Red Hill Bulk Fuel Storage Facility Draft – Work Plan

Pearl Harbor, Hawaii

April 2005

Department of the Navy
Commander
Naval Facilities Engineering Command, Pacific
Pearl Harbor, HI 96860-3134

Indefinite Delivery/ Indefinite Quantity Contract

Contract Number N62742-02-D-1802, CTO 007

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Prepared for:

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Commander
Naval Facilities Engineering Command, Pacific
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Prepared under:

Indefinite Delivery/ Indefinite Quantity Contract
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NAVFAC

Red Hill Bulk Fuel Storage Facility
Draft – Field Sampling Plan
Pearl Harbor, Hawaii
April 2005

IDIQ
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CTO 007

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LIST OF ACRONYMS

AMEC	AMEC Earth and Environmental, Inc.
AOC	Area of Concern
ARAR	Applicable or Relevant and Appropriate Requirements
AST	Aboveground Storage Tank
AVGAS	Aviation Gasoline
bgs	Below existing ground surface
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
COPC	Chemical of Potential Concern
CSM	Conceptual Site Model
CTO	Contract Task Order
DCE	Dichloroethylene
DFM	Diesel Fuel Marine
DO	Diesel Oil
DPP	Department of Planning and Permitting
DQO	Data Quality Objective
EarthTech	EarthTech, Inc.
EAL	Environmental Action Level
EPA	Environmental Protection Agency
F	Fahrenheit
FISC	Fleet Industrial Supply Center
FSP	Field Sampling Plan
GIS	Geographic Information System
HDOH	State of Hawaii Department of Health
IDW	Investigation-Derived Waste
JP-5	Jet Propulsion Fuel
LNAPL	Light Non-aqueous Phase Liquid
mg/kg	Milligrams per kilogram
mg/l	Milligrams per liter
MGD	Million Gallons per Day
MNA	Monitored Natural Attenuation
MOGAS	Motor Gasoline
MP	Monitoring Probe
msl	Mean Sea Level
MW	Monitoring Well
NAPL	Non-aqueous Phase Liquid
NAVFAC	Naval Facilities
NCP	National Contingency Plan
NDS	Navy Distillate
NEESA	Naval Energy and Environmental Support Activity

NSFO	Navy Special Fuel Oil
Ogden	Ogden Environmental and Energy Services Company, Inc.
OWDF	Oil Waste Disposal Facility
PACDIV	Pacific Division
PAH	Polynuclear Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyl
PCE	Tetrachloroethylene (Perchloroethylene)
PID	Photoionization Detector
PVC	Polyvinyl Chloride
PWC	Public Works Center
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
RA	Risk Assessment
RBCA	Risk Based Corrective Action
RHSF	Red Hill Bulk Fuel Storage Facility
RI	Remedial Investigation
SARA	Superfund Amendments and Reauthorization Act
SESOIL	Seasonal Soil Compartment Model
SCS	Site Characterization Study
SI	Site Investigation
SOP	Standard Operating Procedure
SOW	Statement of Work
SSHSP	Site-Specific Health and Safety Plan
SVMW	Soil Vapor Monitoring Well
SVOC	Semi-volatile Organic Compounds
TBC	To Be Considered
TCA	Trichloroethane
TCE	Trichloroethylene
TEC	The Environmental Company, Inc.
TFH	Total Fuel Hydrocarbons
TPH	Total Petroleum Hydrocarbons
UDA	Unauthorized Discharge Area
UIC	Underground Injection Control Line
USEPA	United States Environmental Protection Agency
USN	United States Navy
UST	Underground Storage Tank
VC	Vinyl Chloride
VOC	Volatile Organic Compound
WP	Work Plan
3-D	Three Dimensional
°	degrees

SECTION 1
INTRODUCTION

This document serves as a Work Plan for a Site Investigation (SI) and Risk Assessment (RA) at the Red Hill Bulk Fuel Storage Facility (herein referred to as RHSF) operated by the Fleet Industrial Supply Center (FISC), Pearl Harbor, Hawaii. The study area is defined as Red Hill, Oahu, Hawaii (**Figure 1-1** and **Figure 1-2**). This Work Plan has been prepared by The Environmental Company, Inc. (TEC) and AMEC, Earth and Environmental (AMEC) for Naval Facilities (NAVFAC) Pacific as part of Contract Task Order (CTO) 007. The plan has been prepared on the basis of the Statement of Work (SOW), dated September 1, 2004, and the Technical Proposal and Cost Estimate negotiated on September 15, 2004. All work for these planning documents have been authorized under the U.S. Navy Environmental Contract No. N62742-02-1802.

This Work Plan (WP), along with the companion Field Sampling Plan (FSP) and Quality Assurance Project Plan (QAPP), will be the basis for conducting a SI and RA for the Site. The SI will supplement previous environmental investigations conducted at the site and acquire data to support the RA. This WP provides a summary of the site background, proposed fieldwork, analytical testing program, construction of a geographic information system (GIS) three-dimensional (3-D) model, fate and transport modeling, and conduct of a Tier 3 Comprehensive Risk Assessment.

The WP is divided into the following sections:

- Section 1 provides a site description, location, and general project approach.
- Section 2 provides a summary of previous environmental investigations and describes the physical setting of the RHSF.
- Section 3 presents a preliminary conceptual model for the RHSF and outlines the Chemicals of Potential Concern (COPCs).

- Section 4 identifies focus components for the field investigation activities and Data Quality Objectives (DQOs) to support the activities.

- Section 5 discusses the general protocol for field investigations, data management and validation, preparation of the site characterization report, GIS modeling, fate and transport modeling, conduct of a comprehensive risk assessment, and contingency plan preparation.

- Section 6 presents a proposed project schedule.

- Section 7 provides document references.

Three companion documents supplement this Work Plan. A FSP (provided in **Appendix A**) presents the study design and includes detailed information on sample locations, sampling methods, and environmental matrices for sampling. A QAPP (provided in **Appendix B**) summarizes the analytical chemistry program including sampling methods, desired analytical chemistry quantitation limits, and the general quality assurance program. A Site Specific Health and Safety Plan (SSHSP) provided under separate cover outlines the procedures to protect all personnel present during field activities.

Various supporting documents are provided in the remaining appendices including a summary of construction activities at the facility (**Appendix C**), a previously conducted Preliminary Risk Evaluation (**Appendix D**), regulatory correspondence (**Appendix E**), auxiliary maps, and logs and report excerpts (**Appendix F**), FISC specifications for GIS data presented in Phase SOW (**Appendix G**), and PACDIV standard operating procedures (**Appendix H**).

1.1 Location And Setting

The RHSF is located on the island of Oahu, Hawaii, approximately 2.5 miles northeast of Pearl Harbor. The facility lies along the western edge of the Koolau Range and is situated on a topographic ridge that divides the Halawa Valley and the Moanalua Valley. The site is bordered to the south by the Salt Lake volcanic crater. The Site occupies approximately

144 acres of land. The majority of the surface topography of the Site lies at an elevation of approximately 200 to 500 feet above mean sea level (msl), however, much of the work conducted onsite will be in underground tunnels, which are located between 100 to 120 feet msl. The approximate location of the Site is depicted on the Site Vicinity Map, **Figure 1-1**.

1.2 SITE HISTORY

The facility was constructed by the U.S. Government in the early 1940s and incorporates 20 underground storage tanks (USTs), each with a capacity of approximately 12.5 million gallons (see Site Plan, Figure 1-2). The tanks are constructed of steel and currently contain JP-5 and Diesel Fuel Marine. Previously, several of the tanks have also been used to store Navy Special Fuel Oil, Navy Distillate, aviation gasoline (AVGAS) and motor gasoline (MOGAS). The fueling system is a self-contained underground unit that was installed into native rock comprised primarily of basalt with some inter-bedded tuffs and breccias. Each tank measures approximately 245 feet in height and 100 feet in diameter. The upper domes of the tanks lie at depths varying between approximately 100 feet and 200 feet below the existing ground surface. It is unknown if the tanks are presently leaking; however, on the basis of the previous site investigation and associated analytical data, one or more unauthorized releases have occurred at the site. Additional site history is provided in Section 2.3 and a summary of the facility construction history is provided in **Appendix C**.

1.3 PROJECT OBJECTIVES

The results of a previous Site Investigation (SI) (AMEC, 2002) indicated that petroleum hydrocarbons were reported in rock samples obtained beneath the USTs and that lead was detected in groundwater samples obtained from a monitoring well situated hydraulically down-gradient from the facility. The SI recommended the completion of a comprehensive Risk Assessment (RA) to quantify the risks associated with the observed compounds. In an effort to evaluate current and potential future risks from unauthorized releases to the subsurface the State of Hawaii Department of Health (HDOH), Solid Waste Branch concurred in a letter dated October 10, 2003 (**Appendix E**) that the U.S. Navy would:

- Conduct a comprehensive Tier 3 RA,
- Develop a comprehensive Conceptual Site Model (CSM) incorporating Fate and Transport Models to facilitate preparation of the RA,
- Prepare a Contingency Plan to protect the Navy's groundwater supply at Red Hill, and
- Monitor groundwater in the underlying basal aquifer and at the Public Works Center (PWC) potable water source at Red Hill.

To accomplish these goals, the Navy has adopted the following project objectives:

1. **GIS Model**. Compile existing electronic and hardcopy data regarding past activities at the Site, including lithologic descriptions obtained from excavation and boring logs; facility construction details, and published environmental information. The compiled data will be used to create a three-dimensional (3-D) geographic information system (GIS) model to facilitate data storage and 3-D visualization.

2. **Conceptual Site Model (CSM).** Develop a comprehensive CSM to illustrate potential sources, exposure pathways, and receptors. The CSM will be used to refine the site characterization activities, facilitate fate and transport calculations, and to communicate site conditions to regulators and stakeholders.

3. **Site Characterization Study (SCS).** Conduct a SCS to obtain data necessary to further characterize the documented release and to complete a Comprehensive Risk Assessment. The SCS will include the installation and sampling of groundwater monitoring wells and soil vapor monitoring points and the evaluation of Fate and Transport mechanisms using analytical and numerical modeling techniques.

4. **Applicable or Relevant and Appropriate Requirements (ARARs).** Prepare a list of ARARs and risk-based action levels for potentially impacted media.

5. **Risk Assessment.** Conduct a Tier 3 Comprehensive RA to determine chemicals of potential concern (COPCs), potentially complete exposure pathways, potential receptors, and exposure point action levels for each receptor and media.

6. **Monitoring System.** Develop a groundwater and soil vapor monitoring system that will allow the U.S. Navy to characterize the Site both laterally and temporally for past, present and future releases.

7. **Contingency Plan.** Develop a contingency plan that ensures unacceptable risks to human health and/or the environment from any past, present, and/or future releases are mitigated.

1.4 PROJECT APPROACH

The approach for the RHSF investigation is to obtain and evaluate information necessary to conduct a Tier 3 Comprehensive Risk Assessment, and prepare a Site Contingency Plan. This will be accomplished through the excavation of exploratory borings, installation of groundwater monitoring wells and soil vapor monitoring points, collection and analyses of soil, groundwater, and soil vapor samples from the monitoring network, construction of a GIS-based 3-D Site Model, and contaminant fate and transport modeling. The resulting information will be used to conduct the Risk Assessment and prepare the Contingency Plan. Specific COPCs to be evaluated in soil, groundwater, and soil vapor samples have been selected on the basis of chemical data collected during the previous SI (Ogden 1999) and the evaluation of fuels currently stored onsite. All COPCs are associated with petroleum fuels stored onsite. The proposed site investigation activities are further discussed in Sections 5.1 through 5.5 of this WP and the proposed field activities are further detailed in the FSP (**Appendix A**).

1.5 INVESTIGATIVE TEAM

The prime contractor and investigative team leader for the project is TEC. Primary support contractors include AMEC, Valley Well Drilling, and Accutest, Inc. **Table 1-1** presents a contact listing with a brief description of project responsibilities.

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Table 1-1

Contact Listing

Red Hill Bulk Fuel Storage SI and RA

Pearl Harbor, Hawaii

NAVFAC Pacific		
Project Contract Specialist	Ms. Jean Kuboyama	(808) 471-4666
Remedial Project Manager/Navy Technical Representative	Mr. Glenn Yoshinaga	(808) 472-1416
Fleet Industrial Supply Center		
Terminal Chief	Mr. Michael Gladson	
Technical Representative	Mr. Victor Peters	(808) 473-7890
RHSF Site Supervisor	Mr. Herb Kikuchi	(808) 437-7805 or 479-1063
Public Works Center		
Navy Hydrogeologist	Mr. Paul Eyre	(808) 473-0938
TEC Inc.		
Deputy Program Manager	Ryan Pingree	(808) 554-2433
Project Manager/ Hydrogeologist	Mr. Jeff Hart, R.G.	(808) 554-2433
Senior Risk Assessor	Mr. Glenn Metzler	(808) 554-2433
Regional Manager, Health and Safety Coordinator	Mr. Karl Bromwell	(808) 554-2433
Project Chemist	Mr. Peter Chapman	(808) 554-2433
Onsite Health and Safety Coordinator	Ms. April Chan	(808) 554-2433
Senior Geologist	Ms. Nicole Griffin	(808) 554-2433
Site Technician	Mr. Shawn Macmillan	(808) 554-2433
Project Engineer	Mr. Kevin McNiel, PE	(808) 554-2433

Table 1-1 (continued)

Contact Listing

Red Hill Bulk Fuel Storage SI and RA

Pearl Harbor, Hawaii

Subcontractors		
AMEC Project Manager		
AMEC Site Supervisor	Mr. Larry Demoss	
Valley Well Drilling, Supervisor	Mr. Mike Sober	(808) 682-1767
Accutest Analytical Services, Orlando Florida	Ms. Susan	(407) 425-6700
Pacific Commercial Disposal Services	Mr. Jingbo Chang	(808) 545-4599

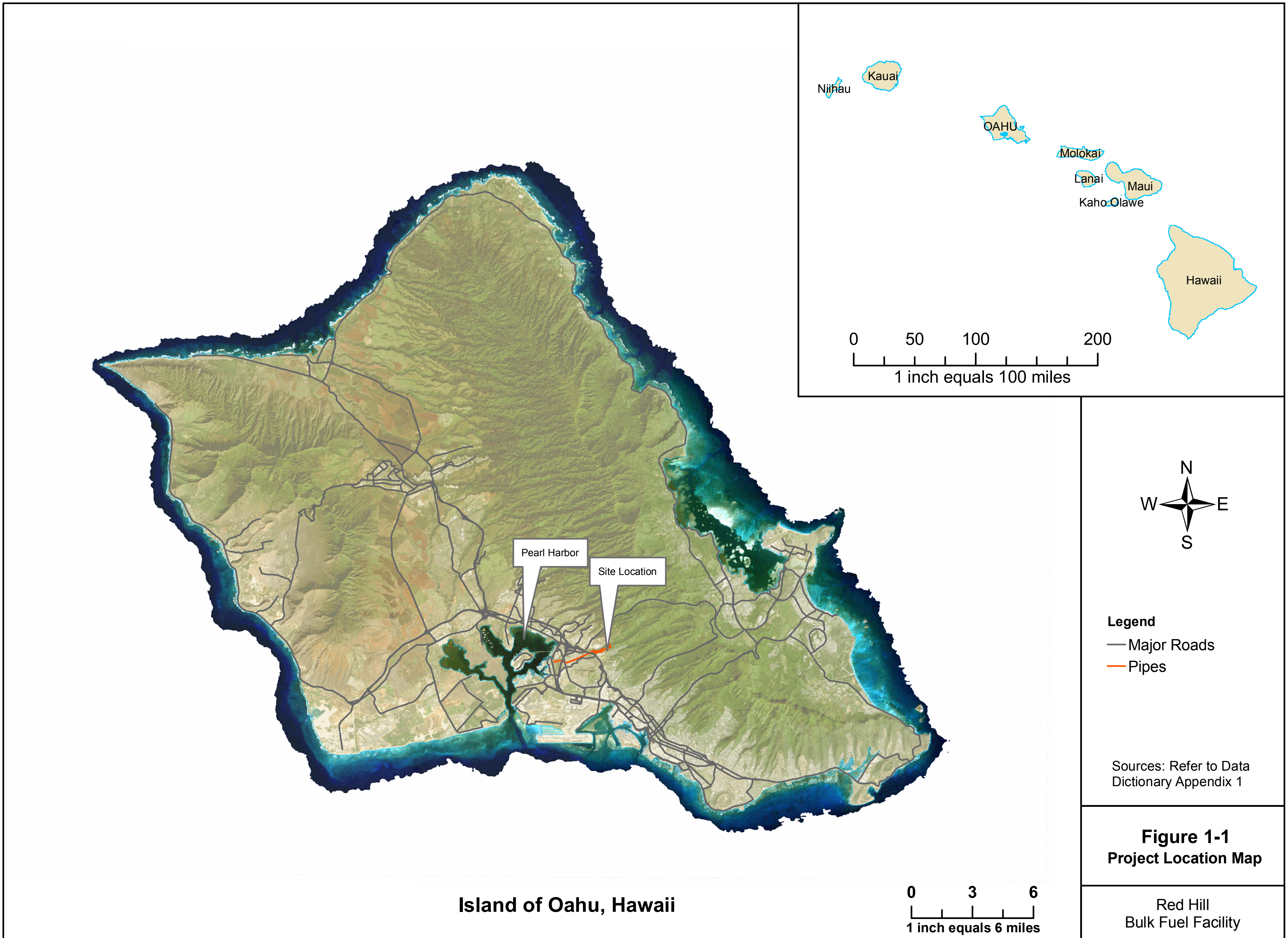
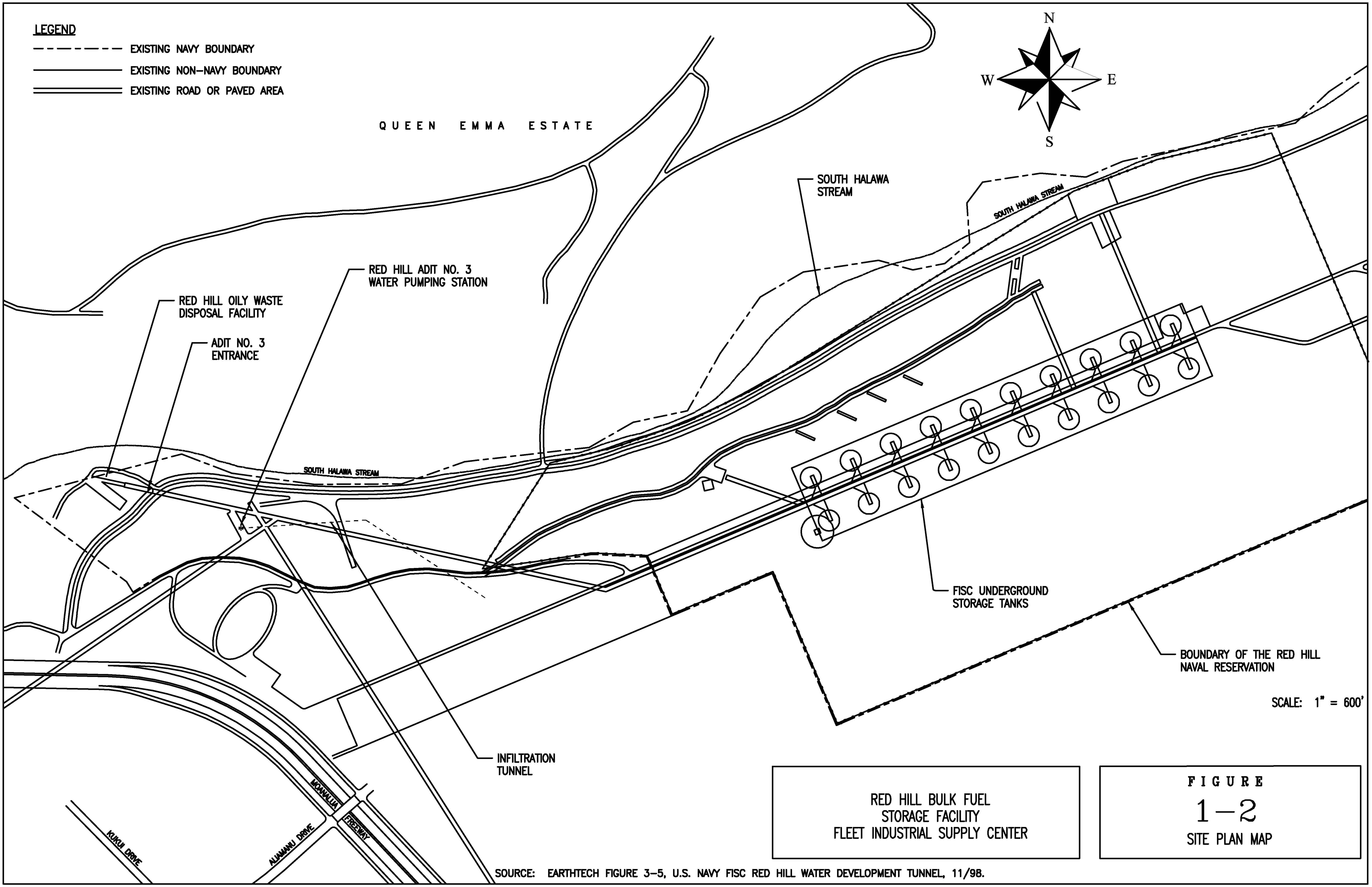


Figure 1-1
Project Location Map

Red Hill
Bulk Fuel Facility



RED HILL BULK FUEL
STORAGE FACILITY
FLEET INDUSTRIAL SUPPLY CENTER

FIGURE
1–2
SITE PLAN MAP

SECTION 2
SITE BACKGROUND

2.1 REGIONAL ENVIRONMENTAL DATA

2.1.1 PHYSICAL SETTING

The island of Oahu, part of the Hawaiian Island chain, lies at the northern margin of the tropics region (**Figure 1-1**). Oahu is located at latitude 21.433 North and longitude 157.966 West. Oahu is the third largest island in the chain and consists of extensive areas of mountainous land as well as coastal plains. The mountainous areas are comprised of two mountain ridges, the Koolau Range along the eastern side of the island, and the Waianae Range along the western side of the island.

2.1.2 LAND USE

Oahu is the center of economic activity for the Hawaiian Islands. Honolulu, located in the south-central portion of the island, is heavily urbanized and densely populated (**Figure 2-1).** The RHSF lies at the northern edge of an urbanized area (**Figure 2-2**) that is zoned Government (**Figure 2-3**). Urbanized areas stretch from the southern coast of Oahu northward, occupying the majority of the coastal plain.

2.1.3 DEMOGRAPHY

Oahu (Honolulu County) has a population of approximately 876,156 people. Populated areas closest to the Red Hill facility are Pearl City and Aiea to the west and Honolulu to south and east. On the basis of 2000 census data, the populations of Pearl City and Aiea are 30,976 and 9,019, respectively, and the population of Honolulu is 371,657 (2000 US Census data). There is a Coast Guard and US Navy housing complex in Aliamanu Crater to the southwest of the RHSF. Pearl Harbor lies to the southwest of the Red Hill facility. The population of the Pearl Harbor military base is unlisted (Ogden, 1999). The nearest residential area is located southeast of the site in Moanalua Valley, directly adjacent to the facility perimeter.

2.1.4 CLIMATE

The prevailing northeast trade winds and the ocean currents cause the air and water of the region to be cooler than other areas of similar latitude. Ocean temperatures range from 75 to 85 degrees Fahrenheit (F) at Honolulu. Northeasterly winds persist most of the year and the northeastern, or windward, side of the island is commonly the wettest. Southerly winds blow for only a few days at a time during the winter months. Most of the severe storms on the island come from the south, as southerly winds pick up moisture from the open ocean before they arrive at the islands. Precipitation is at a maximum at elevations above 2,000 feet mean sea level (msl). October to April is the wet season, and May to September is the dry season. Small areas of northeast Oahu receive annual precipitation greater than 300 inches per year, however, most of the island receives 20 to 75 inches of precipitation annually. Precipitation on the island is most commonly in the form of rain.

2.1.5 REGIONAL TOPOGRAPHY

Topographically, the island of Oahu is divided into four geomorphic regions: the Waianae Mountain Range, the Koolau Mountain Range, the Schofield Plateau, and the Coastal Plains, which form the northwest and south island margins (**Figure 2-1**). The site is located on a ridge between Halawa and Moanalua Valleys and on the lower portion of the southwestern wall of Halawa Valley, the easternmost Koolau stream valley emptying into Pearl Harbor. The valley was formed by the coalescence of two valley heads, drained by the North and South Halawa Streams that merge on the Coastal Plain before emptying into Pearl Harbor. Regional topography in the vicinity of the Site is depicted on **Figure 2-4**.

2.1.6 REGIONAL GEOLOGY

The island of Oahu is comprised of the erosional remnants of two distinct volcanic ranges, the Waianae and the Koolau volcanoes. The Waianae Range covers the western side of the island, and the Koolau Range covers the central and eastern portions of the island. Red Hill is located on the southern edge of the Koolau Range, approximately 2.5 miles northeast of Pearl Harbor. The Koolau formation consists almost entirely of basaltic lava flows that erupted from a fissure line approaching 30 miles in length (Wentworth, 1951) and trending in a northwest rift zone.

During a volcanic quiet period approximately 2 million years, valleys approaching 600 meters in depth were cut into the Koolau volcanic range and sediment accumulated in the valley floors. The erosion of the Koolau volcano resulted in the formation of a delta of sediment consisting of silt and sand. The delta increased in thickness as it approached the sea. The RHSF is located along the topographic ridge that separates the Moanalua and Halawa Valleys. The ridge drops steeply on either side with the aforementioned sediments deposited in the valley bottoms (Williams, 1998).
Both pahoehoe and a'a lava flows are present in the Koolau formation. Pahoehoe is smooth, fine-grained lava with a rope-like appearance and is characterized by thin-walled vesicles. A'a lava is a jagged, blocky lava flow that contains clinker beds. These clinker beds are the more permeable feature of the a'a lava. According to Mink (1999), the a'a lava may act as a very localized confining layer to the basal system with unconfined conditions present just a few feet away. The a'a lava is more abundant in the lower flanks (Wentworth, 1951).

2.1.7 Regional Hydrogeology

Five primary groundwater flow systems have been described on Oahu: Northern, Eastern, Western, Southern, and Southeastern (**Figure 2-5**). The Site is located in the Southern Oahu Groundwater Flow System. The regional groundwater flow in the vicinity of the Site is directed to the southwest (**Figure 2-6**). The geology of the island has been classified into six main aquifer systems, with many sub-systems (**Figure 2-5**). The RHSF lies on a border of two such sub-systems, the Moanalua Aquifer and Waimalu Aquifer (**Figure 2-7).**

The HDOH has adopted the State of Hawaii regional aquifer classification by Mink and Lau (1990, hereafter referred to as "Mink and Lau") to determine the permissible uses for groundwater in the different areas of Hawaii. This classification is used to determine the set of HDOH criteria used for evaluation of soil and groundwater contaminants detected at the site (HDOH 1995). The aquifer classification criteria and groundwater designations are patterned after the EPA Groundwater Protection Guidelines (EPA 1984) and are used in conjunction with the HDOH Soil and Groundwater Action Levels. (EarthTech Phase II RI Report 1999)

2.1.8 Regional Water Quality

Groundwater provides most municipal and domestic water for a large and expanding population on Oahu. Most of the water is derived from extensive volcanic aquifers in thin-bedded basalts in central and southern Oahu. Although depth to groundwater can be as great as 600 to 1,000 feet in the interior of the island, most aquifers are considered unconfined and are vulnerable to contamination. There has been widespread detection of pesticides and herbicides in aquifers situated beneath agricultural lands and reports of volatile organic compounds (VOCs) in aquifers situated beneath known use or spillage (USGS Fact Sheet 006-98, 1998). A study completed in 1999-2001 reported organic compounds in most public water supply wells, but seldom at concentrations exceeding drinking-water standards. **Figure 2-8** depicts the approximate locations and contaminant status of groundwater supply wells in the Pearl Harbor and Honolulu area.

2.2 SITE-SPECIFIC ENVIRONMENTAL DATA

This section outlines the geographic features, land use, soils, geology, and hydrogeology of the site and surrounding areas.

2.2.1 Physical Setting

The RHSF is located on the island of Oahu approximately 2.5 miles northeast of Pearl Harbor. The facility lies along the western edge of the Koolau Range and is situated on a topographic ridge that divides the Halawa Valley and the Moanalua Valley (see **Figure 2-4**). The site is bordered to the south by the Salt Lake volcanic crater. The Site occupies approximately 144 acres of land. The majority of the Site lies at an elevation of approximately 200 to 500 feet above mean sea level (msl). The facility access adits generally exit the lower slopes of the South Halawa Valley. A general facility layout is provided in **Figure 2-9**.

2.2.2 Land Use

Current zoning information obtained from the City and County of Honolulu's Department of Planning and Permitting (DPP) (**Figure 2-3**) indicates that the site is located on federal government land (zoned F1 - Military and Federal) with public land adjacent to the north and northeast (zoned P1 - Restricted Parkland). A high cliff (approximately 100 to 200 feet elevation difference) in the public land area separates the Red Hill Naval Reservation from a mixed industrial area (zoned I2) and a residential area (zoned R5) containing the Halawa Correctional Facility further to the north and northwest. A quarry is located further to the northwest in an agricultural zone (zoned Ag2). The H3 Freeway is located northwest of the quarry.

A residential development, Moanalua Village, is located adjacent to the Red Hill Naval Reservation to the south and east (zoned R5- Residential). Further south is the Moanalua Golf Course (zoned P2- General Parkland and R5- Residential), a section of public land (zoned P1- Restricted Parkland), and the Tripler Army Medical Center (zoned F1- Military and Federal). A high cliff (approximately 100 to 200 feet elevation difference) separates the Red Hill Naval Reservation from Moanalua Village and the Moanalua Golf Course. The area to the northeast of the site is public land, which is mostly forested (zoned P1- Restricted Parkland). Moanalua Valley Park (zoned P2- General Parkland) and more public land (zoned P1- Restricted Parkland) are located to the east of the Moanalua Village residential development.

A gated residential community (zoned A2- Apartments) comprised primarily of townhouses and apartment buildings is located to the southwest of the site and a public school (Red Hill Elementary School) is also present in this area. The Red Hill Naval Reservation continues to the west and is adjacent to the Coast Guard Reservation, which borders Highway 78. Land use relationships are depicted on **Figure 2-2** (land use map), **Figure 2-3** (zoning map), and **Figure 2-10** (urban development map).

The closest residential property is within the area zoned for apartment buildings located approximately 305 feet southwest of Tank 2 and approximately 2,113 feet southwest of Tank 20 (the tank farthest to the east). Red Hill Elementary School is located approximately 1,080 feet southwest of Tank 2 and approximately 2,850 feet from Tank

20. The Moanalua Village residential development is located approximately 880 feet south of Tank 2 and approximately 875 feet south of Tank 20.

2.2.3 PRECIPITATION

The closest weather station is located at Aiea Heights 764.6, Honolulu at approximately 21.40°N latitude and 157.91°W longitude. The elevation at the weather station is approximately 777 feet above mean sea level (msl). The following summary presents mean annual precipitation proximal to the site over a 13-year period from 1982 to 1995.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
mm	105.2	128.9	144.3	130.5	83.4	93.1	114.8	79.5	95.4	130.3	138.1	195.7	1440.1
inches	4.1	5.1	5.7	5.1	3.3	3.7	4.5	3.1	3.8	5.1	5.4	7.7	56.7

2.2.4 VEGETATION COMMUNITIES

As shown in **Figure 2-1**, approximately 15% of the island is urbanized, approximately 65% of the island is non-forested (i.e., grassland, agriculture, scrub-shrub, wetland), and approximately 20% of the island remains forested. For the most part, only the mountainous regions of Oahu remain forested.

The aboveground portion of the Site is inhabited by: (1) Haole koa scrub *(Leucaena leucocephala)*, (2) disturbed habitat, and (3) landscaped areas. Haole koa grows throughout Oahu, primarily in areas that have been disturbed by grazing or human activities (Wagner et al., 1990). The scrub community on Red Hill is dominated by Haole koa, Guinea grass *(Panicum maximum),* and Chinese violet *(Asystasia gangetica).* The disturbed habitat is comprised of weedy plant species that can withstand frequent disturbance by human activities or natural events. Although this vegetation does support some wildlife species, the habitat is considered to be of very low quality and is primarily used by introduced, common urban species (Ogden, 1996).

2.2.5 SENSITIVE SPECIES AND HABITATS

Hawaii is home to numerous federally listed threatened and endangered species, including 44 federally listed animals and 273 federally listed plants. Much of the non-developed portions of Oahu are currently proposed as critical habitat for numerous species. Due to the highly developed nature of the site, it is not anticipated that any Federal or state-listed threatened or endangered species occur onsite. Habitats onsite are not considered sensitive and are dominated by introduced species that do not usually support native species. However, no threatened or endangered species surveys have been conducted at the facility.

2.2.6 TOPOGRAPHY

The ground elevations at the aboveground facilities of the site range from approximately 200 to 500 feet above msl (see **Figure 2-4**). The tops of the bulk fuel storage tanks are approximately 100 to 200 feet below the existing ground surface (bgs), located directly below the aboveground facilities.

2.2.7 SOILS

Soils in the vicinity of the RHSF are mapped as Helemano-Wahiawa association consisting of well-drained, moderately fine textured and fine textured soils. 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 (Soil Conservation Service, 1972).

On the basis of a review of previous investigations performed in the vicinity of the Red Hill facility, soils consisting of clays and clayey gravels are common to a depth of 10 feet bgs. Along the slopes and over much of the open area south of the Schofield Saddle, the basaltic bedrock is covered with 10 to 30 feet of Koolau residuum (Wentworth, 1945). 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 fractured basalts were encountered at depth. The western slope of the Halawa Valley is generally barren of soil and consists of outcropping basalt lava flows to the valley floor.

2.2.8 GEOLOGY

As discussed in **Section 2.1.6**, the RHSF lies along a topographic ridge between the Halawa and Moanalua Valleys. The ridge is a remnant of the original Koolau shield volcano flank and it is composed of basaltic lava flows. The valleys on either side of the ridge are a result of fluvial erosion and are filled with alluvium/colluvium. A review of soil boring logs of boring V1D at the Site indicates that the Site is predominantly underlain by pahoehoe lava with small to medium sized vesicles. Pahoehoe lava is characterized by relatively thin-bedded basaltic flows with abundant thin-walled vesicles.

At a nearby drilling site, approximately 2000 feet southwest of V1D, the EarthTech, Inc. (EarthTech) reported (EarthTech 1999) the basalt bedrock appeared completely dry and massive at approximately 20 feet above msl, which was distinct from the highly fractured basalt overlying this unit and significantly different from the log of V1D. At the southwest location, basal groundwater was encountered directly beneath this massive unit at an elevation of approximately one to two feet below msl. After the monitoring wells were installed, the potentiometric groundwater surface stabilized at an elevation of approximately 16 feet above msl, suggesting that the massive lower basalt acts as a localized low-permeability layer, resulting in the confined groundwater conditions exhibited by the basal aquifer. However, Mink (1999) states that although the a'a lava can act as a local confining unit, it tends to be very limited in extent and, therefore, unconfined conditions may be encountered in close proximity.

Information in the Wilbros Engineers report (1998) supports Mink's findings and states that the RHSF is bounded on each side by deep alluvial fills and sedimentary caprock (marine and terrestrial sediments) in the down-gradient direction. In the area of the lower tunnel and the Red Hill portion of the Harbor Tunnel, the basal aquifer is located in permeable basalt on which the tunnel and tanks are located (Wilbros Engineers, 1998). This further supports Mink's theory that confined conditions are generally limited in extent.

2.2.9 HYDROGEOLOGY

The fuel storage tanks appear to be located above the Moanalua Aquifer system, which is part of the Honolulu Aquifer sector. However, Red Hill effectively serves as a geomorphic boundary between the Honolulu and the Pearl Harbor Aquifers. Therefore, the western part of the site overlies the Waimalu Aquifer system, which is part of the Pearl Harbor Aquifer sector. Both the Moanalua Aquifer and Waimalu Aquifer systems are classified by Mink and Lau as unconfined, basal, and flank. Their status is listed as a currently used, fresh (chloride content below 250 milligrams per liter [mg/l]) drinking water source that is irreplaceable and has a high vulnerability to contamination (Mink and Lau 1990).

The Site is located up-gradient of the Hawaii State Underground Injection Control Line (UIC), which typically segregates potable from non-potable groundwater. The nearest public drinking water well (Halawa Shaft, well number 2354-01) is located hydraulically cross-gradient of the Site. This drinking water well is approximately 5,000 feet to the northwest of the Site and pumps water from the basal aquifer. On average, 11 million gallons per day (MGD) are withdrawn from this location and account for approximately 7% of Honolulu County's water supply (Honolulu Board of Water Supply 2005). In addition, one U.S. Navy drinking water well (2254-01) is located near the site. This well is approximately 3,000 feet to the west of the site and are possibly hydraulically down-gradient from the site. Approximately 4.2 MGD are withdrawn from this location.

On the basis of water table measurements conducted in wells near the site, the basal groundwater potentiometric surface is approximately 16 feet above msl. The groundwater flow in the Red Hill area is expected to be to the southwest toward Aliamanu Crater (see **Figure 2-5** and **Figure 2-6**). Hydraulic conductivity varies from 500 to 1500 feet per day in this area; however, welded tuffs associated with the Aliamanu Crater may have significantly lower permeabilities and may affect the groundwater flow direction from the Site.

2.2.10 Local Water Quality

The basal aquifer is tapped as a source of drinking water by the Navy Public Works Center (PWC) and supplies the drinking water for the Pearl Harbor Naval Complex. The pumping station is located within the lower tunnel system and is situated approximately 0.5 mile to the west of the bulk fuel storage tanks. Regular testing of the basal aquifer is conducted through the PWC pump station by the PWC and HDOH to ensure that the water is maintained within drinking water standards. The analytical program at the PWC pump station addresses VOCs and other petroleum constituents of concern. No indication of petroleum contamination has been reported in basal aquifer water samples collected during periodic monitoring at the PWC pump station. A profile of the tanks and infiltration tunnel is provided in **Figure 2-11**.

2.3 Facility Description and History

Section 2.3 provides an overview of the general site layout and a summary of previous environmental investigations at the RHSF. Additional information regarding construction details and history is provided in Appendix C.

2.3.1 Facility Layout

The RHSF is located on the topographic ridgeline between south Halawa Valley and Moanalua Valley, west of Honolulu. Construction of the RHSF began late in 1940 and was completed in 1943. The facility incorporates 20 underground storage tanks (USTs), each with a capacity ranging from 285,000 barrels to 300,000 barrels, or approximately 12.5 million gallons (**Figure 2-9**).

The tanks are constructed of steel and currently contain Jet Propulsion Fuel (JP-5) and Diesel Fuel Marine. The bulk tanks were constructed in two parallel rows sloping south by southwest towards Pearl Harbor (**Figure 2-9**). The fueling system is a self-contained underground unit that was installed into native rock comprised primarily of basalt with some inter-bedded tuffs and breccias. Each tank measures approximately 245 feet in height and 100 feet in diameter. The upper domes of the tanks lie at depths varying between approximately 100 feet and 200 feet bgs. The tanks are connected by main upper and lower subsurface service tunnels, which contain light rail systems, water, electric utilities, and fuel pipelines. In the lower tunnel, each parallel tank is connected by a short access tunnel, which branches off the main service tunnel and terminates into a face-wall under each tank. Individual tank ancillary piping emerging from each face-wall connects the fuel transmission lines. The fuel pipelines traverse approximately 2.5 miles from the bulk tanks to a pump station at Pearl Harbor. The pump station is used to pump fuel from fuel tankers in Pearl Harbor to the bulk fuel storage facility. **Figure 2-9** depicts the approximate locations of the underground storage tanks and associated appurtenances in relation to nearby improvements and features.

The Navy PWC operates a water pumping station within the lower tunnel system proximal to Adit 3 and situated hydraulically down-gradient from the tank facility. The water pumping station is referred to as the Red Hill Adit No. 3 Water Pumping Station referred to previously as 2254-01 and its location is depicted on **Figure 2-9** and **Figure 2-11**. The water pumping station pumps water from the basal aquifer beneath Red Hill to the Pearl Harbor water distribution system. **Figure 2-11** depicts a generalized vertical cross section of the tank farm and the PWC public water pumping shaft. **Figure 2-12** through **Figure 2-14** provide additional plan views of the facility.

2.3.2 Storage Tank Usage

The tanks have historically contained diesel oil (DO), Navy special fuel oil (NSFO), Navy distillate (NDS), diesel fuel marine (DFM), aviation gasoline (AVGAS), motor gasoline (MOGAS), and jet propulsion fuel (JP-5). Originally, Tanks 3 through 20 contained NSFO and Tanks 1 and 2 stored diesel oil. However, over time, each tank has been utilized to store a variety of different fuel types. Currently, the tanks contain JP-5 or DFM. **Table 2-1** presents a historical record of petroleum storage in the tanks.

2.3.3 Unauthorized Releases

Historically, due to the sensitive classification of the fuel farm as the primary fuel storage facility for Pearl Harbor, public access has been limited and independent investigations to confirm suspected unauthorized releases were not conducted. The Red Hill facility was declassified in 1995. Facility records indicate that suspected or potential leaks may have occurred and have been repaired in several of the tanks. No record of a catastrophic release (such as most or all of a tank's contents being released) has been identified.

2.3.4 Ongoing Site Activities

The RHSF is currently functioning as a storage and distribution center for JP-5 and Diesel Fuel Marine. Ongoing site activities may potentially impact Site access or field investigation schedules. All site access should be coordinated through the RHSF manager. Currently, Tanks 15 and 16 are empty and undergoing maintenance. Tank 16 is expected to be the focus of soil vapor monitoring and just up-gradient from the middle Tank Farm monitoring well proposed to be installed during the current site investigation.

2.5 Previous Investigations

This section provides a summary of environmental investigations conducted at RHSF since the facility has been declassified.

2.5.1 Wilbros Engineering Report

FISC retained Wilbros Engineers to evaluate the conditions of the RHSF and to estimate the impact to the basal aquifer if a major release were to occur. During the environmental impact evaluation, Wilbros Engineers used two hypothetical scenarios of petroleum releases from the large capacity USTs in conjunction with geologic/hydrogeologic data to estimate the potential environmental impact to the potable drinking water source of the basal aquifer. The first scenario comprised a massive petroleum release with no improvements to the facility, and the second scenario included improvements to the facility designed to prevent large-scale impacts to the environment. (Wilbros Engineers, 1998).

Wilbros Engineers determined that, under both scenarios, a massive release of petroleum from storage tank 15 would detrimentally impact the basal aquifer beneath the Red Hill area, but the degree of impact in scenario two was significantly reduced in comparison to scenario one. Wilbros suggested that the lateral spreading of the contaminant would be impeded by the presence of natural groundwater barriers. Red Hill is bounded on each side of the ridge by alluvial fills derived from the Halawa and Moanalua streams (hydraulically cross-gradient) and the sedimentary caprock located near the harbor (hydraulically down-gradient). Wilbros proposed that the valley fill and caprock would act as groundwater barriers, and should help minimize the potential for lateral spreading of fuel in the event of a release (Wentworth, 1951). Because fuel is usually less dense than water, the fuel would primarily impact the upper portions of the aquifer.

Wilbros Engineers (1998) suggested that due to the potential for irreparable damage to the aquifer in the event of a massive release, preventive measures be taken to avoid a catastrophic disruption of potable water service to the Pearl Harbor community.

2.5.2 Ogden Oily Waste Facility RI/FS

Ogden Environmental and Energy Services (Ogden) completed several investigations at the Red Hill Oily Waste Disposal Facility (OWDF), which is located approximately 3,200 feet west of the RHSF tanks. The primary fieldwork for a Remedial Investigation/Feasibility Study (RI/FS) was conducted from August 1991 through June 1992. The results of this investigation were presented in the document entitled, *Technical Review Committee (TRC) Findings Summary, Red Hill Oily Waste Disposal Pit, Naval Supply Center, Pearl Harbor, O'ahu, Hawai'i* (1992). Ogden performed additional field investigation activities in January 1993. The results of the second investigation are presented in the document entitled, *Red Hill Oily Waste Disposal Pit Site Stilling Basin Closure Plan, CTO 0109*, (1993). Additional risk assessment and removal action activities were performed in 1994 and 1995.

The Ogden investigations of the Red Hill OWDF found that the stilling basin contained liquids and solid debris containing VOCs, total petroleum hydrocarbons (TPH) and total fuel hydrocarbons (TFH), semi-volatile organic compounds (SVOCs), and priority pollutant metals. Soil and the perched water system beneath the stilling basin were found to contain VOCs, TPH, TFH, and polynuclear aromatic hydrocarbons (PAHs). Ogden developed plans for closure of the stilling basin by removal of the waste liquids and solid debris and removal of soil containing TPH and PAHs near the base of the stilling basin. Further investigation activities were summarized in the report entitled, *Red Hill Oily Waste Disposal Facility Phase I RI Report, June 1996.*

2.5.3 Earth Tech Oily Waste Facility Investigations

EarthTech performed a Phase II Remedial Investigation (RI) at the OWDF in 1998 (EarthTech, 1999). The objective of the RI was to determine the nature and extent of impact to the soil and groundwater beneath the site resulting from site activities. Four Areas of Concern (AOCs) were identified and investigated during the Phase II RI.

During the investigation, limited areas of soil impacted by TPH were identified near the 8,000-gallon aboveground storage tank (AST) and in the unauthorized discharge area (UDA). PAHs were detected in the soils of the UDA and AST, but with the exception of benzo(a)pyrene, the reported concentrations were less than the Phase II RI OWDF-specific evaluation criteria.

TPH and one PAH compound (pyrene) were detected in a groundwater sample collected from a monitoring well installed within locally perched groundwater at the site. During a second sampling event in this well, PAH compounds were not reported at concentrations greater than the laboratory method detection limit. Neither TPH nor PAH was detected in groundwater samples obtained from within the basal aquifer during the RI sampling. Two VOCs were detected in the basal groundwater samples beneath the OWDF; however, both were characterized as common laboratory contaminants and neither was identified in the liquid or sludge samples obtained from the former stilling basin. Therefore, these two contaminants were eliminated from consideration in the subsequent risk evaluations.

The EarthTech report concluded that transport of contaminants to the basal aquifer from the OWDF would be insignificant. OWDF-related contaminants had not been detected in groundwater samples obtained from within the basal aquifer or from water samples obtained from the Navy's Public Works pumping station located in Adit #3. Therefore, EarthTech recommended no further action regarding the perched groundwater or the basal aquifer beneath the OWDF. A map depicting the approximate locations of the three site monitoring wells completed in the basal aquifer and the respective boring logs and monitoring well completion logs are presented in **Appendix F**.

2.5.4 Ogden/AMEC Red Hill Investigations

In March 1998, the Navy authorized Ogden (subsequently known as AMEC) to proceed with engineering services to identify potential petroleum product releases from the RHSF. The resulting site characterization was conducted in two phases: Phase I - Research Activities and Phase II - Investigation Activities.

2.5.4.1 Phase I Research Activities

Phase I activities were conducted in April 1998 and consisted of site reconnaissance and data gathering. The Phase I operations included interviews and meetings with remedial-project-manager, facility and FISC representatives to determine an efficient method to accomplish the fieldwork required to complete the site investigation. Much of the research focused on resolving the unique technical requirements of drilling in the environmentally sensitive and potentially explosive location within the lower tunnel and tank area.

2.5.4.2 Phase II Investigation Activities

The Navy authorized Ogden to proceed with an initial Phase II site investigation in August 1998. The Phase II investigation activities were conducted in two tasks.

- Task 1: The initial Phase II task comprised a limited investigation of two of the 20 USTs and preparation of an Initial Phase II Investigation Report.
- Task 2: The second task comprised an investigation of the remaining 18 USTs and the basal aquifer, conduct of a screening-level human-health risk evaluation, and preparation of a Phase II Site Investigation (SI) Report.

The Phase II field activities were conducted from October 19 through November 1, 1998. The Phase II activities are fully described in the report entitled "Initial Phase II Site Characterization Report, Fleet Industrial Supply Center, Bulk Fuel Storage Facility at Red Hill" (Ogden, 1999) and are summarized below.

2.5.4.2.1 Task 1 Field Activities

The primary objective of Task 1 was to conduct exploratory borings beneath Tank 9 and Tank 16 to evaluate potential petroleum releases. The condition of the lower tunnel interior walls and fluctuating fuel levels in Tank 16 suggested that leaks had occurred at this location.

Portable drilling equipment was used to advance six exploratory borings through the lower tunnel floor. Three directional borings were advanced (from one drilling location) beneath Tank 9 and three directional borings were advanced (from a second drilling location) beneath Tank 16. To avoid penetration of the concrete and grout backfill surrounding the tanks, the centerline borings beneath each tank were advanced through the tunnel floor at a slight downward angle (approximately 11° to 15° from horizontal). The other two borings at each tank location were advanced with an approximate deflection of 22° right or 35° left from the centerline, with the downward deflection angle similar to the centerline boring (approximately 11° to 15° from horizontal). These type borings are often referred to as "angled" or "slant" borings. The geometric relationships of the angled borings are depicted on **Figure 2-15 and Figure 2-16**.

Bedrock core and/or encountered soils, groundwater, and petroleum product were sampled and analyzed for petroleum constituents. A total of 14 samples (12 core samples, one duplicate core sample, and one fluid sample) were collected for offsite laboratory analyses. The samples were analyzed for TPH by Method-D-Triregional, VOCs by Method 8260, and PAHs by Method 8270. Laboratory results confirmed the presence of petroleum compounds in the bedrock beneath Tank 16. The samples obtained beneath Tank 9 did not contain the analytes at concentrations greater than the laboratory method detection limits.

2.5.4.2.2 Task 2 Field Activities

The Task 2 field investigation activities were conducted during the period from October 29, 2000 through March 9, 2001. The primary objectives of Task 2 were to evaluate potential petroleum releases beneath the remaining 18 tanks and to install two monitoring wells to obtain and analyze groundwater samples from within the basal aquifer and a shallower zone of perched groundwater.

The centerline borings conducted beneath Tank 9 and Tank 16 in Task 1 were over-drilled and converted to vadose zone groundwater/fuel monitoring wells. The other two existing borings beneath each of these tanks were abandoned by filling with grout. One angled boring was also advanced beneath each of the remaining 18 storage tanks (Tanks 1-8, 10-15, and 17-20). Each of the 18 new exploratory borings was subsequently converted to a vadose zone monitoring well. **Figure 2-16** depicts a typical cross section across one of the ten pairs of tanks. All slant boring wells were constructed approximately 80 to 100 feet above the basal aquifer to capture leachate or fuel released beneath the associated USTs.

Two vertical borings were also advanced from within the lower access tunnel to investigate potential impacts to the basal aquifer. One boring (V1D) was advanced into the basal aquifer and one shallower boring (V2S) was advanced to investigate and monitor a zone above the basal aquifer. The borings were converted into monitoring wells and sampled during the March and August 2001 monitoring events. The two vertical monitoring wells are situated hydraulically down-gradient from the tank locations.

The approximate boring locations are depicted on **Figure 2-17.** Note that each boring converted to a monitoring well is numbered in accordance with the corresponding monitoring well and tank number (e.g., boring B-5 was drilled to install monitoring well MW-5 and corresponds to Tank 5). A summary of the boring and monitoring well specifications is presented in **Table 2-2**. Copies of the boring logs and well construction diagrams are provided in **Appendix F**.

One hundred seven (107) samples (87 primary core samples, 10 duplicate core sample, eight fluid samples, and two groundwater samples) were collected during the completion of field activities and subjected to offsite laboratory analyses. Samples were analyzed for TPH by Method 8015 (modified), VOCs by Method 8260, SVOCs by Method OLM03.2, PAHs by Method 8270, and TCLP metals by Method ILM0.40. In addition, four samples (two fluid and two core samples) were collected for fingerprinting analysis using gas chromatography with flame ionization detection (GC/FID) and an electron capture detector (ECD).

Hydrocarbon impacts were noted beneath the tunnel floor and at depth within some of the angle borings advanced beneath the USTs. Six borings (B-1, B-2, B-3, B-6, B-13, and B-20) exhibited evidence of hydrocarbon impacts (i.e., sheen on drill water, hydrocarbon odor, and/or elevated Photoionization Detector (PID) measurements) directly beneath the concrete floor. Hydrocarbon odor and elevated PID readings were observed in core samples obtained at depth in the angle borings located beneath 15 of the 20 tanks (Tanks 1, 3-7, 11-14, and 16-20). **Table 2-3** presents a summary of core sample depths, PID measurements, and physical observations. **Table 2-4** presents a summary of fluids observed. The fingerprinting analyses confirmed that the samples contained petroleum hydrocarbons consistent with those stored in the tanks (**Table 2-5**). **Figure 2-18** and **Figure 2-19** present a plan and cross section view depicting the location of core samples that contained compounds in concentrations greater than HDOH Tier 1 Action Levels. **Table 2-6** provides a summary of results for samples that contained analytes at concentrations greater than the respective laboratory method detection limit.

2.5.4.2.3 Task 2 Preliminary Risk Evaluation

A preliminary screening-level risk evaluation (**Appendix D**) was conducted on the basis of the Task 1 and Task 2 field activity findings. The results of the evaluation indicate that seven constituents were detected in core samples at concentrations of potential concern: ethylbenzene, methylene chloride, 2-methylnaphthalene, naphthalene, phenanthrene, TPH (hydrocarbon range C10-C28), and an unknown hydrocarbon compound. Three constituents were detected in groundwater at concentrations of potential concern: bis(2-ethylhexyl)phthalate, lead, and TPH (hydrocarbon range C10-C28). The field investigation also identified the presence of light non-aqueous phase liquid (LNAPL) within several monitoring wells at the site.

On the basis of the preliminary risk screening, it was recommended that a comprehensive risk assessment be completed to accurately assess current and potential future risk associated with the RHSF. The comprehensive risk assessment should include a site-specific exposure assessment, including the use of fate and transport modeling, to identify potential migration pathways, potential receptor populations, and relevant exposure routes.

2.6 Regulatory Correspondence

In an effort to evaluate current and potential future risks to the basal aquifer underlying the facility and to nearby drinking water wells (including the Navy Pumping Station located directly down-gradient from the USTs), the State of Hawaii Department of Health (HDOH), Solid Waste Branch concurred in a letter dated October 10, 2003 (**Appendix E**) that the US Navy would:

- Conduct a comprehensive Tier 3 Comprehensive RA,
- Develop a comprehensive Conceptual Site Model (CSM) incorporating Fate and Transport Models to facilitate preparation of the RA,
- Prepare a Contingency Plan to protect the Navy's groundwater supply at Red Hill, and
- Monitor groundwater in the underlying basal aquifer and at the PWC potable water source at Red Hill.

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Table 2-1
Historical Summary of Products Stored at the
Red Hill Bulk Fuel Storage Facility

Tank ID	Contents	Date
1	Diesel Oil (DO)	10/26/1942
	JP-5	02/04/1970
2	DO	09/28/1942
	JP-5	1962
3	Navy Special Fuel Oil (NSFO)	01/26/1943
	Navy Distillate (ND)	08/27/1970
	Diesel Fuel, Marine (DFM)	04/03/1973
	JP-5	12/26/1973
4	NSFO	11/15/1942
	ND	02/17/1971
	DFM	06/06/1973
	JP-5	01/26/1974
5	NSFO	12/19/1942
	Empty	04/06/1970
	ND	12/29/1971
	JP-5	Oct-74
6	NSFO	12/30/1942
	Empty	03/29/1970
	ND	02/29/1972
	JP-5	Oct-74
	DFM	01/15/1982
	Empty	07/22/1994
	JP-5	05/19/1995
	Empty	04/15/1998
7	NSFO	03/16/1943
	ND	05/04/1971
	DFM	09/11/1973
	Empty	04/25/1995
8	NSFO	03/02/1943
	ND	05/21/1971
	DFM	09/12/1973
	Empty	04/13/1995
9	NSFO	02/14/1943
	ND	06/23/1972
	DFM	09/13/1973
	Empty	09/14/1995
	JP-5	05/30/1996
10	NSFO	01/26/1943
	ND	06/29/1972
	DFM	09/01/1973
	Empty	10/03/1995
11	NSFO	02/11/1943
	ND	06/29/1972
	DFM	Oct-73
12	NSFO	03/19/1943
	Empty	04/28/1970
	ND	05/26/1972
	DFM	01/29/1981
	Empty	08/24/1994
	DFM	07/25/1995
13	NSFO	03/23/1943
	DFM	04/21/1976
	Empty	12/01/1994
	JP-5	10/04/1995
14	NSFO	03/21/1943
	ND	03/13/1973
	NSFO	10/25/1973
	ND	08/26/1975
	DFM	04/12/1981
	Empty	01/19/1995
	JP-5	04/29/1996
15	NSFO	04/29/1943
	ND	10/27/1972
	DFM	09/14/1973
	Empty	10/02/1998
16	NSFO	05/08/1943
	ND	11/10/1971
	DFM	06/15/1975
	Empty	05/25/1994
	JP-5	10/01/1998
	Empty	11/04/1998
17	NSFO	05/23/1943
	Empty	03/30/1960
	AVGAS	12/11/1964
	MOGAS	08/29/1968
	JP-5	01/15/1969
18	NSFO	06/13/1942
	Empty	03/30/1960
	JP-5 (for leak tests)	May-63
	AVGAS	08/18/1964
	Empty	10/30/1968
	JP-5	01/10/1969
19	NSFO	06/13/1943
	Empty	03/30/1960
	JP-5	01/17/1964
	Empty	Oct-85
20	NSFO	07/20/1943
	Empty	03/30/1960
	JP-5	06/14/1964
	Empty	12/28/1971
	JP-5	04/04/1972
355[a]	Slop Oil	1966

[a] – The slop oil tank (Tank 355) was not included in this investigation.
DO = Diesel Oil
NSFO = Navy Special Fuel Oil
ND = Navy Distillate
DFM = Diesel Fuel, Marine

Table 2-2
Summary of Monitoring Well Installation
Red Hill Bulk Fuel Facilty

Progression	Tank ID	Monitoring Well ID	Date Well Installed	Angle from Horizontal (degree)	Elevation at Ground Surface (Ft AMSL)	Riser Stick-Up (ft, POE)[a]	Total Depth (ft, POE)[a]	Corrected Elevation of Well Total Depth (Ft AMSL)	Vertical Drop (ft) to Bottom of Well from POE Elevation	Number of Isolation Casings	Well Diameter (Inches)	Screen Interval Upper Depth (ft, POE)[a]	Screen Interval Lower Depth (ft, POE)[a]	Screen Length ft long	Depth of Fluid Detected (ft, POE)[a b c]	Corrected Elevation of Fluid Level (ft, POE)[a b c]
1	Tank 01	RH-MW-1	02/09/2001	15	102.66	0.42	129.7	69.09	33.57	2	1.5	109.4	124.4	15	129.4	69.17
2	Tank 02	RH-MW-2	02/07/2001	15	102.31	0.44	124.0	70.22	32.09	1	2.0	104.7	119.7	15	ND	ND
3	Tank 03	RH-MW-3	02/02/2001	15	102.72	0.36	130.2	69.02	33.70	2	1.5	109.9	124.9	15	ND	ND
4	Tank 04	RH-MW-4	01/31/2001	15	102.62	0.36	129.1	69.21	33.41	2	1.5	108.8	123.8	15	ND	ND
5	Tank 05	RH-MW-5	01/29/2001	15	105.98	0.43	124.3	73.81	32.17	1	2.0	104.0	119.0	15	ND	ND
6	Tank 06	RH-MW-6	01/24/2001	15	105.68	0.3	126.6	72.92	32.76	2	1.5	106.3	121.3	15	ND	ND
7	Tank 07	RH-MW-7	01/19/2001	15	113.96	0.33	128.9	80.60	33.36	2	1.5	108.6	123.6	15	ND	ND
8	Tank 08	RH-MW-8	01/17/2001	15	113.67	0.42	127.2	80.75	32.92	2	1.5	107.0	122.0	15	ND	ND
9	Tank 09	RH-MW-9	01/12/2001	11	113.94	0.36	100.0	94.89	19.05	2	1.5	80.0	95.0	15	ND	ND
10	Tank 10	RH-MW-10	01/10/2001	15	113.71	0.39	130.7	79.88	33.83	2	1.5	110.7	125.7	15	ND	ND
11	Tank 11	RH-MW-11	12/19/2000	15	117.98	0.42	131.0	84.08	33.90	2	1.5	95.7	125.7	30	ND	ND
12	Tank 12	RH-MW-12	12/14/2000	15	117.71	0.37	133.6	83.13	34.58	1	2.0	108.3	128.3	20	ND	ND
13	Tank 13	RH-MW-13	12/12/2000	15	121.95	0.39	133.1	87.50	34.45	1	2.0	107.8	127.8	20	132.50	87.66
14	Tank 14	RH-MW-14	12/07/2000	15	121.75	0.33	136.0	86.55	35.20	1	2.0	110.7	130.7	20	135.30	86.73
15	Tank 15	RH-MW-15	12/05/2000	13	125.88	0.36	126.4	97.45	28.43	2	1.5	106.4	121.4	15	ND	ND
16	Tank 16	RH-MW-16A	01/08/2001	11	125.70	0.37	104.8	105.70	20.00	1	2.0	84.5	99.5	15	ND	ND
17	Tank 17	RH-MW-17	11/07/2000	13	129.75	0.27	124.2	101.81	27.94	2	1.5	104.2	119.2	15	114.80	103.92
18	Tank 18	RH-MW-18	11/21/2000	13	129.58	0.33	126.0	101.24	28.34	2	1.5	106.0	121.0	15	ND	ND
19	Tank 19	RH-MW-19	03/02/2001	13	133.68	0.27	121.1	106.44	27.24	2	1.5	101.1	116.1	15	110.52	108.81
20	Tank 20	RH-MW-20	03/05/2001	15	133.54	0.39	127.7	100.49	33.05	2	1.5	107.5	122.5	15	ND	ND
21	Tank 1/2	RH-MW-V1D	02/20/2001	90	102.56	-0.11	100.0	2.56	100.00	4	1.0	89.8	99.8	10	86.28	16.28
22	Tank 1/2	RH-MW-V2S	02/23/2001	90	102.56	-0.14	52.0	50.56	52.00	2	1.5	32.0	47.0	15	ND	ND

[a] Measurements for the riser stick-up, total depth, screened interval, and depth to fluid are **not** angle corrected depth from ground surface measurements.

[b] The depth to fluid provided is an approximation; accurate measurements are not available in angle wells.

[c] Fluid measurements were obtained on 08/24/01.

bgs - below ground surface
ft, POE - feet from boring point of entry
ND - Not detected
Ft AMSL - Feet Above Mean Sea Level

Table 2-3
Summary of Boring Locations with Physical Indications of Petroleum Hydrocarbons Present

Boring Location ID	Depth in Boring of Evidence of PH Observed (ft, POE)	Elevated PID Measurement (ppm)	Sample Obtained for Analysis	Product Observed Beneath Concrete Floor (Yes/No)
B-01	2.00	330.0	X (S01)	Yes (Sheen)
	8.00	573.0	X (S02)	
	59.60	266.0	X (S03)	
	60.70	453.0	X (S04)	
	71.10	478.0	No	
B-02	89.45	74.7	X (S02)	No
B-03	2.00	214.0	X (S01)	No
	7.40	244.6	No	
	42.90	189.2	X (S02)	
B-04	7.00	294.0	No	No
	8.20	180.0	X (S02)	
	15.60	225.0	No	
B-05	7.60	72.0	X (S01)	No
	14.70	63.1	X (S02)	
	55.25	262.0	X (S03)	
	113.30	308.0	X (S04)	
B-06	0.50	78.0	X (S01 L)[a]	Yes
	0.50	78.0	X (S01 S)	
	1.50	74.0	X (S02)[a]	
	11.30	163.0	No	
	19.80	191.0	X (S03)	
	26.10	40.0	No	
B-07	0.50	NM	X (S01)	No
	25.90	110.0	X (S02)	
	40.50	26.5	No	
	93.10	6.6	No	
	105.95	9.6	X (S04)	
	111.20	41.0	X (S05)	
B-08	NA	NM	X (S01)	No
B09A	3.20	NM	X (B09A-1)	No
B-10	NA	NM	No	No
B-11	4.50	14.1	X (S01)	No
	7.40	12.0	No	
	11.30	19.8	X (S02)	
	20.30	3.1	No	
	38.20	9.8	No	
	67.10	24.3	X (S03)	
	85.00	21.4	X (S04)	
	89.50	55.8	No	
	95.00	80.3	X (S05)	
B-12	8.00	0.3	X (S01)	No
	33.50	26.0	X (S02)	
	36.70	2.8	No	
	61.00	1.9	X (S03)	
	62.20	17.3	No	
	107.90	0.7	No	
	121.90	26.4	X (S05)	
B-13	2.00	NM	No	Yes (Sheen)
	10.70	10.7	X (S04)	
B-14	95.50	19.7	X (S04)[a]	No
	101.40	9.1	No	
	116.00	2.0	X (S05)	
B-15	NA	NM	No	No
B16A	NA	NM	No	No
	83.75	NM	X (B16A-4)	
B-17	81.80	83.2	No	No
	90.30	95.1	No	
B-18	121.50	125.8	No	No
B-19	43.00	94.7	X (S01)	No
	51.40	131.0	No	
	60.30	154.0	No	
	62.70	175.0	X (S02)	
	67.80	167.0	No	
	79.90	334.0	No	
	93.20	630.0	X (S03)	
	109.30	350.0	No	
	118.00	406.0	X (S04)	
B-20	2.25	75.1	X (S01)	No
	8.80	375.0	X (S02)	
	116.20	467.0	No	
	125.80	420.0	No	
B-V1D	NA	NM	No	No
B-V2S	NA	NM	No	No

[a] - Sample also obtained for fingerprinting analysis
ft, POE - feet from boring point of entry
NA - Not applicable
NM - Not measured
PH - Petroleum hydrocarbons
ppm - parts per million
X - Sample was obtained for analysis

Table 2-4
Summary of Fluid Levels Detected in Monitoring Wells

Monitoring Well ID	Fluid Media	Elevation at Ground Surface	Date	Depth to Fluid Level (ft, POE)	Corrected Elevation of Fluid Level
RH-MW-1	LNAPL	102.66	03/07/2001	124.2	70.52
			08/24/2001	129.4	69.17
RH-MW-13	LNAPL	121.95	03/07/2001	NFD	NA
			08/24/2001	132.5	87.66
RH-MW-14	LNAPL	121.75	03/07/2001	NFD	NA
			08/24/2001	135.3	86.73
RH-MW-17	LNAPL	129.75	03/07/2001	NFD	NA
			08/24/2001	114.8	103.92
RH-MW-19	Infiltration Fluid	133.68	03/07/2001	113.1	104.41
			08/24/2001	110.52	108.81
RH-MW-V1D	GW	102.56	03/07/2001	86.1	16.46
			08/24/2001	86.28	16.28

LNAPL - Light phase non aqueous phase liquid (which may be mixed with drill fluid)
ft, POE - feet from boring point of entry
NA - Not applicable
NFD - No fluid detected

Table 5
Summary and Comparison of Samples Obtained for Fingerprinting Analysis

Tank Location	Sample ID	Sample Date	Matrix	Sample Depth (ft, POE)	F&B GC Petroleum Hydrocarbon Identification	F&B GC Petroleum Hydrocarbon Characterization	Historical Contents and Start Use Year
6	RH-BR-6-S01 (L)	01/18/2001	Fluid	0.5	Indicative of a mixture of a degraded middle distillates such as kerosene or Jet A.	• Fuel has undergone substantial biological degradation • Lower level of degraded middle distillates (diesel fuel #2) may be present	NSFO - 1942 ND - 1972 JP-5 - 1974 DFM - 1982 JP-5 - 1995
	RH-BR-6-S02	01/19/2001	Core	1.5	Indicative of a mixture of middle distillates, which may include kerosene, JP-5, diesel fuel #2 and similar fuels.	• Mixture of degraded and relatively undegraded fuels	
11	RH-MW-11	12/18/2000	Fluid	20.3	Indicative of a mixture of middle distillates such as diesel fuel #2 or similar fuels.	• Fuel has undergone substantial biological degradation	NSFO - 1943 ND - 1972 DFM - 1973
14	RH-BR-14-S04	12/06/2000	Core	95.5	Indicative of a mixture of middle distillates, which may include kerosene, JP-5, diesel fuel #2 and similar fuels.	• Mixture of degraded and relatively undegraded fuels	NSFO - 1943 ND - 1973 NSFO - 1973 ND - 1975 DFM - 1981 JP-5 - 1996

DFM - Diesel Fuel, Marine
F&B - Friedman & Bruya
GC - Gas chromatograph
JP-5 - Jet Fuel
ND - Navy Distillate
NSFO - Navy Special Fuel Oil

Table 2-6
All Sample Detects Summary (ppm)
Red Hill Bulk Fuel Storage Facility, Oahu, Hawaii

LOCATION	SAMPLE NO	TYPE	SAMPLE DEPTH (ft, poe)	SAMPLE DATE	MEDIA	1,1-Dichloroethylene	2-Methylnaphthalene	4-Methyl-2-pentanone	Acetone	bis(2-Ethylhexyl)phthalate	Chrysene	Dibenzofuran	Ethylbenzene	Fluorene	Lead	m,p xylene	Methyl ethyl ketone	Methylene chloride	Naphthalene	o-xylene	Phenanthrene	Pyrene	Toluene	TPH (C10-C28)	Unknown Hydrocarbon	Xylene (total)
TANK- 1	RH-BR-1-D09	DUP	59.6	02/08/2001	CORE	--	5.02	--	--	--	--	--	--	--	--	--	--	--	1.23	--	--	--	--	890	--	--
TANK- 1	RH-BR-1-S01	REG	2	02/07/2001	CORE	--	--	--	--	--	--	--	--	--	293	--	--	--	--	--	--	--	--	25300	--	--
TANK- 1	RH-BR-1-S02	REG	8	02/08/2001	CORE	--	0.25	--	--	0.162	--	--	--	--	--	--	--	--	--	--	--	--	--	1500	--	--
TANK- 1	RH-BR-1-S03	REG	59.6	02/08/2001	CORE	--	10.2	--	--	--	--	--	--	--	--	--	--	--	3.72	--	--	--	--	2330	--	0.436
TANK- 1	RH-BR-1-S04	REG	61.35	02/08/2001	CORE	--	39.8	--	--	--	--	--	0.49	--	--	--	--	--	16.3	--	--	--	--	3300	--	4.81
TANK- 1	RH-BR-1-S05	REG	129.2	02/09/2001	CORE	--	--	--	--	0.132	--	--	--	--	--	--	--	--	--	--	--	--	--	27.7	--	--
TANK- 1	RH-MW-1-S01	REG	124.2	03/07/2001	DFLNAPL	0.00065	--	--	--	--	--	--	--	--	0.0756	--	--	--	--	--	--	--	--	1.88	--	--
TANK- 1	RH-MW-1-S01	REG	129.4	08/27/2001	DFLNAPL	0.0013	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1.3	--	--
TANK- 2	RH-BR-2-S01	REG	2.5	02/05/2001	CORE	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	910	--	--
TANK- 2	RH-BR-2-S02	REG	89.45	02/06/2001	CORE	--	--	--	--	--	--	--	--	--	--	--	--	0.011	--	--	--	--	--	22.2	--	--
TANK- 2	RH-BR-2-S03	REG	119.9	02/06/2001	CORE	--	--	--	--	--	--	--	--	--	--	--	--	0.0127	--	--	--	--	--	--	--	--
TANK- 3	RH-BR-3-S01	REG	2	01/31/2001	CORE	--	--	--	0.0412	0.159	--	--	--	--	14.5	--	--	--	--	--	--	--	--	386	--	--
TANK- 3	RH-BR-3-S02	REG	46.35	02/01/2001	CORE	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	774	--	--
TANK- 3	RH-BR-3-S03	REG	125.2	02/02/2001	CORE	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	28.9	--	--
TANK- 4	RH-BR-4-D08	DUP	123.9	01/31/2001	CORE	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	14.5	--	--
TANK- 4	RH-BR-4-S01	REG	2.5	01/29/2001	CORE	--	0.392	--	0.045	--	--	--	--	--	84.5	--	--	--	--	--	--	--	--	238	--	--
TANK- 4	RH-BR-4-S02	REG	8.2	01/29/2001	CORE	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1330	--	--
TANK- 4	RH-BR-4-S03	REG	123.9	01/31/2001	CORE	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	49.8	--	--
TANK- 5	RH-BR-5-S01	REG	9.15	01/25/2001	CORE	--	1.85	--	--	--	--	--	--	--	--	--	0.29	--	0.266	--	0.226	--	--	503	--	--
TANK- 5	RH-BR-5-S02	REG	14.7	01/25/2001	CORE	--	--	--	0.0234	0.251	--	--	--	--	24	--	--	--	--	--	--	--	--	11.8	--	--
TANK- 5	RH-BR-5-S03	REG	55.25	01/26/2001	CORE	--	--	--	--	0.178	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
TANK- 5	RH-BR-5-S04	REG	113.3	01/26/2001	CORE	--	--	--	--	0.435	--	--	--	--	2.1	--	--	--	--	--	--	--	--	12.4	--	--
TANK- 5	RH-BR-5-S05	REG	115.3	01/26/2001	CORE	--	--	--	--	0.214	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
TANK- 6	RH-BR-6-D07	DUP	19.8	01/22/2001	CORE	--	--	--	--	0.456	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
TANK- 6	RH-BR-6-S01	REG	0.5	01/19/2001	CORE	--	18.9	--	--	--	--	--	--	--	11.3	--	--	--	--	--	10.9	--	--	10200	--	--
TANK- 6	RH-BR-6-S02	REG	6	01/19/2001	CORE	--	--	--	--	--	--	--	--	--	11.2	--	--	--	--	--	--	8.45	--	43100	--	--
TANK- 6	RH-BR-6-S03	REG	19.8	01/22/2001	CORE	--	--	--	--	0.265	--	--	--	--	--	--	--	--	--	--	--	--	--	8.83	--	--
TANK- 6	RH-BR-6-S04	REG	125.1	01/24/2001	CORE	--	--	--	--	0.375	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
TANK- 6	RH-MW-6-S01	REG	0.5	01/19/2001	DFLNAPL	--	36.8	--	--	--	--	--	--	--	27.5	--	--	--	--	--	--	--	--	29500	--	--
TANK- 7	RH-BR-7-S01	REG	0.5	01/17/2001	CORE	--	--	--	0.0295	--	--	--	--	--	17.6	--	--	--	--	--	--	--	--	631	--	--
TANK- 7	RH-BR-7-S02	REG	25.9	01/18/2001	CORE	--	19.1	--	--	--	--	--	0.122	--	--	--	0.431	--	7.09	--	--	--	--	2420	--	1.23
TANK- 7	RH-BR-7-S03	REG	92.4	01/18/2001	CORE	--	--	--	0.04	--	--	--	--	--	--	--	--	--	--	--	--	--	--	24.4	--	--
TANK- 7	RH-BR-7-S04	REG	105.95	01/19/2001	CORE	--	--	--	--	0.291	--	--	--	--	--	--	--	--	--	--	--	--	--	22.3	--	--
TANK- 7	RH-BR-7-S05	REG	111.2	01/19/2001	CORE	--	--	--	--	0.18	--	--	--	--	--	--	--	--	--	--	--	--	--	208	--	--

Table 2-6
All Sample Detects Summary (ppm)
Red Hill Bulk Fuel Storage Facility, Oahu, Hawaii

LOCATION	SAMPLE NO	TYPE	SAMPLE DEPTH (ft, poe)	SAMPLE DATE	MEDIA	1,1-Dichloroethylene	2-Methylnaphthalene	4-Methyl-2-pentanone	Acetone	bis(2-Ethylhexyl)phthalate	Chrysene	Dibenzofuran	Ethylbenzene	Fluorene	Lead	m,p xylene	Methyl ethyl ketone	Methylene chloride	Naphthalene	o-xylene	Phenanthrene	Pyrene	Toluene	TPH (C10-C28)	Unknown Hydrocarbon	Xylene (total)
TANK- 8	RH-BR-8-S01	REG	0.5	01/15/2001	CORE	--	--	--	--	0.189	--	--	--	--	47.1	--	--	--	--	--	--	--	--	1030	--	--
TANK- 8	RH-BR-8-S03	REG	114.5	01/16/2001	CORE	--	--	--	--	0.123	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
TANK- 9	B09A-1	REG	3.2	10/26/1998	CORE	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	600	--
TANK- 9	B09A-2	REG	97.1	10/27/1998	CORE	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3.5	--
TANK- 9	B09B-1	REG	55	10/29/1998	CORE	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	48	--
TANK- 9	B09B-2	REG	74.6	10/29/1998	CORE	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2.3	--
TANK- 9	B09C-1	REG	50	10/28/1998	CORE	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	6.9	--
TANK- 9	B09C-2	REG	66	10/28/1998	CORE	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3.1	--
TANK-11	RH-BR-11-S01	REG	4.5	12/15/2000	CORE	--	1.56	--	0.0632	0.286	--	--	--	--	4.7	--	0.0165	--	--	--	0.534	--	--	1690	--	0.0084
TANK-11	RH-BR-11-S02	REG	11.3	12/15/2000	CORE	--	6.11	--	0.0243	--	--	0.992	0.002	1.14	--	--	--	--	0.776	--	2.09	--	--	3130	--	--
TANK-11	RH-BR-11-S03	REG	67.1	12/18/2000	CORE	--	--	0.0067	0.0215	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1440	--	--
TANK-11	RH-BR-11-S04	REG	85	12/18/2000	CORE	--	1.78	--	--	--	--	--	--	--	--	--	--	--	--	--	0.926	--	--	2320	--	0.0073
TANK-11	RH-BR-11-S05	REG	95	12/18/2000	CORE	--	6.81	--	--	--	--	--	0.0194	0.72	--	--	--	--	1.09	--	1.5	--	0.0086	2910	--	0.298
TANK-12	RH-BR-12-D06	DUP	104.3	12/14/2000	CORE	--	--	--	--	0.12	--	--	--	--	--	--	--	--	--	--	--	--	--	19.6	--	--
TANK-12	RH-BR-12-S01	REG	8	12/12/2000	CORE	--	--	--	--	0.169	--	--	--	--	--	--	--	--	--	--	--	--	--	31.7	--	--
TANK-12	RH-BR-12-S02	REG	33.5	12/13/2000	CORE	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	232	--	--
TANK-12	RH-BR-12-S03	REG	61	12/13/2000	CORE	--	--	--	--	0.199	--	--	--	--	--	--	--	--	--	--	--	--	--	780	--	--
TANK-12	RH-BR-12-S04	REG	104.3	12/14/2000	CORE	--	--	--	--	0.125	--	--	--	--	--	--	--	--	--	--	--	--	--	77.1	--	--
TANK-12	RH-BR-12-S05	REG	121.9	12/14/2000	CORE	--	3.38	--	--	--	--	--	0.002	--	--	--	--	--	--	--	0.798	--	--	1710	--	0.018
TANK-13	RH-BR-13-D05	DUP	72	12/11/2000	CORE	--	--	--	--	0.566	--	--	--	--	--	--	--	--	--	--	--	--	--	26.1	--	--
TANK-13	RH-BR-13-S01	REG	72	12/11/2000	CORE	--	--	--	--	0.178	--	--	--	--	--	--	--	--	--	--	--	--	--	20.3	--	--
TANK-13	RH-BR-13-S02	REG	100	12/11/2000	CORE	--	--	--	--	0.342	--	--	--	--	--	--	--	--	--	--	--	--	--	31.9	--	--
TANK-13	RH-BR-13-S03	REG	125	12/11/2000	CORE	--	--	--	--	0.416	--	--	--	--	--	--	--	--	--	--	--	--	--	32.6	--	--
TANK-13	RH-BR-13-S04	REG	8	12/12/2000	CORE	--	--	--	0.0216	0.942	--	--	--	--	6.8	--	--	--	--	--	--	--	--	2160	--	--
TANK-13	RH-MW-13-S01	REG	132.5	08/27/2001	DFLNAPL	0.0021	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2.39	--	--
TANK-14	RH-BR-14-D04	DUP	60.5	12/06/2000	CORE	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2090	--	--
TANK-14	RH-BR-14-S01	REG	35	12/06/2000	CORE	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	581	--	--
TANK-14	RH-BR-14-S02	REG	60.5	12/06/2000	CORE	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2810	--	--
TANK-14	RH-BR-14-S03	REG	75	12/06/2000	CORE	--	--	--	--	0.146	--	--	--	--	--	--	--	--	--	--	--	--	--	292	--	--
TANK-14	RH-BR-14-S04	REG	95.5	12/06/2000	CORE	--	57.8	--	--	--	--	--	***1.55***	--	--	--	--	--	11.4	--	12.8	--	0.17	***26200***	--	6.4
TANK-14	RH-BR-14-S05	REG	116	12/06/2000	CORE	--	3.06	--	--	--	--	--	--	--	--	--	--	--	--	--	0.974	--	--	851	--	--
TANK-15	RH-BR-15-D03	DUP	62.5	12/04/2000	CORE	--	--	--	--	0.291	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
TANK-15	RH-BR-15-S01	REG	62.5	12/04/2000	CORE	--	--	--	--	0.206	--	--	--	--	--	--	--	--	--	--	--	--	--	8.05	--	--
TANK-15	RH-BR-15-S02	REG	86	12/04/2000	CORE	--	--	--	--	0.176	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
TANK-15	RH-BR-15-S03	REG	115	12/04/2000	CORE	--	--	--	0.0257	0.191	--	--	--	--	--	--	--	--	--	--	--	--	--	10.7	--	--

Table 2-6
All Sample Detects Summary (ppm)
Red Hill Bulk Fuel Storage Facility, Oahu, Hawaii

LOCATION	SAMPLE NO	TYPE	SAMPLE DEPTH (ft, poe)	SAMPLE DATE	MEDIA	1,1-Dichloroethylene	2-Methylnaphthalene	4-Methyl-2-pentanone	Acetone	bis(2-Ethylhexyl)phthalate	Chrysene	Dibenzofuran	Ethylbenzene	Fluorene	Lead	m,p xylene	Methyl ethyl ketone	Methylene chloride	Naphthalene	o-xylene	Phenanthrene	Pyrene	Toluene	TPH (C10-C28)	Unknown Hydrocarbon	Xylene (total)
TANK-16	B16-DUP	DUP	83.75	10/23/1998	CORE	--	--	--	--	--	--	--	--	6.4	--	0.085	--	--	14	0.071	14	13	--	--	***6600***	0.156
TANK-16	B16A-4	REG	83.75	10/22/1998	CORE	--	--	--	--	--	--	--	0.24	10	--	0.31	--	--	***43***	0.22	23	22	--	--	***11000***	0.53
TANK-16	B16A-5	REG	101.83	10/22/1998	CORE	--	--	--	--	--	--	--	--	4.7	--	--	--	--	--	--	4.4	20	--	--	2800	--
TANK-16	B16B-4	REG	66.15	10/23/1998	CORE	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	6.4	--
TANK-16	B16B-5	REG	75.58	10/23/1998	CORE	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	29	--
TANK-16	B16C	REG	103.6	10/28/1998	DFLNAPL	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.011		--	--	8.1	0.031
TANK-16	B16C-4	REG	60	10/26/1998	CORE	--	--	--	--	--	6.3	--	0.16	12	--	0.059	--	--	***47***	0.082	26	11	--	--	***9400***	0.141
TANK-16	B16C-5	REG	67	10/26/1998	CORE	--	--	--	--	--	--	--	0.054	--	--	0.19	--	--	8.2	0.13	6.5	--	0.048	--	4500	0.32
TANK-17	RH-BR-17-D02	DUP	34	11/10/2000	CORE	--	--	--	--	0.133	--	--	--	--	--	--	--	--	--	--	--	--	0.0029	--	--	--
TANK-17	RH-BR-17-S01	REG	10	11/10/2000	CORE	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	861	--	--
TANK-17	RH-BR-17-S02	REG	34	11/10/2000	CORE	--	--	--	--	0.294	--	--	--	--	--	--	--	**0.0152**	--	--	--	--	--	--	--	--
TANK-17	RH-BR-17-S03	REG	66.2	11/10/2000	CORE	--	--	--	--	0.224	--	--	--	--	--	--	--	**0.0108**	--	--	--	--	--	--	--	--
TANK-17	RH-MW-17-S01	REG	114.8	08/27/2001	DFLNAPL	--	--	--	--	--	--	--	--	--	***0.072***	--	--	--	--	--	--	--	--	--	--	--
TANK-18	RH-BR-18-D01	DUP	116	11/06/2000	CORE	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.0177	--	--	--
TANK-18	RH-BR-18-S02	REG	104.4	11/06/2000	CORE	--	--	--	--	0.93	--	--	--	--	0.55	--	--	--	--	--	--	--	--	--	--	--
TANK-18	RH-BR-18-S03	REG	116	11/06/2000	CORE	--	--	--	--	0.419	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
TANK-19	RH-BR-19-S01	REG	43	11/22/2000	CORE	--	4.31	--	--	0.174	--	--	0.174	--	--	--	--	--	0.682	--	--	--	--	1620	--	0.267
TANK-19	RH-MW-19-S01	REG	110.52	08/27/2001	INFILTWAT	0.0015	--	--	--	0.0078	--	--	--	--	***0.0666***	--	--	--	--	--	--	--	--	--	--	--
TANK-19	RH-MW-19-S01	REG	113.1	03/07/2001	INFILTWAT	0.0014	--	--	--	0.0073	--	--	--	--	***0.0568***	--	--	--	--	--	--	--	--	0.312	--	--
TANK-20	RH-BR-20-S01	REG	0.5	03/02/2001	CORE	--	--	--	--	--	--	--	--	--	9.8	--	--	--	--	--	--	--	--	975	--	--
TANK-20	RH-BR-20-S02	REG	8.8	03/03/2001	CORE	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	794	--	--
VERTICAL WELL-D	RH-MW-V1D-S01	REG	86.1	03/07/2001	GW	--	--	--	--	0.0058	--	--	--	--	***0.015***	--	--	--	--	--	--	--	--	0.883	--	--
VERTICAL WELL-D	RH-MW-V1D-S01	REG	86.28	08/27/2001	GW	--	--	--	--	0.0109	--	--	--	--	***0.0104***	--	--	--	--	--	--	--	--	1.07	--	--
VERTICAL WELL-S	RH-BR-V2S-S03	REG	43	02/23/2001	CORE	--	--	--	--	--	--	--	--	--	4.1	--	--	--	--	--	--	--	--	--	--	--

Abbreviations:

-- Parameter not detected
REG - Regular sample
DUP - Duplicate sample
GW - Groundwater
PPM - parts per million

DFLNAPL - Drill fluid/LNAPL (light non-aquious phase liquid) mixture
INFILTWAT - Infiltration Water
25300 - Analytical result exceeds the Hawaii DOH Tier I Action Level
TPH - Total petroleum hydrocarbon
ft, poe - feet from point of entry

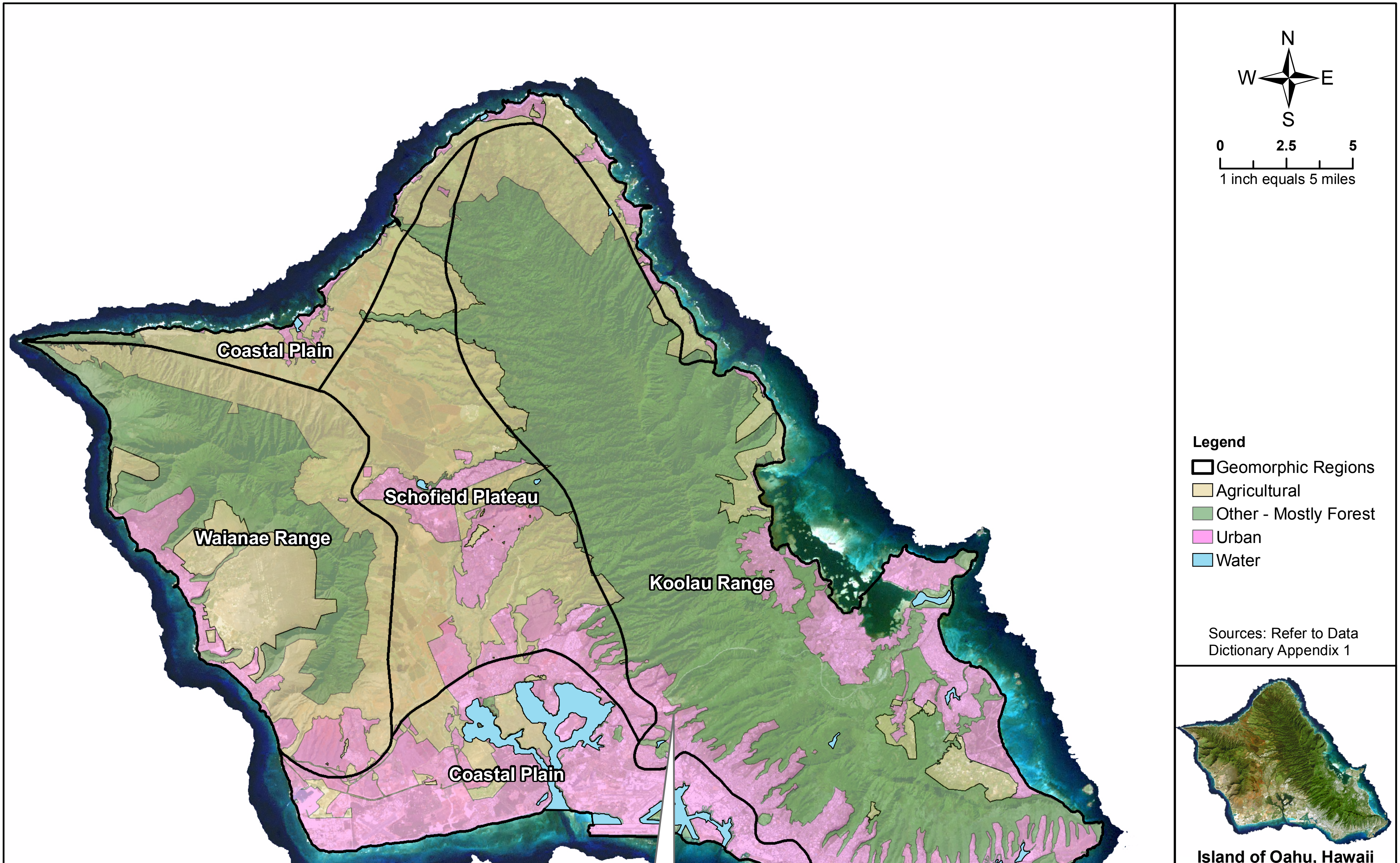
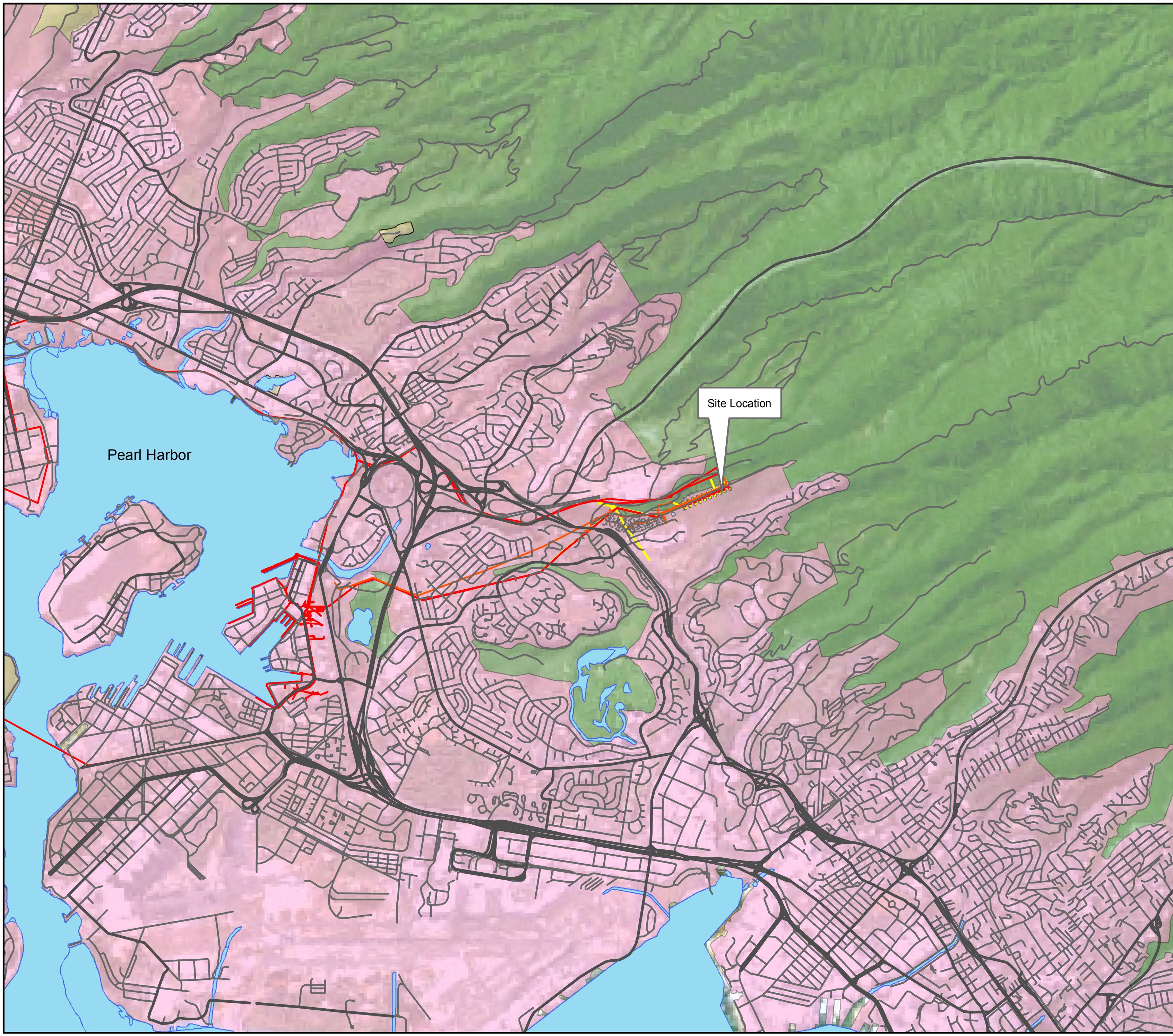


Figure 2-1
Geomorphic Regions

Red Hill
Bulk Fuel Facility



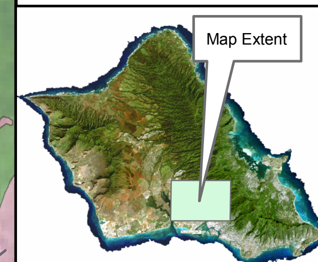
N
W E
S

0 2,500 5,000
1 inch equals 5,000 feet

Legend

- Wetlands
- Roads
- Pipes
- Tunnels
- Agricultural
- Other - Mostly Forest
- Urban

Sources: Refer to Data Dictionary Appendix 1



Island of Oahu, Hawaii

Figure 2-2
Land Use Map

Red Hill
Bulk Fuel Facility

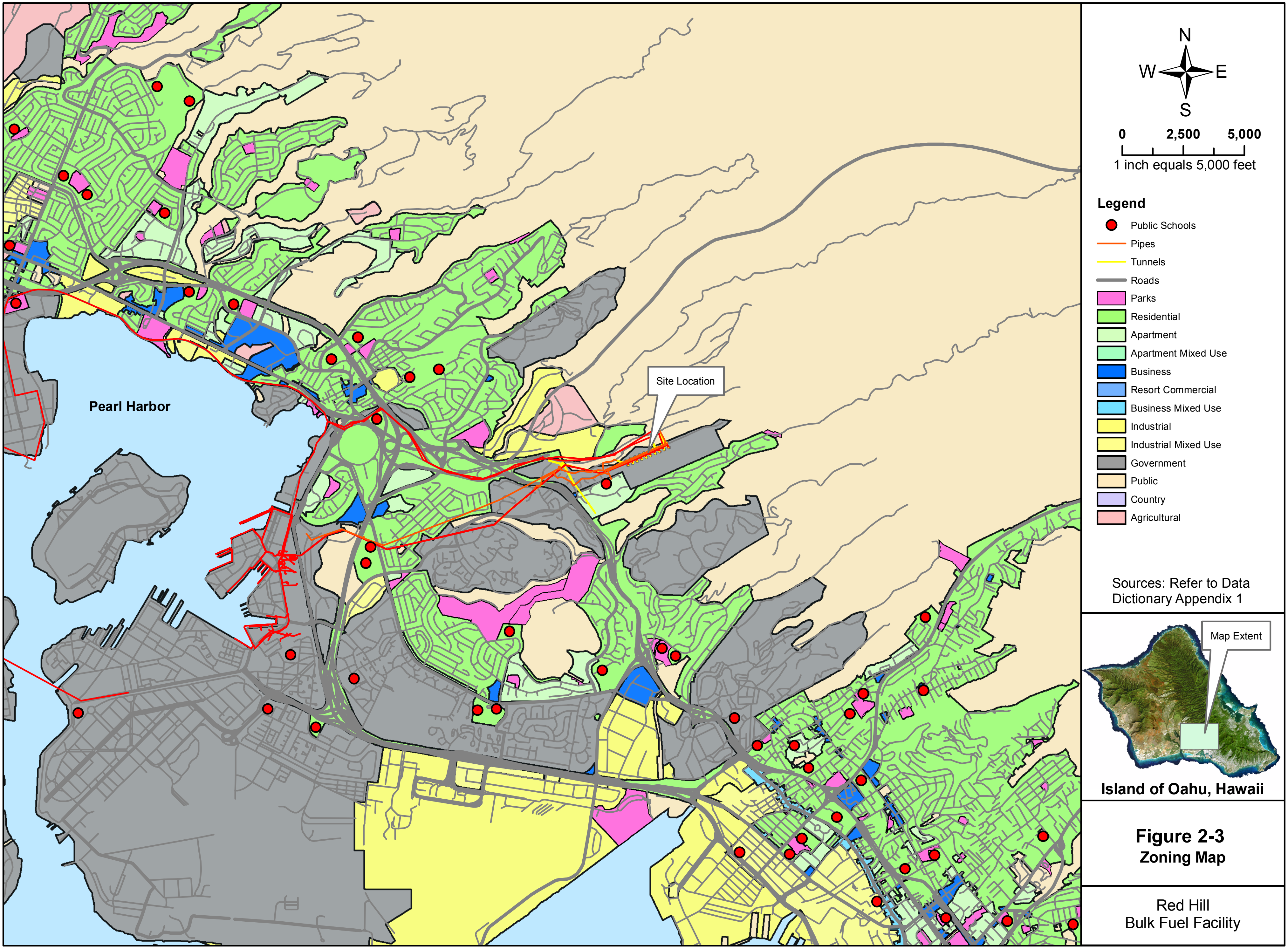


Figure 2-3
Zoning Map

Red Hill
Bulk Fuel Facility

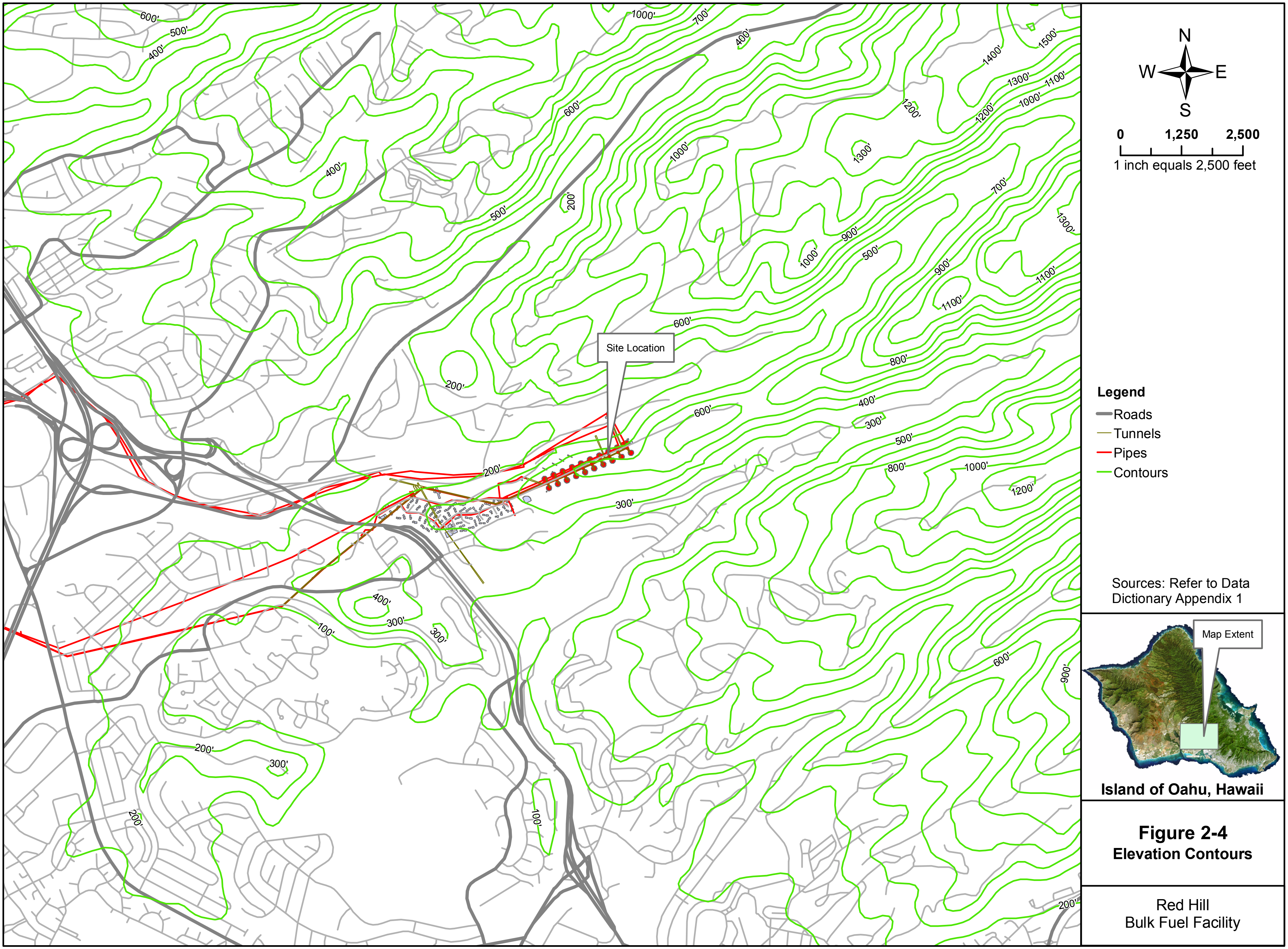
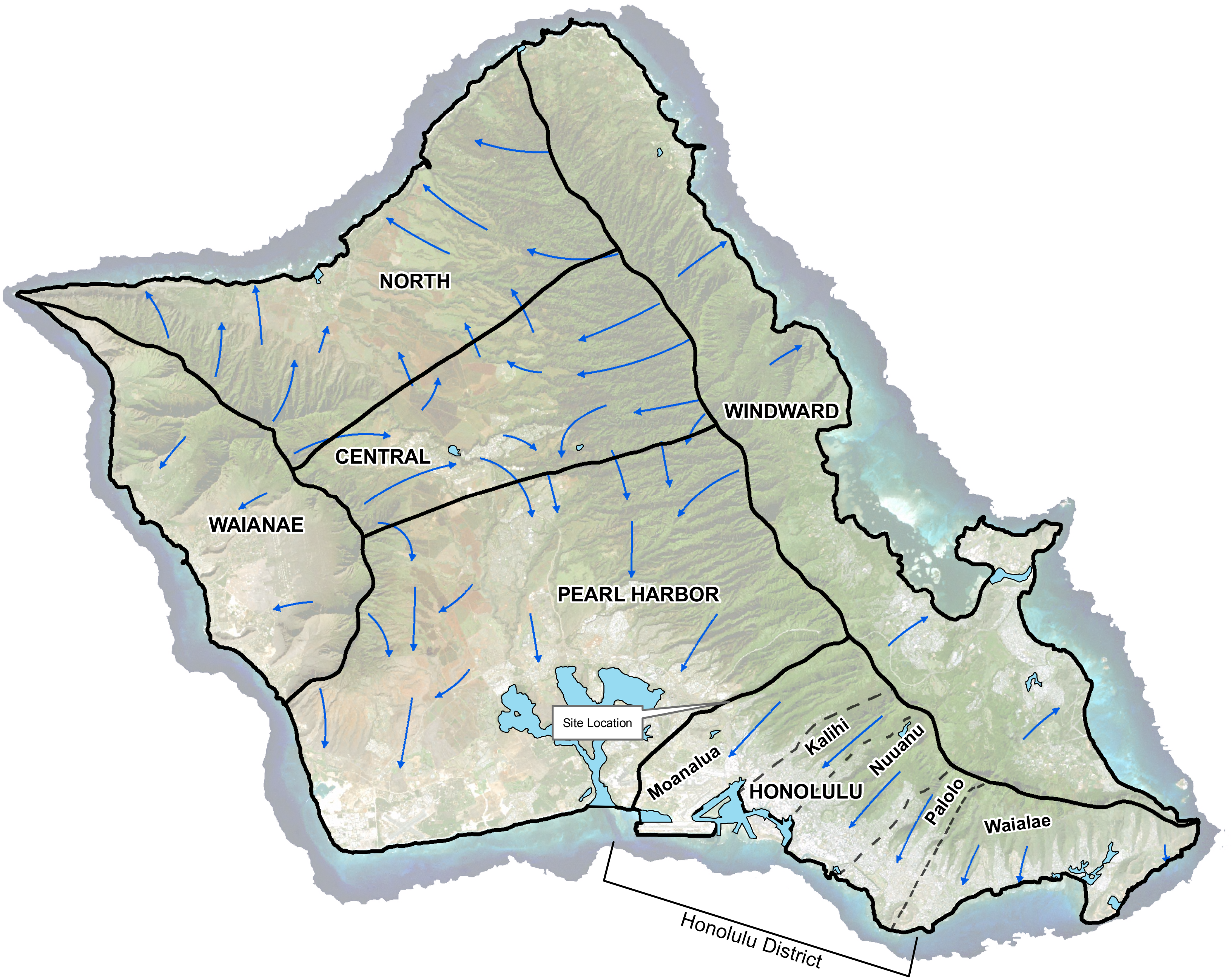
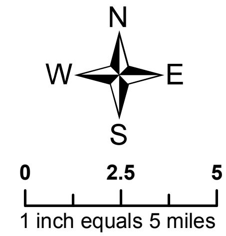


Figure 2-4
Elevation Contours

Red Hill
Bulk Fuel Facility





Legend

- Major Geohydrologic Boundaries
- Sub Geohydrologic Boundaries
- Groundwater Flow Direction
- Water

Sources: Refer to Data Dictionary Appendix 1

Island of Oahu, Hawaii

Figure 2-5
Generalized Groundwater Flow & Geohydrologic Boundaries

Red Hill Bulk Fuel Facility

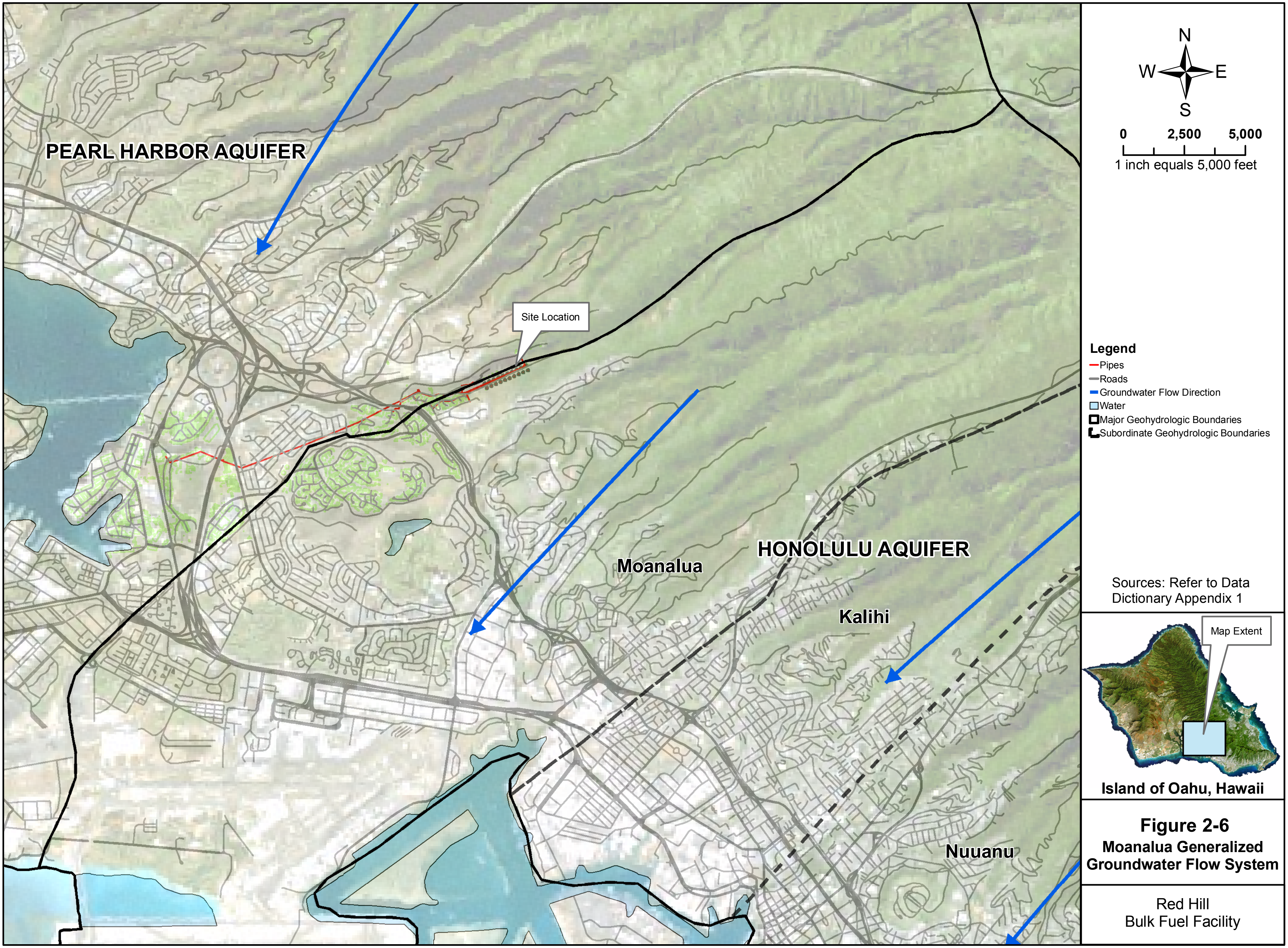
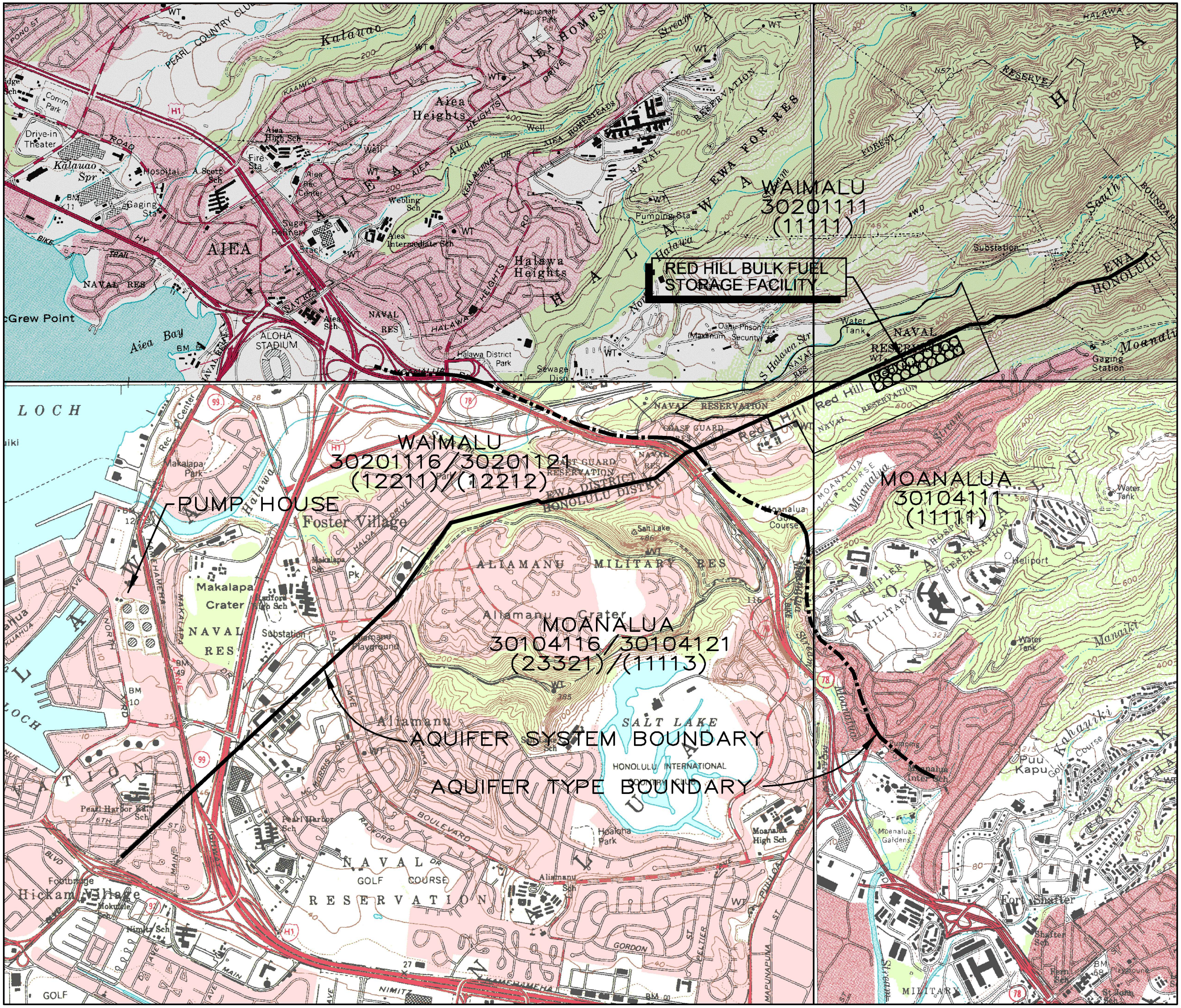


Figure 2-6
Moanalua Generalized Groundwater Flow System

Red Hill Bulk Fuel Facility



N

LEGEND

———	AQUIFER SYSTEM BOUNDARY
— · —	AQUIFER TYPE BOUNDARY
30201111	AQUIFER CODE
(11111)	STATUS CODE

NOTE

SOURCES: MINK & LAU (1990); DLNR (1998); USGS (1983)

250 500 1000 Feet

Figure 2-7
Aquifer System and
Type Boundaries

Red Hill
Bulk Fuel Facility

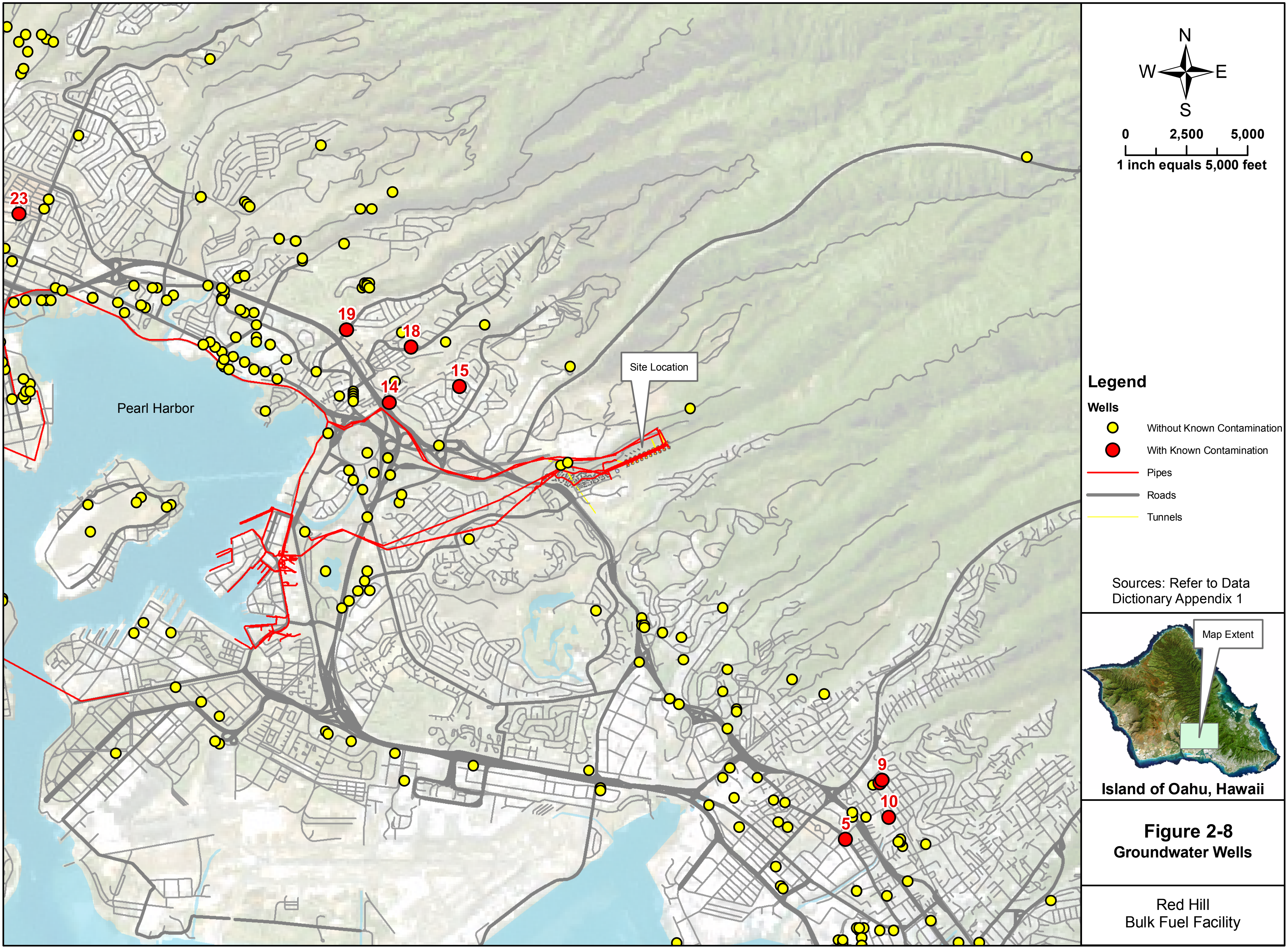


Figure 2-8
Groundwater Wells

Red Hill
Bulk Fuel Facility

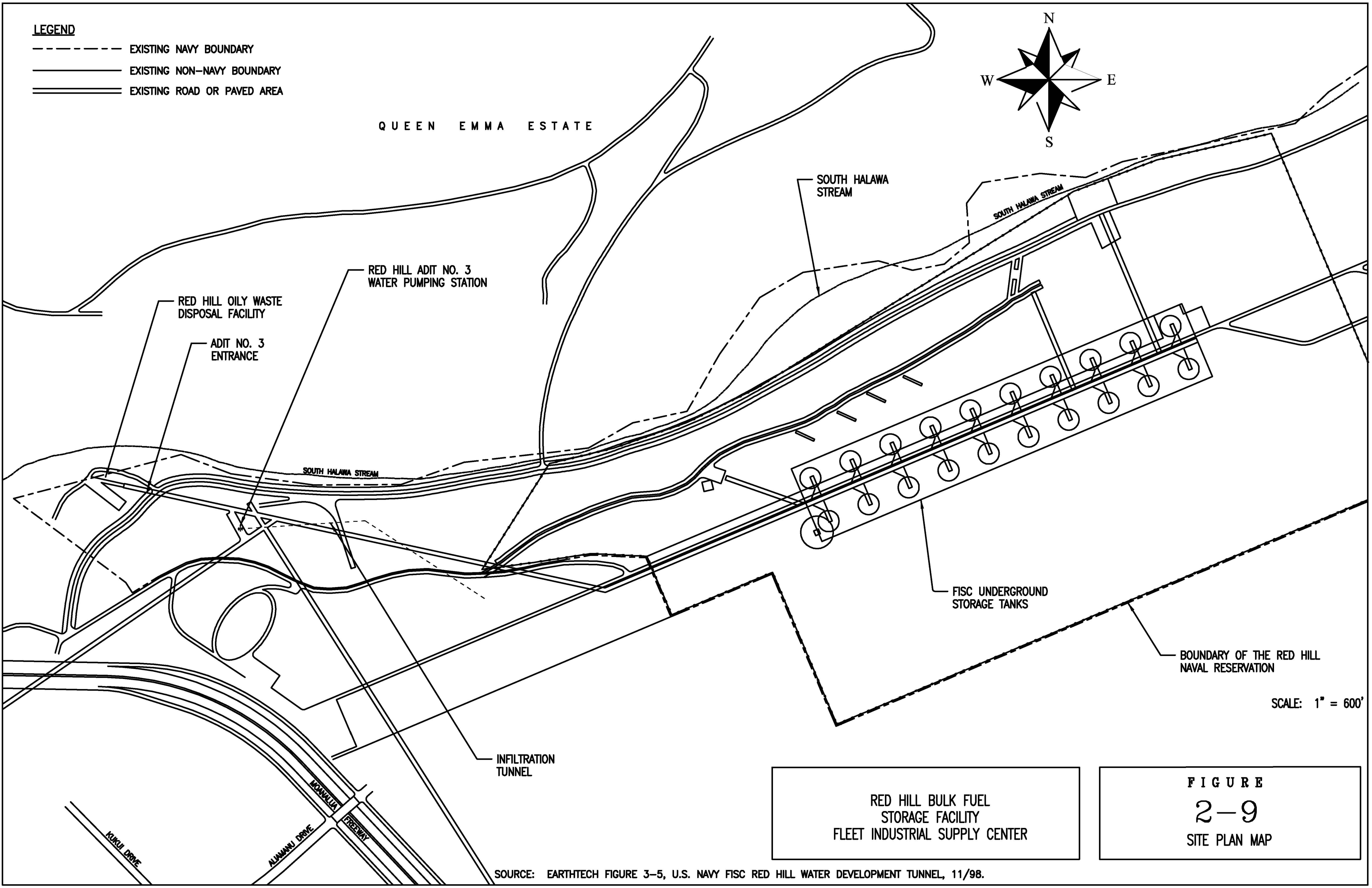
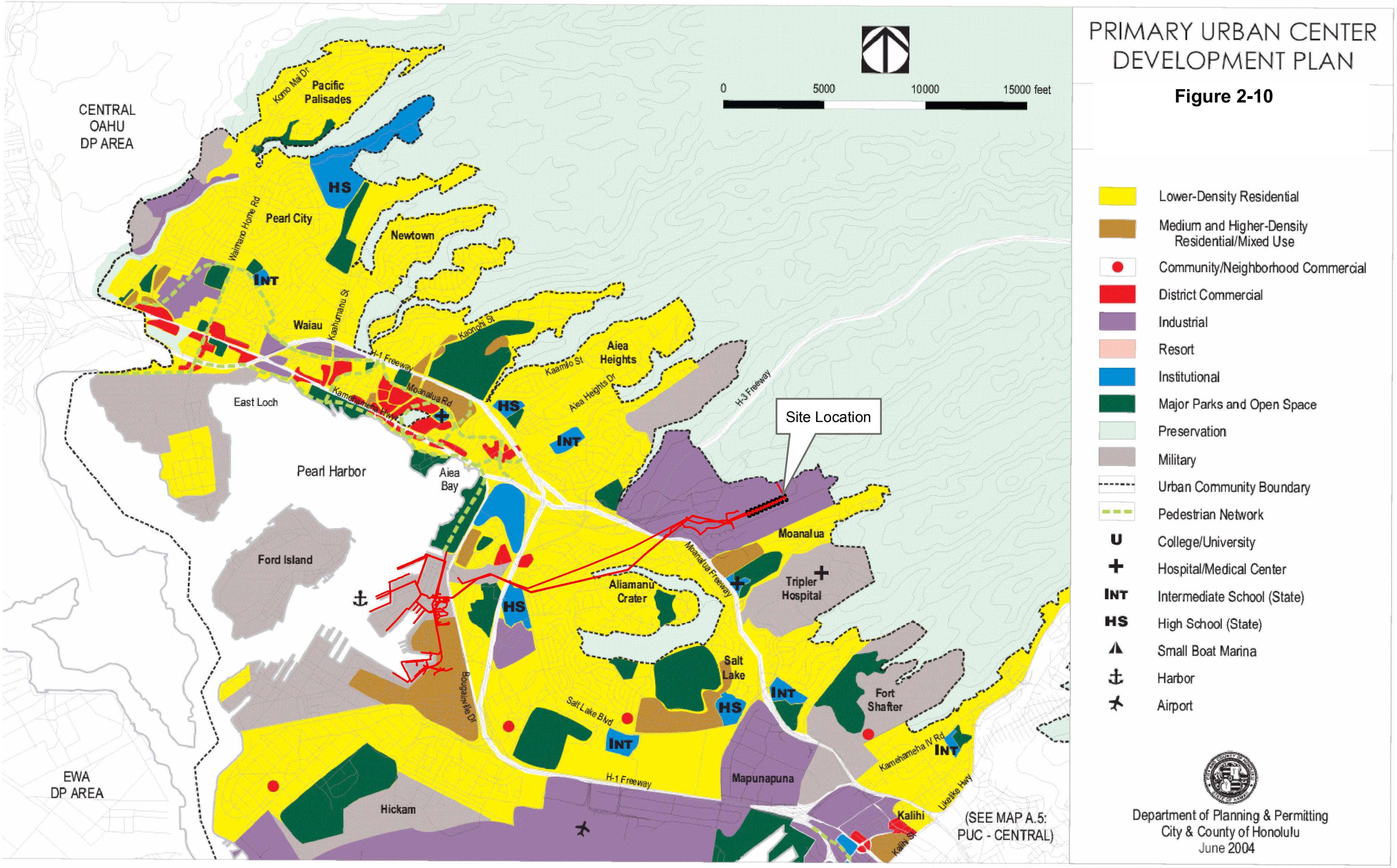
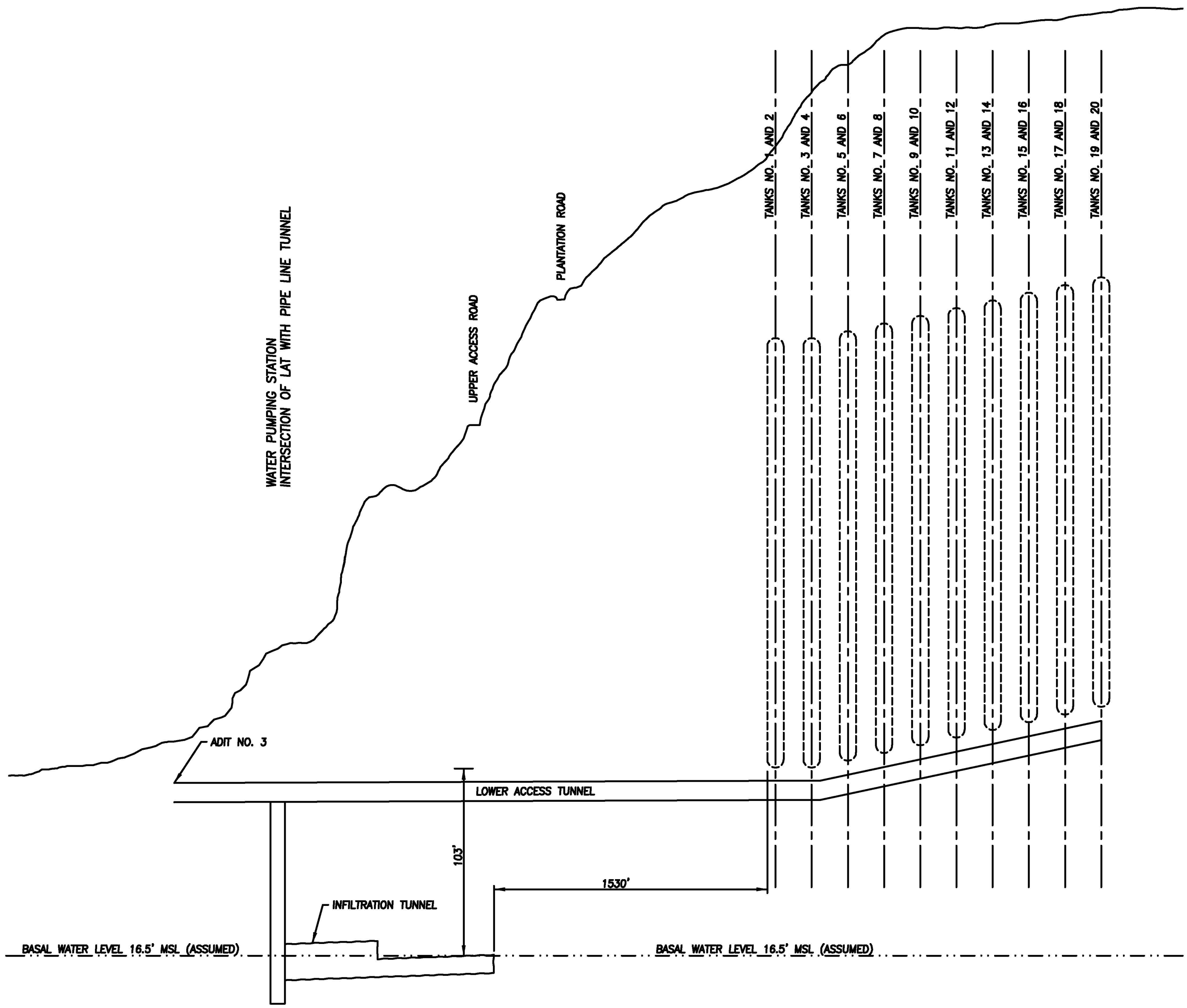


FIGURE 2-9
SITE PLAN MAP


PRIMARY URBAN CENTER
DEVELOPMENT PLAN
Figure 2-10
0
5000
10000
15000 feet
Lower-Density Residential
Medium and Higher-Density Residential/Mixed Use
Community/Neighborhood Commercial
District Commercial
Industrial
Resort
Institutional
Major Parks and Open Space
Preservation
Military
Urban Community Boundary
Pedestrian Network
U College/University
Hospital/Medical Center
INT Intermediate School (State)
HS High School (State)
Small Boat Marina
Harbor
Airport
Site Location
CENTRAL OAHU DP AREA
EWA DP AREA
(SEE MAP A.5: PUC - CENTRAL)
Pacific Palisades
Pearl City
Newtown
Waiau
Aiea Heights
East Loch
Pearl Harbor
Aiea Bay
Ford Island
Moanalua
Tripler Hospital
Aliamanu Crater
Salt Lake
Fort Shafter
Mapunapuna
Hickam
Kalihi
H-1 Freeway
H-3 Freeway
Moanalua Freeway
Kamehameha Hwy
Moanalua Rd
Salt Lake Blvd
Kamehameha IV Rd
Likelike Hwy
Kalihi St
Department of Planning & Permitting
City & County of Honolulu
June 2004

RED HILL BULK FUEL
STORAGE FACILITY
FLEET INDUSTRIAL SUPPLY CENTER

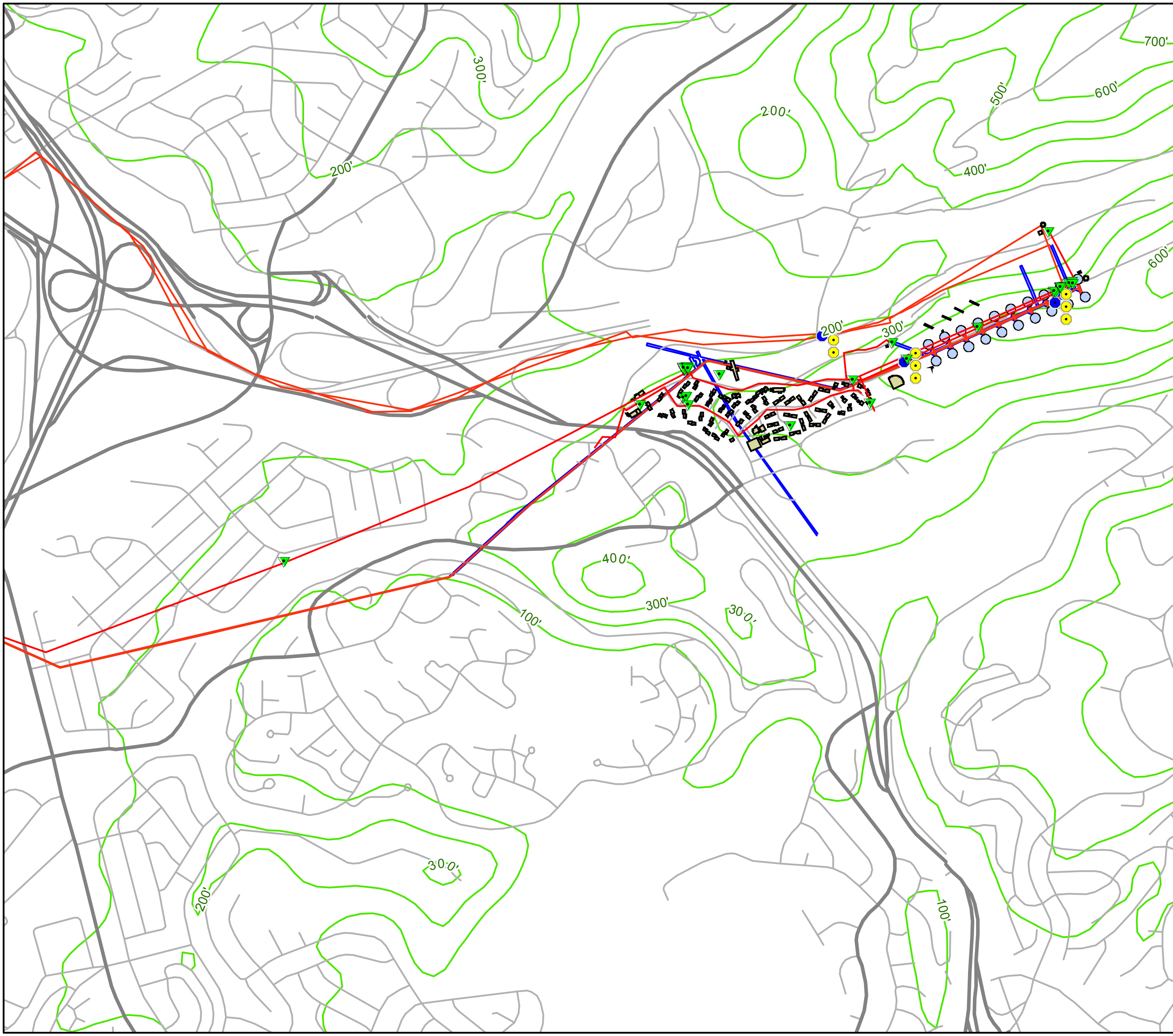


SCALE: HORIZ. 1" = 500'
VERT. 1" = 60'

FIGURE

2–11

BULK FUEL TANK AND
WATER TUNNEL PROFILE



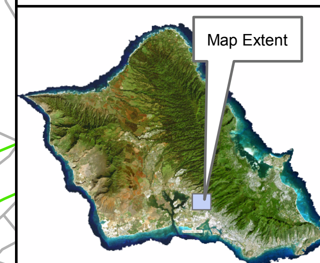
N
W E
S

0 750 1,500
1 inch equals 1,500 feet

Legend

- Water Points
- Survey Points 1
- Survey Points 2
- Pipelines
- Roads
- Tunnels
- Contours
- Fuel Tanks
- Buildings

Sources: Refer to Data Dictionary Appendix 1



Island of Oahu, Hawaii

Figure 2-12
Red Hill - View #1

Red Hill
Bulk Fuel Facility

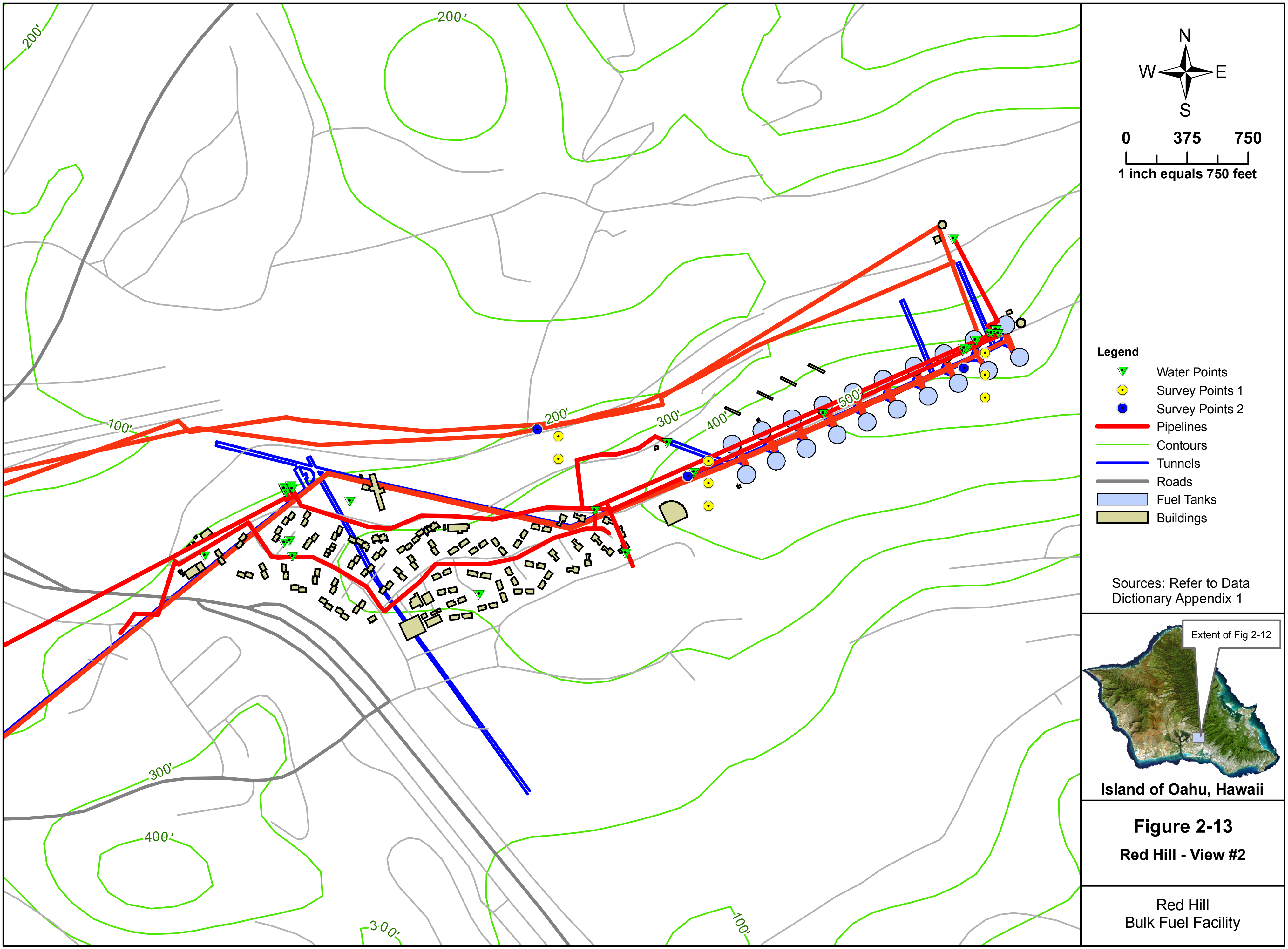


Figure 2-13

Red Hill - View #2

Red Hill
Bulk Fuel Facility

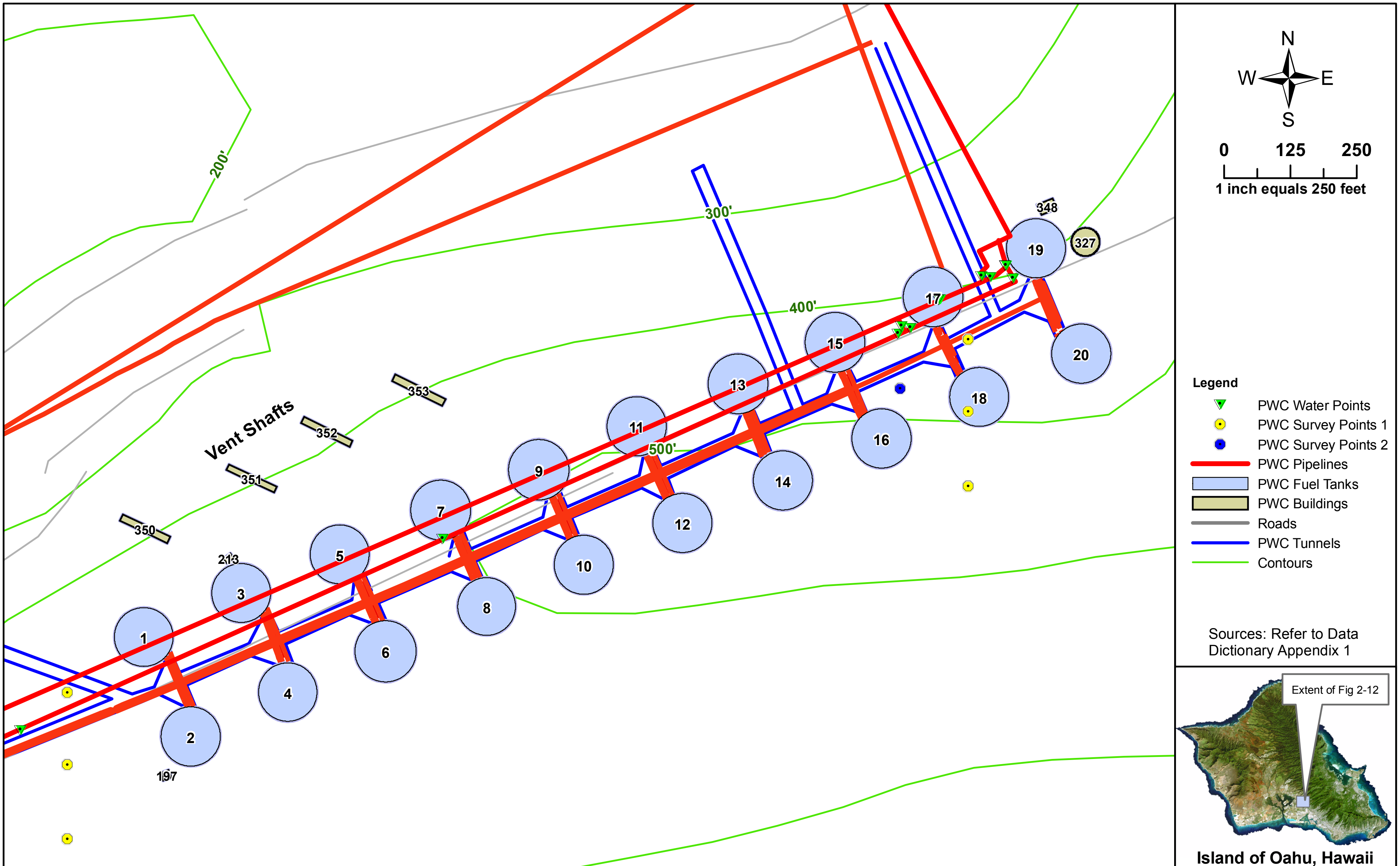
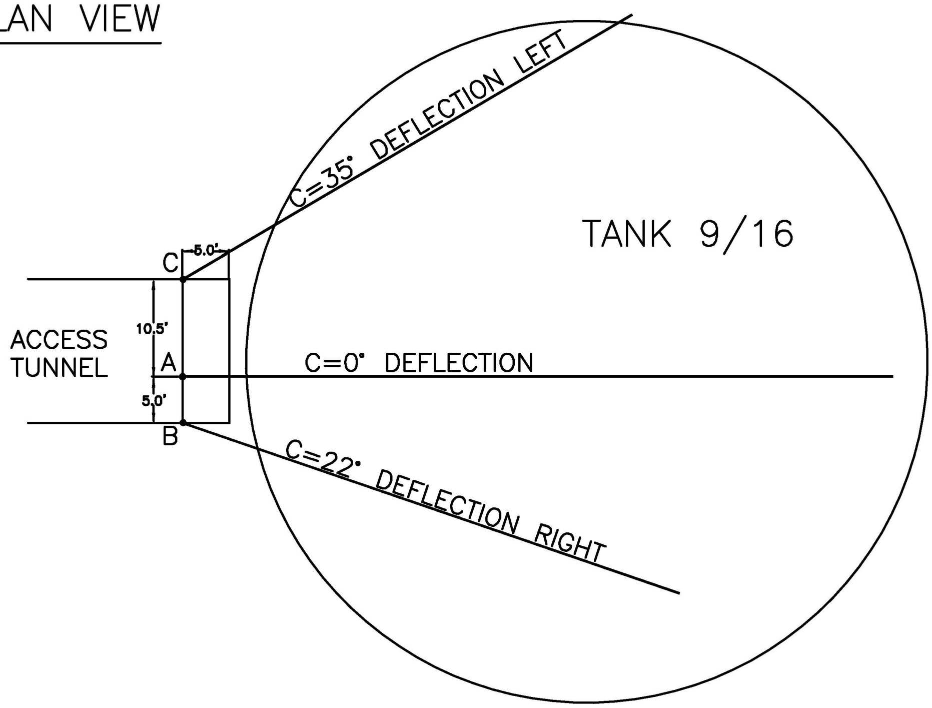


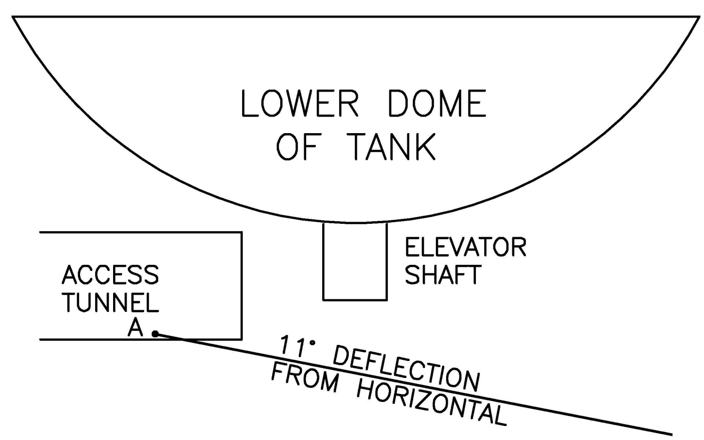
Figure 2-14
Red Hill - View #3

Red Hill
Bulk Fuel Facility

PLAN VIEW



SECTIONAL VIEW

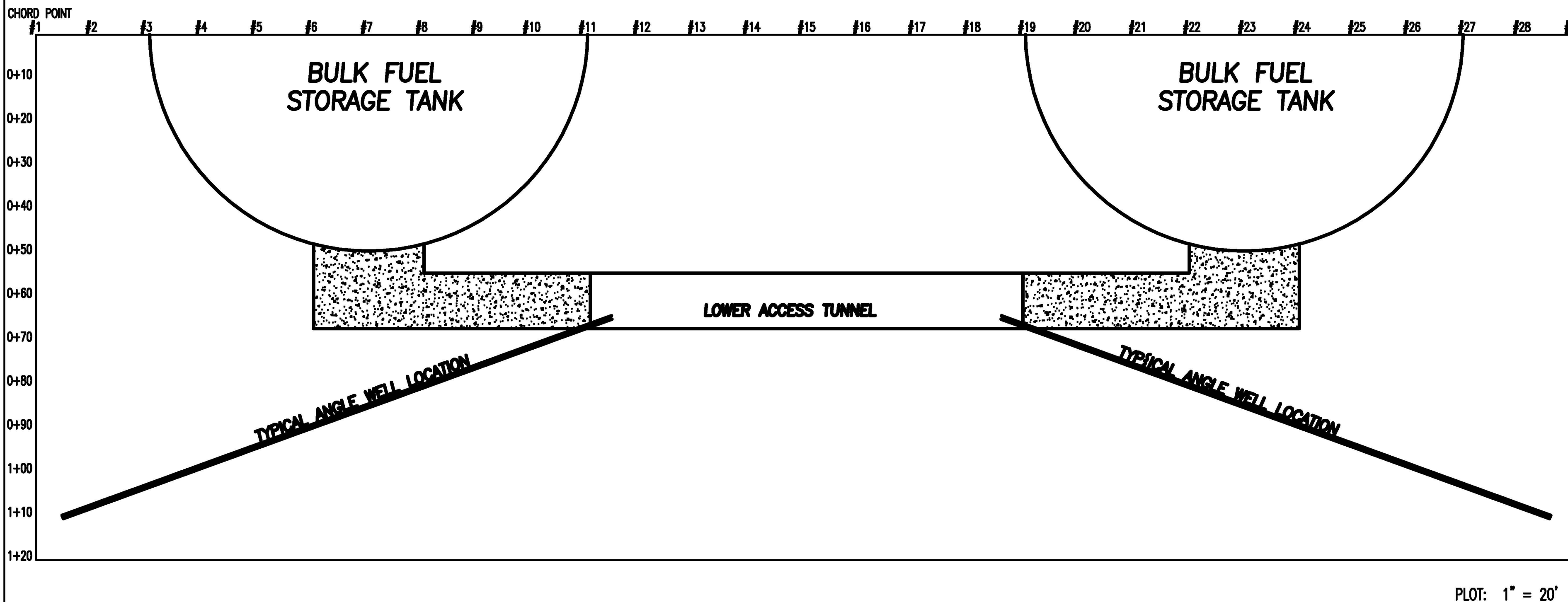


FILE NAME: NAVY\0229\BORING DIAGRAM-T16

BORING	DISTANCE
B09–A	93.80'
B09–B	75.00'
B09–C	72.50'
B16–A	102.70'
B16–B	76.40'
B16–C	74.50'

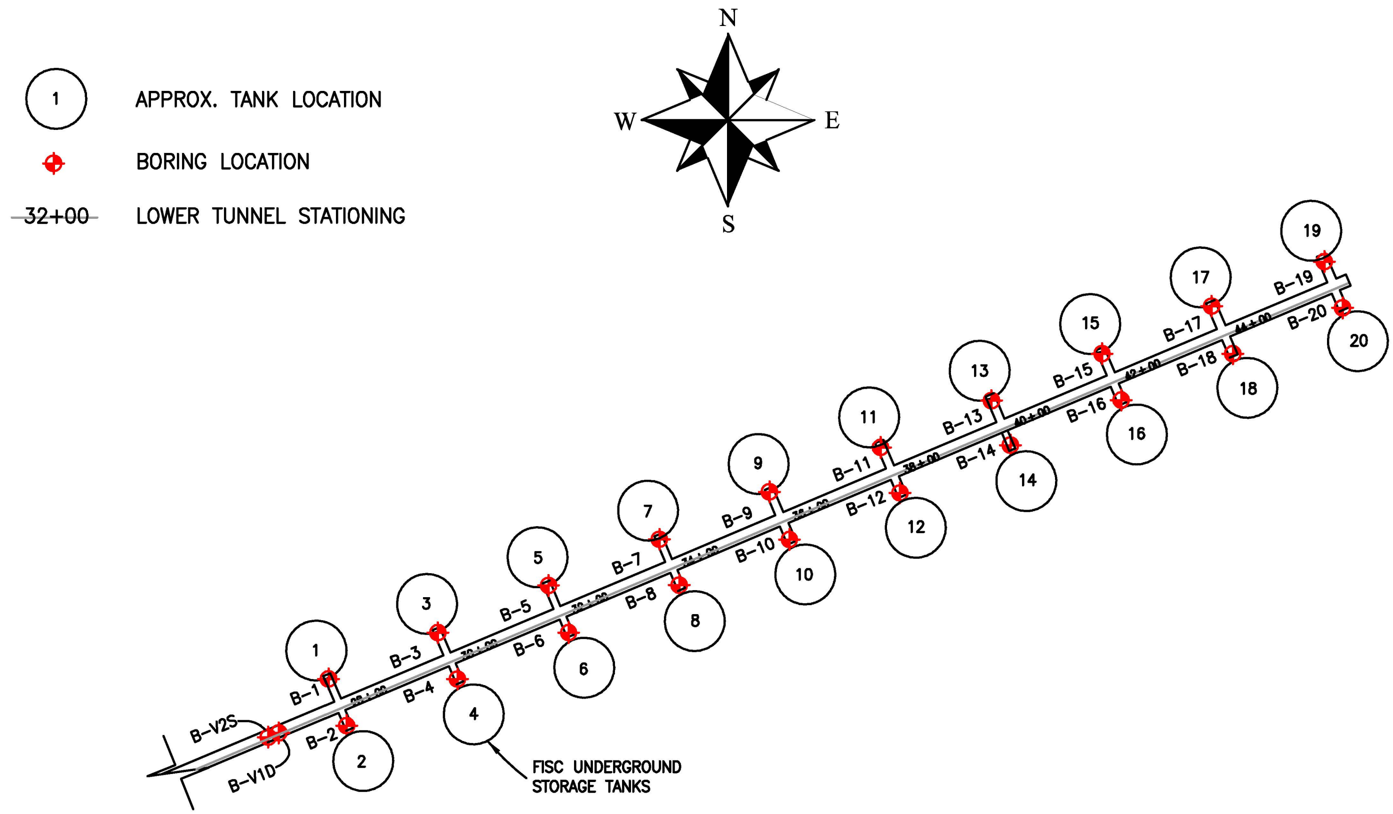
NOT TO SCALE

FIGURE
2–15
LOCATION, ANGLE, AND DISTANCE OF BORINGS
TANK 9 & 16
RED HILL BULK FUEL STORAGE



RED HILL BULK FUEL STORAGE FACILITY
FLEET INDUSTRIAL SUPPLY CENTER

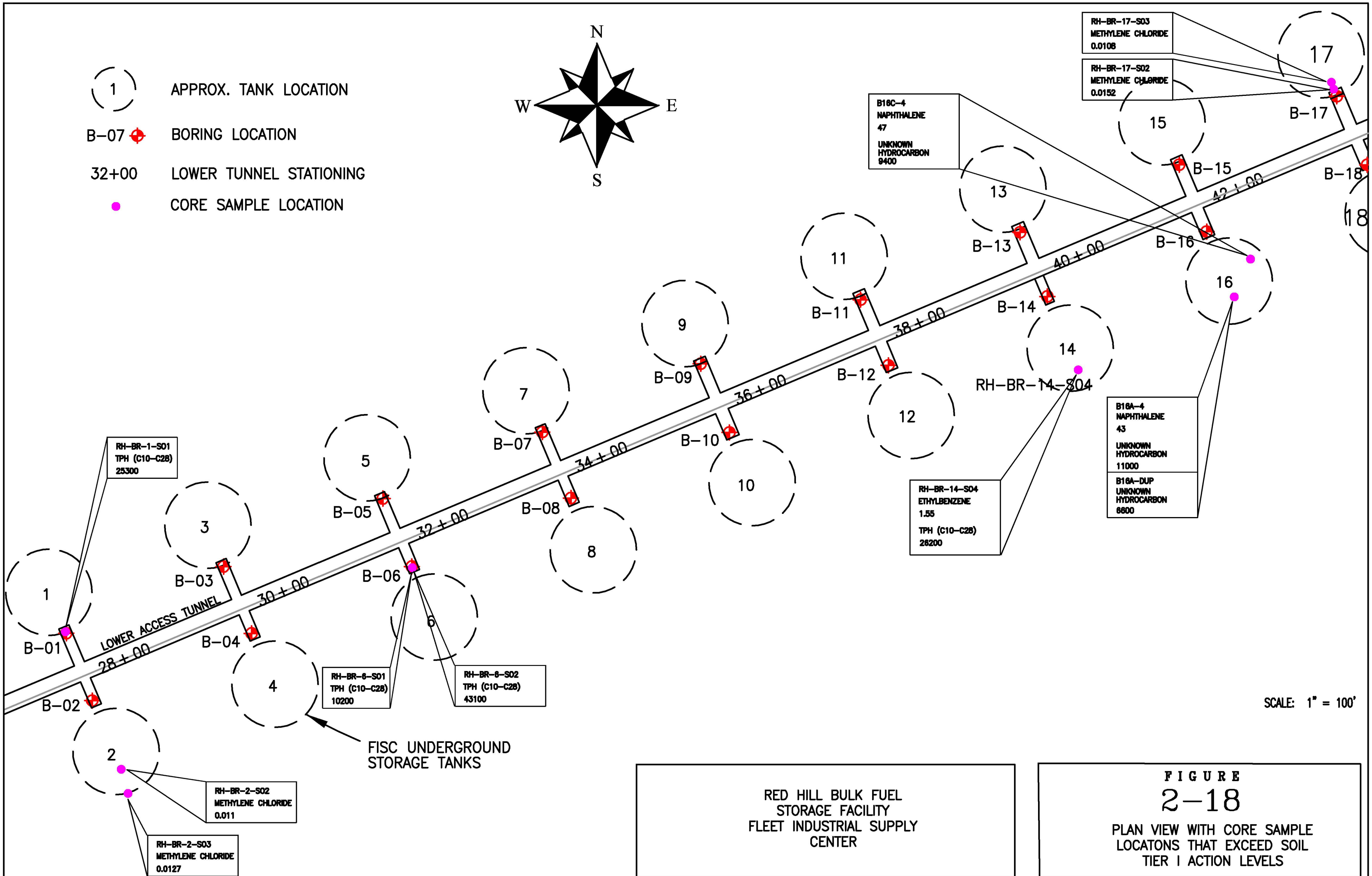
FIGURE
2–16
PROPOSED DRILLING ALIGNMENT



SCALE: 1" = 200'

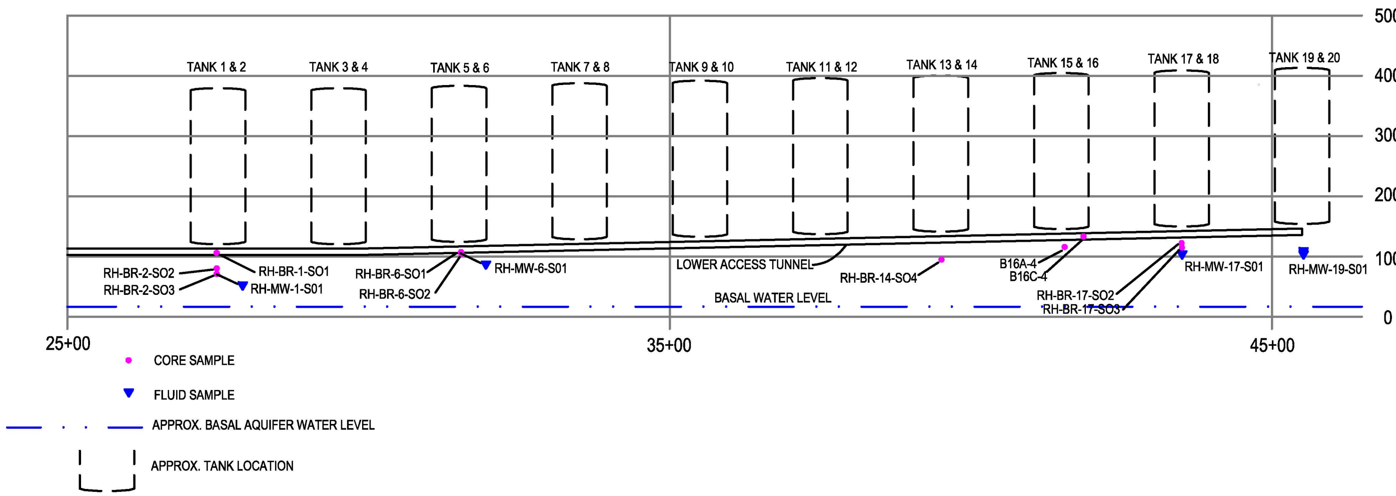
RED HILL BULK FUEL
STORAGE FACILITY
FLEET INDUSTRIAL SUPPLY CENTER

FIGURE
2-17
PLAN VIEW OF BORINGS



RED HILL BULK FUEL
STORAGE FACILITY
FLEET INDUSTRIAL SUPPLY
CENTER

FIGURE
2-18
PLAN VIEW WITH CORE SAMPLE
LOCATONS THAT EXCEED SOIL
TIER I ACTION LEVELS



CORE SAMPLE RESULTS

SAMPLE ID	CONSTITUENTS WHICH EXCEED TIER I ACTION LEVELS	ANALYTICAL RESULTS (PPM)
RH–BR–1–S01	TPH (C10–C28)	25300
RH–BR–2–S02	METHYLENE CHLORIDE	0.011
RH–BR–2–S03	METHYLENE CHLORIDE	0.0127
RH–BR–6–S01	TPH (C10–C28)	10200
RH–BR–6–S02	TPH (C10–C28)	43100
RH–BR–14–S04	ETHYLBENZENE	1.55
	TPH (C10–C28)	26200
B16A–4	NAPHTHALENE	43
	UNKNOWN HYDROCARBON	11000
B16A–DUP	UNKNOWN HYDROCARBON	6600
B16C–4	NAPHTHALENE	47
	UNKNOWN HYDROCARBON	9400
RH–BR–17–S02	METHYLENE CHLORIDE	0.0152
RH–BR–17–S03	METHYLENE CHLORIDE	0.0108

FLUID SAMPLE RESULTS

SAMPLE ID	DATE SAMPLED	CONSTITUENTS ANALYZED	ANALYTICAL RESULTS (PPM)
RH–MW–1–S01	03/07/01	LEAD	0.0756
RH–MW–6–S01	01/19/01	LEAD	27.5
RH–MW–17–S01	08/27/01	LEAD	0.0720
RH–MW–19–S01	03/07/01	LEAD	0.0568
	08/27/01	LEAD	0.0666

RED HILL BULK FUEL STORAGE FACILITY
FLEET INDUSTRIAL SUPPLY CENTER

FIGURE
2–19

CROSS SECTIONAL VIEW WITH SOIL AND FLUID SAMPLE LOCATIONS WHICH EXCEED THEIR RESPECTIVE TIER I ACTION LEVELS

SECTION 3
INITIAL EVALUATION

This section presents the results of a preliminary risk evaluation previously conducted for the RHSF, a preliminary conceptual model of the Site, and identifies Site-specific applicable or relevant and appropriate requirements (ARARs) and to be considered (TBC) benchmarks.

3.1 PRELIMINARY RISK SUMMARY

An initial risk screening level assessment was performed for the RHSF as part of the Phase II SI Report (AMEC, 2002). The results of the screening level assessment indicated that seven constituents were detected in core samples at concentrations of potential concern: ethylbenzene, methylene chloride, 2-methylnaphthalene, naphthalene, phenanthrene, TPH (carbon range C10-C28), and an unknown hydrocarbon. Three constituents were detected in groundwater samples at concentrations of potential concern: bis(2-ethylhexyl)phthalate, lead, and TPH (C10-C28). The investigations also reported the presence of petroleum LNAPL in several monitoring wells at the site. The preliminary risk evaluation conducted for the RHSF is included as **Appendix D**.

On the basis of the preliminary risk screening, it was recommended that a comprehensive risk assessment be completed to assess current and potential future risk associated with the RHSF.

3.2 PRELIMINARY CONCEPTUAL SITE MODEL

Based on the results of the previous investigation and an initial pathway evaluation, a set of preliminary conceptual site model (CSM) graphical interpretations have been prepared to illustrate general geologic, hydrologic and fate and transport principals that are the current paradigm for the project area. These include a topographic relief model (**Figure 3-1**), which illustrates the area of potential impact, including land use, and defines the cross sections A-A' and B-B'.

Figure 3-2 is a CSM describing the hydrogeology and pathways of concern along transect A-A', which runs longitudinally through the Red Hill facility ridge line and illustrates the sources of contamination (primary USTs, secondary vadose zone, and tertiary basal groundwater) with respect to potential receptor endpoints (surface receptors, tunnel receptors, and groundwater supply wells).

Figure 3-3 is CSM describing the hydrogeology and pathways of concern along transect B-B', which runs transverse to the Red Hill facility ridge line and illustrates the sources of contamination (primary USTs, secondary vadose zone, and tertiary basal groundwater) with respect to potential receptor endpoints (valley fill, Halawa and Moanalua streams and groundwater supply wells).

The key information that is provided by these figures is the site geometry and the impacts of site features on potential contaminant migration pathways. Most importantly:

- Releases from the USTs are expected to be focused below the bottom of the tanks due to the concrete liner. The bottom of the tanks are located between 100 (Tank 1) and 150 feet (Tank 20) above MSL, and consistently below the level of the surrounding valley fill, which will act as a barrier to horizontal migration. In addition, the USTs are between 500 and 750 feet horizontally from the valley walls. Lateral movement over this distance is not expected in the fractured basalt. For these reasons, the pathway for LNAPL or leachate to migrate to the valley surface and surface water/sediments is incomplete.

- Releases from the USTs are approximately 300 to 350 feet bgs in a fractured basalt environment. Due to the highly oxygenated subsurface and large distance to the ground surface, and the types of fuel that have been most recently stored in the USTs (Navy Special Fuel Oil, Diesel Fuel Marine, and JP-5, which are relatively low in volatility), volatile compounds are not expected to migrate to the ground surface. For these reasons, the pathway for organic compounds volatilized in soil vapor to migrate to the ground surface is insignificant.

- Releases from the USTs are in close proximity to the lower access tunnels and vapors may volatilize through cracks in the tunnel floor and impact current and future workers. Although the tunnels are ventilated to ensure that breathing conditions are appropriate for onsite workers, this pathway may potentially be complete and therefore should be evaluated in the project Risk Assessment.

- Releases from the USTs may impact the groundwater beneath the USTs, either in the form of contaminated infiltrating rainwater (leachate) where rainwater passes through secondary sources of petroleum adsorbed to the fractured basalt substrate, or as LNAPL in the case of relatively large releases. Soil vapor monitoring points may provide long-term monitoring points for the unsaturated zone beneath each tank, and will be installed and sampled as part of a pilot study during this site characterization study. Two additional monitoring wells will be installed in the lower access tunnel, which will provide three basal water sampling points inside the facility adjacent to the USTs (including the existing V1D well). These will monitor the upper, middle and lower portions of the farm respectively, for groundwater impact within the UST facility.

- Past current or future releases may reach the basal groundwater and migrate as dissolved compounds in the basal aquifer to downgradient supply wells. Currently three nearby wells are within the study area as the closest and most vulnerable to being impacted by releases to groundwater (Board of Water Supply (BOWS) Halawa Pumping Shaft Well No. 2354-01, PWC Red Hill Navy Pumping Shaft Well No. 2254-01, and BOWS Moanalua Supply Well No. 2153-10). These will be evaluated for potential vulnerability using 3 dimensional groundwater modeling techniques and analytical evaluation of the basal aquifer assimilative capacity based on the assessment of natural attenuation parameters.

In addition to the comprehensive graphics, a preliminary Conceptual Site Exposure Model (CSEM) schematic is provided to define the current understanding of the exposure pathways as a facet of the Preliminary Risk Evaluation. The CSEM identifies the relationships among potential sources, release and transport mechanisms, exposure media and routes, and potential receptors at the Site. The preliminary CSEM is presented as **Figure 3-4**. The CSEM defines an exposure pathway as Incomplete, Potentially Complete and Minor, or Potentially Complete and Major.

- o Pathways that are considered Incomplete are defined as pathways in which no contaminants can migrate from the source to the exposure point.

- Pathways that are considered Potentially Complete and Minor are defined as pathways in which, if complete, contaminants concentrations that would reach the exposure points are very small compared to the screening action levels and therefore deemed insignificant in impacting human health and the environment.

- Pathways that are considered Potentially Complete and Major are defined as pathways in which, if complete, contaminants concentrations that would reach the exposure points have the potential to present an unacceptable risk to human health and the environment.

The CSEM identifies several pathways classified as major and potentially complete. These pathways include exposure to potable groundwater through ingestion, dermal contact, and inhalation for residential and occupational receptors. The other potentially complete pathway of concern is soil vapor intrusion to tunnel work areas.

3.3 Project Objectives

The results of a previous Site Investigation (SI) (AMEC, 2002) indicated that petroleum hydrocarbons were reported in rock samples obtained beneath the USTs and that lead was detected in groundwater samples obtained from a monitoring well situated hydraulically down-gradient from the facility. The SI recommended the completion of a comprehensive Risk Assessment (RA) to quantify the risks associated with the observed compounds. In an effort to evaluate current and potential future risks to the subsurface, the State of Hawaii Department of Health (HDOH), Solid Waste Branch concurred in a letter dated October 10, 2003 (**Appendix E**) that the US Navy would:

- Conduct a comprehensive Tier 3 RA,

- Develop a comprehensive CSM incorporating Fate and Transport Models to facilitate preparation of the RA,

- Prepare a Contingency Plan to protect the Navy's groundwater supply at Red Hill, and

- Monitor groundwater in the underlying basal aquifer and at the PWC potable water source at Red Hill.

To accomplish these goals, the Navy has adopted the following project objectives:

1. **GIS Model**. Compile existing electronic and hardcopy data regarding past activities at the Site, including lithologic descriptions obtained from excavation and boring logs; facility construction details, and published environmental information. The compiled data will be used to create a three-dimensional (3-D) geographic information system (GIS) model to facilitate data storage and 3-D visualization.

2. **Conceptual Site Model (CSM).** Develop a comprehensive CSM to illustrate potential sources, exposure pathways, and receptors. The CSM will be used to refine the site characterization activities, facilitate fate and transport calculations, and to communicate site conditions to regulators and stakeholders.

3. **Site Characterization Study (SCS).** Conduct a SCS to obtain data necessary to further characterize the documented release and to complete a Comprehensive Risk Assessment. The SCS will include the installation and sampling of groundwater monitoring wells and soil vapor monitoring points, and the evaluation of Fate and Transport mechanisms using analytical and numerical modeling techniques.

4. **Applicable or Relevant and Appropriate Requirements (ARARs).** Prepare a list of ARARs and TBC risk-based action levels for potentially impacted media.

5. **Risk Assessment.** Conduct a Tier 3 Comprehensive RA to determine chemicals of potential concern (COPCs), potentially complete exposure pathways, potential receptors, and exposure point action levels for each receptor and media.

6. **Monitoring System.** Develop a groundwater and soil vapor monitoring system that will allow the U.S. Navy to characterize the Site both spatially and temporally for past, present and future releases.

7. **Contingency Plan.** Develop a contingency plan that ensures that unacceptable risks to human health and/or the environment from any past present and/or future releases are mitigated

3.4 Applicable or Relevant and Appropriate Requirements And To Be Considered Benchmarks

It is U.S. Navy policy that environmental investigations and removal actions be conducted in accordance with all applicable federal and state ARARs. TBCs may also be used as guidance for evaluating chemicals without ARARs or in situations where ARARs are not sufficiently protective of human health and the environment. ARARs/TBCs are used to determine the scope and extent of cleanup for a site. They help to formulate remedial action alternatives as well as govern the implementation and operation of a selected action.

The following bulleted list provides the ARARs/TBCs that have been considered during this phase of the investigation. Only State of Hawaii requirements are applicable to the Red Hill Site. The State of Hawaii, Department of Health Underground Storage Section is the lead agency responsible for the investigation.

- HAR, Title 11, Chapter 451, *State Contingency Plan* (August 1995)
- Technical Guidance Manual for Underground Storage Tank Closure and Release Response (March 2000)
- Technical Guidance Manual for the Implementation of the Hawaii State Contingency Plan, Risk-Based Corrective Action and Decision Making at Sites with Contaminated Soil and Groundwater, Volume 1 (June 1996).
- Screening for Environmental Concerns at Sites with Contaminated Soils and Groundwater, Volume 1: Summary Tier 1 Lookup Tables (December 2003, Interim Draft.

Potential regulatory requirements for the RHSF include State of Hawaii environmental laws as promulgated by the Hawaii State Contingency Plan and administered by the State of Hawaii Solid and Hazardous Waste Branch, Underground Storage Tank Section and the Hazard Evaluation and Emergency Response Section. ARARs are regulatory requirements that are directly applicable or relevant and appropriate to a contaminant or situation. TBCs are nonpromulgated guidelines or benchmarks that may be considered in determining cleanup levels but are not enforceable guidelines or benchmarks.

3.4.1 ARARs – Defined

Applicable requirements refer to standards and other substantive environmental protection requirements promulgated under U.S. federal or Hawaii state laws that specifically address a circumstance at a hazardous waste site such as the presence of a hazardous substance, pollutant, contaminant, remedial action, or location. "Applicability" implies that the circumstances at the site satisfy all of the jurisdictional prerequisites of a requirement and are legally applicable for the site.

Relevant and appropriate requirements refer to standards and other substantive environmental protection requirements promulgated under U.S. federal or state law that are not legally applicable to a site but address situations sufficiently similar to be of use in evaluating the site. "Relevance" implies that the requirement regulates or addresses situations sufficiently similar to those found at the hazardous waste site. "Appropriateness" implies that the circumstances of a release or threatened release of chemicals are such that use of the standard is suitable. A requirement may be relevant but not appropriate for a site and therefore would not be an ARAR.

3.4.1.1 ARARs for the RHSF

There are no identified ARARs associated with potential soil contamination at the RHSF. There are also no substantive environmental protection requirements for potentially contaminated groundwater wells at the Site. All standards applicable to the RHSF are nonpromulgated advisories put forth by the HDOH. These benchmarks are described below.

3.4.2 TBCs – Defined

To-Be Considered benchmarks (TBCs) are nonpromulgated advisories, guidances or benchmarks that are not generally enforceable. Where no specific ARARs exist for a chemical or situation, or where such ARARs are not sufficient to be protective, guidance documents or advisories may be considered in determining the necessary cleanup level for the protection of human health or the environment. Levels of concern developed during a risk assessment are considered TBCs.

3.4.2.1 TBCs For the RHSF

Nonpromulgated criteria have been identified as potential chemical-specific TBCs for this investigation. They are described below.

3.4.2.1.1 HDOH Tier 1 Environmental Action Levels

As initial guidance, the HDOH recommends that contaminated soil and groundwater discovered at leaking underground storage tank sites be screened to Tier 1, TPH and constituent-specific Environmental Action Levels (EALs). The HDOH stipulates separate action levels for TPH and its indicator chemicals. TPH EALs should be used in conjunction with EALs for these chemicals. Indicator chemicals typically recommended to be included at sites where petroleum mixtures are assumed present include:

Monocyclic Aromatic Hydrocarbons

- Benzene
- Ethylbenzene
- Toluene
- Xylene

Fuel Additives

- MTBE
- Other oxygenates as necessary

Polycyclic Aromatic Hydrocarbons (primarily middle distillates and residual fuels)

- Acenaphthene
- Acenaphthylene
- Anthracene
- Benzo(a)anthracene
- Benzo(b)fluoranthene
- Benzo(g,h,i)perylene
- Benzo(a)pyrene
- Benzo(k)fluoranthene
- Chrysene
- Dibenzo(a,h)anthracene
- Fluoranthene
- Fluorene
- Indeno(1,2,3)pyrene
- Methylnaphthalene (1-and 2-)
- Naphthalene
- Phenanthrene
- Pyrene

Site Category

Under the HDOH 1996 RBCA program, release sites are categorized into groundwater utility scenarios – "Drinking Water Source Threatened" and "Drinking Water Source NOT Threatened". Groundwater utility is determined based on the location of the site with respect to the Underground Injection Control Line and the State of Hawaii *Aquifer Identification and* Classification technical reports prepared by the University of Hawaii. The Tier 1 action levels are further delineated/categorized based on annual rainfall (<200 cm/year and >200 cm/year). The HDOH draft screening guidance further categorizes sites and corresponding EALs by "Release Site ≤ 150 m From a Surface Water Body" and "Release Site > 150 m From a Surface Water Body" (HDOH 2003). This is intended to enhance screening and monitoring of contaminated groundwater in close proximity to surface water bodies. The categories and EALs applicable for the RHSF are:

- Drinking Water Source Threatened

- Rainfall <200 cm/year
- Release Site > 150 m From a Surface Water Body

The RHSF is located hydraulically up-gradient of the UIC line. The nearest BOWS drinking water well (Halawa Shaft, well number 2354-01) is located hydraulically cross-gradient of the Site. This drinking water well is approximately 5,000 feet northwest of the Site and pumps water from the basal aquifer. In addition, a U.S. Navy drinking water well (2254-01) is located approximately 3,000 feet southwest of the site and is possibly hydraulically down-gradient from the site. Because the RHSF is situated above a drinking water aquifer, the Tier 1 standards protective of a drinking water source apply. The nearest surface water body is not located within 150 meters of the RHSF and rainfall is less than 200 cm/year.

Tier 1 EALs are not required, regulatory "cleanup standards" and have currently only been presented in Draft form (December 2003). Use of Tier 1 EALs as actual cleanup levels should be evaluated in view of the overall site investigation results. For the RHSF, a comprehensive site-specific Tier 3 risk assessment will be conducted based on the results of earlier investigations. The applicable screening criteria are summarized in **Table 3-1**.

3.4.2.1.2 Tier 2 and Tier 3 Environmental Risk Assessments

The RHSF is an active petroleum storage facility with a maximum capacity of approximately 240 million gallons. As such, the US Navy will estimate action levels at monitoring points on site that will have the potential to result in unacceptable chemical concentrations at the exposure points (groundwater in nearby supply wells and ambient air in breathing space within the lower access tunnel of the RHSF). The US Navy will estimate these concentrations using accepted analytical and numerical modeling techniques. These site-specific Tier 2 and Tier 3 environmental action levels will be considered site-specific TBCs. The HDOH RBCA approach is a three-tiered system. The RBCA Tier 1 EALS have previously been described. The Tier 1 EALS feature highly conservative recommended soil and groundwater action levels intended for direct comparison to organic compounds or compound classes and heavy metals in both soil and groundwater samples collected at a site. RBCA Tiers 2 and 3 provide guidelines for calculating site-specific criteria based upon encountered geologic conditions and detected COPCs at a site. The RBCA Tier criteria applicable to a site are also determined by the classification of the groundwater beneath a site location, with separate criteria for sites not overlying drinking water sources and more conservative criteria for sites overlying potential drinking water sources. If Tier 1 EALs are exceeded, site-specific information will be utilized to calculate Tier 2 or 3 action level criteria at the RHSF.

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Table 3-1
Screening Criteria
HDOH Tier 1 Environmental Action Levels

Constituent	Soil Action Level, Drinking Water Resource (Soil Leaching)	Soil Action Level, Indoor Air Impacts	Groundwater Action Level, Drinking Water Toxicity	Groundwater Action Level, Indoor Air Impacts	Shallow Soil Gas Action Level, Indoor Air Impacts (residential exposure)
	mg/kg	mg/kg	ug/L	ug/L	ug/m^3
VOCs					
Benzene	0.22	0.67	5	2000	310
Toluene	2.9	650	1000	530000	420000
Ethylbenzene	3.3	4.7	700	14000	2200
Xylenes	2.3	220	10000	160000	100000
MTBE	0.023	5.2	13	62000	24000
SVOCs					
Acenaphthene	16	130	370	4200	220000
Acenaphthylene	100	(soil gas)	240	(soil gas)	150000
Anthracene	2.8	6.1	1800	43	1100000
Benzo(a)anthracene	12	NA	0.092	NA	NA
Benzo(b)fluoranthene	46	NA	0.092	NA	NA
Benzo(g,h,i)perylene	27	NA	1500	NA	NA
Benzo(a)pyrene	130	NA	0.2	NA	NA
Benzo(k)fluoranthene	37	NA	0.92	NA	NA
Chrysene	23	NA	9.2	(soil gas)	NA
Dibenzo(a,h)anthracene	9.9	NA	0.0092	NA	NA
Fluoranthene	250	NA	1500	NA	NA
Fluorene	560	160	240	1900	150000
Indeno(1,2,3)pyrene	24	NA	0.092	NA	NA
Methylnaphthalene (total 1-and 2-)	1.2	110	240	26000	150000
Naphthalene	1.2	23	6.2	31000	3100
Phenanthrene	18	(soil gas)	240	(soil gas)	150000
Pyrene	85	85	180	140	110000
Metals					
Lead	NA	NA	15	NA	NA
Lead, Tetraethyl	NA	NA	15	NA	NA
Lead, Dissolved	NA	NA	15	NA	NA
Total Petroleum Hydrocarbons					
GRO	2,000	(soil gas)	100	(soil gas)	52000
DRO	5,000	(soil gas)	100	(soil gas)	52000

Notes:
(soil gas) = Chemical constants not available for modeling. Use soil gas data to evaluate potential indoor-air concerns.
NA = Not applicable
Reference:
HDOH, 2004
Assumptions:
(1) Rainfall <200 cm/year
(2) Drinking water source threatened
(3) Surface water body is not located within 150 meters of release site.

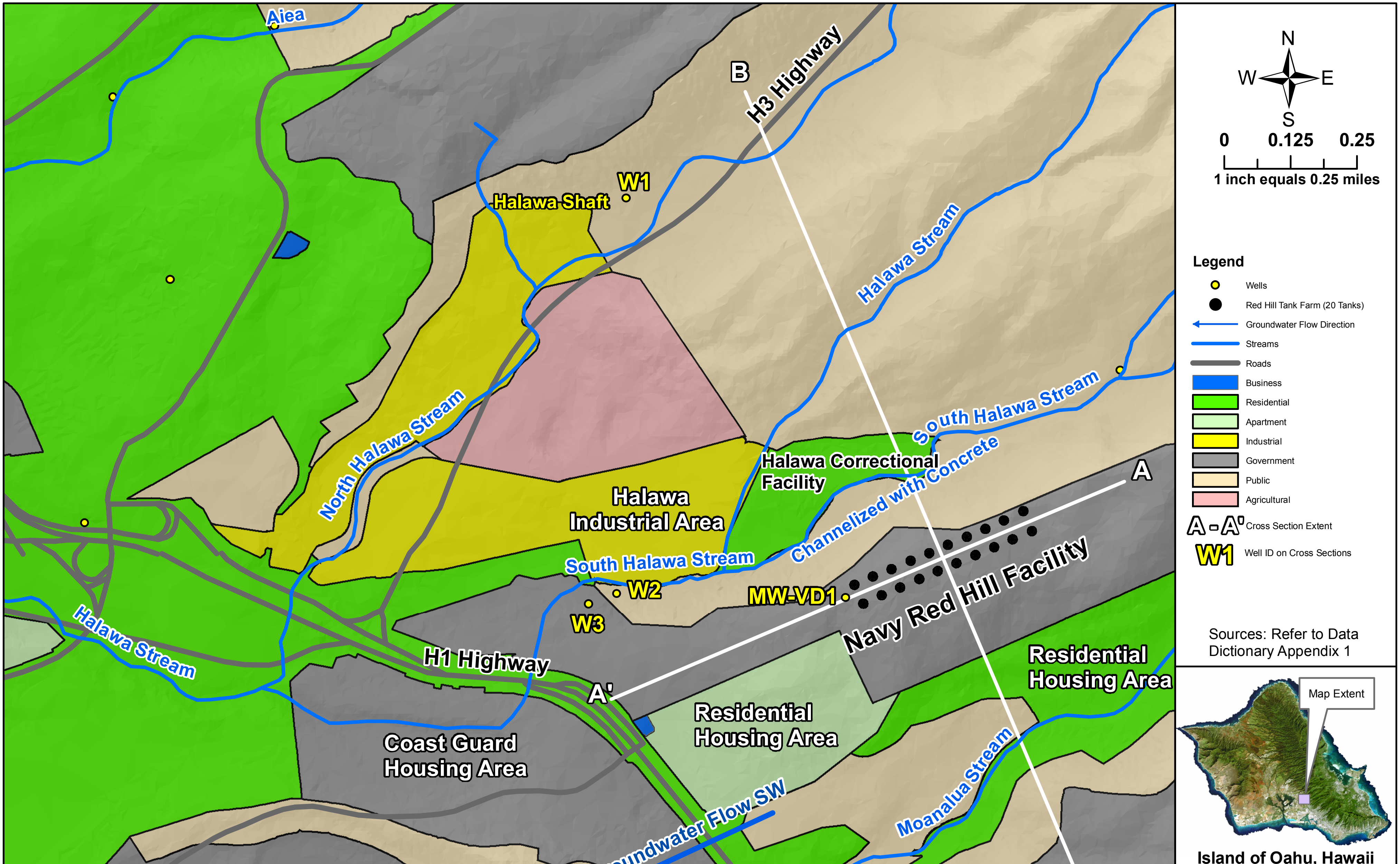
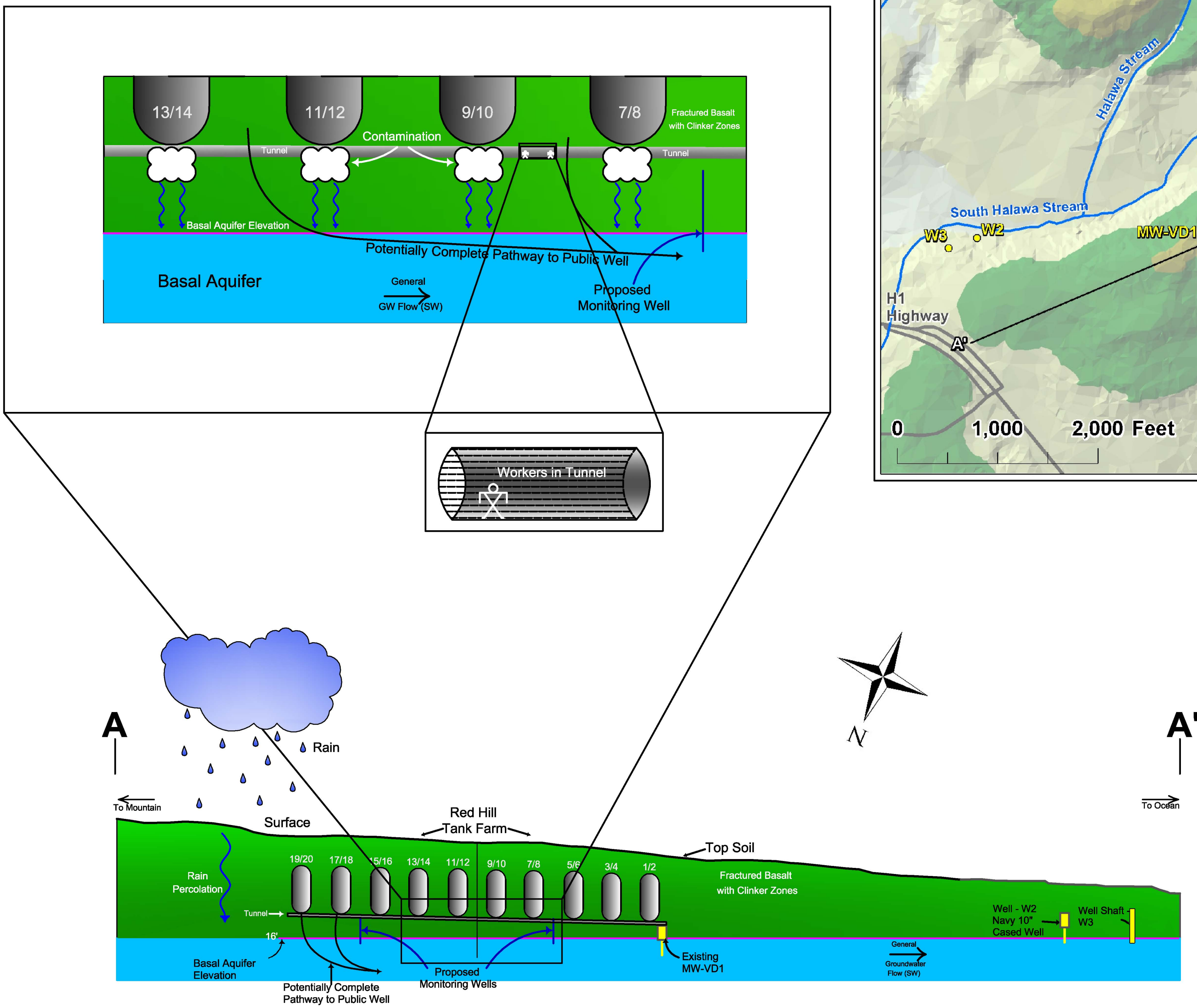
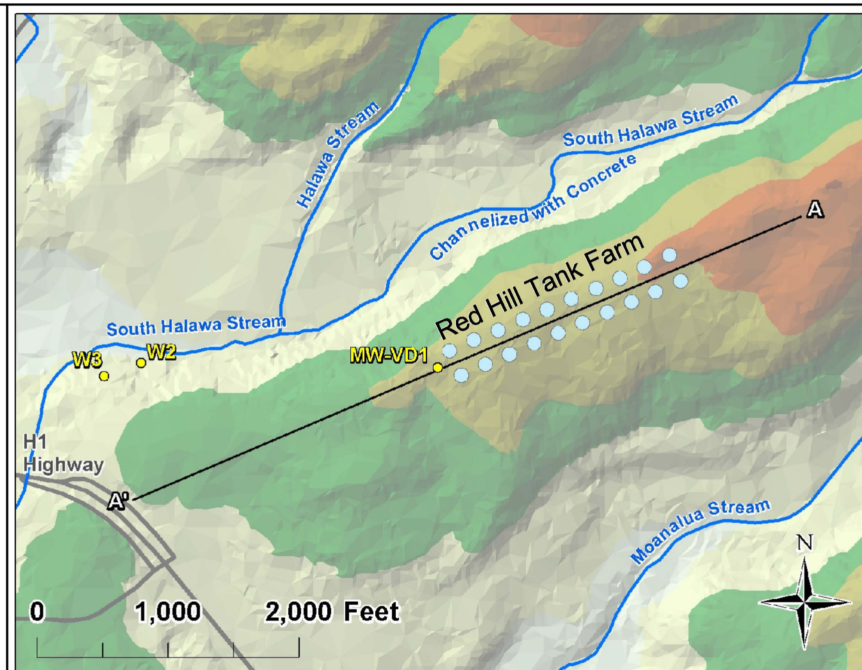


Figure 3-1
Cross Section Extents

Red Hill
Bulk Fuel Facility





Legend

- Basal Aquifer Elevation
- Basal Aquifer
- PWC Wells
- Rivers / Streams
- H3 Highway
- Ground
- Valley Fill

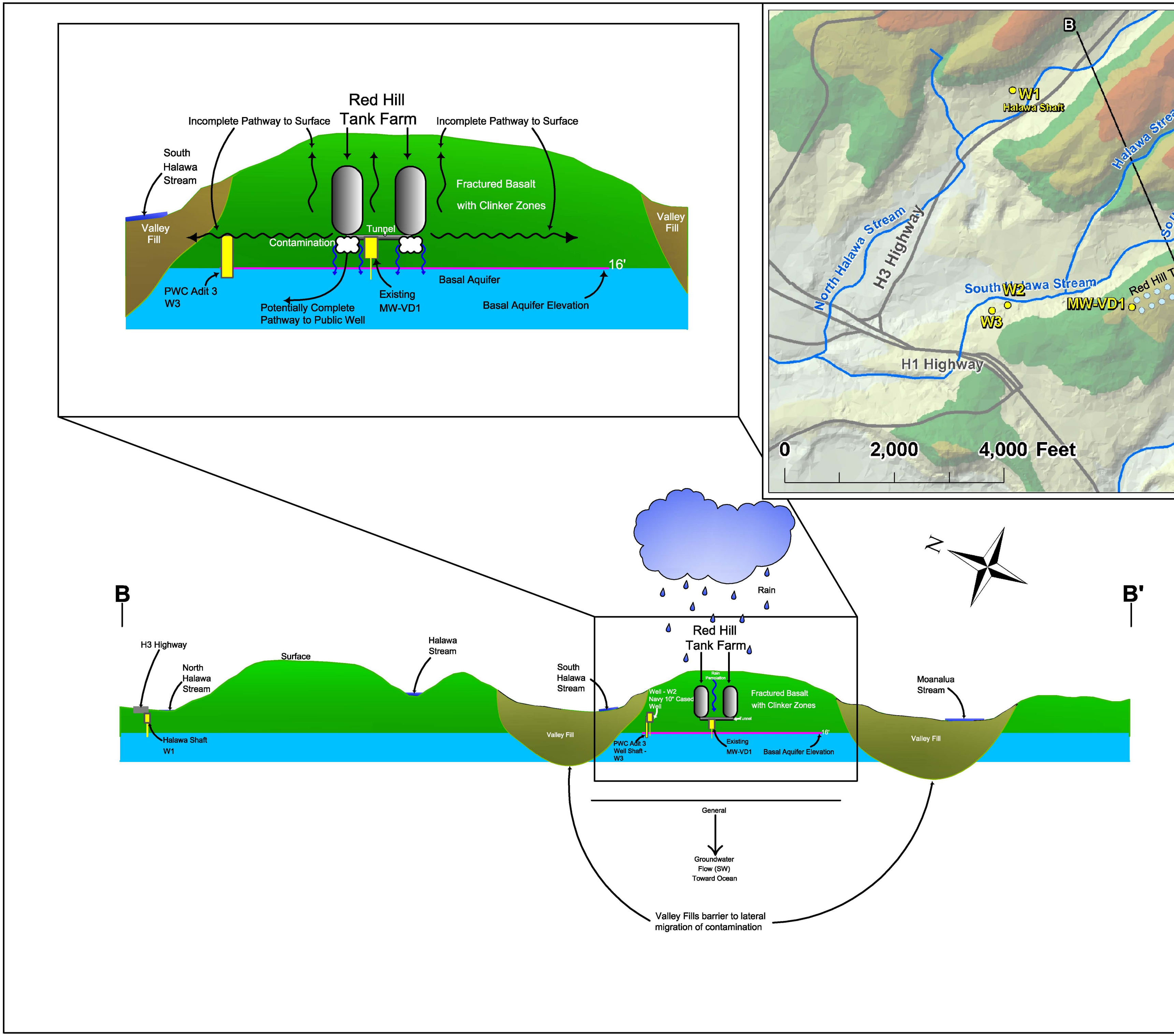
Sources: Refer to Data Dictionary Appendix 1

Conceptual Site Model

Figure 3-2

Cross Section A to A'

Red Hill
Bulk Fuel Facility



Legend

Basal Aquifer Elevation

Basal Aquifer

PWC Wells

Rivers / Streams

H3 Highway

Ground

Valley Fill

Sources: Refer to Data Dictionary Appendix 1

Conceptual Site Model

Figure 3-3

Cross Section B to B'

Red Hill
Bulk Fuel Facility

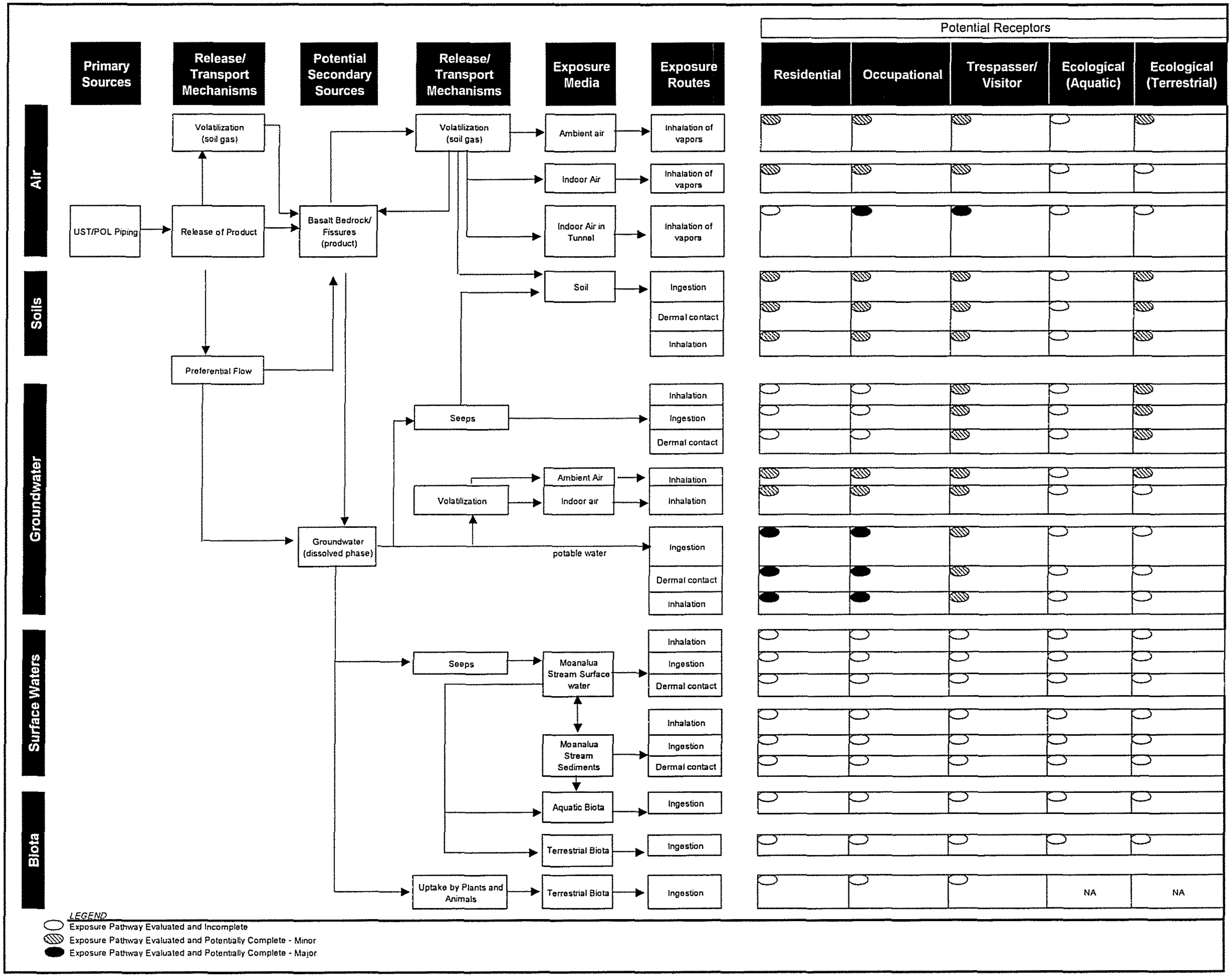


Figure 3-4

Preliminary Conceptual Site Exposure Model

SECTION 4
PROJECT INVESTIGATION RATIONALE

This section identifies the primary focus areas of the Red Hill Bulk Fuel Storage Facility field investigation and data quality objectives (DQOs) associated with the focus areas.

4.1 FOCUS AREAS

The overall project objectives for the RHSF field investigation can be categorized into two main areas of focus:

- **Characterize and monitor the vadose zone and basal groundwater aquifer beneath the RHSF Site** – A groundwater monitoring network will be established to monitor potential releases from the RHSF, evaluate the nature and extent of COPCs, and evaluate the fate and transport of COPCs in the groundwater. Groundwater monitoring wells will be screened across the water table, approximately 10 feet above and 10 feet below the water table (see Section 3 of the FSP [**Appendix A**]). Groundwater sampling will be conducted to measure and characterize COPC concentrations beneath and in the vicinity of the RHSF. Groundwater level measurements will be recorded to evaluate the fluctuation in the local groundwater gradient resulting from seasonal precipitation, and will be used to calibrate the numerical groundwater flow model to be developed in Phase II of the project. A pilot soil vapor monitoring network will be established in a maximum of three existing angle borings to evaluate the feasibility of converting the existing 20 angled-bore monitoring wells to soil vapor monitoring wells. Data collected will be incorporated with existing data from prior investigations and site activities to provide a more complete assessment of COPCs at the Site.

- **Evaluate and mitigate risk factors resulting from potential petroleum product releases at RHSF** - Information obtained during the field investigation activities will be used to support fate and transport modeling and preparation of a comprehensive risk assessment. A 3-D GIS database integrating existing and newly acquired site-specific data will be prepared and used as the basis for a CSM for the RHSF. Hydrologic testing will be conducted in the vicinity of the Navy Red Hill groundwater supply well (No. 2254-01) to develop site-specific hydraulic parameters to aid in the development of the CSM. In turn, the CSM will be used to design and conduct groundwater flow and COPC Fate and Transport modeling in environmental media beneath the Site (e.g., vadose zone transport of soil vapor and liquids, and groundwater transport of NAPL and aqueous phase constituents). The modeling efforts will be supported by physical parameter data obtained by the collection and geotechnical analysis of soil core samples and the conduct of a continuous rate aquifer pumping test using observation wells. The results of the site characterization and modeling efforts will be used to conduct a Comprehensive Risk Assessment for the Site. Finally, the accumulated knowledge of the Site will be used to prepare a Contingency Plan that will be to monitor site characterization data over time and provide long-term actions to mitigate future threats to human health and the environment from unauthorized releases from the Site.

The above focus areas for the RHSF field investigation effort have particular data objectives requiring data input from the investigation activities. Decisions relevant to subsequent activities (e.g., additional sampling) will be made on the basis of results from the RHSF field activities.

4.2 Data Quality Objectives

Particular data objectives, necessary data input, and decisions for the above focus areas for the RHSF field investigation activities are supported through considerations of a formal DQO Process (USEPA 2000a and 2000b). The DQO Process is a seven-step planning approach to develop sampling designs for data collection activities that will support decision making. The seven steps in the DQO process are as follows:

Step 1: State the problem.
Step 2: Identify the decision.
Step 3: Identify the inputs to the decision.
Step 4: Define the boundaries of the study.
Step 5: Develop a decision rule.

Step 6: Specify tolerable limits for decision errors.

Step 7: Optimize the design for obtaining data.

DQOs are qualitative and quantitative statements, developed using the DQO Process, that are intended to clarify study objectives, define an appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions. DQOs for each of the above focus areas for the RHSF field investigation effort are presented in the following sections.

4.2.1 DQOs for Characterization of the Nature of COPCs at RHSF

Data to support characterization of the nature and extent of COPCs in the soil, soil vapor, and basal aquifer for the field investigation activities include measurement of COPC concentrations in samples collected from three types of media beneath the RHSF Site: soil/rock cores, soil vapor, and groundwater. The proposed sampling program approach will meet the DQOs defined for characterization of the COPCs at RHSF. The monitoring well (V1D) installed within the basal aquifer during the previous RI work has been effective in monitoring COPCs. The proposed boring/monitoring well locations are located to monitor different sections of the facility. As such, the facility will be partitioned into Upper Tank Farm (Tanks 20 through 15), Middle Tank Farm (Tanks 14 through 7), and Lower Tank Farm (Tanks 6 through 1). The proposed pilot soil vapor monitoring wells will be installed within existing angled borings located beneath the USTs. Descriptions of the groundwater monitoring well network, pilot soil vapor monitoring network, and media sampling programs are provided in Section 3.0 of the FSP (**Appendix A**).

DQOs and their associated seven-step procedures for the media types to characterize the nature of COPCs for the RHSF field investigation activities are presented in **Table 4-1**.

4.2.2 DQOs for Evaluation of Physical Parameters at RHSF

Supplemental data to support the evaluation of the groundwater and fate and transport modeling efforts will be generated by two approaches:

- collection and evaluation of continuous rate aquifer pumping test data; and
- collection and geotechnical analyses of soil core samples.

The modeling efforts will utilize the analytical chemical COPC data generated during the site characterization field activities. These data will be supplemented by physical parameter estimates derived from the analysis of soil cores and the interpretation of long-term continuous rate pumping test data. The physical parameter data will be site-specific and will provide data to facilitate evaluation of the nature of groundwater and COPC movement in the subsurface. Descriptions of the aquifer test procedures and geotechnical analyses are provided in Section 3.8 of the FSP (**Appendix A**).

DQOs and their associated seven-step procedures for the media types to evaluate the vadose and basal aquifer physical parameters for the field investigation activities are presented in **Table 4-2**.

Table 4-1

Characterization of COPCs at RHSF

DATA QUALITY OBJECTIVE #1[a]

1. <u>State the problem</u> The nature and extent of potential impacts of COPCs in the soil, soil vapor, and groundwater beneath the RHSF Site are not adequately defined. Additional COPC data is needed to perform Fate and Transport and Risk Assessment calculations.
2. <u>Identify the Decision</u> Are detectable levels of COPCs present in the soil, soil gas, or groundwater beneath the RHSF at levels of concern? Levels of concern are based on soil and water quality screening thresholds discussed in Section 3 of this Work Plan.
3. <u>Identify the inputs to the decision</u> • COPCs are measured in the soil core samples. • COPC measurements from collected soil core samples are compared to soil screening thresholds. Screening thresholds are identified in Section 3 of this WP. • COPCs are measured in the groundwater samples. • COPC measurements from collected groundwater samples are compared to water quality screening thresholds. Screening thresholds are identified in Section 3 of this WP. • COPCs are measured in the soil vapor samples. • COPC measurements from soil vapor samples are used to evaluate the feasibility of converting existing angle borings to soil vapor monitoring points.
4. <u>Define the Boundaries of the Study</u> • Soil core samples are collected from within the three (3) new borings excavated to install groundwater monitoring wells at the Site. • Groundwater samples are collected from the existing vertical monitoring well (V1D) and three (3) newly installed monitoring wells that penetrate the basal aquifer underlying the Site. • New borings and wells are located by their association with potential petroleum releases from USTs or are situated up-gradient of the USTs (for use as a background well) as determined during previous site investigations. • Soil vapor samples are collected from within three (3) of the 20 existing shallow angled borings underlying the USTs at the Site.
5. <u>Develop a Decision Rule</u> • COPCs are defined as present in a soil, soil vapor, or groundwater sample if they are measured above the respective laboratory method detection limit applied for COPC measurements. • If measured COPCs exceed screening thresholds, then the COPCs are identified as problematic. Screening thresholds are identified and discussed in Section 3 of this Work Plan.
6. <u>Minimizing Decision Errors</u> • Use of trained collection personnel will minimize decision errors in soil, soil vapor, and groundwater samples collected for the effort. • Use of standard operating procedures in field collections will minimize decision errors in soil, soil vapor, and groundwater samples collected for the effort. • Use of standard laboratory analytical methods will minimize decision errors in resulting COPC measurements in soil, soil vapor, and groundwater samples collected for the effort. Analytical methods and their adequacy for achieving measurement levels to address Levels of concern (e.g., water quality thresholds) are discussed in the companion RHSF QAPP (**Appendix B**). • Collection of samples will be coordinated with information for system variables that may influence measurement results (e.g., rainfall events) to minimize decision errors.

Table 4-1

Characterization of COPCs at RHSF

DATA QUALITY OBJECTIVE #1[a]

7. <u>Optimize the Design for Obtaining Data</u> • Selection of proposed locations for borings, monitoring wells, and soil vapor monitoring points is based on information and COPC measurements obtained during previous Site investigation activities. • Use appropriate analytical chemistry methods for COPC measurements to maximize the likelihood of detecting COPCs in various media samples for levels of concern represented by screening thresholds. Screening thresholds are discussed in Section 3 of this Work Plan and chemistry methods are discussed in the companion RHSF QAPP (**Appendix B**).

[a] The 7-Step DQO progress is defined in Guidance for Data Quality Objectives Process (USEPA 2000a and b).

Table 4-2
Characterization of Vadose and Aquifer Physical Properties at RHSF
DATA QUALITY OBJECTIVE #2[a]

1. State the problem

The nature of the physical properties of the vadose zone and the basal aquifer underlying the Site are not adequately defined to conduct groundwater modeling and COPC fate and transport modeling.

2. Identify the Decision

- What site-specific physical parameters are required as input variables for groundwater modeling and COPC fate and transport modeling?
- What is the best method to obtain the necessary parameters?

3. Identify the inputs to the decision

- Aquifer testing will be conducted to obtain the necessary aquifer parameters.
- Soil core samples obtained from exploratory borings will be subjected to geophysical testing to obtain supplementary aquifer and vadose zone parameters.

4. Define the Boundaries of the Study

- A continuous rate pumping test is conducted within a groundwater well penetrating the basal aquifer. Groundwater monitoring wells at the Site are used as observation wells during the aquifer test.
- Soil core samples are collected from within the three (3) new borings excavated to install groundwater monitoring wells at the Site.

5. Develop a Decision Rule

- Representative aquifer parameters are calculated using standard hydrodynamic relationships to estimate necessary physical parameters such as hydraulic conductivity, transmissivity, and storage coefficient from the aquifer test data.
- Selected physical parameters such as porosity and soil moisture content are measured or calculated from geotechnical analyses of soil core samples.

6. Minimizing Decision Errors

- Use of trained collection personnel will minimize decision errors in soil core samples collected for the effort.
- Use of standard operating procedures in field collections will minimize decision errors in soil core samples collected for the effort.
- Use of standard laboratory analytical methods will minimize decision errors in resulting physical parameter measurements in soil core samples collected for the effort.
- Use of standard hydrodynamic relationships to estimate necessary physical parameters from aquifer test data will minimize decision errors in aquifer characteristics.

7. Optimize the Design for Obtaining Data

- Selection of proposed locations for borings, monitoring wells, and soil vapor monitoring points is based on information obtained during previous Site investigation activities.
- Use appropriate analytical methods to maximize the likelihood of accurately estimating physical parameters in soil core samples.
- Selection of long-term continuous rate pumping test with observation wells to maximize accuracy of aquifer parameter estimation in the basal groundwater aquifer beneath the Site.

[a] The 7-Step DQO progress is defined in Guidance for Data Quality Objectives Process (USEPA 2000a and b).

SECTION 5
PROJECT INVESTIGATION TASKS

This section provides a brief summary of Red Hill data compilation, field investigation, and modeling tasks that will occur during the implementation of these project plans. The field investigation tasks are only briefly discussed, a detailed discussion can be found in the attached FSP companion document (**Appendix A**). The project investigation tasks are presented in the following subsections:

Section 5.1 GIS Database and Model Construction;
Section 5.2 Site Characterization Activities;
Section 5.3 Fate and Transport Modeling;
Section 5.4 Risk Assessment;
Section 5.5 Data Interpretation and Technical Report Development; and
Section 5.6 Contingency Plan Preparation.

5.1 GIS DATABASE AND MODEL CONSTRUCTION

The primary objectives of the GIS model-building task are to collect and integrate site-specific geospatial project data and metadata to facilitate conduct of the site characterization, fate and transport modeling, risk assessment and contingency plan preparation, as well as provide a permanent database for future use by the client. To accomplish these objectives, the collected data will be assembled into a GIS 3-D database. An integrated visualization tool will be developed suing CTECH's Visual Mining System (VMS) 3-D visualization and animation software. Deliverables will include interactive georeferenced files that will provide the facility infrastructure, topographic features, water table surface, site lithology, and the results of environmental studies in a format that can be viewed using free software. The Intergraph FME ESRI Suite has been selected to generate a database in the Geomedia warehouse format, selected to be compatible with the GIS systems currently in use by FISC (i.e., GeoMedia Professional 5.2, GeoMedia WebMap Professional 5.2, GeoMedia Transportation 5.2, and Oracle 8i) and PWC (i.e., ESRI ArcInfo, Arc IMS, ArcView (versions 8 and 3.2) and Oracle). The data will be formatted in accordance with the specifications defined in *FISC*

Specifications for GIS data presented in Phase SOW (**Appendix G**). A proposed GIS activity schedule is presented in **Section 6**.

5.1.1 INITIAL DATA GATHERING AND INTEGRATION

The initial GIS database will be constructed on the basis of existing site-specific data. Site data currently available for GIS database construction includes;

- Existing geologic logs for vertical and angled borings;
- Existing barrel logs from facility construction;
- As-built construction drawings and electronic files of the Red Hill storage and fuel distribution system;
- Electronic topographic information;
- Aerial photographs;
- Building locations;
- Laboratory analytical results;
- Geologic cross sections, and
- Land-use maps and electronic files.

Existing data will be converted from current formats (e.g., paper copy, CAD file) to the appropriate digital format for inclusion in the GIS database.

5.1.2 GIS DATABASE REFINEMENT

The GIS database will be used to generate and manage maps, figures, models, and data throughout the site characterization process. The GIS database will be modified and refined as new data becomes available from the results of the proposed site characterization activities. Site-specific data generated and integrated during the field investigation and modeling activities are anticipated to include:

- New borings logs and rock core information;
- Laboratory analytical results;
- Land survey data;
- Groundwater elevation data;

- Fate and Transport Modeling data;
- Risk Assessment data; and
- Contingency Plan data.

5.1.3 GIS VISUALIZATION TOOL

A digital three-dimensional conceptual site model (CSM) will be constructed using the GIS database. The CSM will facilitate decisions regarding field investigation activities and will be used to visualize and illustrate conditions and processes occurring at the Site. The CSM will be used for the following purposes:

- Create maps and vertical cross-sections of the Site;
- Depict spatial relationships of petroleum sources and other contaminates in the subsurface;
- Visualize potential contaminant migration pathways in the vadose and saturated zones;
- Visualize groundwater flow conditions;
- Facilitate Groundwater Modeling and Fate and Transport Modeling;
- Facilitate a Tier 3 Risk Assessment; and
- Facilitate preparation of a Contingency Plan.

5.1.4 GIS DELIVERABLES

The following products will be delivered to the client:

- GIS database;
- Electronic visualization package data files and output files;
- Interactive model and viewing software;
- Paper hardcopies of selected maps and figures;

A node locked-licensed copy of FME ESRI Suite shall be transferred to FISC following completion of the contract. Data will be delivered to the client in Geomedia Warehouse Database format and in Personal Geodatabase or Shapefile format. A digital 3-D model generated using Mining Visualization System (MVS) will be provided. The 3D model may be viewed by the client using a 4DIM viewer, which is free software designed to view MVS models. Open Flight and VRML versions of the finished 3D model will also be created.

5.2 SITE CHARACTERIZATION ACTIVITIES

Section 5.2 subsections provide a brief synopsis of proposed field activities. A detailed discussion of field activities is provided in the attached FSP companion document (**Appendix A**).

5.2.1 HEALTH AND SAFETY PROTOCOL

Health and Safety protocols are detailed in the SSHSP companion document provided under separate cover (USN 2005).

5.2.2 EXPLORATORY BORINGS AND CORE SAMPLING

Three exploratory borings will be advanced to collect soil and rock samples for laboratory analyses and to install groundwater monitoring wells that penetrate the basal aquifer underlying and adjacent to the Site. Drilling and sampling protocols are detailed in the attached FSP, Sections 3.2 and 3.3 (**Appendix A**). The following activities will be conducted:

- **Excavate and Sample One Up-gradient Background Soil Boring** to evaluate background soil conditions in the vicinity of the RHSF and install a vertical groundwater monitoring well from the existing ground surface at the RHSF. Samples will be evaluated for lithology, and soil overburden will be evaluated for potential surface contamination that may affect groundwater results at this location. The boring/monitoring well will be located adjacent to the Navy rifle range, hydraulically up-gradient from the USTs. An air rotary drill rig will be used to excavate the boring to penetrate the basal aquifer. No coring will be conducted at this location. Rock lithology will be evaluated via cuttings.

- **Excavate and Sample Two Soil Borings** to evaluate bedrock conditions directly beneath the Middle and Upper RHSF and install vertical groundwater monitoring wells within the lower access shaft at the RHSF. A portable drill rig will be used to excavate the borings to penetrate the basal aquifer. Soil Borings will be advanced by continuous coring techniques that will be reviewed by a experienced geologist and environmental professional for fate and transport assessment, as well to determine whether isolation casing will be required to advance the boring without jeopardizing the quality of the basal aquifer at the location. Soil borings will be located as far away from the surrounding USTs as possible (approximately 150 feet) to minimize the potential for encountering highly-petroleum impacted rock that will require isolation casing during excavation.

- **Install Isolation Casing** within the excavated borings as warranted to prevent contaminates migrating into the basal aquifer through the boreholes.

- **Collect Soil and Rock Core Samples** from within the borings for laboratory analysis. Soil and core samples will be selected for analysis on the basis of visual observations and field screening results.

- **Analyze Selected Core Samples** for Site COPCs. Sampling locations are not expected to be impacted in the vadose zone, but are located to optimize groundwater sampling locations.

5.2.3 GROUNDWATER STUDY

The three exploratory borings excavated will be converted to groundwater monitoring wells that penetrate the basal aquifer. These newly installed monitoring wells will be used in conjunction with one existing onsite monitoring well (V1D), at least two existing offsite groundwater monitoring wells (Red Hill Oily Waste Facility MW-08 and Moanalua Valley BOWS Well No. 2253-02), and accessible groundwater production wells (e.g., PWC production well) to characterize and monitor the conditions of the basal aquifer underlying the Site. Well installation, sampling, and aquifer testing protocols are detailed in the attached FSP, Sections 3.2 and 3.3 (**Appendix A**). The following activities will be conducted:

- **Install and Develop Three Monitoring Wells** that penetrate the basal aquifer to establish a groundwater monitoring network at the RHSF (in conjunction with existing monitoring well V1D).

- **Collect Groundwater Chemical Samples** to provide data to characterize the existing groundwater conditions, support fate and transport calculations, facilitate conduct of a Tier 3 comprehensive risk assessment, and monitor natural attenuation processes at the Site using V1D (Lower MW), the Middle MW (MMW) and Upper MW (UMW), as well as the up-gradient background well (BKGMW01). Additional sampling of the Red Hill Pumping Well No. 2254-01 will be accomplished with the assistance of The Dawson Group, who is the Navy contractor that is conducting groundwater sampling there.

- **Conduct Groundwater Level Measurements** to assess the nature of potential long-term changes of the local groundwater gradient. Measurements will be collected at all wells described above, including offsite wells.

- **Perform Aquifer Testing** to characterize hydraulic properties of the basal aquifer underlying the Site. Pumping tests will be conducted using the Navy Red Hill Pumping Station and nearby monitoring wells.

- **Conduct a Land Survey** to document the locations and elevations of the monitoring wells.

- **Analyze Groundwater Samples** for Site COPCs.

5.2.4 SOIL VAPOR PILOT STUDY

A pilot study will be conducted to evaluate the feasibility of using existing angle borings beneath the USTs to install soil vapor monitoring probes for site characterization and long-term monitoring. Three of the twenty existing angle borings will be converted to permanent soil vapor monitoring wells (SVMWs), with each SVMW containing three soil vapor monitoring probes at varying depths. SVMW installation and soil vapor sampling protocols are detailed in the attached FSP, Sections 3.2 and 3.3 (**Appendix A**). The following activities will be conducted:

- **Install Three SVMWs** in existing angle borings to evaluate the feasibility of using the 20 existing borings to establish a soil vapor monitoring network.

- **Collect Soil Vapor Samples** to provide data to supplement rock core analyses regarding the nature of volatile compounds within the vadose zone, provide qualitative information regarding the general location of releases beneath the USTs, and to facilitate evaluation of the SVMWs for long-term monitoring of the vadose zone as part of a Site Contingency Plan.

- **Analyze Soil Vapor Samples** for Site COPCs.

5.2.5 DATA MANAGEMENT AND VALIDATION

- Data management and validation will be performed in accordance with the procedures and protocols specified in Section 6.0 – Data Management and Section 8.0 – Data Validation of the attached QAPP (**Appendix B**).

5.3 CONTAMINANT FATE AND TRANSPORT MODELING

The results of the field investigation and GIS 3-D model construction will be used to conduct fate and transport modeling of COPCs. The fate and transport calculations will be comprised of the following aspects:

- **Soil Vapor** modeling will be conducted to evaluate the potential migration of volatile compounds through the subsurface and to identify potential receptors.
- **Vadose Zone** modeling will be conducted to evaluate the potential migration of LNAPLs or aqueous phase COPCs through the unsaturated zone.

- **Groundwater** modeling will be conducted to estimate groundwater flow conditions and evaluate the potential movement of LNAPL and aqueous phase contaminants in the saturated zone.
- **Potential release** scenarios will be evaluated using the results of the soil vapor, vadose zone, and groundwater models. Scenarios investigated will include the potential role of pipelines as migrations pathways for LNAPLs and dissolved COPCs, potential impact of vadose zone contamination to surface water bodies, and potential impact of soil vapors to human receptors (e.g., workers in access tunnels).

5.4 TIER 3 COMPREHENSIVE RISK ASSESSMENT

The results of the field investigation, GIS 3-D model construction, and Fate and Transport modeling will be used to conduct a Tier 3 Comprehensive Risk Assessment.

5.5 DATA INTERPRETATION AND TECHNICAL REPORT DEVELOPMENT

A comprehensive report will be prepared following the completion of the Risk Assessment. The report will include:

- A summary of previous studies;
- A summary of the existing characterization activities;
- A comprehensive assessment of the nature and extent of contamination;
- A summary of ARARs and TBCs;
- A comprehensive assessment of fate and transport results;
- A comprehensive presentation of the Tier 3 Risk Assessment results;
- A comprehensive set of recommendations and conclusions, including the outline of a Contingency Plan to ensure that current and future risks are properly evaluated and mitigated.

5.6 CONTINGENCY PLAN PREPARATION

The results of the field investigation, GIS 3-D model construction, Fate and Transport modeling, and Tier 3 Risk Assessment will be integrated and used as the basis to prepare a Contingency Plan for the RHSF. The Contingency Plan will consider methods to avoid and mitigate catastrophic releases from the USTs, to minimize impacts to human health and the environment, and to protect the drinking water source of the basal aquifer.

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SECTION 6
PROJECT SCHEDULE

A proposed project schedule in Gant Chart format is presented as **Figure 6-1**. A supplementary schedule detailing GIS activities is presented as **Figure 6-2**.

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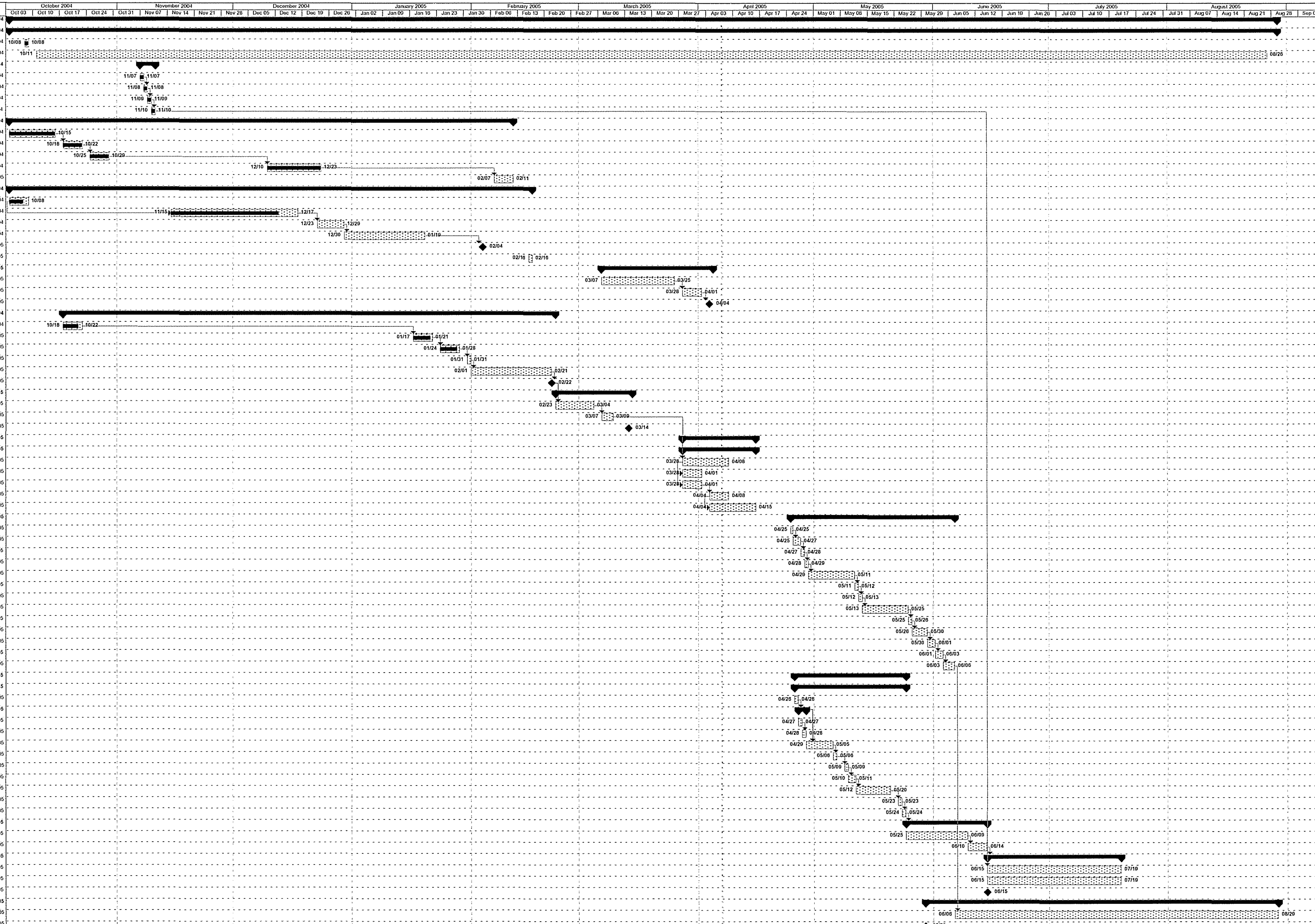
Figure 6-1
Red Hill Phase 1 Proposed Schedule of Activities

ID	ID	Task Name	Start
1	1	**Red Hill Phase 1 Activities**	Mon 10/04/04
2	2	**Task 1 - Project Management - Phase 1**	Mon 10/04/04
3	3	Notice to Proceed	Fri 10/08/04
4	4	Project Management Activities	Mon 10/11/04
5	5	**Task 2 - Kick off Meeting**	Sun 11/07/04
6	6	Mobe to Hawaii	Sun 11/07/04
7	7	Meetings with POCs	Mon 11/08/04
8	8	Site Reconnaissance & Equipment Assessment	Tue 11/09/04
9	9	Demobe from Hawaii	Wed 11/10/04
10	10	**Task 3 - Preliminary Risk Assessment Activities**	Mon 10/04/04
11	11	Files Investigation	Mon 10/04/04
12	12	Site and Area Walk-Over	Mon 10/18/04
13	13	Prepare Maps/Figures	Mon 10/25/04
14	14	Perform Preliminary Exposure Assessment Calculations	Fri 12/10/04
15	15	Attend HDOH Meeting	Mon 02/07/05
16	16	**Task 4 - Draft Work Plan**	Mon 10/04/04
17	17	Prepare Quality Assurance Project Plan	Mon 10/04/04
18	18	Prepare Text. Tables & Figures	Mon 11/15/04
19	19	Submit Draft Work Plan to TEC	Thu 12/23/04
20	20	Navy Review Cycle	Thu 12/30/04
21	21	Submit Draft Work Plan to Navy	Fri 02/04/05
22	22	Submit Work Plan to HDOH During Meeting	Wed 02/16/05
23	23	**Task 5 - Final Work Plan**	Mon 03/07/05
24	24	Address Comments & Submit Report Final	Mon 03/07/05
25	25	Submit Final Work Plan to TEC	Mon 03/28/05
26	26	Submit Final Work Plan to Navy	Mon 04/04/05
27	27	**Task 6 - Draft Health and Safety Plan**	Mon 10/18/04
28	28	Update Previous HSP	Mon 10/18/04
29	29	Prepare Health & Safety Plan	Mon 01/17/05
30	30	Internal Peer Review	Mon 01/24/05
31	31	Submit Draft HSP to TEC	Mon 01/31/05
32	32	Navy Review Cycle	Tue 02/01/05
33	33	Submit Draft Health and Safety Plan to Navy	Tue 02/22/05
34	34	**Task 7 - Final Health and Safety Plan**	Wed 02/23/05
35	35	Address Comments & Submit HSP Final	Wed 02/23/05
36	36	Submit Final HSP to TEC	Mon 03/07/05
37	37	Submit Final Health and Safety Plan to Navy	Mon 03/14/05
38	38	**Task 8 - Project Planning for Field Work**	Mon 03/28/05
39	39	**Subcontracting Subcontractors**	Mon 03/28/05
40	40	Coordinate with all Subcontractors	Mon 03/28/05
41	41	Coordinate with FISC/PWC	Mon 03/28/05
42	42	Security Arrangements	Mon 03/28/05
43	43	Premobe Staff Prep	Mon 04/04/05
44	44	Ship Drilling Equipment to Hawaii	Mon 04/04/05
45	45	**Task 9 - Field Work**	Mon 04/25/05
46	46	Mobilize to Hawaii	Mon 04/25/05
47	47	Set up Activities	Mon 04/25/05
48	48	Meet with POCs	Wed 04/27/05
49	49	Mobilize Equipment to 1st Drilling Location	Thu 04/28/05
50	50	Drill First Vertical Well	Fri 04/29/05
51	51	Perform Geophysical Electrode Insertion	Wed 05/11/05
52	52	Mobilize to 2nd Drilling location	Thu 05/12/05
53	53	Drill Second Vertical Well	Fri 05/13/05
54	54	Perform Geophysical Electrode Insertion	Wed 05/25/05
55	55	Mobilize Equipment out of Tunnels	Thu 05/26/05
56	56	Develop New Wells	Mon 05/30/05
57	57	Sample All Designated Sample Locations	Wed 06/01/05
58	58	Demobe from Hawaii	Fri 06/03/05
59	59	**Task 10 - Geophysical Data Acquisition (Pilot Study)**	Tue 04/26/05
60	60	**Geophysical Field Activities**	Tue 04/26/05
61	61	Mobe Geophysical Crew to Hawaii	Tue 04/26/05
62	62	**Set up Activities**	Wed 04/27/05
63	63	Meet With POCs/Make Access Arrangements	Wed 04/27/05
64	64	Mobilize Equipment To Tunnels	Thu 04/28/05
65	65	EMI Activities (4 slant MWs & 2 new MWs)	Fri 04/29/05
66	66	Geophysical Probe Insertion First MW	Fri 05/06/05
67	67	Geophysical Probe Insertion Second MW	Mon 05/09/05
68	68	Begin Angle Well Modifications (4 slant MWs)	Tue 05/10/05
69	69	Geophysical Testing	Thu 05/12/05
70	70	Demobe Equipment from Tunnels	Mon 05/23/05
71	71	Demobe from Hawaii	Tue 05/24/05
72	72	**Geophysical Data Evaluation**	Wed 05/25/05
73	73	Geophysical Draft Pilot Study Report & Electronic Data Submittals	Wed 05/25/05
74	74	Geophysical Final Pilot Study Report & Electronic Data Submittals	Fri 06/10/05
75	75	**Task 11 - 3D GIS Data Base**	Wed 06/15/05
76	76	Phase 1 - Data Conversion to Digital Format	Wed 06/15/05
77	77	Phase 2 - Data Interpolation	Wed 06/15/05
78	78	Phase 1 3D GIS Data Base Deliverable	Wed 06/15/05
79	79	**Task 12 - IDW Disposal**	Mon 05/30/05
80	80	Core Review & Disposal	Mon 06/06/05
81	81	IDW Disposal Letter	Mon 05/30/05

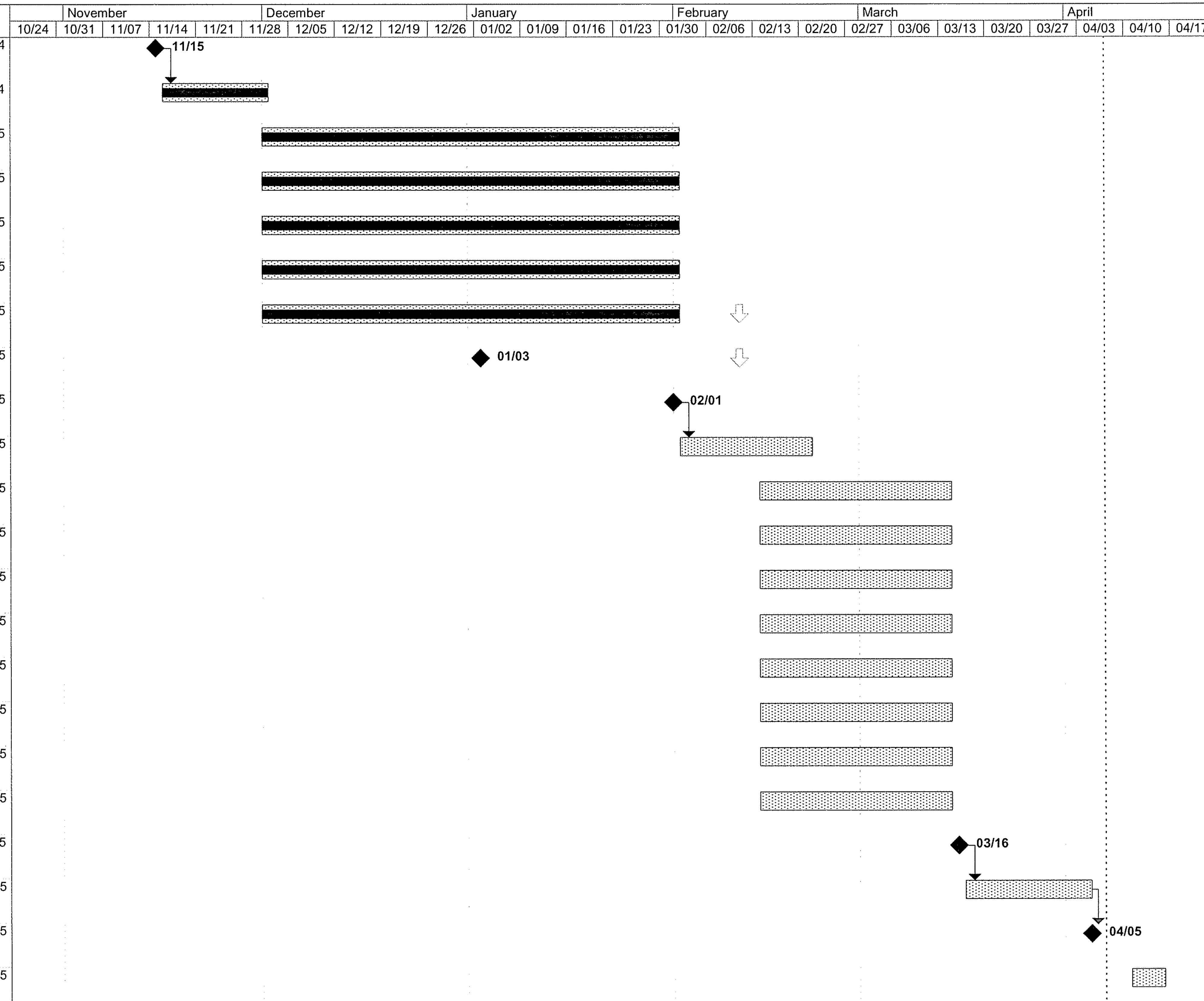


Task | Progress | Summary | Rolled Up Critical Task | Rolled Up Progress | External Tasks | Group By Summary

Critical Task | Milestone | Rolled Up Task | Rolled Up Milestone | Split | Project Summary

Figure 6-2
Schedule of GIS Activities

ID	Indicators	Task Name	Duration	Start	Finish
1	✓	Project Start Date	1 day?	Mon 11/15/04	Mon 11/15/04
2	✓	Data Familiarization / Content Filter	12 days	Tue 11/16/04	Wed 12/01/04
3	✓	Surface Topology - DEM	45 days?	Wed 12/01/04	Tue 02/01/05
4	✓	Surface Plainemetrics - Buildings	45 days?	Wed 12/01/04	Tue 02/01/05
5	✓	Tank Barrel Logs	45 days?	Wed 12/01/04	Tue 02/01/05
6	✓	Tank Features	45 days?	Wed 12/01/04	Tue 02/01/05
7	✓	Fuel Pipeline	45 days?	Wed 12/01/04	Tue 02/01/05
8	✓	FME Software Purchase	1 day	Mon 01/03/05	Mon 01/03/05
9		50% Deliverable	1 day?	Tue 02/01/05	Tue 02/01/05
10		50% Deliverable Modifications	14 days?	Wed 02/02/05	Mon 02/21/05
11		Water Supply	21 days?	Mon 02/14/05	Mon 03/14/05
12		Access Tunnels (Upper and Lower)	21 days?	Mon 02/14/05	Mon 03/14/05
13		Angled Borings	21 days?	Mon 02/14/05	Mon 03/14/05
14		1 Existing Vertical Well	21 days?	Mon 02/14/05	Mon 03/14/05
15		2 Additional Vertical Wells	21 days?	Mon 02/14/05	Mon 03/14/05
16		Aerial Photography / USGS Topo	21 days?	Mon 02/14/05	Mon 03/14/05
17		Basal Aquifer	21 days?	Mon 02/14/05	Mon 03/14/05
18		Data Format Conversion	21 days?	Mon 02/14/05	Mon 03/14/05
19		90% Deliverable	1 day?	Wed 03/16/05	Wed 03/16/05
20		90% Deliverable Modifications	13 days?	Thu 03/17/05	Mon 04/04/05
21		100% Deliverable	1 day	Tue 04/05/05	Tue 04/05/05
22		3D Model Demonstration and Training	5 days?	Mon 04/11/05	Fri 04/15/05



Project: RedHill3DModel

Task | Progress | Summary | External Tasks | Deadline
Split | Milestone | Project Summary | External Milestone

SECTION 7
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