Facility Environmental Report for Contested Case Hearing
No. 19-UST-EA-01

RED HILL BULK FUEL STORAGE FACILITY
JOINT BASE PEARL HARBOR-HICKAM, O‘AHU, HAWAI‘I

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EXECUTIVE SUMMARY

The Red Hill Bulk Fuel Storage Facility (the "Facility") may be the most extensively studied and analyzed underground storage tank ("UST") system in the State of Hawai'i. The groundwater aquifer in the vicinity of Red Hill has been analyzed since the first groundwater monitoring well was installed in 2001 (the current long-term groundwater monitoring program has been implemented since 2005, i.e., for over 15 years, including before and after the 2014 Tank 5 release) and, despite there having been historical releases of hydrocarbon fuel to the groundwater, all the myriad data show that natural processes have inhibited movement of fuel product down to the groundwater, attenuated hydrocarbons in soil and groundwater in the immediate vicinity of the tanks, and kept the drinking water safe. Specifically:

- No petroleum "product"[1] has *ever* been measured in any well during 913 tests conducted over 15 years, including before and after the 2014 Tank 5 Release.
- No analyte has ever been detected at concentrations exceeding very conservative and highly protective regulatory screening levels in more than 790 analyses of "chemicals of potential concern" identified by the regulators in 81 primary samples collected from the groundwater monitoring point at the Navy's drinking water supply well (Red Hill Shaft).[2]
- No specific fuel constituents have ever been detected at concentrations exceeding the highly protective regulatory screening levels in over 6,800 analyses of over 650 samples collected from the "perimeter wells" (i.e., the 16 groundwater monitoring wells other than the 3 wells in the immediate vicinity of the Facility's fuel storage tanks).[3]
- The City and County of Honolulu Board of Water Supply recently acknowledged that its closest water supply well (approximately twice as far from the tanks as the Navy supply well) also remains safe.

While historical releases (prior to 2014) have resulted in some impacts to the aquifer in the immediate vicinity of the tank farm, "natural attenuation" processes continue to bioremediate and otherwise prevent the petroleum hydrocarbons from spreading far from the tanks. For these reasons alone, and given that the extensive environmental monitoring network continues to be regularly sampled, tested, and analyzed, the extensive environmental data set confirms that operation of the Facility is currently "protective of human

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[1] As relevant here, petroleum fuel "product" (also referred to as light nonaqueous-phase liquid ("LNAPL") or "free-phase" petroleum) is lighter than and not very soluble in water. As a result, if product is released in a quantity and in an environment that allows it to travel down through the soil and rock to a groundwater aquifer, the LNAPL floats on top of the groundwater, where its thickness can routinely be measured in a monitoring well.

[2] The State of Hawai'i Department of Health ("DOH") has established Environmental Action Levels ("EALs"), which evaluate a plethora of data from the United States Environmental Protection Agency ("EPA") and leading researcher institutions, and evaluate worst-case pessimistic **risks** under various **exposure pathways**, such as human or ecological **receptors** drinking impacted water. According to DOH, concentrations below the EALs are used to "quickly screen out" "contaminants that do not pose potential concerns." Therefore, the EALs are often referred to as regulatory **screening levels**. Moreover, even "Exceedances of the Tier 1 EALs do not automatically mean that unacceptable risks exist." TGM §§ 2.4.1, 3.10 (DOH 2018b). Here, there have been *zero* exceedances of any fuel constituent in any of the samples taken from the drinking water sampling point.

[3] Of the more than 4,292 analyses of perimeter wells samples, the laboratory reported elevated "TPH" in 8 of the 47 primary samples collected from the Oily Waste Disposal Facility and 1 from the Halawa Deep Monitoring Well. However, as discussed in this report: TPH does not measure specific chemicals, but only measures the total amount of carbon compounds in a given range; no actual fuel-related chemicals were detected in any of those 9 samples; and the chromatograms do not resemble petroleum.

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health and the environment," satisfying the over-arching statutory criteria for issuance of the UST Operating Permit.[4]

In addition to the existing data showing that operation of the Facility is currently protective, continued protectiveness is being ensured by additional work that has been and continues to be conducted under the auspices of the Red Hill *Groundwater Protection Plan* ("GWPP") and the Red Hill *Administrative Order on Consent* ("AOC"). Most of this work significantly exceeds regulatory mandates, is specifically designed to ensure the ongoing safety of the Facility, and is extensively overseen by the environmental regulators and their expert consultants. Among other things:

- The Red Hill groundwater monitoring network continues to be expanded.
- Potential improvements to the soil vapor monitoring program are being evaluated.
- Facility components determined to present the most risk have been and will continue to be upgraded or replaced.
- Operational procedures to prevent and detect releases are being improved upon and expanded.
- Various innovative research studies (many being planned in conjunction with local experts at the University of Hawai'i) to identify or implement additional improvements are being planned or conducted.
  - As one example, an innovative evaluation of biodegradation and depletion of fuel beneath the tanks known as natural source-zone depletion has been conducted, and the results have been subjected to peer review and accepted for publication in a highly respected, peer-reviewed journal.
- Groundwater flow modeling is being conducted, and fate and transport modeling will be conducted after the flow model report is approved.
- Contingency planning is, and will be continually be, updated (typically on a 5-year basis, similar to the UST Operating Permit).

These programs and associated improvements will help ensure protectiveness and keep the regulators apprised of conditions and improvements on an ongoing basis throughout (and beyond) the duration of the 5-year UST Operating Permit.

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[4] HRS §342L-4(c) (the "director [of the DOH] shall issue a permit for any term, not exceeding five years, if the director determines this to be protective of human health and the environment") (emphases added).

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ACRONYMS AND ABBREVIATIONS

AOC	Administrative Order on Consent
BWS	Board of Water Supply, City and County of Honolulu
CSM	conceptual site model
CWRM	Commission on Water Resource Management, State of Hawai‘i Department of Land Natural Resources
DLA	Defense Logistics Agency, United States Department of Defense
DLNR	Department of Land and Natural Resources, State of Hawai‘i
DNAPL	dense nonaqueous-phase liquid
DOH	Department of Health, State of Hawai‘i
EAL	Environmental Action Level
EPA	Environmental Protection Agency, United States
GWPP	Groundwater Protection Plan
HAR	Hawai‘i Administrative Rules
HRS	Hawai‘i Revised Statutes
LNAPL	light nonaqueous-phase liquid
MNA	monitored natural attenuation
NSZD	natural source-zone depletion
QRVA	Quantitative Risk and Vulnerability Assessment
SOW	Statement of Work
TPH	total petroleum hydrocarbons
TIRM	Tank Inspection, Repair, and Maintenance
TUA	Tank Upgrade Alternatives
UH	University of Hawai‘i
USGS	United States Geological Survey
UST	underground storage tank

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1. Introduction

This *Facility Environmental Report* demonstrates how past, present, and anticipated future data, activities, analyses, operational improvements, and upgrades at the Red Hill Bulk Fuel Storage Facility (the “Facility”) show that operation of the Facility is and will continue to be “protective of human health and the environment,” such that a UST Operating Permit for the Facility should issue in accordance with the State of Hawai‘i Underground Storage Tank (“UST”) statute and regulations.[5] Specifically, this report describes how the environmental data and analyses show that the Facility is:

- Currently Protective of Human Health and the Environment (Section 2)
- Will Remain and Continue to Become Even More Protective Over Time (Section 3)

It is assumed that the reader of this report understands that this important strategic Facility was constructed in the early years of World War II underground in the basaltic lava rock at elevations more than 100 feet above the regional drinking water basal aquifer. The Facility’s fuel storage tanks are continually evaluated and upgraded on an ongoing basis, with improvements being made to modernize the equipment and minimize the possibility of a release. Following are brief descriptions of several important background events and programs potentially relevant to the question of environmental protectiveness in this Contested Case.

- **Groundwater Protection Plan (2008; 2014).** In order to ensure protection of human health and the environment, the Navy developed and implemented the State of Hawai‘i Department of Health (“DOH”)-approved *Groundwater Protection Plan* (“GWPP”),[6] which provides for: preventive inspection, maintenance, and repair; leak detection and soil vapor monitoring; long-term groundwater monitoring; and response action contingency planning. All these components are subject to the ongoing scrutiny and approval of the DOH. Notably, the soil vapor monitoring data clearly reflected the 2014 Tank 5 Release, discussed below, and is, therefore, considered a proven backup method of leak detection in excess of the tank tightness testing required by the regulations. The Navy is currently in the process of conducting a pilot test for a continuous soil vapor monitoring program that would further improve this method as a backup to current leak detection methods. Through the Red Hill long-term groundwater and soil vapor monitoring program, the regulators and the public are kept aware of environmental conditions on an ongoing basis and assured that the drinking water remains safe. Figure 1 shows the Facility layout and the groundwater monitoring well network, and Figure 2 depicts the Red Hill pictorial conceptual site model (“CSM”).

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[5] *See* HRS §342L-4(c) (the “director [of the DOH] shall issue a permit for any term, not exceeding five years, if the director determines this to be protective of human health and the environment”) *and* HAR §11-280.1-323(b) (“director shall approve an application for a permit only if the applicant has submitted sufficient information to the satisfaction of the director that … operation of the UST or tank system will be done in a manner that is protective of human health and the environment”) (emphases added).

[6] The GWPP (DON 2014) is available at DOH’s website: https://health.hawaii.gov/shwb/ust-red-hill-project-main/red-hill-technical-documents-2014/.

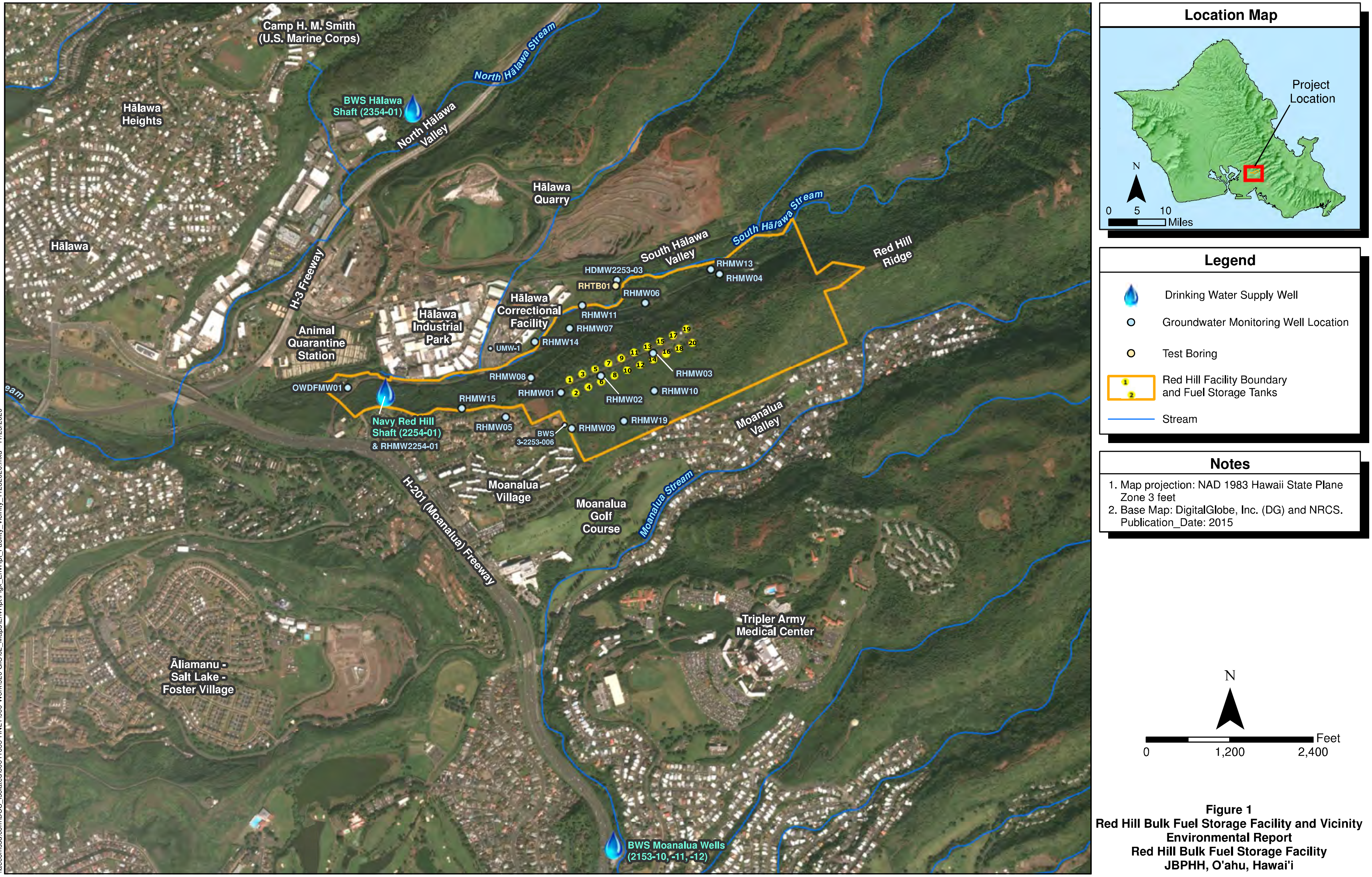

Figure 1
Red Hill Bulk Fuel Storage Facility and Vicinity
Environmental Report
Red Hill Bulk Fuel Storage Facility
JBPHH, O'ahu, Hawai'i

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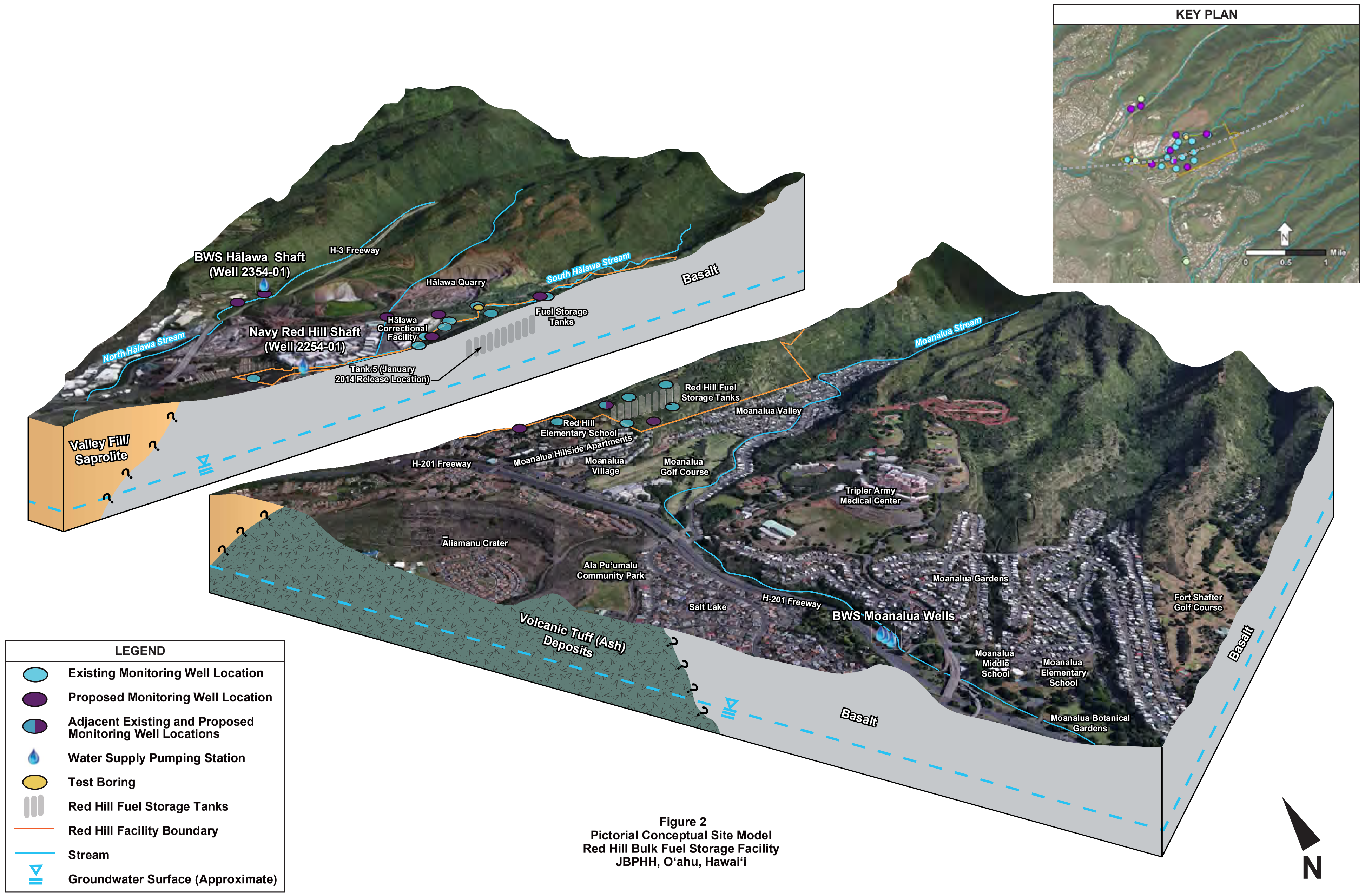

Figure 2
Pictorial Conceptual Site Model
Red Hill Bulk Fuel Storage Facility
JBPHH, Oʻahu, Hawaiʻi

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- **The 2014 Tank 5 Release (2014).** All active Facility fuel storage tanks undergo scheduled routine maintenance upgrades; the upgrade process typically occurs over a 3-year period once a tank is taken out of service. In the course of refilling Tank 5 with kerosene-based JP-8 jet fuel following completion of its scheduled maintenance in 2010–2013, the Navy discovered and reported to DOH a fuel release on January 13, 2014, that was later quantified at approximately 27,000 gallons of JP-8 fuel.

  Importantly, and often lost in public discourse, the 2014 Release was not due to corrosion of the tank; rather, prior to taking the tank out of service for maintenance (which is routinely conducted for all tanks to *prevent* failures due to corrosion), the tank was first confirmed to be intact via a tank tightness test.[7] The release occurred after the repairs were made and was due to a confluence of errors, which were primarily traceable to human error related to inspection of repairs to gas test holes and defective welds on patch plates that were used to cover the gas test holes. Unfortunately, these errors were not caught through the project's quality control and quality assurance provisions, which could have prevented the release. Specifically, the contractor failed to properly inspect the work, failed to properly test the repair work, failed to report the deficiencies, and failed to perform the mandated American Petroleum Institute Standard 653 inspection of repairs and failure to certify that Tank 5 was suitable for service. In addition, the Navy failed to perform satisfactory quality assurance oversight and the Facility operators failed to properly respond to the system's alarms. Thus, the 2014 Tank 5 Release was essentially a perfect storm of errors during the repair project, *not* a failure stemming from corrosion of the tank.

  To ensure that none of these causes are repeated in the future, the Navy has implemented several measures to address each identified failure and ensure proper oversight for tank maintenance activities in the future (NAVFAC EXWC 2017). Additionally, the Navy implemented new standard operating procedures to increase contractor scrutiny and provide additional government oversight during construction. The Navy has put these and other measures into place to ensure that these types of errors and a release similar to what occurred in 2014 will not occur again.

- **Administrative Order on Consent.** As a result of the 2014 Tank 5 Release, the Facility has been the subject of an Administrative Order on Consent ("AOC") signed by the Navy, Defense Logistics Agency ("DLA"), United States Environmental Protection Agency ("EPA"), and DOH since September 2015. The express goal of the AOC is to "to protect drinking water, natural resources, human health, and the environment"; all the AOC Parties agree that the AOC (like the UST permitting program) was specifically designed to be "protective of human health and the environment."[8] All activities conducted under the AOC are subject to the close oversight and scrutiny of both EPA and DOH and essentially serve to ensure achievement of the overarching goal of both the AOC and the UST permitting program, i.e., to ensure that operation of the Facility is "protective of human health and the environment."[9] While much of the work being conducted under the AOC is far beyond any specific requirement in the UST regulations, this work nevertheless provides further assurance of protectiveness. Furthermore, the AOC reserves both DOH and EPA's "authority to take, direct, or order any and all actions necessary to protect public health, any source of drinking water or the environment or to prevent, abate, or minimize an actual or threatened release."[10] To date, neither EPA nor DOH have alleged that conditions at the Facility pose such risks, which is a further indication that the Facility is currently safe. In fact, EPA in 2017 contracted

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[7] *See* Tank Upgrade Alternative ("TUA") and Release Detection *Decision Document* (DON 2019b, at 49–50).

[8] AOC at 1, 2 (EPA Region 9 and DOH 2015).

[9] HRS §342L-4(c) (the "director [of the DOH] <u>shall</u> issue a permit for any term, not exceeding five years, if the director determines this to be protective of human health and the environment") (emphases added).

[10] AOC at 25.

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an independent team of UST experts to conduct an evaluation of the Facility "to provide an overall assessment of the Facility's ability to be operated in a manner that prevents release of fuel into the environment." After a detailed evaluation of operations, system components, and documentation, the "evaluation team did not identify areas of noncompliance with current State or Federal regulations," and the "evaluation team generally found that systems and management practices in place at the Red Hill Facility meet or exceed best practices for petroleum terminals and bulk fuel storage facilities."[11]

Since signing the AOC, the Navy and Defense Logistics Agency ("DLA") (hereafter, for brevity, the "Navy") have expended extensive resources and efforts to fulfill the requirements of the many sections of the AOC Statement of Work ("SOW") (EPA Region 9 and DOH 2015), including measures related to:

- Tank Inspection, Repair, and Maintenance ("TIRM") (AOC SOW § 2)
- Tank Upgrade Alternatives ("TUA") (AOC SOW § 3)
- Release Detection and Tank Tightness Testing (AOC SOW § 4)
- Corrosion and Metal Fatigue (AOC SOW § 5)
- Investigation and Remediation of Releases; Groundwater Protection and Evaluation (AOC SOW §§ 6–7)
- Risk and Vulnerability Assessment (AOC SOW § 8)

The environmental investigations and analyses, in particular, will ultimately form the basis of the next revision to the GWPP, which will then be revised every 5 years thereafter to ensure ongoing environmental monitoring and protection into the future (much like the UST Operating Permit). All these analyses, improvements, repairs, and upgrades conducted under the AOC and GWPP ensure that operation of the Facility is currently protective of human health and the environment and will remain so. The Navy's work under the AOC is shown on Figure 3.

This report attempts to concisely summarize a vast volume of data, analyses, and reports, which collectively show significant improvements that the Navy has already made and still plans to make to the Facility, and shows that operation of the Facility is and will remain protective of human health and the environment. Much of the subject matter and associated source reports is scientifically and technically dense and complicated, and many of the reports being summarized are extremely long. Therefore, this report is an attempt to summarize data and findings, as potentially relevant to this UST Operating Permit proceeding, in as concise yet meaningful a manner as possible.

To this end, several "Sidebars" located at the end of each section of this report explain important details and concepts (sometimes with references to source documents that are listed in Section 4 of this report), in order to keep the main points of this report relatively accessible. In the following pages, Sidebar 1 describes components of the GWPP and the AOC that ensure protection of human health and the environment; Sidebar 2 summarizes the role of the various key government entities, other stakeholders, and technical experts involved in the AOC, GWPP, and this Contested Case Hearing; and Sidebar 3 explains select key terminology used throughout this report.

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[11] *See* Underground Storage Tank System Evaluation Final Report Red Hill Bulk Fuel Storage Facility, Joint Base Pearl Harbor-Hickam June 2017 (Atlas et al. 2017), included as Appendix A to this report, at 1.

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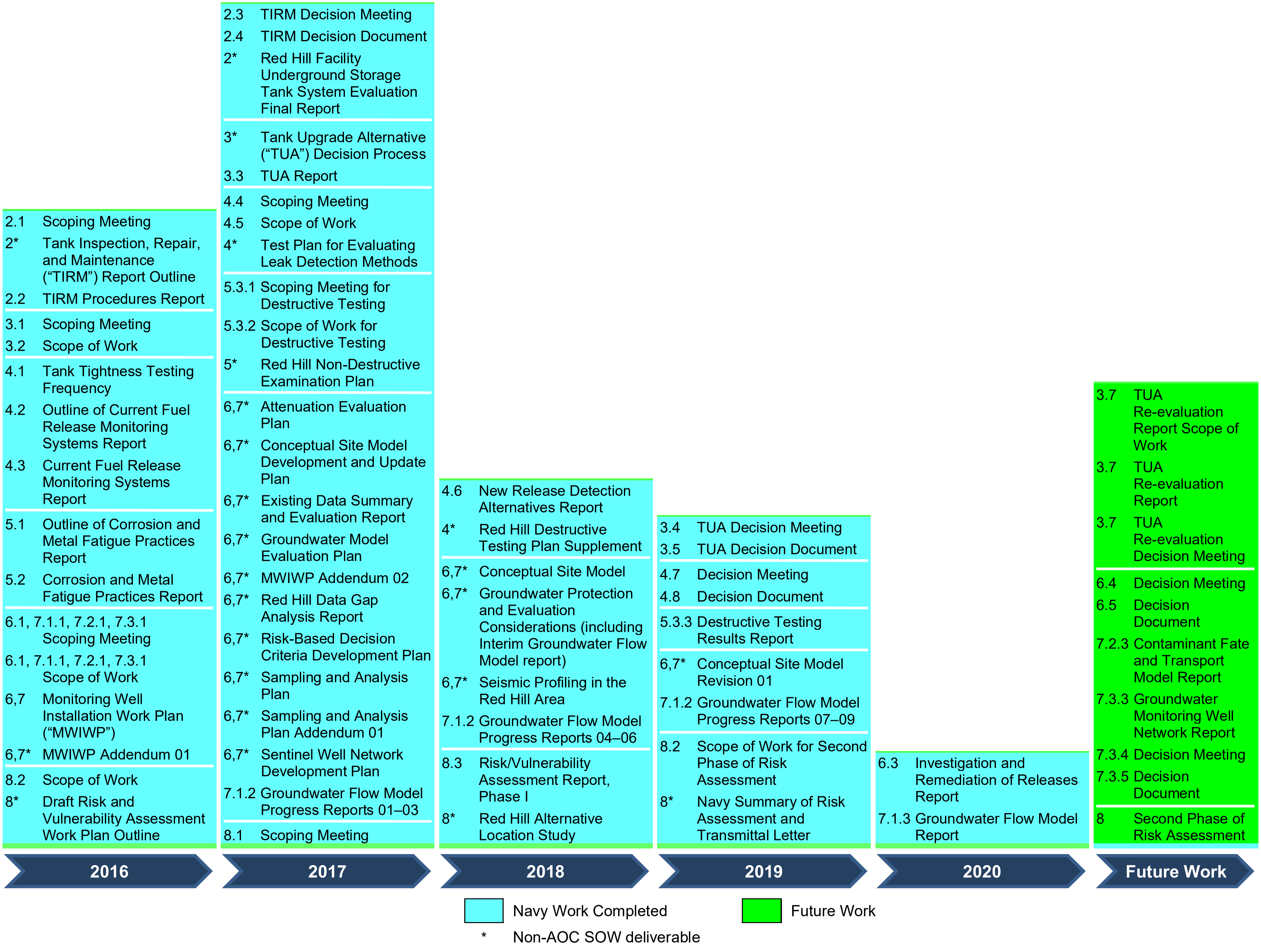
Figure 3: Summary of Work Arising from the Red Hill Administrative Order on Consent (AOC) Statement of Work (SOW)



2016

2.1 Scoping Meeting
2* Tank Inspection, Repair, and Maintenance ("TIRM") Report Outline
2.2 TIRM Procedures Report

3.1 Scoping Meeting
3.2 Scope of Work

4.1 Tank Tightness Testing Frequency
4.2 Outline of Current Fuel Release Monitoring Systems Report
4.3 Current Fuel Release Monitoring Systems Report

5.1 Outline of Corrosion and Metal Fatigue Practices Report
5.2 Corrosion and Metal Fatigue Practices Report

6.1, 7.1.1, 7.2.1, 7.3.1 Scoping Meeting
6.1, 7.1.1, 7.2.1, 7.3.1 Scope of Work
6,7 Monitoring Well Installation Work Plan ("MWIWP")
6,7* MWIWP Addendum 01

8.2 Scope of Work
8* Draft Risk and Vulnerability Assessment Work Plan Outline

2017

2.3 TIRM Decision Meeting
2.4 TIRM Decision Document
2* Red Hill Facility Underground Storage Tank System Evaluation Final Report

3* Tank Upgrade Alternative ("TUA") Decision Process
3.3 TUA Report

4.4 Scoping Meeting
4.5 Scope of Work
4* Test Plan for Evaluating Leak Detection Methods

5.3.1 Scoping Meeting for Destructive Testing
5.3.2 Scope of Work for Destructive Testing
5* Red Hill Non-Destructive Examination Plan

6,7* Attenuation Evaluation Plan
6,7* Conceptual Site Model Development and Update Plan
6,7* Existing Data Summary and Evaluation Report
6,7* Groundwater Model Evaluation Plan
6,7* MWIWP Addendum 02
6,7* Red Hill Data Gap Analysis Report
6,7* Risk-Based Decision Criteria Development Plan
6,7* Sampling and Analysis Plan
6,7* Sampling and Analysis Plan Addendum 01
6,7* Sentinel Well Network Development Plan
7.1.2 Groundwater Flow Model Progress Reports 01–03

8.1 Scoping Meeting

2018

4.6 New Release Detection Alternatives Report
4* Red Hill Destructive Testing Plan Supplement

6,7* Conceptual Site Model
6,7* Groundwater Protection and Evaluation Considerations (including Interim Groundwater Flow Model report)
6,7* Seismic Profiling in the Red Hill Area
7.1.2 Groundwater Flow Model Progress Reports 04–06

8.3 Risk/Vulnerability Assessment Report, Phase I
8* Red Hill Alternative Location Study

2019

3.4 TUA Decision Meeting
3.5 TUA Decision Document

4.7 Decision Meeting
4.8 Decision Document

5.3.3 Destructive Testing Results Report

6,7* Conceptual Site Model Revision 01
7.1.2 Groundwater Flow Model Progress Reports 07–09

8.2 Scope of Work for Second Phase of Risk Assessment
8* Navy Summary of Risk Assessment and Transmittal Letter

2020

6.3 Investigation and Remediation of Releases Report
7.1.3 Groundwater Flow Model Report

Future Work

3.7 TUA Re-evaluation Report Scope of Work
3.7 TUA Re-evaluation Report
3.7 TUA Re-evaluation Decision Meeting

6.4 Decision Meeting
6.5 Decision Document
7.2.3 Contaminant Fate and Transport Model Report
7.3.3 Groundwater Monitoring Well Network Report
7.3.4 Decision Meeting
7.3.5 Decision Document

8 Second Phase of Risk Assessment

🟦 Navy Work Completed
🟩 Future Work
* Non-AOC SOW deliverable

Sidebar 1: Red Hill Groundwater Protection Plan ("GWPP") and Administrative Order on Consent ("AOC")

Red Hill GWPP:

The Red Hill GWPP (DON 2008b; 2014) presents an integrated strategy to manage risks associated with potential inadvertent fuel releases from the tanks by implementing detection and mitigation measures. The Navy first developed the Red Hill GWPP in 2008 at DOH's request after previous environmental investigations (DON 1999; 2002; 2007) showed that past inadvertent releases had impacted the fractured lava rock (basalt) underlying (basal) groundwater and soil vapor beneath the Facility with petroleum hydrocarbons.

The GWPP provides for:

- Preventive inspection, maintenance, and repair in accordance with modified American Petroleum Institute 653 procedure.
- Leak detection and monthly soil vapor monitoring under the fuel storage tanks.
- Quarterly groundwater long-term monitoring in the Red Hill groundwater monitoring network.
- Contingency planning for response actions, including actions that would be required to remediate the basal drinking water aquifer if a large release of fuel were to migrate to the water table.

Generally, the GWPP is slated for updating every 5 years. The Navy updated the GWPP in 2009 and 2014, including modifications to comply with requirements of DOH's Emergency Hazard Evaluation as specified in their Hazard Evaluation and Emergency Response guidance (DOH 2018b). The AOC Parties have agreed that the next update will follow completion of work under AOC SOW Sections 6 and 7.

Red Hill AOC:

As a result of the January 2014 Tank 5 Release of 27,000 gallons of jet fuel following the tank's routine 3-year refurbishment and refilling process, the Navy and DLA (hereafter collectively, "the Navy") entered into an agreement with EPA Region 9 and DOH (the "AOC Regulatory Agencies") under Section 7003 (42 U.S.C. §6973) of the Resource Conservation and Recovery Act. The following signatories (collectively referred to as the "AOC Parties") formalized the *Administrative Order on Consent In the Matter of Red Hill Bulk Fuel Storage Facility*[12] in September 2015 (EPA Region 9 and DOH 2015):

- United States Environmental Protection Agency Region 9 ("EPA")
- Hawai'i State Department of Health ("DOH")
- Commander, Navy Region Hawaii (United States Department of the Navy)
- Defense Logistics Agency (United States Department of Defense)

The Red Hill AOC provides for the performance by the Navy of a release assessment, response(s) to release(s), and actions to minimize the threat of future releases in connection with the field-constructed bulk fuel underground fuel storage tanks, surge tanks, pumps, and associated piping, and on any property that may be affected now or in the future by petroleum or other substances released from the Facility.

The primary objectives of the Red Hill AOC are to:

1. Take steps to ensure that the groundwater resource in the vicinity of the Facility is protected.
2. Ensure that the Facility is operated and maintained in an environmentally protective manner.

The AOC's Attachment A Statement of Work (the "AOC SOW") outlines actions that the Navy must take, along with deadlines for completing each task. These actions are categorized in eight sections that address overall project management, tank infrastructure improvements, environmental investigation and remediation, and risk and vulnerability assessment.

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[12] EPA Docket No: RCRA 7003 R9-2015-01; DOH Docket No: 15 UST-EA-01.

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Sidebar 2: Key Agencies, Stakeholders, and Technical Experts Involved in Red Hill Matters

Four Parties to this Contested Case Hearing:

- **United States Department of the Navy:** Signatory (under Commander, Navy Region Hawaii) to the Red Hill AOC. The Navy is responsible for executing the work specified in the AOC SOW. The Navy Region Hawaii Command oversees all Navy supporting commands involved in the operation and maintenance of Red Hill.
- **State of Hawai'i Department of Health ("DOH"):** Signatory (under DOH's Solid and Hazardous Waste Branch) to the Red Hill AOC as one of two AOC Regulatory Agencies (with EPA) that oversee the Navy's execution of the requirements of the Red Hill AOC. DOH's mission is to protect and improve the health and environment for all Hawai'i residents. In its multiple roles regarding the Red Hill Facility, DOH:
    - Conducts this Contested Case Hearing.
    - Regulates USTs in Hawai'i, including the UST permitting program, both under State authority (Chapter 342L, HRS) and as EPA's delegated authority for implementation of federal UST requirements under the Resource Conservation and Recovery Act.
    - Oversees the Navy's execution of the Red Hill GWPP and (together with EPA) the Red Hill AOC.
    - Reviews permit applications for new monitoring wells for DLNR CWRM (see below).
    - Publishes State environmental screening levels for air, soil, soil vapor, groundwater, sediments, and fresh water including drinking water.
- **Sierra Club of Hawai'i:** Environmental group that submitted comments on the Navy's Draft Permit application on June 18, 2019, requesting that DOH deny the Permit and initiating this Contested Case Hearing.
- **City and County of Honolulu Board of Water Supply ("BWS"):** A Department of the City and County of Honolulu, created and authorized to manage, control, and operate the public drinking water system. BWS provides input on the Red Hill AOC regularly in the form of letters to the AOC Parties, participation in stakeholder meetings, legislative testimony, and community outreach. BWS submitted comments requesting DOH to deny the Navy's UST Permit and subsequently requested to intervene as a party in this Contested Case Hearing.

Other Relevant Entities:

- **Defense Logistics Agency ("DLA"), United States Department of Defense:** signatory (under DLA Energy) to the Red Hill AOC. As the Defense Department's executive agent for bulk petroleum, DLA executes the integrated materiel management responsibility for bulk petroleum owned by the U.S. Department of Defense.
- **United States Environmental Protection Agency ("EPA"):** signatory (under EPA Region 9's Underground Storage Tank Program Office) to the Red Hill AOC as one of two AOC Regulatory Agencies (with DOH) that oversee the Navy's execution of the requirements of the Red Hill AOC. EPA promulgates many of the environmental regulations authorized by Congress, including those related to USTs.
- The **Commission on Water Resource Management ("CWRM")** of the **State of Hawai'i Department of Land and Natural Resources ("DLNR"):** reviews and grants permits for new groundwater wells in the State of Hawai'i. Generally, CWRM manages the *use* and withdrawal of Hawaii's water, whereas DOH protects the *quality* of Hawaii's water.
- **United States Geological Survey ("USGS"):** executes an ongoing detailed groundwater level monitoring program (under its regional Science Center Hawai'i) on behalf of the Navy and participates in the Red Hill AOC Groundwater Modeling Working Group to provide feedback on modelling issues.
- **University of Hawai'i ("UH"):** engaged in a research partnership with the Navy under its College of Engineering and Applied Research Laboratory to develop innovative technology for improving tank maintenance and release detection and prevention procedures at the Facility.

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Sidebar 3: Key Terminology Used in This Report

Geology and Hydrogeology:

- **Saturated zone:** A water-bearing layer of rock or soil that yields water in a useable quantity. The body of water located in the saturated zone is called a groundwater ***aquifer.***
- **Unsaturated zone:** The subsurface zone above the groundwater aquifer. Occurs above the saturated zone. Also called the ***vadose zone.***
- **Basal groundwater aquifer:** The aquifer lying within the "base" of the geologic formation. In Hawaiʻi, these primary drinking water sources occur in the lava rock formations that form the base of each island. Basal aquifers consist of fresh water in contact with and 'floating' on the denser underlying infiltrated saltwater (Freeze and Cherry 1979). At Red Hill, the basal aquifer is more than 100 feet below each tank.
- **Strike and dip:** The orientation of a geologic feature, such as a lava flow. Strike and dip of a rock can influence groundwater flow directions.
- **Basalt:** The volcanic rock that forms the base of the Hawaiian Islands. Not related to the term "basal" (however, in Hawaiʻi, *basal* aquifers happen to exist within the *basalt*). There are several types of basalt (aʻa, pāhoehoe, and clinker) that exhibit different types of properties relative to groundwater flow.
- **Clinker:** Gravel- and cobble-size rubble that is typically formed at the top and bottom of massive lava flows. Unlike massive basalt, which may help to impede downward flow of fluids, clinker is extremely permeable and has the potential to provide preferential pathways, particularly in essentially lateral directions, for migration of groundwater or other fluids.
- **Saprolite:** Highly impermeable weathered rock material, similar to clay, that commonly occurs in Hawaiʻi. In valleys, saprolite is usually overlain by sedimentary deposits of valley fill. Its low permeability can impede the flow of groundwater and the transport of contaminants dissolved in groundwater.
- **Valley fill**: Sedimentary deposits in valleys such as Hālawa and Moanalua that were formed as a result of fluvial erosion. Valley fill deposits are typically relatively low permeability and underlain by saprolite.

Chemistry:

- **Total petroleum hydrocarbons ("TPH"):** a test that measures the amount of carbon compounds in groundwater; often used as a screening tool to check whether petroleum hydrocarbons might be present (Zemo 2016).
- **Light nonaqueous-phase liquid ("LNAPL"):** petroleum-based fuel (such as the jet fuels stored at the Facility) that is lighter than and not very soluble in water**;** also called fuel, petroleum "product," or "free-phase" petroleum. When LNAPL is released in a quantity and in an environment that allows it to travel down through the soil and rock to a groundwater aquifer, the LNAPL floats on top of the groundwater, where its thickness can generally be measured in a monitoring well, if present.
- **Dissolved constituents:** chemicals in the parent fuel that are dissolved in groundwater. The ability of most petroleum fuels to dissolve in water is limited, and concentrations are often measured on the order of parts per million or parts per billion. Dissolved constituents are what are measured in Red Hill analytical groundwater samples.
- **Natural source-zone depletion ("NSZD")** and **monitored natural attenuation ("MNA"):** remediation technologies that allow naturally occurring processes such as bioremediation, oxidation, and volatilization to reduce the volume and toxicity of petroleum releases to the environment (ITRC 2009). Here, NSZD focuses on petroleum "product" in the lava bedrock beneath the tanks, whereas MNA focuses on dissolved constituents in the groundwater.

Infrastructure:

- **Tank farm:** The immediate area containing the Facility's 20 large underground fuel storage tanks, approximately 2,000 feet × 400 feet in area.
- **Near-tank wells** and **perimeter wells:** At the Red Hill Facility, three ***near-tank*** basal groundwater monitoring wells are situated within the Facility access tunnels, underneath the 20 fuel storage tanks, and 16 ***perimeter wells*** (referred to in some reports as "outlying wells") are installed outside the tank farm. Together, these wells compose the Red Hill groundwater monitoring network (*see* Figure 1).

2. Operation of the Facility is Currently Protective of Human Health and the Environment

All the available environmental data, which are summarized in this section, indicate that operation of the Facility is currently protective of human health and the environment. Importantly:

- Fuel product has *never* been measured in *any* groundwater monitoring or supply well.
- The Navy's drinking water supply well, which is tested frequently, remains safe.
- BWS has confirmed that groundwater at its nearing drinking water supply well also remains safe.[13]

Environmental data gathering at Red Hill began in earnest approximately 20 years ago when the first groundwater monitoring well (RHMW01) was installed; since then, the overall environmental monitoring network has expanded considerably. By the mid- to late-2000s, sampling of the lava bedrock (basalt) under the tanks was conducted, a network of vapor monitoring locations was installed beneath the USTs, and the groundwater monitoring well network was expanded to encompass six wells. Since 2014, the Navy (with oversight by and approval from EPA and DOH) has installed an additional 13 monitoring wells (now totaling 19 wells), several of which are innovative multilevel wells that are thought to be the first of their kind in the State of Hawai'i. These multilevel wells can monitor multiple discrete zones to provide a three-dimensional understanding of the subsurface geology, groundwater hydraulics (flow), and groundwater chemistry.

Extensive evaluation of the environmental monitoring data using a wide variety of methods and approaches, including state of the art analyses, has fed into the development of a complex conceptual site model ("CSM") and a set of groundwater flow models describing a range of potential flow conditions as a result of various pumping scenarios. This work is summarized in a host of reports which provide raw and analyzed data and associated evaluations that establish that operation of the Facility is currently protective of human health and the environment, including the finding that natural processes, such as natural source-zone depletion and monitored natural attenuation, have prevented past releases from impacting the drinking water. Section 4 of this report lists some of the most relevant reports prepared pursuant to the GWPP and the AOC, incorporating them into the record in this Contested Case, and provides links to regulator websites where the reports may be downloaded.

The monitoring well network is evaluated by the Navy and the regulatory agencies on an ongoing basis for indications of groundwater flow and the presence and absence of petroleum-related constituents in the regional groundwater and will continue to be for the foreseeable future—far beyond the duration of the 5-year UST Operating Permit. Indeed, even as this Contested Case Hearing proceeds, quarterly groundwater monitoring is ongoing, monthly soil vapor testing is proceeding, and additional wells are being drilled in this hydrogeologically complex environment (at no small cost) to further expand the Navy's groundwater monitoring well network (*see* Figure 4). While all the wells are expected to be monitored for the foreseeable future, many of the wells are expected to be highlighted for use as "sentinel" wells in the future update to the GWPP in order to enable warnings before any hypothetical future release could impact water supply wells. These environmental monitoring systems, as well as the other Layers of Protection (*see* Sidebar 14) maintained by Facility operators, serve to prevent and detect potential releases, confirm that ongoing operations are being conducted in a safe manner, and would provide notice to minimize impacts of hypothetical future releases.

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[13] Letter from BWS to DOH entitled "Honolulu Board of Water Supply Request for Contested Case Hearing Concerning the United States Department of the Navy's UST Permit Application for Red Hill Bulk Fuel Storage Facility," Oct. 29, 2019, *available at* https://www.boardofwatersupply.com/bws/media/redhill/ocr-red-hill-bws-request-for-contested-case-hearing-2019-10-29.pdf, at 2 ("testing conducted to date indicates that water provided by BWS drinking water wells remains compliant with standards for safe drinking water").

Figure 4: Expansion of the Red Hill Groundwater Monitoring Well Network Following the 2014 Tank 5 Release

2005–2008	2009–2013	2014–2015	2016	2017	2018	2019	2020	[2023]	No. of Wells
								RHMW23	27
								RHMW22	26
								RHMW21	25
								RHMW20	24
								RHMW18	23
								RHMW17	22
								RHMW12A	21
								RHMW01R	20
							RHMW19	RHMW19	19
							RHMW16A	RHMW16A	18
							RHMW15	RHMW15	17
						RHMW15	RHMW14	RHMW14	16
						RHMW14	RHMW13	RHMW13	15
					RHMW11	RHMW11	RHMW11	RHMW11	14
				RHMW10	RHMW10	RHMW10	RHMW10	RHMW10	13
			RHMW09	RHMW09	RHMW09	RHMW09	RHMW09	RHMW09	12
			RHMW08	RHMW08	RHMW08	RHMW08	RHMW08	RHMW08	11
			RHMW07	RHMW07	RHMW07	RHMW07	RHMW07	RHMW07	10
			RHMW06	RHMW06	RHMW06	RHMW06	RHMW06	RHMW06	9
		RHMW07	OWDFMW01	OWDFMW01	OWDFMW01	OWDFMW01	OWDFMW01	OWDFMW01	8
		RHMW06	HDMW2253-03	HDMW2253-03	HDMW2253-03	HDMW2253-03	HDMW2253-03	HDMW2253-03	7
	RHMW05	RHMW05	RHMW05	RHMW05	RHMW05	RHMW05	RHMW05	RHMW05	6
RHMW04	RHMW04	RHMW04	RHMW04	RHMW04	RHMW04	RHMW04	RHMW04	RHMW04	5
RHMW03	RHMW03	RHMW03	RHMW03	RHMW03	RHMW03	RHMW03	RHMW03	RHMW03	4
RHMW02	RHMW02	RHMW02	RHMW02	RHMW02	RHMW02	RHMW02	RHMW02	RHMW02	3
RHMW01	RHMW01	RHMW01	RHMW01	RHMW01	RHMW01	RHMW01	RHMW01	RHMW01	2
RHMW2254-01	RHMW2254-01	RHMW2254-01	RHMW2254-01	RHMW2254-01	RHMW2254-01	RHMW2254-01	RHMW2254-01	RHMW2254-01	1

Key dates:

January 2014:	Tank 5 Release
September 2015:	Red Hill AOC signed

🟩	Planned Monitoring Well (location and installation date subject to change)
🟦	Post-2014 Tank 5 Release (2015–2020)
⬜	Pre-2014 Tank 5 Release (2005–2014)

Exhibit N-6I

2.1 NO THREATS TO HUMAN HEALTH OR THE ENVIRONMENT

Appendix B summarizes the vast amount of environmental monitoring data that confirm in no uncertain terms that there are no current impacts to human health or environmental receptors and that the limited groundwater impacts are confined to an area immediately beneath the tanks and are not expanding. Specifically:

- Table B-1 summarizes the 913 measurements made to check whether any petroleum product was present at the groundwater surface in any of the monitoring wells over the course of more than 15 years. As shown in the table, no product was ever measured in any well, including near-tank and perimeter wells, during and after the 2014 Tank 5 Release (this includes near-tank well RHMW02, which is in very close proximity to Tank 5).
- Table B-2 summarizes the results of the analyses of over 650 primary groundwater samples collected over more than 15 years, for which 6,800 analyses of the chemicals of potential concern identified by the regulators were conducted. The data clearly show that most of the wells are not impacted by operation of the Facility over the last 80 years. Most of the impacts are limited to a few analytes (primarily total petroleum hydrocarbons [TPH], naphthalene, and methylnaphthalenes) that are fairly consistently detected toward the middle of the tank farm, most commonly in well RHMW02. These analytes are all organic hydrocarbons that undergo bioremediation and other natural attenuation processes.
- Table B-3 further summarizes the results of long-term groundwater monitoring and shows that exceedances of regulatory screening levels have been primarily limited to a few analytes in monitoring well RHMW02 (located near Tank 5) and, to a lesser extent, RHMW01 (located near Tank 1). As can be seen in the last columns of this table, no analyte has ever exceeded the EALs in any of the perimeter wells,[14] including the nearby drinking water well, with the exception of TPH in some samples taken from the Oily Waste Disposal Facility, which is a separate release site overseen by the DOH, and one anomalous TPH result from the irregularly constructed deep monitor well (HDMW2254-01) that CWRM designed and installed in the past to monitor quantities of water deeper in the aquifer (not aquifer chemistry). Table B-3 thus highlights the fact that the only EAL exceedance in any of the perimeter well samples was for TPH, not any of the actual chemical constituents associated with the fuel stored at the Facility. As described below, laboratory TPH analyses differs from the other analytes in that it does not identify any particular carbon compound that may be present. Further analysis of groundwater chemistry and TPH has indicated that the rare and sporadic TPH detections in some perimeter wells are all associated with well installation and sampling and laboratory methods rather than fuel constituents.
- Section 2.1.1 explains how regulatory screening levels are established with factors of safety to ensure protection of human health and the environment, and Section 2.1.2 discusses the peculiarities and relevance of TPH analyses.
- Composite Figure B-1 (Appendix B) shows that there is no evidence that any dissolved petroleum impacts are increasing over the life of the groundwater monitoring program. Cumulatively, the figures also show that the limited impacts observed near the tank farm (in wells RHMW02 and, to a lesser extent, RHMW01) are not "spreading" to other areas. Rather, the data suggest that impacts are confined close to the tank farm and are naturally attenuating.

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[14] The "perimeter wells" are the 16 groundwater monitoring wells other than the 3 wells in the immediate vicinity of the Facility's fuel storage tanks (i.e., all wells other than RHMW01, RHMW03, RHMW03; *see* Figure 1).

Exhibit N-6I

The raw data underlying the summary provided in Appendix B is available for public review in the quarterly groundwater monitoring and other reports. The most recent quarterly groundwater monitoring report, which includes cumulative groundwater data, is incorporated into this report by reference (*see* Section 4).

Perhaps most importantly, groundwater chemistry data in the vicinity of the Navy's Red Hill Shaft drinking water supply well—the nearest source of drinking water for human receptors—confirms that the groundwater does not pose a threat to human health. The groundwater at Red Hill Shaft, tested for petroleum impacts quarterly at a minimum, has never had any contaminant detected at concentrations above the regulatory screening levels, which were designed by DOH to be categorically protective of human health and the environment, as described below in Section 2.1.1.[15] Although groundwater under parts of the tank farm is moderately impacted by historical (pre-2005) petroleum releases, as discussed in the following subsections, these impacts are not seen at the Red Hill Shaft drinking water source or other perimeter wells. Additionally, all available information confirms that groundwater at the next closest drinking water supply well (0.8 mile northwest of the tank farm)—BWS' Hālawa Shaft—also remains safe.

2.1.1 Conservative and Protective Regulatory Screening Levels

The potential harm posed to humans and the environment can be preliminarily assessed by comparison of laboratory analyses to the highly conservative and protective screening levels established by Federal and State environmental regulatory agencies. Here, the Red Hill groundwater monitoring program screens data against DOH's Tier 1 EALs (DOH 2017, Vol. 1 at 2-1)[16]. According to both EPA and DOH, these are not enforceable limits; rather, these screening levels are highly conservative (i.e., protective) concentrations that are specifically set to screen concentrations of chemicals in soil, soil vapor (i.e., soil gas), and groundwater, considering a wide variety of potential exposure routes, to determine whether there might be appreciable risks.[17,18] According to DOH, concentrations *below* the EALs are used to "quickly screen out"

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[15] In addition to the groundwater testing discussed in this report, there is an extra layer of protection for the drinking water systems. After water is pumped from Red Hill Shaft, it undergoes treatment by chlorination and (in accordance with military drinking water protocol) fluoridation and is then tested again for compliance with State drinking water standards before distribution to the Joint Base Pearl Harbor-Hickam water system (*see* Section 2.3 (a)). While certain analyses (after chlorination) once exceeded exceed EALs for TPH, subsequent analyses confirmed that the TPH was solely the result of reaction of the *chlorinated water* with a laboratory solvent used in the TPH analysis, and was not reflective of aquifer conditions or otherwise related to fuel constituents.

Water extracted from BWS' supply wells (including Hālawa Shaft, which is approximately twice as far from the tank farm as the Navy's well) is also tested regularly for compliance with State drinking water standards, and BWS has confirmed that the groundwater they use is also safe.

[16] Table D-1b. Groundwater Action Levels (Groundwater IS a current or potential drinking water resource and surface water body IS NOT located within 150m of release site) (DOH 2017, Vol. 2 App. 1 at 37). Where an EAL for a given chemical constituent is not established, EPA Regional Screening Levels (EPA 2020) are used for screening Red Hill groundwater concentrations.

[17] Environmental risk assessment uses a risk-based exposure model to first identify the sources and migration pathways of contaminants, and then evaluate the exposure media (e.g., groundwater) and completeness of pathways for human and ecological receptors potentially exposed to these media (*see* Sidebar 4). Among the potentially complete exposure pathways identified at Red Hill, the primary one is offsite human residents using tap water sourced from the Red Hill Shaft water supply well, due to its proximity to the Facility's fuel storage tanks, or, less likely, via BWS' Hālawa Shaft. These receptors could potentially be exposed to chemicals in tap water via direct ingestion and dermal contact, and via inhalation while showering or bathing.

As noted in Sidebar 4, exposure by ecological receptors is considered incomplete or insignificant, such that no potential for risk to ecological receptors has been identified In addition, the primarily human health-based EALs are set to levels that are also protective of ecological receptors.

[18] The Tier 1 EALs used here actually represent the *worst case EAL* calculated for each of the following exposure routes, considering data and studies by EPA and other experts: ingestion of drinking water; discharges to aquatic

"contaminants that do not pose potential concerns"[19] (the EALs are, therefore, commonly referred to as regulatory screening levels, as they are used to "screen out" low-level impacts that do not pose any potential concerns). Even concentrations above the EALs do not necessarily pose a threat:

> "Tier 1 EALs are concentrations of contaminants in soil, soil gas and groundwater above which the contaminants *could* pose a *potential* adverse threat to human health and the environment. … Exceeding the Tier 1 EAL does not necessarily indicate that contamination at the site poses environmental hazards. It does, however, indicate that additional evaluation is warranted. This can include additional site investigation and a more detailed evaluation of the specific, tentatively identified hazards" (DOH 2017, Vol. 1 at 1-4) (emphases added).

DOH's Drinking Water Toxicity EALs are based on EPA Primary Maximum Contaminant Levels (or equivalent) that are allowable by law at the drinking water tap and are considered protective of human health if present in drinking water. In setting these levels, DOH conservatively assumes the continuous use of an impacted water source for 350 days a year for a period of 6 years (DOH 2017). DOH updates the EALs periodically to reflect advances in the understanding of a chemical's or compound's toxicity and physiochemical properties, and the Red Hill groundwater and drinking water monitoring programs always use the most updated EALs in reporting.

Comparison of the data from the long-term groundwater monitoring program to the EALs, as summarized in Appendix B, confirms that the drinking water does not pose even the potential for risk, and that operation of the Facility remains protective of human health and the environment.

2.1.2 Total Petroleum Hydrocarbons ("TPH")

As indicated in Appendix B Table B-3, while there have not been a lot of detections of analytes during groundwater monitoring, the bulk of detections have been identified as TPH. TPH, however, differs from all other analytes in the program because the latter are actual chemicals with known composition and risk profiles. TPH, by contrast, is simply a measure of the total amount—not the types of—carbon containing compounds that are present. Thus, the components of any measured "TPH" may or may not be fuel related and may not even be hydrocarbons (Zemo 2016). In addition, there is no regulatory mandated procedure for analysis of TPH, with every laboratory conducting analysis by slightly different methodologies that should be aligned with regulatory guidance. As might be expected, different carbon compounds can pose a wide variety of risk, ranging from essentially none to significant. As a result, unlike with actual identifiable chemicals, calculation of risk for TPH involves making assumptions regarding the actual composition of the carbon-based mixture. Thus, TPH is more properly understood to be a screening-level measure of *potential* petroleum impacts to groundwater (*see* Sidebar 5).

Consequently, DOH has stated in guidance that the "use of default, carbon range-weighted screening levels for bulk TPH in soil, water, air and soil vapor allows for rapid screening of existing site data. Care should be taken, however, to ensure that the nature of petroleum-related contamination at the site corresponds reasonably well with assumptions used to develop the screening levels."[20] According to DOH, low "Concentrations of TPH in groundwater samples <100 µg/L [parts per billion] in the absence of silica gel cleanup [Sidebar 5] assumed to represent background 'noise' associated with algae and other organic matter

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surface water; vapor intrusion; and gross contamination (i.e., taste, odor, and nuisance). DOH (2017), *Evaluation of Environmental Hazards at Sites with Contaminated Soil and Groundwater,* § 4.4.

[19] *Technical Guidance Manual* § 2.4.1 (emphasis added) (DOH 2018b).

[20] DOH (2018a) at 13.

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and not considered to be reliable indicators of petroleum-related compounds."[21] Thus, due to the uncertainty inherent in TPH analyses, DOH recommends that a site-specific "review of gas chromatograms … can greatly assist in … evaluation" of "the nature of petroleum product(s) released at the site and the reliability of the TPH data."[22] Because TPH results (despite the name of the test) are not actually specific to petroleum,[23] many regulatory guidance documents recommend evaluation of chromatograms to determine whether the material quantified as TPH reflects petroleum.[24] In accordance with these recommendations, the Navy conducted an extensive evaluation of chromatograms which is described below.

The Navy has undertaken extensive analysis of the groundwater chemistry, including TPH, so that groundwater chemistry can be appropriately evaluated. At Red Hill, TPH has been detected in some of the near-tank wells, but only sporadically detected at the Red Hill Shaft sampling point, and there only at concentrations below the EALs. Moreover, detailed chromatogram and other analyses were performed for all the Red Hill data, consistent with DOH guidance, and those analyses showed that the carbon compounds identified as TPH detections in the perimeter wells, including Red Hill Shaft, are not fuel related. Relatedly and importantly, none of the actual discrete petroleum-related signatures that are part of laboratory chromatographic analysis in the samples collected from the drinking water source at Red Hill Shaft or any of the other perimeter wells demonstrate impacts from fuel-related constituents. Thus, impacts to groundwater appear to be limited to the immediate vicinity of the tank farm, and conditions do not currently pose a threat to human health or the environment.

While there have been sporadic low-level detections of TPH at Red Hill Shaft, these detections have been found to be not related to fuel stored at the Facility, but were instead introduced by the chemicals used by the laboratory to conduct the testing. The Navy recently provided the AOC Regulatory Agencies a detailed evaluation of all available TPH chromatograms in the Red Hill groundwater monitoring data set in the perimeter wells, which is included in Appendix C of this document (DON 2020c).

The evaluation concluded:

- **Near-tank wells.** TPH analysis of groundwater samples collected from the three monitoring wells underneath the fuel storage tanks (RHMW01, RHMW02, and RHMW03) exhibit a pattern of fuel degradation byproducts and (for one of these wells, RHMW02) dissolved fuel constituents in groundwater. These impacts are most likely related to pre-2005 releases and do not show an overall increasing pattern over the course of the groundwater monitoring program.
- **Perimeter wells.** There is no evidence of a fuel impact to any perimeter well, including Red Hill Shaft.

Sidebar 5 further details the methodology and challenges associated with analyzing for TPH.

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[21] DOH (2018a), *Collection and Use of Total Petroleum Hydrocarbon Data for the Risk-Based Evaluation of Petroleum Releases,* at 41; *see also* page 12 (recommending comparison of TPH data to "to carbon range-weighed screening levels for TPH based on the assumed, carbon range composition of the specific type of petroleum present" [emphasis added]); *accord* (DON 2019a; 2020b; DOH 2018a; Zemo 2016; SFB RWQCB 2016).

[22] DOH (2018a) at 13; *see also* ITRC (2018) ("Reviewing chromatograms for all TPH detections at any concentration is useful for reducing the uncertainties inherent to TPH analysis").

[23] For example, according to DOH (2018a, at 14), groundwater TPH results can be "biased" (i.e., misleading) due to the presence of "dissolved organic carbon … and other non-petroleum, organic material in samples."

[24] See, e.g., DOH (2018a) at 12–13 (DOH recommends a "review of gas chromatograms" to evaluate "the nature of petroleum product(s) released at the site and the reliability of the TPH data.").

Exhibit N-6I

2.2 NO GROUNDWATER IMPACTS OUTSIDE OF TANK FARM

The environmental data and several studies conducted thereon confirm that although there are impacts to the groundwater in the immediate vicinity of the tanks from historical releases prior to 2005, those impacts are naturally attenuating (which includes but is not limited to natural bioremediation as naturally occurring microbes metabolize the hydrocarbons), are not spreading, and there have been no known fuel-related impacts to *any* of the 16 perimeter wells or regional water supply wells due to 80 years of operation of the Facility. Importantly, the Navy has conducted over 6,800 analyses of the "chemicals of potential concern" in samples collected from 19 groundwater monitoring wells as of the third quarter of 2020. Of these greater than 6,800 analyses, only 16 individual laboratory results have ever exceeded DOH EALs in perimeter wells, all of which were TPH-d. Of those 16, 12 occurred prior to the 2014 Release and only 4 occurred after the 2014 Release. Moreover, all but one of these occurred at the Oily Waste Disposal Facility, which is a separate site that had its own historical releases unrelated to releases from the tanks (DON 1996; 2000) and is now the subject of a different investigation.

Detailed analysis of the chemistry and associated chromatograms (as described in several Navy reports[25] as well as the TPH chromatogram memo[26] included as Appendix C) indicated that while there is evidence of moderate impacts primarily to RHMW02 and, to a much lesser degree, RHMW01, there is no indication of fuel-related impacts to perimeter wells. While certain perimeter wells did have a relatively small frequency of TPH detects, careful analysis of the chemistry and chromatograms indicates that these detects are not fuel related and are associated with chemicals due to well installation, sampling, and chemicals associated with the laboratory analysis itself. These types of TPH detects are not uncommon when analyzing for very low TPH concentrations, and many regulatory agencies, including DOH, caution against relying on low concentration TPH data without careful analysis, such as the Navy has done out of an abundance of caution. In fact, most environmental projects do not analyze for TPH at these low concentrations, for the very reasons mentioned above.

Other discrete studies and evaluations that concluded impacts were limited to the vicinity of the tank farm include:

- **Lines of Evidence for Lack of LNAPL Impacts.** As described in the Red Hill CSM report (DON 2019a, at Appendix B.8), which is incorporated by reference, all groundwater chemistry data were carefully analyzed to better understand the potential impacts to groundwater (*see* Sidebar 7). Twenty-one independent lines of evidence show that there is no evidence of impacts to groundwater from the 2014 Release and no evidence of impacts to perimeter wells from any historical releases.
- **Multiple Impact Factors Analysis.** In an effort to further analyze groundwater chemistry, EPA's expert consultant suggested conducting a multiple impact factors analysis during a March 2019 AOC Technical Working Group Meeting. As described in the CSM report (DON 2019a, at Appendix I), a detailed mathematical multiple impact factor analysis was conducted on the substantial

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[25] DON (2019a). *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; June 30, 2019, Revision 01.*

DON (2018b). *Groundwater Protection and Evaluation Considerations for the Red Hill Bulk Fuel Storage Facility, Joint Base Pearl Harbor-Hickam, O'ahu, Hawai'i; July 27, 2018, Revision 00.*

DON (2020b). *Investigation and Remediation of Releases Report, Red Hill Bulk Fuel Storage Facility, Joint Base Pearl Harbor-Hickam, O'ahu, Hawai'i; March 25, 2020, Revision 00.*

[26] DON (2020c). *Evaluation of Chromatograms for Understanding TPH Detections in Monitoring Wells, Red Hill Bulk Fuel Storage Facility, Joint Base Pearl Harbor-Hickam, O'ahu, Hawai'i.*

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groundwater chemistry data set. This study also showed that none of the chemistry in perimeter monitoring wells was similar to RHMW02, the well with highest dissolved fuel concentrations.

- **TPH Chromatograms Evaluation.** As described in the foregoing, a thorough evaluation of available chromatograms was conducted for samples with detections of TPH to determine whether those detections were indicative of potential fuel impacts from the Facility (DON 2020c). As part of this effort, chromatograms were reviewed to see if the chromatographic signature was related to chromatographic patterns relative to LNAPL fuel, dissolved fuel constituents, and biodegraded fuel. The key finding was that "there have been no observable impacts to perimeter wells as a result of past releases from the Facility." The study also concluded that TPH results at levels below 100 parts per billion (or near the method detection limit) is not a reliable indicator of fuel contamination, due to various factors such as over-integration of baseline noise and introduction of artifacts, as described in DOH's (2018a) guidance. Finally, the near-tank monitoring wells (RHMW01, RHMW02, and RHMW03) were confirmed to exhibit a pattern of fuel degradation byproducts, and RHMW02 also had dissolved fuel constituents.
- **No LNAPL Detections.** *No* distinct fuel product (LNAPL) has *ever* been measured in *any* Red Hill groundwater monitoring well (including those closest to the tanks) as part of any groundwater sampling event (*see* Sidebar 6 and Appendix B, Table B-1).

2.2.1 Dissolved Constituent Impacts Are Confined Near the Tank Farm

Impacts to groundwater from dissolved constituents are confined close to the tank farm, where natural attenuation and bioremediation processes are actively protecting the groundwater and preventing dissolved-phase chemicals from migrating to perimeter monitoring wells and to Red Hill Shaft or other water supply wells. Scientific studies conducted by the Navy (*see* footnote 25) indicate that biodegradation and other natural attenuation processes are protecting the groundwater.

- **Natural Source Zone Depletion.** Above the groundwater at Red Hill, a process known as NSZD is retaining and breaking down the LNAPL, impeding its flow toward the groundwater. This process was quantified by different studies, which were submitted to a leading journal, subject to scientific peer review, and recently accepted and published (McHugh et al. 2020) (the study is reproduced in Appendix D of this report). This natural process is further accelerated at Red Hill by operation of the Facility's tunnel ventilation system, which replenishes high concentrations of oxygen in the surrounding rock, which naturally occurring bacteria utilize to bioremediate residual fuel from past releases.
- **Monitored Natural Attenuation.** That fraction of historical fuel releases that made its way to the groundwater as dissolved constituents is subject to the well-documented and scientifically understood process of MNA (*see* Sidebar 8). This process acts to slow down, immobilize, and break down dissolved-phase hydrocarbons in groundwater.

All these processes attenuate fuel constituents, help immobilize constituents in groundwater, and explain why impacts have not been seen in the perimeter wells. These processes will be further analyzed under DOH and EPA review as part of the contaminant fate and transport modeling effort planned for in the future under the Red Hill AOC. Key concepts that are known to be operating will be further characterized, including:

- **Holding Capacity.** The (basaltic) lava rock formation below the tank and above the groundwater has a significant *holding capacity* (roughly analogous to a sponge), which is described in detail in the vadose zone retention capacity calculations in DON (2018b) (*see* Sidebar 9 and Sidebar 10). This holding capacity helps to impede released fuel from impacting groundwater by retaining the fuel in fractures and pore space of the rock, and this process is further enhanced by the presence of relatively low-permeability geological layers known to be present in Red Hill, which further impede the downward flow of hydrocarbons.

- **Plume Stability.** The dissolved-constituent impacts are confined to groundwater near the tanks and do not appear to be increasing over the life of the groundwater monitoring program. In terms commonly used in the environmental field, this means that the impacts are "stable," "attenuated," and not migrating toward any human or ecological receptors (*see* Sidebar 8).

2.3 RED HILL'S SUBSTANTIAL ENVIRONMENTAL DATA COLLECTION

Red Hill is probably the most extensively studied UST system in the State of Hawai‘i with the largest environmental data set of any UST system in the State. The Navy has collected a plethora of data that have greatly expanded understanding of the geology and hydrogeology at Red Hill, as well as conditions in the underlying groundwater aquifer, which has enabled the studies and conclusions briefly summarized above. The data serve as the foundation for the Navy's AOC environmental investigation findings and will continue to do so as more data are collected and investigations, evaluations, and decision making continue (*see* Section 3). Therefore, it is worth noting the variety of data sources and monitoring locations that have been and continue to be used to ensure that operation of the Facility remains protective of human health and the environment.

Figure 5 overlays all the features and testing locations described below to show the breadth and extent of data considered for the Navy's various environmental studies. This sizable dataset has allowed the Navy to:

- Refine the understanding of the local and regional geology and geohydrology.
- Conduct hydraulic analyses related to groundwater flow.
- Comprehensively evaluate groundwater chemistry.
- Analyze and quantify naturally occurring conditions and processes (NSZD and natural attenuation).
- Develop potential remedial alternatives for hypothetical future fuel releases.

Figure 6a through Figure 6l present different types of data and monitoring locations that have been employed (and which collectively compose Figure 5), which are briefly summarized below.

(a) **Drinking Water Supply Wells.** The three closest drinking water supply wells to the Facility are Red Hill Shaft, Hālawa Shaft, and the Moanalua Wells (Figure 6a).

(1) Red Hill Shaft (Hawai‘i Well Identification [ID] 2254-01) is a potable water pumping station operated by Naval Facilities Engineering Systems Command, Hawaii's Utilities and Energy Division. The pumping station is located within the Facility's lower tunnel system approximately one-half mile *makai* (seaward) of the Facility tanks. The station pumps groundwater from a water development tunnel (also called an infiltration gallery) that extends from the pumping station to within 1,530 feet of the nearest Facility fuel storage tank. The pumping station supplies the Joint Base Pearl Harbor-Hickam water distribution system, which serves approximately 65,200 military workers, members, and their families.

(2) Hālawa Shaft (2354-01) is a municipal water supply well with an associated water development tunnel operated by BWS located approximately 4,400 feet northwest of the tank farm. The pumping station is located in an underground pump room approximately 150 feet below ground. Groundwater is pumped from a water development tunnel to provide municipal drinking water for O‘ahu.

(3) Moanalua Wells 1 (2153-10), 2 (2153-11), and 3 (2153-12) are municipal water supply wells operated by BWS, located approximately 6,650 feet south of the Facility tanks. There is no evidence of groundwater flow from Red Hill toward these wells.

(b) **Groundwater Monitoring Locations.** Since the 2014 Tank 5 Release, the Navy has expanded its basal aquifer monitoring well network from six to currently 19 wells in the Red Hill and South Hālawa Valley area (Figure 6b), with additional wells currently under construction. The Navy plans to further expand the network to a total of at least 27 wells including in North Hālawa Valley by 2023. Beyond helping to ensure that drinking water remains safe through continued, expanded monitoring of groundwater, installation of each new well provides additional information about geologic, geophysical, and hydrogeologic conditions. This information supports the understanding both of impacts of past fuel releases and groundwater flow and contaminant fate and transport.[27] All groundwater monitoring wells in the Red Hill network are sampled quarterly at a minimum; results are reported to DOH in accordance with the Red Hill GWPP. The current groundwater monitoring network is shown in Sidebar 11 and described in Sidebar 12. Results of groundwater monitoring to date are summarized in Section 2. The Navy's planned expansion of the monitoring network is presented in Section 3.1.4. During well construction activities, the Navy collected rock cores from all borings and potable water and unconsolidated material (i.e., soil) samples to monitor the integrity of the well installations and the presence of any subsurface contamination existing above the groundwater table.

(1) *Multilevel Wells.* Of the groundwater monitoring wells, four are innovative multilevel wells with multiple discrete sampling zones extending deep into the aquifer that are thought to be the first of their kind in Hawaiʻi. Each multilevel well has multiple sampling ports installed at different levels in the borehole, enabling investigators to assess conditions at various depths and establish a vertical profile in a single areal space. Collecting the same information from single-level conventional wells would require clusters of individual wells. The acquired data have enabled investigators to better define the nature of subsurface hydrogeology in the valleys and thus support the groundwater flow and contaminant fate and transport modeling efforts under the AOC SOW, as well as the overall Red Hill groundwater monitoring program. Data from these multilevel wells suggest that: groundwater conditions in Hālawa Valley create a hydrodynamic barrier to LNAPL flow toward BWS wells and may also impede the flow of dissolved constituents; upwelling of deeper groundwater is not important when investigating the Facility; and there are no indications of impacts to deeper aquifer zones.

(c) **Test Boring RHTB01.** The Navy drilled this test boring in 2019 to evaluate the nature of the subsurface and extent of valley fill and weathered basalt in the vicinity of Hālawa Deep Monitor Well (HDMW2253-03) in South Hālawa Valley (Figure 6b). DLNR had installed the Hālawa Deep well in 2000 to monitor the deep fresh water–saltwater interface (where the base of the fresh water aquifer transitions to saltwater), rather than environmental conditions related to Red Hill. The test boring provided additional lithologic and geophysical information, including (1) enabling direct correlation of observed geologic conditions with interpreted results of the

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[27] In 2017, BWS installed a groundwater monitoring well (BWS well no. BWS2253-J1; State Well No. 3-2253-006) near the Facility border west of onsite Red Hill monitoring well RHMW09 (*see* Figure 1). Despite repeated Navy requests made at AOC Sections 6 and 7 meetings, BWS to date has not provided the Navy any water level or analytical data for this well to incorporate in the Navy's evaluation of Red Hill groundwater monitoring results, indicating to the Navy instead that the data are under evaluation. To date, BWS has not reported any petroleum impacts to Hālawa Shaft.

Navy's 2017 subsurface structural geology survey transect conducted along that location for its AOC environmental investigation (*see* Item (f)), and (2) improving the understanding of the presence and extent of valley fill and saprolite in South Hālawa Valley, and whether those geologic formations extend below the approximate elevation of the regional basal aquifer. The borehole was not converted to a monitoring well due to its proximity to the Hālawa Deep well. This borehole was also fitted with instruments that provide additional data regarding hydraulic conditions within the valley fill, saprolite, and underlying unweathered basalt volcanics.

(d) **Oily Waste Disposal Facility Monitoring Wells.** The Oily Waste Disposal Facility, located approximately 0.6 mile west and topographically downgradient of the Red Hill Facility, was constructed in the 1940s as a collection point for oily wastewater generated by the cleaning of Red Hill's fuel storage tanks. A series of two reclamation and disposal pits were constructed in the same approximate location and used intermittently from 1943 until 1986, when operations ceased. Several monitoring wells were installed at the site as part of environmental investigations in the 1990s and early 2000s (Figure 6c). The Navy incorporated the geologic and water level data from the boring logs into the CSM. One monitoring well from the earlier environmental investigations (now referred to as OWDFMW01) was added to the Red Hill groundwater monitoring network in 2016.

(e) **Groundwater Level Data Evaluation.** Since 2017, the USGS, on behalf of the Navy, has been executing a detailed groundwater level monitoring program (synoptic study). The USGS has deployed water level instruments (known as transducers) in conventional wells and multilevel wells at the Facility and in the surrounding vicinity (Figure 6d). The Navy initiated the synoptic study to provide data for development of both the CSM and groundwater flow modeling. Data derived from the synoptic study have been used extensively for both purposes.

(f) **Subsurface Structural Geology Surveys.** The Navy conducted subsurface structural geology surveys throughout the Red Hill area in December 2017 to better define subsurface conditions and hydrogeologic boundaries beneath Red Hill, North Hālawa Valley, South Hālawa Valley, and Moanalua Valley (DON 2018a). Results of nine acquired subsurface structural geologic profiles (Figure 6e) showed that valley fill sediments are constrained to the upper ~60 feet below land surface in all three valleys, and the saprolite base (a highly impermeable barrier to groundwater flow) extends to hundreds of feet below sea level in portions of North and South Hālawa Valleys (typical basal groundwater elevations in the Red Hill/Hālawa Valley area are approximately 18–20 feet above sea level).

(g) **Geologic Field Mapping.** The Navy developed a geologic framework model and a three-dimensional regional geologic model of Red Hill and surrounding environs (including North and South Hālawa Valleys, Moanalua Valley, the Salt Lake area, and Pearl Harbor) to provide geologic support for its groundwater flow modeling effort. The three-dimensional geologic model encompassed the groundwater flow model domain and incorporated information from borehole logs, subsurface structural geology surveys, developed cross sections, and published literature. The Navy used this and other data to prepare detailed geologic cross sections by correlating available geologic logs of cores and the results of field mapping conducted with experts from DOH and the University of Hawaiʻi ("UH") along multiple outcrops in the vicinity of Red Hill and within the Moanalua Tunnel (Figure 6f). In addition, the Navy determined accurate strike and dip measurements of the lava flows and the presence of highly porous clinker units within Red Hill. Strike and dip of a rock outcrop can be used to determine the general direction that a fluid can flow. The measurements were used to identify a general dip direction for Red Hill (south-southwest), which can influence groundwater flow. The Navy then oriented the groundwater flow model to match the general dip direction for Red Hill.

(h) **H-3 Geotechnical Borings.** The Navy used boring log data from borings drilled by the Hawai‘i Department of Transportation for the planned construction of the H-3 Freeway to generate a three-dimensional geologic model for input into the groundwater flow model, develop the CSM, and increase overall understanding of groundwater patterns around the Facility. Two sets of geotechnical boring logs from different time frames were used (Figure 6g). The State advanced a series of geotechnical borings in South Hālawa Valley in the 1960s as part of the planning phases for the freeway, which at that time was planned to transit through South Hālawa Valley; and the State advanced a further series of geotechnical borings in North Hālawa Valley as part of the rerouted H-3 Freeway construction project in the 1990s.

(i) **Borings from Other Environmental and Geotechnical Investigations.** A variety of environmental and geotechnical investigations have been conducted both at the Facility and within the general vicinity: URS (2012), Macdonald (1941), Dames & Moore (1991), and PGE (2015). The Navy used the geologic data from these logs to verify their more recent geologic mapping and to develop the CSM and the three-dimensional geologic model (Figure 6h). The water level data were used in conjunction with current groundwater levels to better characterize hydraulic conditions at the Facility.

(j) **Barrel Logs.** The Navy used information from barrel logs prepared during construction of the Facility's fuel storage tanks (DON 1943) to develop geologic cross sections of the tank farm area (Figure 6i). These logs describe the strata of the rock formation along the excavated surface of the cylindrical spaces mined for the tanks. The Navy used the barrel logs in conjunction with more detailed contemporary boring logs and published reports from other hydrogeology investigations of basalt to estimate the porosity and permeability of each different geologic units; evaluated this information to better define the thickness and locations of potential permeable layers or zones; and then estimated likely directions and locations where LNAPL could migrate if released from a tank. Correlation of spatial interpolation of lava tubes and loose rock from barrel log data presents similar orientations to the south-southwest dip direction noted in Item (g), reinforcing the accuracy of the Navy's geologic mapping efforts.

(k) **Soil Vapor Monitoring Data.** Since 2008, the Navy has measured soil vapor concentrations of volatile organic compounds under all the Facility's active fuel storage tanks on a monthly basis (Figure 6j). The results are compared to action levels established in the Red Hill GWPP (DON 2014) and updated by the AOC Regulatory Agencies in 2016 (EPA Region 9 and DOH 2016). The Navy reports all results to DOH in monthly *Soil Vapor Monitoring Reports* for publication on DOH's Red Hill webpages.[28] An exceedance of the action level triggers contingency actions in accordance with the GWPP. In addition, the Navy has used its analysis of soil vapor monitoring results following the 2014 Tank 5 Release to improve its monitoring program so that concentrations can be more reliably evaluated. As shown in Sidebar 13, monitoring results related to the 2014 Tank 5 Release demonstrate that soil vapor monitoring can provide a robust system for detecting a release. As described in Section 3.1.3, the Navy is currently exploring the feasibility of conducting continuous, real-time soil vapor monitoring via a pilot study as one of several systems to enhance its release detection capability.

(l) **Infiltration Testing.** An important factor influencing whether fuel-related constituents can travel down to the basal groundwater table is the amount of rainwater infiltrating through the soil. Generally, increasing amounts of infiltrating rainwater results in more fuel-related constituents migrating down to the groundwater. The Red Hill area is known to contain layers of clayey saprolite that can impede rainwater infiltration. To measure this effect in the surficial soils, the Navy conducted infiltration tests at three locations overlying the ridgetop area of the

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[28] https://health.hawaii.gov/shwb/ust-red-hill-project-main/

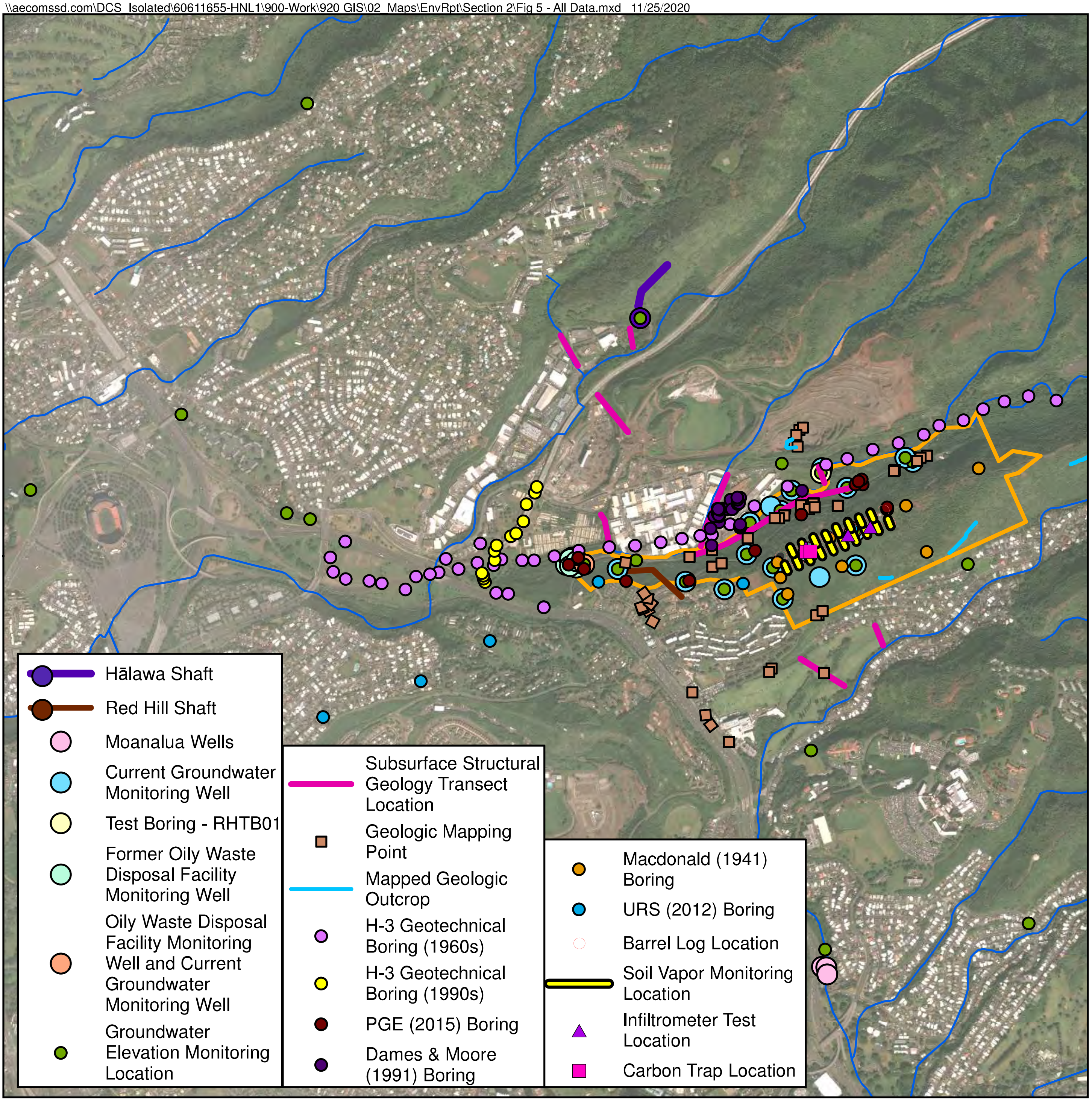
Exhibit N-6I

tank farm in November 2019 (Figure 6k). Due to historical land use conditions at the site, results from the infiltration tests showed higher-than-anticipated levels of infiltration, and investigators were not able to measure infiltration through the underlying saprolite, as had been anticipated.

(m) **Carbon Traps.** The carbon trap method can be used to determine the rate of NSZD (the process by which LNAPL is naturally degraded in the subsurface; *see* Sidebar 8). The method measures the amount of carbon dioxide being generated through the biodegradation of LNAPL, which can be used to calculate that degradation rate. The Navy placed carbon traps at the ground surface and carbon cartridges in the Facility tunnels (Figure 6l) and used the results to determine approximate NSZD rates. This method was also compared to another method that evaluated the heat signature measured in monitoring wells, with a relatively good agreement of NSZD rates.

Exhibit N-6I

\\aecomssd.com\DCS_Isolated\60611655-HNL1\900-Work\920 GIS\02_Maps\EnvRpt\Section 2\Fig 5 - All Data.mxd   11/25/2020



NOTES

1. Map projection: NAD 1983 Hawaii State Plane Zone 3 feet
2. Base Map: DigitalGlobe, Inc. (DG) and NRCS. Publication_Date: 2015

Figure 5
Comprehensive Data Collection Locations
Red Hill Bulk Fuel Storage Facility Environmental Report
Red Hill Bulk Fuel Storage Facility
JBPHH, O'ahu, Hawai'i

Exhibit N-6I

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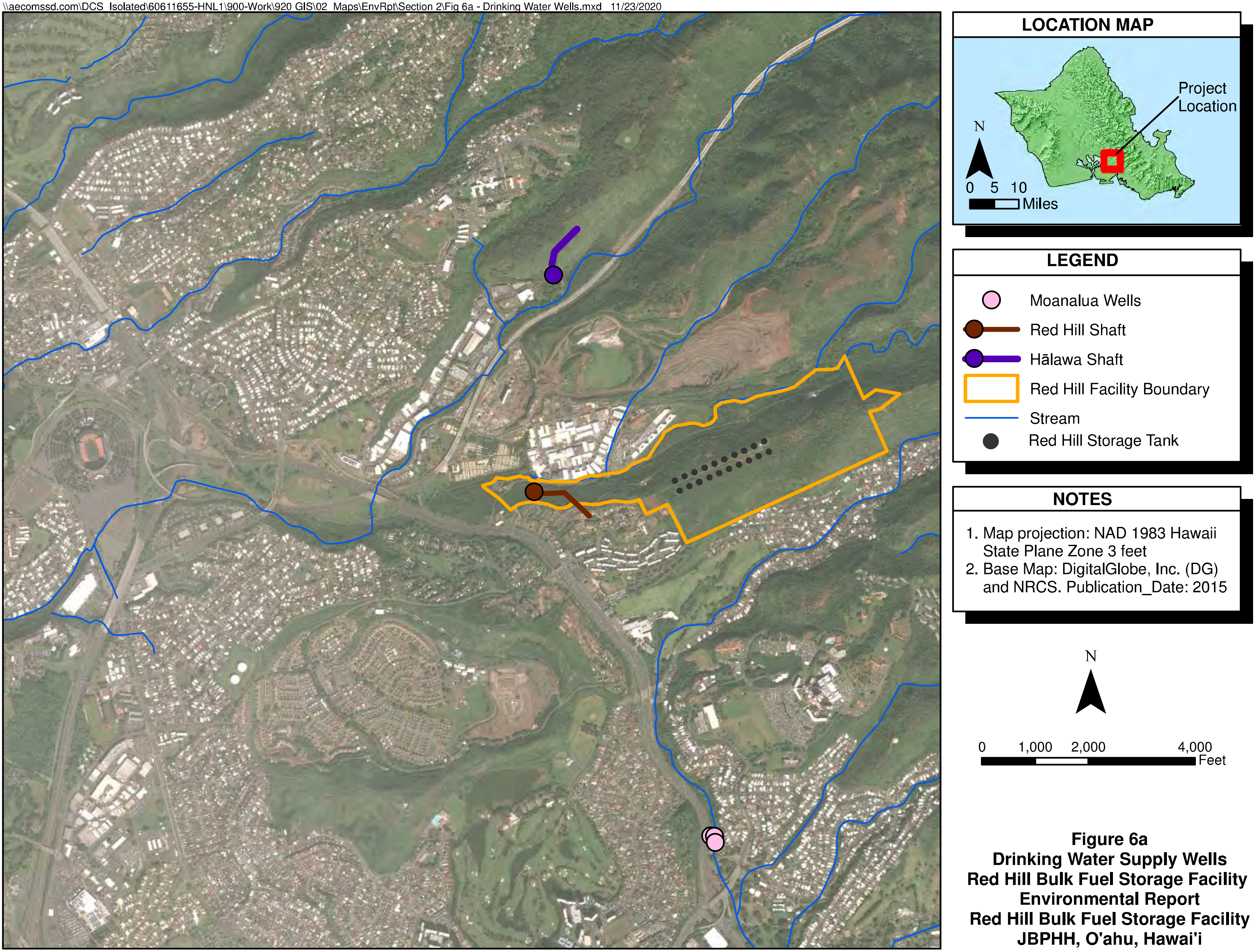
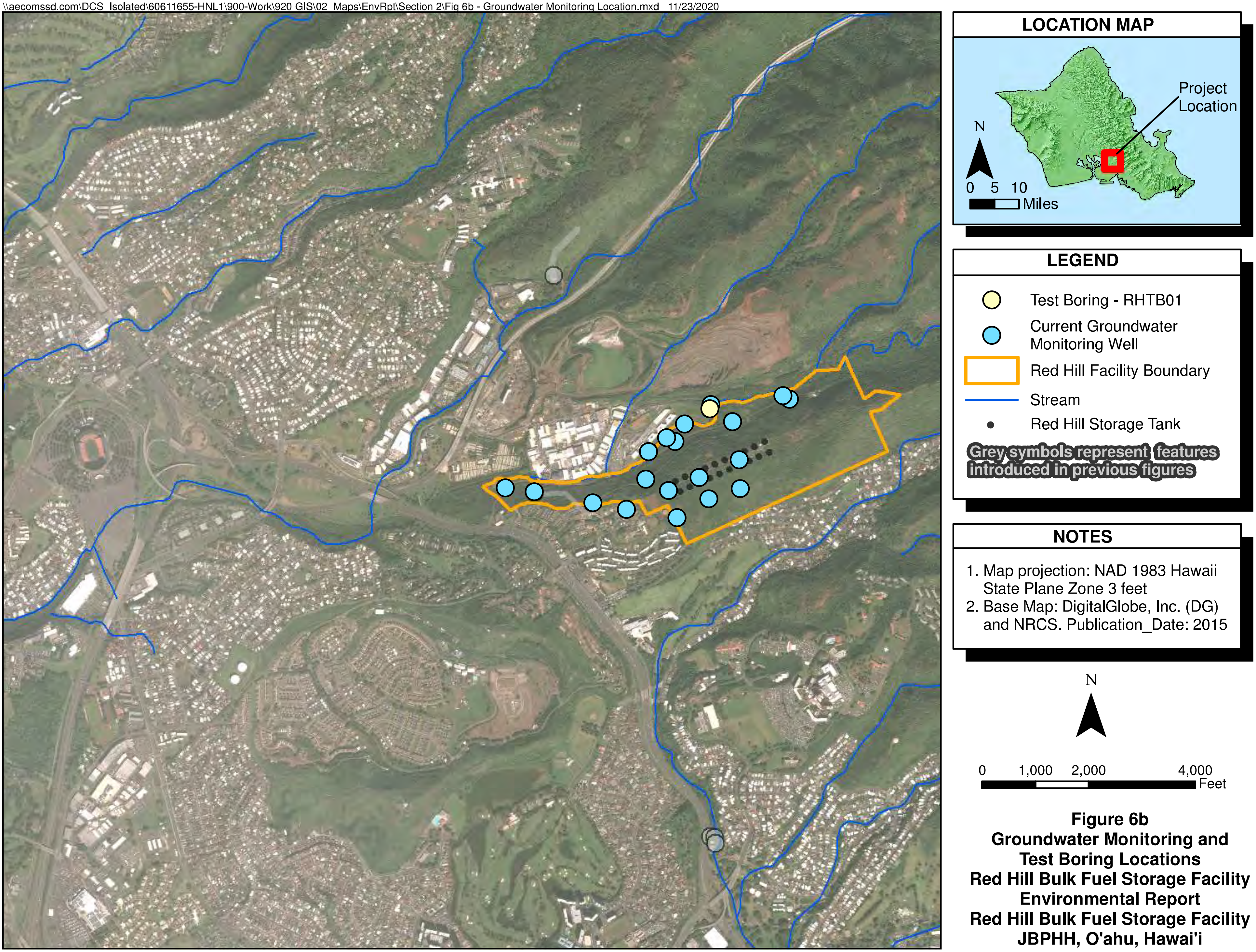


Figure 6a
Drinking Water Supply Wells
Red Hill Bulk Fuel Storage Facility
Environmental Report
Red Hill Bulk Fuel Storage Facility
JBPHH, O'ahu, Hawai'i

Exhibit N-6I

\\aecomssd.com\DCS_Isolated\60611655-HNL1\900-Work\920 GIS\02_Maps\EnvRpt\Section 2\Fig 6b - Groundwater Monitoring Location.mxd 11/23/2020



1. Map projection: NAD 1983 Hawaii State Plane Zone 3 feet
2. Base Map: DigitalGlobe, Inc. (DG) and NRCS. Publication_Date: 2015

Figure 6b
Groundwater Monitoring and Test Boring Locations
Red Hill Bulk Fuel Storage Facility
Environmental Report
Red Hill Bulk Fuel Storage Facility
JBPHH, O'ahu, Hawai'i

N00901

Exhibit N-6I

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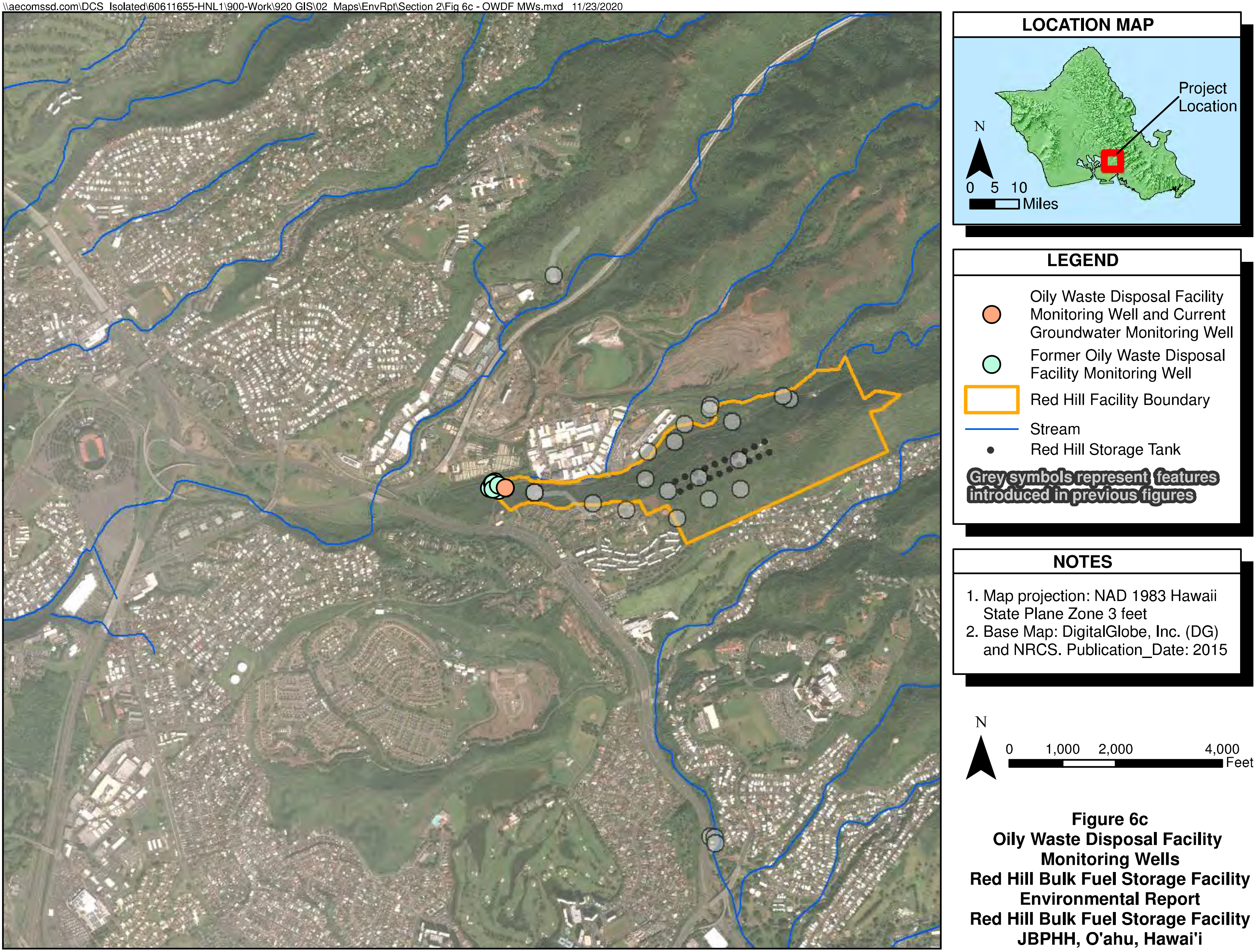

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1. Map projection: NAD 1983 Hawaii State Plane Zone 3 feet
2. Base Map: DigitalGlobe, Inc. (DG) and NRCS. Publication_Date: 2015

Figure 6c
Oily Waste Disposal Facility
Monitoring Wells
Red Hill Bulk Fuel Storage Facility
Environmental Report
Red Hill Bulk Fuel Storage Facility
JBPHH, O'ahu, Hawai'i

Exhibit N-6I

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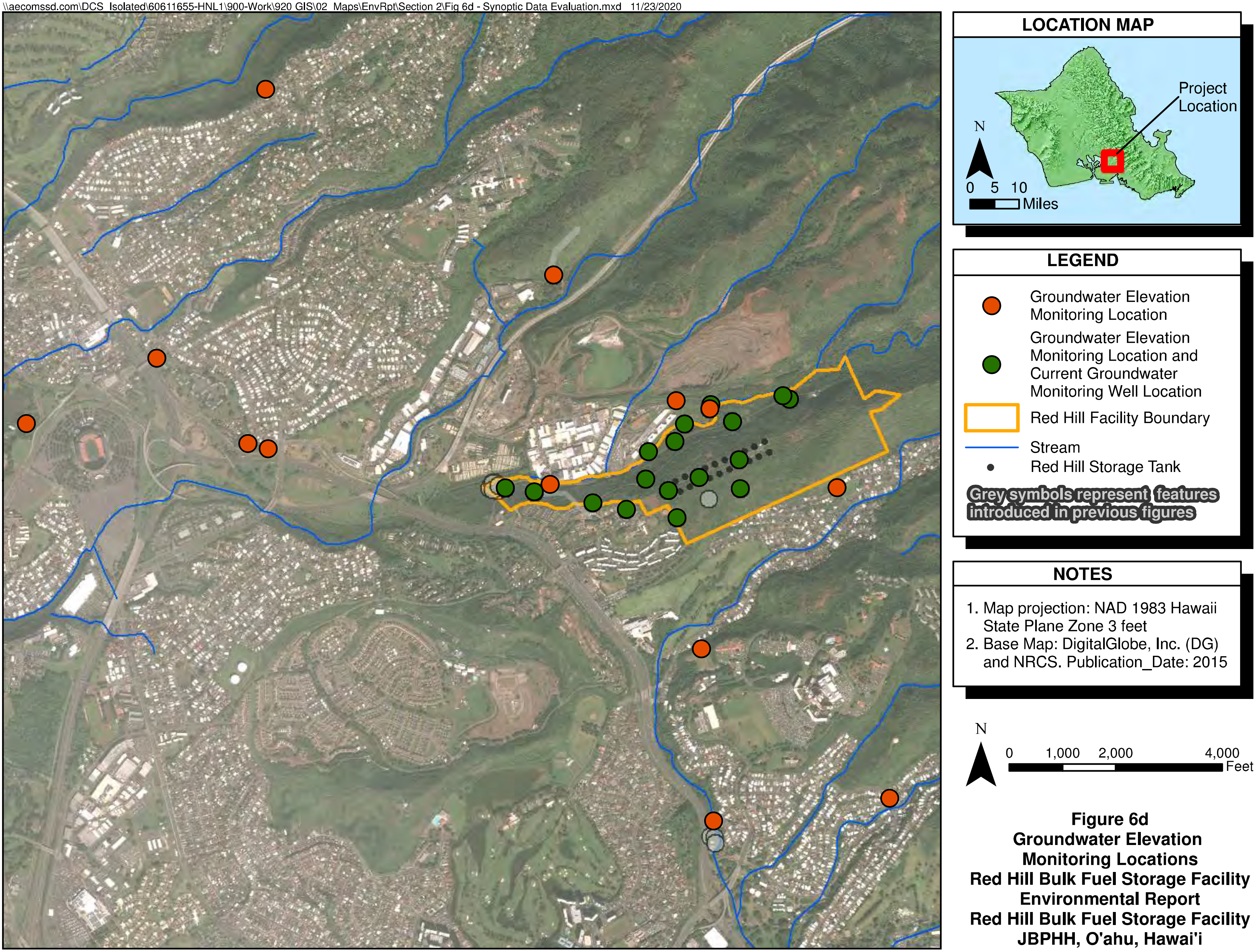

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1. Map projection: NAD 1983 Hawaii State Plane Zone 3 feet
2. Base Map: DigitalGlobe, Inc. (DG) and NRCS. Publication_Date: 2015

Figure 6d
Groundwater Elevation
Monitoring Locations
Red Hill Bulk Fuel Storage Facility
Environmental Report
Red Hill Bulk Fuel Storage Facility
JBPHH, O'ahu, Hawai'i

Exhibit N-6I

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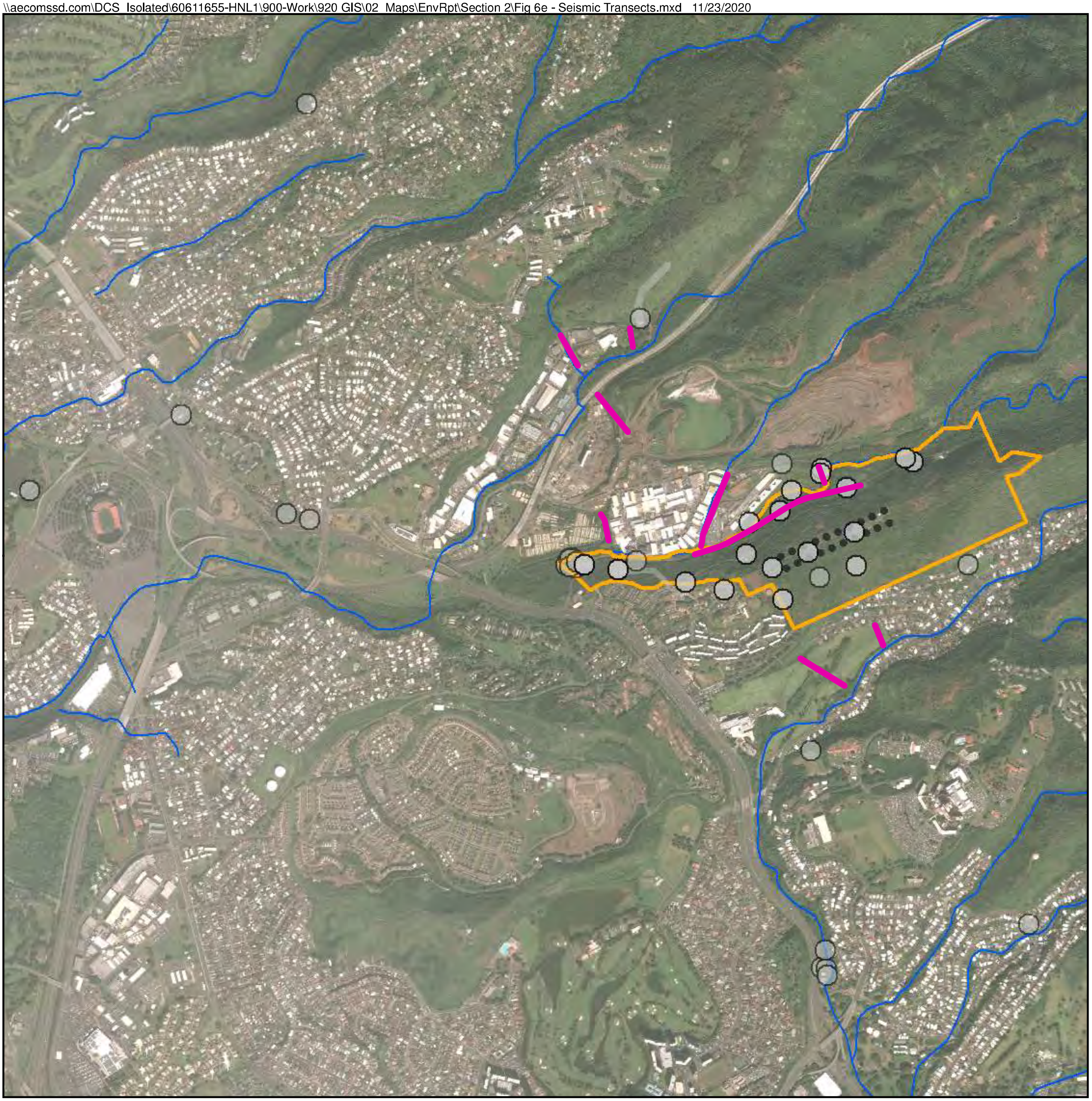
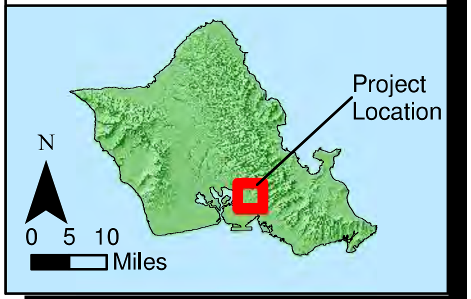
N00904



LOCATION MAP



LEGEND

- Subsurface Structural Geology Transect Location
- Red Hill Facility Boundary
- Stream
- ● Red Hill Storage Tank

Grey symbols represent features introduced in previous figures

NOTES

1. Map projection: NAD 1983 Hawaii State Plane Zone 3 feet
2. Base Map: DigitalGlobe, Inc. (DG) and NRCS. Publication_Date: 2015

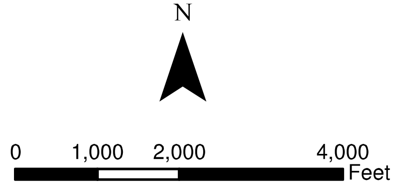


Figure 6e
Seismic Transects
Red Hill Bulk Fuel Storage Facility
Environmental Report
Red Hill Bulk Fuel Storage Facility
JBPHH, O'ahu, Hawai'i

Exhibit N-6I

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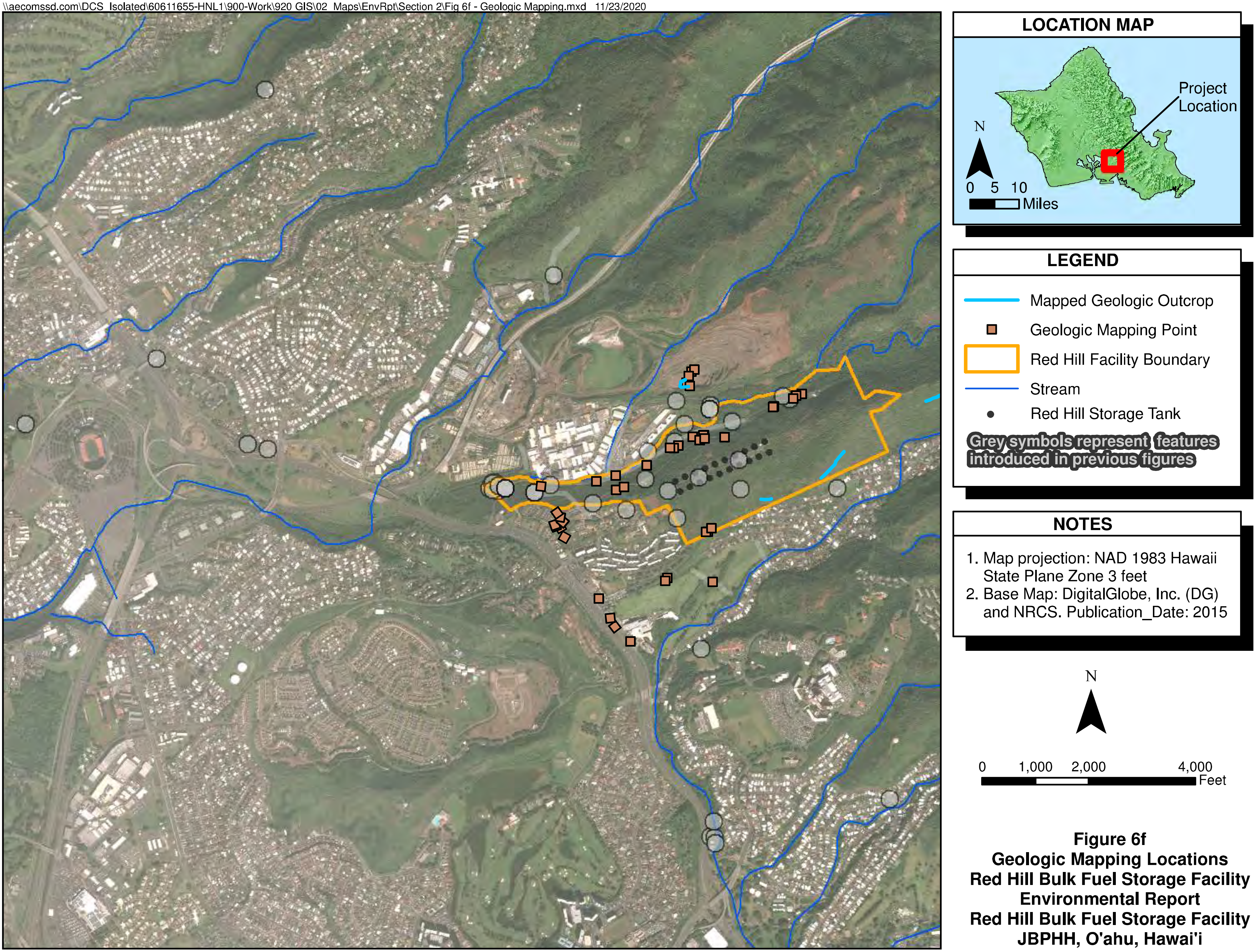

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1. Map projection: NAD 1983 Hawaii State Plane Zone 3 feet
2. Base Map: DigitalGlobe, Inc. (DG) and NRCS. Publication_Date: 2015

Figure 6f
Geologic Mapping Locations
Red Hill Bulk Fuel Storage Facility
Environmental Report
Red Hill Bulk Fuel Storage Facility
JBPHH, O'ahu, Hawai'i

Exhibit N-6I

\\aecomssd.com\DCS_Isolated\60611655-HNL1\900-Work\920 GIS\02_Maps\EnvRpt\Section 2\Fig 6g - South Halawa Borings.mxd 11/23/2020

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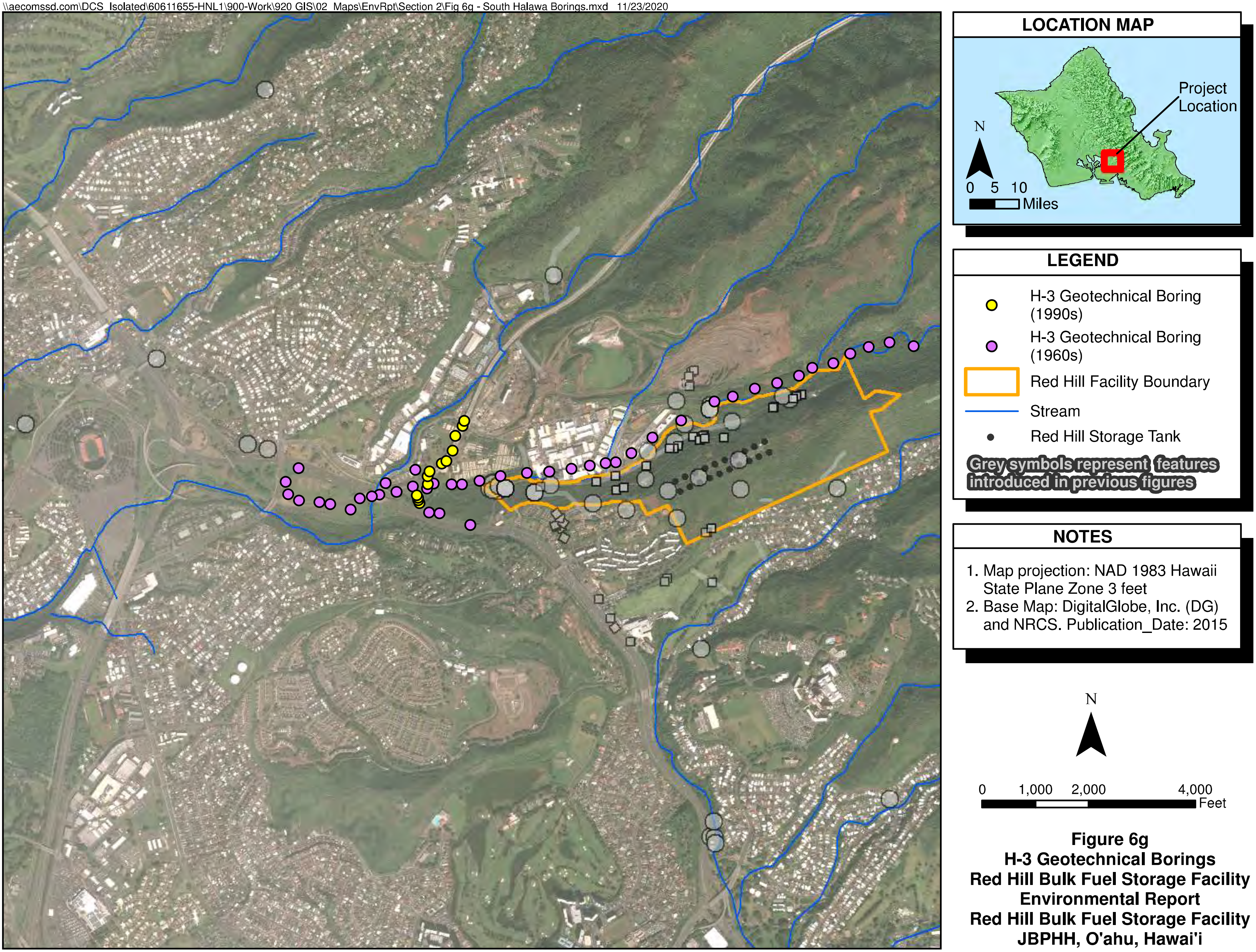

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1. Map projection: NAD 1983 Hawaii State Plane Zone 3 feet
2. Base Map: DigitalGlobe, Inc. (DG) and NRCS. Publication_Date: 2015

Figure 6g
H-3 Geotechnical Borings
Red Hill Bulk Fuel Storage Facility
Environmental Report
Red Hill Bulk Fuel Storage Facility
JBPHH, O'ahu, Hawai'i

Exhibit N-6I

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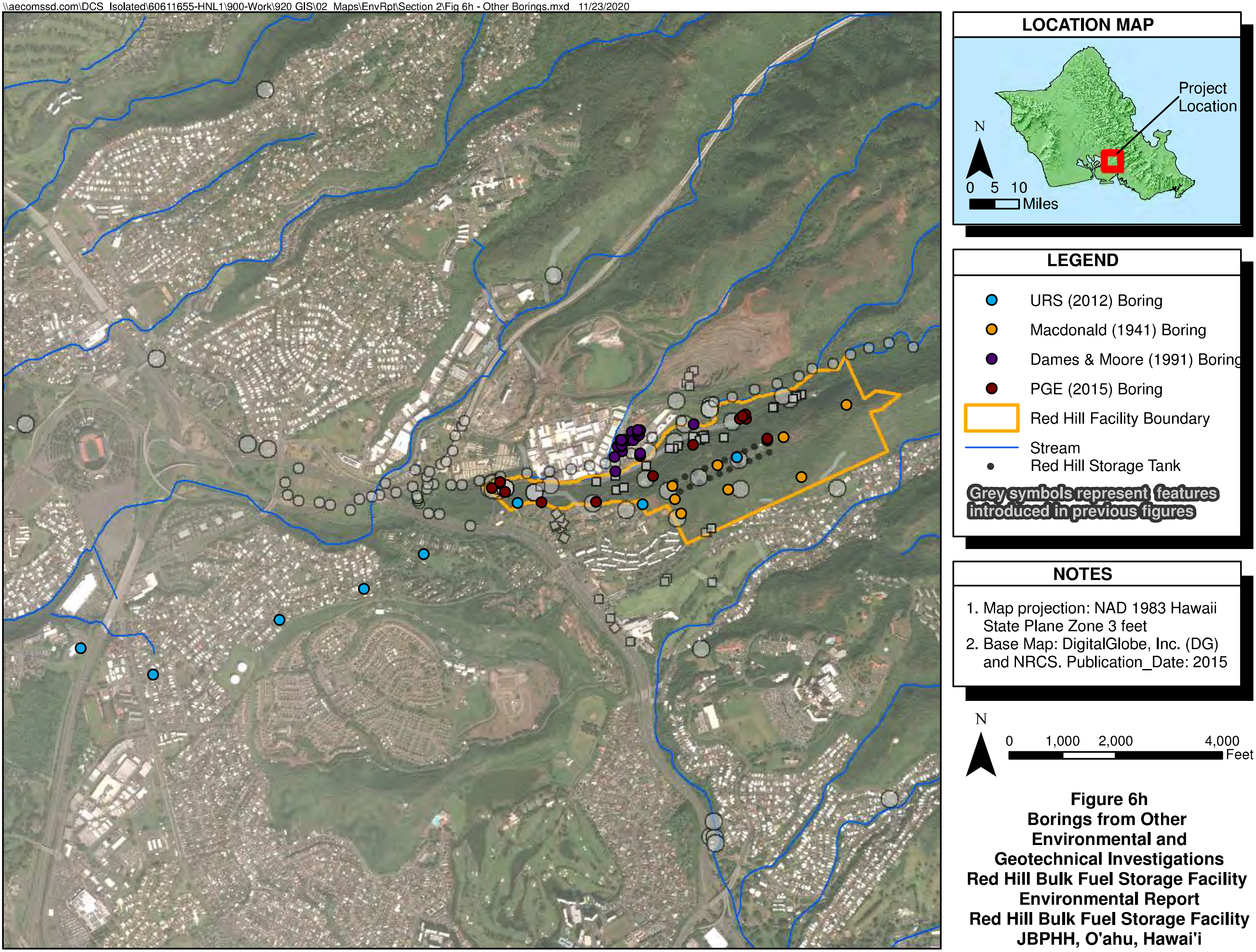

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1. Map projection: NAD 1983 Hawaii State Plane Zone 3 feet
2. Base Map: DigitalGlobe, Inc. (DG) and NRCS. Publication_Date: 2015

Figure 6h
Borings from Other Environmental and Geotechnical Investigations
Red Hill Bulk Fuel Storage Facility Environmental Report
Red Hill Bulk Fuel Storage Facility
JBPHH, O'ahu, Hawai'i

Exhibit N-6I

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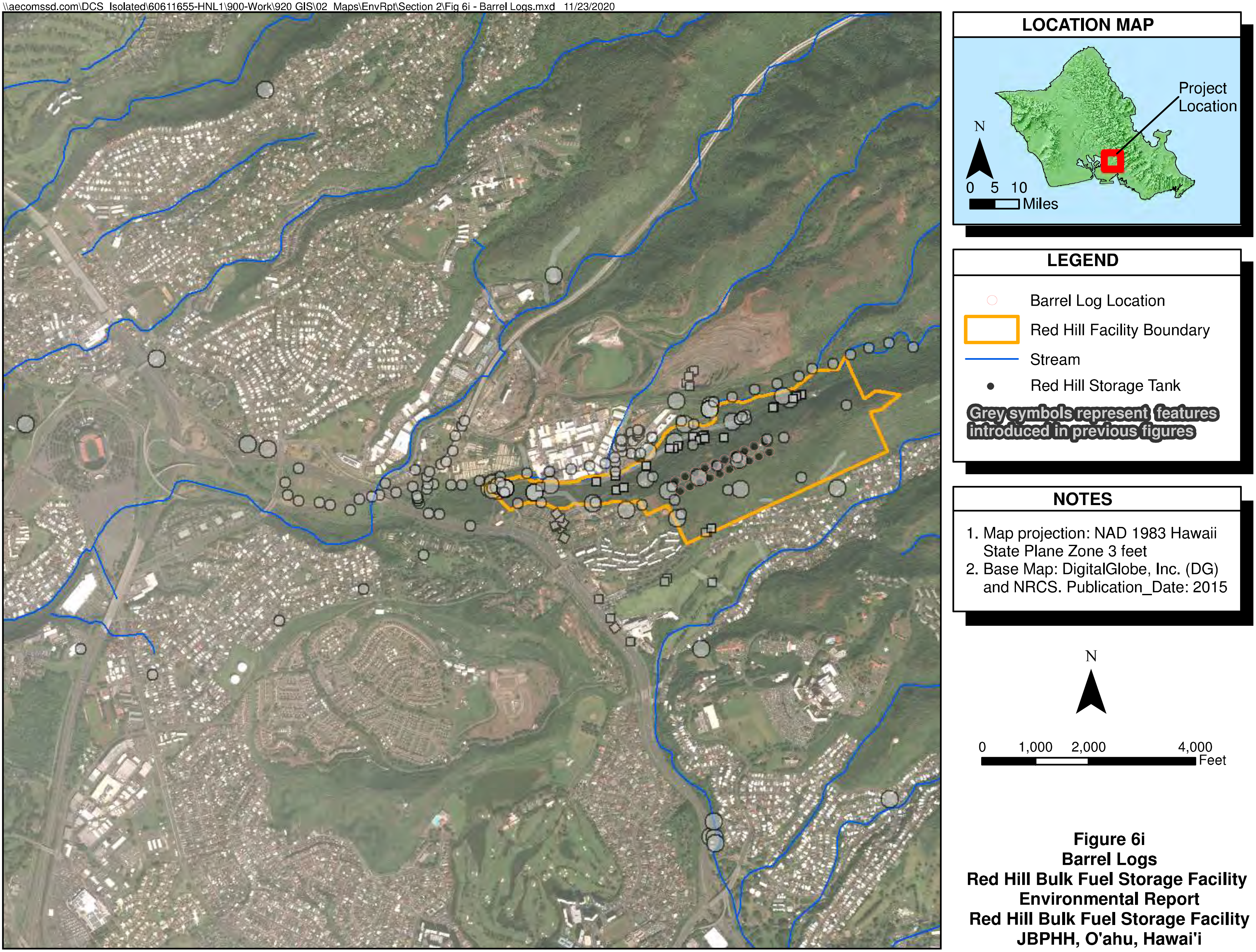

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1. Map projection: NAD 1983 Hawaii State Plane Zone 3 feet
2. Base Map: DigitalGlobe, Inc. (DG) and NRCS. Publication_Date: 2015

Figure 6i
Barrel Logs
Red Hill Bulk Fuel Storage Facility
Environmental Report
Red Hill Bulk Fuel Storage Facility
JBPHH, O'ahu, Hawai'i

N00908

Exhibit N-6I

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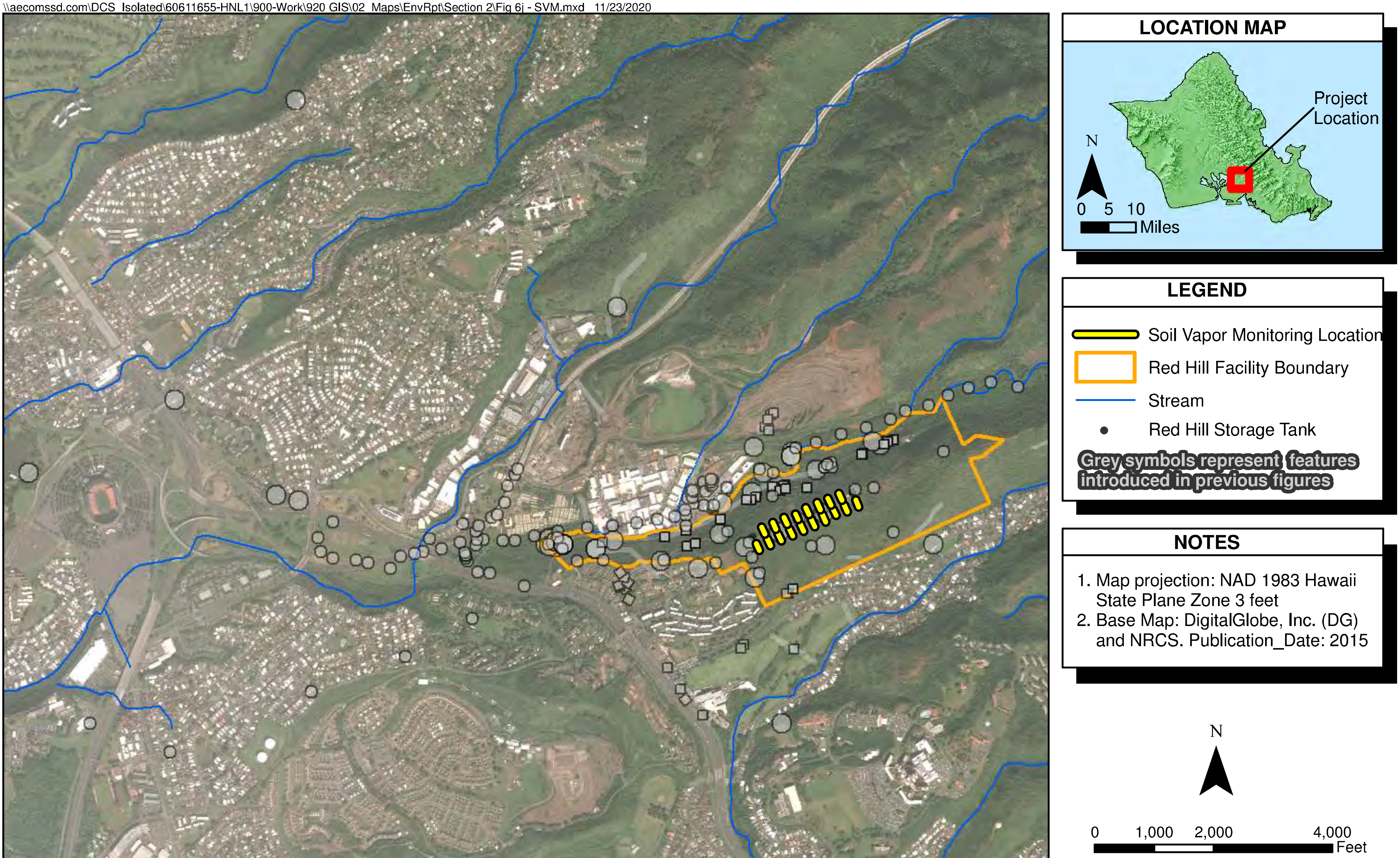

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1. Map projection: NAD 1983 Hawaii State Plane Zone 3 feet
2. Base Map: DigitalGlobe, Inc. (DG) and NRCS. Publication_Date: 2015

Figure 6j
Soil Vapor Monitoring Locations
Red Hill Bulk Fuel Storage Facility
Environmental Report
Red Hill Bulk Fuel Storage Facility
JBPHH, O'ahu, Hawai'i

Exhibit N-6I

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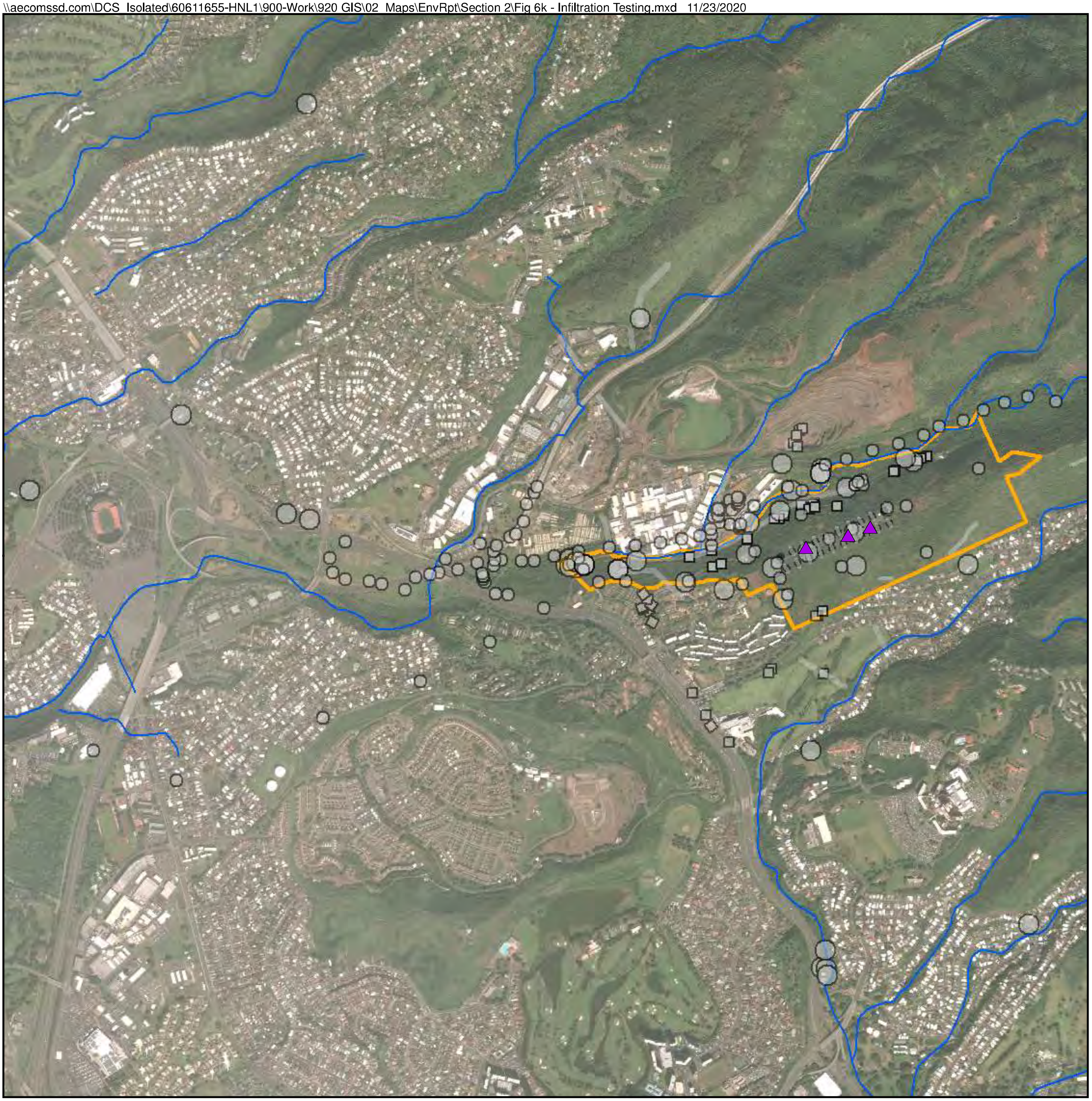
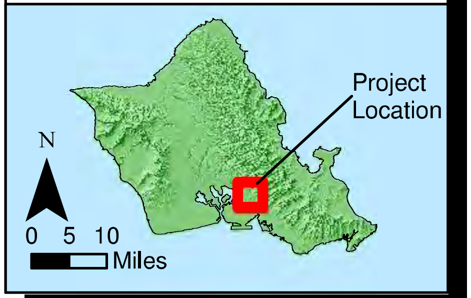


LOCATION MAP



LEGEND

▲	Infiltrometer Test Location
▭	Red Hill Facility Boundary
—	Stream
●	Red Hill Storage Tank

Grey symbols represent features introduced in previous figures

NOTES

1. Map projection: NAD 1983 Hawaii State Plane Zone 3 feet
2. Base Map: DigitalGlobe, Inc. (DG) and NRCS. Publication_Date: 2015

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0 1,000 2,000 4,000 Feet

Figure 6k
Infiltrometer Testing Locations
Red Hill Bulk Fuel Storage Facility
Environmental Report
Red Hill Bulk Fuel Storage Facility
JBPHH, O'ahu, Hawai'i

N00910

Exhibit N-6I

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N00911

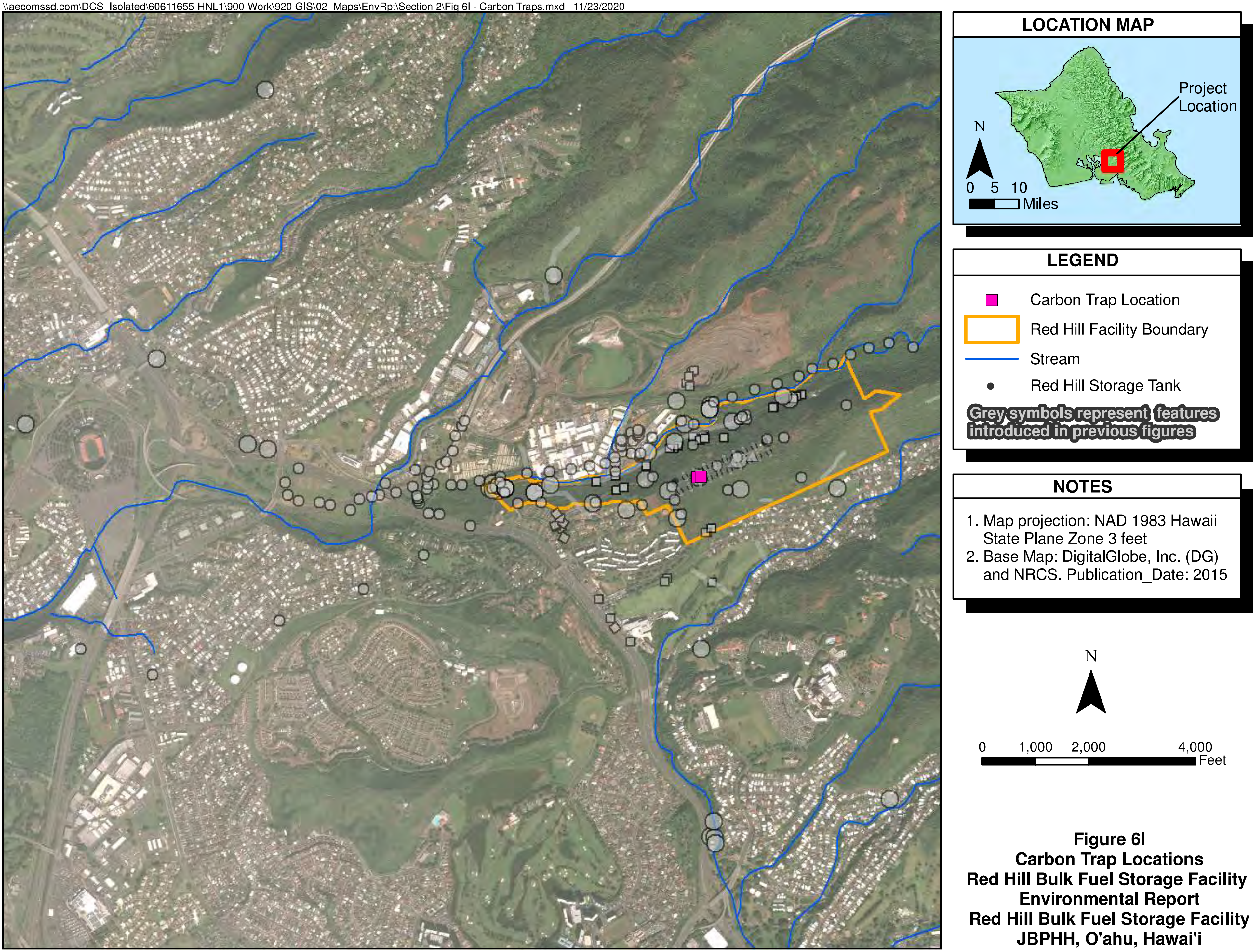


Figure 6I
Carbon Trap Locations
Red Hill Bulk Fuel Storage Facility
Environmental Report
Red Hill Bulk Fuel Storage Facility
JBPHH, O'ahu, Hawai'i

Exhibit N-6I

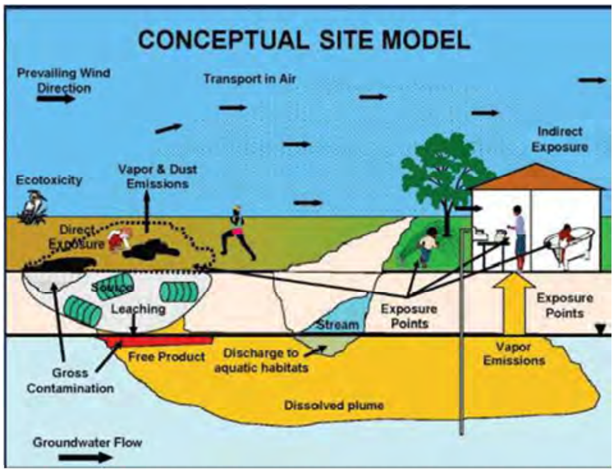
Sidebar 4: Exposure Pathways at Red Hill [Section 2.1.1]

A risk-based exposure model used in environmental risk assessment identifies the sources and migration pathways of chemical contamination, and evaluates the exposure media and completeness of pathways for receptors potentially exposed to these media. A complete exposure pathway includes all the following elements:

- Chemical source(s)
- Affected media
- Chemical release and transport mechanisms
- Routes of exposure
- Human and/or ecological receptors

At the Facility, historical releases prior to 2005 are considered the main source of impacts to groundwater. Potentially contaminated media are unconsolidated materials (i.e., soil), volcanic rock near the tanks, soil or rock vapor within the basalt, tunnel air, groundwater beneath the Facility, and offsite surface water where groundwater could conceivably discharge.

Human receptors that may contact onsite or offsite Facility-impacted media are occupational workers, construction workers, and visitors at the Facility and offsite residents.



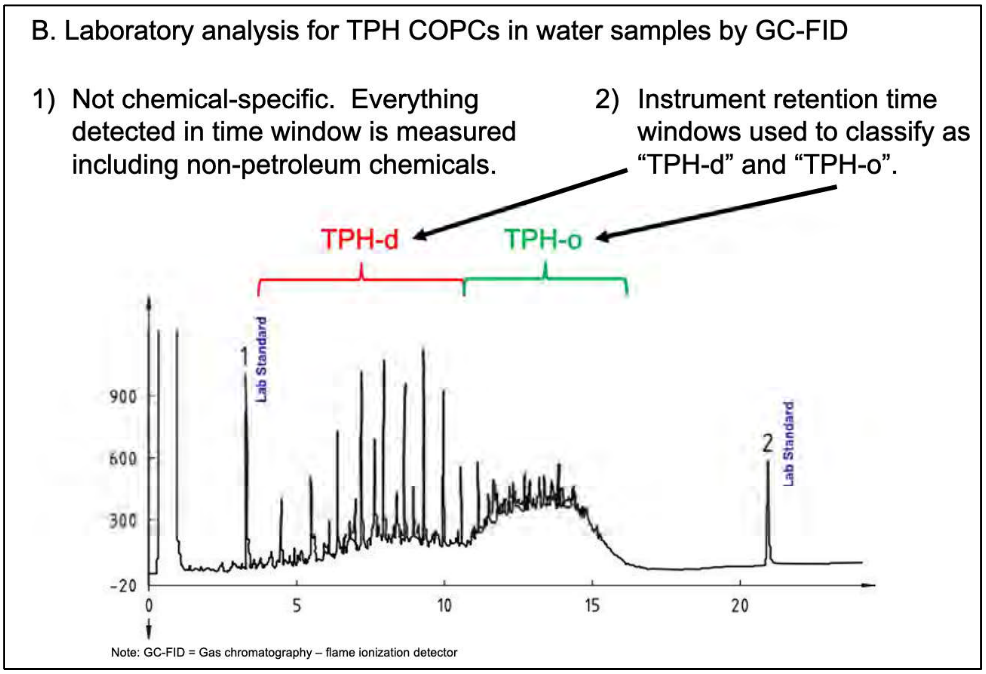
Exposure pathways (DOH 2018a, Figure 3-6)

The primary complete exposure pathway identified at Red Hill is offsite human residents using tap water sourced from the Red Hill Shaft water supply well (DON 2019a, at Section 8). Despite some Red Hill monitoring wells being located within 150 meters of surface water (South Hālawa Stream), there are no indications of any complete pathways to nearby water bodies. Both South Hālawa Stream and Moanalua Stream (in Moanalua Valley east of the Facility) are intermittent streams (USGS 2017) located approximately 100 feet or more above the water table of the basal aquifer. These intermittent streams are also located significantly higher in elevation than groundwater, ruling out potential impacts from groundwater to these streams.

Moreover, the bottoms of the fuel tanks are located at least 50 feet below the bottom of the streams, and the segment of South Hālawa Stream between Red Hill and Hālawa Correctional Facility is concrete-lined. Thus, groundwater conditions do not affect the nearby stream, and analytical results for the Red Hill groundwater monitoring program are, therefore, compared to the human-health-based screening levels based on DOH EALs Table D-1b (DOH 2017).

Sidebar 5: Total Petroleum Hydrocarbons (“TPH”) [Section 2.1.2]

Most constituents included in the Red Hill groundwater monitoring program are individual chemicals (e.g., naphthalene) that are definitively identified through laboratory analysis. In contrast, the three TPH-based analytes are bulk parameters that reflect the total concentration of extracted organics present with gas chromatography retention times within the range of gasoline constituents (TPH-g), diesel constituents (TPH-d), and heavy oil (e.g., motor oil, lubricating oil) constituents (TPH-o) (*see* below figure). The results are referred to as “total petroleum hydrocarbons” because they are intended for petroleum release sites where petroleum constituents are the dominant contaminants.



B. Laboratory analysis for TPH COPCs in water samples by GC-FID

1) Not chemical-specific. Everything detected in time window is measured including non-petroleum chemicals.

2) Instrument retention time windows used to classify as “TPH-d” and “TPH-o”.

Note: GC-FID = Gas chromatography – flame ionization detector

However, constituents quantified as TPH-g, TPH-d, and TPH-o can include petroleum hydrocarbons, petroleum hydrocarbon metabolites, and non-petroleum organic compounds (which could potentially include any carbon containing compound). When non-petroleum compounds (e.g., phthalates) are present in a sample analyzed for TPH, these non-petroleum compounds will be quantified and reported as “TPH” even if they did not originate from petroleum. Hydrocarbon metabolites are mostly polar compounds that form from the biodegradation of petroleum; these compounds have longer gas chromatography retention times and, therefore, commonly appear within the TPH-d range or TPH-o range.

Samples analyzed for TPH-g are typically analyzed using purge and trap to recover the volatile compounds present in the sample, whereas samples analyzed for TPH-d and TPH-o are typically extracted with a solvent, resulting in the recovery of a wider range of organic compounds. The analysis for TPH-d and TPH-o is typically a single analysis with separate concentration results reported for 1) material within the expected carbon range of diesel constituents (TPH-d), and 2) materials within the expected carbon range of heavy oil constituents (TPH-o). Because TPH-d and TPH-o bulk parameters measure extractable organics that are soluble in methylene chloride, they reflect the total concentration of extractable organic compounds within the defined carbon ranges, including petroleum compounds, metabolites, and non-petroleum compounds.

For TPH-d and TPH-o, silica gel cleanup may be used to remove polar compounds (which may include weathered fuel constituents) prior to quantification of total organics in the sample. Comparison of analytical results for a sample with and without silica gel cleanup can be used to evaluate the amount of polar hydrocarbon metabolites and other polar compounds (some of which are naturally occurring) in the sample. Studies have found that in some petroleum hydrocarbon plumes, 90% or more of the constituents measured by TPH-d are polar compounds (Zemo et al. 2013). However, at Red Hill, polar constituents (such as TPH as a whole) are generally confined to groundwater in near-tank monitoring wells. Additional information relating to TPH analytical methods is presented in the Red Hill CSM report (DON 2019a) and in the TPH Chromatograms memo (Appendix C).

Sidebar 6: A Petroleum Release [Section 2.1.2]

All fuels that have been stored at the Facility originate from petroleum, which is derived from naturally occurring crude petroleum oil deposits found underground or from shale oil found in rock. Crude petroleum is a mixture of chemicals, mostly consisting of compounds composed of hydrogen and carbon, known as hydrocarbons. Crude petroleum is refined into various petroleum hydrocarbon fuels, including the jet fuel (very similar to kerosene) that is stored at the Facility.

A petroleum release refers to a release of petroleum hydrocarbons from a storage tank (aboveground or underground) or other fuel container into the underlying environmental media (e.g., soil, groundwater, surface water, sediment). Tank upgrades, combined with proper inspection and repair processes, help to prevent or minimize fuel releases from occurring. In addition, early detection helps to minimize the size of releases, should they occur.

The kerosene-based jet fuels and marine diesel fuel stored at the Facility are middle distillates refined from crude oil. Middle distillates include petroleum hydrocarbons such as naphthalene and methylnaphthalenes, as well as small amounts of more volatile hydrocarbons such as benzene, toluene, ethylbenzene, and xylenes. The volatility of these latter molecules is the result of their structure and aromatic nature, which causes them to rapidly degrade, or even evaporate, following a release.

Nonaqueous-phase liquid is a fluid composed of hydrocarbons that do not mix well with water and form a discrete (multi-phase) layer. These products can be classified as being either less dense than water (light nonaqueous-phase liquid—“LNAPL”, pictured) or more dense than water (dense nonaqueous-phase liquid—“DNAPL”).

LNAPL (comprising most petroleum fuels, including jet fuel) can migrate through the vadose zone to float on top of an unconfined aquifer (or water table), whereas DNAPL can migrate through the vadose zone and through the aquifer, and then accumulate at the bottom of an aquifer. LNAPL is easier to remediate than DNAPL, because more remediation techniques are available and remediation costs are lower. Petroleum hydrocarbons present at the Facility are classified as LNAPL (they are less dense than water).

Petroleum-based diesel fuel
(ENVIRO.wiki 2020b)

LNAPL is readily measured in groundwater monitoring wells because it floats on the surface of the groundwater. The Navy tests for floating LNAPL in four monitoring wells near the fuel storage tanks monthly and also in all wells in the Red Hill groundwater monitoring network during each quarterly groundwater monitoring event. All results are reported to DOH. Fortunately, no LNAPL has ever been measured in any Red Hill monitoring well (*see* Appendix B, Table B-1).

For more information on LNAPL, the American Petroleum Institute has developed a LNAPL Resource Center web page (https://www.api.org/oil-and-natural-gas/environment/clean-water/ground-water/lnapl).

Sidebar 7: Comprehensive Evaluation of Red Hill Groundwater Chemistry [Section 2.1.2]

The Navy's comprehensive evaluation of the entire groundwater monitoring data set clearly indicates that there has been no impact to perimeter wells associated with fuel releases from the Facility (DON 2019a; 2020c). The evaluation does not indicate that the 2014 Tank 5 Release of jet fuel impacted groundwater. The observed impacts to groundwater in some of the near-tank wells (i.e., RHMW01, RHMW02, and RHMW03) are likely attributable to historical leaks, prior to 2005.

Consistent and coinciding detections of chemicals have been reported in RHMW02 over time. These detections are consistent with a nearby LNAPL source in the unsaturated zone and even potentially in upgradient groundwater. Coinciding detections are observed to a lesser extent in RHMW01, indicating that RHMW01 may have some hydraulic connection to RHMW02 located upgradient. Coinciding detections are not observed in RHMW03.

2014 Tank 5 Release. There is evidence of a pre-2005 LNAPL release impacting groundwater upgradient of RHMW02, which is located near Tank 5. The lower concentrations (and non-detections) of chemicals at RHMW01 and RHMW03 compared to RHMW02 are not indicative of LNAPL release to groundwater in the vicinity of these two wells. There are indications of biodegradation at RHMW02 and RHMW01 and marginal indications at RHMW03.

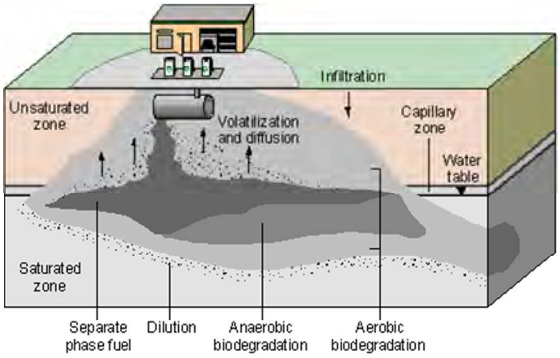
The steady benzene, toluene, ethylbenzene, and toluene trends and consistent naphthalenes weathering ratio at RHMW02 before and after the 2014 fuel release do not support impact at RHMW02 from the 2014 Tank 5 Release. Similarly, there are no consistent observable changes in the concentrations of analyte detections in site wells before and after the 2014 Tank 5 Release.

Impacts to Perimeter Wells. The presence of LNAPL in the area of the perimeter wells would result in a continuing, and consistent impact to wells. There are inconsistent and noncoinciding detections of analytes in perimeter wells. In addition, a wide variety of constituents have been reported in perimeter wells that were not related to petroleum hydrocarbons, such as phthalates and halogenated compounds. These compounds are not associated with fuel and may be indicators of sample or laboratory issues. A detailed analysis of all chemicals resulting in various lines of evidence as well as reviews of TPH chromatograms clearly indicates that none of the perimeter wells has been impacted from fuel releases at the Facility. Low-level chemical detections were associated with chemicals used in well construction and/or artifacts due to sampling, or with laboratory analysis at low concentrations.

The detailed analysis of groundwater chemistry indicates that intermittent low concentrations at perimeter wells are not consistent with fuel releases. The detections of compounds are sporadic and at very low concentrations. There is a similar detection pattern observed across a diverse set of monitoring locations (e.g., Red Hill Shaft, RHMW05, and Hālawa Deep Monitor Well). As these wells have different constructions and are operated differently, the similarity in the detection patterns for some chemicals (e.g., naphthalenes) brings into question the reliability of those data as an indicator of a hydrocarbon release.

Exhibit N-6I

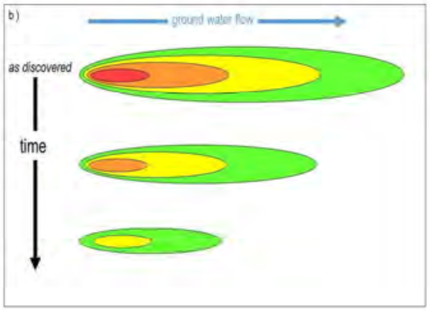
Sidebar 8: Attenuation of Petroleum Constituents [Section 2.1.2]



Conceptual illustration of important natural attenuation processes that affect the fate of petroleum hydrocarbons in aquifers (USGS 2016)

As described by EPA (1999), natural attenuation is “a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater. These in situ processes include biodegradation; dispersion; dilution; sorption; volatilization; radioactive decay; and chemical or biological stabilization, transformation, or destruction of contaminants.”

For petroleum releases, such processes occur both in the source release zone as natural source-zone depletion (“NSZD”) and in the dissolved groundwater plume as monitored natural attenuation (“MNA”) (ITRC 2009). Under favorable conditions, various naturally occurring processes can reduce or eliminate the harmful effects to the environment from a petroleum release to the subsurface.



Evolution of a petroleum plume when the source and concentrations in groundwater both attenuate (ENVIRO.wiki 2020a)

Of these processes, biodegradation is typically the most significant. Biodegradation of petroleum hydrocarbons intrinsically follows and reduces the potential harm of a fuel release. The rate of biodegradation is monitored using analysis of *natural attenuation parameters*—general chemistry indicators such as dissolved oxygen, pH, and carbon dioxide. These, along with the presence of volatile hydrocarbons, can be used to further characterize the timeline of a release.

In the case of petroleum hydrocarbons, naturally occurring bacteria and microorganisms in the subsurface break down the molecules. The bacteria and microorganisms derive energy from the molecules’ decomposition and, depending on the molecular structure, eventually release water and carbon dioxide as byproducts. Biodegradation of petroleum hydrocarbons occurs under both aerobic (oxygenated) and anaerobic (non-oxygenated) conditions.

The Navy’s environmental investigation results under the AOC demonstrate that natural attenuation is occurring in both the unsaturated and saturated zones at Red Hill and acts to degrade contaminants in the environment:

- Excess carbon dioxide and heat are being generated at the Facility, confirming that NSZD of LNAPL is active and ongoing in the vadose zone, and the rates are relatively stable over time.[29]
- Soil vapor monitoring and fingerprinting analysis show that rapid weathering of petroleum is occurring in the unsaturated zone above the basal drinking water aquifer.
- MNA primary and secondary lines of evidence confirm that aerobic and anaerobic biodegradation of dissolved petroleum hydrocarbons is occurring in groundwater. Based on available data, the plume attenuation half-lives for dissolved constituents are likely on the order of 10–100 days.

The Navy’s investigation results indicate that LNAPL from the 2014 Tank 5 Release is retained in the pore spaces of the rock within approximately 30 feet beneath the tanks and has not reached groundwater, situated approximately 100–120 feet beneath the tanks (DON 2018b; 2019a). Accordingly, the Navy’s recommended remedies (currently under review by the AOC Regulatory Agencies) for both the 2014 Tank 5 Release and potentials future releases include NSZD and MNA components (DON 2019a).

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[29] The Navy’s AOC environmental investigation team recently published an article in the *Journal of Contaminant Hydrology* documenting the NSZD conditions observed at Red Hill (McHugh et al. 2020).

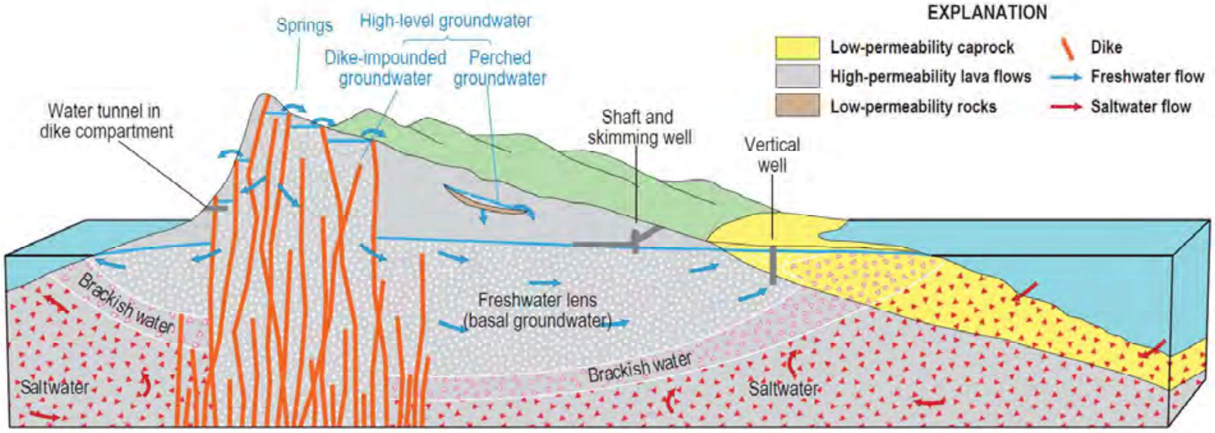
Sidebar 9: Geology and Hydrogeology at Red Hill [Section 2.1.2]

The Facility is constructed within a leeward ridge (Red Hill) on the southwest flank of the Ko'olau shield volcano (one of two shield volcanoes that form the mass of the island of O'ahu) and is primarily underlain by Ko'olau volcanic series basalts. The Ko'olau Basalt, the principal groundwater unit of central and eastern O'ahu (Hunt Jr. 1996), consists of basaltic lava flows that erupted from a fissure line approaching 30 miles in length and trending in a northwest rift zone (Wentworth and Macdonald 1953). Its individual flows average about 10 feet in thickness, but vary locally from 2 to as much as 80 feet depending on the location (Stearns and Vaksvik 1935).

The underlying geology in the Red Hill area is highly heterogeneous (i.e., diverse in composition), which poses significant challenges to both groundwater modeling and the availability of feasible remedies for a petroleum release. Both pāhoehoe and a'ā lava flows as well as associated "clinker zones" are present in the Ko'olau formation. The permeability of these flows (i.e., the ease with which water flows through the aquifer material) varies widely in this environment depending on the individual composition (e.g., presence or absence of highly permeable clinker, voids, cracks, and lava tubes) and geometric orientation (referred to as strike and dip). Of particular note are the clinker flows, which consist of highly permeable, rubblized basalt that typically forms on margins of relatively impermeable basalt flows and can result in subsurface pathways of relatively rapid (primarily lateral) groundwater flow.

The top of Red Hill is overlain with a weathered basalt material called saprolite that is relatively impermeable and similar in composition to a clay. This saprolite significantly reduces the amount of water infiltration from rainfall into underlying basalts and the underground facility. Red Hill ridge drops steeply to the river-eroded valleys on either side, which filled in over time with sedimentary deposits (alluvium and colluvium, also known as "valley fill"). The valley fill is relatively impermeable and is underlain by similarly low-permeability saprolite that formed by the weathering of the underlying basalt. Low-permeability valley fill and saprolite extend below the water table in the valleys surrounding Red Hill, particularly in the center of the valleys and below the streambeds.

The conceptual, generic cross section view of O'ahu hydrogeology depicted below shows the basal groundwater freshwater–saltwater interface, low-permeability caprock, perched water zones, a typical horizontal-shaft water supply ("skimming") well, and regional water flow directions from mountain precipitation recharge to the sea (mauka to makai). Of primary interest near Red Hill is the regional basal aquifer, which is the source for drinking water at Red Hill Shaft and Hālawa Shaft. It exists as a thick lens of fresh water floating on and displacing seawater within the pore spaces, fractures, and voids of the basalt that forms the underlying mass of O'ahu. If this freshwater lens is overpumped, saltwater intrusion from the underlying seawater can occur, rendering the water non-potable. Also present in some areas near Red Hill is "perched water," which occurs where a pocket of infiltrated rainwater, typically limited in volume and lateral extent, is retained above the basal aquifer by an underlying segment of low-permeability material (e.g., clay).



Conceptual hydrogeology of O'ahu
(Source: Izuka et al. 2018; Oki, Gingerich, and Whitehead 1999)

Sidebar 10: Holding Capacity Analyses [Section 2.1.2]

As part of its environmental investigation for the AOC SOW, the Navy analyzed the capacity of the subsurface underneath the Red Hill fuel storage tanks to retain released fuel in naturally occurring pockets and impede its downward migration to groundwater (DON 2018b, at Secs. 6 & 9). The analyses considered both hypothetical sudden releases and hypothetical chronic releases.

Evaluation of available monitoring data indicated that the 2014 Tank 5 Release (approximately 27,000 gallons of JP-8 fuel) was likely retained within the top one-third (approximately 30 feet) of the subsurface between the lower access tunnel (underneath the tanks) and the water table (i.e., the “vadose zone”) with no significant impact to groundwater:

- No LNAPL was observed in any monitoring well, and there was little to no change in dissolved constituents as measured prior to and after the release as part of a forensics analysis.
- Based on this finding, the 2014 release was used along with site-specific geologic data and data from scientific literature to estimate the vadose zone holding capacity for LNAPL.
- This estimated holding capacity was then used to evaluate the LNAPL volume that would be retained mostly or exclusively in the vadose zone for a hypothetical future release that results in no significant impact to groundwater.

Based on this and a parallel evaluation of whether groundwater was impacted from the 2014 Tank 5 Release and reached Red Hill Shaft, the 27,000-gallon release of jet fuel:

- Did not result in the observation of LNAPL in any of the monitoring wells and the Facility.
- Did not result in any measurable increase in chemical concentrations in Red Hill Shaft.

The two evaluations focused on understanding and quantifying this “margin of safety” associated with the 2014 Release to estimate the volume of a hypothetical future sudden release that would not result in exceeding risk-based screening levels at Red Hill Shaft (DON 2018b, at B-i):

Updated holding capacity calculations performed for hypothetical future release scenarios (presented in the Red Hill *Investigation and Remediation of Releases Report*) (DON 2020b, at Appendix E) found that a sudden future release of approximately 120,000 gallons of LNAPL would have, at most, a minimal impact to groundwater and would not likely cause an exceedance of risk-based decision criteria[30] in Red Hill Shaft.

In addition, the calculations showed that a hypothetical chronic release of 2,300 gallons per tank per year (6.3 gallons per tank per day) would be degraded within the vadose zone, resulting in, at most, a minimal impact to groundwater and likely preventing an exceedance of risk-based decision criteria in Red Hill Shaft. In addition, additional criteria were developed that considered pre-existing LNAPL in the basalt that could potentially lower the holding capacities for releases in different areas of the tank farm.

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[30] As detailed in the Navy’s *Risk-Based Decision Criteria Development Plan* (DON 2017a), risk-based decision criteria have been developed to support the AOC SOW Section 6 Investigation and Remediation of Releases project. These criteria are intended to update the Red Hill *Groundwater Protection Plan* (DON 2014), ensuring that drinking water receptors are protected.

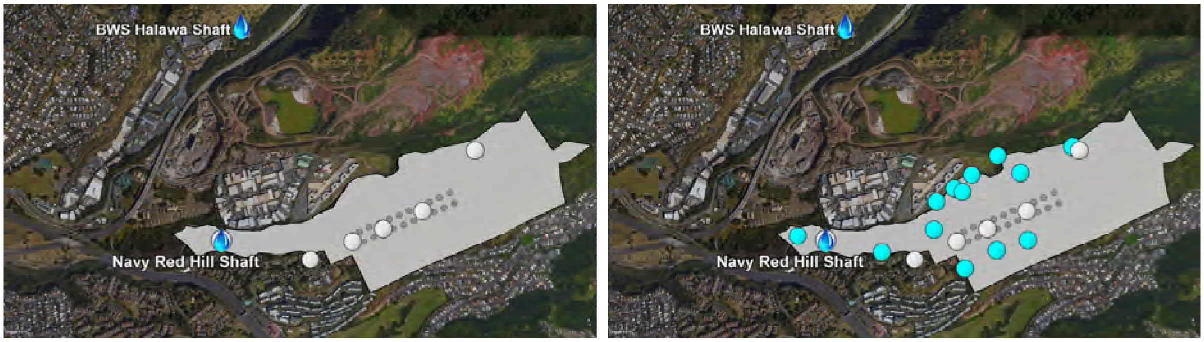
Exhibit N-6I

Sidebar 11: Current Red Hill Groundwater Monitoring Network [Section 2.3 (b)]

The Navy established its Red Hill groundwater monitoring network in 2005 with five monitoring locations, expanded to six at the time of the 2014 Tank 5 Release. Since the 2014 Release, the Navy has added 13 single- and multi-level wells for a total of 19 groundwater monitoring locations today:

Red Hill Groundwater Monitoring Network

○ **Pre-2014 Release Network (6 Wells)** ● **Today’s Network (19 Wells)**



In accordance with the Red Hill GWPP (DON 2014), the Navy conducts groundwater monitoring events at all network locations quarterly at a minimum. The groundwater samples are analyzed by a nationally accredited laboratory and validated by an independent data validator. The Navy closely evaluates all the validated results for data quality, current trends and anomalies, and indications of natural attenuation. The results are provided to DOH in *Quarterly Groundwater Monitoring Reports* for publication on their Red Hill project webpages.[31]

The groundwater monitoring results are also integral to the Navy’s environmental work under the AOC. Installation of each new well provides valuable data about the subsurface (geology, hydrogeology, and water-level measurements) that increase the understanding of both the impacts of past fuel releases and groundwater flow and contaminant fate and transport in the Red Hill area.

Results of the groundwater monitoring conducted to date are summarized in Section 2. The Navy’s continuing expansion of the Red Hill groundwater monitoring network is described in Section 3.1.7 and Sidebar 15.

As shown on Figure 4, the network is planned for further expansion; indeed, even as this Contested Case Hearing proceeds, field crew are drilling new wells and collecting new data.

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[31] https://health.hawaii.gov/shwb/ust-red-hill-project-main/

Exhibit N-6I

Sidebar 12: Wells in the Current Red Hill Groundwater Monitoring Network [Section 2.3 (b)]

Individual wells in the current Red Hill groundwater monitoring network are listed below along with their year and rationale for inclusion in the network:

Monitoring Well	Year Added to Network	Rationale for Inclusion in Network
RHMW2254-01	2005	Monitor groundwater at Navy's Red Hill Shaft (Supply Well 2254-01).
RHMW01	2005	Monitor groundwater directly under tank farm.
RHMW02	2005	Monitor groundwater directly under tank farm.
RHMW03	2005	Monitor groundwater directly under tank farm.
RHMW04	2005	Monitor background conditions in basal aquifer.
RHMW05	2009	Monitor groundwater between tank farm and Red Hill Shaft.
RHMW06	2015	Monitor groundwater between tank farm and BWS Hālawa Shaft (Supply Well 2354-01).
RHMW07	2015	Monitor groundwater between tank farm and BWS Hālawa Shaft.
RHMW08	2016	Monitor groundwater west of tank farm, in general area between tank farm and Red Hill Shaft.
RHMW09	2016	Monitor groundwater southwest of tank farm.
RHMW10	2017	Monitor groundwater south of tank farm.
RHMW11 [a]	2018	Determine if valley fill and saprolite extend below the potentiometric surface of the regional basal aquifer in South Hālawa Valley. Evaluate groundwater flow directions in South Hālawa Valley, groundwater quality between Red Hill and BWS Hālawa Shaft, and potential presence for perched groundwater conditions throughout the entire thickness of the vadose zone in South Hālawa Valley.
RHMW13 [a]	2020	Evaluate groundwater flow north of the tank farm in upper South Hālawa Valley, and groundwater quality to the northwest of Tank 5. Further define geometry of valley fill sediments and saprolite layers in South Hālawa Valley.
RHMW14 [a]	2019	Determine extent of valley fill and saprolite in the area. Evaluate groundwater quality and groundwater flow directions in South Hālawa Valley, and the potential presence for perched groundwater conditions throughout the entire thickness of the vadose zone in the area.
RHMW15 [a]	2019	Improve assessment of the effects of pumping at Red Hill Shaft. Further characterize lithology and evaluate groundwater quality adjacent to the upper reaches of the Red Hill Shaft water development tunnel.
RHMW16A	2020	Evaluate the groundwater quality and potential for flow pathways in both the shallow and deeper portions of the basal aquifer between the Facility tank farm and Hālawa Shaft.
RHMW19	2020	Evaluate groundwater flow directions in the area, and groundwater quality toward Moanalua Valley.
HDMW2253-03 (Hālawa Deep Monitor Well)	2016	Monitor groundwater between tank farm and BWS Hālawa Shaft.
OWDFMW01	2016	Monitor groundwater west of Red Hill Shaft.

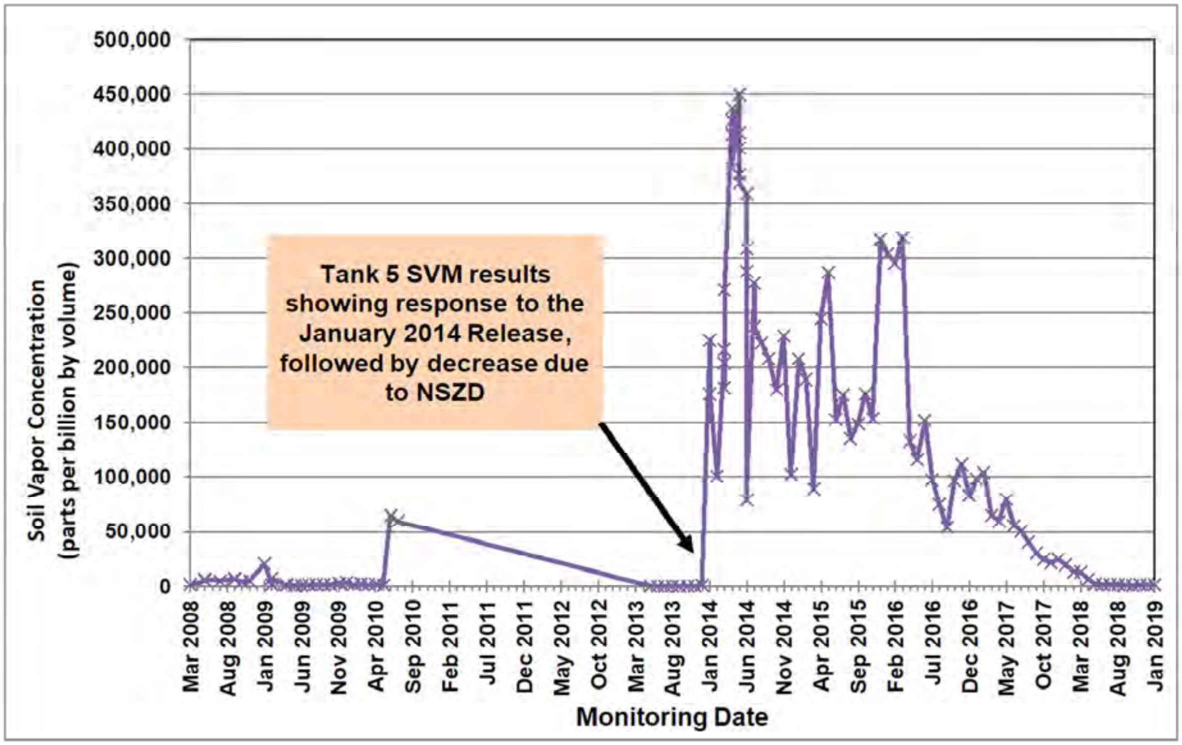
[a] RHMW11, 13, 14, and 15 are installed as multilevel wells, with five to eight discrete sampling zones each.

Exhibit N-6I

Sidebar 13: Soil Vapor Monitoring Results [Section 2.3 (k)]

Since 2008 as required by DOH in accordance with the GWPP (DON 2014), the Navy measures concentrations of volatile organic compounds under the Facility's active fuel storage tanks on a monthly basis. The results are compared to action levels initially established in the GWPP (DON 2014) as updated by the AOC Regulatory Agencies in 2015 (EPA Region 9 and DOH 2016); the results are reported to DOH monthly (DON 2008a). An exceedance of the action level triggers contingency actions in accordance with the GWPP. In addition, analysis of soil vapors resulting from the 2014 release has been used to modify the Navy's monitoring program so that concentration trends can be more reliably evaluated.

As shown in the below chart, soil vapor results related to the 2014 Tank 5 Release demonstrate that soil vapor monitoring can provide a robust system for detection of this type of release. Soil vapor concentrations in the monitoring locations below Tank 5 spiked with the release, with high concentrations continuing through early 2016. Concentrations also increased in this time frame under other nearby tanks. The concentrations later decreased in essentially exponential fashion, as would be expected for conditions related to such a release.



Soil vapor response under Tank 5 after the January 2014 Release

The Navy's plan to conduct a pilot study for a real-time continuous soil vapor monitoring system is discussed in Section 3.1.3.

3. Work Completed, Ongoing, and Planned Will Ensure That the Facility Remains Protective Throughout and Beyond the Duration of the Permit

Taken together, the ongoing environmental monitoring and analyses and upgrades to Facility infrastructure and operations will help ensure that the Facility is operated and maintained in an environmentally protective manner and remain protective of the groundwater resource throughout and beyond the duration of the 5-year UST Operating Permit. Much of this additional work and the improvements planned for implementation and yet to be decided upon under the AOC exceeds Federal and State UST regulatory requirements, will be subject to oversight of and approval by the DOH and the EPA. Thus, while the environmental data show that the Facility is currently protective, ongoing and future improvements will help ensure that the Facility becomes even more protective of human health and the environment, during and past the duration of the 5-year Operating Permit currently under consideration.

3.1 ONGOING AOC WORK ENSURES CONTINUED SAFETY OF THE FACILITY

Work and analyses in progress and yet to be completed under the AOC far exceed regulatory requirements and will ensure the continued safety of the Facility.

3.1.1 Continued Upgrading of Facility Infrastructure and Leak Detection Methods

Facility infrastructure, operational controls, and leak detection activities continue to be upgraded, making releases less and less likely and also enabling the Navy to more quickly detect any potential future releases, in order to minimize their size or duration (making potential impacts to groundwater less likely). As shown in Sidebar 14, the proposed TUA and Release Detection Decision Document[32] identifies the following additional layers of protection for release detection and safe operation of the Facility, which exceed the requirements of the UST regulations:

1. Conduct tank tightness testing (which is the only regulatory requirement for release detection) twice as frequently as required by the regulations.
2. Install permanent release detection equipment.
3. Modify equipment to improve automatic tank gauge precision.
4. Conduct real-time soil vapor monitoring pilot study.
5. Install additional monitoring wells and continue groundwater long-term monitoring (*see* Section 3.1.4)
6. Continue soil vapor monitoring, including testing the feasibility of installing a continuous soil vapor monitoring system (*see* Section 3.1.3).

Of these six completed or ongoing release detection methods, *annual* tank tightness testing is sufficient under the regulations for field-constructed tanks such as those at the Facility[33] and is, therefore, the leak detection method indicated in the Permit application form. Nevertheless, the Navy has already doubled the frequency of the required tank tightness testing and proposes to implement these additional layers of protection. The AOC Regulatory Agencies are closely scrutinizing release detection and upgrade alternatives, agree that the measures listed above are "prudent," and may ultimately require additional

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[32] https://www.epa.gov/sites/production/files/2019-09/documents/red_hill_aoc_tua_proposal_decision_document_20190919.pdf

[33] HAR § 11-280.1-43(10)(A).

Exhibit N-6I

safeguards.[34] The Navy's identification of and commitment to these measures exceeds the requirements of State and Federal UST permitting regulations.

3.1.2 Leak Detection and Tank Tightness Testing

It is important to stress in this Contested Case that, at a Facility such as this, conducting "an annual tank tightness test that can detect a 0.5 gallon per hour leak rate" completely satisfies the Hawai'i UST regulations for leak detection.[35] The Navy has already implemented a tank tightness program that exceeds these requirements. Not only does the Navy currently achieve the required 0.5 gallon per hour detection rate, but the Navy has also committed to conducting these tests twice as often as is required by the Hawai'i UST regulations, i.e., twice a year. The Navy's leak detection program, therefore, exceeds the requirements for the UST Operating Permit. Additional leak detection measures are noted here because of the additional protection they afford, but are more properly addressed under the auspices of the AOC, the full breadth of which is not in dispute here and would overwhelm this proceeding.

3.1.3 Pilot Study for Continuous Soil Vapor Monitoring

As described in previous sections of this report, data from the soil vapor monitoring system clearly reflected the 2014 Tank 5 Release, showing the expected peak and gradual decline in concentrations. As one of the additional layers of protection to enhance release detection, the Navy is currently exploring the viability of continuous, real-time soil vapor monitoring underneath all the active fuel storage tanks with a pilot study (DON 2019b, at 5, 12, 24).[36] The Navy is exploring this study both through its Red Hill environmental investigation team and through collaboration with UH researchers (*see* Section 3.4).

The goals of the pilot study will be to determine:

1. Whether the equipment used for continuous monitoring is sufficiently reliable, robust, and cost effective.
2. How to best conduct real-time soil vapor monitoring and analyze the resultant data.
3. Whether the continuous monitoring results are of sufficient quality to reliably identify a new fuel release while minimizing false-positive[37] release indications.

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[34] During preparation of this report, in a letter dated Oct. 26, 2020, the AOC Regulatory Agencies rejected the TUA and Release Detection Decision Document (DON 2019b) as requiring additional information and analyses. Importantly, the AOC Regulatory Agencies declined to yet weigh upon the sufficiency of the measures proposed by the Navy. The focus of the letter was to request additional data, analyses, and information. As such, the final scope of TUA and release detection measures that will ultimately be implemented has not yet been agreed to. In any case, the AOC Regulatory Agencies recommended implementation of the elements listed here.

[35] §11-280.1-43(10(A).

[36] We note that "soil vapor monitoring" is an approved leak detection method in the State UST regulations. HAR §11-280.1-43(5). Therefore, although not required for this Facility, this is a recognized and approved method of leak detection. Also noteworthy is that those facilities using soil vapor monitoring for leak detection are not required by the regulations to produce continual real time data; rather, the regulations require that soil vapor systems operate such that a release cannot go "undetected for more than thirty-one days." HAR §11-280.1-43(5)(C).

[37] Environmental data typically includes a certain level of "noise," i.e., (in basic terms) variations around the average or actual value. Thus, in this context, "false positives" could include momentary increases in vapor concentrations (e.g., due to varying flow induced by the Facility ventilation fans) that suggest there is a leak when no actual leak has occurred. False positives can be minimized by treating the data in an appropriate fashion.

The pilot study data will also be used to identify action levels for a full-scale continuous monitoring system, should one be developed. This will help to identify new fuel releases while minimizing false positive results. If this approach is deemed appropriate, data can be reviewed and action levels can be refined on a tank-by-tank basis to further improve release-detection capabilities.

3.1.4 Expanded Groundwater Monitoring Network and Continued Long-Term Monitoring

The Navy continues to expand its Red Hill groundwater monitoring network. From 5 wells that were being used before the 2014 Tank 5 Release to 19 wells in operation today, the current plans are to increase that number to 27 wells by 2023 (*see* Sidebar 15).[38] Due to the significant depth to groundwater, the complicated drilling in this heterogenous basaltic environment, and the limited number of on-island contractors (only one) with the equipment capable of performing this complicated drilling, each well takes significant time and care to install and comes at considerable expense. As new basal groundwater monitoring wells come online, they are added to the quarterly groundwater monitoring events, with results reported to DOH and made available to the public on at least a quarterly basis.

Not only will the additional data help document the safety of the drinking water supply, the geologic and hydrogeologic data collected during well drilling and installation will also greatly expand the understanding of subsurface conditions across Hālawa Valley. The Navy will incorporate the additional data to perform future modeling efforts, establish a formal groundwater monitoring network under the AOC SOW, and update the GWPP (*see* Sections 3.1.5–3.1.7).

3.1.5 Groundwater Flow Modeling

Understanding the direction and rate of groundwater flow under a variety of reasonable supply well pumping scenarios is critical to assessing the risk that any hypothetical future fuel leak could pose to local drinking water. Initially, the AOC SOW scoped the groundwater flow model effort as one of updating a model developed for a previous 2007 Facility environmental investigation (DON 2007). The Navy modeling team found that updating the 2007 model was insufficient and recommended additional work, including entirely rebuilding, providing more detail, and expanding the model. Working with the AOC Parties and other stakeholders, the Navy refined the modeling domain to extend approximately 51 square miles from Waimalu Valley in the northwest to Kalihi Valley in the southeast, and from near the Koʻolau crest in the northeast to Pearl Harbor and the Pacific Ocean in the southwest (*see* Location Map, Figure 1), far beyond where any impacts might reasonably be expected. Since there are a range of factors that require consideration, the Navy developed a multi-model approach to bound expected flow conditions (Ajami et al. 2006). Such an effort requires additional work on behalf of the Navy but results in a more reliable range of predictions under given scenarios.[39]

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[38] As is the case with soil vapor monitoring, it bears noting that "groundwater monitoring," although not required for this Facility, is generally an acceptable release detection method under the Hawaii UST regulations. HAR §11-280.1-43(6). While the Navy acknowledges that the depth to water is greater at the Facility than set forth in the regulations, HAR §11-280.1-43(6)(B), the other requirements are generally met. Perhaps most importantly, a compliant groundwater monitoring system must include "methods used can detect the presence of at least one-eighth of an inch of free product on top of the groundwater in the monitoring wells." HAR §11-280.1-43(6)(F). No such free product has ever been measured in any of the (currently 19) groundwater monitoring wells during the entire course of the long-term groundwater monitoring program.

[39] In the past, investigators often tried to complete a single predictive model for a given site. However, there is always a certain level of variation in environmental conditions at any site, especially one as geologically and hydrologically complicated as Red Hill, such that one single model cannot be counted upon to be completely accurate or precise. Therefore, many modern experts recommend the use of a multi-model approach, wherein a set of models are used to analyze different potential aquifer conditions, resulting in models that encompass or "bound" the reasonably likely outcomes (Scavia, DePinto, and Bertani 2016).

The Navy published a set of interim groundwater flow models in its *Groundwater Protection and Evaluation Considerations* report (DON 2018b, at Appendix A), based on the then-existing model. As part of developing the interim model, the Navy developed 49 separate models to initially assess the most important factors affecting groundwater flow. The interim modeling effort indicated that groundwater generally flows from the Facility southwest toward Red Hill Shaft, which pumps a significant amount of water. Comments from the AOC Regulatory Agencies, USGS, BWS, and other stakeholders were considered in developing the more detailed March 2020 *Groundwater Flow Model Report* (DON 2020a), which is currently under review by the AOC Regulatory Agencies. The March 2020 report followed years of development and extensive collaboration with EPA, DOH, USGS, BWS, and other stakeholders and experts, including 15 meetings (so far) of the Groundwater Modeling Working Group established in June 2017 to facilitate this collaboration. The Navy maintained a list of Issues and Action Items as part of each Working Group meeting so that various issues could be tracked and resolved as the modeling effort progressed. In addition, 29 meetings(so far) of the AOC Parties Technical Working Group have been held to deal with ongoing technical issues, many of which related to the modeling effort. During these meeting, various stakeholder raised concerns or made recommendations, many of which the Navy incorporated into the groundwater modeling effort.

The Navy developed the March 2020 groundwater flow model report using a multi-model approach to evaluate the flow of groundwater from beneath the Facility and to compute the source water zones (capture zones) of the Red Hill Shaft and Hālawa Shaft water supply wells under various geologic and pumping conditions.[40] The modeling team used the multi-model approach (Ajami et al. 2006) to bound feasible conditions, some of which were analyzed to address Regulator recommendations and stakeholder (including BWS) comments on previous and interim models. Based on various technical discussions with the AOC Regulatory Agencies and stakeholders, the Navy evaluated and condensed, modified, and added to the initially developed 49 models to present 14 models in the *Groundwater Flow Model Report*. The analyses resulted in several important conclusions:

- Importantly, all models indicated that groundwater from beneath the tank farm is captured by Red Hill Shaft when it is pumping at its regulatory-permitted pumping limit, indicating that the Navy can capture and manage hypothetical future releases, should any reach the groundwater and extend beyond the tank farm (*see* Sidebar 16).
- Certain models showed that if Red Hill Shaft is not pumping, there are potential groundwater flow pathways to drinking water sources such as Hālawa Shaft. In those models, however, the groundwater travel time is relatively long, such that:
  - There is time for natural attenuation to decrease or eliminate potential impacts drinking water (this will be analyzed and scrutinized by the DOH and EPA in future contaminant fate and transport modeling work under the AOC).
  - In the worst-case scenario, there would be advance notice of the potential need to treat hypothetical dissolved constituents, if necessary. Such treatment systems could be similar to the granular activated carbon treatment systems currently used by BWS at other wells

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[40] In general, when water supply wells are pumping, the elevation of the groundwater near the wells decreases, which causes groundwater from other locations to be drawn toward the well under the influence of gravity. The area from which groundwater is drawn to the well is referred to as the well's "capture zone" (also referred to as the well's "source water zone").

on O‘ahu, which are conventional systems that municipal water suppliers around the world successfully rely upon.[41]

The groundwater flow model is expected to be updated upon receipt of comments from the Regulators and other stakeholders. Groundwater flow modeling is not required by the UST regulations, but serves to provide an extra layer of protection, deemed important by the Regulators in the AOC, by enhancing the understanding of environmental conditions and the ability to make predictions and inform the expansion of the groundwater monitoring network and the anticipated update to the GWPP.

3.1.6 Contaminant Fate and Transport Modeling

Once the AOC Regulatory Agencies approve the groundwater flow models, they will be used to conduct the contaminant fate and transport modeling effort to analyze how hypothetical future releases might behave. This modeling effort will analyze how such petroleum hydrocarbons would be naturally attenuated by the aquifer matrix, including bioremediation by naturally occurring bacteria, and how any residual hydrocarbons might flow under various Navy and BWS pumping conditions. The results of the contaminant fate and transport model will be used to help with AOC decision making by providing a better understanding of potential risk to drinking water receptors and groundwater resources under various hypothetical scenarios. These analyses will also be used to establish “sentinel” well locations, which can provide early warning before there are any impacts to drinking water and appropriate trigger levels to activate contingency response plans (*see* Section 3.1.7). Elements expected to be integrated into the contaminant fate and transport model include:

- A focus on particular groundwater flow models that are deemed most appropriate for decision making.
- Refinement of those flow models.
- Potential LNAPL modeling to help understand how a range of fuel releases may behave in the environment.
- Further refinement of natural attenuation processes and rates.

The modeling may show (as is normally the case with hydrocarbons and as is consistent with available data) that a hypothetical release would first have to make its way down to groundwater, would travel slower than the groundwater, and may be partially or completely attenuated prior to reaching particular water supply wells (the farther the well is from the release, the more likely that natural attenuation will protect the resource). Like the groundwater flow modeling, contaminant fate and transport modeling will provide additional information and protection beyond that required by Hawaii’s UST regulations.

3.1.7 Sentinel Well Network

As follow-on work to the AOC SOW contaminant fate and transport modeling and as documented in its *Sentinel Well Network Development Plan* (DON 2017b), the Navy will establish a formal Red Hill monitoring well network to identify possible contaminant migration and thus protect drinking water through the use of regular groundwater monitoring. This network will include any additional sentinel wells in accordance with the AOC SOW and the objectives of the *Sentinel Well Network Development Plan.* The network will be described in a *Groundwater Monitoring Well Network Report* and subsequently formalized in a *Groundwater Monitoring Well Network Decision Document.* Both documents will require AOC Regulatory Agency approval. The Navy will then incorporate the approved network into its update of the

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[41] At their essence, granular activated carbon systems consist of containers full of carbon through which water is passed—the carbon is very effective at filtering out hydrocarbons, not unlike common aquarium filters.

Red Hill GWPP (DON 2014), which will also provide additional long-term protection beyond that required by Hawaii's UST regulations.

3.1.8 Ongoing Five-Year Reviews of the TUA Decision and Release Detection Methods

Two of the key elements to preventing and detecting releases are the TUA and Release Detection methods. As described in this document and other testimony submitted concurrently, while current methods comply with the existing regulations, the Navy is developing its recommendations for additional TUA and Release Detection methods that go beyond the regulatory requirements. The TUA and Release Detection decisions, once approved by the AOC Regulatory Agencies and implemented by the Navy, will also undergo an ongoing 5-year review and renewal process (via TUA *Re-evaluation Reports*) under the AOC. This 5-year review is beyond any requirements for the subject 5-year Operating Permit, but will provide additional protections into the future that will align well with future 5-year renewals of the Facility's UST Operating Permit.

3.2 CONTINUED DATA COLLECTION, REPORTING, AND CLOSE OVERSIGHT BY THE AOC REGULATORY AGENCIES

The plethora of Red Hill area environmental data already collected (*see* Section 2) are even now being added to, and this is likely to remain the case for the life of the Permit. Much of these data have never been collected before in such detail, and the results have vastly increased understanding of the subsurface for all interested parties. The continuing data collection includes:

- Chemical analyses of groundwater samples from the expanding monitoring well network.
- Geologic and hydrogeologic data from the ongoing drilling and installation of new groundwater monitoring wells.
- Monthly LNAPL checks in the near-tank wells; quarterly LNAPL checks in all conventional groundwater monitoring wells.
- Soil vapor monitoring results from underneath the active fuel storage tanks, including potentially continuous monitoring results based on the Navy's planned pilot test (*see* Section 3.1.3).

All the environmental and AOC work is being done under the close scrutiny of the State and Federal AOC Regulatory Agencies, who are updated and provided various reports and groundwater protection data at a minimum of once a month. Based on this and other data, the Navy's continually updates the AOC Regulatory Agencies and DOH under the GWPP, and thence to the public, on environmental conditions, and will continue to do so via:

- Monthly Soil Vapor Monitoring Reports
- Quarterly Groundwater Monitoring Reports
- Quarterly Drinking Water Monitoring Reports
- Quarterly Oil/Water Interface Reports
- Quarterly Release Response Reports
- Ongoing Five-Year Reviews of the TUA and Release Detection Decision, following AOC Regulatory Agency approval of the Navy's Decision Document (DON 2019b)

Taken together, these substantial data gathering and analyses will help the Navy and the Regulators ensure that the Facility remains protective during and beyond the 5-year Operating Permit duration.

More generally, all the work being done and improvements being made under the AOC are subject to approval by the State and Federal AOC Regulatory Agencies and their technical experts. While reasonable people (even reasonable experts) can disagree on particular aspects of the work, progress continues to be made, and the Navy continues to solicit and incorporate outside ideas and expend considerable resources (which have already amounted to $203 million completing AOC work, with another $470 million allocated for future work) to provide the best practicable analyses, solutions, and improvements required to maintain the protectiveness of the Facility. Recent AOC Regulator letters requesting additional work and analyses from the Navy demonstrate that the Regulators are taking a hard look at the data being gathered and the decisions being made and are anticipated to continue to press the Navy for more, in order to ensure ongoing protectiveness beyond the 5-year Operating Permit duration.

Whether or not there is final agreement on every detail of the vast amount of work being conducted under the AOC, and notwithstanding the issuance of a UST Operating Permit, the AOC Regulatory Agencies maintain the ability (under the governing laws and expressly reserved in the AOC) to shut down the Facility if they believe it poses a threat; they have not yet made any indications that the Facility poses such a threat.

3.3 USE OF RISK ASSESSMENT RESULTS TO IDENTIFY NEEDED UPGRADES

Risk assessment under the AOC is a process that is above and beyond any requirement in the UST regulations—such analyses are not required, and we are not aware of another UST facility in Hawai‘i or elsewhere that has embarked upon such a detailed quantitative analysis of risk. The completed Quantitative Risk and Vulnerability Assessment Phase 1 (the “QRVA”) has already proven to be a useful tool when applied appropriately. As the DOH and EPA acknowledged, while there may be disagreements as to the numerical predictions of releases in the QRVA, the report is indisputably useful for deciding between which Facility features to upgrade (EPA Region 9 and DOH 2019). It is important to keep in mind that the QRVA is a highly conservative assessment that:

1. Is *never* normally performed for UST systems.
2. Does not account for Facility upgrades or operational improvements made since 2017 or planned to be made (*see* Sidebar 17 and Sidebar 14).
3. Makes predictions that don’t even align well with the *history* of the Facility, and, therefore, should not be considered a precise estimate of the likelihood of *future* releases.

Importantly, even taking its (now outdated) projections at face value, the QRVA does not predict any releases during the 5-year life of the Permit currently at issue (or during the 25-year maximum time frame for secondary containment) that would exceed the vadose zone holding capacity or (considering NSZD and MNA) otherwise impact human health or the environment (*see* the summary of the Facility’s holding capacity presented in Section 2.2.1; *see also* Sidebar 9 and Sidebar 10).

Moreover, however accurate they may or may not have been in 2017, the QRVA’s predictions of the likelihood of releases will continue to become more outdated as improvements continue to be made under the AOC. In any case, the Navy has already begun evaluating and addressing the “weakest link” Facility components, as identified by the Risk Assessment, and has begun decommissioning nozzles that cannot be inspected or repaired by a human being. Although the precise scope of work for the next phase of risk assessment has not yet been finalized, it is expected to tie together the risk assessment and the modeling effort, in order to estimate potential impacts due to hypothetical releases in order to inform better decision-making for the Facility.

3.4 COLLABORATION WITH OUTSIDE EXPERTS

The environmental data collection and analyses have been conducted with the input of many of Hawaii's leading environmental and groundwater experts, including the Navy, DOH, UH, USGS, DLNR, CWRM, BWS, and their consultants, some of whom are state, national, or globally recognized leaders. Since signing the AOC, the Navy has initiated or participated in numerous meetings with the AOC Regulatory Agencies, technical experts, stakeholders, and other government entities, and has provided testimony at several City and State administrative hearings.

The Navy is closely collaborating with UH in a number of research projects designed to improve the Facility's maintenance and operational procedures and its release detection capabilities (*see* Sidebar 18), including:

- Ultrasonic, infrared, and electromagnetic tank inspection
- Continuous soil vapor monitoring
- Tank inspect and repair protocols
- Advanced microscopic methods for mapping tank corrosion
- Concrete degradation, inspection, and retrofit
- Permanent-magnet, wall-crawling mobile robot for remote inspection of backside corrosion of tank while fuel-submerged
- Microbial degradation of fuel hydrocarbons in subsurface for early detection of releases

In addition, the Navy recently contracted with a specialist contractor to conduct a secondary-containment feasibility study.[42] Thus, the Navy continues to evaluate innovative state of the art solutions for this one-of-a- kind facility.

3.5 COMMUNITY OUTREACH

In addition to a publishing a series of fact sheets, stakeholder letters, and press releases about Red Hill, the Navy has participated with the AOC Regulatory Agencies in Red Hill Public Meetings and Public Workshops annually at a minimum since the AOC was implemented in 2015. These meetings serve to:

- Update the public on the Navy's progress in fulfilling the requirements of the Red Hill AOC in a transparent manner.
- Give the public opportunity to provide valuable input regarding Red Hill in the form of written or oral testimony and comments.

With public gatherings restricted in 2020 due to the coronavirus pandemic, the Navy has started providing quarterly recorded audio casts on its Red Hill webpage[43] to keep the public updated on its latest improvements to the Facility, which are designed to protect the groundwater resource and ensure that the Facility is operated and maintained in an environmentally protective manner.

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[42] The Navy recently outlined its advanced research projects in a presentation to the State's Fuel Tank Advisory Committee, *available at* https://health.hawaii.gov/shwb/files/2020/11/Navy-Presentation-on-All-FCTs-and-Red-Hill_10_30_2020.pdf.

[43] https://www.cnic.navy.mil/regions/cnrh/om/red-hill-tank.html

Exhibit N-6I

Sidebar 14: Facility Improvements Under Other Sections of the AOC SOW [Section 3.1.1]

The AOC directs a process that is working and has led to the implementation of several significant improvements to the Facility's maintenance and operational procedures since 2015. The process has also developed proposed additional improvements to allow the Facility to continue to operate in a manner that protects the environment. The Navy's proposed TUA Decision Document (DON 2019b)[44] describes the following improvements under other sections of the AOC SOW:

Completed or Ongoing:

- More frequent tank tightness testing[45]
- More accurate inventory monitoring and trend analysis using automated fuel handling equipment
- Regulator-approved clean, inspect, and repair process
- More effective identification and repair of existing concrete tanks with steel liners
- Higher standard for tank inspection, repair, and maintenance
- Theater-wide fuel requirements study

Near-Term:

- Enhanced release detection
- Real-time continuous soil vapor monitoring pilot study
- Better tank fill practice and epoxy coating
- Improved accuracy of automatic tank gauging equipment through modification of stilling wells

Mid-Term/Long-Term:

- Reduced risk by decommissioning small nozzles from service
- Experimental pilot project to fully coat interior surface of a tank
- Identification and adoption of the best available practicable technology
- Water treatment plant evaluation

These improvements are in addition to those made under AOC SOW Sections 6 & 7 that are detailed elsewhere in this *Facility Environmental Report*:

- Increased inventory of monitoring wells
- Comprehensive groundwater modeling
- Supplementary approach to release detection via groundwater sampling and soil vapor monitoring
- Inclusive Navy-BWS-USGS synoptic water-level study

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[44] While the AOC Regulatory Agencies rejected the decision document's sufficiency as a basis for final decisions, and requested additional analyses and an update of the decision document prior to finalizing the suite of release detection methods and tank upgrades, it is anticipated that all or most of the measures listed here will be implemented, albeit perhaps in a modified form.

[45] The Navy now conducts tank tightness testing semi-annually—twice the frequency specified in HAR § 11-280.1-43(10)(A): "Conduct an annual tank tightness test that can detect a 0.5 gallon per hour leak rate."

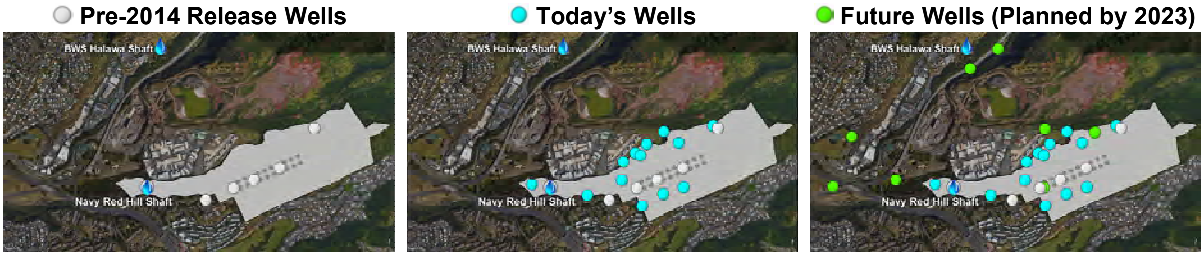
Exhibit N-6I

Sidebar 15: Expansion of the Red Hill Groundwater Monitoring Network [Section 3.1.4]

The current Red Hill groundwater monitoring network is described in Section 2.3 and Sidebar 11 of this report. Indeed, among the eight groundwater monitoring wells the Navy plans to add to the network by 2023, new wells are under construction today. This will expand the network beyond the current perimeter wells into lower Hālawa Valley, South Hālawa Valley, and North Hālawa Valley. This expanded network will provide 27 wells—over five times the number of monitoring locations present at the time of the 2014 Tank 5 Release. The new wells will help to monitor groundwater conditions throughout the Red Hill area and verify that drinking water remains safe. Locations and dates of new monitoring well installations are subject to change.

The eight new wells do not count proposed well pairs, where the Navy plans to install separate adjacent shallow and deep (basal) groundwater monitoring wells to better understand conditions in areas where anomalously high groundwater elevations have been measured in current monitoring wells.

Expanded Red Hill Groundwater Monitoring Network



○ Pre-2014 Release Wells **● Today's Wells** **● Future Wells (Planned by 2023)**

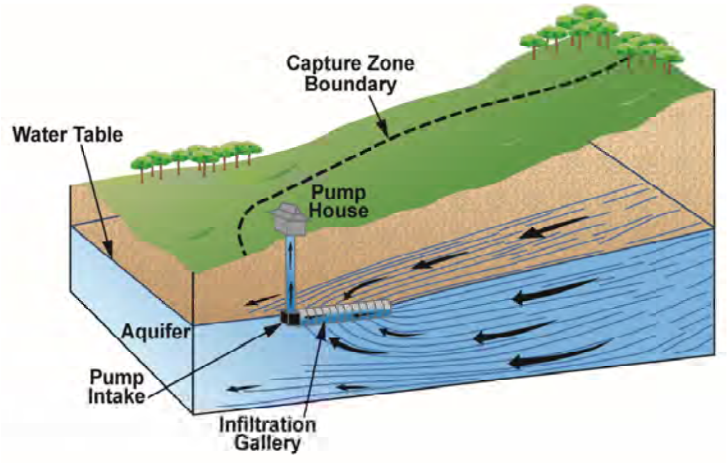
Proposed Monitoring Well	Purpose
RHMW01R	Provide capability to detect floating LNAPL at the basal groundwater surface adjacent to existing monitoring well RHMW01. That cannot be achieved in RHMW01 as its screen is situated below the water table surface.
RHMW12 and RHMW12A	Evaluate the elevation of heads and groundwater chemistry in both shallow groundwater overlying the regional basal aquifer and the regional basal aquifer in South Hālawa Valley. Evaluate groundwater flow patterns as well as the potential for a geologic and hydraulic barrier to groundwater flow within the regional basal aquifer.
RHMW17 and RHMW17A	Focus on shallow groundwater elevations observed in South Hālawa Valley during drilling at other locations. This well pair will be used to evaluate groundwater flow patterns and the potential for a geologic and hydraulic barrier to groundwater flow within the regional basal aquifer. The well pair will also provide a monitoring point for groundwater chemistry to reduce the gap between monitoring locations RHMW06 and RHMW13. RHMW17 would be used to evaluate heads in the upper portion of the regional basal aquifer.
RHMW18	Obtain hydraulic and chemistry data to the west of the Facility tank farm and Red Hill Shaft. Evaluation of regional gradients and impacts of pumping from Red Hill Shaft and Hālawa Shaft will be enhanced with this additional, more westerly well.
RHMW20	Currently, all monitoring wells are clustered around the Facility tank farm and Red Hill Shaft, with very low water level gradients between wells. Evaluation of regional gradients will be enhanced with this additional, more westerly well. This well will also evaluate the extent and impact of tuffs on groundwater flow patterns.
RHMW21	Located significantly downgradient of Hālawa Shaft in the vicinity of Hālawa District Park. Currently, all monitoring wells are clustered around the Facility tank farm and Red Hill Shaft, with very low gradients between wells. Evaluation of regional gradients will be enhanced with this additional, more westerly well.
RHMW22	Proposed location near Hālawa Shaft. Currently, all monitoring wells are clustered around the Facility tank farm and Red Hill Shaft, with very low water level gradients between wells. Evaluation of regional gradients will be enhanced with this additional well. This will be one of two monitoring wells in North Hālawa Valley. Synoptic data from this well will improve understanding of hydraulic characteristics in this area due to Hālawa Shaft pumping.
RHMW23	Proposed location near Hālawa Shaft. Currently, all monitoring wells are clustered around the Facility tank farm and Red Hill Shaft, with very low water level gradients between wells. Evaluation of regional gradients will be enhanced with this additional well. This will be one of two monitoring wells in North Hālawa Valley. Synoptic data from this well will improve understanding of hydraulic characteristics in this area due to Hālawa Shaft pumping.

Exhibit N-6I

Sidebar 16: Establishing a Groundwater Capture Zone [Section 3.1.5]

Should potential future releases impact groundwater beneath the tanks, a “capture zone” can be induced by pumping Red Hill Shaft, as shown in the figure below. With the establishment of a capture zone, contaminated groundwater can be prevented from further migration, extracted, and treated to safe levels.

Understanding capture zones (i.e., source water zones) is a key element of the Navy’s groundwater modeling effort under the AOC. These zones describe the areas in the model area where water can flow to Red Hill Shaft and/or Hālawa Shaft when these drinking water supply wells are pumping at permitted rates. Any contamination in these areas could potentially flow toward these wells (not considering natural attenuation) over certain time periods.



A capture zone created by pumping a well

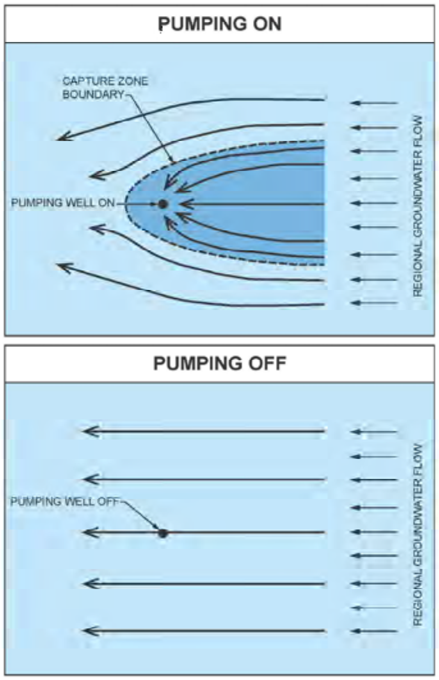
Such understanding of the capture zone created by Red Hill Shaft, even when Hālawa Shaft is pumping, has helped to determine:

- When operating at or near its permitted capacity, Red Hill Shaft can contain potential contaminant migration from beneath the tank farm.
- Where contaminants may potentially flow if Red Hill Shaft is not pumping.
- Groundwater travel times.

This information is critical to decision making as well as to the development of remedies for petroleum releases that the Navy evaluated in its AOC SOW Section 6 *Investigation and Remediation of Releases Report* (DON 2020b) (currently under review by the AOC Regulatory Agencies). In the report, Red Hill Shaft was selected as the key receptor of concern since:

- All current groundwater flow models and associated particle track analyses indicate that shallow groundwater beneath the tank portion of the Facility is within the capture zone of Red Hill Shaft (when Red Hill Shaft is pumping at its permitted rate).
- Groundwater flow rates from the tank farm to Red Hill Shaft are in the range of weeks to months.

Potential contaminant flow in groundwater under various hypothetical scenarios will be evaluated as part of the Navy’s forthcoming contaminant fate and transport modeling effort under the AOC.



Sidebar 17: Preventing a Recurrence of the 2014 Tank 5 Release [Section 3.2]

The 2014 Tank 5 Release that precipitated the Red Hill AOC was a confluence of three factors and was not a leak caused by corrosion of the tanks. Post-release evaluation determined that the release was caused by:

1. Faulty work and poor quality control by the Navy's contractor during the routine 3-year tank rehabilitation process.
2. Lack of quality assurance oversight by the Navy.
3. Operator error in assuming alarms were faulty.

Each of these factors are addressed in the Navy's Tank Inspection, Repair, and Maintenance (TIRM) report (NAVFAC EXWC 2016), with mitigation measures implemented so that none of these causes recurs, let alone in tandem. The AOC-Regulator-approved TIRM Decision Document (NAVFAC EXWC 2017) identifies improvements currently being implemented, planned, or awaiting completion of Navy work by other AOC SOW sections. Several of these improvements exceed the requirements of the AOC SOW and current State regulations:

Improvements Currently Being Implemented:

1. Tank inspection specification: codifies improved inspection procedures and establishes qualification requirements for inspection personnel.
2. Tank repair specification: establishes improved requirements for tank repairs.
3. Construction management: establishes functions and identifies roles and reporting protocol for both Navy and contractor personnel.
4. Contracting: specifies use of standard design-build contracts specific to petroleum, oils, and lubricants work.
5. Tank refilling and return-to-service instruction: establishes tank-specific procedures to ensure completeness of repairs and maintenance.
6. Tank tightness testing frequency: increased frequency of Red Hill tank tightness testing to twice per year, which is double the frequency required by HAR § 11-280.1-43(10)(A).

Improvements Planned for Implementation:

1. Update to tank cleaning specification.
2. Spot coat areas where the coating is currently disbonded, coat patch plates, spot or stripe coat selected areas.
3. Install a slotted aluminum tube in each tank to house probes for the existing Automatic Tank Gauge (ATG) System.
4. Develop as-built drawings of each tank.

Exhibit N-6I

Sidebar 18: Navy's Research Collaboration with University of Hawaiʻi ("UH") [Section 3.4]

With assistance from the office of U.S. Senator Brian Schatz, the Navy has recently partnered with the UH College of Engineering and Applied Research Laboratory to improve understanding of the current conditions of the fuel tanks and how best to maintain and monitor them using cutting-edge technology and techniques. Several proposals are currently under evaluation to explore improvements to tank inspection and repair techniques and protocols, including:

- Conducting an independent assessment of the current conditions of the fuel tanks using existing data and by performing additional independent analyses.
- Investigating inspection techniques and equipment using drones and robotic equipment that can crawl on the sides of the wall when the tanks are both empty and full, using advanced sensing techniques such as infrared thermal imagery to examine the condition of the wall. This will significantly improve the Navy's ability to inspect the tanks more frequently and track any changes to the tank walls much sooner than current technology allows.

  Specifically, this technology provides an improved and more efficient method for conducting rapid scans over wide areas during the initial phase of inspection, that are effective in presenting possible surface defects. Regions of interest that warrant further inspection can be analyzed in greater detail.
- Developing new protocols for measuring and predicting the performance of the tank walls to develop appropriate intervals for making recommendations for repair and maintenance schedules.
- Implementing a real-time system of remote monitoring of conditions via small transmitting sensors installed throughout the tanks.
- Developing solutions for secondary containment.
- Utilizing environmental sensors, advanced data collection, and data analytics using a broad set of data including other environmental elements (such as weather conditions) with the ability to correlate and present multi-dimensional data in a graphical interface.

Other projects the Navy is exploring with UH include the feasibility of real-time soil vapor monitoring under the tanks for more immediate indication of a leak, and natural attenuation studies. Additionally, the Navy collects water samples from its groundwater monitoring network for isotope analysis in a geothermal study being conducted by the UH Water Resources Research Center.

4. Documents Incorporated Into the Record

The Navy has collected a plethora of data and conducted a vast number of analyses for the Facility prior to and pursuant to the AOC, which are described in a host of documents related to the Facility. Several of the documents contain detailed underlying data for the information presented herein or are otherwise considered important enough they incorporate into the record in this contested case. Table 1 lists Red Hill environment-related documents that the Navy submits for incorporation into the record for this Contested Case Hearing; links to official government websites are provided where available.

Table 1: Environmental Documents to be Incorporated Into the Record

Document	URL
1. AOC SOW § 2: Tank Inspection, Repair, and Maintenance (TIRM):	
a. Navy’s TIRM Report	https://www.epa.gov/sites/production/files/2016-10/documents/red-hill-aoc-section-2-2-tirm-report-2016-10-11.pdf
b. Navy’s TIRM Decision Document	https://www.epa.gov/sites/production/files/2017-09/documents/red_hill_aoc_tirm_decision_document.pdf
c. Navy’s Red Hill Facility Evaluation Report (concludes Facility is safe)	https://www.epa.gov/sites/production/files/2017-06/documents/red_hill_facility_compliance_evaluation_report_june_2017.pdf
d. AOC Regulatory Agencies’ Approval of TIRM Decision Document	https://www.epa.gov/sites/production/files/2017-09/documents/epa_and_doh_approval_of_tirm_decision_document.pdf
2. AOC SOW § 3: Tank Upgrade Alternatives (TUA):	
a. Navy’s Proposed TUA and Release Detection Decision Document [a]	https://www.epa.gov/sites/production/files/2019-09/documents/red_hill_aoc_tua_proposal_decision_document_20190919.pdf
b. AOC Regulatory Agencies’ Notice of Deficiencies for the TUA and New Release Detection Alternatives Decision Document (Disapproval)	https://www.epa.gov/red-hill/tank-upgrade-alternatives-red-hill#file-575447
3. AOC SOW § 4: Release Detection/Tank Tightness Testing:	
a. Navy’s Current Fuel Release Monitoring Systems Report	https://www.epa.gov/sites/production/files/2016-04/documents/current-fuel-release-monitoring-systems-report-with-appendices-2016-04-04.pdf
b. AOC Regulatory Agencies’ Approval of Current Fuel Release Monitoring Systems Report	https://www.epa.gov/sites/production/files/2016-09/documents/approval_of_current_fuel_release_monitoring_systems_report_15_sep_2016.pdf
c. Navy’s Proposed TUA and Release Detection Decision Document [a]	https://www.epa.gov/sites/production/files/2019-09/documents/red_hill_aoc_tua_proposal_decision_document_20190919.pdf
d. AOC Regulatory Agencies’ Notice of Deficiencies for the TUA and New Release Detection Alternatives Decision Document (Disapproval)	https://www.epa.gov/red-hill/tank-upgrade-alternatives-red-hill#file-575447
3. AOC SOW § 5: Corrosion and Metal Fatigue Practices:	
a. Navy’s Destructive Testing Results Report	https://www.epa.gov/sites/production/files/2019-07/documents/red-hill-destructive-testing-results-report-20190707.pdf
b. AOC Regulatory Agencies’ Joint Response to Destructive Testing Results Report (Disapproval)	https://www.epa.gov/sites/production/files/2020-03/documents/joint-response-red-hill-corrosion_metal_fatigue_practices_destructive_testing_results-signed-2020-03-16.pdf
c. Navy's Response to AOC Regulatory Agencies’ Disapproval	https://www.epa.gov/sites/production/files/2020-07/documents/red_hill_dtrr_aoc_sow_sec_5_2jun.pdf
d. Regulatory Agencies’ Response (Conditional Approval of Completion of AOC SOW § 5.3.3)	https://www.epa.gov/sites/production/files/2020-07/documents/red_hill_joint_regulatory_agency_response_2020-07-07.pdf
5. AOC SOW § 6: Investigation and Remediation of Releases:	
a. Navy’s Investigation and Remediation of Releases Report [a]	https://www.epa.gov/sites/production/files/2020-04/documents/red-hill-investigation-and-remediation-of-releases-report-rev00-redacted-2020-03-25.pdf

Document	**URL**
6. AOC SOW § 7: Groundwater Protection and Evaluation:	
a. Navy's Groundwater Flow Model Report [a]	https://www.epa.gov/sites/production/files/2020-04/documents/red-hill-groundwater-flow-model-report-redacted-2020-03-25-.pdf
b. Navy's Conceptual Site Model Report, Revision 01	https://www.epa.gov/sites/production/files/2019-07/documents/red_hill_conceptual_site_model_20190630-redacted.pdf
c. Navy's Groundwater Protection and Evaluation Considerations Report	https://www.epa.gov/sites/production/files/2018-09/documents/red_hill_interim_groundwater_flow_model-rev00_2018-07-27-redacted.pdf
7. AOC SOW § 8: Risk/Vulnerability Assessment:	
a. Navy's Quantitative Risk and Vulnerability Assessment ["QRVA"] Phase 1 (Internal Events without Fire and Flooding)	https://www.epa.gov/sites/production/files/2019-06/documents/red_hill_risk_assessment_report_redacted-2018-11-12.pdf
b. Navy's QRVA Transmittal Letter	https://www.epa.gov/sites/production/files/2019-06/documents/risk_assessment_letter_and_summary.pdf
c. Navy's Risk and Vulnerability Assessment Summary, dated May 29, 2019	https://www.epa.gov/sites/production/files/2019-06/documents/risk_assessment_letter_and_summary.pdf
8. Soil Vapor and Groundwater Monitoring Reports:	
a. Navy's Red Hill Groundwater Protection Plan	https://health.hawaii.gov/shwb/files/2018/06/2014-08-encl-1-interim-update-final-gw-protection-plan.pdf
b. Navy's Soil Vapor Monitoring Reports: • Inception to 2015: • 2015 to present:	 • https://health.hawaii.gov/shwb/files/2016/02/2015-09-08-soil-vapor-for-aug-2015.pdf • https://health.hawaii.gov/shwb/files/2020/06/2020-06-12-soil-vapor-measurments-for-May-2020.pdf
c. Navy's 2014 to April 2020 Oil/Water Interface Measurement Quarterly Reports	https://health.hawaii.gov/shwb/files/2020/05/2020-05-07-oil-water-interface-measurement-April.pdf
d. Navy's Second Quarter 2020 Groundwater Monitoring Report	https://health.hawaii.gov/shwb/ust-red-hill-project-main/red-hill-technical-documents-2020/

[a] AOC SOW deliverable currently under review by the AOC Regulatory Agencies.

5. Conclusions

As described in this report, all nearby drinking water sources remain safe; the 2014 Tank Release was not due to corrosion and did not result in any exposure to humans, plants, or animals, and measures have been put in place to prevent any similar release in the future; fuel product has never been detected in any monitoring well; dissolved constituents from historical releases are naturally attenuated in the immediate vicinity of the tank farm; and perimeter wells show no indication of the presence of fuel constituents from the Facility. Thus, while no petroleum facility or activity is risk-free, operation of the Facility is currently protective of human health and the environment and is likely to remain so, especially within the 5-year Permit period (and the timeframe within which the Navy has committed to implementing secondary containment, which the regulations only require to occur by 2038, well beyond the life of the Permit[46]).

Even though the Facility currently complies with the UST regulations, the Navy and Regulators have agreed to collect additional data, perform additional analyses, and make additional improvements over the years. The Regulatory Agencies have demonstrated their attention to the details and continue, along with the Navy, to drive further improvements. Therefore, considering all the Facility upgrades made and planned to be made, along with all the data gathering and analyses, the Facility is protective of human health and the environment and should be permitted to continue to operate for the next 5 years under the watchful eye of DOH and EPA while additional improvements and progress continue to be made under the AOC.

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[46] HAR §11-280.1-21(c).

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