BOARD OF WATER SUPPLY

CITY AND COUNTY OF HONOLULU
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May 27, 2016

Mr. Bob Pallarino
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and

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Dear Messrs. Pallarino and Chang:

Subject: Board of Water Supply (BWS) Comments to the Monitoring Well Installation Work Plan, Red Hill Bulk Fuel Storage Facility

The BWS and its consultants have reviewed the document titled "Monitoring Well Installation Work Plan, Red Hill Bulk Fuel Storage Facility" (MWIWP) dated 29 April 2016 as discussed at the Tuesday 10 May 2016 meeting concerning the Administrative Order on Consent (AOC) work plans for Statement of Work (SOW) Sections 6 and 7. The BWS provides the following comments and recommendations to the draft MWIWP with the goal of ensuring that all work conducted under the final document will produce defensible scientific and engineering results needed to continue to protect our drinking water supplies.

Section 1 – Background

Section 1.2.1.4 *Groundwater* should be revised to explain that perched groundwater, implications of which are discussed in Section 3.2 *Drilling*, is present at many locations, including the basalt and valley fill units in the Red Hill vicinity. The explanation should include what is known about perched water occurrences at Red Hill.

The *Groundwater* sub-section should be revised to explain that the basal aquifer beneath the Red Hill Bulk Fuel Storage Facility (RHBFSF) was designated as a Sole Source Aquifer in 1987 under Section 1424(e) of the Safe Drinking Water Act.

Section 2 – Project Quality Objectives

Section 2.2 *Step 2- Identify the Study Objectives* states that a "...secondary objective is evaluate the nature of petroleum product and constituent chemicals in soil, if present in the vadose and saturated zones underlying and downgradient of the tanks." The proposed well locations are far from the tanks and will only provide any information about fuel contamination in the vadose zone materials "underlying and downgradient" of the tanks if the fuel has migrated long distances laterally from the tanks. Thus the proposed well locations will not likely achieve this important objective and will likely fail to achieve the goal stated in the second sentence of Section 2.1: "Additional monitoring wells are proposed to allow for monitoring the potential migration of light non-aqueous phase liquid (LNAPL) to the groundwater,...". The MWIMP should be revised to include drilling, coring, and installation of vadose zone monitoring wells much closer to the tanks to determine the nature, extent, and migration of fuel contamination in the vadose zone because

1) The roughly 30,000 gallons of fuel released in January 2014 have not yet been mapped out in the sub-surface; and,
2) This large quantity of fuel will likely serve as a continuous source of contamination to our drinking water for years to come.

Section 2.3 *Step 3- Identify the Information Inputs* states that groundwater elevation data will be obtained. This text should be revised to explain that a high-quality survey, such as the first order survey mentioned by Dr. Delwyn Oki of the United States Geological Survey (USGS) during the most recent AOC SOW meeting, will be necessary to obtain sufficient accuracy of groundwater elevations.

Figure 2, which depicts the proposed locations of the new monitoring wells, includes an arrow showing the direction of regional groundwater flow to be roughly south-southwest. This arrow is misleading and should be removed because there is no direct evidence to support such a flow direction. The direction of regional groundwater flow is still uncertain in this area and remains an important question; the depicted arrow indicates only an **assumed** regional flow direction because there is no substantial evidence available yet for flow direction. It is important to note that changes in the pumping rates at the Halawa and Red Hill shafts and other nearby locations can significantly affect heads and therefore groundwater flow direction - see the discussion of "storage head" in Wentworth (1942 and 1951) and Mink (1980). Thus is it is important to report pumping rates and volumes pumped when reporting heads. Also, there is indirect evidence for a northwest flow direction:

1) A number of reports state that groundwater flows from Moanalua valley to Halawa valley and that there is significant uncertainty whether the South and North Halawa valleys act as barriers to flow, including Wentworth (1942), Wentworth (1951), and Mink (1980);
2) A contour plot of observed groundwater heads from the TEC (2010) report shows groundwater flows across Halawa valley to the northwest toward Halawa shaft;

3) Contours of simulated heads in the scenario with no valley fill in groundwater from Oki (2005) show groundwater flowing from the Red Hill vicinity across Halawa valley toward Halawa shaft; and
4) Fuel contamination has been frequently observed at Red Hill Monitoring Well (RHMW)-06, RHMW-07, and the Commission on Water Resources Management (CWRM) Halawa Deep Monitor Well (HDMW) 2253-03, all of which are located to the northwest of the tanks. It is important to note that the CWRM Halawa Deep Monitor Well is also located north of South Halawa stream.

The third bullet item in Section 2.5 *Step 5- Develop the Analytic Approach* should be revised to clarify what will be done if "soil is present below the bottom of the tanks". The material below the tank bottoms is likely to basalt, not soil and none of the proposed wells will intercept the material directly beneath the tanks.

Section 2.6.2 *Managing Decision Error* states that errors in ensuring installation of vertical monitoring wells will be minimized by levelling the drilling rig at least twice per day during drilling. The level of the drill rig is not the only factor important to ensure drilling a "vertical" borehole. Other factors include bottom-hole weight (bottom-hole drill assembly) and rate of advance, which together should be balanced so the drill bit doesn't deflect as it encounters various basaltic intraflow structures. To accurately determine if each borehole is vertical, the driller should stop and trip-out of the hole and run a gyroscopic alignment survey once a day during drilling.

Section 2.7 *Step 7- Develop Plan for Obtaining Data* repeats the statement that the proposed well locations will provide information about "...the nature and extent of LNAPL ... within the vadose zone...". This sentence and all other text should be revised to either 1) explain that the proposed well locations are likely to provide information about LNAPL nature and extent in the vadose zone only if the fuel has migrated long distances laterally or 2) add borings nearer to the tanks that will be much more likely to be useful in mapping out LNAPL nature and extent in the vadose zone.

Section 3 – Monitoring Well Network Design and Rationale

Section 3.1 *Monitoring Well Locations* provides the reasons underlying proposed choices. None of the reasons include providing information about the nature, extent, and migration of LNAPL within the vadose zone cited in Sections 2.2 and 2.7. Please revise all sections to be consistent about the objectives and how the proposed monitoring wells will achieve those objectives.

The second paragraph of Section 3.1 states that "The number of locations proposed in the vicinity of the underground storage tanks (USTs) was limited due to the lack of exposure pathways and to minimize the creation of migration pathways between possible vadose zone contamination and the groundwater aquifer." This statement is both misleading and incorrect. None of the proposed locations are in the "vicinity of the USTs"; this incorrect statement should be revised to eliminate the factual error. Creation of migration pathways by drilling can be entirely avoided with proper planning, drilling, and oversight. A monitoring well can be safely drilled and constructed through contaminated zones without either carrying contaminants downward as the borehole advances or, when completed, acting as a vertical pathway for the downward movement of contaminants. It requires advanced planning and equipment that can implement a cement pressure grouting program within the borehole to seal off a contaminated zone before continuing the advancement of the borehole. Such grouting programs are routinely performed within the drilling industry (for example, see Chapter 10 Well Drilling Methods, Section on Grouting and Sealing Well Casing, p. 317-331, in Driscoll, F.G., 1986, Groundwater and Wells, 2nd edition: Johnson Screens, St. Paul, Minnesota, 1089 p. or Section 10 in the Australian Drilling Industry Training Committee Limited, 1997, Drilling – The manual of methods, applications, and management: CRC Press LLC, Boca Raton, Florida, 615 p.). Why doesn't this work plan include such a cement grouting procedure? It will allow for a more efficient and cost-effective method to cope with either perched water or contaminated zones without having to resort to abandoning the borehole if more than one zone is encountered.

Figure 3, which is used to justify some of the proposed well locations, requires extensive revision before it begins to reflect available data and previous work.

1) Figure 3 depictions of the assumed width and depth of the valley fill and saprolite in the North and South Halawa valleys do not take into account all available data; thus are misleading and could lead to incorrect choices for proposed well locations. Even if the authors of the MWIWP had relied only on Sherrod et al. (2007) or Stearns (1939), the depicted widths of Halawa valley fills are exaggerated by at least 50% beyond those sources. A brief physical visit to South Halawa valley will reveal that deep valley fill (greater than 50 feet in thickness) is confined only to the eastern branch of South Halawa Stream and does not extend to the western branch. The depicted depths of valley fill and saprolite also appear exaggerated and Figure 3 should be revised to reflect Plate 1 of Izuka (1992) and Figure 25 in Wentworth (1942). The enclosed Figure 1 to this letter reproduces the relevant part of Wentworth's Figure 25, which shows two end members, A and B, for the depth of valley fill in the two valleys. Only one deep well (CWRM Deep Monitoring Well HDMW2253-03) has been installed in this area of Halawa valley since Wentworth (1942) and this well appears to intersect the eastern part of the South Halawa valley fill.

2) The proposed monitoring well Red Hill Monitoring Well (RHMW) 09 location is in very close proximity to a monitoring well being planned to be installed by the BWS. We recommend re-locating RHMW09 to the south side of Halawa Valley, along South Halawa stream, within the Red Hill Bulk Fuel facility boundary, such as the location shown in the enclosed Figure 2.

3) Figure 3 shows that the proposed monitoring well RHMW11 intersects the western part of the exaggerated width for valley fill in South Halawa valley. Based on the available data, physical visits to this area, and reports cited above, this proposed well is more likely to intersect Koolau basalt than South Halawa valley fill. Consequently, the proposed location should be reconsidered using the recommended revised Figure 3. Installing the monitoring well on the east side of

South Halawa Valley closer to South Halawa stream will provide a better understanding of any head changes caused by valley fill.

4) At present Figure 3 only shows a combined valley fill and saprolite unit. What are the other units and where do they occur?

5) The BWS Halawa Shaft is projected into the valley fill in Figure 3 which is factually incorrect. Figure 3 should be revised to show that the shaft is northwest of the valley fill in North Halawa valley as shown in cross-section A-A on Plate 1 in Izuka (1992). A perpendicular projection of the dot representing the shaft in the inset to Figure 3 still places the shaft outside of the valley fill to the west or northwest. The current placement and depiction of a well instead of a shaft are likely to only confuse readers. Figure 3 presently appears to imply that Halawa shaft can actually withdraw large amounts of water (6 to 10 million gallons per day) from the valley fill.

6) Given that the North and South Halawa valley fill units were created by incision by meandering streams and later backfilling, defining the width and depth of these units will require more than a single new monitoring well in the Halawa valley area.

The title for Figure 4 states that it is a geological cross-section. However, it does not show any geology and should instead be characterized as a schematic or longitudinal profile.

Sections 3.2, 3.3, 3.4, and 3.5 describe drilling, sampling, monitoring well construction, and surveying, respectively. There are unexpected but large differences between the text descriptions of the monitoring well construction requirements and those shown on Figure 5. For example, the text does not specify what type of grout should be used for the conductor casing, but in Appendix A, Procedure I-C-1 indicates that it should be cement grout like that indicated on Figure 5. None of these text sections, nor Appendix A, Procedure I-C-1, provide specifics with regards to how the cement grout seal will be emplaced in the annulus. This is a significant concern since improper placement of the cement grout within the annulus between the conductor casing and the borehole can create open voids within the annulus and provide a potential vertical pathway for contaminate movement. Given the number of monitoring wells that the Navy has constructed, it is expected that the Navy should have specific plans and procedures for this critical aspect of monitoring well construction.

Another major concern is that below the bottom of the conductor casing the specified grout used to create the seal changes from the far more effective cement to the less effective bentonite. Figure 5 indicates that bentonite chips will be used for a seal in the portion of the borehole hole (potentially spanning more than 200 feet of annulus) from the bottom of the conductor casing to the top of the filter pack. It would be extremely difficult to emplace dry bentonite chips over such a very long interval and achieve a proper seal between the well casing and borehole wall. Such problems likely to be encountered using dry bentonite chips is “bridging” (leaving gaps). Also after the bentonite chips are emplaced they have to be hydrated (to achieve a seal) by adding water to the borehole. However, any bridging within the emplaced bentonite chips will also likely cause incomplete hydration of the bentonite chips and result in a defective bentonite seal. Also the in-well hydration of the dry bentonite chips calls for the introduction of non-formational water to be introduced into the basalt vadose zone which could potentially mobilize contaminants, if present. A better approach would be to use cement grout slurry, or even a bentonite slurry (allowed for in Section 4.3.4, lines 6 – 17) and emplace it using a tremie pipe for this portion of the well seal.

The text sections of this work plan cite American Society for Testing and Materials (ASTM) standards for logging core. The ASTM standard contains generic descriptions and procedures that are of little general usefulness for logging basaltic core for a hydrogeologic/environmental assessment project – like this project. The work plan doesn't contain any details concerning how the various important basalt intraflow structures (e.g., flow top breccias (clinker sub-types), accretionary lava clasts, simple vesicular flow tops, vesicular flow lobes, inflated pahoehoe lobes, spatter-fed pahoehoe lobes, lava tubes, a'a columnar dense interiors, flow-bottom breccias, normal flow bottoms, flow levees, tumuli, rootless spatter cones, etc.) will be included in the descriptive and photo logs or how to recognize and identify the difference between tectonic fractures, primary cooling joints, and drilling-induced fractures. Additionally, the text sections of the work plan fail to provide any direction, guidance, or procedures for how basaltic core should be photographically documented, preserved, and archived other than the generic recommendations from in the ASTM standards. The MWIWP should be revised to state that all cores from new monitoring wells, as well as, cores from existing wells should be logged to note these important intraflow structures, tectonic fractures, primary cooling joints, and drilling-induced fractures.

None of the above described short-falls in basalt core logging, critical component to understanding the geology and hydrogeology beneath the Red Hill area, are addressed in Appendix A - Procedure I-E Soil and Rock Classification. Of the 17 pages in this procedure that specifically address identification and classification of soil (sediments) and rock, 15 pages of the 17 pages are devoted to procedures for describing and classifying soils (sediment) and only 2 pages out of the 17 pages are devoted to describing and classifying generic "rock" which includes basalt. Despite the acknowledged importance of correctly identifying basalt flow features and structures (intraflow structures) in the core, the proposed procedure fails to provide specifics for identifying and describing basalt intraflow structures. The MWIWP should be revised to provide guidelines for identifying, characterizing, and logging these key features.

The MWIWP should be revised to state that all logs, photo logs, and cores from existing and new wells will be made available for inspection on request by Subject Matter Experts and their contractors.

Thank you for the opportunity to comment. If you have any questions, please feel free to call me at (808) 748-5061.

Very truly yours,

ERNEST Y. W. LAU, P.E.
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Enclosures

Figure 1 – Geologic Cross-Section Through Halawa Valley from Wentworth (1942)
Figure 2 – Suggested Alternative Location for RHMW09

References

Izuka, S.K. 1992. Geology and Stream Infiltration of North Halawa Valley, Oahu, Hawaii. USGS Water-Resources Investigations Report 91-4197.

Mink, J.F. 1980. State of the Groundwater Resources for Southern Oahu. Prepared for the Honolulu Board of Water Supply, 148 p.

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. USGS Scientific Investigations Report 2005-5223.

Sherrod, D.R., Sinton, J.M., Watkins, S.E., and Brunt, K.M. 2007. Geologic Map of the State of Hawai`i: U.S. Geological Survey Open-File Report 2007-1089, 83 p., 8 plates, scales 1:100,000 and 1:250,000, with GIS database.

Stearns, H.T. 1939. Geologic map and guide of Oahu, Hawaii: Hawaii Division of Hydrography, Bulletin 2, 75 p.

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

Wentworth, C.K. 1951. Geology and ground-water resources of the Honolulu-Pearl Harbor Area. Prepared for the Honolulu Board of Water Supply, 120 p.

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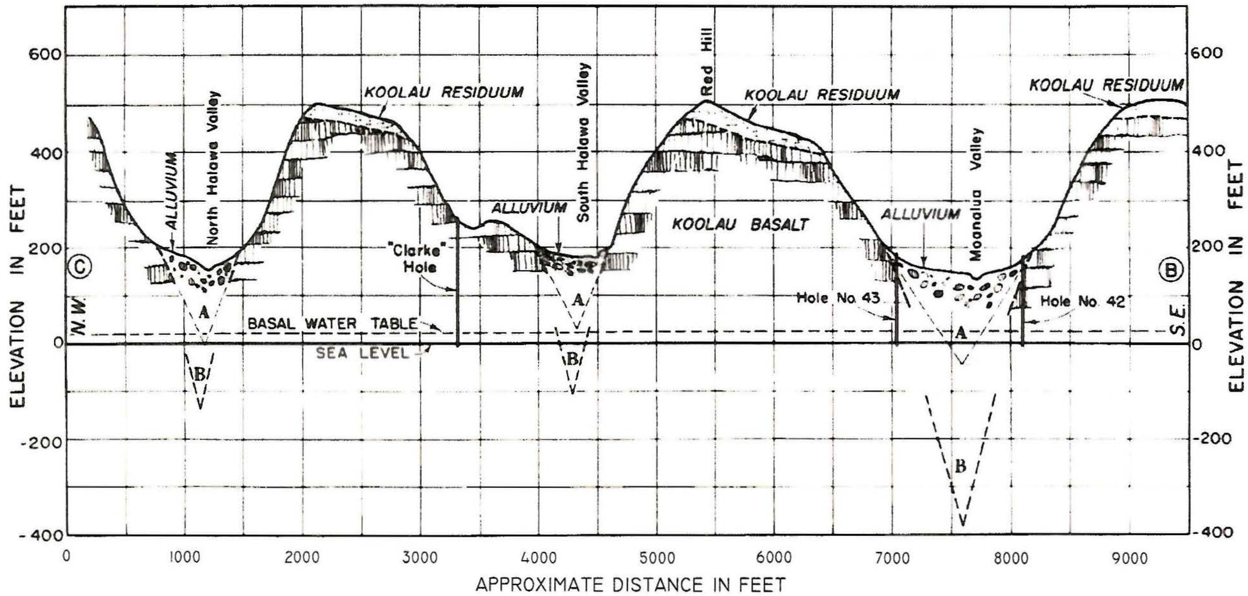
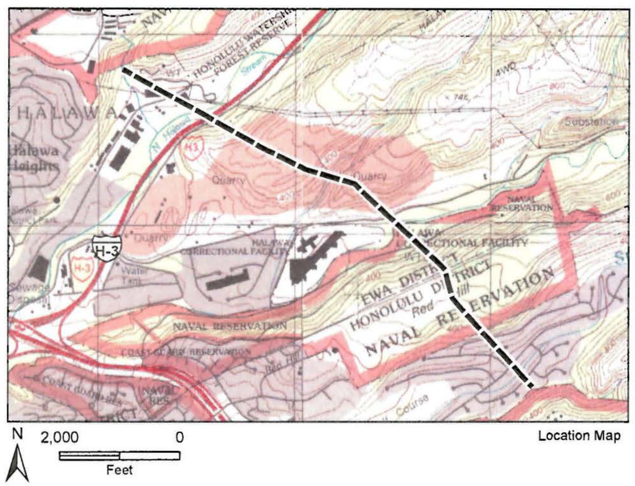


Sources:
Cross section – *Geology and Ground-Water Resources of the Moanalua-Halawa District*, C.K. Wentworth, 1942;
Topo – USGS, 7.5 minute Quad, dated 1998-99

▬ ▬ Approximate Cross Section Location



Per Wentworth, 1942:
"Geologic cross-section from Kalihi to Aiea, along a line tangent to the several 500 foot contour loops on the spur facets. The several drill holes indicated are not on this line but each is projected into the cross-section in a position corresponding closely with its relation to the valley and the valley wall. The basal water table from Kalihi to the east side of Moanalua approximates the elevation of 24 feet (October, 1942); on the west side of Moanalua Valley is a drop of about 0.70 fee, then one to 21.7 west of South Halawa and to 19.50 west of possible rock profiles A and B are based on width and steepness of valley topography. Profile A is about the shallowest that seems plausible; profile B is no deeper than is possible if rock walls continue to steep as some revealed in Palolo Valley by drilling."

Note: The portion of the original cross-section from Kalihi to Moanalua (A to B) is not shown here.

Figure 1
Geologic Cross-Section Through Halawa Valley from Wentworth (1942)

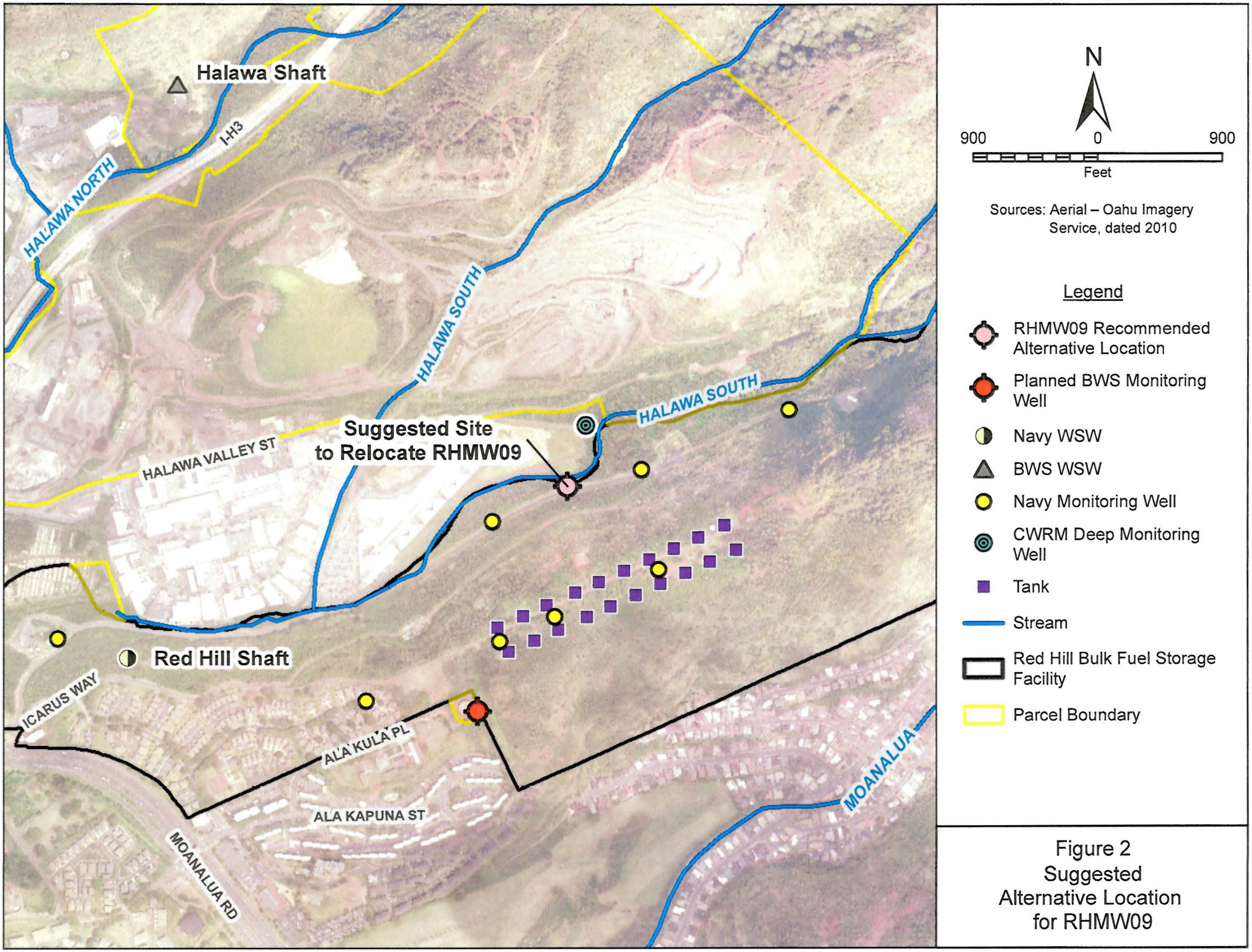


Figure 2
Suggested
Alternative Location
for RHMW09