Environmental Protection Agency (“EPA”) and Hawaii Department of Health (“DOH”), collectively the “Regulatory Agencies”, are providing comments on several key issues for deliverables under development by the U.S. Department of the Navy (“Navy”) and Defense Logistics Agency (“DLA”) and its contractors to satisfy the requirements for Sections 6 and 7 of the SOW for the Red Hill Administrative Order on Consent (“AOC”). The Navy and DLA have made substantial progress in the evaluation of available data, acquisition of new data, and development of a groundwater flow model as a precursor to fate and transport analyses. Recent updates from the Navy and technical meetings on March 4 and March 13-14, 2019 regarding groundwater flow and pending fate and transport modeling efforts have been productive. A contaminant fate and transport model that carefully considers different potential release scenarios will lead to the development of appropriately protective release response plans.

To be useful, models – whether conceptual or numerical representations of groundwater flow and contaminant fate and transport – must incorporate site and area conditions to reasonably explain or simulate observed data, such as hydraulic responses to stresses or the patterns of detection of contaminants following releases. The Navy’s groundwater data is of generally good quality, but at the present time is relatively sparse. Given the highly complex subsurface conditions and a low density of monitoring wells at the Red Hill underground tank farm, the Regulatory Agencies will conservatively interpret data to ensure protection of human health and the environment. Although we agree with much of the Navy’s interpretations, we continue to believe that the relatively sparse data available at present can also support the following interpretations:

1. Fuel-related detections reported in distal groundwater monitoring wells are potentially associated with releases from the tank farm;
2. Persistent, elevated concentrations of petroleum related contaminants in groundwater and soil vapor at the tank farm are consistent with the presence of a residual fuel source in the formation; and
3. Some fraction of the fuel released in 2014 may have reached groundwater, with the remainder retained as residual in the vadose zone and subject to natural attenuation processes.

The Regulatory Agencies received the Navy's request dated March 6, 2019 for a response regarding the lines of evidence presented by the Navy at the February 21, 2019 technical working group meeting. Taken individually, the Navy has produced work that can support the lines of evidence presented, but other interpretations are also able to explain certain aspects of the observed data. The Regulatory Agencies are concerned that some of the Navy's interpretations on the topics detailed below may lead to conclusions that are not at the present time adequately supported or sufficiently conservative.

Topics of Concern:

1. Total Petroleum Hydrocarbons ("TPH") and TPH Related Analyte Detections: At Red Hill, TPH is often the most frequently detected group of compounds and provides interpretive utility. The analytic data set was prepared by certified labs using appropriate and accepted procedures, and, with some exceptions, the reported values are considered valid. TPH is an indication of petroleum impacts in groundwater, and as discussed in DOH guidance documents (HDOH, 2012¹, HDOH 2012c², HDOH 2016³), the risk posed by dissolved-phase petroleum in groundwater can be informed by the range of TPH in addition to individual analytes such as benzene and naphthalene. While the Regulatory Agencies acknowledge that variance in the detection of TPH arises from many factors, including analytical method and differences between laboratories, the variance alone does not negate the value of the data and the pattern of repeated detections. Lab precision in TPH quantification does not imply that TPH detections are false positives: rather, there are other potential explanations for the observed distributions and behavior of TPH.

¹ **HDOH, 2012.** Hawai'i Department of Health, Office of Hazard Evaluation and Emergency Response. Field Investigation of the Chemistry and Toxicity of TPH in Petroleum Vapors: Implications for Potential Vapor Intrusion Hazards. Website URL: <http://eha-web.doh.hawaii.gov/eha-cma/documents/4c0ca6c1-0715-4e0d-811b-33debe220e31>. Local Copy (11.3mb). 2012

² **HDOH, 2012c.** Hawai'i Department of Health, Office of Hazard Evaluation and Emergency Response. Additional Notes on HDOH report Field Investigation of the Chemistry and Toxicity of TPH in Petroleum Vapors. Website URL: [http://www.hawaiidoh.org/tgm-guidance/TPH%20Soil%20Gas%20Report%20\(HDOH%20August%202012\).pdf](http://www.hawaiidoh.org/tgm-guidance/TPH%20Soil%20Gas%20Report%20(HDOH%20August%202012).pdf). Local Copy (13.8mb). August 2012

³ **HDOH, 2016.** Hawai'i Department of Health, Office of Hazard Evaluation and Emergency Response. Technical Guidance Manual for the Implementation of the Hawaii State Contingency Plan, Section 9.3 Petroleum Contaminated Sites. Website URL: <http://hawaiidoh.org/tgm.aspx>. 2016

2. Non-water Table Wells: The Regulatory Agencies concur that there are several wells that, due to their construction and screened interval, are likely not representative of water table conditions. Those wells are, however, reflective of the overall local aquifer system and some exhibit analyte and biodegradation data that are of interpretive value. The Regulatory Agencies believe that all data locations should be considered.
3. 2014 Release Impact to Groundwater: Although the data do not show widespread increases in contaminant levels in groundwater after the 2014 release, the Regulatory Agencies believe there is evidence to suggest that a portion of the 2014 JP8 release may have reached groundwater. First, vapor data indicate possible transport to the northwest outside of the source zone monitoring array. Second, the detection behavior of TPH-diesel and naphthalene at RHMW02 suggests that either dissolved-phase entrainment of petroleum or fuel-related migration to the water table may have occurred near this well. Available data show that the 2014 release did not cause reliable increases in petroleum detections at Red Hill Shaft.
4. Light Non-Aqueous Phase Liquid (“LNAPL”) Presence: Persistent detections of TPH and individual fuel constituents in groundwater are typically interpreted to result from the presence of an LNAPL source. Due to the frequency of elevated detections in RHMW01, RHMW02, and RHMW03, along with the occurrence of occasional detections in distal wells, the Regulatory Agencies conclude it is reasonable to assume that residual LNAPL is present in the subsurface from past releases. Furthermore, despite consensus on the anticipated dilution rates caused at Red Hill Shaft, trace levels of petroleum compounds have been detected in approximately 12% of the samples collected there.⁴ The Regulatory Agencies interpret this information as implying that Red Hill Shaft is a likely receptor, and that some LNAPL mass from the facility may be the cause of those detections. For the Red Hill groundwater system, dissolved-phase fuel impacts are not expected to travel further than approximately 200-ft from the LNAPL source mass, suggesting a relative distance of LNAPL distribution away from the tank farm. This 200-foot estimate is based on Red Hill characteristics reported by the Navy⁵ and is consistent with plume dimension studies.⁶ However, dissolved phase impacts have been detected further than 200 feet from the tank farm, thus atypical transport conditions, such as fast-track transport features (open voids, lava tubes), may also contribute to the detections observed at Red Hill Shaft.

The Navy’s contaminant fate and transport model should recognize the interpretative value and magnitude of the distal detection data along with other indicators of residual contamination (for example, dissolved oxygen depletion), and the presence of an LNAPL mass distribution in the formation that would result in, or contribute to, observed groundwater impact patterns. The Navy should also include risk estimates for scenarios

⁴ NAVFAC. March 2019 Fourth Quarter 2018 Quarterly Groundwater Monitoring Report, Red Hill Bulk Fuel Storage Facility, Joint Base Pearl Harbor- Hickam, O’ahu, Hawai’i, see Table 1-4

⁵ NAVFAC. 2018. Conceptual Site Model, 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

⁶ Rice, D.W., R.D. Grose, J.C. Michaelsen, B.P. Doohar, D.H. MacQueen, S.J. Cullen, W.E. Kastenberg, L.G. Everett, M.A. Marino, 1995. California leaking underground fuel tank (LUFT) historical case analyses. Lawrence Livermore National Laboratory (LLNL). UCRLAR-122207. November.

where vadose transport to groundwater is rapid, and those scenarios should consider petroleum detections reported at distal monitoring locations. The Navy's contaminant fate and transport model should also reflect the effects of cumulative assimilative capacity over time.

5. Electron Acceptor Depletion: To assess whether electron acceptors are depleted requires an understanding of typical ambient concentrations for these species in Hawaiian groundwater. The Navy has concluded that electron acceptors at some monitoring wells are not depleted by determining that concentrations are within the range indicated by a University of Hawaii and U.S. Geological Survey⁷ data set for Oahu that includes wells ranging from pristine to significantly contaminated. Based on a comparison with pristine background concentrations of various electron acceptors, the majority of the Red Hill monitoring network, including RHMW04, shows some level of biodegradation activity which may be attributable, in part, to the tank farm.
6. Potential Contaminant Transport Pathways Remain Uncharacterized: Current Navy presentations discount the possibility of groundwater flow from the Red Hill Ridge to the northwest. The stated rationale is that groundwater flows from areas of highest recharge to coastal areas or submarine discharge. However, it would be more technically correct to state that groundwater flows from areas of high hydraulic potential to areas of low hydraulic potential. Mink (1980)⁸ recognized that the Red Hill side of Halawa Valley has a higher hydraulic potential than the Halawa side of Halawa Valley. Contours of measured groundwater elevations prepared by the Navy⁹ and shown on the attached figures support Mink's hypothesis because they show very little gradient going down the axis of the Red Hill Ridge and a well-defined gradient to the northwest of the underground tank farms. Under certain conditions, particularly when Red Hill Shaft is not pumping, flow from under the upper tank farm to the northwest may occur given what is currently known about saprolite extent and groundwater use. Given the importance of this issue to the DOH Source Water Protection Program, DOH intends to provide additional technical information on this subject in a separate letter.

The Regulatory Agencies are primarily concerned about the potential risks associated with future fuel releases. The Navy's conclusions regarding the topics listed above are not uniquely or exclusively supported by the evidence presented and may ultimately lead to release response actions that underestimate the risk posed by future releases. Given the existing uncertainties and complexities of the site, the Regulatory Agencies specifically request that the Navy bound transport and risk estimates in the models to include scenarios that appropriately recognize the

⁷ Hunt, C.D. 2004. Ground-Water Quality and its Relation to Land Use on Oahu, 2000-01, U.S. Geological Survey Water-Resources Investigation Report 03-4305. 67 p.

⁸ Mink, J.F. 1980. The State of the Groundwater Resources of Southern Oahu. A Report to the Honolulu Board of Water Supply. 83 p.

⁹ NAVFAC. 2018. Conceptual Site Model, 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, Figures 6-8 and 6-12

alternate explanations covered in this letter. We acknowledge the significant effort undertaken by the Navy and look forward to the progress anticipated over the next several months.

Please contact us if you have any questions or concerns.

Sincerely,



Omer Shalev
Project Coordinator
EPA Region 9 Land Division



Roxanne Kwan
Interim Project Coordinator
DOH Solid and Hazardous Waste Branch

Enclosures: Attachment 1: Navy Lines of Evidence
Attachment 2: Groundwater elevations with contours

cc: Mr. Mark Manfredi, Navy (via email)
Ms. Tracy-Joy Saguibo, Navy (via email)
Mr. Cory Waki, Navy (via email)

Summary and Conclusions for Independent Lines of Evidence for Navy's Groundwater Chemistry Analysis

This document summarizes the 22 independent lines of evidence (presented by the Navy during the February 21, 2019 AOC Technical Working Group Meeting [webinar]) on interpretation of groundwater chemistry as it is related to 1) evidence of LNAPL in outlying wells, 2) evidence of impacts to Red Hill Shaft, and 3) evidence of groundwater impacts due to the 2014 release. Each primary line of evidence is also supported by multiple secondary lines of evidence. Unlike many contaminated sites, there are not significant concentrations of chemicals in monitoring wells. Rather, there are only extremely low levels that push the capabilities of most labs that need to be evaluated with caution. There are very few (if any) sites where such emphasis is put on such low-level concentrations.

Groundwater Chemistry as a Function of LNAPL Extent

- No conclusive evidence of measurable LNAPL in Red Hill wells.
- The presence of LNAPL near wells would exhibit both an organic and inorganic footprint (as seen relative to RHMW02).
- The Navy recognizes there is an LNAPL impact in groundwater upgradient of RHMW02 that occurred prior to the 2014 fuel release
- The presence of an LNAPL source in groundwater near a well would result in a continuing impact (chemical signature) to a well rather than random, sporadic, low-level detects.
- This chemical signature would exhibit the following:
 - An organic chemical signature consistent with the fuel type (e.g., jet fuel) and representative of dissolution of the LNAPL source over time (function of Raoult's Law) as well as weathering.
 - An inorganic chemical signature demonstrating biodegradation (e.g., low DO).
- Wells farther away from an LNAPL source would still see reduced concentrations of chemicals based on the factors mentioned above. The chemical signature would be significantly influenced by relative biodegradation of chemical constituents in the dissolved-phase plume (e.g., benzene would degrade relatively quickly as compared to heavier hydrocarbons).
 - Even in this case, it is highly unlikely that the chemical signature would result in random sporadic detections.

Summary of Key Issues

There are major issues with data quality and physical conditions in outlying wells including RHS that indicate no apparent impact from Red Hill Facility operations as follows:

- Lab dependency
 - frequency and locations regardless of concentration
 - Naphthalenes and PAHs in general
 - - variability depending on method
 - TPH
- Oxic environment
- Reducing conditions (ORP < 0 mV) are not present
- Methane not detected
- TICs and nonCOPCs are not remarkable as would be expected from a fuel release

Summary of Primary and Secondary Lines of Evidence for Red Hill Groundwater Chemistry – Navy Evaluation

1. No evidence of nearby LNAPL in outlying wells

Primary LOE:

Secondary LOEs:

1a. Naphthalene (by itself) not good indicator of presence of LNAPL

- i. Sporadic detections
- ii. Very low detection limits susceptible to interferences/artifacts and inherently more variable
- iii. Detections do not often coincide with 1- and 2-methylnaphthalene or TPH detections

1b. Electron acceptors not depleted

- i. Oxidic conditions present

1c. Metabolic byproducts not detected

- i. Methane non-detect
- ii. Ferrous iron most commonly non-detect

1d. No consistent coinciding detections of COPCs and nonCOPCs with naphthalene

- i. BTEX not detected in most outlying wells
- ii. NonCOPCs where detected, detected infrequently – more indicative of sampling/lab artifacts
- iii. NonCOPC detections in outlying wells mainly compounds not associated with fuel
- iv. NonCOPCs that can be present in fuels detected infrequently in outlying wells

1e. TPH should be assessed in context of other COPCs and nonCOPCs

- i. Detections often did not coincide with detections of other COPCs
- ii. TPH a parameter defined by the method used
- iii. Results can include hydrocarbons, metabolites/polar compounds, and anything present detectable by the method
- iv. Absolute values should be interpreted with caution
- v. A detection is not a direct indication of hydrocarbons in GW

1f. TICs not good indicator of presence of LNAPL

- i. TIC identification and concentrations cannot be confirmed w/o comparison to known standard
- ii. Majority of detections not associated with fuel
- iii. Hydrocarbon detections not indicative of a fuel release

1g. Lead scavengers not detected

- i. EPA recommend evaluation of Pb scavengers
- ii. 1,2-DCA used in motor gasoline (not aviation gasoline). Detections of 1,2-DCA in RHMW08 likely from either fumigants or PVC impurity rather than motor gasoline.
- ii. Based on dissolved lead analyses, no evidence of a leaded fuel release

1a. No evidence of impact to other outlying wells from 2014 release:

1h. Continued sporadic BTEX detections with no apparent increase in detection frequency after 2014 fuel release

1i. Continued sporadic naphthalene detections with no apparent increase in detection frequency after 2014 fuel release

- i. Apparent decrease in detection frequency in outlying wells after Q4 2012 to Q3 2014 when CalsciencE/Eurofins stopped detecting naphthalene

2. No evidence of LNAPL nearby Red Hill Shaft

Primary LOE:

Secondary LOEs:

2a. Naphthalene (by itself) not a good indicator of presence of LNAPL near Red Hill Shaft

- i. Sporadic detections
- ii. Very low detection limits susceptible to interferences/artifacts and inherently more variable
- iii. Detections do not often coincide with 1- and 2-methylnaphthalene or TPH detections

2b. Electron acceptors not depleted at Red Hill Shaft

- i. Oxidic conditions present
- ii. Nitrate not depleted
- iii. Sulfate not depleted
- iv. Reducing conditions not present

2c. Metabolic byproducts not detected in Red Hill Shaft

- i. Methane non-detect since Q4 2016
- ii. Ferrous iron most commonly non-detect since Q4 2016

2d. No consistent coinciding detections of COPCs and nonCOPCs with naphthalene

- i. BTEX detected in two samples, not confirmed during subsequent sampling events
- ii. NonCOPC detections mainly compounds not associated with fuel
- iii. Only one detection (Q4 2005) of nonCOPCs related to fuel, non-pyrogenic PAHs

2e. TPH should be assessed in context of other COPCs and nonCOPCs

- i. Detections often not coincident with detections of other COPCs
- ii. TPH a parameter defined by the method used
- iii. Results can include hydrocarbons, metabolites/polar compounds, and anything present detectable by the method
- iv. Absolute values should be interpreted with caution
- v. A detection not a direct indication of hydrocarbons in GW

2f. TICs not good indicator of presence of LNAPL

- i. TIC identification and concentrations cannot be confirmed w/o comparison to known standard
- ii. Majority of detections not associated with fuel
- iii. TMB detections expected to be found with other hydrocarbons if coming from a fuel/LNAPL

2g. Lead scavengers not detected in Red Hill Shaft

3. No evidence of GW impact from 2014 fuel release

Primary LOE:

Secondary LOEs:

3a. No change in BTEX detection occurrences in RHMW02 after 2014 fuel release

3b. Ratio of methylnaphthalenes to naphthalene in RHMW02 did not change after 2014 fuel release

- i. Fresh source of LNAPL in RHMW02 vicinity would change the ratio, as fresh fuel has a different signature than degraded fuel

3c. TPH alone not good indicator of changes in water chemistry at RHMW02 after 2014 release

- i. TPH should be assessed in context of other COPCs and nonCOPCs

3d. Measured TPH concentrations in RHMW02 not good indicator of presence of LNAPL

- i. Results can include hydrocarbons, metabolites/polar compounds, and anything present detectable by the method
- ii. Concentrations/presence of TPH metabolites/polar compounds can be determined by using silica gel cleanup
- iii. Polar compounds more soluble than parent nonpolar/hydrocarbons; therefore, presence of polar compounds/metabolites can result in increased solubility of what is measured as TPH
- iv. Polar compounds/metabolites in RHMW02 more soluble than parent hydrocarbons; what is measured as TPH not indicative of presence of LNAPL from fresh release but is indicative of an older nearby source

3e. No change in COPC detection signature in RHMW02 after 2014 fuel release

- i. Increased number of detections after 2014 release reflective of increased sampling events, not change in GW chemistry

3f. No lead scavengers measured in RHMW02 before or after 2014 fuel release

- i. TIC identification and concentrations cannot be confirmed w/o comparison to known standard
- ii. Majority of detections not associated with fuel
- iii. Hydrocarbon detections not indicative of a fuel release

Summary table: Primary and Secondary Lines of Evidence – Navy’s Groundwater Chemistry Evaluation

1. No evidence of nearby LNAPL in outlying wells

Primary LOE	Secondary LOEs
1a. Naphthalene (by itself) is not a good indicator for the presence of LNAPL	<p>i. There are sporadic detections of naphthalene at outlying wells. Incidence of detections correlates best with labs used rather than where detections occurred and at what concentrations.</p> <ul style="list-style-type: none"> • Naphthalene detections during Q4 2012 to Q1 2015 (Calscience/Eurofins) are suspect. <ul style="list-style-type: none"> – Frequent detections of naphthalene from Q4 2012 to Q3 2014, then all detections stopped from Cal/Euro. <ul style="list-style-type: none"> • No coinciding detections of methylnaphthalenes – The lab that followed after Calscience (CAS/ALS) did not detect naphthalene at a similar frequencies or concentrations, even though the reporting limit was an order of magnitude lower. – Approximately 60% of naphthalene detections in outlying wells occurred during the suspect period of Cal/Euro analysis. The remaining detections are highly sporadic. – All naphthalenes were analyzed by EPA Method 8270 SIM at a time when only two ions were used to identify compounds. Three ions are required to have achieve robust identification. <p>ii. The very low detection limits for naphthalenes (e.g., 0.005 µg/L by CAS/ALS) are susceptible to interferences/artifacts and are inherently more variable.</p>
1b. Electron acceptors are not depleted at outlying wells	<p>i. Oxidic conditions are present at outlying wells</p> <ul style="list-style-type: none"> • DO concentrations ranged from 5.09 to 9.31 mg/L (Q4 2018) at outlying wells that are representative of water table chemistry. <ul style="list-style-type: none"> – RHMW07, RHMW11, and Halawa Deep are not representative of water table chemistry. – The range of DO in Red Hill outlying wells is generally consistent with observed DO in Oahu wells. • Nitrate concentrations range from 2 to 5.5 mg/L (Q4 2018) at outlying wells that are representative of water table chemistry, demonstrating that nitrate is not depleted. • Sulfate concentrations range from 6.9 to 51.3 mg/L (Q4 2018) at outlying wells that are representative of water table chemistry, demonstrating that nitrate is not depleted. • Reducing conditions (ORP < 0 mV) are not present in outlying wells (Q4 2018). • Apart from one sampling event at RHMW08, the ORP has been positive since Q4 2016 at outlying wells representative of the water table.
1c. Metabolic byproducts are not present at outlying wells	<p>i. Methane was not detected in outlying wells (Q4 2018).</p> <ul style="list-style-type: none"> • Methane has not been detected in outlying wells representative of water table chemistry since Q4 2016. <p>ii. Ferrous iron was not detected in RHMW04, RHMW05, RHMW08, RHMW09, RHMW10, and was detected below the limit of quantitation at RHMW06 (0.16 J mg/L) (Q4 2018).</p> <ul style="list-style-type: none"> • Since Q4 2016, ferrous iron has either been nondetect or below the limit of quantitation in outlying wells representative of water table chemistry.
1d. There are not consistent coinciding detections of COPCs and nonCOPCs (e.g., BTEX, methylnaphthalene, nonpyrogenic PAHs) with naphthalene	<p>i. BTEX were not detected in RHMW06, RHMW07, RHMW08, RHMW09, RHMW10, or all levels of RHMW11.</p> <p>ii. BTEX were detected infrequently (1 to 5 times) at the remaining outlying wells over the monitoring period, which is more indicative of sampling/lab artifacts.</p> <ul style="list-style-type: none"> • Concentrations were often below the limit of quantitation and ranged from 0.07 J to 3.8 µg/L. <p>iii. NonCOPC detections in outlying wells consisted mainly of compounds that are not associated with fuel: phthalates, halogenated VOCs, acetone, oxygenated compounds, and pyrogenic PAHs.</p> <p>iv. NonCOPCs that can be present in fuels, such as non-pyrogenic PAHs, were detected infrequently in outlying wells; detections occurred in two samples in RHMW05 and RHMW07, and one sample in RHMW04, indicating sampling/lab artifact issues.</p> <ul style="list-style-type: none"> • Non-pyrogenic PAHs were not detected in RHMW06, RHMW08, or RHMW09.
1e. TPH should be assessed in the context of other COPCs and nonCOPCs, as trend analyses are difficult because of inconsistent methodology and labs	<p>i. TPH is a parameter defined by the method used.</p> <p>ii. TPH results can include hydrocarbons, metabolites/polar compounds and anything present that can be detected by the method.</p> <p>iii. TPH can be used as an indicator parameter for potential impact to GW, but the absolute values should be interpreted with caution. Changes can be method-, lab-related.</p> <ul style="list-style-type: none"> • TPH detection is not a direct indication of hydrocarbons in GW.

1. No evidence of nearby LNAPL in outlying wells

Primary LOE	Secondary LOEs
1f. TICs are not a good indicator of the presence of LNAPL in outlying wells	<ul style="list-style-type: none">i. TIC identification and concentrations cannot be confirmed without comparison to a known standard.ii. Majority of TIC detections are not associated with fuels: phthalates, halogenated compounds, oxygen containing compounds.<ul style="list-style-type: none">• These compounds are likely associated with sample/lab contamination, well construction/maintenance, historical activities at the site unrelated to fuel releases.iii. TIC hydrocarbon detections in outlying wells are only trimethylbenzenes.<ul style="list-style-type: none">• Trimethylbenzene would be expected to be found with other hydrocarbons if coming from a fuel/LNAPL; trimethylbenzene was the only TIC detected in outlying well samples.• Trimethylbenzene was analyzed with Method 8260 in all outlying wells in 2017 and was not detected.
1g. Lead scavengers (1,2-dibromoethane and 1,2-dichloroethane) were not detected in outlying wells except for 1,2-dichloroethane in RHMW08 in 2017	<ul style="list-style-type: none">i. 1,2-dichloroethane was used in motor gasoline (not aviation gasoline). Motor gasoline was stored in Tank 17 prior to 1968. It is likely the detections of 1,2-dichloroethane in RHMW08 are from either fumigants or PVC impurity rather than motor gasoline.ii. Based on dissolved lead analyses, there is no evidence of a leaded fuel release. To adequately evaluate lead in the environment, careful consideration should be given to the local range of background concentrations as well as filtering of water samples, since lead is a naturally occurring element.

1a. No evidence of impact to other outlying wells from 2014 fuel release

1h. Continued sporadic detections of BTEX with no apparent increase in detection frequency after the 2014 fuel release	
1i. Continued sporadic detections of naphthalene with no apparent increase in detection frequency after 2014 fuel release	<ul style="list-style-type: none">i. Apparent decrease in naphthalene detection frequency in outlying wells after the period of Q4 2012 to Q3 2014 when Calscience/Eurofins stopped detecting naphthalene.

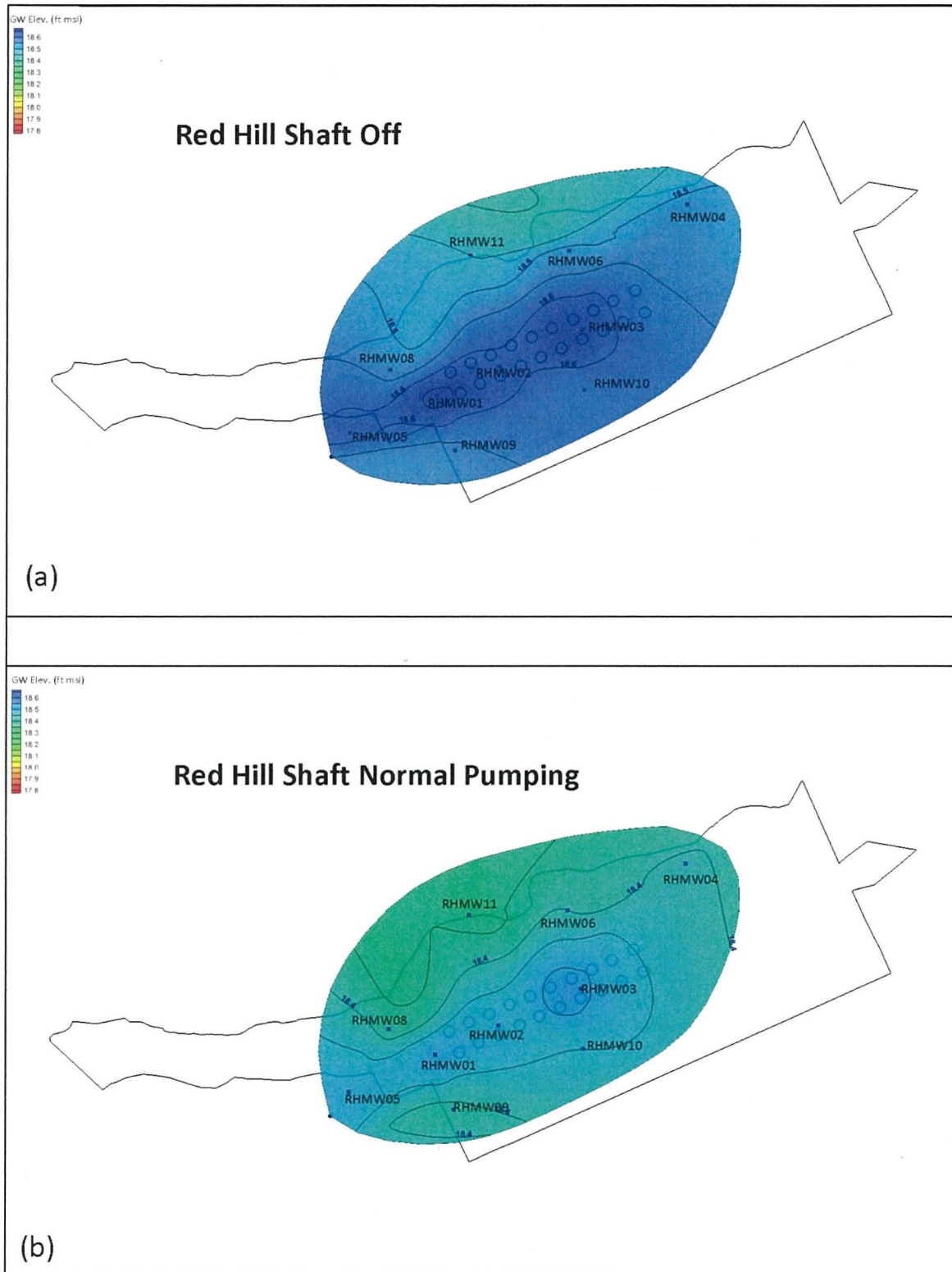
2. No evidence of LNAPL nearby Red Hill Shaft

Primary LOE	Secondary LOEs
2a. Naphthalene (by itself) is not a good indicator of the presence of LNAPL near Red Hill Shaft	<p>i. There are sporadic detections of naphthalene at Red Hill Shaft</p> <ul style="list-style-type: none"> • Naphthalene detections during Q4 2012 to Q1 2015 (CalScience/Eurofins) are suspect <ul style="list-style-type: none"> – Frequent detections of naphthalene from Q4 2012 to Q3 2014, then all detections stopped from Cal/Euro, indicating sampling/lab artifacts. <ul style="list-style-type: none"> • No coinciding detections of methylnaphthalenes – The lab that followed CalScience (CAS/ALS) did not detect naphthalene at a similar frequencies or concentrations even though the reporting limit was an order of magnitude lower. – The concentrations of naphthalene detected during Q4 2012 to Q3 2014 were similar to the concentrations detected in other outlying wells (e.g., Halawa Deep, RHMW05). Similar concentrations would not be expected at these 3 wells with very different constructions <ul style="list-style-type: none"> • Red Hill Shaft – Induced flow • Halawa Deep – Deep borehole with casing ~40 ft below regional aquifer • RHMW05 – Standard monitoring well – All naphthalenes were analyzed by EPA Method 8270 SIM at a time when only two ions were used to identify compounds. Three ions are required to have achieve robust identification. <p>ii. The very low detection limits for naphthalenes (e.g., 0.005 µg/L by CAS/ALS) are susceptible to interferences/artifacts and are inherently more variable.</p> <p>iii. Naphthalene detections do not often coincide with 1- and 2-methylnaphthalene or TPH detections, as would be expected if the detections were due to a nearby LNAPL source.</p>
2b. Electron acceptors are not depleted at Red Hill Shaft	<p>i. Oxidic conditions are present at Red Hill Shaft (DO = 8.7 mg/L during Q4 2018 sampling event).</p> <p>ii. Nitrate was 2.3 mg/L during Q4 2018 sampling event and is not depleted.</p> <p>iii. Sulfate was 15.6 mg/L during Q4 sampling event and is not depleted.</p> <p>iv. Reducing conditions (ORP < 0 mV) were not present.</p>
2c. Metabolic byproducts (methane and ferrous iron) were not detected in Red Hill Shaft (Q4 2018)	<p>i. Methane has been non-detect in Red Hill Shaft since Q4 2016.</p> <p>ii. Ferrous iron has been most commonly non-detect in Red Hill Shaft since Q4 2016, detected concentrations have ranged from 0.17 J to 0.34 mg/L.</p>
2d. There are not consistent coinciding detections of COPCs and nonCOPCs (e.g., BTEX, methylnaphthalene, nonpyrogenic PAHs) with naphthalene	<p>i. BTEX have been detected in two samples (Q4 2012 and Q2 2018) and were not confirmed during the subsequent sampling events.</p> <p>ii. NonCOPC detections in Red Hill Shaft consisted mainly of compounds that are not associated with fuel: phthalates, halogenated VOCs, acetone, oxygenated compounds, and pyrogenic PAHs.</p> <p>iii. NonCOPCs related to fuel, non-pyrogenic PAHs, were detected in only one sample from Red Hill Shaft in Q4 2005.</p>
2e. TPH should be assessed in the context of other COPCs and nonCOPCs as trend analysis is difficult because of inconsistent methodology and labs	<p>i. TPH detections often did not coincide with detections of other COPCs.</p> <p>ii. TPH is a parameter defined by the method used.</p> <p>iii. TPH results can include hydrocarbons, metabolites/polar compounds and anything present that can be detected by the method.</p> <p>iv. TPH can be used as an indicator parameter or potential impact to GW, but the absolute values should be interpreted with caution. Changes can be method-, lab-related.</p> <p>v. TPH detection is not a direct indication of hydrocarbons in GW.</p>
2f. TICs are not a good indicator of the presence of LNAPL in outlying wells	<p>i. TIC identification and concentrations cannot be confirmed without comparison to a known standard.</p> <p>ii. Majority of TIC detections are not associated with fuel: phthalates, halogenated compounds, oxygen containing compounds. <ul style="list-style-type: none"> • These compounds may be associated with sample/lab contamination, well construction/maintenance, historical activities at the site unrelated to fuel releases. </p> <p>iii. TIC hydrocarbon detections in Red Hill Shaft are of trimethylbenzene and two other hydrocarbons (1,2,3,4,5-Pentamethyl-Cyclopentane, and 2-Hexene, 3,5,5-Trimethyl-). <ul style="list-style-type: none"> • Trimethylbenzene would be expected to be found with other hydrocarbons if coming from a fuel/LNAPL; trimethylbenzene was the only TIC detected in outlying well samples. • Trimethylbenzene was analyzed for with Method 8260 in Red Hill Shaft in 2017 and was not detected. • The other TIC hydrocarbons were not detected in RHMW02 or RHMW01; detections are unlikely to be related to RHMW02. </p>
2g. Lead scavengers (1,2-dibromoethane and 1,2-dichloroethane) have not been detected in Red Hill Shaft	

3. No evidence of groundwater impact from 2014 fuel release

Primary LOE	Secondary LOEs
3a. BTEX detection occurrences did not change in RHMW02 after the 2014 fuel release	
3b. The ratio of methylnaphthalenes to naphthalene in RHMW02 did not change after the 2014 fuel release	<ol style="list-style-type: none">i. Fresh source of LNAPL in RHMW02 vicinity would change the ratio as fresh fuel has a different signature than degraded fuel.<ul style="list-style-type: none">• In general, the parent PAH (COPC naphthalene) is less abundant than the sum of the corresponding alkylated PAHs (in this case, COPCs 1-methylnaphthalene and 2-methylnaphthalene, which are the two possible isomers on naphthalene with methyl group substitution) from any petroleum sources.
3c. TPH alone not good indicator of changes in water chemistry at RHMW02 after 2014 release	<ol style="list-style-type: none">i. TPH should be assessed in context of other COPCs and nonCOPCs, as trend analysis is difficult because of inconsistent methodology and labs.<ul style="list-style-type: none">• EPA Method 8015 is a guidance method, not prescriptive, and results in significant variation in analysis between labs.• Changes in analytical lab often coincide with sharp changes in detected TPH concentrations in RHMW02.
3d. Measured TPH concentrations in RHMW02 are not a good indicator of the presence of LNAPL	<ol style="list-style-type: none">i. Results can include hydrocarbons, metabolites/polar compounds, and anything present detectable by method.ii. Concentrations/presence of TPH metabolites/polar compounds can be determined by using silica gel cleanup.iii. Polar compounds are more soluble than parent nonpolar/hydrocarbons; therefore, presence of polar compounds/metabolites can result in increased solubility of what is measured as TPH.iv. Polar compounds/metabolites in RHMW02 are more soluble than parent hydrocarbons; what is measured as TPH not indicative of presence of LNAPL from fresh release, but is indicative of an older nearby source.
3e. COPC detection signature did not change in RHMW02 after the 2014 fuel release	<ol style="list-style-type: none">i. Increased number of sampling events immediately following 2014 fuel release results in an apparent increase in COPC detections. This is a result of more frequent sampling, not of a change in groundwater chemistry.
3f. No lead scavengers (1,2-dibromoethane and 1,2-dichloroethane) were measured in RHMW02 before or after the 2014 fuel release	

Attachment 2: Groundwater Elevations with Countors



Groundwater elevation contours reflecting Red Hill Shaft off (a) and Red Hill Shaft business as usual (b) pumping conditions as reported by the Navy¹⁰.

¹⁰ NAVFAC. 2018, Figures 6-8 and 6-12.