Naval Facilities Engineering Systems Command Hawaii

Quarterly Release Response Report, May 6 and November 20, 2021 Releases Red Hill Bulk Fuel Storage Facility

JBPHH, O‘ahu, Hawai‘i

DOH Facility ID No. 9-102271
DOH UST Release ID No. 210012
DOH HEER Release Incident Case Nos. 20210507-0852, 20211120-2330

April 6, 2022

Main Document

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April 6, 2022

Prepared for NAVFAC Hawaii by

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Executive Summary

This Quarterly Release Response Report was prepared for Naval Facilities Engineering Systems Command (NAVFAC) Hawaii by AECOM for the Red Hill Bulk Fuel Storage Facility (Facility) in accordance with the State of Hawaiʻi Department of Health (DOH) Technical Guidance Manual (TGM). As required by Hawaiʻi Administrative Rules (HAR) § 11-280.1-65.2, Release Response Reporting, this report presents all release response actions taken pursuant to HAR § 11-280.1 during this reporting period (November 6, 2021 to February 4, 2022) as well as a plan for future release response actions to be taken.

This report combines release response reporting for two releases of Jet Propellant Fuel 5 (JP-5) from the Facility, previously reported separately: a May 6, 2021 pipeline breach ("May 6 Release") and a November 20, 2021 fire suppression drain line release ("November 20 Release").

On May 6, 2021, a pressure surge damaged the JP-5 pipeline near Red Hill Tanks 18 and 20. Fuel was released to the tunnel floor, and approximately 1,580 gallons of the released fuel were recovered shortly after the event. It was later determined that the remaining fuel was pumped from the fire suppression retention system into the fire suppression recovery drain line. The fuel remained contained in the fire suppression recovery drain line until it was damaged on November 20, 2021. The fuel released from the November 20, 2021 incident traveled on the concrete tunnel floor toward Adit 3 and collected in a groundwater sump near Adit 3 (Adit 3 Sump). A portion of the fuel was recovered from the sump; the remainder of the fuel entered the soil (or volcanic bedrock) near U.S. Navy Well 2254-01 (Red Hill Shaft), from which some of the fuel entered the Joint Base Pearl Harbor-Hickam (JBPHH) Water Distribution System. The Red Hill Shaft ceased pumping on November 28, 2021 and was isolated from the JBPHH Water Distribution System.

Initial site characterization of the release areas have been completed; additional characterization and monitoring efforts continue. Site characterization efforts completed this reporting period include:

- Soil vapor, groundwater, and product sampling
- Adit 3 tunnel subslab soil vapor observations and organic vapor measurements
- Holding Tank and Leach Tank organic vapor measurements and soil samples
- Monitoring well free product gauging, groundwater headspace, and purge water natural chemistry parameters
- Drinking water observations

Results indicated the following:

May 6 Release (results for samples collected prior to the November 20 Release):

- Potable (drinking) water produced by the Navy Supply Well 2254-01 (also known as Red Hill Shaft) pre-chlorination port did not exceed toxicity-based DOH Environmental Action Levels (EALs). However, two samples from the Red Hill Shaft pre-chlorination port did

exceed the EAL for total petroleum hydrocarbons – residual range organics (TPH-o) on August 5 and 26, 2021.

- Fuel as free product was not detected on the surface of the basal aquifer in any groundwater monitoring well sampled.
- Soil vapor monitoring probes located under Facility tanks in proximity to the May 6 Release were assumed to be impacted by wash water during cleanup activities at that time; therefore, it is not clear whether soil vapor results were representative of conditions in the subsurface outside of the immediate vicinity of the impacted probes.
- Concentrations of petroleum compounds and degradation products for TPH-diesel range organics (TPH-d) exceeded the toxicity-based EAL in groundwater samples from tunnel monitoring wells RHMW03, RHMW02, and RHMW01R (most exceedances occurred in RHMW02 throughout the reporting period) located topographically downgradient of the pipeline breach.
- TPH-d concentrations exceeded the toxicity-based EAL at external well OWDFMW01 near the release point in a single sampling event on October 1, 2021 prior to the November 20 Release.
- Concentrations of polynuclear aromatic hydrocarbons (PAHs) exceeded toxicity-based EALs in groundwater samples from RHMW02 but were within historical range.
- No other groundwater or drinking water sampling locations reported sample results that exceeded toxicity-based EALs for any chemicals of potential concern (COPCs).

November 20 Release:

- JP-5 from the damaged fire suppression drain line in the Adit 3 tunnel was released to the environment from the following locations:
  - Adit 3 Sump
  - Hume drain line connected to the Adit 3 Sump
  - Adit 3 Sump Discharge to Holding Tank and Leach Tank

  Fuel entered the water development tunnel associated with Red Hill Shaft and the JBPHH Water Distribution System as a result of the first two release locations. Fuel was also released through the Leach Tank to the subsurface outside of Adit 3 near Halawa Stream. Additional investigations are ongoing.
- Red Hill Shaft, which has been disconnected from the JBPHH Water Distribution System since November 28, 2021, was connected to a granular activated carbon (GAC) treatment system, which has been employed since January 29, 2022 to create a capture zone to minimize the potential for contaminants to migrate away from Red Hill Shaft.

Planned Future Actions:

Planned future actions include additional site characterization; continued groundwater sampling, soil vapor monitoring, and soil sampling; well installation and plume delineation efforts; and removal actions, as appropriate.

Current and future conditions of the JBPHH Water Distribution System and related activities are now being regulated by DOH Safe Drinking Water Branch. Therefore, investigation and remediation activities for the drinking water system are not addressed in this release response report.

On November 23, 2021, Admiral Paparo, Commander, U.S. Pacific Fleet, directed an independent investigation of the November 20, 2021 release and ordered the investigating officer to determine any connection between the November 20 Release and the May 6 Release. Based on the results of this investigation, the data presented in this report are subject to change.

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Acronyms and Abbreviations

%D	percent difference
%R	percent recovery
°C	degree Celsius
µg/L	micrograms per liter
µg/m^3	micrograms per cubic meter
2-2-BEE	2-(2-butoxyethoxy)ethanol
2-2-MEE	2-(2-methoxyethoxy)-ethanol
AFFF	aqueous film-forming foam
AOC	Administrative Order on Consent
APPL	Agriculture & Priority Pollutants Laboratories, Inc.
ASTM	American Standard Test Method
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylenes
BWS	Honolulu Board of Water Supply
CF&T	contaminant fate and transport
COC	chain of custody
COPC	chemical of potential concern
CSM	conceptual site model
DCA	1,2-dichloroethane
DL	detection limit
DoD	United States Department of Defense
DOH	State of Hawai‘i Department of Health
DQI	data quality indicator
EAL	environmental action level
EDB	1,2-dibromoethane
ELAP	Environmental Laboratory Accreditation Program
Energy	Energy Laboratories, Inc.
EPA	United States Environmental Protection Agency
ER	electrical resistivity
F-24	NATO-grade F-24 jet fuel
F-76	marine diesel fuel
FID	flame ionization detector
ft	foot/feet
GAC	granular activated carbon
GC	gas chromatograph
GPR	ground-penetrating radar
GWPP	Groundwater Protection Plan
H_2SO_4	sulfuric acid
H_3PO_4	phosphoric acid
HAR	Hawai‘i Administrative Rules

HCl	hydrochloric acid
HDPE	high-density polyethylene
HEER	Hazard Evaluation and Emergency Response
HNO_3	nitric acid
ID	identification
IDWST	Interagency Drinking Water System Team
IP	induced polarization
JBPHH	Joint Base Pearl Harbor-Hickam
JP-5	Jet Fuel Propellant Number 5
L	liter
LCS	laboratory control sample
LCSD	laboratory control sample duplicate
LDC	Laboratory Data Consultants, Inc.
L-L Ext	liquid/liquid extraction
LNAPL	light nonaqueous-phase liquid
LOD	limit of detection
LOQ	limit of quantitation
mg/kg	milligrams per kilogram
mL	milliliter
MS	matrix spike
MSD	matrix spike duplicate
msl	mean sea level
$NaHSO_4$	sodium hydrogen sulfate
NAPL	nonaqueous-phase liquid
NATO	North Atlantic Treaty Organization
NAVFAC	Naval Facilities Engineering Systems Command
NAVSUP FLC	Naval Supply Systems Command Fleet Logistics Center
Navy	United States Department of the Navy
ng/L	nanograms per liter
NOI	Notice of Interest
NRH	Navy Region Hawaii
PAH	polynuclear aromatic hydrocarbon
PFAS	per- and polyfluoroalkyl substances
PID	photoionization detector
ppbv	parts per billion by volume
ppmv	parts per million by volume
PVC	polyvinyl chloride
QC	quality control
QSM	Quality Systems Manual
RHSF	Red Hill Shaft pre-chlorination sampling location
RI	remedial investigation
RPD	relative percent difference

RSL	Regional Screening Level
SGC	silica gel cleanup
SGT	silica gel treatment
SHC	saturated hydrocarbon
SIM	selected ion monitoring
SOP	standard operating procedure
SSRBL	Site-Specific Risk-Based Level
SVMP	soil vapor monitoring point
SVOC	semivolatile organic compound
TGM	Technical Guidance Manual
TIC	tentatively identified compound
TOC	total organic carbon
TPH	total petroleum hydrocarbons
TPH-d	total petroleum hydrocarbons – diesel range organics
TPH-g	total petroleum hydrocarbons – gasoline range organics
TPH-o	total petroleum hydrocarbons – residual range organics (i.e., TPH-oil)
U.S.	United States
UIC	Underground Injection Control
USGS	United States Geological Survey
UST	underground storage tank
VOA	volatile organic analysis
VOC	volatile organic compound

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1.0 Introduction and Purpose

On May 6, 2021, a pressure surge damaged the Jet Propellant Fuel 5 (JP-5) pipeline near Red Hill Tanks 18 and 20. Fuel was released to the tunnel floor, and approximately 1,580 gallons of the released fuel were recovered shortly after the event. It was later determined that the remaining fuel was pumped from the fire suppression retention system into the fire suppression recovery drain line. The fuel remained contained in the fire suppression recovery drain line until it was damaged on November 20, 2021. The fuel released from the November 20, 2021 incident traveled on the concrete tunnel floor toward Adit 3 and collected in a groundwater sump near Adit 3 (Adit 3 Sump). A portion of the fuel was recovered from the sump; the remainder of the fuel entered the soil (or volcanic bedrock) near U.S. Navy Well 2254-01 (Red Hill Shaft), from which some of the fuel entered the Joint Base Pearl Harbor-Hickam (JBPHH) Water Distribution System. Red Hill Shaft ceased pumping on November 28, 2021 and was isolated from the JBPHH Water Distribution System. Response activities have been conducted at the site since the May 6 Release and remain ongoing.

This report presents a summary of the combined release response activities performed through February 4, 2022 in response to the May 6, 2021 pipeline breach ("May 6 Release") and the November 20, 2021 fire suppression drain line release ("November 20 Release") at the Red Hill Bulk Fuel Storage Facility ("the Facility"), located at Joint Base Pearl Harbor-Hickam (JBPHH), O'ahu, Hawai'i. Previously, Initial and Quarterly Release Response Reports were prepared for each release, as listed in Section 1.2 below. Specifically, as required by Hawai'i Administrative Rules (HAR) § 11-280.1-65.2, this Quarterly Release Response Report describes:

1) All response actions taken during the quarterly reporting period; and
2) A plan for future release response actions to be taken.

This report summarizes the following activities conducted during this reporting period:

- Soil vapor, groundwater, and product sampling
- Adit 3 tunnel subslab soil vapor observations and organic vapor measurements
- Holding Tank and Leach Tank organic vapor measurements and soil samples
- Monitoring well free product gauging, groundwater headspace, and purge water natural chemistry parameters
- Drinking water observations

This report presents field observations and final analytical results available at the time this report was prepared, including:

- Results from soil vapor field measurements using photoionization detectors (PIDs)
- Results from a fixed-based laboratory for soil vapor Summa canister samples

- Results from monitoring well free-product gauging and headspace measurements
- Pre-validated and post-validated Level II and IV laboratory results for soil, groundwater, and drinking water samples

Current and future conditions of the JBPHH Water Distribution System and related activities are being regulated by DOH Safe Drinking Water Branch. Therefore, investigation and remediation activities for the drinking water system are not addressed in this release response report.

On November 23, 2021, Admiral Paparo, Commander, U.S. Pacific Fleet, directed an independent investigation of the November 20, 2021 release and ordered the investigating officer to determine any connection between the November 20 and May 6 Releases. Based on the results of this pending investigation, the data presented in this report are subject to change.

1.1 Statement of Purpose

Release response activities were performed to address the May 6 Release and the November 20 Release. The Hawai‘i Department of Health (DOH) issued Notice of Interest (NOI) letters for the two events:

- May 6 Release:
  - DOH Hazard Evaluation and Emergency Response (HEER) Release Incident Case No. 20210507-0852 on May 10, 2021 (DOH 2021a)
  - DOH UST Release ID No. 210012 (DOH 2021b)
- November 20 Release:
  - DOH HEER Incident Case No. 20211120-2330 (DOH 2021c)

1.2 Previous Reports

The following documents were previously submitted to DOH:

- May 6 Release:
  - Response to Notice of Interest in a Release or Threatened Release of Hazardous Substance, May 21, 2021
  - Confirmed Release Notification Form, Pipeline Breach in Tunnel, June 21, 2021
  - Initial Abatement Measures and Site Assessment Report, July 12, 2021
  - Initial Site Characterization Report, August 19, 2021
  - Initial Release Response Report, September 17, 2021
  - Red Hill Bulk Fuel Storage Facility Request for Information – Addendum, October 1, 2021

  - Quarterly Release Response Report, Pipeline Breach in Tunnel, December 30, 2021
- November 20 Release:
  - Response to Notice of Interest in a Release or Threatened Release of Hazardous Substance, December 3, 2021 and January 7, 2022
  - Confirmed Release Notification for Fire Suppression Drain Line, December 3, 2021
  - Initial Abatement Measures and Site Assessment Report, December 11, 2021
  - Initial Site Characterization Report, January 7, 2022
  - Free Product Removal Report, January 7, 2022
  - Technical Memorandum, Analysis of Samples from Sump (11/24/2021), Adit 3 (11/24/2021), and Red Hill Shaft Water Gallery (12/2/2021), January 13, 2022
  - Preliminary Site Characterization Plan, January 12, 2022
  - Technical Memorandum, Holding Tank and Leach Tank Site Characterization, January 29, 2022; revised February 23, 2022, pending finalization
  - Initial Release Response Report, Fire Suppression Drain Line, February 24, 2022

2.0 Background

May 6 Release. On May 6, 2021, Navy personnel responded to a reported release of fuel from a distribution pipeline inside the Facility in the vicinity of Tanks 17, 18, 19, and 20 (see Figure 1). The Navy notified DOH of the release within 24 hours. The fuel containment system at Red Hill was used to monitor, detect, and collect the fuel from the pipeline breach.

The Navy provided preliminary findings of the ongoing investigation to DOH on October 1, 2021, indicating that JP-5 fuel was released during a fuel transfer and properly collected by the fuel containment system; there were no leaks from any fuel tanks. The pipeline release was detected immediately, and the Navy captured 1,580 gallons of JP-5 in the tunnel drain capture system, which was followed by a complete washdown of the area with fresh water on May 7, 2021 (DON 2021e).

November 20 Release. On November 20, 2021, a release of JP-5 fuel occurred in the Adit 3 tunnel of the Facility. JP-5 was released from an overhead 14-inch polyvinyl chloride (PVC) fire suppression recovery pipe at a location approximately 400 feet (ft) east of the Adit 3 Red Hill Water Pumping Station and approximately 200 ft east of the upper Pearl Harbor tunnel. The location of the release point was in close proximity to the underlying U.S. Navy Well 2254-01 (Red Hill Shaft) water development tunnel that extends greater than 1,200 ft northeast of the Water Pumping Station at an elevation of approximately 0–20 ft above mean sea level (msl) (see Figure 2).

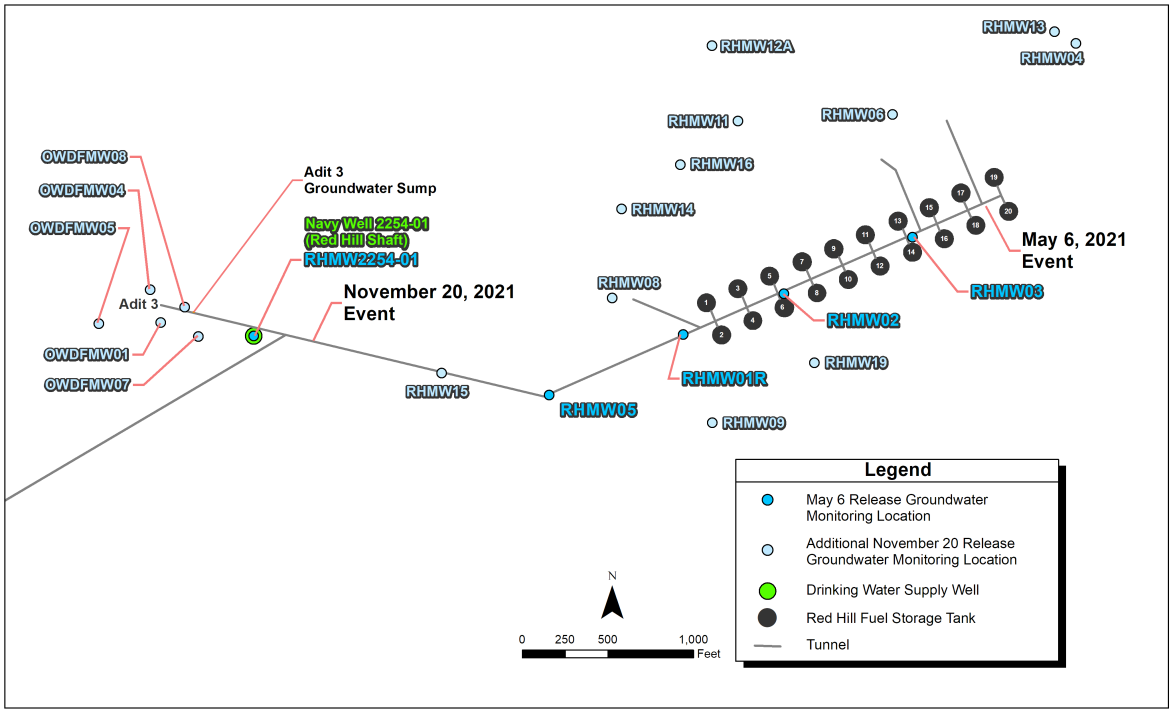


Figure 1: Locations of May 6 and November 20, 2021 Releases and Groundwater Monitoring Wells

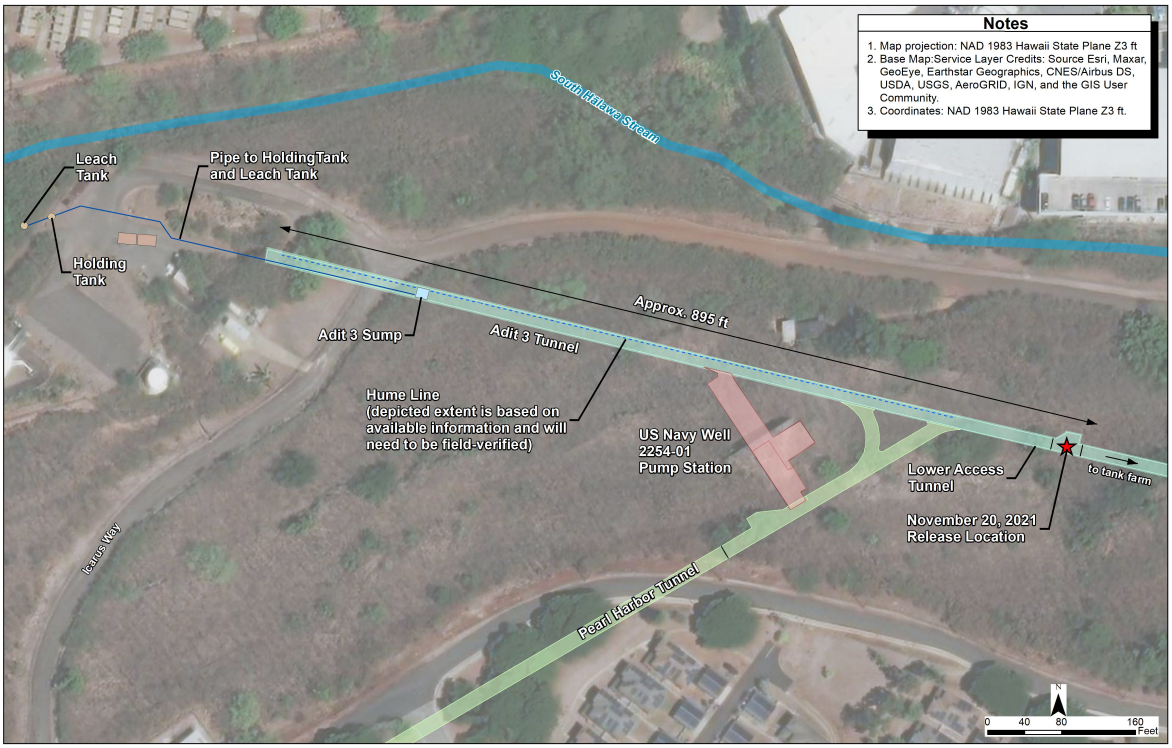


Figure 2: Adit 3 and Pearl Harbor Tunnel Layout Map

Released fuel flowed along the tunnel floor westward past the Pearl Harbor tunnel and the Red Hill Water Pumping Station, which directly overlay the water development tunnel. Fuel accumulated in a groundwater sump (Adit 3 Sump), approximately 750 ft west of the November 20 Release point. JP-5 was recovered from the Adit 3 Sump, connected piping, and the fire suppression recovery pipe.

As a result of the November 20 Release, fuel was likely released to the environment from the Adit 3 Sump, the Hume line, and the Adit 3 Sump drain Holding Tank and Leach Tank. Fuel was observed in the Navy Well 2254-01 (Red Hill Shaft) water development tunnel. Upon confirmation that there was a fuel-like odor in drinking water in homes served by Red Hill Shaft, Navy Well 2254-01 was shut off and isolated from the drinking water distribution system.

2.1 Site Description

The 144-acre underground fuel storage Facility is located in south-central O‘ahu approximately 2–3 miles east of Pearl Harbor, within the Red Hill ridge that divides South Hālawa Valley from Moanalua Valley on the southwest flank of O‘ahu’s Ko‘olau mountain range (Figure 3). The Facility’s twenty fuel storage tanks store and supply fuel for military operations in Hawai‘i and throughout the Pacific. The tank bottoms are situated approximately 100–130 ft above an underlying basal aquifer that is a major municipal and military drinking water source.

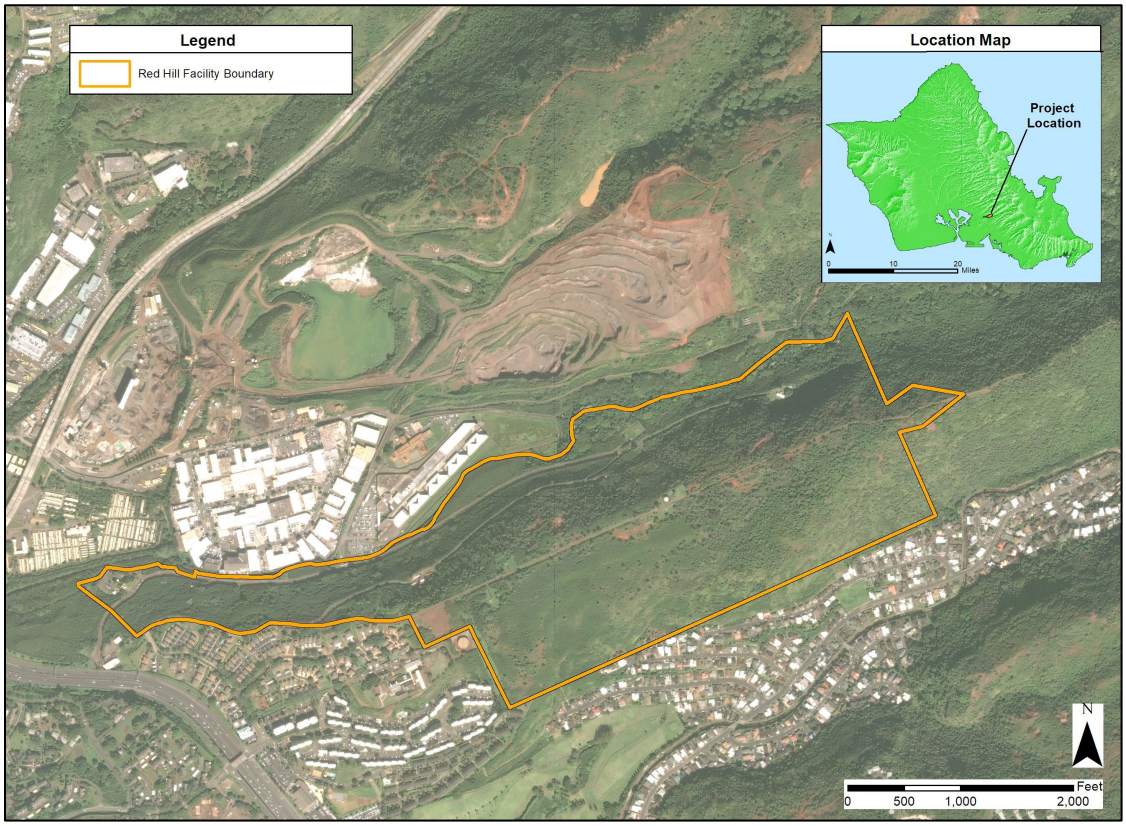


Figure 3: Site Location Map

2.1.1 Climate

Climatological conditions in the vicinity of the Facility consist of warm to moderate temperatures and low to moderate rainfall. The average annual precipitation is approximately 40 inches, which occurs mainly between November and April (Giambelluca, Nullet, and Schroeder 1986). Average temperatures range from the low 60s to high 80s (degrees Fahrenheit) (Juvik and Juvik 1998).

2.1.2 Soils and Geology

The Facility is located within the Koʻolau Volcanic series. The Koʻolau formation at Red Hill consists of the 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). Pāhoehoe and aʻā lava flows are present in the Koʻolau formation. The valleys on either side of Red Hill ridge were formed as a result of fluvial erosion and are filled with sedimentary deposits (alluvium and colluvium), also known as valley fill, underlain by residual (weathered basalt), also known as saprolite. Saprolite zones in Hawaiʻi are typically around 75 ft thick but can be 300 ft thick or greater beneath the valley floors or in areas of high precipitation (Hunt Jr. 1996; Macdonald, Abbott, and Peterson 1983) The results of a recently conducted seismic survey in North and South Hālawa Valleys, Red Hill, and Moanalua Valley (DON 2018a) found that valley fill and saprolite extend much deeper in the valleys surrounding Red Hill, particularly in the center of the valleys and below the streambeds.

Soils in the vicinity of the Facility are mapped as Helemano-Wahiawā association consisting of well-drained, moderately fine-textured and fine-textured soils (USDA SCS 1972). The surfaces of the basaltic flows have been weathered to form reddish-brown clayey silt, which is the basis for the local name "Red Hill." These soils typically range from nearly level to moderately sloping and occur in broad areas dissected by very steep gulches. They formed in material weathered from basalt to a depth of approximately 10 ft below ground surface (bgs). Along the slopes, the basaltic bedrock is covered with approximately 10–30 ft of Koʻolau residuum. These soils were derived from weathering of the underlying basalt bedrock or were deposited as alluvium/colluvium. The younger alluvium/colluvium deposits were derived from fractured basalts and tuff. Beneath the surficial soils, alternating layers of clay and basalts are encountered at depth. The northwestern slope of Red Hill is generally barren of soil and consists of outcropping basalt lava flows to the valley floor.

2.1.3 Surface Water

Surface water features in the general vicinity of the Facility include South Hālawa Stream (an ephemeral stream approximately 600–800 ft north of the tanks), North Hālawa Stream (approximately 4,000–4,500 ft northwest of the tanks), and Moanalua Stream (approximately 1,700–2,000 ft south of the tanks). Potential recharge (run-on and operational water use) from the Hālawa Quarry north of the Facility may also impact groundwater flow in this area. In Hālawa Valley, stream flow may contribute water to perched groundwater within alluvial material (valley fill) but is generally isolated from the underlying basal aquifer. Most precipitation percolates to

the basal aquifer and does not maintain base flows in the streams (Izuka 1992). Groundwater that flows beneath the Facility does not intercept surface water inland of the ocean shoreline (DON 2007). Both South Hālawa Stream and Moanalua Stream (to the north and south of Red Hill ridge, respectively) are located approximately 170 ft or more above the basal water table adjacent to the tanks. The bottoms of the Facility's fuel storage tanks are located at least 50 ft below the bottom of these streams.

2.1.4 Groundwater

In the vicinity of Red Hill, the basal aquifer water table lies between 15 and 20 ft above msl, and regionally groundwater flows toward Pearl Harbor (mauka to makai), although potential exists for variability in localized flow directions depending on geologic formations and other factors.

The Facility is located at the administrative boundary between the Waimalu Aquifer System of the Pearl Harbor Aquifer Sector and the Moanalua Aquifer System of the Honolulu Aquifer Sector. The underlying aquifer is classified as a basal, unconfined, flank-type aquifer and is currently used as a drinking water source.

The Facility is located upgradient of the Hawaii State Underground Injection Control (UIC) Line, which separates potable groundwater from non-potable groundwater. The drinking water supply well closest to the tanks is Red Hill Shaft, located within the Facility's lower access tunnel, located approximately 2,600 ft topographically downgradient of the nearest tank. Red Hill Shaft formerly provided potable water to the JBPHH Water Distribution System, which serves approximately 65,200 military customers; the potable water is now supplied by the Waiawa Shaft, located far to the west of the Facility. Naval Facilities Engineering Systems Command (NAVFAC) Hawaii, Utilities Management Division operates the drinking water system. The nearest Honolulu Board of Water Supply (BWS) public drinking water supply well (BWS Hālawa Shaft Well 2354-01) is located hydraulically cross-gradient of the Facility approximately 4,400 ft northwest of the tanks, where it pumps water from the basal aquifer.

2.2 Historical Land Use

Prior to construction of the tank farm, the surface of Red Hill supported cane and pineapple agriculture. Navy archive images show that the Red Hill ground surface was exposed and modified during construction of the tank farm beginning in 1940. A 1952 aerial photograph shows unmaintained land on the ridge of Red Hill and agriculture on the lower reaches of Red Hill north of the Moanalua Golf Course (DON 2019).

2.3 Current Land Use

The Facility is located on land zoned by the City and County of Honolulu as a mix of F-1 Federal and Military and P-1 Restricted Preservation districts. All major structures at the Facility are located underground. Populated areas closest to the Facility are 'Aiea to the west and Honolulu to the south and east. Honolulu is heavily urbanized and densely populated.

Preservation land is located east and northeast of the Facility boundary. To the southeast are residential single-family homes in Moanalua Valley; a high cliff face with a 100–200 ft elevation difference exists between the Facility and this residential area. Southwest of the tank farm area on the lower southwest flank of Red Hill are the public Red Hill Elementary School and residential apartments, and further west is U.S. Coast Guard Housing on F-1 Military land. North of the western segment of the Facility boundary in South Hālawa Valley is the State Animal Quarantine Station, private businesses in Hālawa Industrial Park, and the State-operated Hālawa Correctional Facility. To the north of the Correctional Facility at the lower reaches of an inter-valley ridge that forms the north wall of South Hālawa Valley is the open-pit Hālawa Quarry operated by the Hawaiian Cement Company.

As shown on Figure 3, the H-201 Moanalua Freeway transits approximately 350–700 ft beyond the Facility's southwest boundary and intersects with the H-1 and H-3 Freeways at the Hālawa Interchange, approximately 1,800 ft west of the Facility. The H-3 Freeway transits northeast from the interchange through North Hālawa Valley and on to O‘ahu's windward side.

2.4 Conceptual Site Model

2.4.1 Facility Construction and Operations

The Facility's twenty bulk fuel underground storage tanks (USTs) were field-constructed of steel-lined concrete in the early 1940s. They are connected to a fuel pumping station at Pearl Harbor via a tunnel system. The Facility is operated by Naval Supply Systems Command (NAVSUP) Fleet Logistics Center (FLC) Pearl Harbor (formerly Fleet and Industrial Supply Center). Each UST has a total capacity of approximately 12.5 million gallons. The fourteen active USTs currently contain either JP-5, North Atlantic Treaty Organization (NATO)-grade F-24 jet fuel (F-24), or Marine Diesel Fuel (F-76).

2.4.2 Subsurface Conditions

The Facility tanks are surrounded by rock in the vadose (i.e., unsaturated) zone, which consists primarily of basalt flows in complex, alternating layers. These heterogeneous layers vary from extremely high to extremely low permeability, with a corresponding varying ability to transmit and hold light nonaqueous-phase liquid (LNAPL), also referred to as free product in this report, depending on the layer's rock type and micro-pore structure (i.e., high ability in high-permeability a‘ā and thin pāhoehoe flows; low ability in massive a‘ā and massive pāhoehoe flows; limited transmissivity but high holding capacity in a‘ā clinker zones). Geologic and water saturation characteristics in the rock surrounding the tanks could cause LNAPL to spread as it moves through the rock. As LNAPL moves through the larger pore spaces, some of it could be trapped in poorly connected fractures and blocked by nearby low-permeability regions or by surface tension and capillary forces of moisture, especially water held in the smaller pores.

Hawaiian volcanic rocks vary in porosity and permeability depending on the emplacement process, lava type, genesis, flow thickness, flow rate, extent, cooling rate, and weathering. Permeability is

typically highest in the relatively thick, unweathered rubbly aʻā clinker zones and intensely fractured zones or lava tubes of pāhoehoe flows. Permeability is much lower in the interior portions of massive flows, weathered interflows, intrusive rocks (dikes and sills), ash beds, and weathered rocks (saprolite) and soil horizons, which can impede both vertical flow and horizontal flow across valleys. Generally, the bulk vertical permeability of the basalt is orders of magnitude lower than the bulk horizontal permeability. Horizontal permeability is higher in the direction that the lava flowed.

Groundwater flow and solute transport are controlled by both the hydraulic conditions (e.g., gradients) and the physical properties of the hydrogeologic units, including hydraulic conductivity, effective porosity, specific yield, specific storage, anisotropy, and dispersivity.

Fresh groundwater inflow originates as deep infiltration of precipitation and seepage from surface water features. According to the United States Geological Survey (USGS), estimates of recharge for Oʻahu for recent conditions (2010 land cover and 1978–2007 rainfall) differ from predevelopment recharge values by only a few percent (Izuka et al. 2018). Spatial distribution of recharge mimics the orographic rainfall pattern—recharge is highest on windward slopes and mountain peaks below the top of the tradewind inversion.

Groundwater outflow includes withdrawals from wells and natural groundwater discharge to springs, streams, wetlands, and submarine seeps. Data collected by the USGS for groundwater levels, saltwater/freshwater interface, spring flow, and stream base-flow indicate an overall reduction in aquifer storage for most areas where groundwater has been extracted; this has caused groundwater levels to decline (Izuka et al. 2018).

Regional groundwater levels decrease from areas of recharge (mauka) to areas of discharge (makai). Locally, water level gradients are extremely low and are influenced by geologic conditions as well as by variability in local pumping stresses from water development shafts and wells.

2.4.3 Exposure Model

Potentially contaminated media are tunnel air; unconsolidated materials, volcanic rock, and soil/rock vapor surrounding the tanks and tunnel; groundwater beneath the Facility with the potential to migrate offsite; and offsite surface water where groundwater may discharge. Human receptors that may contact onsite or offsite Facility-impacted media are Facility occupational workers, construction workers, visitors, and offsite residents. Among the potentially complete exposure pathways identified, the primary pathway of concern is exposure to impacted tap water via direct ingestion and dermal contact, and via inhalation while showering and bathing. Animals and vegetation may also be exposed to tap water as pets or from irrigation. Exposure by ecological receptors is considered incomplete or insignificant (DON 2019).

2.5 Previous Facility Investigations

Previous environmental investigations at the Facility are summarized in Table 2-1, divided into two categories: those preceding the 2015 Administrative Order on Consent (AOC), and those subsequent to its issuance.

Table 2-1: Summary of Previous Red Hill Environmental Investigations

Investigation Report	Summary
Pre-AOC Investigations	
Remedial Investigation [RI] *Phase I and II, Red Hill Oily Waste Disposal Facility* (DON 1996; 2000)	A two-phase RI was initiated in the early 1990s at the Red Hill Oily Waste Disposal Facility. No contaminants were detected in the basal aquifer beneath the site, and DOH issued a concurrence letter for a No Further Action determination in 2005 (DOH 2005).
Facility Site Characterization and Investigation (DON 1999, 2002)	A two-phase investigation initiated in 1998 evaluated the presence of petroleum constituents at the Facility. DOH requested the Navy to conduct quarterly groundwater monitoring, conduct a Tier 3 risk assessment, and develop a contingency plan.
Quarterly Groundwater Monitoring Reports (DON 2005 to present)	Sampling and analysis of Red Hill network groundwater monitoring wells was initiated in 2005 and incorporated into the Red Hill Groundwater Protection Plan (GWPP) (DON 2008a; 2014b); results are reported to DOH.
Technical Report (DON 2007)	An environmental investigation and risk assessment initiated in 2004 included installation of soil vapor monitoring points (SVMPs) in angle borings under the active fuel storage tanks, three additional groundwater monitoring wells in the lower access tunnel, a three-dimensional groundwater model, and a Tier 3 human health risk assessment.
Tank 17 Removal Action Report (DON 2008b)	A limited removal action and site characterization investigation was conducted in June 2008; the report's Environmental Hazard Analysis determined that the release posed no further significant environmental hazards.
Type 1 Letter Report (DON 2010)	A 2010 investigation re-evaluated the DON (2007) groundwater model assumptions and results and the Tier 3 risk assessment results.
Monthly Soil Vapor Monitoring Reports (DON 2014a through present)	Soil vapor PID measurements are collected monthly under the Facility's fuel storage tanks with SVMPs in accordance with the Red Hill GWPP (DON 2008a; 2014b); results are reported to DOH.

Investigation Report	Summary
AOC-Related Investigations *(EPA Region 9 and DOH 2015)*	
Tank 5 Quarterly Release Response Reports (DON 2014a to present	In response to the 2014 fuel release from Tank 5, Navy reports release response actions undertaken in the last 90 days to the DOH.
Seismic Profiling to Map Hydrostratigraphy in the Red Hill Area (DON 2018a)	Presented results and evaluation of nine seismic profiling transects conducted at Red Hill and in North and South Hālawa Valleys and Moanalua Valley to improve understanding of subsurface conditions that affect groundwater flow and CF&T.
Groundwater Protection and Evaluation Considerations for the Red Hill Bulk Fuel Storage Facility (DON 2018c)	Presented an interim environmental analysis of data and an initial analysis of potential environmental risks; interim results of the groundwater flow model; and an evaluation of hypothetical release scenarios.
Conceptual Site Model (DON 2018b; 2019)	Established a basis for evaluating contaminant transport pathways and potential for exposure of human receptors to potentially impacted drinking water.
Groundwater Flow Model Report (DON 2020a)	Refined the previous groundwater flow model to improve understanding of the direction and rate of groundwater flow within the aquifers around the Facility.
Investigation and Remediation of Releases Report (DON 2020b)	Documented the response to the January 2014 Tank 5 release and evaluated potential remedial alternatives for that release and any potential future release.
Evaluation of Chromatograms for Understanding TPH Detections in Monitoring Wells (DON 2020c)	Provided an evaluation of TPH detections in monitoring wells to determine whether those detections are indicative of potential fuel impacts from the Facility.
Initial and Quarterly Release Response Reports, Pipeline Breach in Tunnel and Fire Suppression Drain Line (DON 2021b; 2021d; 2021f; 2022b)	Documented the results of release response efforts for the May 6, 2021 Tunnel Pipeline Breach and the November 20, 2021 Fire Suppression Drain releases.

Notes:

AOC Administrative Order on Consent
CF&T contaminant fate and transport
GWPP Groundwater Protection Plan
HEER Hazard Evaluation and Emergency Response
SSRBL Site-Specific Risk-Based Level
SVMP soil vapor monitoring point
TPH total petroleum hydrocarbons

3.0 Summary of Investigation History

3.1 May 6 Release

A site assessment performed in response to the May 6 Release included soil vapor PID field measurements, soil vapor laboratory sample collection and analysis, groundwater monitoring well free product gauging and headspace measurements, groundwater sampling and analysis, and drinking water sampling and analysis.

3.1.1 Soil Vapor

Figure 4 shows the layout of SVMPs beneath the fuel storage tanks. During the initial soil vapor field measurements on May 10, 2021, the sampling team noted that three SVMP vaults adjacent to Tanks 17, 18, and 20 had been impacted by apparent petroleum-laden wash water from the May 6 Release cleanup within the lower access tunnel. Although the Navy cleaned the compromised vaults and sampling ports, the SVMPs under these tanks continued to present elevated volatile organic compound (VOC) results during subsequent release response SVMP soil vapor sampling rounds (DON 2021a).

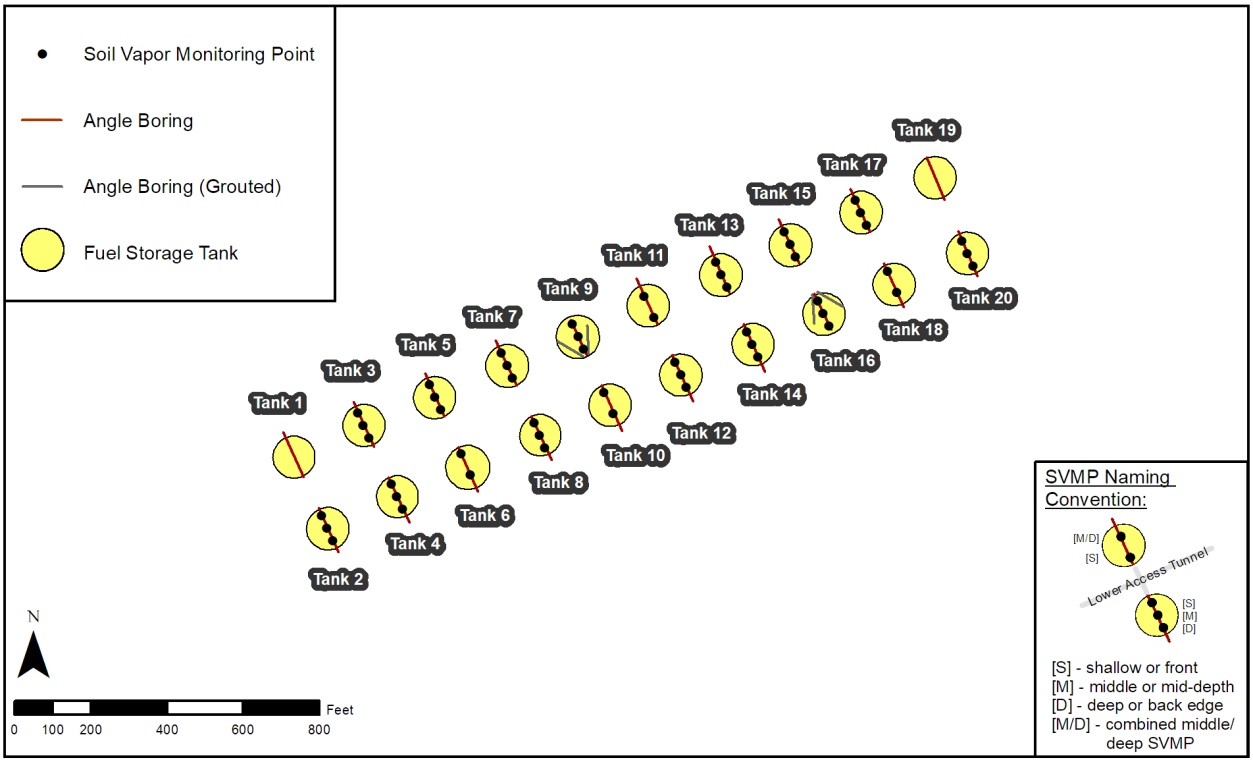


Figure 4: Soil Vapor Monitoring Network Underneath the Red Hill Fuel Storage Tanks

On May 13, 2021, the Navy collected soil vapor field screening samples from the compromised ports to confirm the probes were viable. From May 10 to May 14, the Navy collected for laboratory analysis a Zone 7 sump air sample and soil vapor samples from SVMPs beneath Tanks 13

(SV13S), and 16 (SV16S) as well as the impacted SVMPs under Tanks 17 (SV17S), 18 (SV18S), and 20 (SV20M), as part of the release response sampling program. Additional soil vapor analytical samples were collected monthly and analyzed at a fixed-base laboratory during this reporting period. The soil vapor laboratory sample results from these SVMPs were provided in the Pipeline Breach Initial and Quarterly Release Response Reports (DON 2021d; 2021f).

In addition, soil vapor total VOC concentrations were measured in the field using a hand-held PID at SVMPs. PID measurements were initially collected daily at relevant locations for 1 month. Measurements were then collected twice a week at a reduced number of locations and then transitioned again to weekly at all locations the week of February 7, 2022.

3.1.2 Groundwater and Drinking Water

Figure 1 depicts the approximate location of the May 6 Release, groundwater sampling locations in the Facility's lower access tunnel (RHMW03, RHMW02, RHMW01R, RHMW01, RHMW05, and Red Hill Shaft), and other groundwater monitoring wells in the vicinity of the Facility. For the May 6 Release response water sampling program, RHMW01R, RHMW02, RHMW03, RHMW05, and the groundwater sampling location and drinking water sampling ports at Red Hill Shaft were used to collect groundwater and drinking water samples for chemical analyses from within the Facility lower access tunnel.

RHMW01R was installed in March 2021 adjacent to RHMW01, and was constructed so that its screened section intersects the basal aquifer potentiometric surface to allow potential measurements of free product as LNAPL (none has been detected). RHMW01 was installed in 2005 and was sampled as part of the Red Hill long-term monitoring program. Because RHMW01 was constructed with its screen submerged below the potentiometric surface of the basal aquifer, gauging for the potential presence of LNAPL was not effective at this well.

The location of the May 6 Release was approximately 450 ft from RHMW03, which is topographically downgradient (makai) from the release point and is the nearest groundwater monitoring well to detect potential petroleum entering the basal groundwater. Groundwater monitoring wells RHMW02, RHMW01R, and RHMW05 are located approximately 1,300, 1,900, and 2,800 ft, respectively, topographically downgradient of the May 6 Release location and thus serve as secondary, tertiary, and quaternary groundwater monitoring points. RHMW05 is located between the tanks and Red Hill Shaft and was installed to allow for identification of COPCs in groundwater before they potentially migrated to Red Hill Shaft, which is located approximately 4,400 ft topographically downgradient of the May 6 Release.

Initially, groundwater samples were collected from monitoring wells RHMW03, RHMW02, and RHMW01R once a week for 2 weeks, then three times a week for 3 weeks, then weekly thereafter through September 21, 2021. Monitoring well RHMW05 and groundwater sampling point RHMW2254-01 (located in the Red Hill Shaft Water Gallery) were included in the weekly sampling events from September 21, 2021 until the DOH December 9, 2021 "May 6th Release and

Nov 20th Release Notice of Interests' Groundwater Sampling Plan" (NOI GW Sampling Plan, revised December 27; see Appendix B.8).

Drinking water samples were collected weekly from a sampling port located directly before chlorination at the Red Hill Shaft potable water output from June 3 through November 24, 2021. All groundwater and drinking water samples were analyzed by Agriculture & Priority Pollutants Laboratories, Inc. (APPL) in Clovis, California for the following constituents:

- Benzene, toluene, ethylbenzene, and xylenes (BTEX) by Method 8260C
- TPH in the gasoline range (TPH-g) by Method 8260C, modified
- TPH in the diesel range and oil and residual range (-d/o) by Method 8015C, including 3520 extraction
- Naphthalene, 1-methylnaphthalene, and 2-methylnaphthalene by Method 8270D, including 3520 extraction
- Total organic carbon (TOC)

In addition, on June 24, 2021, one round of samples included analysis for semivolatile organic compounds (SVOCs), including SVOC tentatively identified compounds (TICs) and phenols by Method 8270D to evaluate the possible source for COPC detections.

On September 22, 2021, the Navy received preliminary laboratory analytical results that showed detectable TPH-o concentrations in drinking water samples collected from the Red Hill Shaft pre-chlorination port (designated as sampling location RHSF). In response, the Navy immediately increased the locations and frequency of in-tunnel groundwater monitoring well and pre-chlorination drinking water port sampling as described below:

- On September 23, 2021, both pre-chlorination and post-chlorination drinking water samples were collected for analysis of TPH-d/o, with split samples going to APPL and Energy for expedited analysis.
- Between September 22 and October 6, 2021, daily pre-chlorination port sampling at Red Hill Shaft was conducted with expedited analysis for TPH-d/o by Energy, then weekly through November 17, 2021.
- Between September 29 to November 17, 2021, weekly groundwater split samples were collected from in-tunnel monitoring wells (RHMW01R, RHMW02, RHMW03, and RHMW05) and groundwater sampling point RHMW2254-01. Split sample was analyzed by Energy for expedited TPH-d/o analysis.
- Between September 22 to November 17, 2021, Red Hill Shaft in-tunnel groundwater monitoring well RHMW05 and groundwater sampling point RHMW2254-01 were added to the weekly samples analyzed by APPL for BTEX, TPH-g, TPH-d/o, polynuclear aromatic hydrocarbons (PAHs), and TOC.

- Between September 30 to November 17, 2021, groundwater samples were collected from select external monitoring wells (RHMW04, RHMW06, RHMW08, RHMW09, RHMW10, RHMW12A, RHMW14-03, RHMW16, RHMW19, and OWDFMW01) with expedited analysis for TPH-d/o by Energy to evaluate the potential for offsite impacts.

Free product gauging and groundwater monitoring well headspace measurements were collected daily and then approximately weekly from groundwater monitoring wells RHMW01R, RHMW01 (headspace only), RHMW02, RHMW03, and RHMW05. No free product was observed in these wells.

3.2 November 20 Release

On November 28, 2021, a fuel-like odor was reported in drinking water in homes served by Red Hill Shaft, Navy Well 2254-01. The well was shut off and isolated from the drinking water distribution system. Details regarding the activities that followed are presented in Section 5.2.

4.0 Summary of Data Quality Objectives

4.1.1 Soil Vapor

The Navy installed SVMPs under each of the active Red Hill fuel storage tanks to collect data that provide additional layers of protection to screen for potential releases. These SVMPs are monitored monthly for total VOC vapors as a release detection screening tool that operates in conjunction with other leak detection systems used at the Facility. More frequent monitoring of the SVMPs at Tanks 13 to 20 has been conducted since the May 6 Release.

4.1.2 Groundwater and Drinking Water

The objective of the free product gauging and groundwater monitoring well headspace measurements is to evaluate whether free product has reached groundwater at specific monitoring well locations.

The objective of the groundwater and drinking water sample collection and analysis is to evaluate the nature and extents of impacts to the groundwater.

The usability of data collected depends on its quality, which in turn depends upon a variety of factors. Adhering to proper sample collection techniques, observing and documenting chain of custody (COC) procedures, and using Department of Defense (DoD)-accredited laboratories and approved analytical methods ensure that the quality of data generated meets site characterization objectives.

DOH's technical perspective and regulatory guidance on the characterization of petroleum-impacted soil and groundwater are described in Section 6 (Soil, Soil Vapor and Groundwater Action Levels for TPH) of the DOH document "Evaluation of Environmental Hazards at Sites with Contaminated Soil and Groundwater" (DOH 2017) as follows:

- Petroleum is a complex mixture that degrades into potentially toxic metabolites.
- Non-specific aliphatic and aromatic compounds and related degradation compounds compose the overwhelming majority of the mass collectively referred to as total petroleum hydrocarbons (TPH) (refer to Volume 1, Section 2.6.1).
- Risk to human health and the environment posed by petroleum releases is evaluated in terms of both TPH and individual "indicator" compounds such as benzene, toluene, ethylbenzene, and xylenes (BTEX) as well as naphthalene, 1-methylnaphthalene, and 2-methylnaphthalene and other targeted polyaromatic *[i.e., polynuclear]* hydrocarbons (PAHs). The latter compose only a small percentage of the total mass in fuels and in vapors but can pose a significant risk due to their higher toxicity.
- Concentrations of individually targeted compounds such as BTEX and PAHs should be subtracted from the reported concentration of TPH. This includes soil, vapor, and water samples but is most important for the latter, since dissolved-phase hydrocarbons are anticipated to be dominated by more soluble aromatics. This can only be reliably done, however, if the same analytical method is used for both TPH and individual compounds.
- For risk evaluation, samples should also be evaluated for additives known or suspected to have been pre-blended into the fuel stored in the Red Hill tanks, as well as cleaning agents that might have been used to clean the tunnel after the initial May 6 Release. Additives, including antioxidants, biocides, and fuel system ice inhibitors, are normally pre-blended into stored jet fuel or added during fueling of a plane.

Appendix A, Section 4.1.6 (LNAPL Plume Delineation) of the DOH guidance (DOH 2017) identifies soil borings as parts of the LNAPL characterization process, including the following delineation methods for soil:

- If the depth of the source of a release is known, then the approximate upper extent of that release can be inferred.
- Headspace measurements for volatile organics will typically show an increase in concentration within the LNAPL zones. Plotting these on a simple chart of depth against concentration will typically show the inferred bulk LNAPL zone (mobile or residual).
- Visual and olfactory observations are typically logged as well, giving another indication of the presence of LNAPL.
- Soil samples are often collected and analyzed chemically, which will give another set of clear LNAPL indications. In general, TPH analytical results (for the appropriate fuel carbon range) greater than 250 milligrams per kilogram (mg/kg) are indicative of residual LNAPL (because soil has a limited sorptive capacity).

Target petroleum-related analytes identified in the above guidance are listed in Table 4-1, and relevant DOH Environmental Action Levels (EALs) are listed in Table 4-2.

Table 4-1: Target Analytes for Middle-Distillate Contaminated Media

Petroleum Product	Media	Recommended Target Analytes
Middle Distillates: diesel, kerosene, Stoddard solvents, heating fuels, jet fuels, etc.	Soil	TPH, BTEX, naphthalene, and methylnaphthalenes (1- and 2-)
	Soil Vapor	TPH, BTEX, naphthalene, and methane
	Groundwater	TPH, BTEX, naphthalene, and methylnaphthalenes (1- and 2-)

Source: (DOH 2017 Vol. 2, Table 6-1)

Table 4-2: DOH Environmental Action Levels

Analytical Method	Analyte	Environmental Action Levels (EALs)		
		Soil (mg/kg) [a]	Groundwater (µg/L) [b]	Soil Vapor (µg/m^3) [c]
SW-8260	TPH-g	100 / 450 / 700	500 / 300	4.9×10^6
	Benzene	500 / 1.2 / 0.3	170 / 5	6,300
	Toluene	500 / 820 / 0.78	40 / 1,000	1.8×10^7
	Ethylbenzene	480 / 62 / 0.9	30 / 700	2×10^5
	Xylenes	260 / 130 / 1.4	20 / 10,000	3.5×10^5
SW-8270	Naphthalene	500 / 28 / 3.1	21 / 17	1.1×10^4
	1-Methylnaphthalene	500 / 170 / 0.89	10 / 27	9.8×10^5
	2-Methylnaphthalene	500 / 39 / 1.9	10 / 24	5.6×10^4
SW-8015	TPH-d	500 / 220 / 940	500 / 400	2.2×10^6
	TPH-o	500 / 9,400 / 1,000	500 / 2,400	N/A

Notes:

Source: (DOH 2017) Hawai'I Department of Health Environmental Action Level Surfer (Fall 2017)

N/A Not applicable; EAL not provided

TPH-d TPH-diesel range organics

TPH-g TPH-gasoline range organics

[a] Soil EALs = (Gross Contamination) / (Direct Exposure) / (Leaching to Groundwater) in milligrams per kilogram (mg/kg)

[b] Groundwater EALs = (Odor Taste Threshold) / (Drinking Water Toxicity) in micrograms per liter (µg/L)

[c] Soil Vapor EALs = (Commercial/Industrial Shallow Soil Vapor Action Levels) (Table C) in micrograms per cubic meter (µg/m^3)

5.0 Field Activities

Activities performed to characterize soil vapor and groundwater are described in this section. Field activities conducted as part of the May 6 Release response were performed during the third 90-day

reporting period, from November 6, 2021 to February 4, 2022 (third quarter). Field activities conducted as part of the November 20 Release response began on November 24, 2021. Documenting these two release response efforts has been combined into this single Quarterly Release Response Report format going forward.

5.1 May 6 Release

5.1.1 Soil Vapor Monitoring Under the Tanks

Soil vapor VOC concentrations at SVMPs under the fuel storage tanks were measured in the field using hand-held PIDs at all SVMPs under Tanks 11 through 18 and 20, as shown on Figure 4. Measurements were collected twice a week from June 14 through July 22, 2021, paused for 1 week, and resumed on August 2, 2021.

Field monitoring was conducted using two PIDs to cover a wide range of vapor concentrations. A ppbRAE 3000, which was also used for the routine monthly monitoring, was calibrated using a 10 parts per million by volume (ppmv) isobutylene standard. In addition, a MiniRAE Lite, which was generally used for SVMPs with vapor concentrations above 50 ppmv, was calibrated using a 100 ppmv isobutylene standard.

Soil vapor PID-measured VOC concentrations are summarized in Appendix A.2. As described in Section 3.1, SVMPs at Tanks 17, 18, and 20 were believed to have been impacted by cleanup activities following the pipeline breach, resulting in the increased soil vapor VOC concentrations observed.

Soil vapor samples were also collected from select SVMPs for fixed-base laboratory analysis using EPA Methods TO-15 (Individual VOCs), American Standard Test Method (ASTM) D1946 (Carbon Dioxide, Oxygen, and Methane), and TO-3 (Total VOCs within effective carbon number range of C5–C12). Samples were collected from the following locations:

- May 10–14, 2021: Zone 7 Sump (tunnel air sample), SV13S, SV16S, SV17S, SV18S, SV20S, SV20M
- June 5, 2021: SV17S, SV18S, SV20M
- June 14, 2021: SV15S, SV15D, SV17S, SV17D, SV18S, SV18D, SV20S, SV20D
- July 15, 2021: SV15S, SV15D, SV17S, SV18S, SV18D, SV20M, SV20D
- Monthly since August 2021: SV15S, SV15D, SV17S, SV17D, SV18S, SV18D, SV20M, SV20D

Results for fixed-base laboratory samples collected through January 17, 2022 are presented in Appendix A.4.

5.1.2 Free Product Gauging and Groundwater Monitoring Well Headspace Measurements

Free product gauging and groundwater monitoring well headspace PID measurements were collected at groundwater monitoring wells RHMW01, RHMW01R, RHMW02, RHMW03 and RHMW05. Free product gauging continues to be conducted using an oil/water interface probe. At the request of DOH,[1] the method was changed to add use of a clear bailer to collect a sample from the water surface in the monitoring well and photograph the water in the bailer to demonstrate any evidence of free product. Use of the bailer method began at RHMW03, RHMW02, and RHMW01R on June 2, 2021 and at RHMW05 on June 3, 2021. No free product was observed in these wells during measurements taken between May 12, 2021 and January 24, 2022. A thickness of 0.01 ft was recorded for RHMW01R on February 3, 2022; however, it is possible that the presence of insects on the water surface gave a false reading as the headspace reading was 0.0 ppmv and the bailer sample had no observable free product. A summary of monitoring well headspace and free product gauging measurements is included as Appendix B.2.

5.1.3 Groundwater Sampling and Analysis

Between November 6, 2021 and November 17, 2021, the following locations were sampled as part of the release response actions for the tunnel pipeline breach:

- Groundwater monitoring wells within the lower access tunnel:
  - RHMW03, approximately 450 ft topographically downgradient
  - RHMW02, approximately 1,300 ft topographically downgradient
  - RHMW01R, approximately 1,900 ft topographically downgradient
  - RHMW05, approximately 2,800 ft topographically downgradient and closest tunnel monitoring well to Red Hill Shaft

As described in Section 3.1, groundwater sampling began on May 12, 2021 in response to the May 6 Release, and sampling at these locations during all or some of the events continued from November 6, 2021 through February 4, 2022:

- Beginning on May 12, 2021, initial samples were collected from in-tunnel monitoring wells RHMW03, RHMW02, and RHMW01R following the long-term monitoring groundwater low-flow sampling procedure using a bladder pump, lowered to approximately the middle of the well screen interval, and with appropriate purging prior to sample collection.
- Beginning on June 2, 2021 at the request of DOH, samples were collected from the uppermost portion of the water column using a bailer without purging.

[1] Email from L. Galvez, DOH-HEER, to S. Eng, Navy Region Hawaii; May 28, 2021

- On June 30, 2021, comparison samples from RHMW03, RHMW02, and RHMW01R were collected from:
  - The basal aquifer surface using a bailer
  - Mid-screen depth using a bladder pump in accordance with low-flow methodology
- Beginning on September 22, 2021, samples requiring an expedited turnaround time were also submitted to Energy laboratory for analyses of TPH-d and TPH-o with and without silica gel cleanup (SGC).
- In response to receipt of TPH-o (C24–C40 carbon range organics) detections received on September 22, 2021 for the July 8 and 15, 2021 samples collected at the Red Hill Shaft pre-chlorination port, collection of weekly samples were initiated from the groundwater sampling point RHMW2254-01 at Red Hill Shaft and at RHMW05 during the next weekly groundwater sampling event on September 29, 2021.
- Between September 30 and October 6, 2021, selected external wells (RHMW04, RHMW06, RHMW08, RHMW09, RHMW10, RHMW12A, RHMW14-03, RHMW16, RHMW19, and OWDFMW01) were sampled once for TPH-d and TPH-o. Samples were sent to Energy for testing and analyzed with and without SGC; APPL received aliquots from these samples to analyze for TOC only.

In addition, samples were analyzed by APPL for compounds indicative of middle-distillate fuels (including JP-5 and F-24): TPH-g/d/o, BTEX, and PAHs. If TPH-d/o was detected, the remaining extract underwent SGC and was analyzed for TPH-d/o to quantify the amount of non-polar hydrocarbons compared to total (polar and non-polar) components in those carbon ranges. As described in the TGM, SGC can help evaluate whether TPH is related to fresh petroleum or other sources and can also be used to better understand the amount of natural degradation that is taking place at each well. Samples collected on September 29, 2021 and onward were also analyzed for TOC, a gross measure of all forms of organic carbon including petroleum hydrocarbons and natural organic matter.

5.2 November 20 Release

On November 28, 2021, upon confirmation of a fuel-like odor in drinking water in homes served by Red Hill Shaft, Navy Well 2254-01 was shut off and isolated from the drinking water distribution system. On December 2, 2021, tubing connected to a PID was lowered into Red Hill Shaft, resulting in a maximum reading of 110 ppmv. A bailer sample was collected and indicated a sheen with fuel bubbles floating on the surface. This was the first confirmation of fuel in the Navy Well 2254 01 (Red Hill Shaft) water development tunnel. On December 5, 2021, DOH authorized Navy divers to enter the water development tunnel. Navy divers completed a visual inspection on December 7, 2021 and confirmed the presence of contamination in the initial 350-ft section they were able to access. As soon as DOH approved the Navy skimming plan, on or around December 10, 2021 Navy divers entered the water development tunnel, swam approximately 300 ft east of the Water Pumping Station, and reported observing fuel dripping into the water tunnel.

Skimmers and floating absorbent booms were used to remove the LNAPL fuel from the surface of the water development tunnel and prevent it from floating into the production well chamber. The following subsections describe additional release response actions.

5.2.1 Emergency Groundwater and Product Sampling and Analysis

Groundwater and product samples were collected and analyzed from the Adit 3 Sump, Red Hill Shaft water development tunnel (Water Gallery), and fire suppression drain line to characterize and quantitate the extent and magnitude of fuel impacts from the November 20 Release.

5.2.1.1 ADIT 3 SUMP

On November 24, 2021, free product was observed in the Facility's groundwater sump near Adit 3 (Adit 3 Sump). In response to a request by DOH, a product sample was collected and screened by the Navy Fuels Lab. To further characterize the product, additional samples were collected on November 24, 2021 and analyzed by ALPHA Analytical laboratory for the following constituents:

- Saturated hydrocarbon (SHC) and fingerprinting analysis, with breakdown of carbon ranges
- Paraffins, isoparaffins, aromatics, naphthenes, and olefins

Groundwater samples were also collected on November 24, 2021 from Adit 3 Sump and submitted to ALPHA Analytical laboratory for analysis of the following constituents:

- SHC and fingerprinting analysis, with breakdown of carbon ranges with and without SGC
- SVOCs with and without TICs

Additional product samples were also submitted to Energy for a carbon scan. Groundwater samples were submitted for TPH-g/d/o, and the laboratory's full list of SVOCs and VOCs.

5.2.1.2 RED HILL SHAFT WATER GALLERY

On December 2, 2021, groundwater samples from the Red Hill Shaft Water Gallery were collected and submitted to ALPHA Analytical laboratory for the following analyses:

- SHC and fingerprinting analysis, with breakdown of carbon ranges
- Paraffins, isoparaffins, aromatics, naphthenes, and olefins

5.2.1.3 FIRE SUPPRESSION DRAIN LINE

DOH requested testing of the water/fuel mixture in the fire suppression collection tank; however, none of the fuel/water mixture reached the collection tank. Therefore, the fuel/water mixture remaining in the fire suppression drain line was sampled on January 6, 2022 and submitted to ALPHA Analytical laboratory for analysis of the following constituents:

- SHC and fingerprinting analysis, with breakdown of carbon ranges

- Paraffins, isoparaffins, aromatics, naphthenes, and olefins

Additional product samples were also submitted to Energy for a carbon scan. Groundwater samples were also tested for TPH-g/d/o, and the laboratory's full list of SVOCs and VOCs.

5.2.2 Emergency Subslab SVMP Installation and Monitoring

Between December 15 and 17, 2021, 47 SVMPs were installed into the petroleum-impacted segments of the Adit 3 and Pearl Harbor tunnel floors. Penetrations were drilled though the concrete floor fully penetrating the slab, providing access to sampling organic vapors under the floor slab. SVMPs (i.e., vapor pins) were installed in in the holes to sample vapor below the tunnel floor slab but did not penetrate the base course or native strata. Results from hand-held organic vapor detectors (PIDs) used to sample these SVMPs since December 17, 2021 indicated elevated petroleum vapors under the concrete tunnel floors. Organic vapor maxima, or hotspots, were noted directly over the water development tunnel in the vicinity of the release area, and just before the merge of the Adit 3 tunnel and the Pearl Harbor tunnel. Organic vapors were also elevated at SVMP locations throughout the lower portion of the Adit 3 tunnel, with the highest PID readings surrounding the Adit 3 groundwater sump. On January 11, 2022, five additional SVMPs were installed within the Adit 3 and Pearl Harbor tunnels:

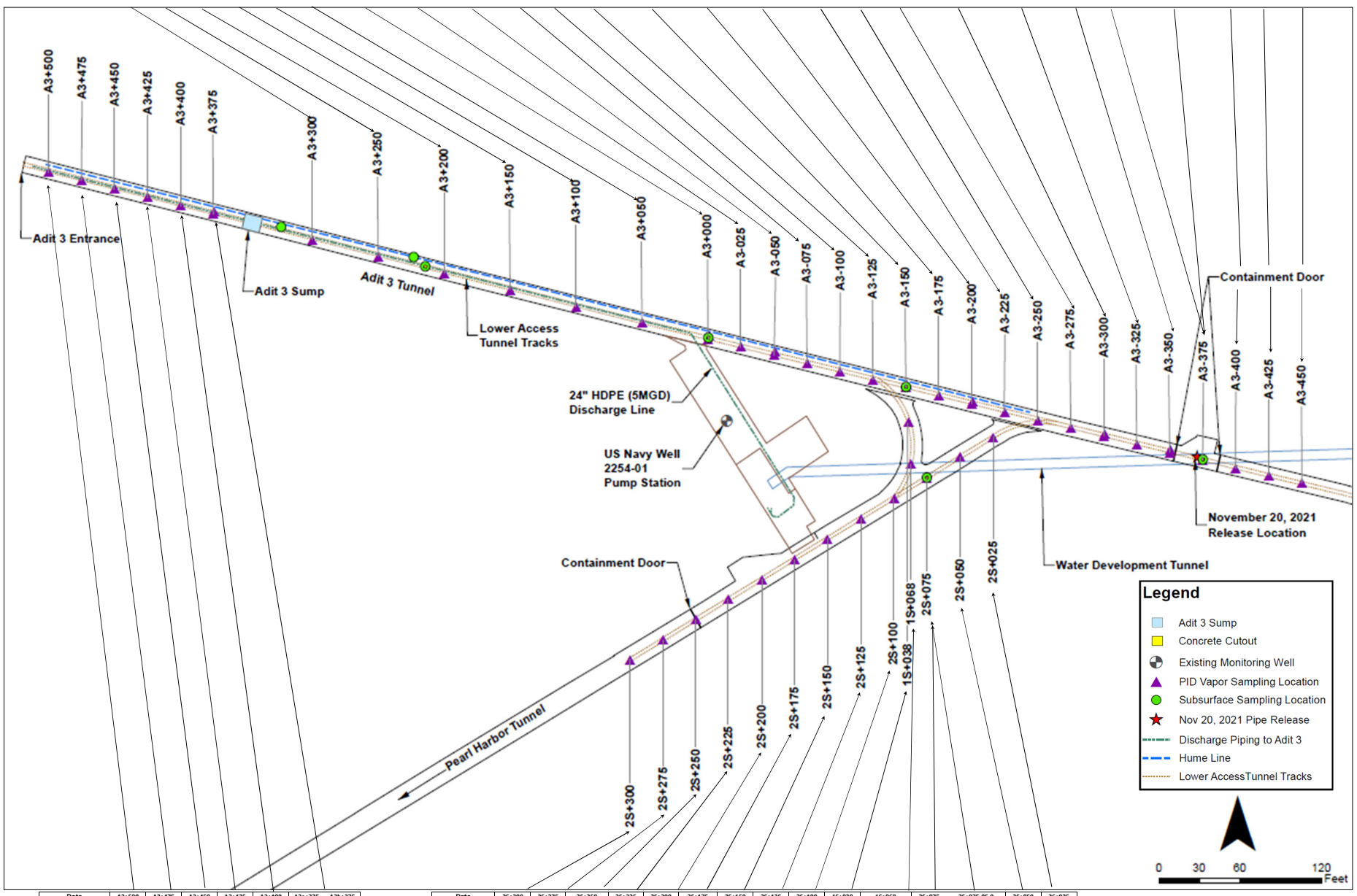
- Two SVMPs were installed approximately 425 and 450 ft east-southeast of Navy Well 2254-01 (Red Hill Shaft) Pump Station, and approximately 50–75 ft east-southeast of the release area, to evaluate potential petroleum hydrocarbon migration east of the release location.
- Three SVMPs were installed approximately 250, 275, and 300 ft southwest of the Adit 3 tunnel merge with the Pearl Harbor tunnel to evaluate potential petroleum hydrocarbon migration south of the expected Hume pipe drainage system.
- A total of 52 SVMPs for the November 20 Release soil vapor monitoring network have been sampled weekly since January 12, 2022, although some SVMPs have provided insufficient vapor to analyze with the PID, likely due to soil moisture or stiff clays.

SVMPs in the Adit 3 and Pearl Harbor tunnels in proximity to the November 20 Release are scheduled for:

- Weekly sampling with hand-held real-time PIDs at all subslab SVMPs.
- Monthly sampling of selected SVMPs that represent focused hotspots and transport pathways for laboratory analysis of TO-3 (total VOCs), TO-15 (BTEX and naphthalene), and ASTM D1946 (oxygen, carbon dioxide, and methane).

Figure 5 depicts the location of each tunnel SVMP and the organic vapors measured between December 17, 2021 and February 3, 2022.

Date	A3+300	A3+250	A3+200	A3+150	A3+100	A3+050	A3a+000	A3b+000	A3-025	A3a-050	A3b-050	A3-075	A3-100	A3-125	A3a-150	A3b-150	A3-175	A3a-200	A3b-200	A3-225	A3-250	A3-275	A3a-300	A3b-300	A3-325	A3a-350	A3b-350	A3-375	A3-375-05.0	A3-400	A3-425	A3-450
2021-12-17	67	101	55	43	39	40	24	33	28	24	35	36	44	29	83	95	69	56	51	13	27	36	56	51	47	36	47	288	NA	2.3	NA	NA
2021-12-20	235	178	88	96	67	85	65	79	57	54	69	NT	65	32	92	108	42	57	69	7	38	58	43	75	142	275	246	290	NA	15	NA	NA
2021-12-21	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	71	78	15	66	68	66	76	72	76	87	181	NA	17	NA	NA
2021-12-22	55	106	51	62	62	37	45	60	42	56	45	12	92	16	69	85	36	36	45	7	30	50	23	35	49	41	49	96	NA	18	NA	NA
2021-12-23	106	350	192	233	205	138	215	203	151	258	101	9.3	302	9	257	321	112	73	157	4	102	121	85	120	163	228	196	407	NA	24	NA	NA
2021-12-24	120	281	282	131	462	101	448	471	105	423	208	NT	407	NT	475	490	71	116	374	NT	97	408	197	73	139	409	155	450	NA	17	NA	NA
2021-12-27	NT	240	79	160	141	99	180	181	106	160	118	NT	264	NT	265	157	66	49	53	NT	36	52	24	36	38	58	26	443	NA	14	NA	NA
2021-12-29	Wet	Wet	76	117	103	45	101	110	65	97	83	NT	203	NT	180	181	53	37	85	Wet	52	68	28	14.2	86	125	81	128	NA	2	NA	NA
2021-12-30	Wet	Wet	74	109	85	45	87	87	47	86	73	Wet	142	Wet	155	153	52	46	82	Wet	56	62	41	54	73	66	88	82	NA	2	NA	NA
2021-12-31	Wet	Wet	175	341	278	65	342	387	111	227	110	Wet	679	Wet	617	682	114	146	403	Wet	228	308	80	135	377	365	408	444	NA	14	NA	NA
2022-01-06	Wet	614	238	426	415	95	497	544	133	118	139	Tight	618	Wet	527	627	358	158	422	Wet	196	370	74	167	399	342	381	410	NA	8	NA	NA
2022-01-12	628	550	184	386	350	64	398	410	98	239	108	Tight	416	Tight	466	547	74	105	342	Tight	174	338	51	132	328	318	401	396	NA	1	1	1
2022-01-19	654	531	148	313	343	65	316	344	89	177	108	Tight	439	Tight	597	622	89	138	312	Tight	160	277	66	134	338	349	450	408	NA	69	55	52
2022-01-26	Wet	667	157	335	320	64	334	386	96	364	99	Tight	624	Tight	538	669	93	81	336	Tight	151	291	53	123	339	352	367	416	NA	3	1	1
2022-02-02	Wet	598	159	391	389	41	400	414	75	219	78	Tight	673	Tight	432	701	109	105	362	Tight	152	365	61	105	374	400	392	399	NA	1	1	2



Date	A3+500	A3+475	A3+450	A3+425	A3+400	A3a+375	A3b+375
2021-12-17	33	4	3	20	55	120	92
2021-12-20	96	56	54	86	244	350	269
2021-12-21	NT	NT	NT	NT	NT	NT	NT
2021-12-22	56	41	43	50	64	115	114
2021-12-23	193	145	160	178	215	405	408
2021-12-24	122	76	82	96	101	201	244
2021-12-27	NT	90	113	159	134	239	281
2021-12-29	Wet	39	44	48	81	196	193
2021-12-30	Wet	43	47	55	63	109	157
2021-12-31	Wet	38	45	62	85	785	673
2022-01-06	Wet	45	53	70	97	560	474
2022-01-12	107	38	45	57	72	486	263
2022-01-19	Wet	42	54	59	72	458	163
2022-01-26	291	30	37	50	64	683	225
2022-02-02	444	17	21	27	36	438	144

Date	2S+300	2S+275	2S+250	2S+225	2S+200	2S+175	2S+150	2S+125	2S+100	1S+038	1S+068	2S+075	2S+075-05.0	2S+050	2S+025
2021-12-17	NA	NA	NA	33	20	40	79	69	49	13	33	89	NA	90	59
2021-12-20	NA	NA	NA	37	39	82	84	83	473	16	21	525	NA	135	110
2021-12-21	NA	NA	NA	42	40	68	43	86	189	NT	NT	238	NA	86	94
2021-12-22	NA	NA	NA	25	28	35	38	38	83	20	28	81	NA	65	39
2021-12-23	NA	NA	NA	82	87	133	132	142	241	81	92	252	NA	192	205
2021-12-24	NA	NA	NA	39	76	127	133	57	260	58	76	577	NA	269	42
2021-12-27	NA	NA	NA	6	35	66	70	67	128	42	43	158	NA	68	39
2021-12-29	NA	NA	NA	23	29	23	29	16	146	27	Wet	143	NA	151	119
2021-12-30	NA	NA	NA	40	36	36	33	32	138	68	58	144	NA	137	103
2021-12-31	NA	NA	NA	58	45	120	99	39	485	65	95	577	NA	536	402
2022-01-06	NA	NA	NA	70	50	112	103	39	521	65	92	607	NA	531	488
2022-01-12	12	12	15	34	41	94	102	84	435	17	19	490	NA	400	376
2022-01-19	1	1	1	1	2	30	43	10	395	79	103	457	NA	378	402
2022-01-26	18	20	20	26	34	66	78	80	444	22	22	510	NA	421	354
2022-02-02	6	5	5	6	12	13	33	31	454	8	9	569	NA	490	56

Figure 5. **Soil Vapor Monitoring Point Results**
December 17, 2021 - February 2, 2022
Adit 3 Tunnel and Pearl Harbor Tunnel

Scale
ppmv
785
650
550
450
350
250
150
50
1

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The origin for the Adit 3 tunnel (A3) is at the eastern edge of the Water Pumping Station doorway; coordinates are in feet and are positive (+) to the east and negative (-) to the west. The origin for the Pearl Harbor Tunnel (S2) is at the Adit 3 merge centerline, and coordinates are positive (+) to the south.

5.2.3 Free Product Gauging and Groundwater Monitoring Well Headspace Measurements

Beginning November 28, 2021, free product gauging and groundwater monitoring well headspace PID measurements were collected weekly at groundwater monitoring wells included in the NOI GW Sampling Plan (Appendix B.8). At the request of DOH, the free product gauging method was changed to using a clear bailer, and consisted of collecting a sample from the water surface in the monitoring well and photographing the water in the bailer to demonstrate any evidence of free product. A summary of monitoring well headspace and free product gauging measurements is provided in Appendix B.3.

5.2.4 Groundwater Sampling and Analysis

As part of the release response for the November 20 Release from the fire suppression drain line, DOH Solid and Hazardous Waste Branch, Underground Storage Tank Program (SHWB-UST) provided the NOI GW Sampling Plan on December 9, 2021 (DOH 2021d) to collect weekly groundwater samples from the following locations, in addition to the monitoring wells sampled for the May 6 Release: RHMW08, RHMW06, RHMW09, RHMW12 (shallow well later removed), RHMW12A, RHMW17 (when complete), RHMW16, OWDFMW01, RHMW11-05, RHMW13-05, RHMW14-03, RHMW15-05, and Adit 3 Sump.

The NOI GW Sampling Plan was revised on December 27, 2021 (Appendix B.8) to monitor the following locations, as depicted on Figure 1:

- Groundwater monitoring wells within the lower access tunnel: RHMW01R, RHMW02, RHMW03, RHMW05
- Groundwater sampling point RHMW2254-01 at Red Hill Shaft
- Select groundwater monitoring wells external to the tunnel:
  - RHMW04, located within the Facility boundary east of the tank farm in a location believed to be hydraulically upgradient from the tanks
  - RHMW06, RHMW08, RHMW11-05, RHMW13-05, RHMW14-03, RHMW15-05 and RHMW16, located within the Facility boundary northeast and northwest of the tank farm in locations along the Facility's northern border
  - RHMW09 and RHMW19, located within the Facility boundary southwest and southeast of the tank farm in locations along the Facility's southern border

  - OWDFMW01, OWDFMW04A, OWDFMW05A, OWDFMW07A, OWDFMW08A, located within the Facility boundary west of Red Hill Shaft
  - RHMW12A, located outside the Facility boundary north of the tank farm on the grounds of the Hālawa Correctional Facility
- Adit 3 Sump

The following analytes, some of which are listed as site cleanup criteria in HAR § §11-280.1-65.3, were analyzed by Energy:

- TPH-d/o by Method 8015, including 3520 extraction
- TPH-g by Method 8260 or 8015
- Full suite VOC by Method 8260
- Full suite SVOC (including naphthalene, 1-methylnaphthalene, 2-methylnaphthalene) by Method 8270 Selected Ion Monitoring (SIM)
- TOC by Method 9060A
- Methane by Method RSK175M
- Lead scavengers by Method 8011 and 8260
- Total and dissolved lead by Method 6020
- Per- and polyfluoroalkyl substances (PFAS) by draft Method 1633 (one-time analysis from RHMW2254-01)
- 2-(2-Butoxyethoxy)ethanol by Method 8015C-DAI (analyte removed in the revised NOI GW Sampling Plan) (DOH 2021d)

Additionally, a sample of free product from RHMW2254-01 and Adit 3 Sump was analyzed by Method 8015 for TPH-g/d/o, as described in Section 5.2.1.

For those samples in which TPH-d/o was detected, the sample was extracted and analyzed for SGC to quantify the amount of non-polar hydrocarbons compared to total (polar and non-polar) components in those carbon ranges. As described in the TGM, SGC can help evaluate whether TPH is related to fresh petroleum or other sources and can also be used to better understand the amount of natural degradation that is taking place in a particular location.

In addition, 2-(2-methoxyethoxy)-ethanol (2-2-MEE), a de-icing additive to JP-5, was analyzed for in the Adit 3 Sump and RHMW2254-01 samples collected on December 21, 2021.

At DOH's request, monitoring wells with sampling zones that intersect the water table were sampled with a bailer for the NOI sampling effort. However, several well sampling zones are

confined and therefore must be sampled with a pump. These well sampling zones, along with other wells with alternative sampling methods, include the following:

- OWDFMW01, OWDFMW04A, OWDFMW05A, OWDFMW07A, OWDFMW8A, RHMW12A, and RHMW16 are sampled with a low-flow pump.
- RHMW11-05, RHMW13-05, and RHMW15-05 are multilevel wells and are sampled according to their Standard Operating Procedures (SOPs).
- RHMW2254-01 is sampled both with a low-flow pump and with a bailer.

The NOI GW Sampling Plan (revised December 27, 2021) is presented in Appendix B.8. Beginning on January 29, 2022, weekly groundwater sampling was reduced to accommodate the installation of transducers and collection of water level data without disturbance of the data logging records as the RHS pump was restarted. The locations sampled during this period included RHMW2254-01, RHMW01R, RHMW19, OWDFMW07A, OWDFMW08A, and the Adit 3 Sump.

5.2.5 Drinking Water Sampling

Daily drinking water sampling conducted in the days immediately following the November 20 Release included extensive activities to address fuel that entered the JBPHH Water Distribution System such as discovery sampling, delineation of impact sampling, distribution line flushing sampling, and final compliance sampling. These activities and results were provided in separate reports through coordination with DOH and EPA.

Drinking water sampling associated with Navy Well 2254-01 (Red Hill Shaft) was discontinued after the pumps were shut down on November 28, 2021 and will not be conducted until further notice and coordination with the DOH Safe Drinking Water Branch.

5.2.6 Holding Tank and Leach Tank Sampling

On December 17, 2021, a buried groundwater Holding Tank and connected Leach Tank were identified at the northwest perimeter of the Facility, adjacent to South Hālawa Stream. These tanks were designed to discharge storm water collected from the sump pump located near the entrance of Adit 3. Both cylindrical concrete tanks are 8 ft tall and 7 ft in diameter, and the Leach Tank was constructed with openings near the tank bottom to allow passage of collected storm water. Upon inspection of the Holding Tank, a fuel/water mixture was identified. The Leach Tank was empty and dry; however, petroleum odors were observed.

The Navy submitted a Preliminary Site Characterization Plan (DON 2022a) to DOH and the U.S. Environmental Protection Agency (EPA) for review on January 8, 2022. DOH and EPA provided comments, and the revised plan was submitted on January 12, 2022. DOH concurred with the revised version on January 24, 2022. Sampling of the Holding Tank and Leach Tank was conducted as described below.

Between January 11 and 13, 2022, 35 primary subsurface soil samples and 3 duplicate soil samples were collected and analyzed by an Environmental Laboratory Accreditation Program (ELAP)-certified laboratory (Eurofins-Seattle, located in Tacoma, Washington) from 21 soil borings adjacent to the groundwater Holding Tank and Leach Tank. The sampling was conducted in accordance with the Preliminary Site Characterization Plan (DON 2022a) and is further detailed in the Technical Memorandum for the Holding Tank and Leach Tank investigation (Appendix E) [forthcoming].

The objectives for the Holding Tank and Leach Tank area subsurface characterization were:

- Determine whether petroleum or petroleum-impacted water entered the Holding Tank and Leach Tank from the Adit 3 Sump groundwater drain line.
- Determine whether petroleum or petroleum-impacted water passed through the Holding Tank and Leach Tank from the Adit 3 Sump groundwater drain line into environmental media (subsurface soil, groundwater).
- If petroleum impacts entered the environment adjacent to the Holding Tank and Leach Tank, evaluate the nature and extent of the contamination by the following methods:
  - Collect one discrete subsurface soil sample from the soil interval with the highest headspace measurement of the subsurface soil core located below 5 ft bgs. Compare the concentrations of site-specific COPCs in the samples to site-specific and constituent-specific DOH Table 2-A Soil Action Levels, as presented in the Preliminary Site Characterization Plan (DON 2022a).
  - Collect one discrete subsurface soil sample from the bottom soil interval in each boring to evaluate the potential for COPCs to have migrated below the bottom of the borehole and potentially into the underlying perched groundwater.

Direct-push soil sampling was conducted between January 11 through 13, 2022 with two Geoprobe track rigs working simultaneously. Over that 3-day period, 23 soil borings were drilled in a step-out manner from the Holding Tank and the Leach Tank. Borings were identified by the direction and distance from a tank. For example, boring HT-N10 was situated approximately 10 ft north of the Holding Tank.

Twenty-one of the borings were sampled for JP-5 constituents in subsurface soil. Soil cores from each boring were screened for organic vapors every 1 ft below 6 ft bgs to determine the most impacted soil core to be submitted for laboratory analysis. Subsurface soil sampling continued vertically at each location until no contamination was observed or until the direct-push sampler could no longer penetrate the subsurface (i.e., encountered refusal). Groundwater was not encountered during the subsurface sampling event.

Soil samples for laboratory analysis were temporarily stored on ice until taken to a warehouse at the end of each sampling day. Samples were then frozen prior to shipment to Eurofins-Seattle for analysis of the following COPCs:

- TPH-g (C6 to C12) by Method 8260/CALUFT
- BTEX by Method 8260D
- TPH-d (C10 to C24) by Method 8015D
- TPH-o (C24 to C40) by Method 8015D
- Naphthalene, 1-methylnaphthalene, and 2-methylnaphthalene by Method 8270E in SIM mode.

One groundwater sample was collected on January 26, 2022 from monitoring well OWDFMW06B, located approximately 20 ft north-northeast of the Holding Tank and screened at the perched aquifer from approximately 25 to 35 ft bgs. The groundwater sample was submitted to Eurofins-Seattle and analyzed for the same parameters as the soil samples.

The Holding Tank and Leach Tank investigation report is presented in Appendix E [forthcoming].

5.2.7 In-Tunnel Characterization

In addition, the Preliminary Site Characterization Plan presented the first phases of a comprehensive site characterization focused on developing remedial alternatives to mitigate impacts of the November 20 Release, which include the following initial in-tunnel activities:

- Geophysical characterization of shallow and deep subsurface features: ground-penetrating radar (GPR) was used clear the subsurface for utilities prior to ground disturbance activities.
- Between January 28, 2022 and February 2, 2022, GPR and surface electrical resistivity (ER)/induced polarization (IP) was used to evaluate subsurface conditions within the impacted portion of the Adit 3 and Pearl Harbor tunnels that have contrasting resistivity values, such as massive bedrock, clays, water saturated strata, and petroleum. This data will be used to facilitate LNAPL downward migration and inform the location of the deeper soil vapor locations), and potentially identify pooled LNAPL in the vadose zone.
- On January 11, 2022, two additional subslab SVMPs were installed east of the release point at Stations A3-425 and A3-450, and three additional SVMPs were installed in the Pearl Harbor tunnel south of the isolation door at stations 2S+250, 2S+275, and 2S+300. Sampling occurred weekly, as described above.

Additional activities (e.g., concrete cutouts and additional soil, water and soil vapor sampling were planned as part of near-surface subslab assessments in hotspots identified by geophysics and SVMP results.

6.0 Sample Control Procedures

Prior to sampling, the field team inspected all supplies and consumables to ensure that they were acceptable for use. Sampling and sample handling procedures were designed to ensure that samples were consistently collected, labeled, preserved, and transported in a manner that maintained their integrity for their intended purposes.

6.1 Sample Containers and Preservation

Soil vapor laboratory samples were collected into Summa canisters as part of the May 6 Release NOI requirement. A memorandum describing the collection of Summa canister samples is provided in Appendix A.1.

Groundwater and drinking water samples for chemical analyses in support of NOI requirements were placed in the sample containers listed in Table 6-1, and soil samples (unconsolidated material) were placed in the sample containers listed in Table 6-2. The samples were preserved as indicated and analyzed within the required holding times. The containers, preservatives, and holding times are specified in the respective EPA SW-846 methods.

Table 6-1: Groundwater, Drinking Water, and Product Sample Containers, Preservatives, and Holding Times

SW-846 Parameter	Number and Type of Containers per Sample	Preservative	Holding Time
VOCs			
VOCs, Benzene, Toluene, Ethylbenzene, Total Xylenes	2 × 40-mL vials, Teflon-lined septum caps	No headspace, cool to ≤6°C and adjust to pH <2 with H_2SO_4, HCl, or solid $NaHSO_4$	Maximum holding time is 7 days if pH >2 or 14 days if pH <2.
TPH			
TPH-g	2 × 40-mL vials, Teflon-lined septum caps	No headspace, cool to ≤6°C and adjust to pH <2 with HCl	Maximum holding time is 7 days if pH >2 or 14 days if pH <2.
TPH-d, TPH-o (without and with silica gel cleanup)	2 × 1-L amber glass, Teflon-lined lid	Cool to ≤6°C and adjust to pH <2 with HCl or H_2SO_4	14 days/40 days [a]
TPH-DRO, Saturated Hydrocarbons Whole Oil Analysis (Product)	2 x 40-mL vials, hard top, Teflon-lined caps	Cool to ≤4°C	NA
SVOCs, PAHs			
SVOCs, 1-Methylnaphthalene,	2 × 1-L amber glass, Teflon-lined lid	Cool to ≤6°C	7 days/40 days [a]

SW-846 Parameter	Number and Type of Containers per Sample	Preservative	Holding Time
2-Methylnaphthalene, Naphthalene			
Fuel Additives			
2-(2-Methoxyethoxy)-ethanol (2-2-MEE)	2 × 1-L amber glass, Teflon-lined lid	Cool to ≤6°C	7 days/40 days [a]
Lead Scavengers			
1,2-Dibromoethane (EDB)	2 × 40-mL vials, Teflon-lined septum caps	No headspace, cool to ≤6°C	7 days
1,2-Dichloroethane (DCA)	2 × 40-mL vials, Teflon-lined septum caps	No headspace, cool to ≤6°C and adjust to pH <2 with H2SO4, HCl, or solid NaHSO4	Maximum holding time is 7 days if pH >2 or 14 days if pH <2.
Natural Attenuation Parameters (NAPs)			
Methane	2 × 40-mL vials, Teflon-lined septum caps	No headspace, cool to ≤6°C and adjust to pH <2 with HCl or H_2SO_4	Maximum holding time is 7 days if pH >2 or 14 days if pH <2.
Total Organic Carbon (TOC)			
TOC	3 × 40-mL amber VOA vials, Teflon-lined lid or 2 × 250-mL amber glass, Teflon-lined lid	Cool to ≤6°C and adjust to pH <2 with H_2SO_4 or H_3PO_4	28 days
Per- and Polyfluoroalkyl Substances (PFAS)			
PFAS	2 × 500 mL + 2 × 60-mL HDPE containers	Cool to ≤ -20 ºC and protected from the light / Cool to 0–6 ºC and protected from the light	90 days / 28 days
Metals			
Total and Dissolved Lead	2 × 250-mL HDPE containers	Cool to ≤6°C and adjust to pH <2 with HNO_3	180 days
Ethanol			
2-(2-Butoxyethoxy)ethanol	2 x 40-mL VOA vials w/ HCl, Teflon-lined septum caps	No headspace, cool to ≤6°C and adjust to pH <2 with HCl	14 days

Notes:

°C degree Celsius
H_2SO_4 sulfuric acid
HCl hydrochloric acid
H_3PO_4 phosphoric acid
HDPE high-density polyethylene
HNO_3 nitric acid
L liter
mL milliliter
NA Not applicable, holding times not provided
$NaHSO_4$ sodium hydrogen sulfate
VOA volatile organic analysis

[a] x days/y days = x days from sample collection to extraction/y days for analysis of extracts following extraction.

Table 6-2: Soil Sample Containers (Unconsolidated Material), Preservatives, and Holding Times

Parameter	Number/Type of Containers per Sample	Preservative	Holding Time
TPH-g, VOCs			
TPH-g, Benzene, Toluene, Ethylbenzene, Total Xylenes	2 × 10 mL water-preserved with magnetic stir bar; 1 × 5-mL methanol-preserved; Teflon-lined septum caps	Cool to 4 ±2°C or frozen at -7°C	Samples shipped at 4 ±2°C must be received by laboratory within 48 hours and frozen upon receipt; Samples frozen must be analyzed within 14 days.
TPH			
TPH-d, TPH-o (without and with silica gel cleanup)	1 × 8-oz. glass jar, Teflon-lined lid	Cool to 4 ±2°C or frozen at -7°C	14 days/40 days [a]
PAHs			
1-Methylnaphthalene, 2-Methylnaphthalene, Naphthalene	1 × 8-oz. glass jar, Teflon-lined lid	Cool to 4 ±2°C or frozen at -7°C	14 days/40 days [a]

Notes:

mL milliliter
oz. ounce
°C degree Celsius

[a] x days/y days = x days from sample collection to extraction/y days for analysis of extracts following extraction.

6.2 Chain of Custody

Chain-of-custody (COC) documentation was maintained for samples during all phases of sample collection, transport, and receipt and internal transfer within the laboratory.

6.3 Laboratory Analytical Methods

Soil vapor samples were analyzed for organic vapors using hand-held real-time PIDs, which provided semi-quantitative data. These data were collected using SOPs to ensure reproducible and comparable data sets.

Groundwater samples were analyzed for VOCs, BTEX, and DCA by EPA Method 8260; TPH-g by EPA Method 8015 or 8260, TPH-d and TPH-o by EPA Method 3520/8015; TPH with SGC by EPA Method 3630/8015; SVOCs by EPA Method 8270C; PAHs, 1-methylnaphthalene, 2-methylnaphthalene, and naphthalene by EPA Method 8270 SIM; 2-2-MEE by EPA Method 8270D Modified; 2-(2-butoxyethoxy)ethanol (2-2-BEE) by EPA Method 8015C-DAI; EDB by EPA Method 8011; methane by Method RSK175 Modified; TOC by EPA Method 9060A; total and dissolved lead by EPA Method 6020; and PFAS by EPA Draft Method 1633.

With DOH approval, bromomethane and benzidine were removed from the full VOC/SVOC list on January 20, 2022 to improve Energy's reporting delay and throughput, since both compounds are known to be very reactive and tend to recover lower, outside of quality control (QC) limits. In order to meet QSM requirements, Energy would re-extract samples for the entire VOC/SVOC list of compounds, which takes an additional 18 hours to complete, thus delaying results to be furnished in a timely manner. Additionally, historical and NOI groundwater results indicate that both compounds have not been detected.

Soil samples for site characterization were analyzed for BTEX and TPH-g by EPA Method 8260; PAHs 1-methylnaphthalene, 2-methylnaphthalene, and naphthalene by EPA Method 8270; TPH-d and TPH-o by EPA Method 3510/8015; and TPH with SGC by EPA Method 3630/8015.

6.4 Laboratory Sample Preservation Procedures

Laboratory samples for groundwater, and drinking water were preserved as described in Section 6.1.

7.0 Field Observations during Sampling

Field observations made during sampling activities are described below.

7.1 May 6 Release

7.1.1 Soil Vapor Monitoring Observations

Ambient PID measurements (i.e., measurements of tunnel air) in the area of the SVMPs at Tanks 17, 18, and 20 were elevated following the pipeline breach. The ambient PID measurements have generally decreased since May 2021. Some of the elevated ambient PID readings may be

associated with Facility operation and maintenance activities, such as application of epoxy coatings to Facility infrastructure, which may be a source of VOCs in ambient air.

7.1.2 Free Product Gauging and Groundwater Monitoring Well Headspace Observations

Between May 12, 2021 and February 3, 2022, free product and organic vapor headspace measurements were collected at RHMW01, RHMW01R, RHMW02, RHMW03, and RHMW05. No free product was observed in any groundwater monitoring wells during any of the monitoring events, regardless of the method used (either oil/water interface probe or bailer). Petroleum odors in the ambient tunnel air were sometimes noted by field staff when free product gauging and groundwater monitoring well headspace PID measurements were conducted. Ambient PID measurements are included in the summary of monitoring well headspace and free product gauging measurements presented in Appendix B.2.

At RHMW01R, the oil-water interface probe sensor emitted a beep, suggesting the presence of product. However, small insects observed at the surface of the water may have interfered with the sensor, resulting in a false reading. The headspace reading was 0.0 ppmv, and the bailer sample had no observable free product. Product was not detected in RHMW01R during any previous monitoring events.

7.1.3 Groundwater and Drinking Water Sampling Observations

Prior to collecting groundwater samples, monitoring well headspace PID measurements and free product gauging were conducted, as described in Section 5.1.2. No free product or sheen was observed in any of the monitoring wells during any sampling event, consistent with previous observations. Free product was observed in RHMW2254-01 on December 2, 2021 and continues to be observed through video monitor in the vicinity of the pump intake.

During groundwater and drinking water sampling, organic odors were observed in monitoring wells RHMW01, RHMW02, and RHMW03; however, the intensity of the odors decreased from previous sampling events. Strong odors were observed in RHMW2254-01.

In addition to the pre-chlorination drinking water samples collected at Navy Well 2254-01 (Red Hill Shaft), post-chlorination drinking water samples were collected on November 10, 17, and 24, 2021 as requested by DOH. Observations included the following:

- No sheen or color was recorded during the pre- or post-chlorination sampling events.
- Ambient organic vapor readings during pre-chlorination sample events were 0.0 ppmv on November 10, 2021; 0.1 ppmv on November 17, 2021; and 0.6 ppmv on November 24, 2021.
- No odor was recorded during the post-chlorination sampling events.

7.2 November 20 Release

7.2.1 Emergency Groundwater and Product Sampling Observations

RHMW2254-01 was sampled weekly from November 24, 2021 through February 4, 2022. Beginning on December 8, 2021, RHMW2254-01 was sampled with both a bailer and dedicated low-flow bladder pump.

- An oily sheen was observed on December 8 and 15, 2021, and January 10, 2022.
- A headspace organic vapor reading (110 ppmv) measured 30 ft above the water development tunnel water surface was recorded on December 8, 2021.
- A headspace organic vapor reading (78.4 ppmv) measured 50 ft above the water development tunnel water surface was recorded on December 15, 2021.
- Ambient background organic vapor readings varied between 0.0 ppmv and 0.6 ppmv over the sampling period.
- Floating particulates were observed on two occasions.

Ambient PID measurements are included in the summary of monitoring well headspace and free product gauging measurements presented in Appendix B.3.

Fuel product was collected from the fire suppression drain line on January 6, 2022. After the line was opened during sampling, downwind organic vapor readings spiked at 36.1 ppmv, indicating the presence of organic vapors.

Adit 3 Sump samples were collected during eight sampling events from December 15, 2021 through February 4, 2022:

- Headspace VOC readings were recorded as 52.7 ppmv (December 15), 41.2 ppmv (December 20), 39.8 ppmv (January 3), 7.4 ppmv (January 11), 8.0 ppmv (January 20), and 23.9 ppmv (January 24). Headspace VOC readings were not recorded for Adit 3 Sump during the December 27 and February 3 collection dates.
- There were no noted observations of color, odor, or sheen.

7.2.2 Adit 3 Subslab Soil Vapor Probe Installation and Monitoring Observations

Forty-seven subslab SVMPs were installed in the Adit 3 and Pearl Harbor tunnels between December 15 and 17, 2021. Soil vapor samples were collected and measured using real-time organic vapor analyzers (hand-held PIDs).

- In general, organic vapors were measured using a ppbRAE, and oxygen and carbon dioxide were measured using a MultiRAE.

- PID readings were collected on December 17, 20, 21, 22, 23, 24, 27, 29, 30, and 31, 2021; on January 6, 12, 19, and 26, 2022; and on February 2, 2022.
- Between December 17 and 21, 2021, samples were measured with a PID calibrated using 10 ppmv isobutylene. Because maximum PID readings were greater than 100 ppmv, the PID was calibrated using 100 ppmv isobutylene for samples measured from December 22, 2021 through February 2, 2022.
- On December 21, 2021, the ppbRAE lamp was contaminated during sampling, as indicated by elevated ambient readings. The 20 SVMPs recorded prior to the lamp contamination were considered valid and reported.
- On December 22, 2021, the MultiRae PID was used to measure SVMPs due to the contaminated lamp on the ppbRAE. It was noted that readings were significantly lower than the previous ppbRAE readings. This is likely due to the built-in moisture corrections in the ppbRAE. The ppbRAE was thereafter chosen as the detector that would be used for comparability.
- Between December 17 and 27, 2021, the areas of soil vapor maxima were:
  - A zone between A3+250 and A3+375, in the vicinity of the Adit 3 Sump
  - A zone between A3-325 and A3-375, in the vicinity of the release area
  - A zone between 2S+25 and 2S+100, near the start of the Pearl Harbor tunnel
- Heavy rain events occurred between December 27, 2021 and January 5, 2022, resulting in significant groundwater passing under the tunnel floor subslab and being pumped from the Adit 3 Sump for removal and disposal. Observations during and after these rain events included the following:
  - Soil vapor could not be collected from A3-075, A3-125, and A3-225.
  - Soil vapor could not be collected from 1S+68 on December 29, 2021.
  - Following these rain events, an additional area of soil vapor maxima was observed between A3-150 and A3-100.

7.2.3 Free Product Gauging and Groundwater Monitoring Well Headspace Measurement Observations

Between November 20, 2021 and February 3, 2022, free product, ambient air, and organic vapor headspace were measured in the monitoring wells described below and at groundwater sampling point RHMW2254-01. The results are presented in Appendix B.3. The following observations were made:

- No free product was observed in any groundwater monitoring wells during any monitoring event, regardless of the method used (either oil/water interface probe or bailer).

- RHMW12A, RHMW16, OWDFMW01, OWDFMW04A, OWDFMW05A, OWDFMW07A, and OWDFMW08A have submerged well screens. RHMW11, RHMW13, RHMW14, RHMW15 are closed systems with sampling ports below the water level surface. Free product was not present in the samples from these wells.
- Most groundwater monitoring well headspace VOC readings were less than 10 ppmv, with the following exceptions:
  - Headspace VOC readings in the in-tunnel monitoring wells were up to 422.3 ppmv on December 27, 2021 and January 3, 2022. Since January 10, 2022, PID readings in all in-tunnel monitoring wells were 0 to 0.1 ppmv.
  - Headspace VOC readings in RHMW2254-01 on December 8 and 15, 2021 were up to 110.1 ppmv. All other PID readings in RHMW2254-01 were 1.6 ppmv or less.
  - For wells outside the tunnel, only two measurements (one in RHMW13 at 10.9 ppmv and one in OWDFMW08A at 19.8 ppmv) exceeded 10 ppmv. Heavy rain and numerous site activities, vehicles, and equipment may have affected these readings.

7.2.4 Groundwater Sampling Observations

Prior to collecting groundwater samples, monitoring well headspace organic vapor measurements and free product gauging were conducted, as described in Section 5.2.3. Groundwater chemistry parameters measured during well purging are included in Appendix B.4.

- With the exception of groundwater sampling point RHMW2254-01, no free product or sheen was observed in any sampling location during any sampling event, consistent with previous observations.
- Color, odor, and sediment were observed occasionally at monitoring wells during the sampling events, most often with bailed wells located inside the tunnel (RHMW02, RHMW03, and RHMW05).
- Trace amounts of sediment were noted on two occasions at RHMW04 and RHMW08, with each well having one instance of the bailer hitting the bottom of the well and potentially stirring up settled material.
- Organic odor was noted twice during sampling of RHMW08 and once during sampling of OWDFMW01.

7.2.5 Drinking Water Sampling Observations

Drinking water sampling associated with Navy Well 2254-01 was discontinued after the pumps were shut down on November 28, 2021 and will not be conducted until further notice and coordination with the DOH Safe Drinking Water Branch.

7.2.6 Holding Tank and Leach Tank Sampling Observations

Specific field observations made during soil boring and sampling activities are described in detail in the Technical Memorandum for the Holding Tank and Leach Tank investigation (Appendix E) [forthcoming]. In general, the boring logs identified disturbed subsurface soil to depths as deep as 20 ft in some cases, as evidenced by man-made debris. Other general observations included:

- Oily sediment was observed on the bottoms of both the Holding Tank and the Leach Tank.
- The direct-push rig encountered refusal at various depths in 22 of the boreholes drilled, ranging from 6 ft bgs at LT-N25 to 26 feet bgs at HT-N10.

One groundwater sample was collected on January 26, 2022 from the perched water well OWDFMW06B, located approximately 20 ft north-northeast of the Holding Tank. The following observations were noted:

- No sheen or oil was observed in the sampling bailer.
- Headspace organic vapor reading collected from the well casing was 158.7 ppmv using a miniRAE.
- Depth to water below top of casing was 29.06 ft.
- A petroleum-like odor was detected that was not present before November 20, 2021.

8.0 Data Quality

Field and laboratory QC measures are described below. When applicable, corrective actions were implemented when control limits for field or laboratory QC measurements were not met.

8.1 Laboratory Quality Control

Laboratory QC samples for soil vapor Summa canisters, groundwater samples, and drinking water samples are described below.

8.1.1 Soil Vapor Samples

Laboratory QC samples included method blank, laboratory control sample (LCS), and laboratory control sample duplicate (LCSD) analyses.

8.1.2 Groundwater and Drinking Water Samples

Laboratory QC samples included method blanks, LCSs/LCSDs, matrix spikes/matrix spike duplicates (MSs/MSDs), and duplicates as described in the U.S. Department of Defense (DoD) Quality Systems Manual (QSM) Version 5.3 (DoD and DOE 2019) and the AOC Red Hill Sampling and Analysis Plan Addendum 01 (DON 2017d).

8.2 Field Quality Control

Field QC samples for groundwater including trip blanks and equipment rinsates were collected according to the procedures described in NAVFAC Pacific Environmental Restoration Program Project Procedure III-B, *Field QC Samples* (Water, Soil) (DON 2015). Field QC samples are listed in Table 8-1.

Table 8-1: Measurement Performance Criteria – Field QC Samples

QC Sample	Analytical Group [a]	Frequency [b]	DQI	Measurement Performance Criteria
Field duplicate	VOCs, TPH-g, TPH-d, TPH-o, PAHs, SVOCs	10% of primary samples collected per matrix per analytical method	Field sampling precision	RPD ≤50% water [c]
Trip blank	VOCs, TPH-g, methane, lead scavengers	At minimum, one per cooler containing VOCs, TPH-g, Methane, lead scavengers samples	Contamination during sample transport	≤1/2 of LOQ
Field blank	VOCs, TPH-g, TPH-d, TPH-o, PAHs, SVOCs	Once per source of decontamination water per sampling event	Adequacy of the decontamination water quality or potential for contamination due to field conditions	≤1/2 of LOQ
Equipment rinsate	VOCs, TPH-g, TPH-d, TPH-o, PAHs, SVOCs	5% of primary samples collected per matrix per analytical method	Adequacy of the decontamination process	≤1/2 of LOQ

Notes:

% percent
DQI data quality indicator
LOQ limit of quantitation
RPD relative percent difference

[a] Refer to Section 6.3 for the list of analytes within analytical groups.

[b] Per Project Procedures Manual Procedure III-B, Field QC Samples (DON 2015); refer to Procedure III-B Section 5 for a summary of QC samples by project location, matrix, and analytical group.

[c] Per Project Procedures Manual Section II, *Data Validation Procedures* (DON 2015).

[d] One equipment blank was collected from the bailer used to sample RHMW03 to demonstrate equipment cleanliness. As all monitoring locations have dedicated bladder pumps and dedicated bailers, no reusable sampling equipment is used, thus no additional equipment blank was collected.

8.3 Data Quality Assessment

The Data Quality Assessment presented below incorporates groundwater sampling data for the May 6 Release in the lower access tunnel and for the November 20 Release from the fire suppression drain line.

The objective of data validation is to provide data of known quality for project decisions. Data quality is judged in terms of precision, accuracy, representativeness, comparability, completeness, and sensitivity. The analytical laboratory data for the groundwater and drinking water monitoring events were submitted to a third-party data validator (Laboratory Data Consultants, Inc. [LDC]) for data validation and assessment. Groundwater and drinking water sample analysis and third-party data validation are complete for results received for June 24 and 30, July 29, and September 22, 23, 24, 25 and 29, 2021 collection events; data validation from June 17 through October 6, 2021 for some data sets is ongoing and will be provided when complete. Additional validated data have been provided for the May 6 Release that was not included in the December 30, 2021 Quarterly Release Response Report; however, further validated data are pending. Validated data for the November 20 Release are also pending and will be provided for the next quarterly Release Response Report. Data quality assessment for the groundwater and drinking water results are as follows.

8.3.1 Precision

Precision is defined as the reproducibility of replicate measurements. Precision is evaluated by the relative percent difference (RPD) of field duplicates, LCS/LCSD, MS/MSD, and laboratory duplicate results.

LCSs/LCSDs were analyzed as required by the method. RPDs were within QC limits and were not flagged or rejected with the following exceptions:

- September 29, 2021 sampling event: Total organic carbon for RHMW01R, RHMW02, RHMW03, and RHMW05 were flagged as estimated (J) since RPDs were above QC limits.

No other precision concerns were identified during validation of sample results.

8.3.2 Accuracy

Accuracy is defined as the degree of conformity of a measurement to a standard or true value. Accuracy is evaluated through measurement of the percent recovery (%R) of an analyte in a reference standard or spiked sample. Accuracy also encompasses the percent difference (%D) between the initial calibration verification and the continuing calibration verification. Accuracy limits for surrogates, LCS, MS, and MSD samples are either prescribed by the DoD or established by the individual laboratory. The acceptance criteria for accuracy are dependent on the analytical method and based on historical laboratory or DoD data.

The %Rs and %Ds were within QC limits and were not flagged or rejected with the following exceptions:

- June 24, 2021 sampling event: semivolatile standard (hexachlorocyclopentadiene) was flagged to exclude data (X) for all non-detects because LCS %Rs were significantly below QC limits. TPH as extractables (TPH-d/o with SGC) for RHMW01R detected results were flagged as high-biased (J+) because surrogate %Rs were above QC limits.
- July 29, 2021 sampling event: 1-methylnaphthalene, 2-methylnaphthalene, and naphthalene for RHMW03 non-detected results were flagged as non-detect estimated (UJ) because surrogate %Rs were below QC limits.
- September 22, 2021 sampling event (Energy results): TPH as extractables (TPH-d/o with SGC) for RHMW02 detected results were flagged as low-biased (J-), and non-detected results were flagged as non-detect estimated (UJ) because surrogate %Rs were below QC limits.
- September 29, 2021 sampling event (APPL results): 1-methylnaphthalene, 2-methylnaphthalene, and naphthalene for RHMW02 and RHMW03 non-detected results were flagged as UJ and low-biased (J-) for detected results because surrogate %Rs were below QC limits. Additionally, TPH as extractables (TPH-d/o without SGC) for RHMW01R, RHMW02, RHMW03, and RHMW05 detected results were flagged as high-biased (J+) because LCSs and LCSDs were above QC limits.
- September 29, 2021 sampling event (Energy results): TPH as extractables (TPH-d/o with and without SGC) for RHMW02 and RHMW03 detected results were flagged as low-biased (J-), and non-detected results were flagged as non-detect estimated (UJ) because surrogate %Rs were below QC limits.
- October 4, 2021 sampling event (Energy results): TPH as extractables (TPH-d/o with and without SGC) for RHMW12A and RHSF, pre-chlorination point detected results were flagged as low-biased (J-), and non-detected results were flagged as non-detect estimated (UJ) because surrogate %Rs were below QC limits.
- October 20, 2021 sampling event (APPL results): TPH as extractables (TPH-d/o with and without SGC) for RHMW01R, RHMW03, and RHMW05 non-detected results were flagged as non-detect estimated (UJ) because surrogate %Rs were below QC limits.
- November 17, 2021 sampling event (APPL results): 1-methylnaphthalene, 2-methylnaphthalene, and naphthalene for RHMW02 detected results were flagged as low-biased (J-) because surrogate %Rs were below QC limits.

No other accuracy concerns identified during validation affected sample results.

8.3.3 Representativeness

Representativeness is the degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, or an environmental condition. Representativeness can be supported by using regulator-approved, industry-standard sampling and analysis protocols that were developed to address a specific data quality objective of the sampled medium.

During the quarterly release response sampling rounds:

- Groundwater samples were collected in accordance with procedures described in the DOH-approved AOC Statement of Work Sections 6 and 7 Work Plan/Scope of Work (DON 2017a) and the associated project Sampling and Analysis Plan and addenda (DON 2017b; 2017c; 2017d), including standardized sample collection methods identified in NAVFAC Pacific Environmental Restoration Program Project Procedure I-C-3, *Monitoring Well Sampling* (DON 2015).
  - This procedure collects groundwater samples from a specific depth directly beneath the water table using a low-flow pumping strategy and will not collect LNAPL or the compounds in the LNAPL/groundwater interface, generally of dissolved constituents within the aquifer.
  - Therefore, the results from these samples represent groundwater from one depth, below the water table.
- Groundwater samples were collected with a bailer, based on DOH's request.[2]
  - Sampling with a bailer was requested to collect water at the groundwater/air interface along with any potential LNAPL that may be present. Sampling with a bailer may introduce air and turbulence to the sample, which may volatilize VOCs in the groundwater matrix. The bailer technique is also less repeatable, and therefore adds a degree of variability into the results, which may be less representative of actual conditions at the water table.
  - In addition, DOH requested no purging to be associated with this method; therefore, the methodology is likely to be affected by any localized equilibrium within the well and filter pack, and not represent water flowing through the aquifer.

On June 30, 2021, the Navy conducted a comparative sampling event in which a bailer sample and a low-flow pump sample were collected from each of RHMW01R, RHMW02, and RHMW03. These results are provided in Appendix B.6. The data, summarized in Table 8-2 for TPH-d and

[2] Email from L. Galvez, DOH-HEER, to S. Eng, Navy Region Hawaii; May 28, 2021

TPH-o, indicate that the bailer sampling methodology results in higher reported concentrations, particularly in the TPH-o analyses.

Table 8-2: Comparison of TPH-d/o Results – Bailer vs. Low-Flow Pump SOPs

Location	TPH-d (µg/L)			TPH-o (µg/L)		
	Bailer	Low-Flow Pump	RPD (%)	Bailer	Low-Flow Pump	RPD (%)
RHMW01R	270 J	200 J	30	210 J	ND	N/A
RHMW02	1,800	1,800	0	320	210 J	42
RHMW03	220 J	160 J	32	350	200 J	55

Notes:

J estimated concentration
N/A not applicable
ND not detected
RPD relative percent difference

Representativeness is also evaluated through compliance with the method-recommended sample holding time and sample preservation methods and through the analysis of blank samples, including method blank, equipment blank, field blank, and trip blank samples (DoD 2021). All sample holding times and sample preservation were evaluated in accordance with EPA SW-846 method recommendations and DoD QSM Version 5.3 (DoD and DOE 2019).

All samples were associated with a trip blank and laboratory calibration, preparation, or extraction blanks. There were no detections in the trip blanks collected for all sampling events. None of the groundwater sample results were flagged for laboratory blank contamination due to groundwater sample results being non-detect or being detected greater than 5 times the blank concentration with the following exception:

- June 24, 2021 sampling event: Semivolatile TIC concentrations for all samples were compared to concentrations detected in laboratory blanks. The sample concentrations were either not detected or were significantly greater than the concentrations found in the associated laboratory blanks.
- September 29, 2021 sampling event: TPH-o concentrations for RHMW01R, RHMW02, RHMW03, and RHMW05 for all samples were compared to concentrations detected in laboratory blanks. Due to laboratory blank contamination, results were qualified as not detected or estimated in those samples.
- October 2, 2021 sampling event (Energy results): Cooler temperature for Red Hill Shaft pre-chlorination point samples were reported at 18.2 °C upon laboratory receipt, which exceeded the temperature requirement of 4 $\pm$ 2 °C; therefore, TPH as extractables concentrations were flagged as non-detect estimated (UJ).

- October 3, 2021 sampling event (Energy results): Cooler temperature for Red Hill Shaft pre-chlorination point samples were reported at 17.6 °C upon laboratory receipt, which exceeded the temperature requirement of 4 ± 2 °C; therefore, TPH as extractables concentrations were flagged as non-detect estimated (UJ).
- October 4, 2021 sampling event (Energy results): Cooler temperature for RHMW12A and Red Hill Shaft pre-chlorination point samples were reported at 18 °C upon laboratory receipt, which exceeded the temperature requirement of 4 ± 2 °C; therefore, TPH as extractables detected concentrations were flagged as low-biased (J-), and non-detected results were flagged as non-detect estimated (UJ).
- October 5, 2021 sampling event (Energy results): Cooler temperature for Red Hill Shaft pre-chlorination point were reported at 13.7 °C upon laboratory receipt, which exceeded the temperature requirement of 4 ± 2 °C; therefore, TPH as extractables detected concentrations were flagged as low-biased (J-), and non-detected results were flagged as non-detect estimated (UJ).

No other representativeness concerns were identified during validation of the sample results.

8.3.4 Completeness

Completeness is defined as the overall percentage of valid analytical results (including estimated results) compared to the total number of analytical results reported by the analytical laboratory.

None of the rejected data caused a data gap for the monitoring event. Data was rejected for hexachlorocyclopentadiene for all samples collected on June 24, 2021; however, the SVOC constituent is not regularly monitored for the release response program and is not understood to be associated with the fuel stored at the Facility; rather, this constituent is monitored for the Drinking Water Program and has not had any previous detects in the pre- and post-chlorination drinking water samples. The completeness of the data (99 percent) met the 90 percent completeness goal.

8.3.5 Comparability

Comparability expresses the confidence with which one data set can be compared to another. Comparability can be related to accuracy and precision because these quantities are measures of data reliability. Data with acceptable precision and accuracy are considered comparable if collection techniques, analytical procedures, methods, and reporting are equivalent.

The laboratories used standard analytical methods for all analyses. In all cases, the detection limits (DLs) and limits of detection (LODs) attained were below the specified LOQs. Target analytes detected below the LOQs flagged (J) by the laboratory should be considered estimated. The data presented can be compared to and evaluated against regulatory standards as required for this report.

8.3.6 Sensitivity

The LOQs are established by the laboratory based on the LODs or instrument DLs and limits established for the various methods. The LOQs and LODs for samples may require adjustment by the laboratory due to matrix interference or when high levels of target analytes necessitate dilution before analysis. Matrix interference and sample dilutions decrease sensitivity and increase the LOQs/LODs. No results in this data set had increased LOQs or LODs that impacted sensitivity and data usability.

8.4 Conclusions

The precision, accuracy, representativeness, comparability, completeness, and sensitivity criteria were evaluated by LDC in Carlsbad, California, the project third party data validators. With some limited exceptions, the criteria were met for groundwater and drinking water Level IV sample data packages that were available for the June 24 and 30, July 29, and September 22, 23, 24, 25 and 29, 2021 sampling events. The third-party data assessment concluded that all data generated during the monitoring events reported herein are usable for the intended purpose with the limitations described above. Complete validation reports received to date are presented in Appendix D.2.

Groundwater and drinking water sample analysis and third-party data validation are ongoing and pending completion for a number of samples collected between June 17, 2021 and February 4, 2022; these results will be included in the next Quarterly Release Response Report. Laboratory and field data quality will be fully assessed pending availability of additional laboratory and third-party data validation reports.

9.0 Analytical Results

9.1 May 6 Release

9.1.1 Soil Vapor Analytical Results

9.1.1.1 FIELD MEASUREMENTS

Maximum PID readings recorded during the first 3 months following the May 6 Release have been analyzed to determine the extent impacts associated with the release. Maximum PID readings from this time period are summarized in Table 9-1. This includes data collected between May 10 and August 7, 2021 at SVMPs below Tanks 13, 14, 15, 16, 17, 18, and 20. The maximum PID soil vapor concentrations show:

- The area of elevated vapor concentrations is in the vicinity of Tanks 17, 18, and 20.
- PID readings above 10,000 parts per billion by volume (ppbv) were observed at SV17S, SV17M, SV17D, SV18S, SV18D, SV20M, and SV20D. PID readings above 100,000 ppbv were observed at SV17S, SV18S, and SV20M.

- In contrast, maximum PID readings at the Tank 16 SVMPs over this period were less than 1,000 ppbv, and maximum PID readings at Tank 14 and 15 SVMPs were less than 2,000 ppbv.

Table 9-1: Soil Vapor Monitoring Results from May 10 through August 7, 2021

SVMP	Maximum Reading (ppbv)
SV13S	3,006
SV13M	3,109
SV13D	4,532
SV14S	1,164
SV14M	1,057
SV14D	1,401
SV15S	1,694
SV15M	not sampled
SV15D	866
SV16S	886
SV16M	709
SV16D	691
SV17S	181,733
SV17M	92,333
SV17D	19,367
SV18S	146,667
SV18D	121,333
SV20S	9,837
SV20M	232,667
SV20D	17,277

Biweekly PID monitoring is ongoing to document changes in soil vapor concentrations over time. A complete set of soil vapor monitoring PID data for all SVMPs sampled since the May 6 Release is provided in Appendix A.2, and SVMP sampling locations are shown on Figure 4. PID results over time for SVMPs at Tanks 17, 18, and 20 are presented on Figure 6.

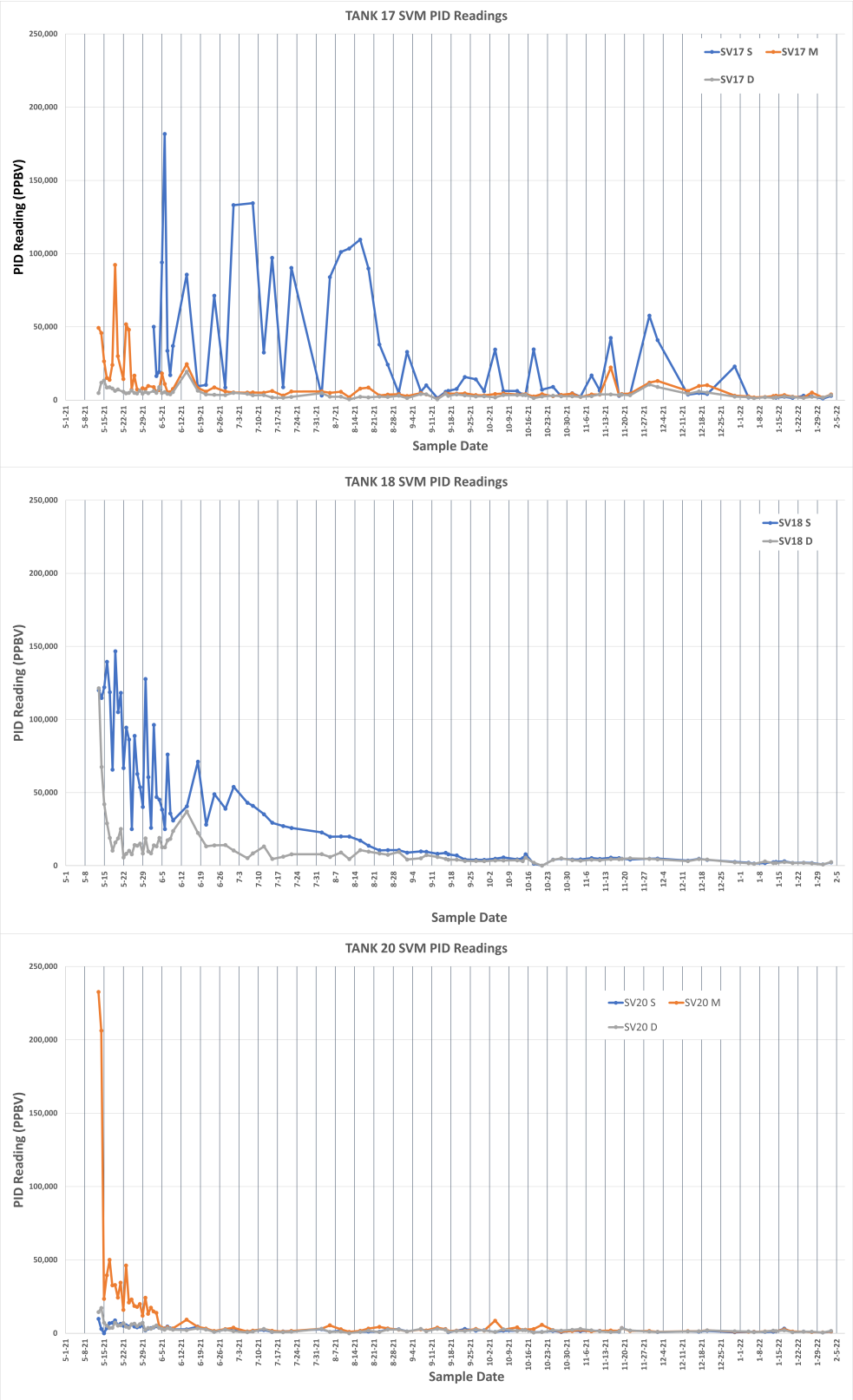


Figure 6: PID Readings Over Time for Tank 17, 18, and 20 SVMPs

- At Tank 17, the highest PID reading (181,733 ppbv) was recorded on June 6, 2021 at SV17S, and PID readings have generally declined since that time.
- At Tank 18, the highest PID reading (146,667 ppbv) was recorded on May 19, 2021 at SV18S, and PID readings have generally declined since that time.
- At Tank 20, the highest PID reading (232,667 ppbv) was recorded on May 13, 2021 at SV20M, and PID readings have generally declined since that time.

In January 2022, PID readings were typically below 10,000 ppbv at all SVMPs beneath the fuel storage tanks.

9.1.1.2 FIXED-BASE LABORATORY MEASUREMENTS

Analytical results were obtained for 40 soil vapor laboratory samples and one tunnel air laboratory sample collected between May 11, 2021 and January 17, 2022. Soil vapor chromatograms are presented in Appendix A.3.

Individual VOC Compounds by Method TO-15

The measured concentration of individual VOCs serves to identify the "fingerprint" of the May 6 Release (i.e., the individual VOCs most characteristic of the release). Of the petroleum hydrocarbons on the TO-15 reporting list, only five hydrocarbons were detected in one or more samples at a concentration above 1,000 micrograms per cubic meter ($\mu g/m^3$), while no other individual hydrocarbons were detected in any samples at concentrations above 200 $\mu g/m^3$:

- Ethylbenzene
- Total xylenes
- 4-Ethyltoluene
- 1,3,5-Trimethylbenzene
- 1,2,4-Trimethylbenzene

Thus, these five petroleum VOCs appear to be most characteristic of the release. Individual hydrocarbon concentrations above 1,000 $\mu g/m^3$ were observed only during the May and June 2021 sampling events, and only in samples from SV17S, SV18S, and SV20M. For the July to September 2021 sampling events, the maximum individual hydrocarbon concentration was 1,2,4-trimethylbenzene at 550 $\mu g/m^3$ in the July 2021 sample from SV17S. At SV18S and SV20M, individual hydrocarbon concentrations decreased rapidly, with no individual hydrocarbons measured at concentrations above 20 $\mu g/m^3$ during the December 2021 or January 2022 sample events.

Total VOCs by Method TO-3

For the soil vapor samples, total VOC concentrations by Method TO-3 ranged from non-detect (typically <50 ppbv) to 150,000 ppbv. Total VOC concentrations have decreased over time from a maximum of 150,000 ppbv (at SV20M) for the May 2021 sampling event to a maximum of 520 ppbv (at SV17S) for the January 2022 sampling event.

In addition to quantification of total VOC concentrations, each Method TO-3 analysis yields a flame ionization detector (FID) chromatogram that can be used for qualitative analysis of the sample composition, including evaluation of weathering. The laboratory also uses a mixture of 25 individual VOCs as the calibration standard for TO-3. These 25 VOCs have known retention times in the gas chromatograph (GC) column (see Appendix A.4), and these retention times can be used to tentatively identify some of the individual peaks on the sample chromatograms.

Appendix A.4 provides the FID chromatograms for the six samples collected from SV17S from May 2021 through January 2022. These chromatograms show a distinct pattern of weathering consistent with a new release of JP-5 in May 2021 followed by weathering of that material over time:

- The chromatogram for the earliest sample collected from SV17S on May 13, 2021 shows the bulk of the material in the sample with an elution time between nC8 (n-Octane) and nC12 (n-dodecane), consistent with JP-5. The chromatograms for both the May 13 and June 5, 2021 samples also show a number of discrete peaks eluting before nC8, consistent with a small fraction of hydrocarbons more volatile than nC8, which is expected for fresh JP-5.
- In the June 14 and July 15, 2021 samples, the peaks before nC8 have largely disappeared, consistent with the expected loss of the most volatile constituents early in the weathering process. In these two chromatograms, the nC10 (n-decane) and nC11 (n-undecane) peaks are the two most prominent peaks on the chromatogram.
- In the chromatograms from the August 2021 through January 2022 sample events, the nC10 and nC11 peaks become less prominent, consistent with the observation that n-alkanes typically degrade more rapidly than other hydrocarbons (e.g., Kaplan et al. 1996; Baedecker et al. 2017). In addition, these chromatograms show a larger fraction of material eluting after nC12 (n-dodecane), indicating continued disappearance of the more volatile fraction of the fuel and possibly the generation of hydrocarbon metabolites with longer retention times.

Overall, the sequence of chromatograms for samples collected from SV17S since May 6, 2021 are consistent with a new release of JP-5 in May 2021 and with weathering of that release over time.

Comparison of Total VOCs by Method TO-3 to Field Measurements by PID

The comparability between total VOCs (C5 to C12) by lab method TO-3 and field PID readings was evaluated by comparing paired measurements from May 2021 to January 2022. For samples with the highest vapor concentrations (i.e., >50 ppmv), a good correlation was observed between the PID readings and the total VOC concentration by TO-3. For these higher PID reading samples, the total VOC concentration by TO-3 ranged from 29% to 138% of the PID reading, with a median value of 62%. However, for samples with a PID reading between 0.1 and 50 ppmv, the total VOC concentration by TO-3 ranged from 5% to 72% of the PID reading, with a median value of 9% of the PID reading (Figure 7). As discussed in the September 2021 Initial Release Response Report (DON 2021d), the difference between PID reading and TO-3 results does not appear to be primarily attributable to material eluting outside of the TO-3 quantitation window (i.e., effective carbon range of C5–C12). This analysis has been conducting using the monitoring results from May to September 2021. The results obtained since September 2021 continue to exhibit a similar high bias in PID reading relative to the TO-3 results.

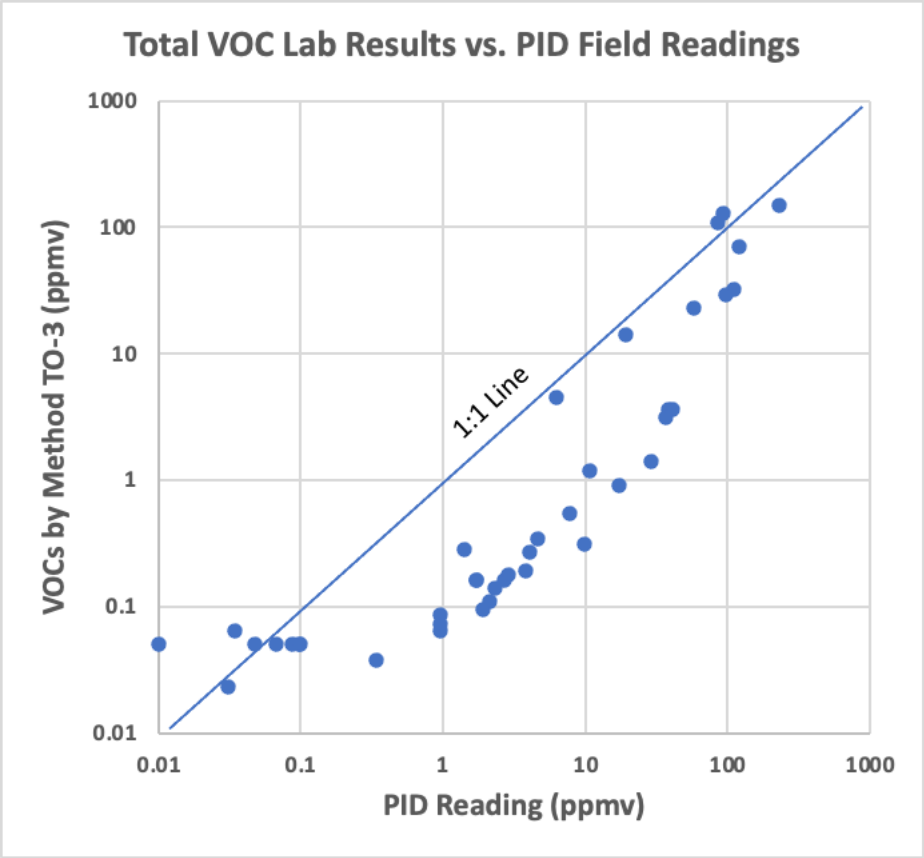


Figure 7: Comparison of PID Readings and Total VOC Concentrations by Method TO-3 – Paired Measurements Collected from May to September 2021

Carbon Dioxide, Oxygen, and Methane: The soil vapor samples collected from the SVMPs located beneath the fuel storage tanks from May 2021 through January 2022 all exhibited high oxygen (i.e., generally 20% to 22% oxygen), low carbon dioxide (<0.2% to 1.5%) and non-detect methane (<0.2%). These results are comparable to oxygen, carbon dioxide, and methane concentrations measured in those locations in 2017 (DON 2019, Appendix B.3).

Mass spectrometry and FID chromatograms for the final soil vapor laboratory results are presented in Appendix A.4. Laboratory reports providing analytical results for TO-15 (individual VOCs), ASTM D1946 (carbon dioxide, oxygen, and methane), and TO-3 (total VOCs in the effective carbon number range C5–C12) are provided in Appendix C.

9.1.2 Groundwater Analytical Results

Appendix B.1 provides a summary of samples collected, laboratory analytical methods, and status of sample delivery group reports. Groundwater analytical results presented in this report for the May 6 Release include results that were provided as Level II, Level IV and validated data packages by the time of drafting of this report, for samples collected through November 17, 2021. Third-party data validation has been and continues to be conducted by LDC; the data packages for which validation has been completed are presented in this report as fully validated. Preliminary data are not presented in this report. When available, complete laboratory data will be provided as final and fully validated, Level IV data packages. The Level II and IV groundwater sample results from samples collected through February 4, 2022 are presented in Appendix B.6.

As described in Section 5.2.3, groundwater samples collected through September 23, 2021 were sent to APPL for analysis. Due to delayed results, beginning on September 22, 2021, Energy was contracted to provide expedited results to increase the timeliness of sample analyses and reporting, due to the detections of TPH-o in samples collected from the Red Hill Shaft pre-chlorination port. Energy was contracted to analyze daily samples for TPH-d/o, while APPL continued to analyze samples for all COPCs on a weekly basis. In addition, RHMW05 and RHMW2254-01 were included in the sampling program in accordance with the Red Hill GWPP (DON 2014b).

In addition to contracting Energy to address the timeliness of analytical monitoring results, the Navy and DOH met on November 16, 2021 to identify root causes and discuss recommendations for revisions to the Red Hill program analytical requirements to include alternate laboratories, analytical methods, and reduction of the analyte sampling list to ensure future timely reporting of analytical results based on realistic reporting requirements and realistic laboratory turnaround time requirements. The Navy is proceeding with many of these actions and awaiting further feedback on others.

Groundwater results were screened against the DOH Tier 1 EALs, Table D-1b (i.e., groundwater EALs for sites where groundwater is a current or potential drinking water resource and the nearest surface water body is not located with 150 meters of release site) (DOH 2017). As applicable, the results were also compared to the SSRBLs for benzene and TPH-d. Implementation of the SSRBLs

is described in the Red Hill GWPP (DON 2014b). The SSRBLs were incorporated into the February 4, 2016 AOC Statement of Work Sections 6 and 7 scoping completion letter (EPA Region 9 and DOH 2016). Appendix B.6 provides a monitoring well-specific summary of Level II and IV results. Chromatograms from the May 6 Release collected between October 27 through November 17, 2021 are presented in Appendix B.7. Chromatograms are included for each sample with additional field observation information such as ambient/headspace PID readings, color, and odor. Final Level II and IV reports are presented in Appendix D.1.

9.1.2.1 Groundwater Total Petroleum Hydrocarbon Results

Appendix B.6.5 presents analytical results for TPH-g, TPH-d, and TPH-o at RHMW03, RHMW02, RHMW01R, RHMW05, groundwater sampling point RHMW2254-01, and the Red Hill Shaft pre-chlorination drinking water port compared to EALs. Note that TPH-o has a lower EAL of 500 µg/L for potential taste and odor concerns, and a higher EAL of 2,400 µg/L for human health risk associated with tap water use. Gaps in the continuous lines between data point markers represent periods when the COPC was not detected.

- **TPH-g:** Results are available from May 12 through November 17, 2021:
  - The EAL for TPH-g is 300 µg/L, and the LOD was 18 µg/L during this period.
  - TPH-g results were detected above the detection limit in samples from at RHMW01R, RHMW02, and RHMW03 and was not detected at RHMW05 and RHMW2254-01 during this period. No concentrations exceeded the EAL. The maximum concentration (230 µg/L) was detected in RHMW02.
- **TPH-d:** Results are available from May 12 through November 17, 2021:
  - The EAL for TPH-d is 400 µg/L, and the LOD was 300 µg/L for APPL and 140–150 µg/L for Energy during this period.
  - For in-tunnel wells, TPH-d was detected frequently at RHMW01R, RHMW02, and RHMW03 at concentrations that exceeded the EAL. The highest concentrations (maximum concentration 3,600 µg/L) were detected at RHMW02. Detected concentrations at RHMW05 and RHMW2254-01 were less frequent and did not exceed the EAL. There were two detected results at RHMW2254-01, with a maximum concentration of 190 J µg/L on November 17, 2021.
  - Groundwater samples from exterior wells RHMW04, RHMW12A, RHMW16, RHMW19, and OWDFMW01 reported TPH-d concentrations ranging from 47 J µg/L at RHMW04 to 420 µg/L at OWDFMW01, which was the only EAL exceedance.
  - SGC procedures were conducted on the extracts of all samples in which TPH-d was detected to evaluate the nature of the organic compounds in the sample. Analytes measured following the SGC process are considered petroleum hydrocarbons (non-polar) and the portion of the analytes removed by SGC are either polar degradation products of petroleum hydrocarbons or non-petroleum-related carbon

compounds. Results following SGC extraction indicated significant degradation of weathered petroleum hydrocarbons. In RHMW02 where the highest TPH-d concentrations were detected, The average combined (polar and non-polar) concentration was approximately 2,404 µg/L compared to approximately 597 µg/L of non-polar compounds after SGC, indicating that approximately 75% of the compounds were degradation products or non-petroleum-related carbon compounds. In two samples from RHMW2254-01 in which TPH-d was detected, no non-polar compounds were detected in the SGC extraction, indicating that only degradation products or non-petroleum-related carbon compounds were measured at this location.

- **TPH-o:** Results are available from May 12 through November 17, 2021:
  - The EAL for TPH-o is 500 µg/L for taste and odor and 2,400 µg/L for human health risk associated with tap water use. The LOD was 300 µg/L for APPL and 120–150 µg/L for Energy during this period.
  - Concentrations of TPH-o were detected in numerous samples from RHMW01R, RHMW02, and RHMW03 including concentrations that exceeded the EAL. The most frequent concentrations that exceeded the EAL (sixteen) and highest detected concentrations occurred at RHMW03 (maximum concentration of 860 µg/L on August 26, 2021). None of these samples exceeded the toxicity-based EAL of 2,400 µg/L.
  - RHMW05 and RHMW2254-01 were sampled weekly with a bailer from September 29 through November 17, 2021. TPH-o was detected in 11 samples from RHMW05 (maximum concentration of 490 J+ µg/L on September 29, 2021) and in four samples from RHMW2254-01 (maximum concentration of 370 µg/L on November 17, 2021) below the taste and odor EAL.
  - Groundwater samples from exterior wells RHMW04, RHMW06, RHMW10, RHMW12A, RHMW16, RHMW19, and OWDFMW01 reported TPH-o ranging from 140 J µg/L at RHMW10 to 380 µg/L at RHMW19, which were below the EALs.
  - SGC analyses were conducted on all extracts of samples in which TPH-o was detected to evaluate the nature of the organic compounds measured at the select wells. Results following SGC extraction at RHMW01R, RHMW02, and RHMW05 indicated that degradation products were the main component of the material measured in these samples in this carbon range.
  - In 41 samples from RHMW03 in which TPH-o was detected, 16 samples detected non-polar compounds in the SGC extraction, with an average total TPH-d/o concentration of approximately 406 µg/L compared to an average of approximately 98 µg/L of non-polar compounds after SGC. In four samples from RHMW2254-01 in which TPH-o was detected, two had detectable non-polar compounds in the SGC extract. These results indicated that a mixture of polar and nonpolar compounds was present in the samples in this carbon range.

9.1.2.2 GROUNDWATER BTEX RESULTS

Samples from monitoring wells RHMW01R, RHMW02, RHMW03, RHMW05, groundwater sampling point RHMW2254-01, and the Red Hill Shaft pre-chlorination port were analyzed for BTEX compounds during 34 monitoring events between May 12 and November 17, 2021.

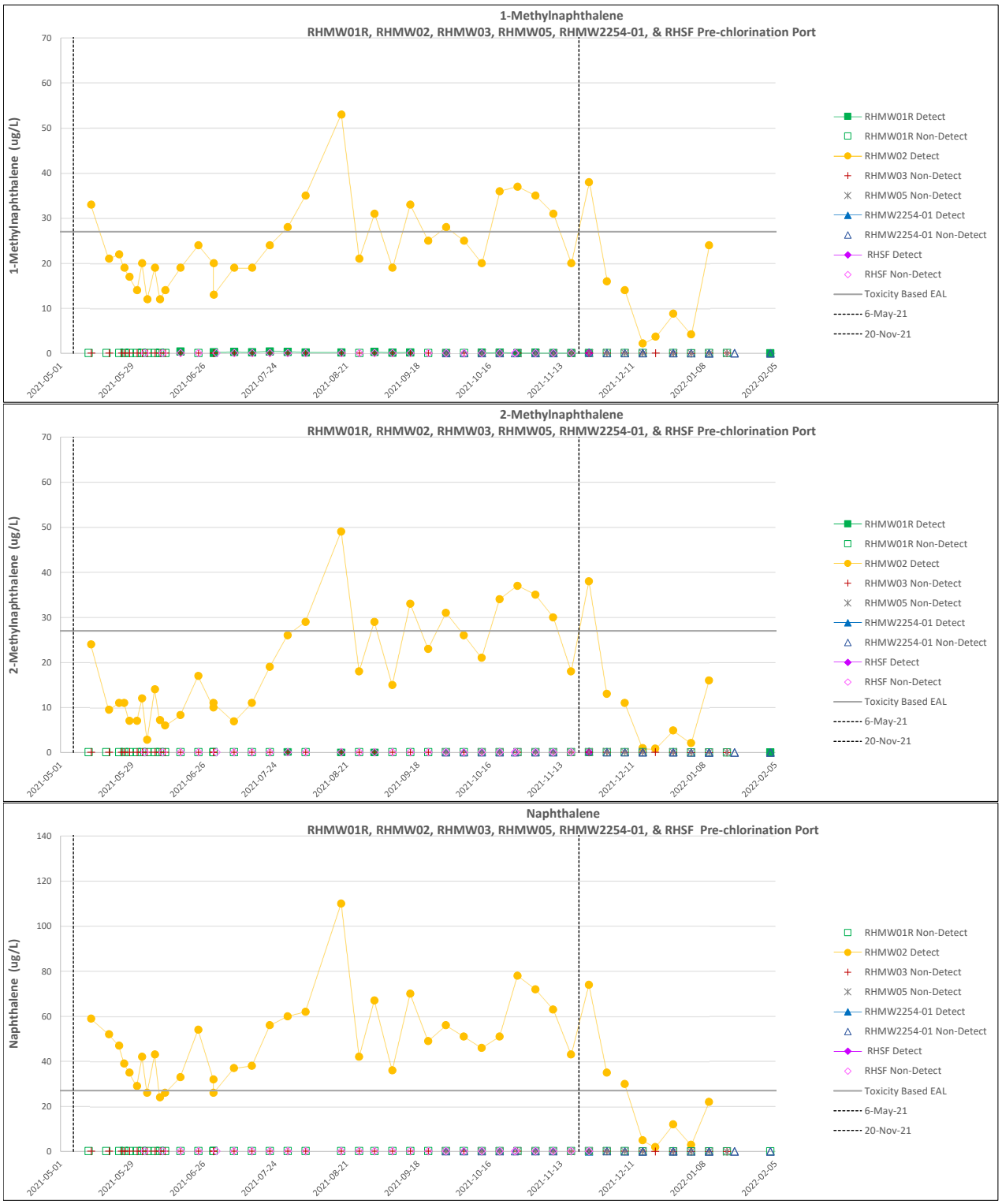
During the sampling events for which Level IV data packages have been completed, five samples from RHMW02 contained ethylbenzene and one sample contained total xylenes. Ethylbenzene detections ranged from 0.23 J µg/L to 0.3 J µg/L during the August 5, September 22, October 6, October 20, and October 27, 2021 sampling events; total xylene was detected at 0.47 J µg/L during the October 20, 2021 sampling event. These results were below the EAL of 30 µg/L for ethylbenzene and 20 µg/L for total xylenes. No other BTEX compounds were detected in any other sample.

9.1.2.3 GROUNDWATER PAH RESULTS

Figure 8 presents release response analytical results for PAHs (naphthalene, 1-methylnaphthalene, and 2-methylnaphthalene) from monitoring wells RHMW01R, RHMW02, RHMW03, RHMW05, groundwater sampling point RHMW2254-01, and the Red Hill Shaft pre-chlorination drinking water port.

Samples from 34 sampling events between May 13 and November 17, 2021 were analyzed for PAHs. The number of samples collected ranged from 35 to 39 samples, including field duplicates along with two samples collected on June 30, 2021 with a bailer and low-flow to distinguish if methods would affect results, as explained in the December 30, 2021 Quarterly Release Response Report. PAHs were detected at monitoring wells RHMW01R and RHMW02:

- **Naphthalene:**
  - Naphthalene was detected in 35 reported samples collected from RHMW02, ranging from a minimum of 24 J- µg/L on June 9, 2021 to a maximum of 110 µg/L on August 19, 2021. All detected concentrations exceeded the EAL of 17 µg/L.
- **1-Methylnaphthalene:**
  - 1-Methylnaphthalene was detected in 22 of the 39 reported samples collected from RHMW01R, ranging from a minimum of 0.085 J µg/L on September 29, 2021 to a maximum of 0.43 µg/L on June 17, 2021. No concentrations exceeded the EAL of 10 µg/L.
  - 1-Methylnaphthalene was detected in all 35 samples collected from RHMW02, ranging from a minimum of 12 J- µg/L on June 4 and 9, 2021 to a maximum of 53 µg/L on August 19, 2021. All detected concentrations exceeded the EAL of 10 µg/L.



Notes:

[1] Field duplicate sample results are omitted for visual clarity.

Figure 8: PAH Results Over Time for RHMW01R, RHMW02, RHMW03, RHMW2245-01, and Red Hill Shaft Pre-chlorination Port

- **2-Methylnaphthalene:**
  - 2-Methylnaphthalene was detected in 4 of 39 reported samples collected from RHMW01R, ranging from a minimum of 0.064 J µg/L on September 1, 2021 to a maximum of 0.17 J µg/L on July 29, 2021. No concentrations exceeded the EAL of 10 µg/L.
  - 2-Methylnaphthalene was detected in all 35 reported samples collected from RHMW02, ranging from a minimum of 2.8 µg/L on June 4, 2021 to a maximum of 49 µg/L on August 19, 2021. Of the 35 detected concentrations, 27 exceeded the EAL of 10 µg/L.

Appendix B.6 provides a monitoring well-specific summary of Level II and IV results. Final Level II and IV reports are presented in Appendix D.1.

9.1.3 Drinking Water Analytical Results

Drinking water samples were collected from the Red Hill Shaft pre-chlorination port as part of the investigation following the May 6 Release. Appendix B.1 provides a summary of the analytical program and status of laboratory results and deliverables. Appendix B.6 provides a monitoring well-specific summary of Level II and IV results. Chromatograms from October 26 to November 24, 2021 for the May 6 Release are presented in Appendix B.7. Final Level II and IV reports are presented in Appendix D.1.

As described in Section 5.2.3, APPL analyzed release response drinking water samples since June 3, 2021. Beginning September 22, 2021, Energy was contracted to provide expedited results to increase the timeliness of sample analyses and reporting, due to the detections of TPH-o in samples collected from the Red Hill Shaft pre-chlorination port. Energy was contracted to analyze daily samples for TPH-d/o, and APPL continued to analyze samples for all COPCs on a weekly basis.

9.1.3.1 Drinking Water Total Petroleum Hydrocarbon Results

Release response drinking water analytical results for TPH-g, TPH-d, and TPH-o from the Red Hill Shaft pre-chlorination port along with the EALs are presented in Appendix B.6 and summarized below. Note that TPH-o has an EAL of 500 µg/L for potential taste and odor concerns, and an EAL of 2,400 µg/L for human health risk associated with tap water use.

- **TPH-g:**
  - The EAL for TPH-g is 300 µg/L, and the LOD was 18 µg/L during this period.
  - TPH-g was not detected in samples from the Red Hill Shaft pre-chlorination port during this period.

- **TPH-d:**
  - The EAL for TPH-d is 400 µg/L, and the LOD was 300 µg/L for APPL and 140–150 µg/L for Energy during this period.
  - Red Hill Shaft was sampled daily from September 22 through October 5, 2021 or weekly at the Red Hill Shaft pre-chlorination port from June 3 through September 22, 2021 and from October 6 through November 24, 2021; three samples were collected from the post-chlorination point on September 23, November 10, and November 17, 2021. TPH-d was detected in 4 of the 66 samples, ranging from 40 J µg/L from the pre-chlorination point on November 17, 2021 to 260 J µg/L from the post-chlorination point on November 17, 2021.
- **TPH-o:**
  - The TPH-o EAL for taste and odor is 500 µg/L, and the residential tap water toxicity-based TPH-o EAL is 2,400 µg/L. The LOD was 300 µg/L for APPL and 140–150 µg/L for Energy during this period.
  - Between June 3 and November 24, 2021, TPH-o was detected in 21 of 66 samples analyzed, with reported concentrations ranging from 100 J µg/L on October 5, 2021 to a maximum concentration of 540 µg/L on August 5, 2021, which exceeded the taste and odor EAL but were considerably below the residential tap water toxicity-based EAL.
  - On July 22, September 15, 22, and 29, and November 10, 2021, TPH-o was detected by APPL along with elevated blank contamination in associated method blanks. These samples are undergoing data validation to determine the validity of the reported results.

9.1.3.2 Drinking Water BTEX Results

Samples from 38 sampling events between June 3 and November 24, 2021 were analyzed for BTEX compounds. BTEX compounds were not detected in any of the samples analyzed from the Red Hill Shaft pre-chlorination or post-chlorination port.

9.1.3.3 Drinking Water PAH Results

Samples from 38 sampling events between June 3 and November 24, 2021 were analyzed for the selected PAHs. PAH compounds were not detected in any of the samples analyzed from the Red Hill Shaft pre-chlorination or post-chlorination port.

9.2 November 20 Release

Information on field measurements and analytical results for the various samples described in Section 5.0 are provided in the following sections.

9.2.1 Emergency Groundwater and Product Sampling Analytical Results

Emergency groundwater and product sampling was conducted for forensic analysis at the Adit 3 Sump, RHMW2254-01, and the fire suppression drain line. DOH requested testing of the water/fuel mixture in the fire suppression collection tank; however, none of the fuel/water mixture reached the collection tank. Instead, the fuel/water mixture remaining in the fire suppression drain line was sampled on January 6, 2022 and submitted to ALPHA Analytical laboratory. Results of the forensics analysis are described below.

Forensics and Data Evaluation. A forensics investigation and data evaluation were conducted to assess the distribution of LNAPL that was released from an overhead 14-inch PVC pipe located by the Adit 3 Water Pumping Station. These data were evaluated and presented in a Technical Memorandum, which is included as Appendix B.5.

Data collected from the Adit 3 Sump, Red Hill Shaft Water Gallery, and the fire suppression system suggest that:

- The magnitudes of the C9–C44 carbon range concentrations in the water samples from the Adit 3 Sump (sample identification (ID) number ERH1968) and Red Hill Shaft Water Gallery (sample ID number ERH2051) were consistent with the presence of LNAPL or free product.
- The composition of the product samples from the Adit 3 Sump and the fire suppression system, along with the groundwater samples from the Adit 3 Sump and the Red Hill Shaft Water Gallery, were consistent with the hydrocarbon signature of JP-5.

Further information is detailed in the Appendix B.5 Technical Memorandum.

Following the November 20 Release, Simple Green All Purpose Cleaner was the cleaning solution initially reported to have been used during the cleanup of the Adit 3 tunnel floor. A representative sample Simple Green All Purpose Cleaner was analyzed for TPH. Detects were present within the TPH range, although the chromatographic profile did not resemble fuel. Since Simple Green is water-soluble and biodegradable, metabolites would be produced that are measured and reported as TPH. It was later determined that Extreme Simple Green Aircraft & Precision Cleaner was used for cleanup.

In addition, samples collected from the Adit 3 Sump and RHMW2254-01 on December 21, 2021 were analyzed for 2-2-MEE, a de-icing additive to JP-5. Analytical results indicated 2-2-MEE was not detected at RHMW2254-01 or in the product sample from Adit 3 Sump. However, the non-detect result in the sample collected from Adit 3 Sump may have been due to a higher reporting limit since the product sample was diluted. The 2-2-MEE reported concentration in the biphasic water sample collected from Adit 3 Sump was 32,000 µg/L, which was consistent as 2-2-MEE is readily soluble in water.

9.2.2 Emergency Subslab Soil Vapor Monitoring Results

Figure 5 provides the results of soil vapor monitoring from subslab SVMPs installed into the floors of the Adit 3 and Pearl Harbor tunnels. The origin for the Adit 3 tunnel (A3) is at the eastern edge of the Water Pumping Station doorway; coordinates are in feet and are positive (+) to the west and negative (-) to the east. The origin for the Pearl Harbor Tunnel (2S) is at the Adit 3 merge centerline, and coordinates are positive (+) to the south.

The results indicate that:

- Elevated organic vapor concentrations were observed in the subslab throughout much of the Adit 3 tunnel (SVMP array A3) from the release area west towards the Adit 3 portal.
- Organic vapor concentrations declined over a short distance to the east-southeast of the release area as observed at SVMPs A3-400, A3-425, and A3-450.
- Local soil vapor maxima were located in segments of the Adit 3 (A3) and Pearl Harbor tunnels (S2) that overlie the water development tunnel, including:
  - In the Adit 3 tunnel vicinity of the release area between A3-325 to A3-375
  - In the upper Pearl Harbor tunnel, just southwest of the merge, between S2+25 and S2+100
- Other local maxima occurred in the Adit 3 tunnel:
  - Between the Pearl Harbor tunnel merge and the Water Pumping Station, between A3-100 and A3-150
  - In the vicinity of the Adit 3 Sump where fuel accumulated during the release, between A3+250 and A3+375

9.2.3 Free Product Gauging and Groundwater Monitoring Well Headspace Measurements

Free product was detected in the groundwater monitoring wells or groundwater sampling point RHMW2254-01, as described in Section 7.2.3. Free product gauging and groundwater monitoring well headspace measurements collected through February 3, 2022 are presented in Appendix B.3.

9.2.4 Groundwater and Product Analytical Results

As part of the release response for the November 20 Release from the fire suppression drain line, DOH provided the NOI GW Sampling Plan on December 9, 2021 (DOH 2021d), directing the Navy to collect weekly groundwater samples from the following locations in addition to the monitoring wells sampled for the May 6 Release: RHMW08, RHMW06, RHMW09, RHMW12 (shallow well later removed), RHMW12A, RHMW17 (when complete), RHMW16, OWDFMW01, RHMW11-05, RHMW13-05, RHMW14-03, RHMW15-05, and Adit 3 Sump.

Groundwater results were screened against the DOH Tier 1 EALs, Table D-1b (i.e., groundwater EALs for sites where groundwater is a current or potential drinking water resource and the nearest surface water body is not located with 150 meters of release site) (DOH 2017). As applicable, the results were also compared to the SSRBLs for benzene and TPH-d. Implementation of the SSRBLs is described in the Red Hill GWPP (DON 2014b). The SSRBLs were incorporated into the February 4, 2016 AOC Statement of Work Sections 6 and 7 scoping completion letter (EPA Region 9 and DOH 2016). Analytical results for the groundwater samples are summarized below. Appendix B.6 provides a monitoring well-specific summary of Level II and IV results. Chromatograms from samples collected from November 24, 2021 through February 4, 2022 are presented in Appendix B.7. Chromatograms are included for each sample with additional field observation information such as ambient/headspace PID readings, color, and odor. Final Level II and IV reports are presented in Appendix D.1.

9.2.4.1 Total Petroleum Hydrocarbon Results

Appendix B.6 presents release response analytical results for the November 20 Release monitoring wells compared to EALs. TPH-o has a lower EAL of 500 µg/L for potential taste and odor concerns and a higher EAL of 2,400 µg/L for human health risk associated with tap water use. Gaps in the continuous lines between data point markers represent periods when the COPC was not detected.

- **TPH-g:** Results are available from November 24, 2021 until February 4, 2022:
  - TPH-g results were detected above the detection limit in samples from RHMW01R, RHMW02, RHMW03, RHMW05, RHMW06, RHMW11-05, RHMW2254-01, and the Adit 3 Sump. No samples exceeded the EAL for TPH-g. The maximum detected concentration was 159 µg/L. TPH-g was not detected at all other wells.
- **TPH-d:** Results are available from November 24, 2021 through February 4, 2022:
  - For in-tunnel sample locations RHMW01R, RHMW02, and RHMW2254-01, TPH-d was detected at concentrations above the EAL.
  - Three of 15 TPH-d concentrations detected at RHMW01R (maximum concentration was 570 µg/L on December 1, 2021)
  - In 15 samples from RHMW01R in which TPH-d was detected, 10 had low-level detectable amounts of non-polar compounds in the SGC extraction, indicating that degradation products were the main component of the material measured in these samples in this carbon range.
  - All 10 detected concentrations at RHMW02 (maximum concentration was 4,200 µg/L on January 3, 2022)
  - In 10 samples from RHMW02 in which TPH-d was detected, 10 samples contained detectable non-polar compounds in the SGC extraction. The average combined (polar and non-polar) concentration was approximately 2,780 µg/L compared to

approximately 424 µg/L of non-polar compounds after SGC, indicating that approximately 81% of the compounds were degradation products.

- 21 of 24 results detected at RHMW2254-01 (maximum concentration was 142,000 µg/L on December 8, 2021)
- The next highest result at RHMW2254-01 was 2,400 µg/L in a sample collected with a bailer on December 21, 2021
- In 21 samples from RHMW2254-01 in which TPH-d was detected, 17 samples contained detectable non-polar compounds in the SGC extraction. The average combined (polar and non-polar) concentration was approximately 7,019 µg/L compared to approximately 6,604 µg/L of non-polar compounds after SGC, indicating that only approximately 7% of the compounds were degradation products.
- A reduction in TPH-d and TPH-o concentrations were observed since the December 8, 2021 collection date (142,000 µg/L) to February 3, 2022 (non-detect for low-flow sampling for TPH-d and TPH-o; 130 J µg/L and 280 J µg/L, respectively, with bailer method) following skimming operations in the Shaft. Since samples are collected from approximately mid-screen after purging with the low-flow method while bailer sampling does not include purging and collects samples from the surface, there is a discrepancy with sample results between both methods. Additional information regarding bailer vs. low-flow methods can be referenced in Section 8.3.3 of the December 30, 2021 Quarterly Release Response Report (DON 2021f).
- For in-tunnel wells RHMW03 and RHMW05 (maximum TPH-d concentration was 360 µg/L, which was below the EAL). For samples in which TPH-d was detected, polar compounds were detected in the SGC extraction.
- For exterior wells RHMW04, RHMW11-05, RHMW13-05, RHMW15-05, RHMW16, RHMW19, OWDFMW01, OWDFMW04A, OWDFMW05A, and OWDFMW08A, no detected TPH-d results exceeded the EAL. The maximum detected concentration was 360 µg/L in RHMW11-05 on January 6, 2022. In all samples in which TPH-d was detected, no non-polar compounds were detected in the SGC extraction, indicating that only degradation products were measured at these locations.
- For exterior wells RHMW06, RHMW08, RHMW09, and RHW14-03, detected results exceeded the EAL. The maximum concentration was 1,300 µg/L at RHMW08 on December 1, 2021. In three samples from RHMW06 in which TPH-d was detected, one sample had detectable non-polar compounds in the SGC extraction, indicating that the majority was degradation products measured at this location. At RHMW08, RHMW09, and RHMW14-03, no non-polar compounds were detected in the SGC extraction, indicating that only degradation products were measured at these locations.
- Adit 3 Sump included detected results from all six samples collected by bailer ranging from 320 µg/L on February 3, 2022 to 171,000 µg/L on January 3, 2022. Five results

exceeded the EALs. In six samples from RHMW2254-01 in which TPH-d was detected, five samples contained detectable non-polar compounds in the SGC extraction; however, one sample is pending an SGC result. The average combined (polar and non-polar) concentration was approximately 1,924 µg/L compared to approximately 1,420 µg/L of non-polar compounds after SGC, indicating that approximately 26% of the compounds were degradation products.

  - Wells where TPH-d was not detected included RHMW12A and OWDFMW07A.

- **TPH-o:** Results are available from November 24, 2021 through February 4, 2022:
  - In-tunnel wells RHMW01R, RHMW02, and RHMW03 had detected concentrations of TPH-o in all samples collected by bailer. Detected concentrations ranged from 120 J µg/L at RHMW01R on January 10, 2022 to 1,300 µg/L at RHMW02 on December 1, 2021, which exceeded the taste and odor EAL. For samples in which TPH-o was detected, only one sample from each well detected non-polar compounds in the SGC extraction, indicating that mostly degradation products were measured at these locations.
  - At in-tunnel well RHMW05, TPH-o was detected in 9 of 11 samples collected by bailer. The highest concentration collected on December 1 and 8, 2021 was 450 µg/L for both dates, which were below the EAL. In samples from RHMW05 in which TPH-o was detected, no non-polar compounds were detected in the SGC extraction, indicating that only degradation products were measured at this location.
  - At in-tunnel groundwater sampling point RHMW2254-01, TPH-o was detected in 20 of 24 samples collected by bailer and low-flow pumping. Concentrations ranged from 100 J µg/L on December 15, 2021 to 580 µg/L on January 3, 2022. Four results exceeded the taste and odor EAL. In 20 samples from RHMW2254 01 in which TPH-o was detected, 12 contained detectable non-polar compounds in the SGC extraction. The average combined (polar and non-polar) concentration was approximately 284 µg/L compared to approximately 95 µg/L of non-polar compounds after SGC, indicating that approximately 62% of the compounds were degradation products.
  - At exterior wells RHMW04, RHMW11-05, RHMW12A, RHMW15-05, RHMW16, RHMW19, OWDFMW01, OWDFMW04A, OWDFMW05A, and OWDFMW08A, no detected TPH-o concentrations exceeded the EAL. The maximum detected concentration was 480 µg/L in RHMW11-05 on January 6, 2022. In samples from all wells except RHMW19, no non-polar compounds were detected in the SGC extraction, indicating that only degradation products were measured at these locations. One sample at RHMW19 had detectable non-polar compounds in the SGC extraction, indicating that the majority was degradation products measured at this location.
  - At exterior wells RHMW06, RHMW08, RHMW09, RHMW14-03, the maximum detected TPH-o concentration was 1,200 µg/L in RHMW08 on December 1, 2021, which exceeded the taste and odor EAL. In four samples from RHMW06 in which

TPH-o was detected, one had detectable non-polar compounds in the SGC extraction, indicating that the majority was degradation products measured at this location. For the other wells, no non-polar compounds were detected in the SGC extraction, indicating that only degradation products were measured at these locations.

- At Adit 3 Sump, TPH-o was detected in all six samples collected by bailer at concentrations ranging from 120 J µg/L on February 3, 2022 to 640 µg/L on January 3, 2022, which exceeded the taste and odor EAL. Three samples contained detectable non-polar compounds in the SGC extraction; one sample is pending the SGC result. This indicates that a mixture of polar and nonpolar compounds was present in these samples in this carbon range.
- Wells at which TPH-o was not detected included RHMW13-05 and OWDFMW07A.

9.2.4.2 BTEX AND VOC RESULTS

Samples from the November 20 Release monitoring wells were analyzed for BTEX, lead scavengers, and the laboratory's full suite VOCs from December 13, 2021 through February 4, 2022.

During the sampling events for which Level II and Level IV data packages have been completed, the following compounds were detected:

- **BTEX:** Results are available from November 24, 2021 through February 4, 2022.
  - November 20 Release monitoring wells with BTEX detects included the following:
    - Adit 3 Sump: benzene and toluene were detected at 0.19 J and 1.3 µg/L. Ethylbenzene detections ranged from 0.11 J µg/L to 2.3 µg/L. Total xylenes detections ranged from 0.16 J µg/L to 27 µg/L, which exceeded the EAL.
    - RHMW2254-01: ethylbenzene was detected in two samples, 0.06 J and 0.63 J µg/L, respectively. Total xylenes were detected in four samples with concentrations ranging from 0.067 J µg/L to 7.2 µg/L. Toluene was detected on December 8, 2021; however, this detection may have included contributions from an outside source since trip blanks also contained ethylbenzene and toluene. Detected results did not exceed the EAL.
    - RHMW02: ethylbenzene detections ranged from 0.11 J µg/L to 0.21 J µg/L. Total xylenes concentrations ranged from 0.12 J µg/L to 0.16 J µg/L. Both compounds were previously detected and is consistent with the May 6 Release response sampling efforts. Detected results did not exceed the EALs.
    - RHMW12A: toluene was detected at 0.22 J µg/L; however, this detection may have included contributions from an outside source since trip blanks also contained toluene. Detected results did not exceed the EAL.

- **Lead Scavengers:** Results are available from December 13, 2021 through February 4, 2022.
  - All results for EDB were not detected above the detection limit.
  - DCA detections did not exceed EALs, and included the following wells:
    - RHMW04: 0.75 J µg/L, detected on January 4, 2022.
    - RHMW05: detections ranged from 0.17 J µg/L on December 27, 2021 to 0.22 J µg/L on January 10, 2022.
    - RHMW08: detections ranged from 0.22 J µg/L on January 4 and 18, 2022 to 0.24 J µg/L on December 28, 2021.
    - RHMW09: 0.23 J µg/L detected on December 24, 2021.
- **VOCs**: Results are available from December 13, 2021 through February 4, 2022.
  - The EALs and LODs for the VOCs are presented in the summary table in Appendix B.6.2. The LODs are below the EALs for compounds where EALs have been established.
  - No detected results for VOCs exceeded EALs. VOC detections for November 20 Release monitoring wells included the following:
    - Adit 3 Sump: bromodichloromethane and dibromomethane was detected at 0.12 J and 0.2 J µg/L, respectively, on January 20, 2022. Methyl ethyl ketone was detected at 4.2 J µg/L on January 20, 2022. Bromoform detections ranged from 0.34 J µg/L to 1.5 µg/L. Chlorodibromomethane detections ranged from 0.16 J µg/L to 0.28 J µg/L. Chloroform detections ranged from 0.21 J µg/L to 1.2 µg/L.
  - RHMW2254-01: chloroform was detected at 0.096 J on February 3, 2022. Bromoform detections ranged from 0.15 J µg/L to 0.66 J µg/L. Chorodibromomethane detections ranged from 0.09 J µg/L to 0.23 J µg/L.
  - RHMW11-05: styrene detections ranged from 0.12 J µg/L to 0.36 J µg/L.
  - OWDFMW01: chloroform detections ranged from 0.15 J µg/L to 0.18 J µg/L.
  - OWDFMW04A: chloroform detections ranged from 1.6 µg/L to 2.1 µg/L.
  - OWDFMW08A: chloroform detections ranged from 0.085 J µg/L to 0.19 µg/L.
  - BTEX and VOCs were not detected in samples from RHMW01R, RHMW03, RHMW06, RHMW14-03, RHMW15-05, RHMW16, RHMW19, OWDFMW05A, and OWDFMW07A.

9.2.4.3 SVOC Results

Samples collected from monitoring wells for the November 20 Release were analyzed for PAHs and the laboratory's full suite of SVOCs from November 24, 2021 through February 4, 2022. The EALs and LODs for the detected SVOCs are presented in the summary table in Appendix B.6.3.

Figure **8** presents analytical results for PAHs (naphthalene, 1-methylnaphthalene, and 2-methylnaphthalene) compared to EALs.

During the sampling events for which Level II and Level IV data packages have been completed, the following SVOCs were detected:

- **Naphthalene:** Results are available from November 24, 2021 through February 4, 2022.
  - The EAL for naphthalene was 17 µg/L. Energy's LOD was 0.048–0.11 µg/L during this reporting period. Detections included the following:
  - RHMW02: detected in all eight samples at concentrations ranging from 2.3 µg/L on December 20, 2021 to 74 µg/L on November 24, 2021. Four detected concentrations exceeded the EAL. Detections were consistent with historical results for this well.
  - At RHMW08, RHMW2254-01, and OWDFMW08A, no detected naphthalene results exceeded the EAL. The maximum detected concentration was 0.12 J µg/L in RHMW2254-01 on November 24, 2021.
- **1-Methylnaphthalene:** Results are available from November 24, 2021 through February 4, 2022.
  - The EAL for 1-methylnaphthalene is 10 µg/L. Energy's LOD was 0.048–0.11 µg/L during this reporting period. Detections included the following:
  - At sampling locations RHMW01R, RHMW08, RHMW2254-01, and OWDFMW08A, no detected results exceeded the EAL. The maximum detected concentration for 1-methylnaphthalene was 0.17 J µg/L in RHMW2254-01 on November 24, 2021.
  - RHMW02: detected in all eight reported samples, ranging from a minimum of 2.2 J µg/L on December 15, 2021 to a maximum of 38 µg/L on November 24, 2021. Four detected concentrations exceeded the EAL. Detections were consistent with historical results for this well.
- **2-Methylnaphthalene:** Results are available from November 24, 2021 through February 4, 2022.
  - The EAL for 2-methylnaphthalene is 10 µg/L. Energy's LOD was 0.048–0.11 µg/L during this reporting period. Detections included the following:
  - At sampling locations RHMW01R, RHMW08, RHMW2254-01, and OWDFMW08A, no detected 2-methylnaphthalene concentrations exceeded the EAL. The maximum concentration was 0.19 J µg/L in RHMW2254-01 on November 24, 2021.
  - RHMW02: detected in all eight reported samples, ranging from a minimum of 0.86 J µg/L on December 20, 2021 to a maximum of 38 µg/L on November 24, 2021. Four detected concentrations exceeded the EAL. Detections were consistent with historical results for this well.

- Naphthalene, 1-methylnaphthalene, and 2-methylnaphthalene were not detected above the detection limit at RHMW03, RHMW04, RHMW05, RHMW06, RHMW09, RHMW12A, RHMW11-05, RHMW13-05, RHMW14-03, RHMW15-05, RHMW16, RHMW19, OWDFMW01, OWDFMW04A, OWDFMW05A, OWDFMW07A, and Adit 3 Sump.
- **SVOCs:** Results are available from November 24, 2021 through February 4, 2022.
  - The EALs and LODs for the SVOCs are presented in the summary table in Appendix B.6.2. The LODs are below the EALs for compounds where EALs have been established. SVOC detections included the following:
  - At wells RHMW01R, RHMW08, RHMW09, RHMW13-05, and RHMW19, at least one detected concentration of bis(2-ethylhexyl)phthalate was detected above the EAL. The maximum detected concentration was 16 µg/L in RHMW13-05 on December 22, 2021.
  - Detected concentrations of bis(2-ethylhexyl)phthalate at RHMW11-05 and RHMW16 did not exceed the EAL. The maximum concentration was 2.2 J µg/L in RHMW16 on December 22, 2021.
  - RHMW2254-01: bis(2-ethylhexyl)phthalate was detected in one of 13 samples, at 2.6 J µg/L on January 3, 2022; results did not exceed the EAL. Di-n-butyl phthalate was detected at 2.9 J, and 3.1 J µg/L, respectively on January 20, 2022; concentrations did not exceed the EAL.
  - Adit 3 Sump: bis(2-ethylhexyl)phthalate was detected in one of four reported samples, at 3.3 J µg/L on December 27, 2021, which exceeded the EAL.
  - SVOCs were not detected above the detection limits at RHMW02, RHMW03, RHMW04, RHMW05, RHMW06, RHMW12A, RHMW11-05, RHMW13-05, RHMW14-03, RHMW15-05, OWDFMW01, OWDFMW04A, OWDFMW05A, OWDFMW07A, and OWDFMW08A.
  - Bis(2-ethylhexyl)phthalate is a common laboratory contaminant and is used as a plasticizer in many plastic materials, including tubing commonly used by laboratories. Bis(2-ethylhexyl)phthalate is also found in laboratory extraction equipment and glassware surfaces, causing false positive results. Other sources of contamination are degradation of the well casing, microbial action (iron bacteria) on sample tubing, and abrasion on well casing, bailer, and rope associated with bailing procedures. It is recommended to further investigate the source of bis(2-ethylhexyl)phthalate contamination by collecting equipment and field blanks.
- **SIM PAHs:** Results are available from November 24, 2021 through February 4, 2022.
  - EALs for PAHs are several magnitudes lower than what the 8270 method can detect. PAH EALs range from 0.02 µg/L to 15 µg/L, while SVOC via Method 8270 is not sensitive enough to detect lower than the PAH EALs (lowest detection limit is 1.1 µg/L), which the SIM can provide (lowest detection limit is 0.018 µg/L).

  - SVOC detections that exceeded the EAL for at least one compound included the following wells:
  - RHMW01R: anthracene exceeded the EAL at 0.032 J µg/L on February 3, 2022.
  - RHMW02: benzo(a)anthracene and benzo(a)pyrene exceeded the EALs at 0.045 J and 0.16 µg/L respectively, on January 10, 2022.
  - RHMW12A: benzo(a)anthracene and dibenzo(a,h)anthracene exceeded the EALs at 0.032 J and 0.081 J µg/L, respectively on January 5, 2022.
  - OWDFMW08A: benzo(a)anthracene exceeded the EAL at 0.035 J µg/L on February 2, 2022.
  - Adit 3 Sump: SVOC compounds that exceeded the EALs include benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, and indeno(1,2,3-cd)pyrene.
- SIM PAHs were not detected above the detection limits at RHMW04, RHMW05, RHMW06, RHMW08, RHMW11-05, RHMW14-03, RHMW15-05, RHMW16, RHMW19, RHMW2254-01, OWDFMW04A, and OWDFMW05A.

The majority of the PAH detections were sporadic and consistently near the detection limits; therefore, baseline noise was likely a contributing factor to the PAH detections in various wells. However, PAH detections at RHMW12A and Adit 3 Sump were also due to contributing external sources other than JP-5 since RHMW2254-01 is known to have JP-5 product, yet PAHs have never been detected there.

Contributing external sources to PAH contamination could potentially include additional activities that have occurred at RHMW12A and Adit 3 Sump. After the completion of RHMW12A, the PVC casing became compromised and bentonite/grout fell into the well, which may have contributed to PAH detections. Additionally, Adit 3 Sump is affected by multiple sources of PAHs such as wash water used within the tunnel that may have been in contact with the sump, along with vehicular and equipment exhaust deposition that may have impacted the sump.

9.2.5 Drinking Water Analytical Results

Following the November 20 Release, drinking water sampling associated with Navy Well 2254-01 (Red Hill Shaft) was discontinued after the pumps were shut down on November 28, 2021.

9.2.6 Holding Tank and Leach Tank Sampling Analytical Results

Analytical results of soil and groundwater for the Holding Tank and Leach Tank investigation are presented in Appendix E [forthcoming] and summarized below.

9.2.6.1 TPH-g (Carbon Range C6–C12) Soil Sample Results

TPH-g analysis included the carbon range of C6–C12, which overlaps significantly with the TPH-d carbon range of C10–C24. Of the 35 subsurface soil samples analyzed for TPH-g, the following exceedances were noted:

- The leaching to groundwater EAL of 696 mg/kg in 6 samples
- The direct exposure EAL of 451 mg/kg in 8 samples
- The gross contamination (odor) EAL of 100 mg/kg in 13 samples

9.2.6.2 Volatile Organic Compound BTEX Soil Sample Results

None of the 35 subsurface soil samples exceeded any DOH EALs for BTEX. In two samples, benzene was not detected but the limit of detection exceeded the DOH EAL for leaching to groundwater due to the requirement for sample dilution prior to analysis.

9.2.6.3 TPH-d (Carbon Range C10–C24) and TPH-o (Carbon Range C24–C40) Soil Sample Results

TPH-d analysis included the carbon range of C10–C24, which overlaps significantly with the TPH-g carbon range of C6–C12. Of the 35 subsurface soil samples analyzed for TPH-d, the following exceedances were reported:

- The leaching to groundwater EAL of 940 mg/kg in 7 samples
- The direct exposure EAL of 219 mg/kg in 13 samples
- The gross contamination (odor) EAL of 500 mg/kg in 9 samples

In addition, the sediment sample from the Leach Tank ("LT-Sediment") exceeded all action levels for TPH-d and had the maximum TPH-d concentration measured on site of 13,000 mg/kg.

None of the soil samples collected exceeded the DOH EALs for TPH-o during this investigation.

9.2.6.4 Naphthalene, 1-Methylnaphthalene, and 2-Methylnaphthalene Soil Sample Results

The naphthalenes have the lowest Soil Action Levels for leaching to groundwater that is a drinking water source, ranging from 0.9 mg/kg for 1-methynaphthalene to 3.1 mg/kg for naphthalene:

- Naphthalene exceeded the leaching to groundwater EAL of 3.1 mg/kg in 3 subsurface soil samples.
- 1-Methylnaphthalene exceeded the leaching to groundwater EAL of 0.89 mg/kg in 10 subsurface soil samples.

- 2-Methylnaphthalene exceeded the leaching to groundwater EAL of 1.9 mg//kg in 6 subsurface soil samples.

In addition, the Leach Tank sediment sample (LT-Sediment) exceeded all three naphthalene-related Soil Action Levels, with the highest concentrations of naphthalene at 7.2 mg/kg, 1-methylnaphthalene at 52 mg/kg, and 2-methylnaphthalene at 74 mg/kg.

9.2.6.5 GROUNDWATER ANALYTICAL RESULTS

One groundwater sample was collected for laboratory analysis from OWDFMW06B on January 26, 2022. Fuel-related constituents (including TPH-g, TPH-d, naphthalene, 1-methylnaphthalene, and 2-methylnaphthalene) were detected, which indicates that petroleum-related impacts may be present in the perched aquifer, but there were no exceedances of applicable EALs.

10.0 Summary of Results and Extent and Magnitude of Contamination

This section summarizes the results presented in Section 9.0 and provides historical context for evaluating the impacts of the May 6 and November 20 Releases.

10.1 May 6 Release

10.1.1 Extent and Magnitude of Soil Vapor Impacts

Following the May 6 Release that occurred in the lower access tunnel adjacent to Tanks 17, 18, 19, and 20, a series of measurements of total VOCs and individual VOC compounds were collected from SVMPs below Tanks 13, 14, 15, 16, 17, 18, and 20 using hand-held PIDs for field measurements and Summa canisters for fixed-base laboratory analysis. As noted in Section 3.1, SVMPs under the tanks closest to the May 6 Release (Tanks 17, 18, and 20) exhibited elevated detections; however, these SVMPs were compromised with petroleum-laden water during the cleaning of the tunnel following the pipeline breach. The petroleum-laden cleaning water may be the source of VOCs observed in vapor samples from these SVMPs.

10.1.1.1 FIELD MEASUREMENTS

Field measurements showed significantly higher total VOCs from SVMPs under Tanks 17, 18, and 20 compared to the other SVMPs analyzed, with a maximum result of 232,667 ppbv at SV20M measured on May 13, 2021. In comparison, the maximum total VOC result from the remaining tanks was 3,109 ppbv at SV13M below Tank 13 on July 19, 2021.

PID results at all the SVMPs under Tanks 17, 18, and 20 have declined since May 2021. No PID reading above 10,000 ppbv was recorded in January 2022.

10.1.1.2 FIXED-BASE LABORATORY SAMPLE RESULTS

Since May 2021, Summa canister samples have been collected monthly and analyzed for total VOCs by Method TO-3 and for individual VOC compounds by Method TO-15.

- **Total VOCs by Method TO-3:**
  - Total VOC concentrations by Method TO-3 are positively correlated with field PID readings (i.e., samples with higher field PID readings generally have higher total VOC concentrations; see Figure 7).
  - However, TO-3 concentrations reported by the laboratory were often lower than the corresponding field PID readings. For 22 samples with a PID reading between 100 ppbv and 50,000 ppbv, the median TO-3 concentration was 9% of the PID reading. For seven samples with PID readings above 50,000 ppbv, the median TO-3 concentration was 62% of the PID reading.
  - Similar to the field PID readings, the TO-3 concentrations support the conclusion that impacts from the May 6 Release were limited to Tanks 17 to 20, and that total VOC concentrations below these tanks are decreasing over time.
- **Individual VOC Compounds by Method TO-15:**
  - At SVMPs below Tanks 17, 18, and 20, ethylbenzene, total xylenes, 4-ethyltoluene, 1,2,4-trimethylbenzene, and 1,3,5-trimethylbenzene were detected at concentrations greater than or equal to 1,000 $\mu g/m^3$ in one or more samples. These higher individual hydrocarbon concentrations were limited to the three SVMPs that have exhibited the highest PID results (SV17S, SV18S, and SV20M). No other individual hydrocarbons were detected at concentrations above 200 $\mu g/m^3$ in any of the 40 soil vapor samples.
  - Individual hydrocarbon concentrations have decreased over time, with no detections above 20 $\mu g/m^3$ during the December 2021 or January 2022 sampling.
- **TO-3 Chromatograms:**
  - The TO-3 FID chromatograms provide additional qualitative evidence of weathering and attenuation of the fuel since the May 6 Release. The chromatograms from May and early June 2021 are consistent with fresh JP-5, while the chromatograms from late June, and monthly sampling from July 2021 through January 2022 show progressive weathering characterized by loss of volatile constituents eluting before nC8 followed by reduction of the n-alkane chromatogram peaks (see Appendix A.4 for the SV17S chromatograms).

For all soil vapor samples, concentrations of carbon dioxide (1.5% or less), oxygen (20% or higher) and methane (ND, <0.2%) were similar to those measured in 2017, indicating that conditions remain favorable for ongoing aerobic biodegradation of past hydrocarbon releases.

10.1.2 Extent and Magnitude of Groundwater Impacts

Groundwater sample analytical results are provided in Appendix B.6 to evaluate potential changes in groundwater quality following the May 6 Release. Historical results from long-term monitoring groundwater samples collected quarterly between October 2018 and April 2021 were compared to release response groundwater samples collected at the same locations between May 12 and November 20, 2021.

- **RHMW03:**
  - The average concentrations of TPH-o in the historical and release response samples were 237 µg/L and 444 µg/L, respectively, with release response samples consisting of non-polar petroleum hydrocarbons and polar degradation products.
  - The average concentrations of TPH-d in the historical and release response samples were similar (243 µg/L and 251 µg/L, respectively).
- **RHMW02:**
  - The average concentration of TPH-o in the historical and release response samples were 221 µg/L and 343 µg/L, respectively, with release response samples consisting mainly of polar degradation products. The maximum concentration of 560 µg/L slightly exceeded the TPH-o taste and odor EAL of 500 µg/L. but did not exceed the toxicity-based EAL of 2,400 µg/L.
  - The average concentration of TPH-d in the historical and release response samples were similar (1,914 µg/L and 2,211 µg/L, respectively), with release response samples well within the historical range and continuing to be composed mainly of polar degradation products. The TPH-d EAL of 400 µg/L has historically been exceeded in this well.
- **RHMW01R (Release Response Data) and RHMW01 (Historical Data):**
  - TPH-o was not detected in historical samples but was detected in release response samples with an average of 216 µg/L; however, SGC analyses suggest that 88% of the TPH-o detected were degradation products. No TPH-o EALs were exceeded.
  - The average concentration of TPH-d in the historical and release response samples were 191 µg/L and 271 µg/L, respectively. SGC analyses indicate that approximately two thirds of the TPH-d were degradation products. The maximum release response concentration of 670 µg/L exceeded the TPH-d EAL of 400 µg/L.
  - Neither 1-methylnaphthalene nor 2-methylnaphthalene was detected in historical samples, compared to average concentrations in the detected release response samples of 0.23 µg/L and 0.11 µg/L, respectively. No results exceeded the EAL of 10 µg/L for these compounds.

- **RHMW05:**
  - Generally, low levels of TPH-o and TPH-d (below the LODs) were detected in both historical and release response samples (between 50 J µg/L and 150 J µg/L), although no non-polar compounds were detected in the SGC analyses.

Chromatograms for RHMW05, RHMW03, RHMW02, and RHMW01R are presented in Appendix B.7. Additional details of historical detections are available in the Red Hill Final Second Quarter 2021 - Quarterly Groundwater Monitoring Report (DON 2021c).

10.1.3 Extent and Magnitude of Drinking Water Impacts

Release response drinking water sample results are provided in Appendix B.6. The release response to the tunnel pipeline breach includes systematic sampling of the Red Hill Shaft pre-chlorination port, described in detail in Sections 3.1 and 9.1.3. Weekly sampling of the Red Hill Shaft pre-chlorination port for TPH-g/d/o, BTEX, and select PAHs was conducted between June 3 and November 20, 2021. Following the laboratory's reporting of organic compounds detected in the TPH-o carbon range (C24–C40), daily sampling of the Red Hill Shaft pre-chlorination port for TPH-d/o, including additional TPH-d/o analysis on the SGC extract of these samples, was conducted between September 22 and October 6, 2021.

Between July 8 and September 1, 2021, organic compounds were detected in the TPH-o analyses of samples collected at the Red Hill Shaft pre-chlorination port ranging from 230 J µg/L to 540 µg/L (August 5, 2021). During this period, two of these samples exceeded the TPH-o taste and odor EAL of 500 µg/L; no samples exceeded the TPH-o human health toxicity-based EAL of 2,400 µg/L.

TPH-o was detected in four additional samples between September 15 and 29, 2021 and was associated with detectable levels of TPH-o organics in laboratory method blanks. These samples are undergoing third-party data validation to assess validity.

Between September 22 and October 20, 2021, a secondary laboratory (Energy) was contracted to provide expedited turnaround time for daily samples of TPH-d/o and to address method blank contamination issues. Over that period, 23 samples are reported herein, with one TPH-o result (100 J µg/L) measured above the detection limit but below the LOD (140 µg/L) and the EAL.

Following the November 20 Release, drinking water sampling associated with Navy Well 2254-01 (Red Hill Shaft) was discontinued after the pumps were shut down on November 28, 2021. Drinking water sampling will not be conducted until further notice and coordination with the DOH Safe Drinking Water Branch.

10.2 November 20 Release

10.2.1 Extent and Magnitude of Soil Vapor Impacts

Figure 5 presents the soil vapor data associated with the November 20 Release. Soil vapor results in the first 900 ft of the Adit 3 tunnel and northernmost 300-ft extent of the Pearl Harbor tunnel indicates elevated organic vapor measurements (ranging from less than 1 to 785 ppmv). Local soil vapor maxima are located in segments of the Adit 3 (A3) and Pearl Harbor tunnels (S2) that overlie the water development tunnel, including:

- In the Adit 3 tunnel, in the vicinity of the release area, between A3-325 and A3-375
- In the upper Pearl Harbor tunnel, just southwest of the merge, between S2+25 and S2+100

Other local maxima were measured in the Adit 3 tunnel:

- Between the Pearl Harbor tunnel merge and the Water Pumping Station, between A3+100 and A3+150
- In the vicinity of the Adit 3 Sump where fuel accumulated during the release, between A3+250 and A3+375

10.2.2 Extent and Magnitude of Groundwater Impacts

Data collected from the Adit 3 Sump, Red Hill Shaft Water GalleryRHMW2254, and the fire suppression system suggest that:

- The magnitudes of the C9–C44 carbon range concentrations in the water samples from the Adit 3 Sump (sample ID number ERH1968) and Red Hill Shaft Water Gallery (sample ID number ERH2051) were consistent with the presence of LNAPL or free product.
- The composition of the product samples from the Adit 3 Sump and the fire suppression system, along with the groundwater samples from Adit 3 and Red Hill Shaft Water GalleryRHMW2254, were consistent with the hydrocarbon signature of JP-5.
- Data collected generally suggest no changes to the interior wells (RHMW01R, RHMW02, and RHMW03) since the November 20, 2021 release with the exception of TPH-d in RHMW02, which showed an increase in January.
- Data collected from the outlier wells where TPH-d is above the EAL (400 µg/L) suggest that most of the TPH-d detections have been single events that have not been repeated except for RHMW08. Chromatograms of these detections do not clearly match chromatograms of groundwater sampling point RHMW2254-01 or soluble compounds in JP-5.

Further information is detailed in the Technical Memorandum presented in Appendix B.5.

10.2.3 Extent and Magnitude of Drinking Water Impacts

The Red Hill Shaft pre-chlorination port was sampled once prior to the shutdown of pumping on November 28, 2021. Concentrations of TPH-o were detected at levels below the EAL. Concentrations of 1-methynaphthalene, 2-methylnaphthalene, and naphthalene were also detected at concentrations equal to or below the EAL. Significant impacts to the water gallery including the detection of LNAPL on the groundwater source has occurred, and Red Hill Shaft has been and remains disconnected from the drinking water system.

10.2.4 Holding Tanks and Leach Tank Subsurface Soil and Groundwater

The following evidence indicates that fuel was likely released from the Holding Tank and Leach Tank into the subsurface soil beneath the tanks:

- Fuel-related analytes were detected at the highest concentrations on site in the sediments collected from the Leach Tank floor.
- PID headspace measurements and subsurface soil sample results from soil borings located nearest to both tanks show the highest concentrations of TPH-g, TPH-d, and naphthalenes with the exception of LT-N25 at the 16–17 ft depth interval, which had the highest concentration of TPH-d (5,900 mg/kg).

Although there were significant TPH-g exceedances, the chromatograms reveal that most of the measured constituents were in the upper part of the TPH-g carbon range (i.e., the higher molecular weight) and do not indicate a gasoline release. The chromatograms were reviewed by the project forensic chemist, who identified the chromatographic signature as very similar to JP-5.

No groundwater was encountered during drilling and sample collection; however, well OWDFMW06B is located within 30 ft of the Holding Tank and is screened in the perched groundwater system located approximately 30–36 ft bgs at that location. Elevated headspace PID readings and petroleum odors were observed after the November 2021 release, and laboratory analyses of one groundwater sample indicated that petroleum-related impacts may be present in the perched aquifer at concentrations below applicable regulatory screening levels.

11.0 Conclusions and Recommendations

11.1 Conclusions

11.1.1 May 6 Release

Biweekly PID monitoring and monthly laboratory analysis of samples since May 2021 have documented decreasing petroleum vapor concentrations at all of the SVMPs impacted by the May 6 Release. PID readings at the SVMPs from Tanks 17, 18, and 20 have decreased by more than 90% from the peak concentrations recorded shortly after the release. Concentrations of total VOCs (by Method TO-3) and individual VOCs (by TO-15) have shown similar decreases. These

decreases are consistent with natural attenuation of the May 6 Release. Monthly PID monitoring would likely be sufficient to document ongoing natural attenuation of this release.

Prior to the May 6 Release, a PID reading above 50,000 ppbv was used as a threshold for collection of vapor samples for laboratory analysis. Unless an unexpected increase in PID readings above this 50,000 ppbv threshold is observed, additional laboratory analysis is likely to provide an improved understanding of ongoing natural attenuation.

Groundwater monitoring requirements for the May 6 and November 20 Releases have been combined into a single plan to assess and evaluate the groundwater impacts from both releases as well as potential migration of contaminants from other past releases. Future conclusions regarding the groundwater data will be combined unless specific results can confidently be tied to a particular release.

11.1.2 November 20 Release

On December 2, 2021, water from the water development tunnel was sampled with a bailer, and a a sheen with fuel bubbles floating on the surface was observed in the bailer. An additional sample was collected from fuel within the Adit 3 Sump that was attributed to the release. Both LNAPL samples were analyzed by specialized petroleum fingerprinting methods, and the results were evaluated by a petroleum forensic chemist with the following observations:

- Both samples were unweathered.
- Both samples represented similar JP- 5 fuel, likely from the same source.

Fifty-two SVMPs were installed in the impacted tunnel floors during two events: from December 15 through 17, 2021 and on January 11, 2022.

Between December 17, 2021 and January 14, 2022, 12 SVMP sampling events were conducted using hand-held PIDs, which identified elevated organic vapors in the first 900 ft of the Adit 3 tunnel floor, and the northernmost 200 ft of the Pearl Harbor tunnel floor, with maxima in areas of the tunnel that directly overlie the water development tunnel, as well as adjacent to the Water Pumping Station and adjacent to the Adit 3 Sump.

Groundwater data gathering and evaluation are ongoing with conclusions to be provided in a future report.

11.2 Recommendations and Planned Future Actions

Extensive sampling and monitoring activities in response to both the May 6 and November 20 Releases are ongoing. Data are being collected to:

- Evaluate the impacts and extent of the releases to the environment.

- Evaluate the effectiveness of the Red Hill Shaft capture zone in containing impacted groundwater and preventing additional migration of contaminants.
- Monitor potential future migration of contaminants and potential impacts to offsite receptors.
- Evaluate remediation alternatives and determine future remediation strategies.
- Conduct pilot testing as needed to evaluate remediation effectiveness and optimize remedial alternatives.

During the next phase of the tunnel site characterization, an additional three shallow subsurface SVMPs, one intermediate SVMP, and one deep nested SVMP will be installed.

A Preliminary Site Characterization Plan was developed and finalized on January 12, 2022 (DON 2022a). The following release response actions for the vadose zone were outlined in the Plan and were performed:

1) A subsurface soil sampling investigation of the Adit 3 Sump drain Holding Tank and Leach Tank area of concern
2) Additional characterization of the Adit 3 tunnel
3) Development of additional mitigation actions based on the results of the preliminary studies

The results of the site characterization investigation will be provided in a future report once laboratory analytical reports have been finalized.

The Navy recommends continued site characterization, removal actions, and data gathering and associated analyses in coordination with DOH.

In response to concerns regarding the timeliness of laboratory reporting, the Navy and DOH met collaboratively on November 16, 2021. In this meeting, the group identified root causes and developed a strategy for ensuring timely responses based on realistic reporting requirements and realistic laboratory turnaround time requirements. The Navy is revisiting these recommendations as well as some additional measures to improve the timeliness of laboratory reporting with the intent of immediate implementation upon regulatory agency approval. This strategy will be implemented in future deliverables to the stakeholders.

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