REGION 9
SAN FRANCISCO, CA 94105

July 29, 2024

Rear Admiral Stephen Barnett
Navy Closure Task Force - Red Hill
850 Ticonderoga Street, Suite 110
Joint Base Pearl Harbor-Hickam, Hawai'i 96860
[via email only: stephen.d.barnett.mil@us.navy.mil]

Subject: EPA Review of:

- *Technical Memorandum: In-Progress Data Report, Adit 3 Site Characterization, Red Hill Bulk Fuel Storage Facility, Joint Base Pearl Harbor-Hickam, Oahu, Hawaii*, dated February 14, 2023
- *Site Characterization Report*: *November 2021 JP-5 Release in Adit 3, Operable Unit 1, Red Hill Bulk Fuel Storage Facility, JBPHH, O'ahu, Hawai'i*, dated May 2023.

Dear Rear Admiral Barnett:

Thank you for submitting the *Technical Memorandum: In-Progress Data Report, Adit 3 Site Characterization, Red Hill Bulk Fuel Storage Facility, Joint Base Pearl Harbor-Hickam, Oahu, Hawaii*, dated February 14, 2023 ("Tech. Memo") and the *Site Characterization Report*: *November 2021 JP-5 Release in Adit 3, Operable Unit 1, Red Hill Bulk Fuel Storage Facility, JBPHH, O'ahu, Hawai'i*, dated May 2023. ("SCR"). Although these documents were not submittals under the 2015 AOC, they are important records of work the Navy completed after the 2021 releases. Future environmental work for these operable units should be submitted as deliverables for EPA approval under the Phase II Closure plan pursuant to Section 7 of the 2023 Consent Order. These operable units should be considered in the investigation phase of work and should be given a unique name for future reference, such as Adit 3 Investigation.

EPA engaged our contractor, S.S. Papadopulos & Associates, Inc. (SSPA), to aid in the review of the Tech Memo and the SCR. SSPA's evaluation focused on data, and assessed the technologies used. In summary, additional work is needed to adequately define the nature and extent of impacts from the release of Jet Fuel Propellant 5 (JP-5) in the Adit 3 Tunnel of the Facility on November 20, 2021. Please incorporate the recommendations from the attached memo in future deliverables.

If you have any questions regarding this letter, please contact me at cohen.matthew@epa.gov or (415) 972-3691.

Sincerely,

/s/

Matthew Cohen PG
Red Hill Project Coordinator
U.S. Environmental Protection Agency, Region 9

Enclosure: Technical Memorandum - Adit 3 Document Review – Tasks 7 & 8

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S.S. PAPADOPULOS & ASSOCIATES, INC.
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Technical Memorandum

Date:	July 18, 2024
From:	Kristen Slawter (SSP&A), Shelly Griffin (SSP&A), and Ben Petersen (SSP&A)
To:	Lynn Brockway (USEPA Region 9)
Cc:	Kenneth Dixon (USEPA Region 9)
Project:	SSPA-1857
Subject:	**Adit 3 Document Review – Tasks 7 & 8**

1 Introduction

On May 15, 2023, the United States Environmental Protection Agency ("USEPA") Region 9 tasked S.S. Papadopulos & Associates, Inc. ("SSP&A") with 14 discrete tasks related to the review of site documents and data from the Red Hill Bulk Fuel Storage Facility, Joint Base Pearl Harbor-Hickam, Oahu, Hawaii ("Facility"). This memorandum summarizes the technical review of site documents performed in support of Tasks 7 and 8.

Tasks 7 and 8 are to review the following documents:

- **Task 7** – *Technical Memorandum: In-Progress Data Report, Adit 3 Site Characterization, Red Hill Bulk Fuel Storage Facility, Joint Base Pearl Harbor-Hickam, Oahu, Hawaii*. Navy Facilities and Engineering Command, Hawaii, JBPHH, HI, February 14, 2023. ("Tech. Memo").
- **Task 8** – *Site Characterization Report*: *November 2021 JP-5 Release in Adit 3, Operable Unit 1, Red Hill Bulk Fuel Storage Facility, JBPHH, O'ahu, Hawai'i*. Navy Facilities Engineering Systems Command, May 2023. ("SCR").

These documents summarize Site Characterization activities performed between December 2, 2021 and January 31, 2023 in response to a release of Jet Fuel Propellant 5 (JP-5) in the Adit 3 Tunnel of the Facility on November 20, 2021.

Specific objectives for the document reviews assigned in Tasks 7 and 8 are to 1) identify data gaps in the Adit 3 site characterization investigations performed thus far, and 2) assess the technologies used in the Adit 3 site characterization investigations and identify those that may be useful for a Facility-wide Site Assessment.

2 Background

The Facility is a former Navy fuel storage facility located approximately 2-3 miles east of Pearl Harbor in O'ahu, Hawai'i. The Facility was built between 1940 and 1943 to house 20 large-capacity underground storage tanks ("Tank Farm"). Fuel from the Tank Farm, which at various times included Navy Special Fuel Oil ("NFO"), Marine Fuel (e.g. F-76), Aviation Gasoline ("AVGAS"), and Jet Fuel (e.g. JP-5 and JP-8), was conveyed to the Navy Facility at Pearl Harbor through fuel transmission lines that run along the interior of a tunnel system that connect the two facilities. The tunnel from the Tank Farm connects to the "Pearl Harbor Tunnel" via the "Adit 3 Tunnel." A water supply Pump Station is located approximately 147 feet (ft) east of the junction between the Pearl Harbor and Adit 3 tunnels. Drinking water is pumped from the basal aquifer through Navy Well 2254-01 (a.k.a. Red Hill Shaft [RHS]), which consists of a vertical shaft connected to a horizontal "Water Development Tunnel."

On November 20, 2021, JP-5 fuel, which had been recovered from a release at the Tank Farm in May 2021, was released from an overhead fire suppression recovery drain line in the Adit 3 Tunnel. The November release occurred approximately 425 ft east of the Pump Station ("Release Area"), 135 ft east of the junction with the Pearl Harbor Tunnel, and approximately 80 ft above the location where the Water Development Tunnel crosses under the Adit 3 Tunnel. JP-5 fuel flowed westward along the Adit 3 Tunnel and accumulated in an underground sump ("Adit 3 Sump") and sanitary storage tank, located near the Adit 3 entrance. Automatic overflow pumps in the Adit 3 Sump and sanitary storage tank were activated and pumped JP-5 fuel into underground holding and leach tanks ("Holding Tank and Leach Tank") and an above ground sanitary waste holding tank ("Collection, Holding, and Transfer [CHT] Tank").

On November 28, 2021, Navy Well 2254-01 was shut off and isolated after it was confirmed that fuel had impacted the Navy drinking water distribution system. Light Non-Aqueous Phase Liquid (LNAPL), suspected of being JP-5 from the release, was observed in a groundwater sample collected from the Water Development Tunnel on December 2, 2021.

The ensuing Site Characterization investigations are documented in the Tech. Memo and SCR, which are the subjects of this review.

3 Document Review

The Tech. Memo and SCR summarize data collection activities and results from the Site Characterization investigations conducted in response to the November 20, 2021 Adit 3 fuel release. The Tech. Memo presents data and laboratory reports for soil vapor, soil, and groundwater samples collected between December 17, 2021 and November 28, 2023. The Tech. Memo also includes a technical memorandum prepared by GSI Environmental ("Product Forensics Technical Memorandum") that summarizes analytical results for LNAPL samples collected on September 9, 2022. The SCR includes the data presented in the Tech. Memo but also includes results through January 31, 2023 and narrative descriptions of the study area, the soil vapor, soil, and groundwater investigation activities, field observations, geophysical surveys, data quality, results, a Conceptual Site Model (CSM), and recommendations. A crosswalk of document elements is presented in Table 1 of this document. Due to the overlapping content, this review is focused primarily on the information and data presented in the SCR. The information and data presented in the SCR was checked against the Tech. Memo to identify discrepancies, or missing or incomplete information. Review of the geophysical investigations (SCR Appendices A.1 and A.2) is included in this Tech. Memo as Appendix A.

This Technical Memorandum (TM) is organized into the following sections: a) Summary of Investigation Activities, Results and CSM; b) Appropriateness of Data Collection, Analysis, and Use; c) Evaluation of Data Gaps; d) Evaluation of Technologies Used; e) Summary; and Appendix A.

3.1 Summary of Investigation Activities, Results, and CSM

This section summarizes the investigation activities, results, and CSM described in the SCR.

3.1.1 Overview

The Tech. Memo and SCR are focused on Operable Unit (OU)-1 of the Adit 3 subsurface investigation. This includes the shallow subsurface (i.e. < 6 ft) of soil, rock, and groundwater located below the tunnel floor and above the bottom of a shallow water layer located approximately 12 ft below the tunnel floor (btf). The study area includes the westernmost 1300 ft of the Adit 3 tunnel and the northernmost 430 ft of the Pearl Harbor Tunnel. The period of time covered by the Tech. Memo and SCR extends from November 20, 2021 through January 23, 2023. The SCR describes the OU-1 investigation as an initial phase of the ongoing environmental investigation. The analytical suite focused on middle range distillate petroleum and target "indicator chemicals" as indicated in HDOH Fall 2017 guidance, Figure 2-4. The SCR describes the principal study questions to be:

- What is the extent and magnitude of JP-5 that remains in the environment within the Study Area that would have the potential to threaten human health and the environment?
- What are the migration pathways that could transport chemical of potential concern (COPCs) from the environment to receptors at concentrations that could pose unacceptable risk?
- What are the primary and secondary media of concern that can be treated to mitigate the migration of COPCs to COPCs to receptors at concentrations that could pose an unacceptable risk?
- Who/what are the human and environmental receptors that may be at unacceptable risk from COPCs that remain in the environmental from the November 2021 release?

3.1.2 Vapor Screening and Sampling

This section discusses sub-slab soil vapor screening and sub-slab and shallow soil vapor sampling.

3.1.2.1 Soil Vapor Screening

In December 2021, 47 sub-slab soil vapor monitoring points (SVMPs) were installed in the Adit 3 and Pearl Harbor tunnels. An additional five SVMPs were installed on January 22, 2022. The depths for the sub-slab SVMPs were not identified in the SCR or Tech. Memo.

Sub-slab SVMPs were monitored with handheld photoionization detectors (PIDs) and multi-gas meters on a weekly basis between December 13, 2021 and July 11, 2022 and then monthly thereafter with additional, out-of-frequency, readings collected after qualifying rain events (i.e., ≥1 inch of rain accumulation within a 24-hour period). The SCR and Tech. Memo refer to the PID readings as "Real-Time Semi-Quantitative Screening" (see Section 3.2.1 on Appropriateness of Data Collection and Analysis Activities).

Results from the sub-slab SVMP screening are presented in SCR Figures 6-1 and 6-4 and Appendix B, Table App B-1. Soil vapor concentrations are also presented with geophysical survey results in the SCR Appendix A - HGI Phase II report Figures 17-19; 23-25; 29-31; 35-37; 41-43. Note: Figure 6-1 is cut off in the SCR and cannot be properly reviewed. However, Figure 1 of the Tech. Memo is roughly equivalent [see TM Table 1].) Field forms documenting instrument calibration and ambient conditions were not included in the SCR or Tech. Memo.

Results were used to 1) identify locations for shallow sub-surface investigations; 2) evaluate sub-slab SVMP soil vapor trends with time; and 3) correlate anomalies in geophysical data to volatile organic compound (VOC) concentrations. The evaluation of sub-slab SVMP soil vapor trends with time are presented in SCR Figure 6-4 and described as "Diminishing concentrations over time, likely due to infiltration, degradation, and volatilization, leading to lower JP-5 concentrations in the shallow subsurface directly beneath the tunnel floors" (SCR, pg. 20).

See Section 3.2.1 for discussion on the appropriateness of using SVMP PID screening to make conclusions about the location, trends, and concentration of LNAPL in the sub-surface.

3.1.2.2 Soil Vapor Sampling

Select sub-slab and shallow gas samples were collected using Summa canister sampling methods for analysis by TO-15 for total petroleum hydrocarbons (TPH) (C5-C12), TO-3 for BTEX and naphthalene, and ASTM D1946 for CO_2, O_2, and methane. Fourteen (14) unique locations were sampled with the active soil vapor sampling approaches between February 2022 and January 2023. The first round of samples in February 2022 only included three (3) sample locations. These locations were not sampled again in the subsequent December 2022 and January 2023 sampling events.

Results are presented in SCR Figures 8-4 through 8-6 and Tables 8-14 through 8-22. Figure 8-7, which is supposed to show soil vapor sample results from January 2023, is missing and Figures 8-4 and 8-5 are only partially viewable. Figure 8-4, soil vapor sample results from February

2022, is produced as Figure 2 in the Tech. Memo but the December 2022 results are not available in either document (TM Table 1). Similarly, Tables 8-14, 8-17, and 8-20 are only partially viewable and only the February 2022 results are included in the Tech. Memo.

3.1.3 Geophysical Investigations

A review of the geophysical investigations performed by hydroGEOPHYSICS in January/February 2022 and November 2022 can be found in Appendix A of this TM.

3.1.4 Sub-Surface Investigations

Investigations of sub-surface media were conducted in two phases. An initial investigation, conducted between March and April 2022, consisted of field observations and multi-media sampling (soil, groundwater, and LNAPL) from six shallow trenches and associated shallow borings, excavated through the Adit 3 and Pearl Harbor tunnel floors. The trenches were excavated to a depth of 0.5 to 3 ft btf and one boring was installed within each trench to a maximum depth of 6 ft btf. Based on observations from this initial investigation, a second phase of shallow subsurface investigation was conducted between June 23, 2022 and January 18, 2023. A total of 23 "step-out" borings were completed in the Adit 3 and Pearl Harbor tunnels, at a maximum depth of 6 ft btf, for soil and groundwater sampling. Seven (7) of these borings were converted to temporary wells in September 2022 for additional groundwater sampling. The field activities and observations associated with the two phases of subsurface investigations are summarized in the sections below.

3.1.4.1 Trench, Trench Boring, and Step-Out Boring Sampling

The purpose of the shallow trench and trench boring investigation was to 1) locate and investigate the Hume drain, which was proposed as potential conduit for JP-5 migration, and 2) collect information on the nature and extent of JP-5 contamination in the shallow subsurface. The purpose of the step-out boring investigation was to 1) characterize the shallow subsurface and 2) delineate the lateral extent of LNAPL (i.e., JP-5) in the shallow subsurface.

In March 2022, six (6) shallow trenches were cut through the concrete floor of the Adit 3 and Pearl Harbor tunnels. The Hume drain was located approximately 3 ft btf along the north side of Adit 3. Surface material was screened using a PID. Sub-slab surface material, which consisted of "thin layers of fill sand and gravel" under the tunnel floor and "a concrete foundation…and loose sediments to approximately 2 ft btf" at the Release Area, were sampled using Multi-Increment Sampling (MIS) techniques (SCR, pg. 23 and 33). The depths of the fill material between the concrete and underlying a'a bedrock were not provided in the SCR or Tech. Memo.

Each trench was designated as a decision unit (DU) and "30 increments and 5 cubic centimeters of soil" were collected for each MIS sample (SCR, pg. 33). One trench, A3-150-TR, was sampled in triplicate. The MIS surface soil samples were submitted to Eurofins for the following analyses:

- TPH-g by Method 8260
- TPH-d/o by Method 8015D
- BTEX by Method 8260D
- Naphthalenes by Method 8270E Selected Ion Monitoring (SIM)

After trench MIS sampling, five (5) borings were drilled inside the trenches using a handheld hammer drill to a maximum depth of 6 ft btf. Boreholes were screened using a PID. Groundwater was encountered between approximately 3 and 5 ft btf in three of the five borings (A3+215-BH, A3+000-BH, and A3-150-BH). A "strong organic odor" and LNAPL were observed at A3+000-BH, which is located in Adit 3 adjacent to the Pump Station, and a "minor organic odor" was observed at A3-150-BH. SVMPs were installed at a depth of 5 ft btf in the two borings that did not encounter groundwater (i.e. 2S+075-SVMP and A3-375-SVMP). The trenches and trench boreholes were then backfilled and covered in April 2022.

Beginning in March 2022 through January 18, 2023, 28 step-out borings were drilled to a maximum depth of 6 ft btf using a handheld hammer drill. The SCR notes that "[w]hen drilling was in rock, no soil was recovered, and no samples were collected for screening or laboratory analysis" and "[l]ithologic logging could not be completed due to the drilling method" (SCR, pgs 24-25). Data gaps related to the drilling method are discussed further in Section 3.3.1 of this TM.

Recovered drill cuttings were screened using a PID at 1-ft intervals. The section with the highest PID reading was selected for soil sampling and screened for LNAPL using Oil in Soil, a field hydrocarbon test kit. The Oil in Soil field test kit was used to screen 17 of the 28 step-out borings listed in SCR Table 5-2 and of these, nine (9) borings tested positive for hydrocarbons.

Twenty-five (25) soil samples were collected from the trench and step-out borings. Due to low soil recovery from the hammer drilling process, drill cuttings from trench and step-out borings were analyzed for TPH-d/o and naththalenes in the 25 samples and TPH-g and BTEX were analyzed in only three (3) samples.

Results from the MIS trench sampling are provided in SCR Figure 8-1 and Tables 8-2 through 8-4. Results of the Oil in Soil hydrocarbon field tests are presented in SCR Table 5-2. Soil sampling results from the trench and step-out borings are presented in SCR Figure 8-2 and Tables 8-5 through 8-7. PID screening results for the trenches, trench borings, and step-out borings are presented in SCR Tables 6-1 through 6-3. As with previously described SCR figures and tables, several tables and figures are cut off and only partially viewable in the SCR. However, these tables and figures are reproduced in the Tech. Memo (see TM Table 1).

Discrepancies between the SCR and Tech. Memo tables and figures are also described in TM Table 1.

3.1.4.2 Groundwater Sampling

Perched groundwater was encountered in three (3) of the trench borings and an unspecified number of step-out borings. Water levels, product gaging, and PID screening were conducted as boreholes were completed and then weekly starting in May 2022. Water levels and free product (i.e. LNAPL) levels were collected with an oil/water interface probe. These results are presented in SCR Table 6-3.

In March and April 2022, groundwater samples were collected by bailer from three (3) boreholes (A3+325-BH, A3+215-BH, and A3+015-BH). One borehole, A3+015-BH, was sampled again in May 2022. (Note: the SCR text states that groundwater was sampled from two boreholes but results from the three boreholes are presented in the tables and figures from the SCR and Tech. Memo).

In September 2022, seven (7) boreholes were converted into temporary wells using prepacked 5-ft screens (A3+375-TW, A3+325-TW, A3+210-TW, A3+050-TW, A3+015-TW, A3-010-TW, and A3-040-TW). Micro-Diver (Van Essen Instruments) pressure transducers were placed in the temporary wells for continuous water-level monitoring. Water-level data from the seven (7) temporary wells, along with precipitation data, are presented for September 2022 through January 2023 in SCR Figure 6-6.

In September 2022, groundwater samples were collected from the seven (7) temporary wells using low-flow methods. According to the Tech. Memo, four (4) of the samples (A3+375-TW, A3+325-TW, A3+210-TW, and A3+150-TW) were "determined to be water without a sheen and were analyzed as groundwater" and three (3) of the samples (A3+015-TW, A3-010-TW, and A3-040-TW) "were determined to be LNAPL or water with a sheen, and were analyzed as product" (Tech. Memo, pg. 4). Only one (1) round of groundwater sampling was collected from the temporary wells (see Section 3.3.2 on data gaps).

Groundwater samples from the boreholes and temporary wells were submitted to Eurofins for the following analyses:

- TPH-g by Method 8260
- TPH-d/o by Method 8015D
- BTEX by Method 8260D
- Naphthalenes by Method 8270E SIM

The SCR describes the borehole groundwater results as "semi-quantitative" and the temporary well groundwater results as "a quantitative data set for decision-making" (SCR, pg. 17). See Section 3.2.3 for additional discussion on the appropriate use of data.

PID, water levels, and product levels are reported in SCR Table 6-3 and water-level data from in-well transducers are displayed in Figure 6-6. Groundwater analytical results are presented in SCR Figure 8-3 and Tables 8-14 through 8-16. (Note: groundwater results for each of the seven (7) temporary wells are shown in Figure 8-3 but only groundwater results for the four (4) temporary wells without a sheen are included in Tables 8-14 through 8-16). As with previously described SCR figures and tables, several tables and figures are cut off and only partially viewable in the SCR. However, these tables and figures are reproduced in the Tech. Memo (see TM Table 1). Discrepancies between the SCR and Tech. Memo tables and figures are also described in TM Table 1.

3.1.4.3 LNAPL Sampling

As discussed above, LNAPL or sheen was observed in one trench boring (A3+000-BH) in March 2022 and in samples from three (3) temporary wells (A3+015-TW, A3-010-TW, and A3-040-TW). Additionally, nine (9) borings were positive for LNAPL using the qualitative hydrocarbon test kit (Oil in Soil) and sheen or free product were indicated at least once in 14 borehole and temporary well locations (SCR Table 6-3).

The SCR indicates that the LNAPL observed in A3+000-BH was sampled and "underwent forensic analysis for saturated hydrocarbon (SHC) analysis" (SCR, pg. 17). These results are not discussed further in the SCR or Tech. Memo. A laboratory report from Alpha Analytical for the A3+000-BH LNAPL sample is included in Appendix C.1 of the SCR.

In September 2022, three (3) samples from the temporary wells and one sample from a deep SVMP (A3-010-DSVMP) were submitted to Alpha Analytical for the following analyses:

- SHC by EPA 8015D (modified)
- Paraffins, Isoparaffins, Aromatics, Naphthalenes, and Olefins (PIANO) by EPA 8260

The samples consisted of LNAPL from A3-010-TW and A3-040-TW, groundwater from A3+015-TW, and groundwater with a sheen from A3-010-DSVMP. Laboratory reports and a TM by GSI Environmental, which briefly summarizes the Alpha Analytical results, are included in SCR Appendix C.2.

Section 8.4 of the SCR (pg. 42) indicates that TPH-d and TPH-o for these samples are calculated from the SHC analysis and BTEX and naphthalenes are reported from the PIANO analysis. The temporary well results presented on SCR Figure 8-3, therefore, display results from different methods, which are not directly comparable. See Section 3.2.2 for additional discussion of the appropriate use of data.

3.1.5 Conceptual Site Model

The SCR describes a CSM of the site geology, migration pathways, and series of events that occurred at the time of the release. A detailed description of those events can be found in section 9.0 of the SCR. A summary of the SCR CSM and series of events is described below:

- On November 20 and 21, liquid containing JP-5 was released from a broken valve on a fire-suppression drain line, flooding the Adit 3 lower access tunnel.
- These liquids "migrated through cracks and openings in the tunnel floor", into utility corridors, the Adit 3 sump and sanitary sewer tank, and the underlying fractured basalt.
- Some of the liquid from the sump and sewer tank was pumped into a "Holding Tank and Leach Tank system and to a Collection, Holding and Transfer Tank" located outside the Adit 3 west entrance.
- JP-5 was observed migrating into the RHS water tunnel during a ROV inspection.
- "Perched groundwater" immediately below Adit 3 contains "elevated" dissolved concentrations of JP-5, and the perched water limits the vertical migration of contamination.
- Potential receptors include onsite workers through inhalation, direct exposure, or ingestion and residential and commercial/industrial consumers of the basal groundwater.

3.2 Appropriateness of Data Collection, Analysis, Use

This section discusses SSP&A's assessment of the appropriateness of data collection, analysis, and use for Site Characterization investigations conducted in response to the release of JP-5 in the Adit 3 Tunnel.

SSP&A identified the following limitations regarding the Site Characterization activities and use of data.

3.2.1 Soil Vapor Monitoring

Overreliance on PID screening as a "Semi-Quantitative" technique – When used properly, PID screening can provide useful qualitative information on the relative amounts of volatile organic compounds which are ionized. However, the amplitude of a PID reading does not directly correspond to LNAPL mass. PIDs in general are not as sensitive to aliphatic hydrocarbons (see ASTM 2006 and HDOH, 2012) which compositionally dominate JP-5. PIDs are sensitive but not selective tools used for field screening. PIDs measure ionized VOCs in the air and display a total sum of all detected compounds ionized by the internal lamp. Displayed values on PIDs are dependent on the lamp used, the correction factor (if applied), the calibration gas used, the presence or absence and distribution of compounds, and the specific ionization potential of each compound, among other factors. PIDs are limited to screening for compounds ionized by the internal lamp and therefore highly dependent on the lamp used. In the SCR, the model of the

PID was indicated; however, in both the SCR and the Tech. Memo, the lamp installed in the PID was not indicated. It is also unknown if there were changes to the lamp used during the screening activities. Field documentation of equipment used with lamp types is critical for the interpretation of screening results and any apparent trends. For example, a compound may comprise a high percentage of the total VOCs present in a material but may not ionize by the PID in equilibrium with concentrations present in the vapor, thus making the PID measurement biased low. A change in the composition of VOCs present (not total VOC concentrations) may bias a PID reading low or high, depending on the lamp used. The SCR presents the PID field screening measurements as VOC concentrations and does not include a discussion of the limitations of the technology where conclusions are drawn from the PID screening measurements. For example, the SCR states "The [sub-slab SVMP PID] readings showed a site-wide decrease in VOC concentrations over time…" (SCR, pg. 12). The interpretation that site-wide VOC concentrations have decreased is not appropriate based on the technology utilized (e.g. PID). A review of field notes and forms from the SVMP PID screening events, which include information on the lamp utilization in the PID(s) and the ionization potential of target compounds based on the lamp(s), is necessary prior to conclusions regarding trends in total VOC concentrations.

PID and SVMP sample results may not be representative of sub-slab and sub-surface conditions. Review of the PID and multi-gas meter screening results presented in Appendix B and the soil vapor sample results from February and December 2022 and January 2023, indicate that soil vapor data contained elevated levels of oxygen (i.e. potential tunnel air). This may bias the screening and soil vapor results low and makes interpretations less reliable. For example, ambient or atmospheric air is typically indicated when measured O_2 is near ambient conditions of 20.9%; soil and subslab areas can be depleted in comparison. State specific guidance, such as Delaware Department of Natural Resources and Environmental Control Standard Operating Procedure Sub-Slab Air Sample (Soil-Gas) indicates that short circuiting (i.e. pulling of atmospheric conditions) occurs if measured oxygen during purging is >18.8% or remains more than 2% of measured ambient conditions (DNREC-RS, 2023). Oxygen levels in PID screening results were >18.8% in the majority of records in Appendix B. Similarly, O_2 was >18.8% in 15 out of the 16 soil vapor sample results that can be viewed in SCR Figures 8-4 and 8-5 and Tables 8-14, 8-17, and 8-20.

Soil vapor sampling and sub-slab monitoring in an area with complex subsurface features or where the lithology and subsurface utilities are not well documented may be more representative of the location of vapor pathways and vapor accumulation areas as opposed to the location of LNAPLs, contaminated water, or contamination "hot spots". When field documentation and/or understanding of the subsurface is incomplete, extra care must be taken when interpreting vapor results, especially if they are interpreted as locations of NAPL or product .

PID screening measurements as VOC concentrations may have been used in Appendix A.1 and A.2 geophysical investigation reports. The April 2022 geophysical report makes conclusions such as, "[…] these sections correspond to increasing VOC concentrations from the soil vapor measurements along the tunnel." The data presented by hydroGEOPHYSICS has labeled the VOC concentrations with the units of ppb, while screening measurements collected from PID are represented as ppmv and laboratory analytical data were in $\mu g/m^3$. Based on the data included in the Tech. Memo and SCR, only three (3) analytical soil vapor measurements had been collected by April 2022. The appearance of data in Appendix A.1 indicates higher resolution vapor data than the three (3) samples collected in February 2022. As previously mentioned, there is a limitation to the use of PID obtained screening data, the interpretation of total VOCs, and conclusions drawn from this type of data. It is unclear if the data provided to hydroGEOPHYSICS was a record of PID screenings or if additional analytical soil vapor samples were collected which are not disclosed in the SCR or Tech. Memo. Inferences made about the location of features based on these PID measurements should be made with caution. In order to better understand the geophysical reports' interpretations and recommendations, the source of the VOC concentration data used needs to be determined. For additional discussion on the use of the "VOC concentrations" data in the geophysical investigation reports, see Appendix A.

3.2.2 Misrepresentation of Data Comparability

The groundwater data presented in SCR Figure 8-3, displays groundwater results obtained from different sampling and analytical methods together without clearly distinguishing the different data sets. The comparability of results obtained by different sampling and analytical methods is also not addressed in the SCR or Tech. Memo. This may lead to inaccurate interpretations. For example, upon first look it would appear that BTEX, naphthalenes, and TPH decreased dramatically at A3+015-BH/TW between when the borehole was sampled in April-May 2022 and when the temporary well was sampled in September 2022. However, the borehole samples were collected using bailer sampling methods, which are more likely to capture a higher proportion of LNAPL components near the groundwater surface in a stratified water column. Low-flow methods sample from deeper in the water column and are more representative of the fully dissolved LNAPL components.

Additionally, the BTEX, naphthalenes, and TPH results presented for A3-015-TW are based on forensic SHC and PIANO methods whereas A3-015-BH and other groundwater results are based on less selective methods. In particular TPH-d/o, based on the forensic SHC method, are calculated values and represent the sum of individual hydrocarbon compounds in the diesel and oil range. TPH-d/o from method EPA 8015 are bulk parameters that integrate all hydrocarbon and non-hydrocarbon compounds that elute in the diesel and oil range. The bulk TPH-d/o values, therefore, will always be higher than the TPH-d/o values calculated from the SHC method. Also, only the bulk TPH-d/o values are relevant for comparison to HDOH Environmental Action Levels (EALs).

3.2.3 Mischaracterization of Analytical Data

Throughout the SCR and Tech. Memo, analytical results from borehole groundwater samples are referred to as "semi-quantitative" while analytical results from temporary wells are referred to as "quantitative" and "for decision-making." The reason for this distinction is not explained in the text but it implies that the borehole groundwater data cannot be relied upon for Site Characterization and decision-making. From an analytical perspective, the borehole groundwater data was obtained using the same approved methods as the temporary well groundwater data and is therefore equally quantitative. It is possible that by calling the borehole groundwater data "semi-quantitative" the SCR means that the results are less representative of groundwater than the temporary well data. This may be true, as the boreholes are undeveloped and LNAPL constituents from overlying stratigraphy could seep into the borehole and therefore, the groundwater sample. While the borehole results are not directly comparable with the temporary well data (see above), they do provide useful quantitative information about the extent and composition of LNAPL in the subsurface six (6) months prior to the collection of groundwater from the temporary wells. This is, in fact, one of the only lines of evidence to evaluate how the composition of contamination has changed through time. For these reasons, it is not appropriate to dismiss the borehole groundwater data as "semi-quantitative".

3.2.4 Conceptual Site Model Discussion

The SCR posits in the CSM that "It is reasonable to believe that the perched water has limited the vertical migration of JP-5 below the perched groundwater in those areas where the perched groundwater is present" (SCR, pg. 43). The CSM goes on to indicate that the LNAPL thickness would have to exceed the thickness of the perched water zone for the LNAPL to pass the perched water zone (SCR, pg. 45). This does not take into account the vertical migration and entrapment of LNAPL caused by water-level fluctuations. When water levels fall, LNAPL is transported downward due to gravity. When water levels rise again, some of the LNAPL will become entrapped in the water or in pore spaces and fractures at lower depths. This is known as the "smear zone." LNAPL in the smear zone may act as a continual source of dissolved contaminates to the perched water as well as a source of LNAPL to the deeper vadose zone and ultimately the basal aquifer (Alden et al., 2024). For example, perched water at A3-040-TW, which has free product ranging from a sheen to 0.58 ft thick, fluctuated by approximately 2 ft in response to precipitation events in November and December 2022. Water level and product thickness measurements are only available at this location between August 8, 2022 and January 30, 2023; however, given the response to the December 2022 precipitation event, it is likely that water levels fluctuated by at least 2 ft, if not more, in response to larger precipitation events that occurred in December 2021, just after the release, and January, April, and May 2022 (see Figure

2-3 SCR). These water-level fluctuations may facilitate the transport of product to deeper portions of the vadose zone.

3.3 Evaluation of Data Gaps

This section describes the data gaps and limitations that were identified during this review. Data gaps and limitations are organized into the following categories: a) Lack of Lithologic Information, b) Data Trends with Time, c) Analytes, and d) Scope Limitations.

3.3.1 Lack of Site-Specific Lithologic Information

A comprehensive evaluation of the lithology at the Site is absent. Descriptions of the underlying geology at the Site are limited to a general discussion of regional geology (SCR, pgs 5-6). Lithologic descriptions of core material were not presented in either the SCR or Tech. Memo and it was stated that "[l]ithologic logging could not be completed due to the drilling method" (SCR, pg. 25). Understanding the local lithology at the Site is important for evaluating the fate and transport of contaminants from the release area, tunnels, and Adit 3 sump. Regardless of drilling method, a boring log for each boring should have been completed as a standard practice. These boring logs at the very least should have contained the thickness of concrete slab, and if observing and documenting the lithology was not possible, then description of drilling activities, including drill speed variation with depth, should still have been documented. Boring logs were not included in either the SCR or Tech. Memo. Additionally, the lack of lithologic information limited the utility of the geophysical investigations. Specifically, stratigraphic boundaries identified using ground-penetrating radar could not be characterized due to the lack of geologic information. Further discussion on geophysical interpretations can be found in Appendix A.

3.3.2 Data Trends with Time

The SCR describes sub-slab soil vapor screening results (i.e. PID results) as decreasing with time, "likely due to infiltration, degradation, and volatilization" (SCR, pg. 20). This hypothesis could be evaluated, at least partially, by analyzing groundwater samples over time to identify potential trends in the composition and concentration of JP-5 contamination. However, groundwater samples were only collected from the temporary wells once during the reporting period covered in the SCR and Tech. Memo. This offers a snapshot of the groundwater conditions approximately ten (10) months after the fuel release. Additional groundwater sampling and comparison with previous results would provide information on the progress of degradation and changes in concentration of dissolved constituents with time.

3.3.3 Vapor Sample Design

In order to properly interpret results from screening or sampling of air (including, soil gas, sub-slab, and ambient air), the screening and sampling needs to be conducted with consideration and documentation of activities, practices, and conditions that may impact the results of screening or sampling. Trends may be imparted onto data based on site activities or environmental conditions. The SCR notes rainfall in the document (SCR pg. 19) as a potential reason for increases in concentrations; however, not included is a discussion and/or interpretation of results due to potential impacts from air handling systems, use of heating/air conditioning systems, tunnel pressures resulting from air handling system operations (positive or negative), vehicle/trolly use and location during sampling, product loading/moving in piping during sampling/screening activities, etc. all of which may present short (hour to day) or long-term (week to month) trends to air/vapor sample concentrations.

Ambient air screening measurements and/or analytical results were not included in the SCR. In order to attribute and understand the VOC concentrations of screened or sampled air, it is important to have a sampling design that has clearly collected ambient air conditions. Understanding ambient air conditions aids in attributing impact of activity on the samples, interpreting results, and making sound conclusions by recording site activities prior to and during the screening and sampling. A review of tightness testing and field procedures indicating the appropriate seals are tested and in place for the SVMP is crucial for the interpretation of screening and sampling results obtained using these SVMPs. Additionally, cataloging utilities and pathways (cracks, penetrating pipes or fasteners, etc.) that may allow for ambient air to enter the area of the SVMP is a critical portion of interpreting results from SVMP screenings or sampling and is essential when oxygen percentages are over 18.8%. It is unclear in the SCR if additional procedures were taken, such as helium shrouding, to determine if a leak was present in the sampling system and port. In order to evaluate the conclusions made from these results the field collection information should be included. The CSM presented in the SCR (SCR pg. 42) discusses the movement of JP-5 through cracks and openings from switch penetration into the sub surface; however, a discussion of vapors migrating along the same routes is lacking.

3.3.4 Analytes

The analytes reported and discussed in the SCR and Tech. Memo were limited to the target analytes for middle-distillates described in the Department of Health (DOH) regulatory guidance document: *Evaluation of Environmental Hazards at Sites with Contaminated Soil and Groundwater* (DOH, 2017). These include TPH, BTEX, and naphthalene for soil, soil vapor, and groundwater samples, as well as methylnaphthalenes in soil and groundwater and methane in soil vapor. Other indicators of JP-5 contamination or degradation were not assessed. These include the following:

- Additives – DOH guidance specifies that known or suspected additives should be evaluated. Examples of known or suspected fuel additives, which are included in the long term monitoring (LTM) sampling program for the tank farm at the Red Hill facility, include 2-(2-Methoxyethoxy)Ethanol (2-MEE), Phenol, and 1,2-Dibromoethane. Additionally, 2-MEE was detected at concentrations ranging from 1200 to 2000 mg/L in

JP-5 product sampled during de-fueling (see DLA Fuels, Laboratory Reports SDGs 23G0041 and 23G0043 Revision 2, available in the facility database[1]).

- Additional indicator compounds – Trimethylbenzenes (TMB) are a common component of middle distillates and the 1,2,4-TMB isomer was detected at 18,000 μm/m^3 in vapor analysis from February 2022. This detection was greater than any other compound detected in sample 2S075-GSN01-000.0-021822. TMBs have also been detected in JP-5 fuel samples collected during de-fueling activities at the Red Hill tank farm. The highest concentrations were detected for the 1,2,4-TMB isomer and ranged from 3,510 to 6,370 mg/kg (see DLA Fuels, Alpha Analytical SDGs L2338337 and L2338338, available in the facility database). Although TMBs elute in the TPH analysis and therefore contribute to the measured TPH value, the selective analysis of individual TMB compounds may serve as a tracer for the transport of JP-5 contamination.
- TPH with silica gel cleanup (SGC) – Polar compounds are produced as petroleum degrades, through both biologic and weathering processes (ITRC, 2018). SGC removes the polar degradation products so that the hydrocarbon fraction can be isolated and quantified. The difference between the TPH and TPH with SGC measurements provides an estimate for the amount of polar compounds in the sample. Fresh fuels consist primarily of hydrocarbons so the TPH and TPH with SGC values will be similar. However, the more degraded the fuel is, the higher the percent polar fraction will be. Degradation, and therefore the percent polar fraction, typically increases with time and distance from the source (ITRC, 2018). Polar compounds have different properties than hydrocarbons, for example, they are typically more soluble and more likely to partition into groundwater. Therefore, TPH with SGC can provide important qualitative information about the composition, age, and mobility of contamination.

Additional analytes that are not related to JP-5 contamination but should nonetheless be assessed are per- and polyfluoroalkyl substances (PFAS). This is recommended because the JP-5 fuel was stored in a fire suppression drain line when it was released into the Adit 3 tunnel. If the fuel encountered residual PFAS-containing fire suppression materials while in the drain line, then it is possible that PFAS were released along with the fuel.

3.3.5 Scope Limitations

As discussed previously, the scope of the Site Characterization investigations presented in the SCR and Tech. Memo are limited to extent and characterization of JP-5 contamination in the

[1] https://synectics.net

shallow sub-surface (i.e., the top 6 ft btf) between approximately 75 ft east of the Release Area and the Adit 3 sump and the northernmost 300 ft of the Pearl Harbor Tunnel. This scope does not investigate how JP-5 contamination may have migrated, both vertically and laterally, with time. Specific examples of data gaps related to the limited scope are as follows:

- The scope of the investigations conducted thus far is focused exclusively on JP-5 contamination from the November 20, 2021 release. Potential contamination from previous releases has not been considered or investigated.
- Lack of sub-surface investigation east of the release area – The potential for the presence of contamination east of the Release Area has not been thoroughly investigated. The investigations relied on PID measurements to identify locations for further sub-surface trench and soil boring investigations. Three SVMP monitoring points are located to the east, and within 75 feet, of the Release Area but, presumably because of the low organic soil vapor headspace results from these SVMPs, no soil borings were drilled in this area. While information collected by PID is useful for screening and identifying highly contaminated areas, it cannot be used to determine an area is free of contamination. The contamination east of the release area may simply be in a deeper portion of the sub-surface or more VOCs may be depleted. Additional boreholes east of the Release Area would help assess the presence or absence of contamination migration in this area.
- Evaluation of vertical and lateral migration of contamination – Questions about the extent and magnitude of JP-5 that remains in the environment cannot be sufficiently addressed based on the limited scope of this study. The potential for vertical and/or lateral migration of JP-5 contamination in the sub-surface has not been fully evaluated. The investigations thus far have focused exclusively on soil, rock, soil vapor, and groundwater in the top 6 ft of the study area. However, there was most certainly vertical transport of JP-5 through the vadose zone to depths greater than 6 ft because LNAPL reached the basal aquifer within eight (8) days of the release. Furthermore, as LNAPL moves down through the vadose zone it may intersect fractures or zones of low or high permeability that would cause the LNAPL to spread laterally. The occurrence of perched groundwater may limit the vertical migration of LNAPL in areas where it is present, but there could still be a substantial amount of LNAPL mass below the perched groundwater due to lateral migration from areas where the perched groundwater is absent, such as the Release Area.

  Also, the assessment of sub-surface conditions and the extent of contamination has been focused on the areas underlying the Adit 3 and Pearl Harbor tunnels. The lateral extent or continuity of contamination, lithology, and perched groundwater surrounding (i.e. perpendicular to) the tunnels cannot be assessed from the data collected thus far.

  Future sub-surface investigations at Adit 3 should include additional borings that 1) extend to the basal aquifer, 2) transect the perched groundwater and 3) step-out from the tunnel footprint.

3.4 Evaluation of Technologies Used

This section describes the pros and cons of the various technologies used in the Site Characterization investigations at Adit 3.

- Field Screening: PID & Multi-gas Meter

In both the Tech. Memo and SCR data was presented to have been collected from SVMPs from PIDs and multi-gas meters. PIDs are useful screening tools for real time data; however, they are limited in the selectivity of chemicals and in the response to individual chemicals. PIDs tend to target (have higher relative responses) to aromatic hydrocarbons and are not good indicators of total TPH levels in soil vapors without inclusion of an appropriate correction factor for mixtures with high percentages of aliphatic hydrocarbons. This is an especially important consideration for middle range distillates like JP-5. PIDs are useful tools for monitoring breathing and ambient air and can assist with determining placement of analytical measurement samples for indoor air collection. Field screening with a PID can assist with determination of potential vapor pathways or regions with accumulation of vapors (i.e. "hot spots" and "cold spots") or as a line of evidence in directing investigative sampling efforts.

Multi-gas meters are important for monitoring the composition of gases and for the determination of leaks, connections with ambient/atmospheric air, and the potential for aerobic or anaerobic degradation/activity, and for monitoring breathing zone spaces. Clarification is needed on screening measurements collected with the multi-gas meter(s) in the SCR. Inclusion of additional data to Table App B-1 and/or correction to text in Section 5.1.1 is needed in order to clarify the disagreement between sections. Section 5.1.1 of the SCR states, "Periodic and out-of-frequency subslab vapor monitoring included collecting VOC measurements (parts per million by volume [ppmv]) with a PID; and O_2 (%), CO_2 (%), and carbon monoxide (%) with a multi-gas meter, as described in Section 6.0." Section 6.1 states "Real time semi-quantitative screening from the subslab and shallow SVMPs using handheld PIDs and multi-gas meters (see Appendix B for results)." Appendix B, Table B-1 shows the following column headers: "Location; Location of Probe; Date; Time; Organic Vapor (ppmv); Oxygen (%); Carbon Monoxide (%); Methane (%)".

- Field Screening: Oil in Soil

The use of hydrocarbon field screening techniques is recommended as a low-cost way to assess the presence of hydrocarbon contamination. If used in conjunction with other confirmatory techniques, the use of hydrocarbon field screening kits can reduce the overall number of analytical samples needed. However, field screening techniques such as Oil in Soil, should not be relied upon to delineate the presence or absence of hydrocarbon contamination. Analytical methods are more selective and sensitive and should be used to confirm the presence or absence of hydrocarbon contamination. The Oil in Soil test kit, for example, indicated a negative response for the presence of hydrocarbons in core material from A3-040-BH/TW (SCR

Table 5-3), whereas analytical soil sampling indicated TPH-d present at a concentration of 1800 mg/kg (SCR Table 8-5). The website for the Oil in Soil test kit indicates that it is capable of detecting hydrocarbons within ±500 mg/kg (https://www.oil-in-soil.com/oil-in-soil).

- Sampling: MIS

MIS techniques are recommended in the HEER Office Technical Guidance Manual (TGM) (HEER, 2017). This sampling technique is useful when DUs can be delineated and when laterally and vertically continuous sections of soil can be sampled. Samples for each DU interval are combined and analyzed to provide a single mean value for which to compare the DU with appropriate reference limits. However, due to the poor soil recovery from the hammer drilling process, MIS sampling at Adit 3 could only be performed in the sub-slab fill material. Future assessments of other Facility study areas should consider the drilling method and local lithology to evaluate if MIS sampling would be appropriate.

- Sampling: Summa Canister (active soil vapor – see HEER Section 7.8; Table 7-3)

Active soil vapor sampling was completed at this site in conjunction with soil vapor screening by PID. The active sampling was completed using 1-L (100% certified) Summa Canisters. The documents reviewed do not indicate the length of time the Summa canisters were allowed to draw for or the flow rate, leak detection procedures, or other pertinent field collection data. Due to the estimated location of the perched water table, moisture could have been a concern for the collection of these samples.

In HEER Office TGM Section 7.8, Sampling Approaches and Equipment, details and compares sampling approaches for soil vapor and indoor air and contains a detailed discussion of the benefits and disadvantages. Summa cannisters are widely used, familiar to most consultants, can obtain low detection levels, and are easily shipped. The fixed volume of summa canisters can lead to problems obtaining volume in tight formations. Other complexities with Summas include performing leak tests and set up can be difficult for new professionals, those with little experience, and difficult in certain site-specific conditions. Summa cannisters are considered more representative of vapor conditions than smaller volume samplers such as sorbent tubes; however, both are recommended for middle rage distillates in HEER (Section 7.8). Summa canisters are limited to the collection of VOCs over a restricted volatility range; however, for JP-5 related contamination this should be of little impact if VOC contamination at the Study Area is limited to volatiles of JP-5. Summa cannisters are susceptible to moisture, proximity to water in the perched zone should be considered in draw rates. Further discussion of active and passive sampling and the advantages and disadvantages can be found in HEER Section 7.

- Sampling: Handheld Hammer Drilling

Boreholes drilled using handheld hammer techniques resulted in low recovery of soil from the Adit 3 study area. The SCR even states that "[w]hen drilling was in rock, no soil was recovered" (SCR, pg. 24). The lack of soil recovery and lithologic descriptions resulted in important data gaps that limited the technical assessment of sub-surface conditions. The benefit of using a handheld hammer drill is that it can be used in areas that are not accessible to larger drilling rigs. However, it is recommended that other drilling methods be used, when possible, in order to improve soil recovery and lithologic documentation.

- Geophysical: Electrical Resistivity (ER) and Induced Polarization (IP)

Based on the results of the Jan/Feb 2022 HGI Geophysical Investigation Report, additional ER and IP investigations are not recommended in environments similar to Adit 3. A detailed discussion of the results and rationale for this recommendation can be found in Appendix A of this TM.

- Geophysical: Ground Penetrating Radar (GPR)

Based on the results of the Jan/Feb 2022 and November 2022 HGI Geophysical Investigation Reports, 1) additional analyses are needed to determine whether specific GPR data analysis techniques can potentially identify the presence of LNAPL in the subsurface and 2) additional GPR investigations may be appropriate in certain circumstances. A detailed discussion of the results and rationale for these recommendations can be found in Appendix A of this TM.

4 Summary

In summary, the Site Characterization investigations performed at Adit 3 in response to the November 20, 2021 JP-5 fuel release suffer from 1) the limited scope of the investigations, 2) overreliance on screening techniques (e.g. PID measurements), 3) lack of boring logs, lithologic descriptions, and soil recovery, and 4) improper characterization and use of sample data.

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Appendix A
Geophysical Investigations

1 SCR Geophysical Investigations Technical Review

hydroGEOPHYSICS (HGI) was contracted to perform geophysical investigations with the objectives of determining potential geophysical methods and technologies capable of characterizing the subsurface geology; identifying migration pathways, obstructions, and additional investigation areas; and potentially detecting the presence of NAPL. Two investigations were performed, the first (Appendix A.1) in January and February 2022, and the second (Appendix A.2) in November, 2022. The first geophysical investigation consisted of electrical resistivity/induced polarization surveying (ER/IP) and ground penetrating radar (GPR) methods, while the second investigation consisted of GPR methods only. A detailed description of the ER, IP, and GPR techniques can be found in Appendix A.1.

2 Electrical Resistivity (ER)/Induced Polarization (IP)

2.1 ER/IP Survey Design and Forward Modelling

Various ER/IP "arrays", which describe electrode layout and data acquisition schemes, can be employed. Arrays and data acquisition schemes offer different advantages and disadvantages in terms of vertical and horizontal resolution, imaging depth, and sensitivity to electrical interference. Prior to collecting ER/IP data, HGI performed forward modeling and inversions to identify limitations of the ER collected within a tunnel.

Two scenarios were tested. The first scenario compared the effects of ER data collected inside a tunnel as opposed to the ground surface. Most ER inversion software assumes a "2D halfspace", where the space above the electrodes is a very good insulator, e.g. the atmosphere, so no electrical current can flow in this region. Because the data were to be collected inside Adit 3 but the 2D halfspace was assumed, the effect of the material to the sides and above the tunnel on the inversion process was unknown. To test these sensitivities, three separate models were constructed by varying the location of a low conductivity feature above, to the side, and below the tunnel. Results showed that low conductivity anomalies above the tunnel had little to no effect on resistivity models, anomalies to the side of the tunnels may have more subtle but noticeable effects, and anomalies beneath the tunnel showed the largest sensitivity to the final models. The second scenario simulated the effect of the Red Hill Water Development Tunnel, as a water or air-filled tunnel beneath Adit 3, on the ER data. Modeling determined the tunnel would not likely be imaged using the ER technique. HGI also concluded this method was unlikely to image preferential pathways between the Adit 3 and the water development tunnel.

2.2 ER/IP Field Data Collection

During January and February 2022, 1,300 ft of ER/IP data were collected inside Adit 3, starting at the west entrance to the east, including 430 ft beyond the release area. Three different array types were collected to determine which provided the best quality data. An additional 420 ft of

ER/IP data were collected starting from the eastern spur of the Pearl Harbor Wye towards the south, using the array determined to provide the best data quality. Data collection methods appeared to meet industry standards and are not discussed further.

2.3 ER/IP Data Analysis and Inversion

Prior to modelling and inversion, raw ER data were filtered to remove obvious or statistical outlier data likely affected by interference from metal and/or utilities. Poor quality IP data were identified and rejected using a curve matching technique described in Appendix A.1, pg. 15. Modeling and inversion of filtered data was performed using Res2DINV, a well-documented ER/IP inversion software. These techniques appear to meet or exceed industry standards.

2.4 ER/IP Model Results, Interpretation, and Limitations

The final resistivity and chargeability models were interpreted, to the extent possible, by HGI for interference from utilities/metal, subsurface geology, and potential correlations between chargeability and hydrocarbons. Each of these items are discussed below.

2.4.1 Interference from Utilities

The ER and IP methods are especially sensitive to metal conductors, and utilities are pervasive within Adit 3 and the Pearl Harbor Tunnel. The most common method to limit interference from metallic infrastructure is to collect ER/IP data at large distances from the interference source. This was not an option given the limited space within the tunnels.

Even after poor quality data rejection, HGI identified numerous and extensive zones within the models that were affected by utilities. These areas were identified as “No Coverage” on the figures. The pervasiveness of interference from utilities severely limited the usefulness of the remaining resistivity and chargeability data.

Not considered in the report is that while data with obvious signs of interference from utilities can be removed prior to modeling, interference that causes subtle to moderate changes in measured data are nearly impossible to identify and address without very detailed knowledge of the position, location, size, and electrical properties of the subsurface structures. These smaller magnitude effects on measured data will still produce consequential distortions in modeled data. Given the complexity of utilities present in the tunnels, their influence cannot be avoided, and attempts to minimize interference through incorporation of their structure into the forward modeling process is likely impractical or impossible.

2.4.2 Subsurface Geology Interpretations

ER and IP data are commonly correlated to known geological features using geologic maps, lithology logs, rock exposures, or other sources of geologic information that can be used to “ground truth” the ER and IP models. Other than a general knowledge of typical local geology in the area, HGI had no other information with which to interpret the ER/IP data. HGI relied on typical resistivity and chargeability values for geologic materials and their own experience to interpret the modeled data. The lack of confirmative data increases the uncertainty in geologic interpretations. HGI's forward modeling and inversion testing prior to collecting field data also determined preferential flow paths through the vadose zone were not likely to be imaged. Combined with the interference from metallic infrastructure, geologic interpretation of either the resistivity or chargeability models is not warranted.

2.4.3 Correlations to Presence of Hydrocarbons

HGI discusses that a "slightly elevated IP response" could be "indicative of hydrocarbons, clay or volcanic materials such as tuff". HGI appears to base the possible correlations between elevated IP responses and VOC concentrations on visual inspection of the figures. A quantitative evaluation of chargeability versus VOC concentrations could be performed by cross-plotting these values.

The presence of NAPL has been associated with changes in chargeability in some studies, but the mechanism for the IP responses is not always well understood. IP responses due to hydrocarbons are commonly associated with hydrocarbon biodegradation. Results from ER/IP monitoring studies related to NAPL are usually qualitative and should not be solely relied on for the purposes of establishing a contaminant's concentration, presence, or lack thereof. Given the known interference from metallic infrastructure and other possible explanations for elevated IP responses, such as the presence of clay, the usefulness of IP for inferring the presence of NAPL is likely low.

2.4.4 ER/IP Model Heterogeneity

The ER/IP models for both Lines 1 and 2 show strong heterogeneity in resistivity and chargeability values. Some heterogeneity is expected in the near surface, but usually these heterogeneities can be explained by observed surface features, utilities, or known geologic changes. Resistivity and chargeability variations to the degree modeled beneath Lines 1 and 2 are not consistent with geologic or subsurface features. HGI identified 24 metallic infrastructure responses and labeled them as areas of "No Coverage" in their figures. They also note that the zone of influence for these regions is generally much larger than the infrastructure creating the interference. The near surface heterogeneity along the entirety of both ER/IP lines is exceptionally high and suggests interference from near surface infrastructure is not limited to the zones labeled as No Coverage.

Generally, ER and IP models are more homogeneous at greater depths, resulting from the decreasing resolution with depth of the ER/IP method. Model variations at deeper depths are usually caused by large geologic features, such as faults or large-scale changes in lithology.

Abnormally large, abrupt, near vertical changes as seen in numerous locations in Line 1 usually result from interference from metallic infrastructure.

2.4.5 HGI Recommendations

HGI proposed surface deployed ER surveying above Adit 3 and surrounding areas to avoid the effects of metallic infrastructure on the measurements. Surface deployed ER would likely not suffer similar interference as the tunnel deployed surveys, but the elevation of the proposed surveys would be hundreds of feet higher than the tunnel surveys. The resulting model resolutions at depths of interest would likely be too low to be of value for site characterization.

3 GPR Surveying

In January and February 2022, HGI collected GPR data along approximately 1300 ft of Adit 3, 420 ft of the Pearl Harbor tunnel, and within each lower access tunnel near tanks 17 through 20. 50 MHz, 100 MHz, and 200 MHz unshielded antennae were used. During November 2022, additional GPR data were collected in Adit 3 using 250 MHz, 500 MHz, and 1000 MHz shielded antennae. Three lines were collected: one along each side and one down the middle between the rail tracks.

3.1 GPR Interpretation Methodologies

GPR data were interpreted and analyzed using three different methodologies: 1) creation of a radargram, 2) the power spectra of each GPR trace, and 3) the filtered mean amplitude of traces with time.

Radargrams are the most common GPR interpretation method, which consists of displaying signal traces along a 2D profile. The radargram was used to visually interpret subsurface boundaries, such as the bottom of concrete or the water table. Radargrams are especially useful for identifying buried piping and conduits, which are identifiable as distinct hyperbola.

The power spectra is the square of the Fourier transform for each GPR trace. The power spectra are displayed as the relative magnitudes of the frequencies that make up each trace. Studies have shown reductions and/or changes in the overall power spectra may occur in the presence of LNAPLs.

The filtered mean amplitude method attempts to compare the amplitudes of uncontaminated zones with contaminated zones. Similar to the power spectra method, some studies have shown that the overall amplitude is reduced in the presence of LNAPL.

Neither the power spectra nor filtered mean amplitude methods are solely sensitive to the presence of LNAPL, which are also affected by other conditions such as saturation and geology. HGI uses these methodologies to ‘recommend anomalies for additional exploration’ with the understanding of the inherent non-uniqueness of the interpretation methods.

3.2 Jan/Feb 2022 GPR Investigation

For the Jan/Feb 2022 investigation, HGI selected low to moderate frequency, unshielded antennae. The resolution and depth of investigation of GPR data are both affected by an antenna's frequency. Lower frequency antennae usually allow for deeper investigation but with lower resolution, while higher frequency antennae can provide more resolution but at shallower depths. The unshielded antennae were chosen since they are more powerful than shielded antennae and can penetrate deeper into the subsurface. In the right conditions, a 50 MHz antenna could potentially image depths down to the water development tunnel.

During this first investigation, the unshielded antenna experienced problems with air wave reflections off of tunnel walls and strong interference from utilities. The 50 MHz and 100 MHz data contained so much interference that HGI focused their analyses on the 200 MHz data. Even the 200 MHz data, however, still suffered from utility and air wave interference, making data interpretation difficult. HGI returned in November 2022 and collected better quality, shielded GPR data along Adit 3. As a result, only the November 2022 data are discussed in this memo.

3.3 November 2022 GPR Results, Interpretations, and Limitations

A detailed description of GPR collection and methodologies for the November 2022 GPR investigation can be found in Appendix A.2. The use of shielded, higher frequency antennae for this investigation allowed for some interpretation of subsurface features. The GPR radargrams were interpreted for "two types of anomalies", stratigraphic layers (geology) and (potentially) the water table; the power spectra and filtered mean amplitude were interpreted for the potential presence of LNAPL. The depth of investigation was limited to a maximum of 12 ft in the 250 MHz data.

Similar to the Jan/Feb 2022 investigation, the GPR data were strongly affected by the presence of metallic infrastructure. The middle line, collected between the center of the tracks, was generally unusable "due to the metal cross ties buried beneath the rails."

3.3.1 Geology

HGI used data from all three antennae to interpret subsurface layering. Due to a lack of lithologic information, only the thickness of the concrete floor could be interpreted with certainty. The concrete floor varied in thickness from approximately 6 to 9 inches and contained metal reinforcement that varied in depth and spacing. Depending on the location, one or two layers ranging in thickness from 1 to 2 ft were commonly interpreted in the top 4 ft. Geologic interpretation of the layers could not be performed due to the lack of lithologic information.

3.3.2 Water Table

Using the radargrams and water levels provided by AECOM, HGI interpreted a laterally continuous water table along Adit 3 from distance 00-40 to near the west entrance of Adit 3 at 00+500. Interpretations of reflectors associated with the water table can be difficult, even with groundwater-level data for comparison. Without lithologic information available, it is unknown whether the water-level measurements are measuring levels in a highly porous layer, such as gravel, or in a lower porosity bedrock. If the water-level measurements are being measured from within a massive basalt, a laterally continuous GPR reflector off the water table would be unlikely. The reflector would more likely represent a lithology change and not the water table.

3.3.3 Correlations to the Presence of LNAPL

The power spectra and the filtered mean amplitude were used to identify the potential presence of LNAPL in the subsurface. Identifying LNAPL using the power spectra generally requires a very clear change in frequencies or amplitudes. The report does explain that the changes in power spectra could be due to a number of other factors (e.g. moisture, clay, etc.), but it should be emphasized that, based on the results in this report, relying on the power spectra to map LNAPL is not possible. The report also suggests there exists "a loose qualitative association with dampened amplitude and high soil vapor." Any association of "Soil Vapor Concentration" and a dampened amplitude is not obvious from inspection of the amplitude figures.

The lack of confirmation data linking power spectra variations or the filtered mean amplitude reductions to the presence of LNAPL means interpretations made using these methodologies are currently speculative. Additional data or analysis, such as a cross-plot of power spectra and measured LNAPL thickness, could determine the efficacy of these methods for identifying LNAPL in the subsurface. Without verification, the utility of these methods within Adit 3 remains unproven.

3.3.4 Utilities

Metallic infrastructure, such as metal pipes, can be identified within the radargrams, suggesting GPR could be useful for mapping the tunnel infrastructure.

4 Conclusions

4.1 <u>ER/IP</u>

Based on HGI's Appendix A.1 report, the ER/IP data collection methods, modeling and inversion methodologies, and quality assurance/quality control (QA/QC) generally meet or exceed standard practices. Despite these practices, the unique site conditions (inside of a tunnel with significant metallic infrastructure) resulted in ER and IP data that, in our view, are not usable.

4.2 GPR

Similar to HGI's ER/IP investigation, the GPR data collection methods, processing, and analyses meet or exceed standard practices. A lack of geologic information and interference from metallic infrastructure, however, severely limit the usefulness of the GPR data.

GPR radargrams were interpreted for subsurface layering. Without lithologic information for comparison, the layering information adds little to site characterization.

HGI attempted to infer the potential presence of LNAPL in the subsurface through power spectrum and filtered mean amplitude analyses of the GPR data. These two analyses may provide useful information regarding the presence of LNAPL, but no evidence provided in the report verifies the effectiveness of the methods.

4.3 Recommendations

Based on a review the SCR and Appendices A.1 and A.2, SSP&A makes the following recommendations:

- The surface deployed ER/IP methodologies are inappropriate for the conditions inside of Adit 3. ER/IP surveying should not be performed in similar conditions.
- A lack of detailed lithologic information hampered interpretation of all geophysical data collected. Geophysical data, specifically the GPR radargram layering and water table interpretations, should be reinterpreted using detailed lithologic information.
- Currently, the efficacy of the GPR power spectrum and filtered mean average methodologies at the site is not established. An analysis to determine any correlations between HGI's geophysical interpretations and the presence of LNAPL or other indicators of contamination should be performed. As a first step, relevant power spectrum or filtered mean amplitude data should be cross-plotted to a contamination indicator.
- Shielded, higher frequency GPR data, e.g. 500 MHz and 1000 MHz, showed effectiveness in detecting subsurface utilities. If subsurface utilities need to be located and identified, GPR may be considered a viable option.
- The three largest impediments to the HGI geophysical investigations were 1) a lack of geologic information with which to interpret the geophysical data, 2) interference from utilities, and 3) limited resolution of the geophysical techniques at depth. Performing borehole or cross-hole geophysical surveys, where geophysical measurements are taken from within a borehole, could potentially solve these three problems. Deep borings in locations of interest could be drilled and lithologically logged, providing information needed for more accurate geophysical interpretation. Geophysical surveying would be performed inside the borehole, away from the metallic infrastructure. Finally, the geophysical instrumentation would be in closer proximity to the geology of interest,

providing higher resolution information. Numerous borehole geophysical methods are available for structural, geologic, and hydrogeologic characterization.

Table 1

Task 7 and 8 Document Crosswalk and Incomplete Information

Site Characterization Report -November 2021 JP-5 Release in Adit 3, Operable Unit 1 Red Hill Bulk Fuel Storage Facility			Technical Memorandum: In-Progress Data Report, Adit 3 Site Characterization, Red Hill Bulk Fuel Storage Facility		
Document PDF page	**Table of Contents Description**	**Description of missing or incomplete information.**	**Document PDF page**	**Description**	**Comments**
Figures					
71	1-1 Vicinity Map	PDF page does not include the full Map. Map/page appears to be cropped.	--	--	No corresponding figure in the TechMemo
72	2-1 Site Features Map for Adit 3 Tunnel	PDF page does not include the full Map. Map/page cropped.	--	--	No corresponding figure in the TechMemo; Site features are displayed on Figure ES-1
77	5-1 Subslab Soil Vapor Monitoring Points	PDF page does not include the full Map. Map/page appears to be cropped. Unable to determine all locations of subslab vapor monitoring points.	26	Figure 2 Soil Vapor Sample Results From Selected Sub-slab Soil Vapor Monitoring Points	Figure 2 includes SVMP locations that match the locations on the section of Figure 5-1 that are visible but Figure 2 does not include the SVMP location names.
78	5-2 Geophysical Survey, February 2022	PDF page does not include the full Map. Map/page appears to be cropped. Unable to determine all locations of geophysical survey from this figure.	--	--	No corresponding figure in the TechMemo
79	5-3 Shallow Trench Sampling Locations	PDF page does not include the full Figure. Page appears to be cropped. Unable to determine all locations of Shallow Trench Samples from this figure.	--	--	No corresponding figure in the TechMemo; Trench and trench boring locations are displayed separately on Figure 3 and 4, respectively.
80	5-4 LNAPL Step-Out Boring, Temporary Wells.	PDF page does not include the full Figure. Page appears to be cropped. Unable to determine all locations of LNAPL Step-Out Boring Temporary Wells from this figure.	--	--	No corresponding figure in the TechMemo; Step-out boring locations are displayed on Figure 4.
81	6-1 Soil Vapor Monitoring Point Results, December 17, 2021 - January 9, 2023	PDF page does not include the full Figure. Page appears to be cropped. Unable to determine all locations and results from soil vapor sampling from this figure.	25	Figure 1 Sub-slab Soil Vapor Monitoring Point Handheld Photoionization Detector Results	PID results from December 17, 2021 - November 28, 2022; Figure 1 does not include results from December 2022 and January 2023 (n=3) that are included in Figure 6-1.
88	8-1 Soil Sample Results from Tunnel Floor Cutout Trenches	PDF page does not include the full Figure. Page appears to be cropped. Unable to determine all locations and results from this figure.	27	Figure 3 Soil Sample Results from Tunnel Floor Cut-Out Trenches	Matches the section of Figure 8-1 that is visible

Table 1

Task 7 and 8 Document Crosswalk and Incomplete Information

Site Characterization Report -November 2021 JP-5 Release in Adit 3, Operable Unit 1 Red Hill Bulk Fuel Storage Facility			Technical Memorandum: In-Progress Data Report, Adit 3 Site Characterization, Red Hill Bulk Fuel Storage Facility		
Document PDF page	**Table of Contents Description**	**Description of missing or incomplete information.**	**Document PDF page**	**Description**	**Comments**
89	8-2 Soil Sample Results from Tunnel Floor Boreholes	PDF page does not include the full Figure. Page appears to be cropped. Unable to determine all locations and results from this figure.	28	Figure 4 Soil Sample Results From Tunnel Floor Boreholes	Matches the section of Figure 8-2 that is visible
90	8-3 Groundwater Sample Results from Tunnel Floor Boreholes and Temporary Wells	PDF page does not include the full Figure. Page appears to be cropped. Unable to determine all locations and results from this figure.	29	Figure 5 Groundwater Sample Results from Tunnel Floor Boreholes and Temporary Wells	Matches the section of Figure 8-2 that is visible
91	8-4 Soil Vapor Sample Results From Selected Subslab Soil Vapor Monitoring Points (February 2022)	PDF page does not include the full Figure. Page appears to be cropped. Unable to determine all locations and results from this figure.	26	Figure 2 Soil Vapor Sample Results From Selected Sub-slab Soil Vapor Monitoring Points	Matches the section of Figure 8-3 that is visible
92	8-5 Soil Vapor Sample Results From Selected Subslab Soil Vapor Monitoring Points (December 2022)	PDF page does not include the full Figure. Page appears to be cropped. Unable to determine all locations and results from this figure.	--	--	No corresponding figure in the TechMemo
--	8-6 Soil Vapor Sample Results From selected Subslab Soil Vapor Monitoring Points (January 2023)	Is not included in document.	--	--	No corresponding figure in the TechMemo
93	Preliminary Conceptual Site Model	PDF page does not include the full Figure. Page appears to be cropped. Unable to review the graphical representation of the conceptual site model.	--	--	No corresponding figure in the TechMemo
Tables					
127-129	Table 8-2 Subsurface Soil Sample Results from Adit 3 Trenches	Table is cropped/cut off and incomplete inclusion of data.	13-Nov	Table 4. Subsurface Soil Sample Results from Adit 3 Trenches	Matches the section of Table 8-2 that is visible

Table 1

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Site Characterization Report -November 2021 JP-5 Release in Adit 3, Operable Unit 1 Red Hill Bulk Fuel Storage Facility			Technical Memorandum: In-Progress Data Report, Adit 3 Site Characterization, Red Hill Bulk Fuel Storage Facility		
Document PDF page	**Table of Contents Description**	**Description of missing or incomplete information.**	**Document PDF page**	**Description**	**Comments**
	Table 8-3 Subsurface Soil Sample Statistics from Adit 3 Trenches	Table is missing the number detected and % detected for Benzene, Toluene, and Ethylbenzene	14	Table 5. Subsurface Soil Sample Statistics from Adit 3 Trenches	Includes one (1) detection and 7% detected for Benzene, Toluene, and Ethylbenzene; Section 8.1.1.3 lists a 13% detection rate for Benzene.
132-136	Table 8-5 Subsurface Soil Sample Results from Adit 3 Boreholes	Table is cropped/cut off and incomplete inclusion of data.	15-19	Table 6. Subsurface Soil Sample Results from Adit 3 Boreholes	Matches the section of Table 8-5 that is visible
138	Table 8-7 Sample Locations Exceeding DOH EALs for Soil by COPC in Boreholes	Table is cropped/cut off and incomplete table notes.	--	--	No corresponding table in the TechMemo
139	Table 8-8 Groundwater Sample Results from Adit 3 Bore Holes	Table is cropped/cut off and incomplete inclusion of data.	21-22	Table 8. Groundwater Sample Results from Adit 3 Bore holes and Temporary Wells	Matches the section of Table 8-8 that is visible
142	Table 8-11 Groundwater Sample Results from Adit 3 Temporary Wells	Table is cropped/cut off and incomplete inclusion of data.	21-22	Table 8. Groundwater Sample Results from Adit 3 Bore holes and Temporary Wells	Table 8 includes results for four (4) temporary wells. Additional wells not included.
145	Table 8-14 Soil Vapor Sample Results from Adit 3 Soil Vapor Monitoring Points (February 2022)	Table is cropped/cut off and incomplete inclusion of data.	9	Table 2. Soil Vapor Sample Results from Adit 3 Soil Vapor Monitoring Points	Matches the section of Table 8-14 that is visible
148-149	Table 8-17 Soil Vapor Sample Results from Adit 3 Soil Vapor Monitoring Points	Table is cropped/cut off and incomplete inclusion of data.	--	--	No corresponding table in the TechMemo
152-153	8-20 Soil Vapor Sample Results from Adit 3 Soil Vapor Monitoring Points (January 2023)	Table is cropped/cut off and incomplete inclusion of data.	--	--	No corresponding table in the TechMemo

Table 1

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Document PDF page	**Table of Contents Description**	**Description of missing or incomplete information.**	**Document PDF page**	**Description**	**Comments**
298-324	Unknown	PDF pages do not include the full Figures. Pages appear to be cropped. Unable to review the figures.			
Appendices					
159-324	Appendix A -- Geophysical Investigation Reports	PDF pages 298-324 do not include the full Figures. Pages appear to be cropped. Unable to review the figures.	--	--	No corresponding information in the TechMemo
325-365	Appendix B -- SVMP PID Natural Gas Data	Included 97 unique location IDs, text has 52 SVMP locations	--	--	No corresponding information in the TechMemo
366-1235	Appendix C -- Product Technical Evaluation	Includes laboratory report(s) for LNAPL samples and GSI Environmental's technical memo.	31-136	Appendix C -- Product Forensics Technical Memorandum	Corresponds to PDF pages 1129-1235 SCR
1236-1798	Appendix D -- Level II Laboratory Sample Delivery Group Reports	Corresponds to Tech Memo pages PDF 1026-1588, although more data is reported in the text, tables, and figures.	1026-1588	Appendix E -- Laboratory Data Packages	Corresponds to PDF pages 1236-1798 SCR
1799-2687	Appendix E -- Analytical Chemistry Data Validation Reports	Includes same data validation reports as Tech Memo pages 137-1025.	137-1025	Appendix D -- Data Verification/Validation	Corresponds to PDF pages 1799-2687 SCR